CONSTRUCTION EQUIPMENT MANAGEMENT FOR ENGINEERS, ESTIMATORS, AND OWNERS

DOUGLAS D. GRANSBERG
CALIN M. POPESCU
RICHARD C. RYAN

Taylor & Francis

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CRC Taylor & Francis
Taylor & Francis Group
Boca Raton London New York

CRC is an imprint of the Taylor & Francis Group,
an informa business

Published in 2006 by
CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-10: 0-8493-4037-3 (Hardcover)
International Standard Book Number-13: 978-0-8493-4037-6 (Hardcover)
Library of Congress Card Number 2005046733

Library of Congress Cataloging-in-Publication Data

Gransberg, Douglas D.
Construction equipment management for engineers, estimators, and owners / Douglas Greenberg [i.e. Gransberg], Calin M. Popescu, Richard C. Ryan.
p. cm. -- (Civil and environmental engineering ; 21)
ISBN 0-8493-4037-3
1. Construction equipment--Management. 2. Engineering--Equipment and supplies--Management. 3. Construction industry--Management. I. Popescu, Calin. II. Ryan, Richard C. III. Title. IV. Series.

TA213.G68 2006
624.068'2--dc22 2005046733

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Preface

Construction Equipment Management for Engineers, Estimators, and Owners is intended to be a reference book for construction project managers, estimators, construction equipment fleet managers, and professional engineers. The book also contains information relevant to both the public and private sectors. It contains a great deal of "hands-on, how-to" information about equipment management based on the authors' personal construction experiences throughout the world. It is written as a guide for individuals who need to estimate the cost of equipment on a given project and do not have data at their fingertips because their routine business does not involve a lot of equipment-related construction. The authors also hope that their book will be useful to the public agency equipment manager whose need is to minimize equipment costs rather than to maximize the profit earned by the equipment.

The book is useful to all parties in the architecture, engineering, and construction industries as well as to project owners. The first chapter describes the evolution of construction equipment and serves to set the stage for the following chapters that provide specific up-to-date information on the state of art in the area. The chapters on estimating equipment ownership and operating costs and determining economic life and replacement policy will be of great value to construction estimators. The chapters on determining the optimum mix of equipment and estimating the equipment productivity show the estimator how to maximize the profit of an equipment-intensive construction project. The chapter on scheduling demonstrates how to convert a linear schedule into a precedence diagram for use in a project that has a mandated scheduling methodology. This information has not been published before to the best of our knowledge and demonstrates to the equipment manager how to ensure that a production-driven, equipment-intensive project can be scheduled to achieve target production rates and hence target equipment-related unit costs and profits.

The book also shows managers and engineers how to avoid making costly common mistakes during project equipment selection. It contains a matrix that will help the novice equipment manager select the proper piece of equipment based on the requirements of the project. It is full of detailed examples of the types of calculations made to allow both public and private equipment-owning organizations to determine an optimum equipment utilization plan for any project regardless of their levels of experience. Finally, the equipment safety chapter describes how to develop an Occupational Safety and Health Administration (OSHA) job safety analysis for an equipment-intensive project, thus making this onerous and essential task easier for the equipment manager.

This book is the brainchild of Dr. Calin Popescu of the University of Texas and flows from an early work undertaken to support his graduate civil engineering class in construction equipment management. Dr. Popescu's focus was on equipment used for heavy-civil projects. Professor Richard Ryan of the University of Oklahoma blended much of his work on managing construction equipment in building construction for his construction science undergraduate class on construction equipment into Dr. Popescu's outline to produce a reference that for the first time treats both horizontal and vertical construction projects. Dr. Doug Gransberg added his research on optimizing equipment fleet size and composition as well as his experience in applying engineering economics and simulations to produce a comprehensive treatise on this subject that ranges from the rigorous mathematical analysis of equipment operations to the pragmatic discussion of the equipment maintenance programs needed to guarantee the production assumed in a cost estimate. The authors hope that the combination of both the analytical and practical aspects will result in a reference document that will be of value to a wide range of individuals and organizations within the architecture, engineering, and construction industries.

Douglas D. Gransberg
Calin M. Popescu
Richard C. Ryan

Authors

Douglas D. Gransberg is the Sam K. Viersen, Jr. presidential professor of construction science at the University of Oklahoma. He received both his B.S. and M.S. degrees in Civil Engineering from Oregon State University and Ph.D. in civil engineering from the University of Colorado at Boulder. He is a registered professional engineer in Oklahoma, Texas, and Oregon, a certified cost engineer, a designated design-build professional, and a chartered surveyor by the Royal Institute of Chartered Surveyors in the U.K. Before moving to academia in 1994, Professor Gransberg spent over 20 years in the U.S. Army Corps of Engineers. He also owns an active construction management consulting practice, with many clients from the public sector, such as the Federal Highway Administration, Naval Facilities Engineering Command, U.S. Agency for International Development, transit authorities in New York City and Washington, D.C., and the Montana, Oklahoma, Texas, and Washington State Departments of Transportation. Professor Gransberg has taught continuing professional education seminars across the nation in the area of design-build contracting, architect-engineer design contracting, and cost engineering for the American Society of Civil Engineers for the past 9 years. He was appointed as innovative contracting subject matter expert for the Federal Highway Administration's Accelerated Technology Transfer Program in 2004. He has published more than 60 journal articles and reports.

Calin M. Popescu has a B.S. in engineering, an M.S. in engineering economics, and a Ph.D. in project management from the Construction Institute and Polytechnic Institute of Bucharest, Romania. He is a registered professional engineer in Texas. Between 1958 and 1974, as a construction/project manager, he supervised a variety of large construction projects like hotels, low cost large scale apartment buildings, power plants, paper mill, and industrial complexes in Romania. For 30 years starting from 1974, he taught various courses in the areas of construction engineering and project management in the civil engineering department at the University of Texas at Austin. He has published extensively in referred journals and conference proceedings, and has authored/coauthored 8 books. Dr. Popescu has made many presentations at national and international professional societies and taught many short courses and seminars for the construction industry. Since 1982, he has been the owner and CEO of C&C Consultants, Inc., specializing in construction disputes with national and international clients. He is a founding member of the project management charters in Austin, Texas and Bucharest, Romania.

Richard C. Ryan is a professor of construction science at the University of Oklahoma. He received his B.S. in building construction and M.S. in construction management from Texas A&M University. He is a certified professional constructor and member of the American Institute of Constructors. Before moving to academia in 1990, Professor Ryan spent over 11 years as a partner in R&R Construction. He continues to provide design consultation and building services. He is an active program developer and instructor for the United Brotherhood of Carpenters and Joiners' Superintendent and Foremen Training programs. He has published over 30 journal articles and has contributed chapters to books.

Contents

1 Evolution of Heavy Construction Equipment

1.1 INTRODUCTION

Buildings are connected to the earth by foundation systems to achieve stability. Utilities are located underground so that they are not visible and not placed in the way of other systems. Building sites are shaped to drain water away from the structure to a safe place. Bridges spanning rivers and valleys or tunnels through mountains provide suitable safe surfaces for travel. Refineries provide fuel for cars traveling on our highways and bridges. Dams are built to change the face of the earth, harness to change natural power, and provide an essential resource to our existence, namely water. Construction of these projects requires heavy equipment or "big iron" to assist many of the work activities. At the start of the 21st century, construction accounted for approximately 10% of the U.S. gross national product and employed approximately 4.5 million people. Heavy construction equipment is one of the primary reasons construction has reached this status. In fact, the role of heavy construction equipment today is "mission critical" and indirectly influences the quality of our lives everyday.

Heavy construction work typically requires high-volume or high-capacity equipment. These requirements are typically driven by the large amount of work to be done and the amount of time to complete it. This work can further be classified by whether the construction is vertical or horizontal. Vertical construction typically requires less surface work, earth moving, and excavating and more lifting. Horizontal construction typically requires more surface work and limited lifting.

1.2 ROLE OF HEAVY CONSTRUCTION EQUIPMENT

Today contractors undertake many types of construction activities that require different types, sizes, and groupings of equipment for earth moving, excavating, and lifting. There is a piece of equipment for practically any work activity, large or small. Construction equipment today is specifically designed by the manufacturer to perform certain mechanical operations that accomplish a work activity. Working capacity is a direct function of the size of the machine and the power of the motor. These simple relationships exist — the larger the machine, the more power required for the operation, the greater the production capacity, and the greater the cost to own and operate.

The dependency and need for heavy construction equipment have grown with the size and complexity of construction projects. The development of automated heavy construction equipment for earthmoving, excavating, and lifting occurred in the last two centuries. Operating and mechanical principles for most types of equipment are basically the same as when they first evolved many centuries ago. It should be noted that mechanical operations are typical for most basic classifications of equipment. For example, most front-end loaders work

TABLE 1.1
Level of Equipment Use by Type of Construction

Types of Construction	Level of Use	Work Activities
Residential	Light	Finish site work, foundation excavation, ground material moving, up to three-story lifting, pneumatic assembly tools
Commercial	Moderate	Rough and finish site work, stabilizing and compacting, multiple story material and man lifting, ground and on-structure material moving, miscellaneous types of assembly and support equipment
Industrial	Heavy	Large volume rough and finish site work, stabilizing and compacting, ground and on-structure material moving, multiple story heavy lifting and precision placing, numerous miscellaneous special types of equipment for assembly and support
Highway	Intense	Mass dirt and material excavating and moving, stabilizing and compacting, ground material moving and hoisting, concrete and asphalt paving and finishing, miscellaneous special types of equipment for support
Specialty	Intense	Pipeline, power, transmission line, steel erection, railroad, offshore, pile driving, logging, concrete pumping, boring and sawing, many others

the same way mechanically. They scoop at ground level, carry the load, hoist the load, and dump the bucket forward. Caterpillar front-end loaders basically work the same way as Samsung or Case front-end loaders.

Today it is assumed that if equipment does not exist to perform a necessary task, it can be designed and built. Heavy construction equipment manufacturers are very responsive to market needs and feedback from users. Quite simply, design development of heavy construction equipment is driven and evolves from the needs of the user market. Table 1.1 lists the major types of construction, the levels of typical equipment use, and examples of the work activities performed in the various types of construction.

Whether self-performing or subcontracting the work, it is the job of the project planner, estimator, and field superintendent to match the right type of machine or combinations of machines to the work to be performed. How effectively this is done will greatly influence the success of a construction project. The selection of a piece of heavy construction equipment a buyers considers today is similar to selection of a car models and accessories. There are many models of each type of equipment. The operator's cab can include air-conditioning and special ergonomic seats and controls. These are not exactly luxury amenities, but most equipment is bought for dirty outdoor work and has the basic amenities. Different selections can be made for the motor, transmission, controls, wheels, buckets, blades, and numerous other items. There are accessories and attachments for most types of work.

1.3 TOOLS TO MACHINES

Development of tools started with humans. Hands and teeth were the first tools. They were used to pick, dig, break, scrape, and shape. They were used to make other tools and shelter. Simple tools were eventually used to create a better living environment. As the tools improved, the amount and speed with which construction work could be done increased. Therefore the scale and complexity of construction projects increased. This same development cycle continues today. A very important point to remember is that the evolution limitations for heavy construction equipment lie within the construction market that is serviced.

Why use the term "evolution"? As with all inventions, dramatic steps are the results of development and testing. This is very true for the evolution of heavy construction equipment. Most major heavy construction equipment advances have been made in the last 175 years. Where we are today is not the result of one single invention, but a culmination of numerous mechanical and operating advancements. Heavy construction machines used today are the result of improvement after improvement based on the need to work more efficiently, effectively, and safely. Simply put, the design and development goal is always to reduce cost, increase speed, and enhance safety.

In parallel with equipment development, the study of productivity and cost for equipment have also become more sophisticated. Machines are designed to be extensions of the operators. Manufacturers are able to provide tested and documented technical and operating information to better help users understand impacts on their work production. Very importantly, they are able to communicate best practices to increase production and promote safe operation.

Many fundamental mechanical and operating principles for earth moving, excavating, compacting, and lifting equipment were proven and documented well before 1800. The challenge was to mechanize crude man-, horse-, mule-, or ox-drawn construction equipment that had evolved over several centuries of design enhancement. Finding a greater and more reliable power source and mechanizing the operation were key motivators for design change.

Discussion in this book will focus on the time period beginning in the early 1800s. At the turn of the 19th century, the power source for heavy construction equipment was changing from man or livestock power to steam. "One of the earliest steam-powered dredges was one recorded working in 1796 for the Port of Sunderland, England" [3]. Waterways, canals, and ports were the main modes of transporting goods so it makes sense that floating equipment powered by steam would be developed for maintenance and new construction. The first primitive roads were constructed for horse-, mule-, and ox-drawn carriages and wagons. While crude roads were constructed, perhaps as importantly, merchants were realizing that newly constructed railroads were faster and more reliable than canals for transporting large amounts of goods. The push for railroad construction in the mid-1800s was a huge catalyst for the development of land-operating earthmoving, excavating, and lifting machines.

> Historians point to the late 19th century as the era of turning-point developments in construction equipment, when industry was responding to America's growing needs. At that time, three main elements to construction equipment emerged — the power system, the carriage system and the on-board operating system. These systems were developed essentially in response to the needs of the railroad industry [2].

The availability of Cyrus McCormick's reaper in 1831 opened a new era for the development of mechanized equipment [4]. Figure 1.1 shows McCormick's invention that started the transition from tools to machines. His reaper was a mechanized land-operating unit pulled by a horse. The turning wheel on the reaper supplied power to operate a reciprocating knife that cut the grain. The primary reason for the huge success of this machine was that two people could do the job of 14 men with reaping hooks. The benefits were obvious. The ability to perform the work of many people is one of the primary reasons for the development of heavy equipment today.

McCormick was a pioneer in the use of customer-based business practices for his equipment sales too. He guaranteed coverage of 15 acres a day or the customer's money back. He allowed farmers to buy on credit and pay for purchases using an installment plan by which payment could be made over time. He educated his customers with demonstrations and training and advertised using satisfied customer testimonials. He set a fixed price for his

FIGURE 1.1 Cyrus McCormick's reaper. (Photo Courtesy of Wisconsin Historical Society Collection.)

reaper, removing the uncertainty of pricing. He developed interchangeable replacement parts and stocked them for immediate installation. He trained mechanics and traveling salesmen to service his customers. Equipment manufacturers use these business practices today as part of their marketing strategies in an ever-increasing competitive market.

1.4 DEVELOPMENT OF EARTHMOVING, EXCAVATING, AND LIFTING MACHINES

The need to lower excavation costs for railroad construction led to the development of the first steam-powered single-bucket land excavator designed by William S. Otis in 1835 shown in Figure 1.2. The shovel was rail-mounted and depended on tracks for mobility. This is perhaps the first manufactured piece of self-powered, land-operating heavy construction equipment.

Over the next several decades, the development of other tools that could be towed or pushed created a need for an equipment to replace livestock or humans as the sources of power. The first engine-powered farm tractor, the steam-powered Garrett 4CD, was introduced in 1868. Development of this tractor formally started the evolution of heavy construction equipment. Tractors ran on steel tires and soon began to be manufactured in different sizes. Numerous accessories were developed for use with a tractor. Blades were attached to the tractor front to push dirt around. Buggies pulled by tractors were used to transport excavated soil. Tractors were used for a long time as the power components for many different types of construction equipment. It was not until the mid-1900s that manufacturers started developing integrated machines designed as one unit.

The Holt Manufacturing Company manufactured the first steam-crawler tractor in 1904. It is shown in Figure 1.3. This started a new direction for industry as the back wheels were replaced with tracks. The front wheel is called a tiller wheel.

The tractor loader shown in Figure 1.4 was manufactured in the 1920s and included a cable-operated bucket attached to the front. Dirt was loaded into the bucket by propelling the tractor into a dirt pile.

Because of the market-driven nature of the development of construction equipment, historical events played a major role in creating the need for larger capacities and faster

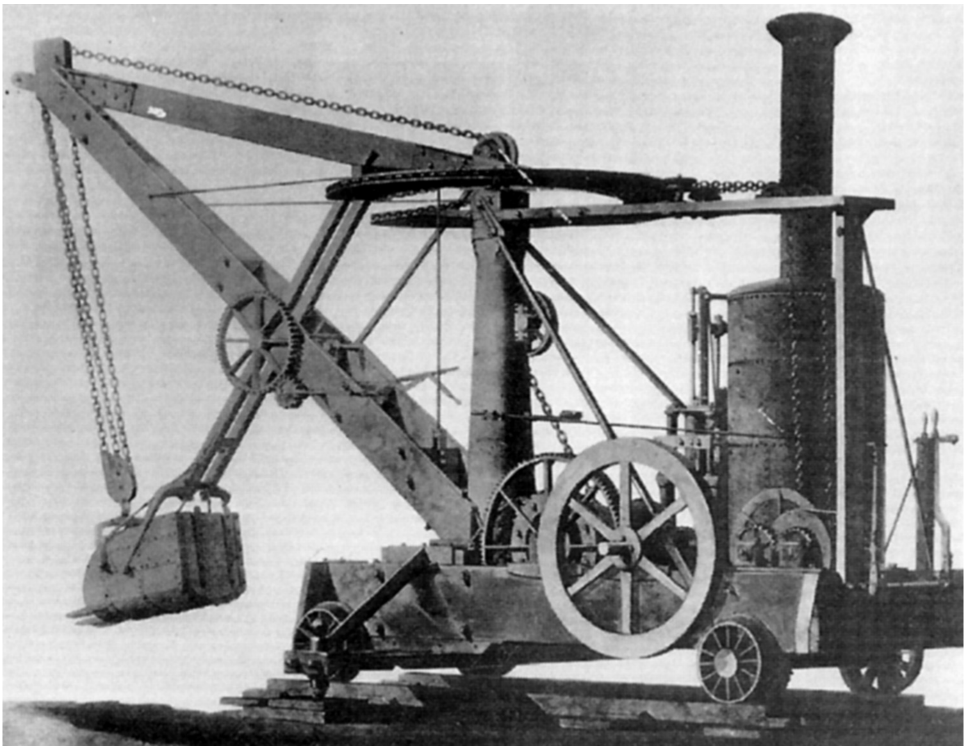

FIGURE 1.2 Otis steam excavator. (Photo Courtesy of Keith Haddock Collection.)

and safer operating equipment. The mass production of the Model T automobile in 1913 was perhaps one of the greatest indirect influences on the evolution of heavy construction equipment. The demand for roadways created a huge need for greater capacity and more powerful earth moving and excavating equipment. Ever since the enactment of the first

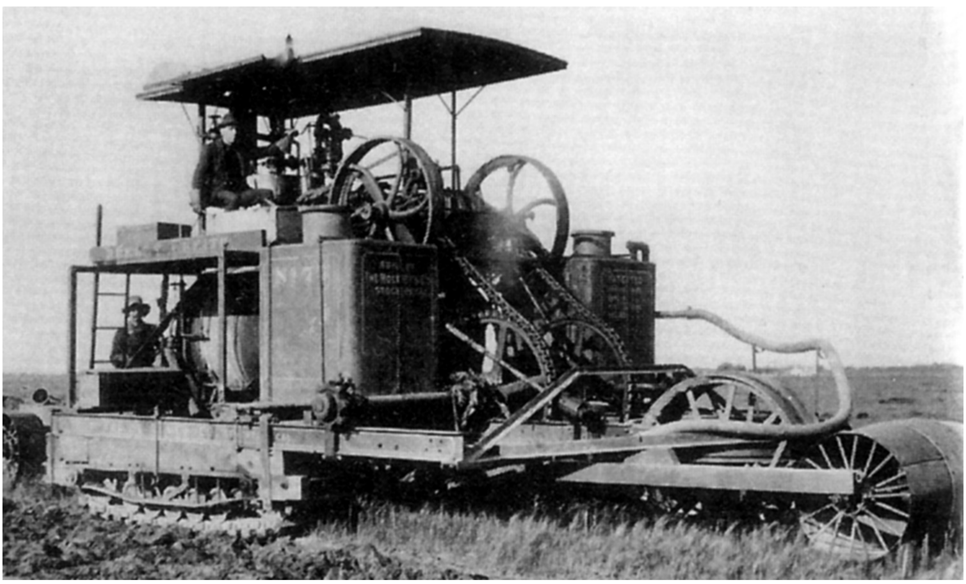

FIGURE 1.3 Holt steam crawler. (Photo Courtesy of Caterpillar Inc. Corporate Archives.)

FIGURE 1.4 Fordson tractor loader. (Photo Courtesy of Keith Haddock Collection.)

Federal Aid Road Act in 1916, the federal aid highway system has created more need for heavy construction equipment than any other sector of the economy.

Both world wars placed demands on heavy construction equipment manufacturers for different types and more versatile machines. The boom after World War II saw hydraulics replace cables as a means of equipment control. In the 1950s engines, transmissions and tires evolved into predictable efficient and maintainable components of heavy construction equipment.

Figure 1.5 depicts the major stages of infrastructure development along a time line showing first implementations of commercially available earth moving and excavating construction equipment [3,5].

With the completion of the expansion of the railroad system and dam construction, the 1960s saw an increasing amount of work in crowded urban areas. This setting brought on a new set of safety and operating considerations. The 1960s saw tremendous advances in construction techniques and associated technology for high-rise construction. The 1970s became the decade of steel-frame skyscraper construction in metropolitan areas. Development efforts were focused on building mechanized cranes with safer and more reliable control

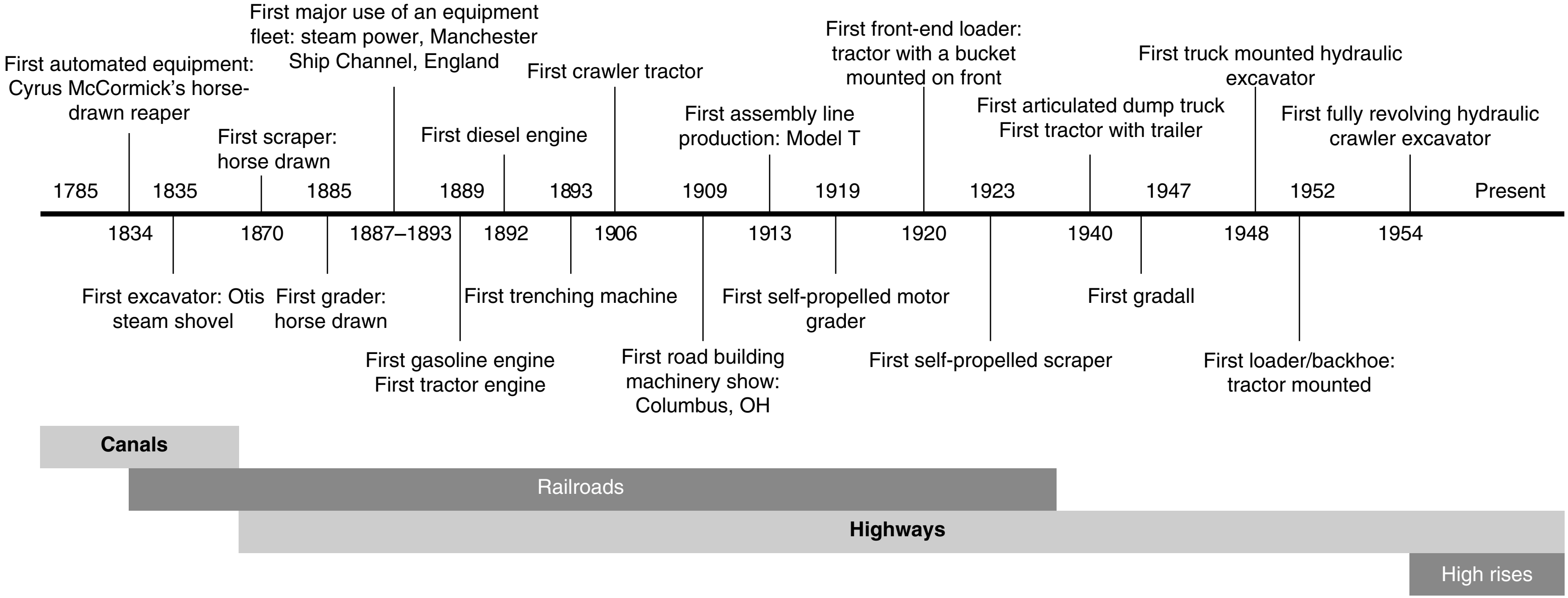

FIGURE 1.5 Earthmoving and excavating equipment development time line.

systems that could serve greater heights and capacities. It became obvious that the ability to lift greatly influenced the efficiency of building higher structures. Figure 1.6 depicts the major stages of infrastructure development along a time line showing first implementations of commercially available lifting equipment [1].

Public attention and funding were also focused on designing and building mass-transit systems, water supply and treatment facilities, and utility and communications facilities. The Occupational Safety and Health Administration (OSHA) was created in 1971. Ensuring safe and healthful working conditions for working men and women included ensuring the safety of construction equipment. Protective cab enclosures, automatic safety devices, noise, vibration, and dust control were only a few of the issues concerning construction equipment that OSHA included in its regulations.

1.5 HEAVY CONSTRUCTION EQUIPMENT TODAY

Today there are an estimated 1.3-million off-highway machines operating in the United States alone. Civil, highway, and building construction companies are the largest users. Table 1.2 to Table 1.4 show major heavy construction equipment manufacturers located around the world. An "x" in a column denotes the production of this type of earthmoving, excavating, compacting, or lifting equipment by the specific manufacturer. The largest equipment producer in the world is Caterpillar.

Standard Industrial Classification (SIC) categories are used by the Department of Labor — OSHA to classify manufacturers. Statistical data related to the manufacture of equipment used in the construction industry can be found in the two SIC categories listed below [6].

- Construction Machinery and Equipment — SIC 3531: This category includes "establishments primarily engaged in manufacturing heavy machinery and equipment of a type used primarily by the construction industries."
- Industrial Trucks, Tractors, Trailers, and Stackers — SIC 3537: This category includes "establishments primarily engaged in manufacturing industrial trucks, tractors, trailers, stackers (truck type), and related equipment, used for handling materials on floors and paved surfaces in and around industrial and commercial plants, depots, docks, airports, and terminals."

1.6 FUTURE OF HEAVY CONSTRUCTION EQUIPMENT

The physical needs to perform construction work have not changed very much. The work to be done changes based on the type of project, but the activities that have to be performed are similar for all projects. Activities include site work, the base or foundation, structure, and associated parts or connections. It could be a building, highway, dam, or refinery. The amount and types of machines required may vary, but the need for heavy construction equipment will always exist.

Development and evolution of heavy construction equipment is predictable in many ways. If we need bigger, we build bigger. If we need something new, we build it. Tempered by economic reality, equipment will be refined with necessity driving the design and development just as it has from the beginning. That is the past and the future for heavy construction equipment development.

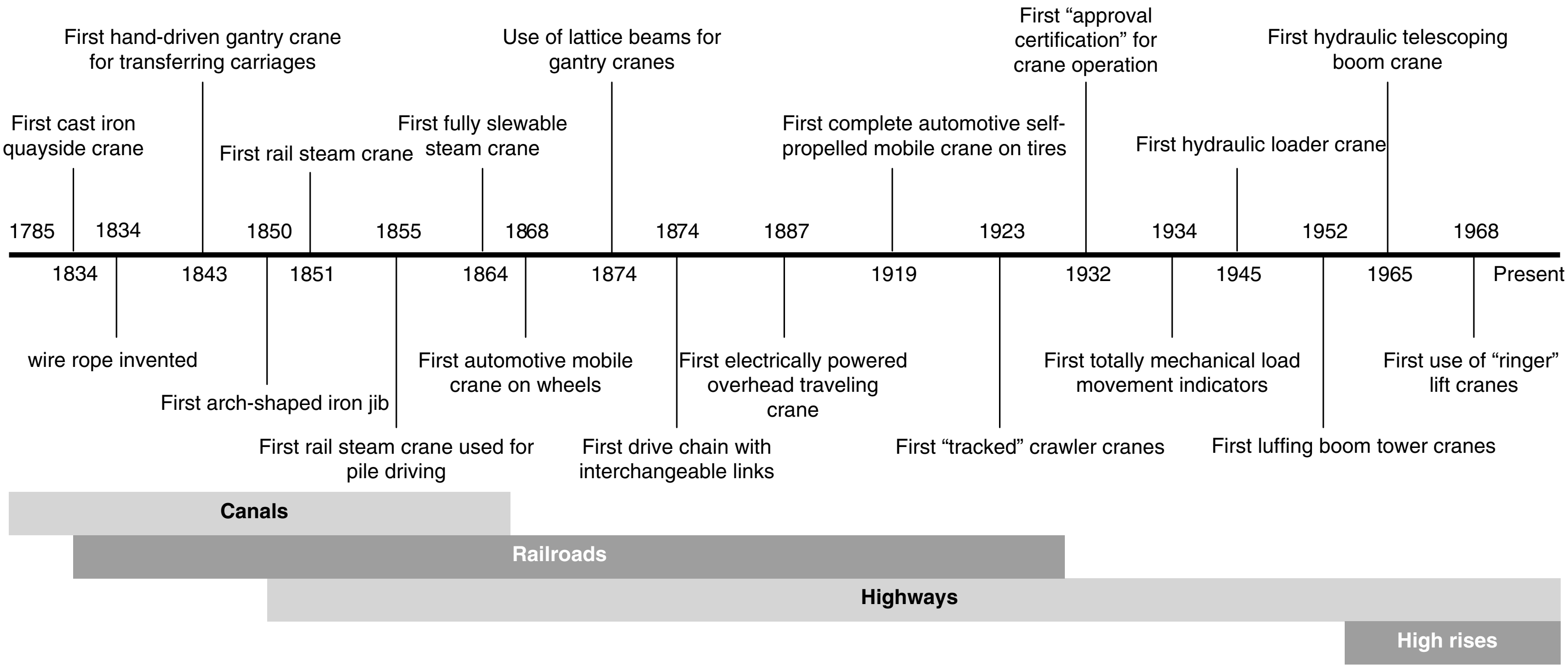

FIGURE 1.6 Lifting equipment development time line.

TABLE 1.2
Heavy Equipment Manufacturers (Earth moving)

	Tractor	Bulldozer	Motor Grader	Scraper	Wheel Loader	Front-End Loader	Truck
Aichi							
Allmand							
Alitec							
Al-Jon				×			
American							
Ammann							
ASV					×		
Badger							
Bitelli							
Bomag							
Bobcat					×		
Broderson							
Bronto							
Carelift							
Case	×	×	×		×	×	×
Caterpillar	×	×	×	×	×	×	×
Champion			×				
Daewoo					×	×	
Deere	×	×	×	×	×	×	×
Demag/Terrex							
Ditch Witch							
Dresser		×			×	×	×
Dynapac							
Galion			×				
Gehl					×	×	
Genie							
Gradall							
Grove							
Halla							
Hamm							
Hitachi					×		×
Hypac							
Hyster							
Hyundai		×			×	×	
Ingersoll-Rand						×	
JLG							
JCB					×	×	×
Kawasaki					×		
Kobelco							
Komatsu		×	×		×	×	×
Kroll							
Kubota	×				×		
Little Giant							
Letourneau					×	×	
Liebherr		×			×	×	×

Continued

TABLE 1.2 (Continued)
Heavy Equipment Manufacturers (Earth moving)

	Tractor	Bulldozer	Motor Grader	Scraper	Wheel Loader	Front-End Loader	Truck
Link Belt							
Lull							
Manlift							
Manitex							
Manitowoc							
Marklift							
Mitsubishi		×	×		×		×
Moxy							×
Mustang					×		
National							
New Holland	×	×	×		×	×	
Parsons							
Pettibone							
Potain							
Rammax							
Sakai							
Samsung						×	
Schaeff/Terex					×	×	
SDM (Russian)		×	×		×	×	×
Sellick							
Shuttlelift							
Simon							
Sky Trac							
Snorkle							
Starlifter							
Stone							
Sumitomo							
Superpac							
Takeuchi						×	
Terex				×	×	×	×
Terramite						×	
Tesmec							
Toyota							
Upright							
Wabco			×				
Wacker							
Waldon		×				×	
Vermeer		×					
Volvo			×		×	×	×
Yuchai		×					

It is interesting to note that earthmoving, excavating, compacting, and lifting mechanical principles incorporated into today's designs will probably not change much in the future. These principles have not changed since man started developing tools. Perhaps the definition of "earthmoving" will be changed to include surface material from another planet. The work environment, power source, and operator may change drastically to something that we have

TABLE 1.3
Heavy Equipment Manufacturers (Excavating and Compacting)

	Excavating			Compacting			
	Excavator	Backhoe	Trencher	Soil	Asphalt	Pneumatic	Landfill
Aichi							
Allmand		×					
Alitec				×			
Al-Jon							×
American							
Ammann				×			
ASV							
Badger	×						
Bitelli				×	×	×	
Bomag				×	×	×	×
Bobcat	×	×					
Broderson							
Bronto							
Carelift							
Case	×	×	×	×	×		
Caterpillar	×	×	×	×	×	×	×
Champion							
Daewoo	×						
Deere	×	×					
Demag/Terrex							
Ditch Witch			×				
Dresser		×					
Dynapac				×	×	×	
Galion							
Gehl	×						
Genie							
Gradall	×						
Grove							
Halla	×						
Hamm				×	×	×	
Hitachi	×						
Hypac				×	×	×	
Hyster							
Hyundai	×						
Ingersoll-Rand	×	×		×	×	×	
JLG							
JCB	×	×					
Kawasaki							
Kobelco	×	×					
Komatsu	×	×					
Kroll							
Kubota							
Little Giant							
Letourneau							
Liebherr	×	×	×				
Link Belt	×						

Continued

TABLE 1.3 (Continued)
Heavy Equipment Manufacturers (Excavating and Compacting)

	Excavating			Compacting			
	Excavator	Backhoe	Trencher	Soil	Asphalt	Pneumatic	Landfill
Lull							
Manlift							
Manitex							
Manitowoc	×						
Marklift							
Mitsubishi							
Moxy							
Mustang	×						
National							
New Holland	×	×					
Parsons			×				
Pettibone							
Potain							
Rammax				×	×	×	
Sakai				×	×	×	
Samsung	×						
Schaeff/Terex	×						
SDM (Russian)	×			×	×	×	
Sellick							
Shuttlelift							
Simon							
Sky Trac							
Snorkle							
Starlifter							
Stone				×	×		
Sumitomo	×						
Superpac				×	×	×	
Takeuchi	×						
Terex	×	×		×	×		×
Terramite		×					
Tesmec			×				
Toyota							
Upright							
Wabco							
Wacker				×	×		
Waldon							
Vermeer	×		×				
Volvo	×	×					
Yuchai	×						

not imagined or not yet discovered. As long as big structures are assembled and rest on surfaces, there will be a need for heavy construction equipment.

Several notable trends are emerging in the design and manufacturing of these machines. Application of computer technology will provide the most significant changes in equipment design and use. Computer control of equipment systems is used to regulate and control fuel delivery and efficiency, exhaust emissions, hydraulic systems, power transfer, load sensing,

TABLE 1.4
Heavy Equipment Manufacturers (Lifting)

	Mobile Tires	Mobile Tracks	Tower	Forklift	Personnel Lift
Aichi					×
Allmand					×
Alitec					
Al-Jon					
American		×			
Ammann					
ASV					
Badger					
Bitelli					
Bomag					
Bobcat					
Broderson	×				
Bronto	×				
Carelift	×				
Case	×				
Caterpillar	×				
Champion					
Daewoo				×	
Deere					
Demag/Terrex	×	×			
Ditch Witch					
Dresser					
Dynapac					
Galion					
Gehl	×				
Genie	×				×
Gradall	×				
Grove	×				×
Halla					
Hamm					
Hitachi		×		×	×
Hypac					
Hyster	×			×	
Hyundai				×	
Ingersoll-Rand	×			×	×
JLG	×				×
JCB	×			×	
Kawasaki				×	
Kobelco					
Komatsu					
Kroll			×		
Kubota					
Little Giant		×			
Letourneau			×		
Liebherr	×	×	×	×	
Link Belt	×	×			

Continued

TABLE 1.4 (Continued)
Heavy Equipment Manufacturers (Lifting)

	Mobile Tires	Mobile Tracks	Tower	Forklift	Personnel Lift
Lull	×				
Manlift					×
Manitex	×			×	
Manitowoc		×	×		
Marklift					×
Mitsubishi				×	
Moxy					
Mustang				×	
National	×				
New Holland	×				
Parsons					
Pettibone	×				
Potain	×		×		
Rammax					
Sakai					
Samsung					
Schaeff/Terex					
SDM (Russian)				×	
Sellick	×				
Shuttlelift	×				
Simon					×
Sky Trac	×				
Snorkle					×
Starlifter		×			
Stone					
Sumitomo					
Superpac					
Takeuchi					
Terex	×	×	×		×
Terramite					
Tesmec					
Toyota				×	
Upright					×
Wabco					
Wacker					
Waldon				×	
Vermeer					
Volvo					
Yuchai					

and operation tracking, recording, and regulating. Wireless technologies will increase monitoring and controlling features for equipment fleet management and production, eventually making remote operation of equipment a commercially available reality.

Lighter weight and stronger components made possible by advances in development of composite materials and alloys are making it possible for manufacturers to make smaller equipment units with greater power and productivity characteristics. These advancements reinforce the trend to reduce construction equipment size and increase its capability and versatility.

Environmental considerations and mandates will play a larger role in the development of construction equipment. This will always remain an important consideration for equipment design. As with vehicles, incorporation of pollution control systems and sensing equipment will become more prevalent as environmental concerns become greater. As new power solutions such as alternate cleaner performing fuels, electric power, and hydrogen fuel cells are developed and incorporated into automobiles, they will probably be developed to power heavy construction equipment too.

Equipment models will incorporate more operator amenities. Ergonomic features such as customizable seats, user-friendly controls and foot pedals, noise control, and optimal cab orientation will become standard features.

Several notable trends are expected in the construction industry. The equipment rental and leasing markets for construction equipment will continue to grow. The minimization of cost and liability for contractors needing specific equipment for short durations drives this industry. The used equipment market has found a home on the Internet. It is the ideal medium for advertising and communicating to the worldwide market. The ability to conveniently sell and purchase used equipment has reduced the liability of ownership arising when contractors might purchase a piece of equipment for a specific project and sell it at the project's end.

The public works and infrastructure construction market should be consistent due to necessary replacement in the next few decades. Rehabilitation of road surfaces and bridge repair will be a large segment of this market, placing consistent demands on civil contractors. The amount of local, state, and federal funding for these projects will obviously influence the amount of work. Environmental cleanup has a potential to create a small boom in the construction equipment and employment market. These types of risky construction activities will see the development of robotics and remote systems. Residential, commercial, and industrial markets will continue to fluctuate based on the changing economic climate.

A major challenge for the U.S. construction equipment industry will be adjustment to the emerging and dynamic global economy. U.S. companies are faced with increasing competition from foreign manufacturers in countries like South Korea, Japan, Germany, and the U.K. The number of companies manufacturing construction machinery, industrial trucks, and tractors has decreased in the last 20 years. This trend will likely continue as large companies absorb smaller companies to minimize competition and offer more diverse ranges of equipment.

The following statement sums up the impact of construction equipment on our past and probably on our future:

> In a period of less than 50 years, American engineering and construction delivered such colossal feats as the skyscraper and the interstate highway system. None of these would have been possible in such a historically short period of time without the aid of construction equipment. Construction equipment and machinery were, in effect, great inventions which became the instruments that turned other great ideas and designs into reality [2].

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2 Cost of Owning and Operating Construction Equipment

2.1 INTRODUCTION

A thorough understanding of both estimated and actual costs of operating and owning equipment drives profitable equipment management. This chapter develops that understanding in detail and helps the reader understand the calculations that go into determining the fundamental costs for an equipment-intensive project.

Plant, equipment, and tools used in construction operations are priced in the following three categories in the estimate:

1. *Small tools and consumables*: Hand tools up to a certain value together with blades, drill bits, and other consumables used in the project are priced as a percentage of the total labor price of the estimate.
2. *Equipment usually shared by a number of work activities*: These kinds of equipment items are kept at the site over a period of time and used in the work in progress.
3. *Equipment used for specific tasks*: These are capital items and used in projects such as digging trench or hoisting material into specified slots. This equipment is priced directly against the take-off quantities for the Project it is to be used on. The equipment is not kept on-site for extended periods like those in the previous classification, but the equipment is shipped to the site, used for its particular task, and then immediately shipped back to its original location. Excavation equipment, cranes, hoisting equipment, highly specialized, and costly items such as concrete saws fall into this category.

This chapter's focus is on estimating the cost of owning and operating construction equipment of the third category. For contractors in the heavy civil construction industry, the cost of owning and operating equipment is a key part of doing business in a profitable manner. Failing to properly estimate equipment cost has led many contractors into hardship. Without knowing the actual equipment ownership costs, contractors might report higher-than-justified paper profits due to inaccurate accounting practices that do not factor the cost of idle equipment into the company's overall profit picture. Then at the end of the year, they find that they had not accounted for the incurred costs of idle equipment impacting the actual profit margin. This situation is particularly dangerous in a declining market where the contractor's annual volume is lower than normal due to fewer projects getting executed. It can also happen in growing companies that have not yet developed a mature database to estimate actual equipment costs.

Total equipment costs comprise two separate components: ownership costs and operating costs. Except for the one-time initial capital cost of purchasing the machine, ownership costs are fixed costs that are incurred each year, regardless of whether the equipment is operated or idle. Operating costs are the costs incurred only when the equipment is used. Each cost has different characteristics of its own and is calculated using different methods. None of these methods will give exact costs of owning and operating equipment for any given set of circumstances. This is because of the large number of variables involved, which is because of the uncertain nature of the construction business. One should consider these estimates as close approximations while calculating ownership and operating costs.

2.2 OWNERSHIP COST

Ownership costs are fixed costs. Almost all of these costs are annual in nature and include:

- Initial capital cost
- Depreciation
- Investment (or interest) cost
- Insurance cost
- Taxes
- Storage cost

2.2.1 Initial Cost

On an average, initial cost makes up about 25% of the total cost invested during the equipment's useful life [1]. This cost is incurred for incurred for getting equipment into the contractor's yard, or construction site, and having the equipment ready for operation. Many kinds of ownership and operating costs are calculated using initial cost as a basis, and normally this cost can be calculated accurately. Initial cost consists of the following items:

- Price at factory + extra equipment + sales tax
- Cost of shipping
- Cost of assembly and erection

2.2.2 Depreciation

Depreciation represents the decline in market value of a piece of equipment due to age, wear, deterioration, and obsolescence. Depreciation can result from:

- Physical deterioration occurring from wear and tear of the machine
- Economic decline or obsolescence occurring over the passage of time

In the appraisal of depreciation, some factors are explicit while other factors have to be estimated. Generally, the asset costs are known which include:

- *Initial cost*: The amount needed to acquire the equipment
- *Useful life*: The number of years it is expected to be of utility value
- *Salvage value*: The expected amount the asset will be sold at the end of its useful life

However, there is always some uncertainty about the exact length of the useful life of the asset and about the precise amount of salvage value, which will be realized when the asset is disposed. Any assessment of depreciation, therefore, requires these values to be estimated. Among many depreciation methods, the straight-line method, double-declining balance method, and sum-of-years'-digits method are the most commonly used in the construction equipment industry [2] and will be discussed below. At this point, it is important to state that the term depreciation as used in this chapter is meant to represent the change in the assets value from year to year and as a means of establishing an hourly "rental" rate for that asset. It is not meant in the same exact sense as is used in the tax code. The term "rental rate" is the rate the equipment owner charges the clients for using the equipment, i.e., the project users "rent" the equipment from its owner.

In calculating depreciation, the initial cost should include the costs of delivery and start-up, including transportation, sales tax, and initial assembly. The equipment life used in calculating depreciation should correspond to the equipment's expected economic or useful life. The reader can consult the references at the end of this chapter for a more thorough discussion of the intricacies of depreciation.

2.2.2.1 Straight-Line Depreciation

Straight-line depreciation is the simplest to understand as it makes the basic assumption that the equipment will lose the same amount of value in every year of its useful life until it reaches its salvage value. The depreciation in a given year can be expressed by the following equation:

$$D_n = \frac{\mathrm{IC} - S - \mathrm{TC}}{N} \tag{2.1}$$

where D_n is the depreciation in year n, IC the initial cost (\$), S the salvage value (\$), TC the tire and track costs (\$), N the useful life (years), and $D_1 = D_2 = \cdots = D_n$.

2.2.2.2 Sum-of-Years′-Digits Depreciation

The sum-of-years'-digits depreciation method tries to model depreciation assuming that it is not a straight line. The actual market value of a piece of equipment after 1 year is less than the amount predicted by the straight-line method. Thus, this is an accelerated depreciation method and models more annual depreciation in the early years of a machine's life and less in its later years. The calculation is straightforward and done using the following equation:

$$D_n = \frac{(\text{year ``}n\text{'' digit})}{1 + 2 + \cdots + N}(\mathrm{IC} - S - \mathrm{TC}) \tag{2.2}$$

where D_n is the depreciation in year n, year n digit is the reverse order: n if solving for D_1 or 1 if solving for D_n, IC the initial cost (\$), S the salvage value (\$), TC the tire and track costs (\$), and N the useful life (years).

2.2.2.3 Double-Declining Balance Depreciation

The double-declining balance depreciation is another method for calculating an accelerated depreciation rate. It produces more depreciation in the early years of a machine's useful life than the sum-of-years'-digits depreciation method. This is done by depreciating the "book value" of the equipment rather than just its initial cost. The book value in the second year is merely the initial cost minus the depreciation in the first year. Then the book value in the next year is merely the book value of the second year minus the depreciation in the second year, and so on until the book value reaches the salvage value. The estimator has to be careful when using this method and ensure that the book value never drops below the salvage value:

$$D_n = \frac{2}{N}(\mathrm{BV}_{n-1} - \mathrm{TC}) \tag{2.3}$$

where D_n is the depreciation in year n, TC the tire and track costs ($), N the useful life (years), BV_{n-1} the book value at the end of the previous year, and $\mathrm{BV}_{n-1} \geq S$.

Example 2.1 Compare the depreciation in each year of the equipment's useful life for each of the above depreciation methods for the following wheeled front-end bucket loader:

- *Initial cost*: $148,000 includes delivery and other costs
- *Tire cost*: $16,000
- *Useful life*: 7 years
- *Salvage value*: $18,000.

A sample calculation for each method will be demonstrated and the results are shown in Table 2.1.

Straight-line method: From Equation 2.1, the depreciation in the first year D_1 is equal to the depreciation in all the years of the loader's useful life:

$$D_1 = \frac{\$148{,}000 - \$18{,}000 - \$16{,}000}{7\ \text{years}} = \$16{,}286/\text{year}$$

Sum-of-years'-digits method: From Equation 2.2, the depreciation in the first year D_1 and the second year D_2 are:

$$D_1 = \frac{7}{1+2+3+4+5+6+7}(\$148{,}000 - \$18{,}000 - \$16{,}000) = \$28{,}500$$

$$D_2 = \frac{6}{1+2+3+4+5+6+7}(\$148{,}000 - \$18{,}000 - \$16{,}000) = \$24{,}429$$

Double-declining balance method: From Equation 2.2, the depreciation in the first year D_1 is

$$D_1 = \frac{2}{7}(\$148{,}000 - \$16{,}000) = \$37{,}714$$

and the "book value" at the end of Year 1 = $148,000 – $16,000 – $37,714 = $94,286.

However, in Year 6, this calculation would give an annual depreciation of $7,012 which when subtracted from the book value at the end of Year 5 gives a book value of $17,531 for Year 6. This is less than the salvage value of $18,000; therefore, the depreciation in Year 6 is

TABLE 2.1
Depreciation Method Comparison for Wheeled Front-End Loader

	Year						
Method	**1**	**2**	**3**	**4**	**5**	**6**	**7**
SL (D_n)	$16,286	$16,286	$16,286	$16,286	$16,286	$16,286	$16,286
SOYD (D_n)	$28,500	$24,429	$20,357	$16,286	$12,214	$8,143	$4,071
DDB (D_n)	$37,714	$26,939	$19,242	$13,744	$9,817	$6,543	$0
DDB (BV)	$94,286	$67,347	$48,105	$34,361	$24,543	$18,000	$18,000

reduced to the amount that would bring the book value to be equal to the salvage value or \$6,543, and the depreciation in Year 7 is taken as zero, which means that the machine was fully depreciated by the end of Year 6.

Selecting a depreciation method for computing ownership cost is a business policy decision. Thus, this book will method any particular. The U.S. Internal Revenue Service publishes a guide that details the allowable depreciation for tax purposes, and many companies choose to follow this in computing the ownership costs. As stated before, the purpose of calculating the depreciation amount is to arrive at an hourly rental rate so that the estimator can use this figure out the cost of equipment-intensive project features of work, and not to develop an accounting system that serves to alter a given organization's tax liabilities. While this obviously impacts a company's ultimate profitability, this book separates tax costs from tax consequences, leaving the tax consequences of business policy decisions for the accountants rather than the estimators.

2.2.3 Investment (or Interest) Cost

Investment (or interest) cost represents the annual cost (converted into an hourly cost) of capital invested in a machine [2]. If borrowed funds are utilized for purchasing a piece of equipment, the equipment cost is simply the interest charged on these funds. However, if the equipment is purchased with company assets, an interest rate that is equal to the rate of return on company investment should be charged. Therefore, investment cost is computed as the product of interest rate multiplied by the value of the equipment, which is then converted into cost per hour of operation.

The average annual cost of interest should be based on the average value of the equipment during its useful life. The average value of equipment may be determined from the following equation:

$$P = \frac{\mathrm{IC}(n+1)}{2} \tag{2.4}$$

where IC is the total initial cost, P the average value, and n the useful life (years).

This equation assumes that a unit of equipment will have no salvage value at the end of its useful life. If a unit of equipment has salvage value when it is disposed of, the average value during its life can be obtained from the following equation:

$$P = \frac{\mathrm{IC}(n+1) + S(n-1)}{2n} \tag{2.5}$$

where IC is the total initial cost, P the average value, S the salvage value, and n the useful life (years).

Example 2.2 Consider a unit of equipment costing \$50,000 with an estimated salvage value of \$15,000 after 5 years. Using Equation (2.5), the average value is

$$\begin{aligned} P &= \frac{50{,}000(5+1) + 15{,}000(5-1)}{2(5)} \\ &= \frac{300{,}000 + 60{,}000}{10} \\ &= \$36{,}000 \end{aligned}$$

2.2.4 Insurance Tax and Storage Costs

Insurance cost represents the cost incurred due to fire, theft, accident, and liability insurance for the equipment. Tax cost represents the cost of property tax and licenses for the equipment. Storage cost includes the cost of rent and maintenance for equipment storage yards, the wages of guards and employees involved in moving equipment in and out of storage, and associated direct overhead.

The cost of insurance and tax for each item of equipment may be known on an annual basis. In this case, this cost is simply divided by the hours of operation during the year to yield the cost per hour for these items. Storage costs are usually obtained on an annual basis for the entire equipment fleet. Insurance and tax costs may also be known on a fleet basis. It is then necessary to prorate these costs to each item. This is usually done by converting the total annual cost into a percentage rate, then dividing these costs by the total value of the equipment fleet. By doing so, the rate for insurance, tax, and storage may simply be added to the investment cost rate for calculating the total annual cost of investment, insurance, tax, and storage [2].

The average rates for interest, insurance, tax, and storage found in the literature are listed in Table 2.2 [2–5]. These rates will vary according to related factors such as the type of equipment and location of the job site.

2.3 TOTAL OWNERSHIP COST

Total equipment ownership cost is calculated as the sum of depreciation, investment cost, insurance cost, tax, and storage cost. As mentioned earlier, the elements of ownership cost are often known on an annual cost basis. However, while the individual elements of ownership cost are calculated on an annual cost basis or on an hourly basis, total ownership cost should be expressed as an hourly cost.

After all elements of ownership costs have been calculated, they can be summed up to yield total ownership cost per hour of operation. Although this cost may be used for estimating and for charging equipment cost to projects, it does not include job overhead or profit. Therefore, if the equipment is to be rented to others, overhead and profit should be included to obtain an hourly rental rate.

Example 2.3 Calculate the hourly ownership cost for the second year of operation of a 465 hp twin-engine scraper. This equipment will be operated 8 h/day and 250 days/year in average conditions. Use the sum-of-years'-digits method of depreciation as the following information:

- *Initial cost*: $186,000
- *Tire cost*: $14,000
- *Estimated life*: 5 years

TABLE 2.2
Average Rates for Investment Costs

Item	Average Value (%)
Interest	3–9
Tax	2–5
Insurance	1–3
Storage	0.5–1.5

- *Salvage value*: \$22,000
- *Interest on the investment*: 8%
- *Insurance*: 1.5%
- *Taxes*: 3%
- *Storage*: 0.5%
- *Fuel price*: \$2.00/gal
- *Operator's wages*: \$24.60/h

$$\text{Depreciation in the second year} = \frac{4}{15}(186{,}000 - 22{,}000 - 14{,}000) = \$40{,}000$$
$$= \frac{40{,}000}{8(250)} = \$20.00/\text{h}$$

Investment cost, tax, insurance, and storage cost:

$$\text{Cost rate} = \text{investment} + \text{tax, insurance, and storage} = 8 + 3 + 1.5 + 0.5 = 13\%$$

$$\text{Average investment} = \frac{186{,}000 \pm 22{,}000}{2(5)} = \$20{,}800$$

$$\text{Investment, tax, insurance, and storage} = \frac{84{,}000(0.18)}{2000} = \$7.56/\text{h}$$

$$\text{Total ownership cost} = 16.53 + 7.56 = \$24.09/\text{h}$$

2.4 COST OF OPERATING CONSTRUCTION EQUIPMENT

Operating costs of the construction equipment, which represent a significant cost category and should not be overlooked, are the costs associated with the operation of a piece of equipment. They are incurred only when the equipment is actually used. The operating costs of the equipment are also called "variable" costs because they depend on several factors, such as the number of operating hours, the types of equipment used, and the location and working condition of the operation.

The operating costs vary with the amount of equipment used and job-operating conditions. The best basis for estimating the cost of operating construction equipment is the use of historical data from the experience of similar equipment under similar conditions. If such data is not available, recommendations from the equipment manufacturer could be used.

2.4.1 Maintenance and Repair Cost

The cost of maintenance and repairs usually constitutes the largest amount of operating expense for the construction equipment. Construction operations can subject equipment to considerable wear and tear, but the amount of wear varies enormously between the different items of the equipment used and between different job conditions. Generally, the maintenance and repair costs get higher as the equipment gets older. Equipment owners will agree that

TABLE 2.3
Range of Typical Lifetime Repair Costs from the Literature [2,5,6]

	Initial Cost without Tires (%)		
	Operating Conditions		
Equipment Type	**Favorable**	**Average**	**Unfavorable**
Crane	40–45	50–55	60–70
Excavator crawler	50–60	70–80	90–95
Excavator wheel	75	80	85
Loader track	80–85	90	100–105
Loader wheel	50–55	60–65	75
Motor grader	45–50	50–55	55–60
Scraper	85	90–95	105
Tractor crawler	85	90	95
Tractor wheel	50–55	60–65	75
Truck, off-highway	70–75	80–85	90–95

good maintenance, including periodic wear measurement, timely attention to recommended service and daily cleaning when conditions warrant it, can extend the life of the equipment and actually reduce the operating costs by minimizing the effects of adverse conditions. All items of plant and equipment used by construction contractors will require maintenance and probably also require repairs during the course of their useful life. The contractor who owns the equipment usually sets up facilities for maintenance and engages the workers qualified to perform the necessary maintenance operations on the equipment.

The annual cost of maintenance and repairs may be expressed as a percentage of the annual cost of depreciation or it may be expressed independently of depreciation. The hourly cost of maintenance and repair can be obtained by dividing the annual cost by its operating hours per year. The hourly repair cost during a particular year can be estimated by using the following formula [2]:

$$\text{Hourly repair cost} = \frac{\text{year digit}}{\text{sum-of-years'-digits}} \times \frac{\text{lifetime repair cost}}{\text{hours operated}} \tag{2.6}$$

The lifetime repair cost is usually estimated as a percentage of the equipment's initial cost deducting the cost of tires. It is adjusted by the operating condition factor obtained from Table 2.3.

Example 2.4 Estimate the hourly repair cost of the scraper in Example 2.3 for the second year of operation. The initial cost of the scraper is \$186,000, tire cost \$14,000, and its useful life is 5 years. Assume average operating condition and 2000 h of operation per year.

$$\text{Lifetime repair cost factor} = 0.90$$

$$\text{Lifetime repair cost} = 0.90(186{,}000 - 14{,}000) = \$154{,}800$$

$$\text{Hourly repair cost} = \frac{2}{15}\left(\frac{154{,}800}{2000}\right) = \$10.32/\text{h}$$

TABLE 2.4
Range of Typical Tire Life from the Literature [2,5]

	Average Tire Life (h)		
	Operating Conditions		
Equipment Type	**Favorable**	**Average**	**Unfavorable**
Loader wheel	3200–4000	2100–3500	1300–2500
Motor grader	5000	3200	1900
Scraper single engine	4000–4600	3000–3300	2500
Scraper twin engine	3600–4000	3000	2300–2500
Scraper elevating	3600	2700	2100–2250
Tractor wheel	3200–4000	2100–3000	1300–2500
Truck, off-highway	3500–4000	2100–3500	1100–2500

2.4.2 Tire Cost

The tire cost represents the cost of tire repair and replacement. Because the life expectancy of rubber tires is generally far less than the life of the equipment on which they are used on, the depreciation rate of tires will be quite different from the depreciation rate of the rest of the vehicle. The repair and maintenance cost of tires as a percentage of their depreciation will also be different from the percentage associated with the repair and maintenance of the vehicle. The best source of information in estimating tire life is the historical data obtained under similar operating conditions. Table 2.4 lists the typical ranges of tire life found in the most recent literature on the subject for various types of equipment.

Tire repair cost can add about 15% to tire replacement cost. So, the following equation may be used to estimate tire repair and replacement cost:

$$\text{Tire repair and replacement costs} = 1.15 \times \frac{\text{cost of a set of tires (\$)}}{\text{expected tire life (h)}} \tag{2.7}$$

2.4.3 Consumable Costs

Consumables are the items required for the operation of a piece of equipment that literally gets consumed in the course of its operation. These include, but are not limited to, fuel, lubricants, and other petroleum products. They also include filters, hoses, strainers, and other small parts and items that are used during the operation of the equipment.

2.4.3.1 Fuel Cost

Fuel consumption is incurred when the equipment is operated. When operating under standard conditions, a gasoline engine will consume approximately 0.06 gal of fuel per flywheel horsepower hour (fwhp-h), while a diesel engine will consume approximately 0.04 gal/fwhp-h. A horsepower hour is a measure of the work performed by an engine.

The hourly cost of fuel is estimated by multiplying the hourly fuel consumption by the unit cost of fuel. The amount of fuel consumed by the equipment can be obtained from the historical data. When the historical data is not available, Table 2.5 gives approximate fuel consumption (gal/h) for major types of equipment.

TABLE 2.5
Average Fuel Consumption Factors (gal/h/hp) [2,5]

	Working Conditions (gal/h/hp)		
Equipment Type	**Favorable**	**Average**	**Unfavorable**
Loader track	0.030–0.034	0.040–0.042	0.046–0.051
Loader wheel	0.020–0.024	0.027–0.036	0.031–0.047
Motor grader	0.022–0.025	0.029–0.035	0.036–0.047
Scraper single engine	0.023–0.026	0.029–0.035	0.034–0.044
Scraper twin engine	0.026–0.027	0.031–0.035	0.037–0.044
Tractor crawler	0.028–0.342	0.037–0.399	0.046–0.456
Tractor wheel	0.020–0.028	0.026–0.038	0.031–0.052
Truck, off-highway	0.017–0.029	0.023–0.037	0.029–0.046
Truck, on-highway	0.014–0.029	0.020–0.037	0.026–0.046

Example 2.5 Calculate the average hourly fuel consumption and hourly fuel cost for a twin-engine scraper in Example 2.3. It has a diesel engine rated at 465 hp and fuel cost $2.00/gal. During a cycle of 20 s, the engine may be operated at full power, while filling the bowl in tough ground requires 5 s. During the balance of the cycle, the engine will use no more than 50% of its rated power. Also, the scraper will operate about 45 min/h on average. For this condition, the approximate amount of fuel consummated during 1 h is determined as follows:

Rated power: 465 hp
Engine factor: 0.5
Filling the bowl, 5 s/20 s cycle = 0.250
Rest of cycle, 15/20 × 0.5 = 0.375
Total cycle = 0.625
Time factor, 45 min/60 min = 0.75
Operating factor, 0.625 × 0.75 = 0.47
From Table 2.5: use "unfavorable" fuel consumption factor = 0.040
Fuel consumed per hour: 0.47(465)(0.040) = 8.74 gal
Hourly fuel cost: 8.74 gal/h ($2.00/gal) = $17.48/h.

2.4.3.2 Lubricating Oil Cost

The quantity of oil required by an engine per change will include the amount added during the change plus the make-up oil between changes. It will vary with the engine size, the capacity of crankcase, the condition of the piston rings, and the number of hours between oil changes. It is a common practice to change oil every 100 to 200 h [6].

The quantity of oil required can be estimated by using the following formula [6]:

$$q = \frac{0.006(\text{hp})(f)}{7.4} + \frac{c}{t} \tag{2.8}$$

where q is the quantity consumed (gal/h), hp the rated horsepower of engine, c the capacity of crankcase (gal), f the operating factor, t the number of hours between changes, the consumption rate 0.006 lbs/hp-h, and the conversion factor 7.4 lbs/gal.

The consumption data or the average cost factors for oil, lubricants, and filters for their equipment under average conditions are available from the equipment manufacturers.

2.4.4 Mobilization and Demobilization Cost

This is the cost of moving the equipment from one job site to another. It is often overlooked because of the assumption that the previous job would have already paid for it. Regardless of these calculations, the costs of equipment mobilization and demobilization can be large and are always important items in any job where substantial amounts of equipment are used. These costs include freight charges (other than the initial purchase), unloading cost, assembly or erection cost (if required), highway permits, duties, and special freight costs (remote or emergency). For a $3-million earthmoving job, it is not unusual to have a budget from $100,000 to $150,000 for move-in and move-out expenses. The hourly cost can be obtained from the total cost divided by the operating hours. Some public agencies cap the maximum amount of mobilization that will be paid before the project is finished. In these instances, the estimator must check the actual costs of mobilization against the cap. If the cap is exceeded, the unrecovered amount must be allocated to other pay items to ensure that the entire cost of mobilization is recovered.

2.4.5 Equipment Operator Cost

Operator's wages are usually added as a separate item and added to other calculated operating costs. They should include overtime or premium charges, workmen's compensation insurance, social security taxes, bonus, and fringe benefits in the hourly wage figure. Care must be taken by the companies that operate in more than one state or that work for federal agencies, state agencies and private owners. The federal government requires that prevailing scale (union scale) of wages be paid to workers on its project regardless of whether the state is a union state or not. This is a requirement of the Davis Bacon Act [7] and most federal contracts will contain a section in the general conditions that details the wage rates that are applicable to each trade on the project.

2.4.6 Special Items Cost

The cost of replacing high-wear items, such as dozer, grader, and scraper blade cutting and end bits, as well as ripper tips, shanks, and shank protectors, should be calculated as a separate item of the operating cost. As usual, unit cost is divided by the expected life to yield cost per hour.

2.5 METHODS OF CALCULATING OWNERSHIP AND OPERATING COST

The most common methods available are the caterpillar method, Association of General Contractors of America (AGC) method, the Equipment Guide Book (EGB) method, the dataquest method, the Corps of Engineers method, and the Peurifoy method. Each method is described below and three examples are given in Appendix A.

2.5.1 Caterpillar Method

The Caterpillar method is based on the following principles [8]:

1. No prices for any items are provided. For reliable estimates, these must always be obtained locally.

2. Calculations are based on the complete machine. Separate estimates are not necessary for the basic machine, dozer, control, etc.
3. The multiplier factors provided will work equally well in any currency expressed in decimals.
4. Because of different standards of comparison, what may seem a severe application to one machine owner may appear only average to another. Therefore, in order to better describe machine use, the operating conditions and applications are defined in zones.

2.5.1.1 Ownership Costs

Ownership costs are calculated as a sum of costs incurred due to depreciation, interest, insurance, and taxes. Usually depreciation is done to zero value with the straight-line method, which is not based on tax consideration, but resale or residual value at replacement may be included for depreciation or tax incentive purposes. Service life of several types of equipment is given in the *Caterpillar Performance Handbook* [8]. Acquisition or delivered costs should include costs due to freight, sales tax, delivery, and installation. On rubber-tired machines, tires are considered as a wear item and covered as an operating expense. Tire cost is subtracted from the delivered price. The delivered price less the estimated residual value results in the value to be recovered through work, divided by the total usage hours, giving the hourly cost to project the asset's value. The interest on capital used to purchase a machine must be considered, whether the machine is purchased outright or financed. Insurance cost and property taxes can be calculated in one of the two ways.

2.5.1.2 Operating Costs

Operating costs are based on charts and tables in the handbook. They are broken down as follows:

1. Fuel
2. Filter, oil, and grease (FOG) costs
3. Tires
4. Repairs
5. Special items
6. Operator's wages

The factors for fuel, FOG, tires, and repairs costs can be obtained for each model from tables and charts given in the *Caterpillar Performance Handbook* [8]. Tire costs can be estimated from previous records or from local prices. Repairs are estimated on the basis of a repair factor that depends on the type, employment, and capital cost of the machine. The operator's wages are the local wages plus the fringe benefits. Table 2.6 is an example of the application of this method for a truck-mounted crane.

2.5.2 Corps of Engineers Method

This method is often considered as the most sophisticated method for calculating equipment ownership costs because it not only covers economic items but also includes geographic conditions. This method generally provides hourly use rates for construction equipment based on a standard 40-h workweek. The total hourly use rates include all costs of owning and operating equipment except operator wages and overhead expenses. The ownership portion of the rate consists of allowances for depreciation and costs of facilities capital cost of money (FCCM). Operating costs include allowances for fuel, filter, oil, grease, servicing the equipment, repair and maintenance, and tire wear and tire repair [9].

TABLE 2.6
Caterpillar Method Example for 150 Ton Truck Crane

Truck-mounted crane 150 ton w/260′ Lattice boom	Estimated annual use in hours = 1590 h	Tires drive = \$7040
Equipment horsepower: 207; carrier horsepower 430	Total expected use in hours = 20,000 h	Fuel cost = \$2.00/gal
Average conditions of use	Useful life = 20,000/1590 = 12.58 years	Sales tax = 8.7%
	Tires front = \$3520	Factor = factor taken from the reference manual [4]

Calculation of Depreciation Value

1. Delivered price (including taxes, freight, and installation)		
List price		= \$1,197,389.00
Discount: at 7.5%	Less	= \$89,804.00
	Subtotal	= \$1,107,585.00
Sales tax: at 8.7%		= \$96,360.00
	Subtotal	= \$1,203,945.00
Freight: 1913 cwt (\$3.08/cwt)		= \$5892.00
		= \$1,203,837.00
2. Less tire replacement costs		
Front: \$3520		
Drive: \$7040		= \$10,560.00
3. Delivered price less tires		= \$1,193,277.00
4. Net value for depreciation		= \$1,193,277.00

Ownership Cost

5. Depreciation = [net value]/[depreciation period in hours]
   = \$1,193,277.00/20,000 = \$59.66
6. Interest, insurance, taxes: interest = 6.75%; insurance = 3%; taxes = 2%

$$\text{Interest: } \frac{[(12.58 \pm 1)/2(12.58)](1{,}193{,}277)(0.12)}{1590} = \$27.44/\text{h}$$

$$\text{Insurance: } \frac{[(12.58 + 1)/2(12.58)](1{,}193{,}277)(0.03)}{1590} = \$12.20/\text{h}$$

$$\text{Taxes: } \frac{[(12.58 + 1)/2(12.58)](1{,}193{,}277)(0.02)}{1590} = \$8.13/\text{h}$$

= \$47.77

7. *Total hourly ownership cost* = \$107.43

Operating Cost

8. Equipment	Factor (hp)(fuel cost per gallon)	
Equipment	(0.038)(207)(2.00) = \$15.73	
Carrier	(0.006)(430)(2.00) = \$5.16	
9. FOG cost		= \$20.89
10. Tires		
(Replacement cost)/(Estimated life in hours) = 10,560/2500		= \$4.22
11. Repairs: [Factor (delivered price less tires)]/1590 = 0.07(1,193,277)/1590		= \$52.53
12. *Total hourly operating cost*		= \$77.64
13. *Operators hourly wage* = \$25.90		
14. *Total Ownership and Operating Cost*		= \$210.97

Summary

Ownership cost per hour	= \$107.43
Operating cost per hour	= \$77.64
Operator wage per hour	= \$25.90
Total cost per hour	= \$210.97

Source: W.S Lambie, Methods of deciding overhaul or replacement. In *Handbook of Construction Management and Organization* 2nd ed., New York, Van Nostrand Reinhold Co., 1980, pp. 160–166. With permission.

The standby hourly rate is computed from the average condition by allowing the full FCCM hourly cost plus one half of the hourly depreciation.

2.5.2.1 Ownership Costs

The Corps of Engineers method operates on the following principles:

1. Depreciation: It is calculated by using the straight-line method. The equipment cost used for depreciation calculation is subtracted by tire cost at the time the equipment was manufactured. Another cost that has to be subtracted is salvage value. It is determined from the *Handbook of New and Used Construction Equipment Values* (Green Guide) and advertisements of used equipment for sale displayed in current engineering and construction magazines [3]. The expected life span of the equipment is designated from the manufacturers' or equipment associations' recommendations.
2. FCCM: The Department of the Treasury adjusts the cost of money rate on or about 1st January and 1st July every year. This cost is computed by multiplying the cost of money rate, determined by the Secretary of the Treasury, by the average value of equipment and prorating the result over the annual operating hours. It is normally presented in terms of FCCM per hour.

It should be noted that licenses, taxes, storage, and insurance cost are not included in this computation. Instead, they are considered as indirect costs.

2.5.2.2 Operating Costs

1. *Fuel costs*: Fuel costs are calculated from records of equipment consumption, which is done in cost per gallon per hour. Fuel consumption varies depending on the machine's requirements. The fuel can be either gasoline or diesel.
2. *FOG costs*: FOG costs are usually computed as percentage of the hourly fuel costs.
3. *Maintenance and repair costs*: These are the expenses charged for parts, labor, sale taxes, and so on. Primarily, maintenance and repair costs per hour are computed by multiplying the repair factor to the new equipment cost, which is subtracted by tire cost, and divided by the number of operating hours.
4. *Hourly tire cost*: This is the current cost of new tires plus the cost of one recapping and then divided by the expected life of new tires plus the life of recapped tires. It has been determined that the recapping cost is approximately 50% of the new tire cost, and that the life of a new tire plus recapping will equal approximately 1.8 times the "useful life" of a new tire.
5. *Tire repair cost*: This cost is assumed to be 15% of the hourly tire wear cost.

Table 2.7 is an example of how this method is applied to the same piece of equipment as in Table 2.6.

2.5.3 Associated General Contractors of America (AGC) Method

This method enables the owner to calculate the ownership and operating costs to determine capital recovery [10]. Rather than dealing with the specific makes and models of the machines, the equipment is classified according to capacity or size. For example, this method computes the average annual ownership expense and the average hourly repair and maintenance expense as a percentage of the acquisition costs.

TABLE 2.7
Corps of Engineers Method Example for 150 Ton Truck Crane

Truck-mounted crane 150 ton w/260′	Tires front = \$3520
Lattice boom	Tires drive = \$7040
Equipment horsepower: 207; carrier horsepower 430	Fuel cost = \$2.00/gal
	Sales tax = 8.7%
Average conditions of use	Factor = factor taken from the reference manual [5]
Estimated annual use in hours = 1590 h	
Total expected use in hours = 20,000 h	
Useful life = 20,000/1590 = 12.58 years	

Factors for Calculations

1. Hourly expense calculation factors		
Economic key		= 20
Condition		= average
Discount code: B = 7.5% or S = 15% use the lower		= 0.075
Life in hours		= 20,000
Salvage value percentage		= 0.20
Fuel factor (equipment)		= 0.026
Fuel factor (carrier)		= 0.005
FOG factor		= 0.276
Tire wear factor (front)		= 0.97
Tire wear factor (drive)		= 0.78
Repair cost factor		= 0.90
Labor adjustment factor		= 0.88
Calculate Depreciation Value		
2. Delivered price (at year of manufacture)		= \$1,197,389.00
Discount: \$1,197,389.00(0.075)	Less	= \$89,804.00
	Subtotal	= \$1,107,585.00
Sales tax: \$1,107,585.00(0.087)		= \$96,360.00
	Subtotal	= \$1,203,945.00
Freight: 1913 cwt (\$3.08/cwt)		= \$5892.00
	Total equipment value for depreciation	= \$1,203,837.00
3. Depreciation period		
20,000 h/1590 h/year		= 12.58 years
Ownership Cost		
4. Depreciation		
Tire cost index (Appendix A)		
(TCI for year of equipment manufacture)/(TCI for year of equipment use)		
2373/2515 = 0.944		
Depreciation value (hourly)		
[[TEV(1 – SLV)] – [TCI(tire cost)]]/life in hours		
[[\$1,203,837.00(1 – 0.20)] – [0.944(\$10,560)]]/20,000		= \$47.90
5. Facilities capital cost of money		
Average value factor		
[(useful life − 1)(1.0 + SLV)] + 2.0]/[2(useful life)]		
[(12.58 – 1)(1.0 + 0.20)] + 2.0]/[2(12.58)] = 0.632		
FCCM		
TEV(AVF)(adjusted cost of money)/annual hours use		
\$1,203,837.00(0.632)(0.034)/1590		= \$16.35
6. *Total hourly ownership cost*		= \$64.25

Continued

TABLE 2.7 (Continued)
Corps of Engineers Method Example for 150 Ton Truck Crane

Operating Cost	
7. Fuel costs Factor (hp)(fuel cost per gallon)	
Equipment (0.026)(207)(2.00) = $10.76/h	
Carrier (0.005)(430)(2.00) = $4.30/h	
Total hourly fuel cost	= $15.06
8. FOG cost: FOG factor(fuel cost)(labor adjustment factor)	
Equipment (0.276)($10.76)(0.88) = $2.61/h	
Carrier (0.276)($4.30)(0.88) = $1.04/h	
Total hourly FOG cost	= $3.65
9. Repair cost:	
Economic adjustment factor (Appendix E)	
Economic index for year of manufacture/economic index for year of use	
EAF = 5729/5310 = 1.079	
Repair factor: RCF(EAF)(LAF) = 0.90 (1.079)(0.88) = 0.855	
Repair cost [TEV – (TCI)(tire cost)](RF)/life	
[$1,203,837.00 – (0.944)($10,560.00)][0.855]/20,000	
Total hourly repair cost	= $51.29
10. Tires	
Tire wear cost	
[1.5(tire cost)]/[1.8(wear factor)(tire life in hours)]	
Front tires: [1.5($3520)]/[1.8(0.97)(2500)]	= $1.21
Drive tires: [1.5($7040)]/[1.8(0.78)(2500)]	= $3.01
Total hourly tire wear cost	= $4.22
Tire repair cost	= $0.56
[1.5(tire wear cost)(LAF)]	
[1.5(4.22)(0.88)]	
Total hourly tire repair cost	
11. Sum 7–10	
12. *Total hourly operating cost*	= $69.17
13. *Operators hourly wage*	= $25.90
14. *Total Ownership and Operating Cost*	= $101.47
Summary	
Ownership cost per hour	= $64.25
Operating cost per hour	= $69.17
Operator wage and fringes per hour	= $25.90
Total cost per hour	= $159.32

Source: From D. Atcheson. *Earthmoving Equipment Production Rates and Costs*. Venice, FL: Norseman Publishing Co., 1993. With permission.

2.5.3.1 Ownership Cost

The ownership costs considered in this method are the same as described in the Caterpillar method; however, replacement cost escalation is also considered. Depreciation is calculated by the straight-line method and includes purchase price, sales tax, freight, and erection cost, with an assumed salvage value of 10%. Average economic life in hours and average annual operating hours are shown for each size range. Replacement cost escalation of 7% is designed to augment the capital recovery and to offset inflation and machine price increase. Interest on the investment is assumed to be 7%, whereas taxes, insurance, and storage are taken as 4.5%.

2.5.3.2 Operating Costs

Maintenance and repair costs are calculated based on an hourly percentage rate times the acquisition cost. It is a level rate regardless of the age of the machine. This expense includes

TABLE 2.8
AGC Method Example for 150 Ton Truck Crane

Truck-mounted crane 150 ton w/260′
Lattice boom
Equipment horsepower: 207; carrier horsepower 430

Average conditions of use
Estimated annual use in hours = 1590 h
Total expected use in hours = 20,000 h
Useful life = 20,000/1590 = 12.58 years

Tires front = $3520
Tires drive = $7040
Fuel cost = $2.00/gal
Sales tax = 8.7%
Factor = factor taken from the reference manual [4]

Factors for Calculations

1. Depreciation	= 15.00%
Replacement cost escalation	= 7.00%
Interest on investment	= 7.00%
Taxes, insurance, and storage	= 4.50%
Total ownership expense	= 33.50%
Repair and maintenance expense	= 19.40%
Salvage value	= 10.00%

Ownership Cost

2. Acquisition cost = (list price – tire cost)(1 – SV)
= ($1,203,837.00 – $10,560)(1.0 – 0.1) = $1,083,453
3. Average hourly
Ownership expense = total ownership
expense/annual use = 33.5%/1590 h = 0.0211
Average hourly ownership cost = 0.0211($1,083,453)/100 = $228.61

Operating Cost

4. Repair and maintenance expense rate = 19.4%/1590 = 0.0122
Average hourly repair and maintenance cost = 0.0122($1,083,453)/100 = $132.18
5. *Total hourly operating cost* = $132.18
6. *Operators hourly wage* = $25.90
7. *Total Ownership and Operating Cost* = $386.69

Summary

Ownership cost per hour	= $228.61
Operating cost per hour	= $132.18
Operator wage per hour	= $25.90
Total cost per hour	= $386.69

Source: J. Douglas. Equipment costs by current methods. *Journal of Construction Division ASCE* 104(C02), 1978, 191–225. With permission.

field and shop repairs, overhaul, and replacement of tires and tracks, etc. The FOG costs and operator's wages are not considered in this method. Table 2.8 shows how the AGC method is applied to the crane example.

2.5.4 Peurifoy/Schexnayder Method

R.L. Peurifoy is considered by many to be the father of modern construction engineering. His seminal work on the subject, now in its sixth edition [6], set the standard for using rigorous engineering principles to develop rational means for developing cost estimates based on equipment fleet production rates. These methods will be discussed in detail in Chapter 5 of this book. Therefore, it is important that his particular approach to determining equipment ownership costs be included in any discussion of the subject.

TABLE 2.9
Peurifoy/Schexnayder Method Example for 150 Ton Truck Crane

Truck-mounted crane 150 ton w/260′
Lattice boom
Equipment horsepower: 207; carrier horsepower 430

Average conditions of use
Estimated annual use in hours = 1590 h
Total expected use in hours = 20,000 h
Useful life = 20,000/1590 = 12.58 years

Tires front = \$3520
Tires drive = \$7040
Fuel cost = \$2.00/gal
Sales tax = 8.7%
Factor = factor taken from the reference manual [6]

Factors for Calculations

1. Interest = 6.75%
   Taxes, insurance, and storage = 3.75%
   Salvage value = 20%
   Repair and maintenance = 37% depreciation cost
   Tire repair cost = 16% of straight-line depreciated tire cost

Equipment under load 30% of the operating time
Carrier under load 10% of the operating time
Use 50-min productive hour

Ownership Cost

2. Initial cost = (list price – tire cost)
   From Table 2.7, line 2 = (\$1,203,837.00 – \$10,560) = \$1,083,453
   Equivalent uniform annual cost of IC = A_{IC}=IC[$i(1+i)^n/[(1+i)^n-1]$]
   \$1,083,453[$0.0675(1+0.0675)^{12.58}/[(1+0.0675)^{12.58}-1]$] = \$143,749/year
   Equivalent uniform annual cost of SV = A_{SV}=SV[$i(1+i)^n-1$]]
   0.20(\$1,083,453) [$0.0675/[(1+0.0675)^{12.58}-1]$] = \$12,752/year
3. Hourly ownership cost = (A_{IC} – A_{SV})/annual use

Hourly ownership cost = (\$143,749/year – \$12,752/year)/1590	= \$82.39
Hourly taxes, insurance, and storage cost = 0.0375(\$1,083,453)/1590	= \$22.55
Total hourly ownership cost	= \$107.94

Operating Cost

4. Fuel cost = combined factor(consumption)(hp)(cost per gallon)
   Equipment load factor: Lifting = 1.00(0.30) = 0.30
   Return = 0.75(0.70) = $\frac{0.53}{0.83}$
   Carrier load factor : Running = 1.00(0.10) = 0.10
   Idle = 0.50(0.90) = $\frac{0.45}{0.55}$
   Time factor: 50 min/60 min = 0.83
   Equipment combined factor = (0.83)(0.83) = 0.69
   Equipment fuel cost = 0.69(0.03 gal/hp-h)(207 hp)(\$2.00/gal) = \$8.57/h
   Carrier combined factor = (0.83)(0.55) = 0.46
   Carrier fuel cost = 0.46(0.04 gal/hp-h)(430 hp)(\$2.00/gal) = \$15.82/h

Combined hourly fuel cost = 0.85(8.57) + 0.15(15.82)	= \$9.66
Hourly repair and maintenance cost = 0.37(\$82.39/h)	= \$30.48
FOG cost = use Table 2.7, line 8	= \$3.65
Tire use cost = \$10,560/2500 h = \$4.22/h	
Tire repair cost = [\$10,560/2500 h](0.16) = \$0.68/h	
Total tire cost	= \$4.90
5. *Total hourly operating cost*	= \$48.69
6. *Operators hourly wage*	= \$25.90
7. *Total Ownership and Operating Cost*	= \$182.53

Summary

Ownership cost per hour	= \$107.43
Operating cost per hour	= \$48.69
Operator wage per hour	= \$25.90
Total cost per hour	= \$182.53

Source: R.L Peurifoy and C.J Schexnayder *Construction Planning*, *Equipment and Methods*, 6th ed. New York: Mc Graw-Hill, 2002.

2.5.4.1 Ownership Cost

This method assumes the straight-line method for depreciation. The value of the equipment is depreciated to be zero at the end of the useful life of the equipment. The ownership costs are based on an average investment cost that is taken as 60% of the initial cost of the equipment. Usually equipment owners charge an annual fixed rate of interest against the full purchase cost of the equipment. This gives an annual interest cost, which is higher than the normal. As the cost of depreciation has already been claimed, it is more realistic to base the annual cost of investment on the average value of equipment during its useful life. This value can be obtained by taking an average of values at the beginning of each year that the equipment will be used, and this is the major difference between the Peurifoy method and the other methods. The cost of investment is taken as 15% of the average investment.

2.5.4.2 Operating Costs

As the tire life is different from that of the equipment, its costs are treated differently. The maintenance cost is taken as 50% of the annual depreciation, the fuel and the FOG costs are included, whereas the operator wages are not included. Table 2.9 finishes by showing how this method is applied to the crane example.

2.5.5 Comparison of Costs Calculated by Different Methods

It is interesting to note that each method arrives at a different hourly rental rate for the same piece of equipment. This illustrates the statement made earlier in this chapter that the method used to arrive at a number is largely a business policy decision rather than a technical decision. Table 2.10 is a summary of the four previous examples and furnishes an interesting comparison of the business decisions made by each group.

The first notable aspect is that the AGC method yields the highest rental rate. Perhaps this is because the AGC is a trade organization for construction contractors and as a result, there is a bias to be conservative in the published method for calculating an equipment rental rate. Pursuing that line of reasoning, the rate obtained by using Corps of Engineers method is the lowest. The Corps is a large public owner who may have a bias to keeping the cost of equipment on its projects as low as possible. The remaining two fall somewhere in the middle as each really has no constituency to protect. In actuality, each equipment-owning organization will have its own internal method for arriving at these rates that will satisfy the financial accounting needs of that company. These published methods are primarily used in negotiations between a owner and a contractor as a means to determine if the contractor's internal equipment rates are fair and reasonable.

2.6 SUMMARY

This chapter has provided information and data to allow the estimator who does not already have an internal method to calculate the cost of owning and operating a piece of construction

TABLE 2.10
Summary of Different Methods for Calculating Equipment Ownership and Operating Costs

Item	Caterpillar	Corps of Engineers	AGC	Peurifoy/Schexnayder
Ownership cost per hour	\$107.43	\$64.25	\$228.61	\$107.43
Operating cost per hour	\$77.64	\$69.17	\$132.18	\$48.69
Operator wage per hour	\$25.90	\$25.90	\$25.90	\$25.90
Total cost per hour	\$210.97	\$159.32	\$386.69	\$182.53

equipment. The information can be used in several ways. First, it could be used as a reference for setting an internal standardized method for calculating equipment rental rates. Second, it could be used to perform an independent estimate of rates that are proposed for a given project to determine if they appear to be fair and reasonable. Finally, it can be used as a mutually agreed standard for calculating these types of rates during contract or change order negotiations. In any event, the estimator must strive to use the best numbers available at the time and to ensure that all the costs of both owning and operating the equipment are included in the final rate.

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3 Equipment Life and Replacement Procedures

3.1 INTRODUCTION

Once a piece of equipment is purchased and used, it eventually begins to wear out and suffers mechanical problems. At some point, it reaches the end of its useful life and must be replaced. Thus, a major element of profitable equipment fleet management is the process of making the equipment replacement decision. This decision essentially involves determining when it is no longer economically feasible to repair a broken piece of machinery. Thus, this chapter presents the three components of the economics of equipment management decision making:

- *Equipment life*: Determining the economic useful life for a given piece of equipment
- *Replacement analysis*: Analytical tools to compare alternatives to replace a piece of equipment that has reached the end of its useful life
- *Replacement equipment selection*: Methods to make a logical decision as to which alternative furnishes the most promising solution to the equipment replacement decision.

This chapter will also provide standard definitions for equipment life in terms of both theoretical and practical replacement methods as well as introduce and review several options for replacement analysis and replacement equipment selection.

Equipment life can be mathematically defined in three different ways: physical life, profit life, and economic life. All the three aspects must be defined and calculated when considering equipment life because they furnish three important means to approach replacement analysis and ultimately to make an equipment replacement decision. The concepts of depreciation, inflation, investment, maintenance and repairs, downtime, and obsolescence are all integral to replacement analysis and will be explained in this chapter with examples to demonstrate the use of the economic calculations. Combination of these concepts and processes allows the equipment manager to properly perform replacement analysis and to make reasonable equipment replacement decisions.

The economic life, alternative selection, and replacement timing of equipment can be determined using replacement analysis. The methods can be categorized as either theoretical replacement methods or practical replacement methods. The theoretical replacement methods include:

- Intuitive method that can be used by owners of small equipment fleets
- Minimum cost method that can be used by public agencies with large equipment fleets
- Maximum profit method that can be used by construction contractors and others who own large equipment fleets
- Payback period method, which is based on engineering economics and can be generally applied

- Mathematical modeling method, which furnishes a theoretical basis for developing some of the equipment cost input for computer simulations, used to optimize equipment fleet size and composition.

While most of the above methods are taken from academic journals and text books, they provide an excellent theoretical foundation and act as a base for understanding the empirical methods used in the industry. These practical replacement methods are used both in the public and private sectors. The replacement methods used by state departments of transportation in Texas, Montana, and Louisiana are detailed later in this chapter as examples of public sector methods. Regardless of the category, each method considers a number of variables to perform the replacement analysis and to logically make the equipment replacement decision. Finally, sensitivity analysis is sometimes required and included in some of the methods.

3.2 EQUIPMENT LIFE

Construction equipment life can be defined in three ways: physical life, profit life, and economic life. Figure 3.1 shows graphically how these different definitions relate to the life cycle of a typical piece of an equipment [1]. One can see in the graph that over the physical life of the machine, it takes sometime for the new machine to earn enough to cover the capital cost of its procurement. It then moves into a phase where the equipment earns more than it costs to own, operate, and maintain, and finishes its life at a stage when the costs of its maintenance are greater than what it earns during the periods when it is in operation.

3.2.1 Physical Life

Physical life is the age at which the machine is worn out and can no longer reliably produce. At this point, it will usually be abandoned or scrapped. As construction equipment ages,

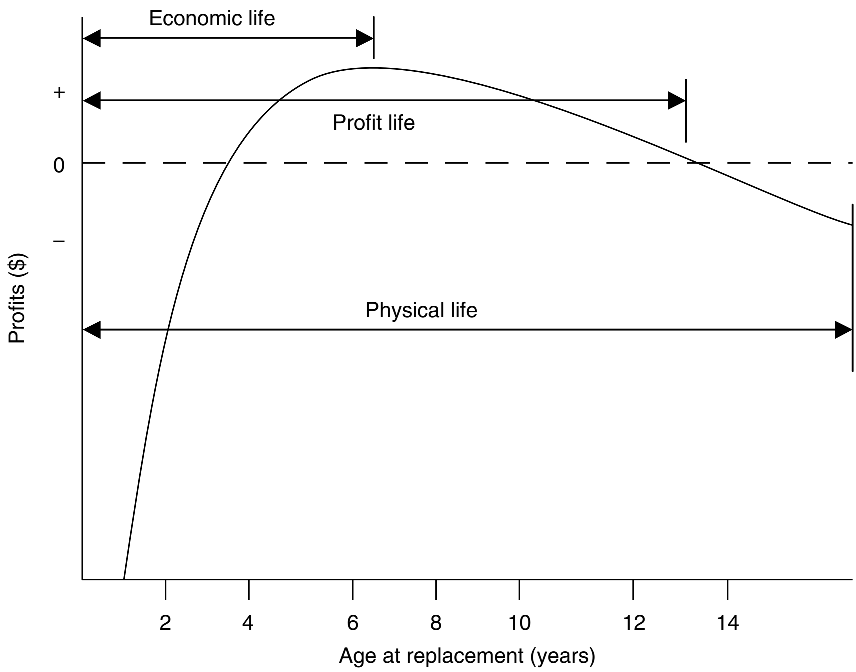

FIGURE 3.1 Equipment life definitions after Douglas. (From J. Douglas. *Construction Equipment Policy,* New York: McGraw-Hill, 1975, pp. 47–60.)

maintenance and operating costs increase. The length of a piece of equipment's physical life and the rate at which its operating costs rise are affected by the care it receives while in use, the nature of the job it is doing, and the quality of the maintenance it receives [1]. The axiom holds that regular expenditure of small amount of money for preventive maintenance abrogates the need to spend a large amount of money to replace major operating components. Thus, two completely identical pieces of equipment could in fact have widely varying physical lives depending on their maintenance and the severity of their operating conditions.

3.2.2 Profit Life

Profit life is the life over which the equipment can earn a profit. The retention beyond that point will create an operating loss [1]. This essentially is the point where the machine seemingly spends more time in the repair shop than it does on the project site. Increasingly costly repairs exacerbate profit life as major components wear out and need to be replaced. Thus, the equipment manager must be able to identify when a particular machine is nearing or has reached this point and plan to replace it with a new machine while the major components are still functional.

3.2.3 Economic Life

Economic life equates to the time period that maximizes profits over the equipment's life. Equipment owners constantly strive to maximize production while minimizing the cost of production. Thus, selecting economic life span as the metric to make the equipment replacement decision is in fact optimizing production with respect to profit. Figure 3.1 illustrates how the economic life of equipment is shorter than the physical life and ends when the profit margin associated with a given machine reaches its highest point. Therefore, the proper timing of equipment replacement prevents an erosion of profitability by the increased cost of maintenance and operation as the equipment ages beyond its economic life. Owners can determine the most economical time to replace the equipment by keeping precise records of maintenance and repair costs. Determination of the appropriate timing to replace a piece of equipment requires that its owner include not only ownership costs and operating costs, but also other costs that are associated with owning and operating the given piece of equipment [1, 2]. These include depreciation, inflation, investment, maintenance, repair, downtime, and obsolescence costs.

3.2.3.1 Depreciation Costs and Replacement

The dictionary defines depreciation as "a decrease in the value of property through wear, deterioration, or obsolescence" [3]. In terms of equipment, the depreciation is the loss in value of equipment from the time it is purchased to the time it is out of service or replaced. Table 3.1 is a generalized analysis of the life of a hypothetical piece of equipment and shows how to arrive at an hourly cost resulting from depreciation and the need for replacement. In this case, the book value is the actual amount to be realized on a trade-in and assumes that the annual increase of the average cost of construction equipment is approximately 5% per year. One can see from the table that the average hourly cost of depreciation is not linear and actually decreases as the equipment hours over which it is applied increases.

3.2.3.2 Inflation

Like every product, equipment replacement costs are affected by economic and industrial inflation. Economic inflation is defined as the loss in buying power of the national currency, and industrial inflation is the change in construction costs due to long- and short-term

TABLE 3.1
Depreciation and Replacement Costs

End of Year	Replacement Cost	Book Value	Loss on Replacement	Cumulative Use (h)	Cumulative Cost per Hour
0	30,000	30,000	0	0	0
1	31,500	22,500	9,000	2,000	4.50
2	33,000	18,000	15,000	4,000	3.75
3	34,500	15,100	19,400	6,000	3.23
4	36,000	12,800	23,200	8,000	2.90
5	37,500	10,600	26,900	10,000	2.69
6	39,000	9,100	29,900	12,000	2.49
7	40,500	7,900	32,600	14,000	2.33
8	42,000	6,800	35,200	16,000	2.20

fluctuations in commodity pricing. For example, the consumer price index is a widely reported inflation index that seeks to model the purchasing power of the U.S. consumer dollar. It acts as a measure of economic inflation because it measures inflation across the general economy. The unprecedented rise in the price of steel during 2004–2005 would be an example of industry inflation because it is specific to the construction industry. While the inflation should always be considered in equipment replacement decision making, its effects can be ignored if the equipment manager uses a comparative analytical method because it can be assumed to affect all alternatives equally [4].

3.2.3.3 Investment Costs

Investment costs include interest, insurance, taxes, and license fees beyond the initial acquisition cost of equipment. Investment cost can be reduced to a percentage of initial equipment cost as shown in Table 2.2. Table 3.2 continues the hypothetical example and illustrates how hourly investment cost can be calculated. In accordance with the typical values shown in Table 2.2, the investment cost in this example is assumed to be 15% per year.

TABLE 3.2
Investment Costs

Year	Investment Start of Year	Depreciation	Investment End of Year	Investment Cost	Cumulative Investment Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	30,000	7,500	22,500	4,500	4,500	2,000	2.25
2	22,500	4,500	18,000	3,375	7,875	4,000	1.97
3	18,000	2,900	15,100	2,700	10,575	6,000	1.76
4	15,100	2,300	12,800	2,265	12,840	8,000	1.61
5	12,800	2,200	10,600	1,920	14,760	10,000	1.48
6	10,600	1,500	9,100	1,590	16,350	12,000	1.36
7	9,100	1,200	7,900	1,365	17,715	14,000	1.27
8	7,900	1,100	6,800	1,185	18,900	16,000	1.18

3.2.3.4 Maintenance and Repair Costs

Maintenance and repair costs are the crux of the equipment replacement decision and result from the cost of labor and parts used to maintain and repair the given piece of equipment. This is an incredibly dynamic system and can be affected by the following factors:

- Type of equipment
- Age of the equipment
- Operating conditions
- Operating skill of the operator
- Daily care by the operator
- Maintenance department
- Frequency and level of preventive maintenance.

As a result, it is very important to keep accurate cost records to estimate maintenance and repair costs. Table 3.3 illustrates an example of how to calculate hourly maintenance and repair costs [5].

3.2.3.5 Downtime

Downtime is the time when equipment does not work due to repairs or mechanical adjustments [1]. Downtime tends to increase as equipment usage increases. Availability, the portion of the time when equipment is in actual production or is available for production, is the opposite of downtime. For example, if the equipment's downtime is 10%, then its availability is 90%.

The downtime cost includes the ownership cost, operating cost, operator cost, and productivity loss caused by the loss of equipment availability. Table 3.4 shows a method to calculate the hourly downtime cost. In the table, the direct cost of productivity loss is not computed because it is not easily quantified as a dollar value. However, it is described as a weight factor where maximum availability is held equal to 1.0 and proportionate loss in availability carries a weightage less than 1.0. Productivity is a measure of the equipment's ability to produce at the original rate. The productivity decrease results in the increase in production cost because the operating time of the equipment should be extended or more equipments should be deployed to get the same production rate. As shown in Table 3.4, if the cumulative costs per hour are calculated and the productivity factors are known, the

TABLE 3.3
Maintenance and Repair Costs

Year	Annual Maintenance and Repair Cost	Cumulative Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	970	970	2,000	0.49
2	2,430	3,400	4,000	0.85
3	2,940	6,340	6,000	1.06
4	3,280	9,620	8,000	1.20
5	4,040	13,660	10,000	1.37
6	4,430	18,090	12,000	1.51
7	5,700	23,790	14,000	1.70
8	6,290	30,080	16,000	1.88

TABLE 3.4
Downtime Costs Example

Year	Downtime (%)	Operating Cost	Downtime Cost per Hour	Downtime Cost per Year	Cumulative Downtime Cost	Cumulative Use (h)	Cumulative Cost per Hour	Productivity Factor	Cumulative Cost per Hour	Productivity Adjusted Cumulative Cost per Hour
1	3	7	0.21	420	420	2,000	0.21	1.00	0.21	0.21
2	6	7	0.42	840	1,260	4,000	0.32	0.99	0.32	0.32
3	9	7	0.63	1,260	2,520	6,000	0.42	0.98	0.43	0.44
4	11	7	0.77	1,540	4,060	8,000	0.51	0.96	0.53	0.55
5	13	7	0.91	1,820	5,880	10,000	0.59	0.95	0.62	0.65
6	15	7	1.05	2,100	7,980	12,000	0.67	0.94	0.71	0.76
7	17	7	1.19	2,380	10,360	14,000	0.74	0.93	0.80	0.86
8	20	7	1.40	2,800	13,160	16,000	0.82	0.92	0.89	0.97

TABLE 3.5
Obsolescence Costs per Hour for the Life of the Equipment

Year	Obsolescence Factor	Equipment Cost per Hour	Obsolescence Cost per Hour	Obsolescence Cost per Year	Cumulative Cost	Cumulative Use (h)	Cumulative Cost per Hour
1	0.00	7.00	0.00	0	0	2,000	0.00
2	0.06	7.00	0.42	840	840	4,000	0.21
3	0.11	7.00	0.77	1,540	2,380	6,000	0.40
4	0.15	7.00	1.05	2,100	4,480	8,000	0.56
5	0.20	7.00	1.40	2,800	7,280	10,000	0.73
6	0.26	7.00	1.82	3,640	10,920	12,000	0.91
7	0.32	7.00	2.24	4,480	15,400	14,000	1.10
8	0.37	7.00	2.59	5,180	20,580	16,000	1.29

productivity-adjusted, cumulative cost per hour can be found by dividing the cumulative cost per hour by the productivity factor.

3.2.3.6 Obsolescence

Obsolescence is the reduction in value and marketability due to the competition between newer and more productive models [4]. Obsolescence can be subdivided into two types: technological and market preference. Technological obsolescence can be measured in terms of productivity. Over the short term, technological obsolescence has typically occurred at a fairly constant rate. Market preference obsolescence occurs as a function of customers' taste. This is much less predictable, although just as real, in terms of lost value. The market preference obsolescence is not considered in Table 3.5 due to the difficulty in quantifying its value.

Obsolescence is an extremely important factor to be considered in the highly competitive construction industry. Owning the latest technology equipment gives a contractor an edge over the competition in that enhanced technology generally equates with increased rates of production, translating into decreased production costs. Thus, holding onto older pieces of equipment, even though they are functioning perfectly well, can in fact reduce the contractor's ability to submit competitive bid prices simply because the older equipment fleet cannot produce at the same rates as the competitors' newer equipment. Chapter 7 explains in great detail on how to compute the hourly rental rate used for estimating equipment costs and shows that the cost is a direct function of the equipment's productivity. Table 3.5 shows the cost increase resulting from retaining old equipment that might be replaced with newer ones, which can produce at higher rates and result in lower unit costs.

3.2.3.7 Summary of Costs

Assuming a constant dollar value, the costs for each component discussed in the previous sections can be accumulated and the piece of equipment's economic life can be measured by identifying the year in which the minimum cost per hour occurs. This is shown in Table 3.6. Table 3.7 takes this idea one step further by calculating the loss incurred at each year in the equipment life assuming that it is replaced in each given year. Through these analyses, it can be concluded that the minimum cost is \$6.82/h and the economic life of the

TABLE 3.6
Summary of Cumulative Costs per Hour

	Year							
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Depreciation and replacement ($/h)	4.5	3.75	3.23	2.9	2.69	2.49	2.33	2.2
Investment ($/h)	2.25	1.97	1.76	1.61	1.48	1.36	1.27	1.18
Maintenance and repairs ($/h)	0.49	0.85	1.06	1.2	1.37	1.51	1.7	1.88
Downtime (productivity adjusted) ($/h)	0.21	0.32	0.44	0.55	0.65	0.76	0.86	0.97
Obsolescence ($/h)	0	0.21	0.4	0.56	0.73	0.91	1.1	1.29
Total ($/h)	7.45	7.10	6.89	6.82	6.92	7.03	7.26	7.52

equipment is the fourth year. Therefore, the acquisition of the new equipment should be considered in the fourth year.

Now the reader can see the logic behind the determination of a piece of equipment's economic life. Various methods for determining the optimum replacement timing will be discussed in subsequent sections.

3.3 REPLACEMENT ANALYSIS

Replacement analysis is a tool with which equipment owners time the equipment replacement decision. Through this analysis, the cost of owning the present equipment is compared with the cost of owning potential alternatives for replacing it. The following sections explain both theoretical and practical methods to accomplish this important equipment management task.

3.3.1 THEORETICAL METHODS

Dr. James Douglas, professor emeritus at Stanford University, wrote a seminal work on this subject in his 1975 book, *Construction Equipment Policy* [1]. In that work, he posited four different theoretical approaches to establishing an equipment replacement policy based on a

TABLE 3.7
Losses Resulting from Improper Equipment Replacement

Replaced at End of Year	Cumulative Use (h)	Cumulative Cost per Hour	Minimum Cost per Hour	Extra Cost per Hour	Total Loss
1	2,000	7.45	6.82	0.63	1,256
2	4,000	7.10	6.82	0.28	1,125
3	6,000	6.89	6.82	0.07	400
4	8,000	6.82	6.82	0.00	0
5	10,000	6.92	6.82	0.10	1,005
6	12,000	7.03	6.82	0.20	2,439
7	14,000	7.26	6.82	0.44	6,134
8	16,000	7.52	6.82	0.70	11,125

rigorous and rational analysis of cost, time, and production. Douglas' theoretical methods for performing replacement analysis include the intuitive method, the minimum cost method, maximum profit method, and the mathematical modeling method. The value in these different approaches lies in the fact that each method can be applied to a different type of equipment owner. The intuitive method acts as a baseline against which other methods can be compared. It is simply the application of common sense to decision making. The minimum cost method fits very nicely into a public construction agency's equipment management policy as the focus on replacing equipment at a point in time where the overall cost of operating and maintaining a given piece of equipment is minimized and hence the strain on the taxpayer is also reduced. The maximum profit method furnishes a model for construction contractors and other entities that utilize their equipment in a profit-making enterprise to make the replacement decision with an eye on their bottom line. Finally, the mathematical modeling method fulfills a need for a rigorous analytical approach to this decision for those who will eventually utilize computer-based simulations to assist in optimizing equipment fleet size and composition for large equipment-intensive projects. Thus, these will be discussed first and a discussion of the payback period method [6], a method drawn from engineering economics, will also be included. The following example will be used for better understanding of the intuitive method, minimum cost method, maximum profit method, and payback period method. These methods will be demonstrated using the following example with current equipment pricing drawn from the Corps of Engineers Equipment Ownership Manual EP 1110-1-8 [7].

Example 3.1 An aggregate producing company presently owns a fleet of 7.5 cubic yard on-highway dump trucks that cost \$65,000 each. These trucks are currently 1-year-old and the annual maintenance and operating cost is \$30,000 per truck for the first year and increases by \$2000 each year. The revenue of each truck is \$70,000 for the first year and decreases by about \$1750 per year thereafter. The owner of the company visits a national equipment show and after talking to one of the salespersons at the show comes back and asks his equipment fleet manager to take a look at replacing the current dump trucks with a new model that employs a new technology, which will reduce maintenance expenditure. The new proposed replacement trucks are of the same size and cost \$70,000 each. The annual maintenance and operating cost is \$30,000 per truck for the first year but only increases by \$1500 per year thereafter. The revenue of each truck is the same as for current model truck. This company uses the double-declining balance method for calculating depreciation. The trucks currently in use will be called as the "current trucks" and the new model trucks will be called as the "proposed truck" in the tabular examples that follow.

3.3.1.1 Intuitive Method

Intuitive method is perhaps the most prevalent one for making replacement decisions due to its simplicity and reliance on individual judgment. This method mainly depends on professional judgment or an apparent feeling of correctness to make replacement decisions. Equipment is often replaced when it requires a major overhaul or at times at the beginning of a new equipment-intensive job. In addition to these situations, availability of capital is often a decisive factor because no reserve has been built up in anticipation of replacement. However, none of these judgmental decisions has a sound economic basis to be used as a criterion for an orderly, planned replacement program.

Even though the example can be solved with the intuitive method, there is no rational answer for the economic life of both types of trucks. This means superficially that retaining the current trucks seems to be better in sense that they are only 1 year old, earning revenues at the same rate as the new trucks. As the potential reduction in maintenance costs does not seem to be particularly dramatic, the owner will probably choose to keep using the current trucks that cost $5000 less than the proposed trucks. In this case, it is clearly seen that long-term maintenance and operating cost is overlooked by "professional judgment" [1].

3.3.1.2 Minimum Cost Method

Minimizing equipment costs is always an important goal for equipment owners. However, it is paramount to public agencies that own large and small fleets of construction equipment, as they have no mechanism to generate revenue to offset their costs. To achieve this goal, the minimum cost method focuses on minimizing equipment costs based on not only cost to operate and maintain (O&M costs) a piece of equipment but also the decline in its book value due to depreciation. This is quite straightforward and furnishes a rational method to conduct the objective comparison of alternatives rather than the intuitive method's professional judgment. For the sake of simplicity, the example shown in this chapter of minimum cost method does not include many of the costs discussed in Chapter 2, and the reader will need to determine which of the following it will include when implementing this equipment replacement decision-making methodology: penalty costs for downtime, obsolescence cost, labor cost, tax expenses (consideration of depreciation methods available), and inflation. Table 3.8 and Table 3.9 show how the economic life of each alternative is determined.

The economic life of a machine is determined by the year in which the average annual cumulative cost is minimized. This will result in the lowest cost over a long period of time. It is observed that this occurs at the end of the eighth year for the current truck in Table 3.8 and ninth year for the proposed truck in Table 3.9. This means that the minimum average annual costs for the current trucks and proposed trucks are $44,989 and $43,699, respectively. Table 3.10 shows the comparison of cumulative average annual costs of both types of trucks side by side. It allows the analyst to make a direct comparison of not only the projected annual cost for the current equipment but also a comparison on an annual basis of the average annual costs for each alternative.

TABLE 3.8
Average Annual Cumulative Costs of the Current Trucks

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$39,000	$26,000	$56,000	$56,000	$56,000
2	$32,000	$23,400	$15,600	$47,600	$103,600	$51,800
3	$34,000	$14,040	$9,360	$43,360	$146,960	$48,987
4	$36,000	$8,424	$5,616	$41,616	$188,576	$47,144
5	$38,000	$5,054	$3,370	$41,370	$229,946	$45,989
6	$40,000	$3,033	$2,022	$42,022	$271,967	$45,328
7	$42,000	$1,820	$1,213	$43,213	$315,180	$45,026
8	$44,000	$1,092	$728	$44,728	$359,908	$44,989
9	$46,000	$655	$437	$46,437	$406,345	$45,149
10	$48,000	$393	$262	$48,262	$454,607	$45,461
11	$50,000	$236	$157	$50,157	$504,764	$45,888
12	$52,000	$141	$94	$52,094	$556,859	$46,405

TABLE 3.9
Average Annual Cumulative Costs of the Proposed Trucks

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$42,000	$28,000	$58,000	$58,000	$58,000
2	$31,500	$25,200	$16,800	$48,300	$106,300	$53,150
3	$33,000	$15,120	$10,080	$43,080	$149,380	$49,793
4	$34,500	$9,072	$6,048	$40,548	$189,928	$47,482
5	$36,000	$5,443	$3,629	$39,629	$229,557	$45,911
6	$37,500	$3,266	$2,177	$39,677	$269,234	$44,872
7	$39,000	$1,960	$1,306	$40,306	$309,540	$44,220
8	$40,500	$1,176	$784	$41,284	$350,824	$43,853
9	$42,000	$705	$470	$42,470	$393,295	$43,699
10	$43,500	$423	$282	$43,782	$437,077	$43,708
11	$45,000	$254	$169	$45,169	$482,246	$43,841
12	$46,500	$152	$102	$46,602	$528,848	$44,071

In Douglas' minimum cost method, the decision to replace equipment is made when the estimated annual cost of the current machine for the next year *exceeds* the minimum average annual cumulative cost of the replacement. In this example, the current truck's estimated annual cost for next year (i.e., end of Year 2) is $47,600 and the minimum average annual cumulative cost of the proposed truck is $43,853. Thus, if the object is to minimize costs, this analysis leads to a decision to replace the current-year old trucks with the newer model. Again looking at Table 3.10, one can see that comparing the average annual cumulative costs of the two trucks, the proposed model begins to have lower costs in Year 5. However, to achieve that benefit, the company must buy the new trucks.

TABLE 3.10
Comparison of Average Annual Cumulative Costs

		Average Annual Cumulative Cost	
End of Year	Annual Cost	Current Trucks	Proposed Trucks
1	56,000	56,000	58,000
2	47,600	51,800	53,150
3	43,360	48,987	49,793
4	41,616	47,144	47,482
5	41,370	45,989	45,911
6	42,022	45,328	44,872
7	43,213	45,026	44,220
8	44,728	44,989	43,853
9	46,437	45,149	43,699
10	48,262	45,461	43,708
11	50,157	45,888	43,841
12	52,094	46,405	44,071

TABLE 3.11
Average Annual Cumulative Profits of the Current Trucks

End of Year (1)	Annual Revenue (2)	Annual Cost (3)	Annual Profit (4) = (2) – (3)	Cumulative Profit (5)	Average Annual Cumulative Profit (6) = (5)/(1)
1	$70,000	$56,000	$14,000	$14,000	$14,000
2	$68,250	$47,600	$20,650	$34,650	$17,325
3	$66,500	$43,360	$23,140	$57,790	$19,263
4	$64,750	$41,616	$23,134	$ 80,924	$20,231
5	$63,000	$41,370	$21,630	$102,554	$20,511
6	$61,250	$42,022	$19,228	$121,783	$20,297
7	$59,500	$43,213	$16,287	$138,070	$19,724

3.3.1.3 Maximum Profit Method

This method is based on maximizing equipment profit. The method should be used by the organizations that are able to generate revenue and hence profits from their equipment. It works very well if the profits associated with a given piece of equipment can be isolated and clearly defined. However, it is not often easy to separate annual equipment profit from entire project or equipment fleet profit. When it proves impossible, the minimum cost method should be used to make the replacement decision. The example used in the previous section will be continued in the following tables and paragraphs. Table 3.11 and Table 3.12 illustrate how to determine the economic life of the two alternatives using profit as the metric to make the replacement decision.

Table 3.11 and Table 3.12 show the necessity to calculate the economic lives of the alternatives in the example using the maximum profit method. The economic life of equipment is the year in which the average annual cumulative profit is maximized. This results in higher profits over a long period of time. In Table 3.11, the economic life of the current trucks is at the end of the fifth year because the average annual cumulative profit is maximized in that year by $20,511. The maximum average annual cumulative profit of $24,486 is in the fourth year for the proposed trucks in Table 3.12. The proposed trucks should replace the current trucks because the maximum average annual cumulative profit of the proposed trucks, $24,486, is more than that of the current trucks, $20,511.

TABLE 3.12
Average Annual Cumulative Profits of Proposed Trucks

End of Year (1)	Annual Revenue (2)	Annual Cost (3)	Annual Profit (4) = (2) – (3)	Cumulative Profit (5)	Average Annual Cumulative Profit (6) = (5)/(1)
1	$70,000	$48,300	$21,700	$21,700	$21,700
2	$68,250	$43,080	$25,170	$46,870	$23,435
3	$66,500	$40,548	$25,952	$72,822	$24,274
4	$64,750	$39,629	$25,121	$97,943	$24,486
5	$63,000	$39,677	$23,323	$121,266	$24,253
6	$61,250	$40,306	$20,944	$142,210	$23,702
7	$59,500	$41,284	$18,216	$160,426	$22,918
8	$57,750	$42,470	$15,280	$175,705	$21,963

The next issue in this method is to identify the proper timing of the replacement. This occurs when the estimated annual profits of the current equipment for the next year *falls below* the average annual cumulative profit of the proposed replacement. In this example, the current trucks' estimated annual profits never exceed \$24,486, which is the average annual profit of the proposed model so that they should be replaced immediately.

3.3.1.4 Payback Period Method

The payback period is the time required for a piece of equipment to return its original investment by generating profit [6]. The capital recovery is calculated using the total of net savings on an after-tax basis and the depreciation tax benefit disregarding financing costs. This method furnishes a metric that is based on time rather than money and allows the comparison of alternatives based on how long it takes for each possible piece of equipment to recover its investment. The payback period method is useful when it is hard to forecast equipment cash flow due to market instability, inherent uncertainty, and technological changes. This method springs from classical engineering economic theory and thus does not seek to identify the economic life of the equipment or economic effects beyond the payback period. Therefore, it is recommended that this method be used in conjunction with other analysis methods to furnish another slant on the view optimizing the equipment replacement decision. Again, the previous example will be utilized to demonstrate the mechanics of this method.

For the current trucks in Example 3.1, the payback method is calculated as follows:

Initial cost of the current truck = \$65,000
Cumulative profits for the first 3 years = \$57,790
Difference = \$65,000 – \$57,790 = \$7210
Profit of the fourth year = \$23,134
Proportional fraction of the third year = \$7210/\$23,134 = 0.31
Payback period for the current trucks = 3.31 years.

For the proposed trucks, the payback method is calculated as follows:

Initial cost of the proposed truck = \$70,000
Cumulative profits for the first 2 years = \$46,870
Difference = \$70,000 – \$46,870 = \$23,130
Profit of the third year = \$25,952
Proportional fraction of the third year = \$23,130/\$25,952 = 0.89
Payback period for the proposed trucks = 2.89 years.

As shown in the above calculation, the 2.89-year payback period of the proposed replacement trucks is shorter than that of the 3.31-year payback period of the current trucks. This tells the analyst that the proposed replacement equipment will return its investment to the owner 5 months faster than the current fleet. Therefore, replacement is once again indicated. Combining this knowledge with the previous analysis involving cost and profit makes a clear case for replacing the current fleet with the new model equipped with the latest technology. These three methods combine to provide a powerful set of analytical tools for making this critical decision.

3.3.1.5 Mathematical Modeling Method

The advent of computer application for construction management problems has furnished a simple and accurate means to solve problems related to complex interrelated systems containing dozens of input parameters. Modeling construction equipment systems is both appropriate and efficient as it provides the estimator or project manager the ability to control the level of complexity of the input and tailor the output to meet the needs of organization. Utilizing a computer model to furnish the output to assist in making the all-important equipment replacement timing and selection decision allows for more than technical accuracy to be achieved. It also creates a continuity of institutional equipment management policy that can be carried from one manager to the next without a loss in institutional knowledge. It serves as a means to codify business decision making based on a rigorous engineering economic analysis. Again, the early work done by Douglas will be reviewed and discussed as it provides a solid foundation of theoretical basis on which to build a model tailored specifically for its own organization. The model developed at Stanford University's Construction Institute in 1970s is conceptually very simple and can be best described as a discounted cash flow model [1]. It models revenues and costs as exponential functions. The latter are subtracted from the former and discounted to their present values to yield the present worth of profits after taxes.

A mathematical model is a function or group of functions comprising a system. Douglas specifies that the model must include the following factors [1]:

- Time value of money
- Technological advances in equipment (obsolescence)
- Effect of taxes (depreciation techniques, etc.)
- Influence of inflation, investment credit, gain on sale
- Increased cost of borrowing money
- Continuing replacements in the future
- Increased cost of future machines
- Effect of periodic overhaul costs and reduced availability

Other factors important to revenue are increased productivity (productivity obsolescence), availability of machines (maintenance policy), and deterioration of the machine with age. Additionally in this model, revenues and costs may be classified as follows:

- Revenues from the service of the machines
- Maintenance and operating costs, including annual fixed costs, penalties, and overhead
- Capital costs, including interest on investment, depreciation charges, and interest on borrowed funds
- Discrete costs such as engine, track, and final drive overhauls
- Income and corporation taxes, considering depreciation method, recapture of income on sale, and investment credit [1]

The goal of this method is to maximize the difference between revenue and the expected value of the cost. At this point, the reader can consult references at the end of the chapter for the complex mathematical details of Douglas' model itself.

3.3.2 Practical Methods

Public and private equipment owners have developed their own policies for making equipment management decisions. They are typically based on empirical data as well as past experience. The reader can learn a lot by studying these methods and can develop an understanding of what is behind each of the systems. These methods represent a wealth of knowledge built from decades of equipment management experience. By seeking to understand these methods and combining that knowledge with the analytical methods discussed in the previous section, equipment managers effectively enlarge the toolbox with which they can deal with the day-to-day issues of managing a fleet of construction equipment.

3.3.2.1 Public Agency Methods

As previously stated, public agencies do not have a profit motive when it comes to setting equipment replacement policy. Thus, their decision criterion must in some way relate to minimizing the costs of owning, operating, and maintaining the fleets of equipment that they manage. Additionally, public agencies often must make their equipment purchasing decisions based on not only routine equipment requirements but also ensuring that equipment on hand has sufficient capacity to be used in emergency situations such as floods, landslides, and other natural disasters. As a result, they may own pieces of equipment that are not technically matched to the work for which they are routinely assigned. This obviously will have an impact on the annual amount of usage and in the case of undersized equipment, the severity of the conditions in which they may be used. Thus, public agencies have evolved an equipment management strategy that is based largely on empirical terms that flow from the experiences of public equipment managers. This is often translated to a specified fixed amount of usage in terms of mileage or engine hours that defines the equipment's economic life regardless of the actual O&M costs that are incurred on a given piece of equipment. Some agencies also select cost points for equipment O&M costs that are defined in terms of a percentage of book value of the machine at which replacement is directed. Most agencies employ schedules or benchmarks for classes of equipment based on the criteria of age and usage, and included life repair costs as well as the equipment's condition. To give the reader a good cross section of public agency methods, the methods used by the Texas, Montana, and Louisiana departments of transportation (DOTs) are reviewed in the following sections.

3.3.2.1.1 Texas Department of Transportation

The Texas Department of Transportation (TxDOT) has equipment replacement criteria that are based on age, usage (miles or hours), and estimated repair costs. It is the most complex of the methods adopted by the three DOTs reviewed in this section and thus is presented first. TxDOT's equipment fleet is quite large comprising approximately 17,000 units. This fleet is used to furnish in-house road maintenance and small construction on the state's 301,081 total miles of roads and highways. With a fleet this large, the annual disposal program involves the replacement of approximately 10% of the total fleet [7]. There are 25 subordinate districts in TxDOT that each manage their own portion of the TxDOT fleet. The evaluation of the existing equipment for replacement is done at the district level subjectively using input from equipment, maintenance, and field personnel. This input is then combined with objective equipment performance data that includes age, miles (or hours) of operation, downtime, as well as operating and maintenance costs, to arrive at the final decision on which units to keep and which ones need to be replaced. The replacement decision is made 1 year before a given piece of equipment hits its target age, usage, and repair cost level to allow sufficient time for the procurement of the replacement model.

In 1991, the department fielded the TxDOT equipment replacement model (TERM) to identify fleet candidates for equipment replacement. The model was based on research of other DOT policies and an analysis of actual equipment costs incurred by TxDOT prior to that date. The logic of the model is expressed in the following terms:

> . . . each equipment item reaches a point when there are significant increases in repair costs.Replacement should occur prior to this point. Ad hoc reports were developed and are monitored annually to display historical cost information on usage and repairs to identify vehicles for

> replacement consideration. From this historical information, standards/benchmarks for each criteria [sic] are established for each class of equipment [7].

Input data for the TERM comes from TxDOT's equipment operations system (EOS), which has historical equipment usage and cost data dating back to 1984. EOS captures an extensive amount of information on all aspects of equipment operation and maintenance. Using the model's logic is relatively simple. First, the EOS historical cost data is processed against three benchmarks for each identified equipment class on an annual basis. The three criteria to be checked are

1. Equipment age
2. Life usage expressed in miles (or hours)
3. Inflation adjusted life repair costs expressed as a percentage of original purchase cost which has been adjusted to its capital value

Next, when a given piece of equipment exceeds all of the above criteria, it is identified as a candidate for replacement. Finally, the owning district makes the subjective evaluation of the given item of equipment including downtime, condition of existing equipment, new equipment needs, identified projects, and other factors. A final decision on whether or not to replace is then made. TERM is not meant to replace the knowledge of the equipment manager. It does furnish a good tool to assist in the decision-making process.

3.3.2.1.2 Montana Department of Transportation

Like TxDOT, the Montana Department of Transportation (MDT) evaluates its equipment fleet annually to make a decision on which pieces of its equipment fleet should be replaced. It uses the expected annual costs of new equipment as the metric against which current equipment is measured. In calculating this cost, the following factors are considered:

- The expected annual costs of the existing equipment
- The purchase price of the new equipment
- Its depreciation
- Its expected life

To be classified as a potential replacement alternative, the new equipment must meet the following criteria: the total costs of owning the equipment for its useful life is equal to the total loss in value for its useful life plus the total costs of operating the equipment over a specified number of years. Time value of money is accounted for using classical engineering economic theory for the single present worth (SPW) and uniform capital recovery (UCR) mathematical equations. The replacement analysis of MDT uses three equations:

- Equivalent annual costs of new equipment
- Salvage value
- Annual cost of an existing unit

The decision criterion for equipment replacement is that the equivalent annual ownership cost of the new equipment must be less than the annual cost of the current equipment. Thus, this method is able to first identify economical candidates to serve as alternatives against which the current equipment can be assessed and an objective criterion on which the replacement decision can be made [2].

3.3.2.1.3 Louisiana Department of Transportation and Development

Louisiana Department of Transportation and Development (LaDOTD) invested in a research project conducted at Louisiana State University as a means of determining optimal equipment replacement policy [8]. The project specified the following decision criteria:

> disallow the application of maintenance funds for major repairs to equipment that has reached 80 percent of its economic life or if the repair cost will exceed 50 percent of the book value of the equipment.

The report uses the same definitions for economic life as were proposed by Douglas [1] and were discussed in the earlier sections of this chapter. It was anticipated that net savings would be obtained after a 4-year period by increasing capital investment to decrease the cost of equipment operations, assuming the use of economic predictions. Accumulated costs for each unit were compared with the limits of the repair costs in order to identify "uneconomical" equipment that needs critical repairs. This critical repair method was very effective in verifying the optimum time for changing each unit. The method successfully calculated the optimum replacement point with 96% of certainty, and allowed the LaDOTD to set up the priority ranking of replacement needs. As a result, available funds can be allocated and used effectively [2, 8].

3.3.3 Sensitivity Analysis on Theoretical Methods

Construction equipment fleet managers must make an assumption to predict future costs. In doing this, variables are introduced into the computations that can influence the outcome of the equipment replacement decision. Therefore, it is important to understand the dynamics of the equipment replacement decision method. This understanding is gained through sensitivity analysis. Riggs and West [6] define sensitivity analysis as "a second look at an economic evaluation." Its purpose is to highlight those assumptions for input variables that could most easily change the decision if the assumption used for their value is off. By methodically evaluating the sensitivity of each input variable, the analyst gains an insight that gives confidence with which the final decision can be made. In other words, if the outcome is found to be highly sensitive to a given variable and the assumption for that variable's value is not made with strong historical back up, the confidence in the output's correctness drops dramatically. Conversely, if the outcome of the method is found to be insensitive to variations in the input values, then confidence in the answer's correctness is high.

For example, the actual value of fuel costs and operator costs strongly affects the predicted value of future operating costs. Due to inherent fluctuations in the oil market and labor market, these are difficult to predict for the short term. Equipment replacement methods require that these estimates be made for the long-term economic life of the piece of equipment under analysis. Therefore, to increase the confidence in the results, a sensitivity analysis is performed. This involves the following steps:

- Listing the parameters most likely to affect the estimated future cost figures
- Determining a probable range over which these parameters may vary
- Determining the effect on the estimated future cost figures of the parameters ranging over their probable range

When a future cost is significantly affected by the ranging variable, the cost estimate is said to be very sensitive to that variable [6]. The sensitivity analyses are preformed on the equipment replacement analysis methods proposed by Douglas [1] using the information supplied in Example 3.1.

TABLE 3.13
Average Annual Cumulative Costs of the Current Trucks (20% Depreciation)

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$52,000	$13,000	$43,000	$43,000	$43,000
2	$32,000	$41,600	$10,400	$42,400	$85,400	$42,700
3	$34,000	$33,280	$8,320	$42,320	$127,720	$42,573
4	$36,000	$26,624	$6,656	$42,656	$170,376	$42,594
5	$38,000	$21,299	$5,325	$43,325	$213,701	$42,740
6	$40,000	$17,039	$4,260	$44,260	$257,961	$42,993
7	$42,000	$13,631	$3,408	$45,408	$303,369	$43,338
8	$44,000	$10,905	$2,726	$46,726	$350,095	$43,762
9	$46,000	$8,724	$2,181	$48,181	$398,276	$44,253

3.3.3.1 Sensitivity Analysis on Minimum Cost Method

In Table 3.8, showing the average annual cumulative costs of the current trucks, the annual depreciation rate of 40% was used to calculate the annual depreciation expenses. Also, the annual maintenance and operating cost is $30,000 per truck for the first year and increases by $2000 each year. For performing the sensitivity analysis on the minimum cost method, two input parameters, the annual depreciation rate and the annual maintenance and operating cost, are selected on equipment replacement decision analysis for the current trucks. First, the annual depreciation rate is changed to 20% and then 60% fixing the annual maintenance and operating costs. The results are shown in Table 3.13 and Table 3.14, respectively.

When the depreciation rate is decreased to 20%, the average annual cumulative cost is the minimum of $42,573 in the third year from the ninth year with the original 40% depreciation assumption. When the assumption is taken to be 60%, the economic life is at the end of the eighth year (the lowest average annual cumulative cost of $45,120 will occur over a period of eighth year). Thus, this method is found to be sensitive to the depreciation assumption.

TABLE 3.14
Average Annual Cumulative Costs of the Current Trucks (60% Depreciation)

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$26,000	$39,000	$69,000	$69,000	$69,000
2	$32,000	$10,400	$15,600	$47,600	$116,600	$58,300
3	$34,000	$4,160	$6,240	$40,240	$156,840	$52,280
4	$36,000	$1,664	$2,496	$38,496	$195,336	$48,834
5	$38,000	$666	$998	$38,998	$234,334	$46,867
6	$40,000	$266	$399	$40,399	$274,734	$45,789
7	$42,000	$106	$160	$42,160	$316,894	$45,271
8	$44,000	$43	$64	$44,064	$360,957	$45,120
9	$46,000	$17	$26	$46,026	$406,983	$45,220

TABLE 3.15
Average Annual Cumulative Costs of the Current Trucks (O&M at $1000)

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$39,000	$26,000	$56,000	$56,000	$56,000
2	$31,000	$23,400	$15,600	$46,600	$102,600	$51,300
3	$32,000	$14,040	$9,360	$41,360	$143,960	$47,987
4	$33,000	$8,424	$5,616	$38,616	$182,576	$45,644
5	$34,000	$5,054	$3,370	$37,370	$219,946	$43,989
6	$35,000	$3,033	$2,022	$37,022	$256,967	$42,828
7	$36,000	$1,820	$1,213	$37,213	$294,180	$42,026
8	$37,000	$1,092	$728	$37,728	$331,908	$41,489
9	$38,000	$655	$437	$38,437	$370,345	$41,149
10	$39,000	$393	$262	$39,262	$409,607	$40,961
11	$40,000	$236	$157	$40,157	$449,764	$40,888
12	$41,000	$141	$94	$41,094	$490,859	$40,905

Second, it is assumed that the annual maintenance and operating cost increases by $1,000 instead of $2,000, fixing the annual depreciation rate of 40%. As a result, the minimum average annual cumulative cost changed from $44,989 at the end of the eighth year as shown in Table 3.8 to $40,888 at the end of the 11th year as shown in Table 3.15.

If the increase in annual operating and maintenance cost is changed to $3,000, the lowest average annual cumulative cost is $47,828 in the sixth year as shown in Table 3.16. Thus, the method is found to be sensitive to this parameter as well.

Given the outcome of the sensitivity analysis on the minimum cost method, the equipment manager should ensure that the values that are used for both the depreciation cost and the O&M costs are the best numbers possible based on historical records. The lesson here is that arbitrarily making an assumption without fundamental information on which to base that assumption can yield vastly different answers from what may indeed be the actual numbers.

TABLE 3.16
Average Annual Cumulative Costs of the Current Trucks (O&M at $3000)

End of Year (1)	Annual O&M Cost (2)	Book Value	Annual Depreciation Expense (3)	Annual Cost (4) = (2) + (3)	Cumulative Cost (5)	Average Annual Cumulative Cost (6) = (5)/(1)
1	$30,000	$39,000	$26,000	$56,000	$56,000	$56,000
2	$33,000	$23,400	$15,600	$48,600	$104,600	$52,300
3	$36,000	$14,040	$9,360	$45,360	$149,960	$49,987
4	$39,000	$8,424	$5,616	$44,616	$194,576	$48,644
5	$42,000	$5,054	$3,370	$45,370	$239,946	$47,989
6	$45,000	$3,033	$2,022	$47,022	$286,967	$47,828
7	$48,000	$1,820	$1,213	$49,213	$336,180	$48,026
8	$51,000	$1,092	$728	$51,728	$387,908	$48,489
9	$54,000	$655	$437	$54,437	$442,345	$49,149
10	$57,000	$393	$262	$57,262	$499,607	$49,961
11	$60,000	$236	$157	$60,157	$559,764	$50,888
12	$63,000	$141	$94	$63,094	$622,859	$51,905

3.3.3.2 Sensitivity Analysis on Maximum Profit Method

In the maximum profit method, the average annual cumulative profits of the two alternative trucks are driven by the decrease rate of the annual revenue and the change in annual cost as shown in Table 3.10. In this table, the annual cost is related to the annual depreciation rate, and the maintenance and operating cost. Therefore, the sensitivity analysis on the current trucks for this method will be done using three parameters: the annual depreciation rate, the maintenance and operating cost, and annual revenue. First, as in the previous section, the annual depreciation rate is varied at 20% and then 60% while the annual O&M cost increase rate and the annual revenue decrease rate are fixed to allow a judgment to be made regarding the sensitivity of the output to the change in this particular assumption. Next, O&M cost increase rate is varied at \$1000/year and \$3000/year to check its sensitivity. Finally, with the depreciation rate and O&M cost rate fixed, the decrease rate in annual revenues is varied at \$875/year and \$2625/year for the last sensitivity check. Table 3.17 reports the results of the three sensitivity analyses.

Looking first at the sensitivity to the depreciation rate assumption, one can see that varying this rate has a huge impact on the economic life of the truck when defined by maximizing the average annual cumulative profits with the greatest effect, as seen at the low end of the spectrum. The O&M and revenue rate assumptions also have an impact but are not as great as the depreciation assumption as they only change the economic life by 1 year.

3.3.4 Comparison and Discussion of Sensitivity Analysis Results

It is interesting to note the change in sensitivities as one moves from the minimum cost method to the maximum profit method. However intuitively, there should be some difference as the maximum profit method has one additional parameter, and the introduction of the additional parameter would be expected to change the mathematical dynamics of the analysis. From the sensitivity analysis on the minimum cost method, it can be concluded that the increase in the rate of the annual maintenance and operation costs is more sensitive than the depreciation rate. In other words, the replacement analysis based on the minimum cost method can be more affected by the change of the rate of annual increase of the maintenance and operating cost than that of the annual depreciation rate. Sensitivity analysis output can be described visually through the use of a tornado diagram. Figure 3.2 is the tornado diagram for this analysis. The amount of change in parameter value shifts the output value from its centroid, which is based on the expected values of the varying parameters, implies the level of sensitivity. Thus, the length of the output range that is produced by the change in input variable is roughly proportional to the level of sensitivity. So, as the range bar for O&M costs is longer than the one for depreciation rate, as shown in Figure 3.2, the average minimum annual cost is most sensitive to this parameter.

Figure 3.3 is the tornado diagram for the maximum profit method, and it clearly shows that the annual depreciation rate is the most sensitive of the input parameters. Thus, if the equipment owners want to maximize the average annual cumulative profit, they need to find the ways of controlling the annual depreciation rate, which will be more effective than to try preventing annual revenue from decreasing. Sensitivity analysis gives the equipment owner a "feeling" for how accurate the estimates that are made in this important step can be. It adds objective analytical information to the process and in doing so, decreases uncertainty while increasing confidence in the final solution.

Therefore, it can be seen that there is a wide range of choice in equipment replacement decision-making methods. Thus, equipment owners should carefully decide which methods they can use in this process and which parameters they can control to either minimize cost or

TABLE 3.17
Average Annual Cumulative Profits (AACP) of the Current Trucks

End of Year (1)	AACP (20% Depreciation)	AACP (40% Depreciation)	AACP (60% Depreciation)	AACP (O&M Increase by $1000)	AACP (O&M Increase by $2000)	AACP (O&M Increase by $3000)	AACP (Revenue Decrease by $875)	AACP (Revenue Decrease by $1750)	AACP (Revenue Decrease by $2625)
1	$27,000	$14,000	$1,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000
2	$26,425	$17,325	$10,825	$17,825	$17,325	$16,825	$17,763	$17,325	$16,888
3	$25,677	$19,263	$15,970	$20,263	$19,263	$18,263	$20,138	$19,263	$18,388
4	$24,781	$20,231	$18,541	$21,731	$20,231	$18,731	$21,544	$20,231	$18,919
5	$23,760	$20,511	$19,633	$22,511	$20,511	$18,511	$22,261	$20,511	$18,761
6	$22,632	$20,297	$19,836	$22,797	$20,297	$17,797	$22,485	$20,297	$18,110
7	$21,412	$19,724	$19,479	$22,724	$19,724	$16,724	$22,349	$19,724	$17,099

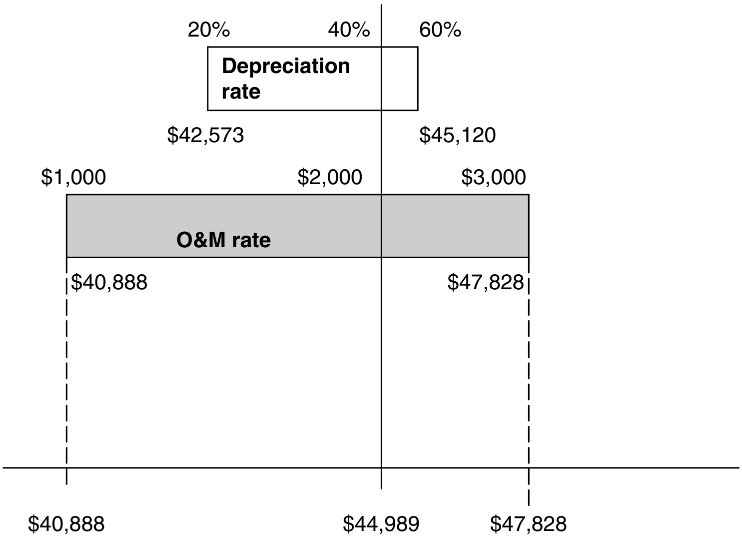

FIGURE 3.2 Tornado diagram for minimum cost sensitivity analysis on the current trucks.

maximize profits. They can then back up this by considering the results of a sensitivity analysis done on the assumptions that were made in the chosen method, and thereby feel more confident that they have indeed made the correct decision based on the available facts.

3.4 REPLACEMENT EQUIPMENT SELECTION

Picking the right piece of equipment to replace an existing one is a complicated decision that involves more than running the numbers to see if the new model will add value to the bottom line. With the seemingly exponential growth in machine technology as well as information technology that supports the construction industry, making the wrong replacement can be a costly mistake not only in terms of higher than expected ownership costs due to lower than expected production, but also in the loss of market share that occurs when a company's

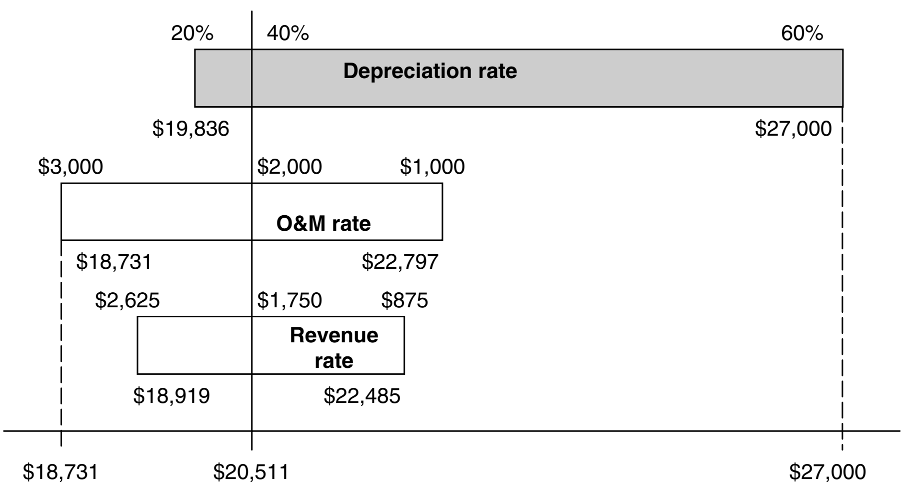

FIGURE 3.3 Tornado diagram for maximum profit sensitivity analysis on the current trucks.

operating costs exceed the industry norms. Therefore, the remainder of this chapter will be devoted to discussing the qualitative issues that should also be considered after the mathematical models are complete and the economic answers are on the table.

3.4.1 Replacement Decision Making

Replacing equipment involves more than just upgrading to the latest model. Timing the replacement is a difficult question that requires a thorough examination of company strategies and policies regarding cost of capital and capital budgeting. The previous methods furnish a great starting point, but they are inherently simplified, disregarding many important factors that cannot be generally modeled like tax status, the effect of owning capital equipment on the company's balance sheet, and on its stock price. Thus, when developing a process for equipment replacement policy, laying the foundations for decision making, which involves both qualitatively and quantitatively examining alternatives and selecting a means in which to make the investment decision, is the key to success.

3.4.1.1 Decision-Making Foundations

Every equipment management group should have a clear procedure to help it make equipment replacement decisions in a consistent manner every time the topic must be addressed. The fundamental foundation for equipment replacement decision making includes the following factors:

- Identify the decision-maker
- Define the defender (the current equipment) and the challengers (potential replacements)
- List the qualitative and quantitative decision factors

First, it is imperative that investment decisions are made by one or more persons who have been entrusted with the responsibility and authority to procure equipment as required by the organization's mission. This entity will be termed the "decision-maker" in the following discussion. The knowledge of financial management, accounting, procurement, equipment, and operations is essential to decision-makers. The decision-makers must be vested with the authority to buy and sell in accordance with current operational needs and the organization's strategy for future growth. To avoid suboptimizing the equipment fleet's capacity, the decision-makers should be able to make their choices from an unlimited set of potential pieces of replacement equipment and not be saddled with a requirement to only buy from specific manufacturers.

Industrial engineers like to use the term "defender–challenger analysis" when methodically comparing alternatives using engineering economic theory [6]. This term works very well in equipment replacement decision making, and hence for the purpose of the following discussion, the existing piece of equipment will be called the "defender" and the potential replacement candidates will be called the "challengers." It is important to define exactly what these alternatives are and what each consists of in terms of technology, capacity, productivity, and safety before starting the analysis. It may be expedient to take a given base model of equipment and develop several challengers that have different components and qualities. In this way, a logical analysis of the different "bells and whistles" can be accomplished and each can be compared to the defender to determine if adding a given optional component actually adds value to the equipment as it adds cost.

Finally, a means for evaluating qualitative factors should be developed and used after the quantitative analysis is complete. The qualitative factors can be used in several ways. First, they can be considered only as a "tiebreaker." In other words, if two alternatives were very close together quantitatively, the alternative that furnishes the greatest number of qualitative advantages would be selected. The second way would be to assign some form of numerical weighting to each qualitative factor and incorporate an evaluation of those factors into the quantitative analysis using utility theory [6] or some other analytic method to quantify the inherently qualitative feature of an alternative. Finally, the qualitative factors can be separated into two groups: factors that are required and factors that are merely desired. A required factor on a new dump truck might be a factory-installed global positioning system (GPS) unit to allow the company to track the location of its vehicles using a previously purchased GPS system that is currently in operation. A desired factor might be a preference for a given manufacturer's vehicle based on that company's good reputation for service. In this case, a challenger that did not have all the required factors would be eliminated at the outset of the analysis as unacceptable. Then the desired factors would be used as the tiebreaker in the same fashion as the first method. Examples of qualitative factors include the availability of a given replacement, its strategic value for potential growth and expansion in the company, and the ability to take advantage of market opportunities for preferred financing and other perquisites.

3.4.1.2 Examination of Alternatives

When a piece of equipment is determined as needing replacement, five different alternatives that need to be considered are:

- Overhaul the existing equipment
- Rent a new piece of equipment
- Lease a new piece of equipment
- Purchase a new piece of equipment
- Purchase a used piece of equipment

The benefits and costs of each alternative should be considered throughout the decision process. Each alternative should be weighed on a common scale for both quantitative and qualitative factors.

3.4.1.3 Decision to Invest

The final decision to invest (or not invest) in a replacement should be made within the framework of capital budgeting decisions and include a quantitative analysis of cost and the time value of money. Equally as important in the decision process are qualitative factors and their impact on the firm. As a final check, the decision-maker should insure that the decision passes the common sense test by including all important decision factors and answering the following questions such as:

- Is it a worthwhile thing to do?
- Is it the best way to do it?
- Is this the best period of time over which to do it?

3.4.2 General Factors

Once the decision to buy new equipment is made, the equipment manager should consider the following four factors [5]:

- Machine productivity
- Product features and attachments
- Dealer support
- Price

3.4.2.1 Machine Productivity

Every equipment owner wants to buy the optimum size and the best quality equipment at the lowest cost. It is important to select the size of machine that will deliver the best productivity for a given job. Chapter 5 furnishes several analytical methods that help to make this decision. Additionally, the owner's past experience is very good factor for supporting the mathematical output. The equipment dealer should have the latest data on machine capability under various operating conditions, which can then be used in the models shown in Chapter 5. Additionally, before purchasing, the equipment manger should differentiate the primary usage of the machine from its secondary usage. For example, a tracked excavator is primarily used to dig trenches and other excavations. However, when used on a pipe installation crew, it can also serve secondarily as the means for picking the pipe off a truck and placing them in the trench. Focusing on the major required function of the machine makes it easier to determine the proper size or capacity and as well as any required machine attachments.

When purchasing large pieces of equipment, factors, such as transportability between work sites and the legal restrictions to movement, must also be considered. Finally, as new technology is procured, training for operators must be available in a timely manner and should not be cost-prohibitive.

3.4.2.2 Product Features and Attachments

Selecting the right equipment with the adequate attachments not only increases productivity but also decreases downtime. For example, wheel-loader production can be increased by adding automatic bucket controls, special-purpose buckets, and optional counterweights [5]. The equipment manager should be careful not to add special attachments that do not enhance the economics of the overall system. Qualitative factors such as safety must also be considered when considering attachments and special product features. Factors such as mechanical compatibility with other types of equipment that enhance the ability of the maintenance crew to perform its duties often payoff in reduced downtime and reduced spare parts costs.

3.4.2.3 Dealer Support

Dealer support determines the ability of a piece of equipment to achieve its prescribed production rates. The ability to get spare parts in a timely manner, the availability of service facilities and qualified technicians, and the transparency of the dealer's web site all play an important part in ensuring maximum equipment availability. From the day the equipment is purchased until the day it is traded-in on a new piece, it is the performance of the dealer that determines whether that machine will perform as anticipated. The dealer's reputation for user-friendly support and customer-oriented action is a qualitative factor that can ultimately make or break a fleet of heavy construction equipment's profitability. Thus, this factor should be given special priority in the final equipment purchase decision.

3.4.2.4 Price

The equipment replacement decision-making methods detailed in earlier sections of this chapter require a purchase price and a salvage value as input. While this might be the final factor considered in machine selection, it becomes the fundamental factor that will drive the final decision. Resale price, maintenance and repair costs, and the cost of special features and attachments should be factored into the decision as well. A life cycle cost mentality should be used when looking at prices. A machine may cost less initially, but it could be more expensive to operate and maintain, quickly wiping out any initial savings. A purchase price should be coupled with satisfactory performance as well as dealer parts and service support to ensure that actual equipment availability meets the assumptions made in the analysis. When all the factors have been weighed, then the equipment manager is ready to arrive at the best decision. In an excellent work on equipment management, Bonny and Frein summed up the price issue in the following quotation:

> The total cost of owning and operating a machine, and not the machine price, should be the decision maker in equipment selection [5].

3.5 SUMMARY

This chapter defined and discussed three types of equipment life: physical life, profit life, and economic life. It explained on the concepts of depreciation and replacement, inflation, investment, maintenance and repairs, downtime, and obsolescence that impacted the equipment replacement decision. Replacement analysis was introduced by demonstrating theoretical replacement methods by a continuing example, and practical replacement methods were also described. The concept of sensitivity analysis was applied to two of the theoretical methods to demonstrate gain accuracy and confidence in the output of the analyses. Finally, the decision-making process for replacement equipment selection was introduced in a step-by-step fashion and the four general factors, which should be considered after replacement decision is made, was explained.

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4 Earthmoving, Excavating, and Lifting Equipment Selection

4.1 INTRODUCTION

The crux of equipment selection lies in finding the right tool for a given job. It means ensuring that the given piece of equipment is configured in a manner that allows it to maximize its production potential as well as minimize downtime. As such, there are a number of basic considerations for selecting the right piece of equipment for any given task.

4.2 BASIC CONSIDERATIONS FOR EQUIPMENT SELECTION

Equipment costs rank second to labor costs in terms of uncertainty and in their effect on the outcome of anticipated profit for a construction project. Selection of the right piece of equipment, like the right man for the job, affects field productivity. Productivity directly influences profitability. Using a machine that does not have enough capacity will slow down productivity. Using a machine with too large capacity might increase productivity to some extent, but will ultimately negatively affect profitability, because of the cost of operation of the oversized machine. Pairing machines with mismatched capacities are not efficient and will not yield the optimum unit price for the work.

The first equipment selection step involves matching the right machine to the work activity (see Table 4.5). The work activity includes all factors associated with the specific physical task. Each piece of construction equipment is specifically designed by the manufacturer to perform certain mechanical operations that accomplish the work activity. Mechanical operations are typical for each classification of earthmoving, excavation, and lifting equipment. For instance, all front-end loaders work in the same way. They are built to scoop at ground level, carry the load, hoist the load, and dump the bucket forward. Whether a Caterpillar, Case, or JCB loader, they all mechanically operate similarly. Using a front-end loader to excavate a deep hole would not be a proper use of the machine. Failure to match the machine to the work task usually results in operating inefficiency and placing the machine at risk due to improper use. The same can be said for a Manitowoc, Grove, or Link Belt mobile crane. They all basically work the same and are designed to lift and swing loads.

Two types of failure can occur for all equipment. Structural or mechanical failure occurs when the machine is overloaded or stressed beyond the physical capabilities of its components. This could mean a lattice boom buckling when lifting a load that is too heavy or a loader with an oversized bucket working too many repetitions in the heat of the day and the motor locking. Stability failure occurs when the machine is overloaded or placed in a situation where it cannot remain balanced and upright. This could mean a crane hoisting an unbalanced load causing it to overturn, though the boom remained intact or a loader traveling on an uneven surface with a dense load too high, causing the machine to nose-dive on the uneven surface, though all parts of the machine are intact and still operable. Using machines matched to the task will greatly increase the chance of avoiding failures and should be a primary goal of equipment selection.

One of the most important considerations when selecting a piece of equipment is the availability of the right machine with proper and timely service, maintenance, and repair. The right machine must not only match mechanical functions, but also power, capacity, and control requirements. Equipment discussed in this book is considered standard equipment with parts and service readily available. Dealer or rental agency location proximity and staff competency will influence downtime and turnaround for service.

The physical properties of clay, gravel, organic matter, rock, sand, or silt to be moved or excavated has a direct influence on the type and capacity of equipment selected for a specific work activity. The ease or difficulty of removing and handling soil or any material directly influences the amount of machine productivity. This will also determine capacities and types of buckets, blades, and attachment or accessories. How the soil breaks apart or sticks together will influence how much can be put in a bucket, blade, bowl, or bed. A front-end loader bucket will hold more slightly wet sandy clay soil than dry sand. The composition of the soil and the amount of moisture in the soil influence the heaped capacity that the bucket can hold or the blade can push.

Soil type and stability are also important to the engineer because the size of the particles, physical properties, and behavior when the moisture content is changed greatly influences the site and foundation design. Sometimes the soil must even be replaced or stabilized using other types of soils or additives. These decisions influence the types and capacities of the equipment needed by the contractor for the site work and ultimate construction of the foundation system.

The type and condition of the working surface and the distance to be traveled affect the choice of tires or tracks. This will be discussed in more detail in an upcoming section in this chapter. Desired productivity is also a major influence on earthmoving, excavating, and lifting equipment selection. Meeting the schedule for the quantity of work to be accomplished is the goal. The required hourly production of a piece of machinery is primarily determined by the amount of work to be done and how fast it has to be done. The amount of time the contractor wants to spend or has to spend on excavation or earthmoving will greatly influence the size of machinery chosen for the work. If there is a large volume of dirt that needs to be moved quickly, a large piece of machinery will probably be most efficient. If there is a small amount of dirt to be excavated, a smaller piece of machinery makes more sense. Lifting production is heavily dependent on ground and on-structure craft support efficiency. Lifting capacity and vertical hoist speed are the primary equipment influences on lifting production.

The following basic relationships exist for equipment selection:

- As equipment productivity increases so does the initial purchase price, operating, and maintenance costs.
- As equipment capacity increases, so does the hourly production.
- As equipment productivity increases, the unit cost ($/cubic yard, $/square foot, $/ton, $/load) for the work decreases.

Equipment selection demands attention to all of these considerations and others. As efficiency is achieved, the unit cost decreases. Therefore the contractor can bid more competitively for large quantities of work. The objective is to match the right piece of machinery with the most optimal working capacity to the desired budget and schedule. Whether owning or renting, to be profitable equipment must earn more money than it costs. Consideration of equipment needed for the construction during the design phase and proper equipment selection for bidding and construction are vital elements to a successful project. Profitability for the user is most influenced by the ability to keep the equipment busy and maintain it properly. Typically equipment, like a car, does not appreciate in value over time. The more the equipment is operated, the more maintenance it requires.

Equipment selection is typically company-specific and directly influenced by specific project and financial considerations. Equipment needs are further influenced by the complexity and uniqueness of a specific work activity. Contractors typically stretch the versatility of a piece of equipment by using it for multiple types of work. The goal is always to match the best hourly cost to the required production for the work activity.

4.3 EARTHMOVING AND EXCAVATING CONSIDERATIONS

Whether the working equipment moves on tracks or tires has a major influence on productivity (how much dirt can be moved or excavated in a certain amount of time or how fast material can be transported). Both types of movements offer advantages and disadvantages based on working and surface conditions.

4.3.1 TRACKS AND TIRES

Usable force available to perform work depends on the coefficient of traction of the work surface and the weight (lbs) carried by the running gear or wheels. The amount of tractive force necessary to push or pull a load is important for sizing the right machine. Manufacturers provide rimpull or drawbar pull tables for most of their equipment models showing tractive power that can be delivered at specified operating speeds. This information can be used to verify a machine's ability or capacity to work in specified job conditions (primarily rolling or surface resistance and grade resistance) and achieve the desired production.

Coefficients of traction vary based upon the travel surface. They measure the degree of traction between the wheel or track and travel surface. Slick surfaces have lower coefficients of traction than rougher surfaces (assuming both surfaces are relatively level and flat). Coefficients of traction for rubber-tired vehicles range from 0.90 for a concrete surface, 0.20 for dry sand to 0.12 for ice. Typically, coefficients of traction tables are available in equipment performance handbooks. The better the traction generated by the piece of equipment on the travel surface, the shorter the travel time and less wear and tear on the piece of equipment. Simply stated, maximum tractive effort (drawbar or rimpull in pounds) equals the equipment weight multiplied by the coefficient of traction of the travel or work surface.

This formula calculates the maximum amount of force that can be generated for a load on a surface. Excess tractive effort generated by the equipment will cause the tires or tracks to spin. Overloading will cause this result. The machine's engine provides the power to overcome the resistances and move the machine. The engine must be sized or matched to meet the tractive effort required to the capabilities of the machine. The model selected would be appropriate if it can generate enough tractive effort to perform the specific task without overburdening the machine.

Tracked equipment is designed for work activities requiring high tractive effort (drawbar) or the ability to move and remain stable on uneven or unstable surfaces. Tasks such as pushing over trees, removing tree stumps, or removing broken concrete flatwork require a very high pushing force. The tracked bulldozer is ideal for this type of work. Tractive effort results from the track cleats or grousers gripping the ground to create force necessary to push or pull dirt, material, or any other piece of equipment. Tracked equipment is most efficient when used for short travel distances less than 500 ft. Figure 4.1 shows a typical piece of heavy construction equipment running on tracks. Most loaders on construction sites run on tires.

Tracks can be metal or rubber. Metal tracks are more durable and can withstand much greater abuse than rubber tracks. Heavy-duty dirt moving equipment will almost always run

FIGURE 4.1 Tracked loader.

on metal tracks. Rubber tracks are lighter and best for smaller equipment working in organic matter and surfaces requiring minimal disturbance. Tracks come in varying widths and thicknesses. The width of the track shoe determines the ground pressure. The wider the track the more surface area covered and the wider the load distribution. Wider track shoes have greater flotation on the work surface. The heavier the track, the more power required to make it move. Narrow track shoes are better for harsh irregular hard work surfaces. Shoes are typically designed with single or double grousers. Single grouser shoes are better for developing traction and double grouser shoes typically are less damaging to travel or work surfaces.

It should be noted that tracked equipment typically marks or gouges the surface on which it is operating. Skid-steer types of equipment (bulldozers and loaders) will gouge the surface with the track cleats when they turn. To avoid "customizing" a parking lot surface, plywood can be laid, on which the tracked equipment can maneuver, and rubber or padded tracks or use a tired piece of equipment could be used. A hot asphalt surface typically will mark or rip with tires or tracks unless the surface is protected.

Tired equipment is more mobile and maneuverable than tracked equipment. Machines can achieve greater speed and therefore are better for hauling. However, pulling ability is reduced to reach a higher speed. Tired equipment is more efficient than tracked equipment when the distance is greater than 500 ft. The tire diameter and width, tread design, and inflation pressure influence the ability to roll. The larger the tire, the more power required to make it roll. Tread and track design influence the ability to grip the travel surface. A more pronounced deeper tread grips better. The inflation pressure also influences how much resistance the tire has on the travel surface. The less the inflation pressure, the greater the surface area covered by the tire, the harder it is to roll and more buoyant the equipment.

Rolling resistance is the resistance of a level surface to a uniform velocity motion across it. It is the force required to shear through or over a surface and is also termed wheel resistance (e.g., a truck tire developing friction on the road surface as it turns). Rolling resistance has two components: surface resistance and penetration resistance. Surface resistance results from the equipment trying to rollover the travel surface material. Penetration resistance results from the equipment tires sinking into the surface. Obviously, this resistance will vary greatly with the type and condition of the surface over which the equipment is moving. Simply put, soft surfaces have higher resistance than hard surfaces. On a hard surface, a highly inflated tire has less rolling resistance than a less inflated tire, primarily because of less tire surface area coming in contact with the road surface. A highly inflated tire has greater rolling resistance in sand than a less inflated tire because it will sink deeper into the rolling surface. The rolling resistances shown in Table 4.1 are adapted from John Schaufelberger's book, *Construction Equipment Management* [3]. The table shows several surfaces and their rolling resistances. Rolling resistance is expressed in pounds of resistance per ton of vehicle or equipment weight. The rolling resistance is greater for a loaded piece of equipment than when it is unloaded. Use the loaded weight of the equipment (equipment including fuel and lubricants plus load) in tons when calculating resistance.

When there is no real penetration into the travel or operating surface, the rolling resistance is about 40 lbs/ton. The weight of the equipment should include the load. When a tire sinks in the mud until it is stable, the rolling resistance as it tries to climb out of the rut increases about 30 lbs/ton (2000 lbs) for each inch of penetration.

The following example calculates the amount of tractive effort a scraper must generate to overcome the resistance of the working surface.

Example 4.1 Calculate the tractive effort generated by a 92,000 lbs loaded scraper traveling on a maintained dirt haul route where the tires sink about 2″ into the travel surface.

92,000 lbs/2000 lbs/ton = 46 tons.
Rolling resistance = 46 tons (50 lbs/ton) = 2300 lbs.
Penetration resistance = 2″(46 tons) (30 lbs/ton/inch) = 2760 lbs.
Total tractive effort = 2300 lbs + 2760 lbs = 5060 lbs.

With this number, the equipment manager can refer to the manufacturer's performance specs to select a piece of equipment that can generate enough power (in this case rimpull) to overcome this resistance.

Grade resistance is the force-opposing movement of a vehicle up a frictionless slope (does not include rolling resistance). The effort required to move a vehicle up a sloping surface increases approximately in proportion to the slope of the surface. The effort required to move a vehicle down a sloping surface decreases approximately in proportion to the slope of the surface. For slopes less than 10%, the effect of grade increases for a plus slope and decreases for a minus slope. The required tractive effort increases or decreases 20 lbs per gross ton of weight for each 1% of grade.

Example 4.2 The scraper in the previous example must haul up a 3% grade on part of the haul route.

TABLE 4.1
Rolling Resistances

Surface	Rolling Resistance (lbs/ton)
Asphalt/concrete	40
Maintained dirt	50
Poorly maintained dirt	Up to 120
Packed sand/gravel	60
Loose sand/gravel	Up to 200

Grade resistance = 3% (46 tons) (20 lbs/ton/% grade) = 2760 lbs.
Total resistance = rolling resistance + penetration resistance + grade resistance
Total resistance = 2300 lbs + 2760 lbs + 2760 lbs = 7820 lbs.

The typical total resistance of surfaces over which tired equipment must work should be considered when choosing the equipment. This will influence how big the engine should be to power the equipment to overcome the resistances, the type and size of tires, and other operating decisions. Table 4.2 shows basic work requirements and the preferance of tracks or tires for the work requirement.

4.3.2 Buckets and Blades

Buckets come in many shapes and sizes. Most can be easily replaced or changed quickly "on the fly." The shape of the bucket and the teeth or penetration edge is greatly influenced by the material that is to be excavated or moved. A bucket designed for moving loose gravel should not be used to dig into hard material. As the material to be worked becomes harder, typically buckets become slimmer and more elongated. Loaders, backhoes, and excavators typically have standard buckets that can be used for a wide range of material types and uses. Buckets can have jaws or apparatus for grasping irregularly shaped loads such as concrete chunks with rebar protruding or jaws that can be used to cut structural members for demo.

The size of the bucket and ultimate payload must be matched to the power of the equipment. Weight represents the safe operational pounds that the excavating, hauling, or moving unit can accommodate. Placing a large bucket on a piece of equipment with a small capacity engine will not be efficient. This will overburden the equipment and wear the engine out prematurely. Manufacturer's suggestions should be followed for the bucket size selection. A broad bucket requires more power to push through material than a narrow bucket. However, broad larger buckets are ideal for loose sand or gravel moving.

Buckets vary in width, depth, and structure depending on the match to the power of the machine and the type of material that is excavated or moved. Narrow sleek buckets with teeth are designed for penetration of a hard digging surface. The buckets used for moving material

TABLE 4.2
Track or Tire Choice

Requirement	Best Choice
High tractive effort required	Tracks
Low tractive effort required	Tires
Stable work surface	Tires
Unstable work surface	Tracks
Short push or travel distance	Tracks
Long push or travel distance	Tires
Muddy work conditions	Tracks
Side sloping	Tracks
Loading heavy unstable loads (dump truck)	Tracks
Maneuverability required	Tires
Speed required	Tires

are typically wider and may not have teeth. The need for penetration power is dependent upon the density of the digging surface. Most equipment models have a standard bucket or range of types and sizes specified for that machine. The bucket typically is included as part of the purchase price. Most equipments have specially designed bucket and attachment systems so that the bucket can be changed easily and quickly. Figure 4.2 shows basic bucket shapes and teeth designed for the type of digging work to be done.

Bucket 1 is for digging in moderate to hard abrasive materials. Pieces welded on the side near the teeth help penetration and holding the load. Bucket 2 is for digging fragmented rock, frozen ground, and highly abrasive compacted materials. It is taller and thinner than bucket 1. The extra pieces on the front bucket edges protect the bucket sides. Bucket 3 is for digging hard rock and work areas where material is undisturbed or poorly prepared. The thin streamline curved design and sharp irregular teeth configuration make penetration easier. Bucket 4 is for bank forming, ditch cleaning and finishing, and loose material movement. There are no teeth on bucket 4.

Along with the bucket, the bucket teeth or tips are very indicative of the type of work that the equipment is set up to do. Teeth might be permanently part of the bucket, attached by bolts, welded or some other means. These teeth might actually have added tips. If teeth are temporarily connected, as their edges wear out they can be replaced easily. Like the bucket, teeth selection is greatly influenced by the density of the material to be excavated or moved.

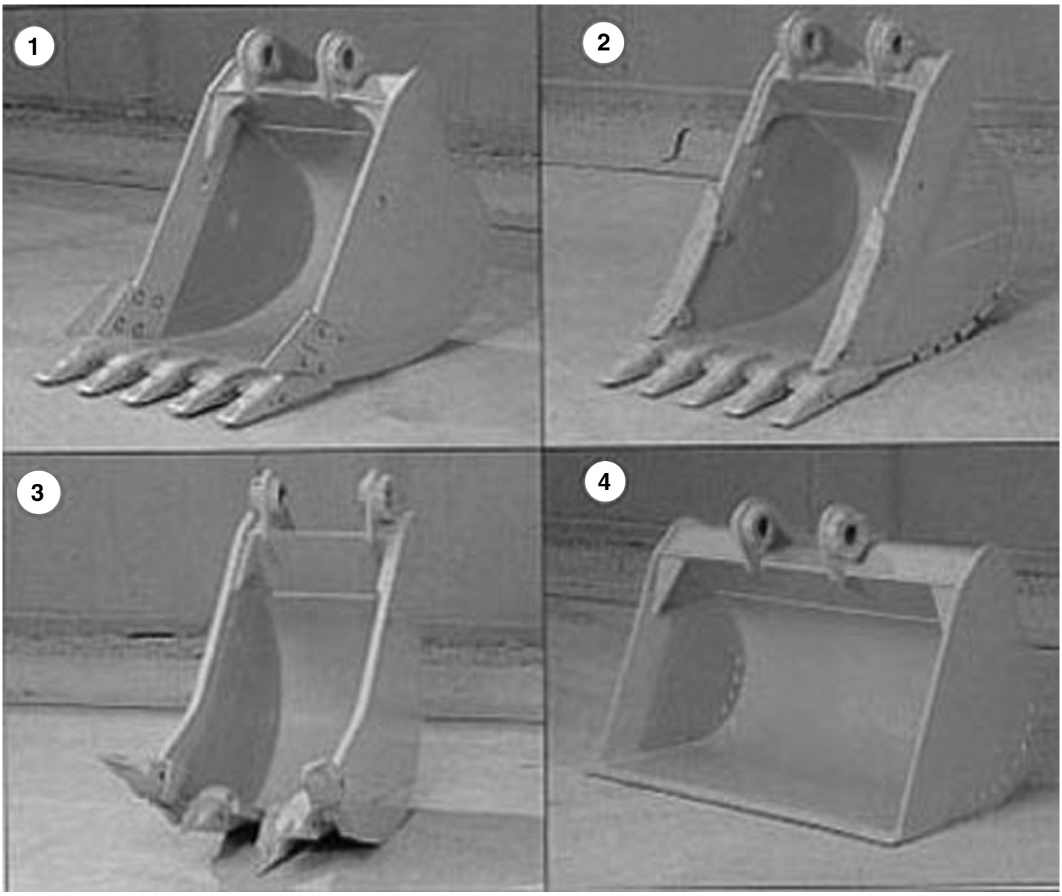


FIGURE 4.2 Typical Caterpillar hoe buckets. (Caterpillar Inc. With permission.)

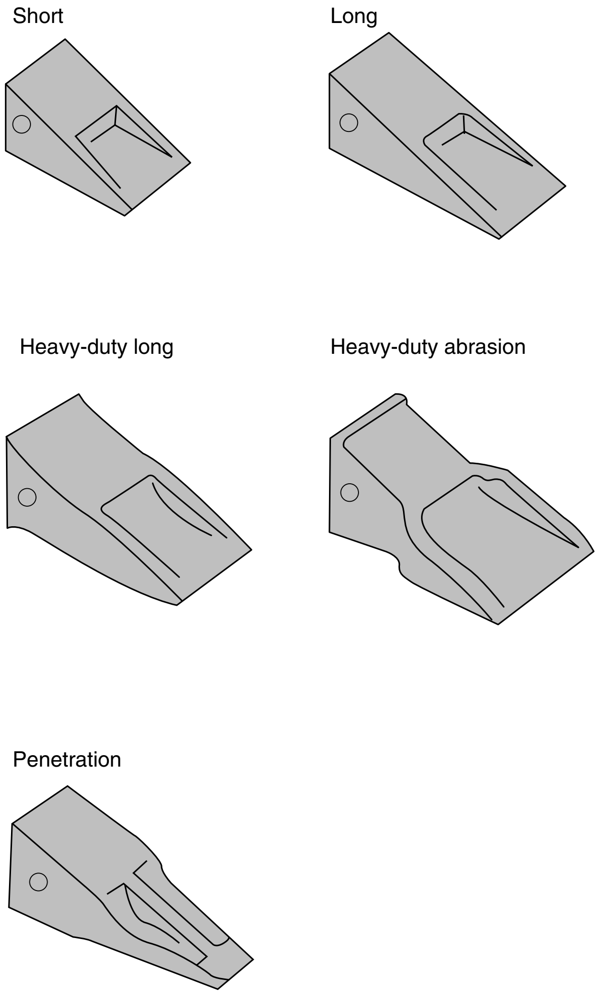


FIGURE 4.3 Teeth options. (Caterpillar Inc.)

The penetration of the bucket into the digging surface is easier using sharper, longer, and narrower teeth. Figure 4.3 shows teeth or tip options that are offered on Caterpillar excavating equipment.

Short teeth are used for regular penetrating and breaking apart material. Long teeth are used for chiseling into and breaking apart a packed surface. Heavy-duty long teeth are wider like a chisel and used for breaking apart a packed surface. Heavy-duty abrasion teeth cover more surface area and are used for fitting under a load or breaking apart a larger area. Penetration teeth are used for heavy duty penetrating and breaking apart dense material.

Bucket payload can be measured by volume or weight. Volume is typically stated as struck measure of loose volume meaning that the material excess is scraped off flush with the top of the bucket (excavator) or the bowl (scraper or dump truck) or heaped at a specific angle of repose meaning that the soil will support or cling together when piled and maintain this configuration. Figure 4.4 is reproduced from 30th edition of the *Caterpillar Performance Handbook* [1] and shows these two measures.

The heaped capacity of a bucket or a bowl can be calculated using the fill factor for the type of soil that is moved or excavated. Different soils have different fill factors. Stickier soil

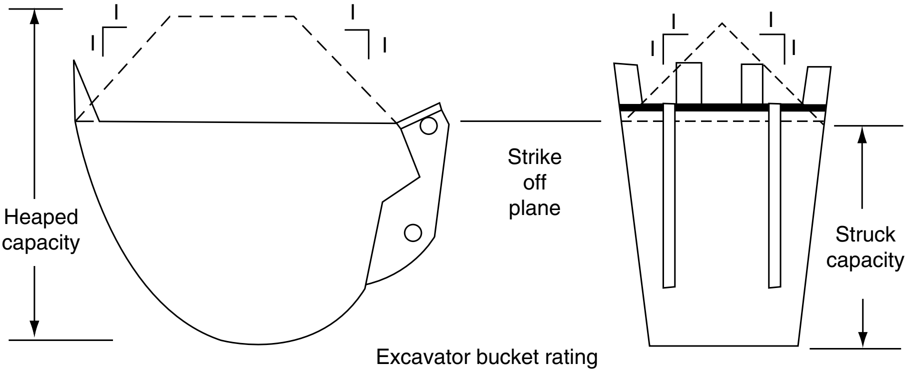


FIGURE 4.4 Struck and heaped bucket capacity. (Caterpillar Inc.)

has a greater fill factor, therefore more can be heaped into the bucket or the bowl. The amount of moisture in the soil will influence the fill factor. The average bucket payload equals the heaped bucket capacity times the bucket fill factor. Table 4.3 is adapted from fill factors [1] listed in the *Caterpillar Performance Handbook* shows different types of soils and respective fill factors.

Weight represents the safe operational pounds that the hauling or the moving unit can accommodate. The pounds per loose cubic yard of dirt or material times the heaped bucket cubic yard capacity can be used to determine the load weight. Each machine is rated for how many pounds it can structurally lift and remain stable. This information is provided by the manufacturer's equipment specifications. If a subcontractor is paid by the load to haul in or haul off, it is good practice to periodically verify if the trucks are filled to capacity each time the truck is loaded. The best way to do this is to climb up and take a look.

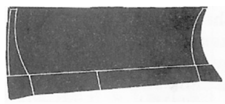
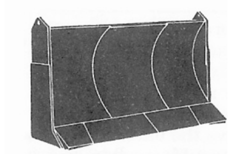
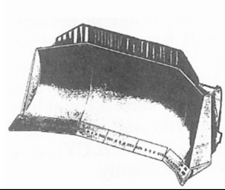
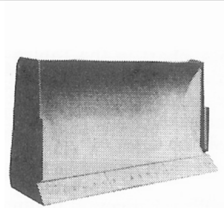
Like buckets, blades should match the expected work task. A typical blade configuration is like a "C" from top to bottom. As the blade is moved forward and tilted, the bottom of the blade acts as a cutting edge and the top edge rolls the materials forward. It is like the material "boiling" in front of the blade. Different types of materials accumulate in front of the blade differently. Like bucket payload, blade payload is influenced by type of the soil that is moved. Basic blade classifications are shown in Table 4.4.

Other types of blades are made for specific uses such as tree cutting, land clearing, and deep cutting and penetration:

TABLE 4.3
Typical Fill Factors

Type of Soil	Fill Factor (%)
Moist loam or sandy clay	100–120
Sand and gravel	100–120
Hard clay	85–100
Broken rock	75–90
Rock	60–75

TABLE 4.4
Common Dozer Blades

	• A Blade
	• C Blade
	• U Blade
	• S Blade

Source: Caterpillar Inc.

- Angle (A): Used primarily for side casting material; excellent for drainage ditch excavation, wider than an S blade; used for fine grading and surface removal; not recommended for rock or hard digging surfaces
- Cushion (C): Used primarily with scrapers for "on the go" push loading; can be used for lighter excavation and other general tasks
- Universal (U): Used for moving big loads over longer distances; curved shape and side and top extensions reduce the spillage of loose material; best suited for lighter materials
- Straight (S): Used primarily for shallow surface removal, land clearing; designed to push dirt for short distances, stumps and demo; versatile, lightweight and maneuverable, handles a wide range of materials

Figure 4.5 illustrates the method suggested by the *Caterpillar Performance Handbook* for calculating a bulldozer blade load in the field using the grouser marks in the work surface as a reference for measurement [1].

To perform this measurement, the operator makes a normal pass, pushes a pile of soil, and measures it using the following process:

- *Measurement Step 1*: Measure the average height (H) of the pile in feet. Hold the tape vertically at the inside edge of each grouser mark. Sight along the top of the pile at these points and record the observed H. Calculate the average H from the two observations.

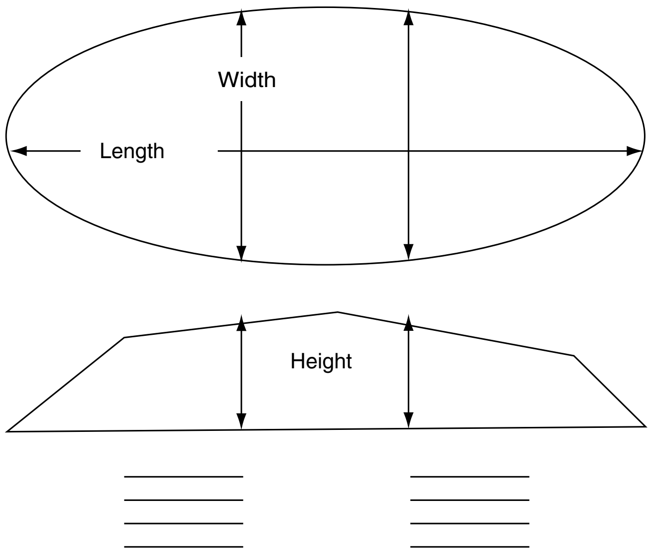


FIGURE 4.5 Dozer blade payload.

- *Measurement Step 2*: Measure the average width (W) of the pile in feet. Hold the tape 0-end of the tape vertically above one side of the pile at the inside edge of a grouser mark. Sight downward and measure at the corresponding opposite side of the pile. Do this at the inside edge of the other grouser mark. Calculate the average W.
- *Measurement Step 3*: At the greatest length (L) of the pile in feet, hold the tape horizontally over the pile with the 0-end of the tape over one end. Sight downward and measure at the corresponding opposite point at the other end of the pile.

$$\text{Blade load(lcy)} = 0.0138(WHL) \tag{4.1}$$

where lcy is loose cubic yards.

Another method can be used to field measure and determine a typical blade load. It is based on measuring the pushed pile similarly. It should be noted that in the following equation, L is the length or width of the blade, not the measured length and width of the pile:

$$\text{Volume} = (0.375)(WHL)/27\text{cf/cy} \tag{4.2}$$

Knowing the actual field, the measured blade load based on the actual soil type that is excavated or pushed can be used to determine a more exact estimated hourly production. If exact production calculations have to be done, measuring and averaging several excavated blade loads in the field is advisable.

There are three basic blade adjustments that the operator can control for operation. The blade can pitch, allowing the operator to vary the angle of attack of the blade's cutting edge with the ground (digging). The blade can angle, allowing the operator to turn the blade so that it is not perpendicular to the direction of travel (side casting). The blade can tilt, allowing the operator to move the blade vertically to permit concentration of tractor driving power on a limited length of the blade (sloping).

4.3.3 Accessories and Attachments

Today there are accessories and attachments available for every major type of equipment for practically every type of construction activity. Excavators, backhoes, and loaders are designed to use many attachments, making them very versatile machines to have on a project. Equipment suppliers should be consulted to see what is available for a specific task. Accessories and attachments must be chosen based on compatibility with the machine size and attachment setup. Performance specifications might be consulted for the attachment's designed working ranges and capabilities. Many times attachments or accessories are rented and used on a one-time basis for a short duration.

Accessories utilizing wireless and computer technologies include systems to remotely and automatically control blade lift and equipment control, security and tracking systems, and alert or warning systems for maintenance, repair, fuel and lubricant levels, and diagnostics. Development of technology-based accessories will continue as equipment is designed for more specific applications and different working environments and conditions.

4.3.4 Earthmoving and Excavating Work

For purposes of the following discussion, note that equipment manufacturers publish equipment performance manuals containing design specifications, performance criteria, and projected costs of using their equipment. The information is typically organized by the equipment type and model. These manuals also include guidelines and suggestions for equipment use, equipment accessories, and other related information. For specific equipment information, the performance manual should be consulted for actual specifications and operating capacities.

"Earthmoving" typically occurs during the initiation of the project. The selection of appropriate equipment, equipment groups, or a subcontractor with the right equipment and enough "big iron" to do the work efficiently and on time are important. Typically underground utilities or foundation preparation is not started until the rough earthwork or earthmoving is done. On a large project with many mobile pieces of equipment moving a large amount of dirt, earthmoving can be a rather dangerous. Constantly operating the equipment creates noise and dust. Minimizing these factors for the safety of personnel on site is a major management responsibility. The contractor should have a plan to control this.

The following "rules of thumb" based on hauling distance should be considered when selecting an earthmoving equipment. These are guidelines and job or site conditions that may influence actual criteria. If the distance that the dirt must be moved is less than about 500′, then a bulldozer or loader might be used. Bulldozers cut and push the surface dirt using a blade. Many times a bulldozer is the first piece of equipment on the job. Loaders are not very effective for excavating, but are great for carrying or loading excavated dirt one bucket at a time. If the distance is 350′ to 500′, but less than about 2 miles, then a scraper might be used. The scraper can excavate, haul, and dump. If the dirt must be moved far than 2 miles, then the best choice is to use front-end loaders to load the excavated soil into dump trucks and haul it to another location.

"Excavating" can mean removing the top layer of soil and vegetation as the job starts or digging a huge hole to place a building foundation for a skyscraper. Excavating equipment is typically used to dig, move, or load earth. Some machines perform excavation as well as earthmoving. The scraper and bulldozer are examples of machines that excavate and move earth. However, they would not be very effective for digging a square hole 30-ft deep. Each type of excavating machine digs differently and is used for specific work activities and site and work conditions. Regardless of the type of project, excavation is necessary for site preparation, underground utility installation, foundation construction, and landscaping.

To accomplish this, one piece of machinery may be used, but most of the time a combination of several pieces of equipments are required.

Hoes or excavators dig below grade or below the tires or tracks of the digging machine. The area covered by the reach of the boom and arm of the excavator is called the digging envelope. The depth to which the tip of the bucket teeth can reach below the machine tracks to remove a bucketful of dirt is the digging depth. The deeper the hole, the longer the reach required and the more stress placed on the boom and digging arm or stick of the machine. Typically the deeper the hole, the bigger the machine required (unless possibly the soil is noncohesive like sand). Figure 4.6 shows a typical side view of the designed working envelope for an excavator.

Figure 4.6 shows the depth and height that the boom and arm can reach. When selecting an excavator, not only must the basic machine be considered, but also the boom and arm lengths and configurations as well. The optimum digging depth for a boom and arm is about 60 to 70% of the machine's reach below grade. To dig a trench 10′ deep, the excavator would have a rated digging depth of about 17′.

The maximum depth of cut is the rated depth that the blade or the bucket can cut into the soil in one pass. A pass can be considered one time through the cycle to fill the bucket or the blade. An efficient operator will set the bucket or the blade just deep enough so that when one

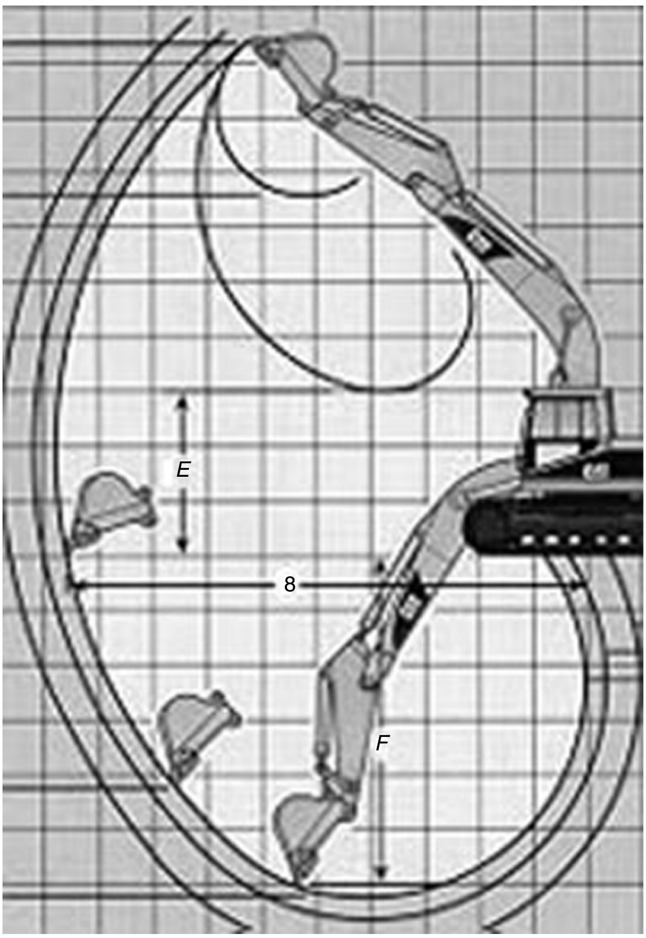


FIGURE 4.6 Caterpillar excavator digging envelope. (Caterpillar Inc.)

motion or cycle is complete, the bucket or the blade will be filled to its rated capacity. Whether a blade or a bucket, the deeper the cut, the more effort required for the equipment to push the blade edge or the bucket teeth into and through the material to be excavated. The deeper the penetration, the faster the blade or the bucket will fill. This shortens the push distance or reduces the extension of the excavator's boom, reducing the cycle time and increasing the production. The trade-off is higher operation costs (more fuel, lubricant, higher maintenance) because the machine must work harder to dig deeper. Optimum motor efficiency (most economical operation) is achieved when the equipment excavates at the optimum depth of cut for that size of motor, blade or bucket, and soil type.

Crowding force is the operational force required to push the edge or the bucket teeth into the material face. It can be done mechanically, like an excavator or front shovel or by driving into the material face like a loader. Breakout force is the operational force necessary to break material apart once the bucket teeth or edge is set. Breakout force is developed by curling the bucket downward "to the machine" like the excavator, or upward "away from the machine" like the front shovel. Greater force is required to break hard-packed material vs. loose sandy material. Typically this means greater power and larger and more durable mechanical components.

The horizontal angle in degrees (plan view) between the position of the bucket when it is digging and its position when it discharges its load is the angle of swing. If the angle of swing is increased, the digging and dumping cycle time is increased, thus reducing production and increasing cost. Ideal production is achieved when the angle of swing equals 90°. For maximum efficiency when setting up an excavator to dig a trench and load dump trucks with the excavated dirt, the loading path or spot of the trucks should be perpendicular to the direction of the excavator's tracks at 90° or less.

Figure 4.7 shows an excavator working on a surface below grade called a "bench." The figure also shows how a flat surface is created next to the hole where a concrete drainage culvert is built. If the soil is really unstable, benching the edges of the hole may be required instead of sloping. It is like stair-stepping the excavation. The bench can also serve another purpose. In this case, the bench provides a surface for equipment to move and work. By working on this lower surface, the excavator's digging depth can be increased. Note the backhoe and bulldozer in the background. Several excavators could be placed on ascending benches to accommodate the depth of the dig. The bottom excavator is actually performing the excavation.

FIGURE 4.7 Excavator on a bench.

As it digs, it swings and dumps the spoil on the next bench up. Other excavators placed on the benched areas pass the soil up out of the hole to be stored, spread, or hauled away.

Front shovels excavate above grade or into a material face or pile above the operating surface. Their production cycle is similar to an excavator: dig, backtrack, dump, reposition, and start over. Shovels digging into dense material typically operate on tracks. Shovels used for material rehandling where digging is not required might operate on tires. Front-end loaders operate similarly to front shovels, but are made for scooping at ground level, not excavating. They are classified similarly by their upward scooping motion. For optimum depth of cut, the bucket should be filled when it reaches the top of the face in one pass. This depends on the type of material and the size of the bucket. Optimum digging height for most shovels is between 40 and 50% of the rated maximum digging height. Breakout force is developed by crowding the material away from the shovel by pushing the bucket teeth into the material face and curling the bucket upward and toward the machine.

4.3.4.1 Earthmoving and Excavating Work Activities

The following discussion focuses on three common earthmoving and excavating work activities that require heavy equipment. The listed equipment packages are groups of heavy equipment that typically work together to perform this task. Each piece of equipment in the package plays a specific role in the series of activities required to perform the task efficiently and effective. Equipment packages will vary based on the volume of work, desired productivity, equipment availability, and specific work conditions and needs.

Rough site excavation or site leveling is done in the following sequence:

1. A surveyor stakes the area outlining the perimeter of the work and details the depth of the cuts or fills.
2. A motor grader or bulldozer strips the surface of vegetation and debris.
3. A bulldozer with a ripper makes a pass over the area to be cut. It is advisable to rip a couple of inches deeper than the actual cut to be made. The loosened soil provides better traction for the bulldozer than a hard denser undisturbed surface.
4. A bulldozer removes the topsoil layer, pushing it into an out of the way stockpile to be spread when final grading and landscaping are done.
5. The bulldozer pushes dirt into piles to be moved to areas of the site needing fill or to be stockpiled at a remote location.
6. Several scrapers assisted by a bulldozer are used for mass surface excavation and to haul the excavated dirt to another location on site.
7. A motor grader spreads the dumped dirt at the new location.
8. Excavators dig rough detention areas.
9. Excavated soil is loaded into dump trucks by front-end loaders to be hauled off site.
10. A bulldozer and motor grader are used to finish the rough leveling of the site and detention areas.

Trench excavation for underground utilities is done in the following sequence:

1. A surveyor stakes the route of the trench and details the depth of cut.
2. A bulldozer and motor grader are used to grub, clear, and stabilize the surface.
3. An excavator or backhoe is used to scoop the dirt from the trench and pile it parallel to the trench. (Dense soils might require use of a trencher.)
4. A forklift is used to unload, move, and hold the pipe while it is prepared for installation.

5. The excavator lifts and places the pipe in the trench.
6. A front-end loader is used to backfill the trench when the installation is complete.

Foundation excavation and backfill is done in the following sequence:

1. A surveyor stakes the foundation perimeter and details the depth of cut once the rough excavation is complete.
2. Excavators dig the hole and place the soil next to the hole.
3. Front-end loaders are used to move this soil to an on-site stockpile.
4. Or excavators dig the hole and directly load the dump trucks.
5. Or front-end loaders are used to load dump trucks, hauling the spoil to a remote location.
6. Backhoes are used to excavate tighter areas and in the hole.
7. When the foundation is complete, front-end loaders move and dump stockpiled soil to backfill against the foundation.
8. Small skid-steer loaders are used to carry dirt to confined areas and places where less fill is required.
9. The backfill is then compacted against the foundation walls.

Table 4.5 lists common earthmoving and excavation work activities and the types of equipment typically included in the equipment package.

4.4 EARTHMOVING EQUIPMENT SELECTION

Earthmoving equipment included in this discussion are:

- Bulldozers
- Front-end loaders
- Motor graders
- Scrapers
- Trucks

4.4.1 Bulldozers

A bulldozer is a tractor unit with a blade attached to its front. The blade is used to push, shear, cut, and roll material ahead of the tractor. It is an ideal surface earthmover that performs best at about 3 mph. Each model of bulldozer has an operating range for blade size and adjustment. Larger machines have greater operating ranges than smaller machines. A larger machine can pitch and tilt deeper than a smaller machine typically. For heavy civil work, bulldozer blade widths can range from 8′ to 22′ and operating weights can range from about 7 tons to over 120 tons. Maximum digging depth ranges from about 1.5′ to 2.5′.

Figure 4.8 shows a dozer that was used with the mega-terrain leveler shown in Figure 4.9, excavating the foundation hole for a high-rise condominium building in Austin, Texas.

The hard clay-like soil had to be ground up, pushed into piles by the bulldozer, and then loaded by front-end loaders into dump trucks to be hauled away. This was more efficient than using excavators due to the denseness of the soil.

The bar connecting the blade to the body of the bulldozer is parallel to the travel surface and just above it. This positioning can deliver maximum forward force to push a pile of dirt or a scraper. Note the pistons connected to the blade. These pistons control the tilt of the blade,

TABLE 4.5
Earthmoving and Excavating Work Activities and Equipment Packages

Activity	Dozer	Loader	Grader	Scraper	Dump Truck	Backhoe	Excavator	Front Shovel
Excavating above grade								×
Excavating below grade	×			×		×	×	
Grubbing	×						×	
Heavy ripping	×							
Light ripping			×					
Tree stump removal	×						×	
Topsoil removal/storage	×		×	×				
Rough cutting	×			×			×	
Rough filling	×	×		×	×			
Finish grading			×					
Foundation excavation						×	×	
Foundation backfilling		×				×	×	
Footing excavation						×	×	
Road base construction	×	×	×		×			
Temporary road construction	×	×	×		×			
Haul road maintenance			×					
Culvert placement	×		×		×	×	×	
Earth berm/dam construction	×		×		×			
Drainage ditch maintenance						×	×	
Haul less than 500′	×	×						
Haul 500′ to 2 miles				×				
Haul over 2 miles					×			
Soil windrowing	×		×					
Soil spreading	×	×	×	×	×			
Excess loose soil removal		×			×			
Deep trench excavation							×	
Shallow trench excavation						×		
Trench backfilling	×	×				×	×	
Utility pipe placing — small						×	×	
Utility pipe placing — large							×	
Trench box placement/movement						×	×	
Debris/trash removal		×			×		×	
Rock removal	×	×			×		×	
Asphalt paving removal	×	×			×		×	
Concrete removal	×	×			×		×	
Structure demo	×	×			×		×	
Assisting scrapers	×			×				
Towing other equipment	×	×						
Concrete placement — bucket							×	
Crane pad construction	×		×		×			
Detention pond excavation	×			×			×	
Benching	×		×				×	
Side sloping	×							

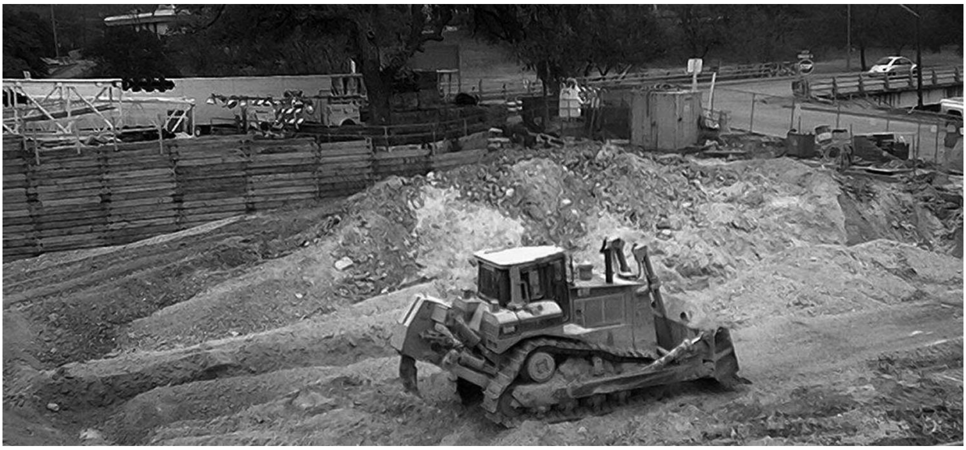


FIGURE 4.8 Elevated sprocket bulldozer with ripper.

how deep the penetration and the cut. The frame or cage over the operator is the rollover protection system (ROPS).

The single shank (can be multiple smaller shanks) ripper attachment is used to penetrate tough surface material. It is lowered into the work surface just like the blade. If the work surface is hard and compact, the dozer will make a pass with the ripper first, breaking up the soil and follow another pass using the blade. Many times, this is the first activity done on an undisturbed surface prior to cutting and filling. Shorter ripper shanks are used for disturbing dense material, thus minimizing breakage. Longer shanks are used for disturbing less dense, but more organic, material. The depth of ripper penetration in dense material will influence the speed of the bulldozer. Ripping production is based on the dozer speed and the distance covered in a time unit measure (ft/min).

The elevated sprocket configuration is not as common as the elliptical configuration seen on most bulldozers. The final drives (round gear above middle bar) are higher in the work area than on an elliptical track. This helps to isolate the drive from ground impacts. This is much better suited for rough, rocky, and uneven working conditions.

FIGURE 4.9 Terrain leveler.

Along with surface excavation, bulldozers are typically used with scrapers for excavation. A typical production cycle for excavation or pushing a scraper is to position, push, backtrack, and maneuver into position to make contact and push again. Speeds are typically low and influenced by the type and density of the material that is excavated or moved. Speed empty is usually the maximum that can be achieved in the travel distance.

4.4.1.1 Bulldozer Production

Time components used for most tractor-powered equipment production cycles are similar to those of the working bulldozer described in this section. Typical production cycles for earthmoving equipment are very similar as well. Exact components will vary based on the work setup and operation. The typical production cycle is the following:

1. The bulldozer positions to start excavation
2. The bulldozer scoops or digs for the length of a pass to fill the blade
3. The bulldozer hauls the load by rolling, crawling, pushing, or pulling
4. The load is discharged or dumped at the desired location
5. The bulldozer repositions to exit the dumpsite
6. The bulldozer backtracks to the loading location

Most efficient and safe production is achieved when the machine is going forward. The time component for each part of the cycle is influenced by many factors, primarily by speed and distance of travel. The production cycles for bulldozers, front-end loaders, motor graders, scrapers, and trucks are all similar to the cycle described above. There are similarities in the example problems for each of these types of earthmoving equipments. Bulldozer production is typically not dependent on other equipment. Bulldozers are usually the first pieces of equipment on the site. Production is based on the width of the blade, the depth of cut, and the travel, backtrack, and return times. Dozer production with scrapers will be discussed in the scraper section of this chapter.

Example 4.3 A Case 750K bulldozer with a 8′ blade is to be used to excavate and push fairly loose dirt. According to the soils report, the dirt to be moved has a 23% swell factor. When the dozer is hauled to the site a couple of blade loads are excavated to estimate a typical load. The average $H = 4'$, the average load width is 6′, and the load length is 9′. Actually observing and recording times for individual cycles and then finding the average observed cycle time is probably the most accurate way to estimate a typical production cycle time. The load time suggested by the manufacturer is about 0.08 min. Once the blade goes through the cut, the haul push is about 200′ with an average speed of about 2.6 mph. Backtrack distance is about 240′ and the dozer will travel at a speed of about 3.2 mph. Once back to the hole, the dozer takes about 0.06 min to reposition. The Case dealer suggests an O&O cost of about \$55/h. Your operator costs about \$23/h with contractor outlay. What is the unit cost for the work if there is about 1200 bcy of surface dirt that must be moved by the 750 K?

1. How much dirt (lcy) can be moved in one production cycle?

$$V = [(0.0138)(6')(4')(9')] = 2.98\text{lcy/blade load}$$

Note: Performance criteria and costs used in all example problems are hypothetical.

2. How much dirt (bcy) can be moved in one production cycle? The quantity takeoff is in bcy so the lcy load must be converted to bcy.

$$2.98 \text{ lcy}/1.23 \text{ lcy}/\text{bcy} = 2.42 \text{ bcy}/\text{production cycle}$$

3. What is the cycle time for one production cycle?

$$\text{Haul time} = 200'/[(3.2\,\text{mph})(88'/\text{min}/\text{mph})] = 0.87 \text{ min}$$
$$\text{Backtrack time} = 240'/[(3.2 \text{ mph})(88'/\text{min}/\text{mph}) = 0.85 \text{ min}$$
$$\text{Cycle time} = \text{load} + \text{haul} + \text{backtrack} + \text{reposition}$$
$$= 0.08\,\text{min} + 0.87\,\text{min} + 0.85\,\text{min} + 0.06\,\text{min} = 1.86\,\text{min}$$

4. What is the work hour productivity if the operator works 50 min per 60-min hour?

$$\text{Work hour productivity} = [(\text{load volume(bcy)})(50\,\text{min})]/\text{cycletime}$$
$$= [(2.42 \text{ bcy/load})(50\,\text{min})]/1.86 \text{ min/cycle}$$
$$= 65.05 \text{ bcy/work hour}$$

5. How long will it take to move the 1200 bcy?

$$1200\,\text{bcy}/65.05\,\text{bcy/h} = 18.45\,\text{h. Use } 18.50 \text{ work hours}$$

6. How much will it cost?

$$\$\,55/\text{h} + \$\,23/\text{h} = \$\,78/\text{h} \times 18.50\,\text{h} = \$\,1443$$

7. What is the unit cost to perform the work?

$$\$\,1433/1200\,\text{bcy} = \$\,1.203/\text{bcy} \text{ to move the dirt with the Case 750K bulldozer}$$

4.4.2 Front-End Loaders

Front-end loaders typically are tractor powered and operate on tires. They are typically articulated and very maneuverable, making them ideal for constricted areas. They are used primarily for material moving and re-handling. They are ideal for scooping and hauling materials in storage piles, where it is to be permanently placed, or loading it into dump trucks. Loaders are ideal for dumping soil back into the hole after the necessary below grade work is done. Tracked loaders may be required for extreme surface conditions demanding greater traction or stability. Every concrete or asphalt batch plant has a tire equipped front-end loader to stock the feed to the batch hopper with aggregate and sand.

Fixed cycle times for loaders (raise, dump, and lower the bucket) range from about 9 s to about 20 s depending on the size of the loader. General-purpose bucket capacities range from about 0.75 to 18 lcy. Figure 4.10 shows a small loader that is ideal for confined spaces and smaller loads.

These small loaders are very maneuverable and are ideal for use in constricted limited working areas. They are used often for moving sand within slab forms or with fork attachments to carry brick, mortar, or sand. They are excellent for surface movement of small amounts of material. These machines are generally referred to as "Bobcats," which was a

FIGURE 4.10 Skid-steer loader.

small skid-steer loader manufactured by Melrose. Readily available attachments include augers, cold planers for light milling, landscape tillers and rakes, trenchers, vibratory compactors, and brooms.

4.4.2.1 Loader Production

Loaders are used many times with feed hoppers and dump trucks. The loader is sized by the demand of the feed hopper or the size and number of dump trucks that can be filled. Production cycle components are similar whether running on tracks or tires. The work surface stability will influence the cycle time. Small skid-steer loaders are very maneuverable and cycle times might be less.

Example 4.4 A Cat 950G wheel loader with a 4.25 lcy heaped bucket is to be used to move fairly loose stockpiled dirt onto a conveyor running under the road. The conveyor is carrying the dirt to another part of the site. The dirt will be used to fill that side of the project site. The *Cat Performance Manual* suggests a cycle time (load, dump, maneuver) of about 55 s for the way you have the work setup and an O&O cost of about \$31/h. Your operator costs about \$23/h. The conveyor will haul about 280 lcy/h. Will the production of the loader keep up with the conveyor?

1. How much dirt (lcy) can be moved in one production cycle?

$$V = 4.25\,\text{lcy/cycle}$$

2. What is the cycle time for one production cycle?

$$\text{Cycletime} = 55\,\text{s/cycle}/60\,\text{s/min} = 0.92\,\text{min}$$

3. What is the work hour productivity if the operator works 50 min per 60-min hour?

$$\begin{aligned}\text{Work hour productivity} &= [(\text{load volume(lcy)})(50\text{ min})]/\text{cycletime}\\ &= [(4.25\text{ lcy})(50\text{ min})]/0.92\text{ min/cycle}\\ &= 231\text{ lcy/work hour}\end{aligned}$$

Based on this calculation, the 950G will be short about 49 lcy/h. Assuming one cannot change the work layout, options to meet the necessary 280 lcy/h production include a larger bucket on the 950 (for this situation, probably not feasible), a larger loader or two smaller loaders.

4. What is the daily cost for using this loader if the conveyor runs 11 h/day?

$$\$\,31 + \$\,23 = \$\,54/\text{h} \times 11\text{ h/day} = \$\,594/\text{day}$$

5. What is the unit cost per day to use the 950G loader?

$$231\text{ lcy/h}(11\text{ h/day}) = 2541\text{ lcy/day}$$
$$\$\,594/\text{day}/2541\text{ lcy/day} = \$\,0.233/\text{lcy}$$

4.4.3 Motor Graders

This type of equipment has been around since the start of road building, though originally powered by a team of oxen, mules, or horses. The need for a smooth stable travel surface has always been an important part of a road system. Another name for a motor grade is “maintainer.” This name is appropriate because this equipment is typically used to maintain grade and a smooth surface for rural nonpaved travel roads or haul routes on construction sites. The grader is a long tractor-driven piece of equipment with a blade mounted underneath as shown in Figure 4.11.

FIGURE 4.11 Motor grader.

The blade is used to push dirt straight ahead or to the side at a desired level. The grader can be used for light surface excavation, but is mainly used to move soil to create a level surface. Note the ring to which the blade is attached underneath the frame. This ring can be swiveled vertically and the casting angle of the blade adjusted on it. The blade can be angled to shape road banks. Standard blade widths range from 12′ to 14′ and speed in midrange gear is approximately 6 mph. Front tires are usually leaning to resist the force created when the blade is cutting and side casting the material.

As the dirt is pushed ahead of the blade it fills voids in the surface over which it is moving. Excess dirt is pushed into other surface voids or to the side. When the dirt is cast to the side of the grader, this is called a windrow (row of piled dirt). Usually a front-end loader will follow behind the grader to scoop up excess dirt in the windrow if necessary. For a small amount of excess, a backhoe scoop can be used. Laser level readers can be attached to the motor grader blade so that the operator can establish a desired elevation using the level signal, not having to rely on feel and experience as much. The grader depth of cut is adjusted based on the signal setting.

4.4.3.1 Motor Grader Production

On large dirt-moving jobs, the motor grader operator is responsible for the movement, spotting, and leveling of the delivered fill. This operator is like an equipment group foreman. The delivered fill might be from the other side of the project site or brought from a pit miles away. Since soil is leveled and compacted by lift, where and how much soil should be dumped must be managed for efficient spreading as it is delivered. In road base construction, the grader is typically the last major earthmoving equipment used during compaction.

Graders are usually set up to run in linear or rectangular patterns. Production is measured in area covered in a certain amount of time (square feet per hour, cubic feet per hour). When grading linearly, the operator usually has the blade dropped (cutting) until the end of the pass, turns, drops the blade, and grades the opposite direction. When grading an area for a parking lot, two methods of the rectangular patterns can be used. Using the "back and forth" method, the operator travels with the blade down to the end of the pass, picks up the blade, backtracks, drops the blade, and starts over. Using the "looping" method, the operator drops the blade for the pass, lifts the blade at the end of the pass, turns the grader in an arc to the other direction, and drops the blade for this pass. The process is repeated until the area is covered with the grader traveling in a forward loop or oval as many times as necessary to cover the surface. To set the "looping" coverage pattern, the turning radius of the motor grader must be considered. The turning radius is typically listed in the performance spec for the model.

Grader production for road maintenance is pretty much linear. For mass earthmoving projects, grader production must be matched to production of other equipment (usually scrapers or dump trucks) in the equipment package dumping material to be spread in lifts. Linear grading productivity is estimated using:

1. V, the average grading speed
2. W, the grading width (width of blade if pushing straight ahead perpendicular to travel direction)
3. OF, the the operating factor
4. N, the number of passes required to cover the area to be graded (width of the road base)

Example 4.5 A Volvo G740B motor grader with a 14′ blade is to be used to knock down dirt on a 66′ wide × 9800′ long road base area. The effective grading width is 12′. The average speed will be around 3 mph. The number of passes required is two to reach the desired smoothness. In the following passes, sf denotes square feet and sy denotes square yards.

1. What is the work hour productivity if the operator works 50 min per 60-min hour?

$$\begin{aligned}\text{Work hour production} &= [(V)(5280'/\text{mile})(W)(\text{OF})]/[(9\,\text{sf/sy})(N)]\\ &= [(3\text{ mph})(5280'/\text{mile})(12')(0.83)]/[(9\,\text{sf/sy})(2)]\\ &= 8765\,\text{sy/h}\end{aligned}$$

2. How long will it take to grade the road base?

$$(66' \times 9{,}800')/9\,\text{sf/sy} = 71{,}867\,\text{sy}/8{,}765\,\text{sy/h} = 8.2\,\text{h}$$

4.4.3.2 Box Blades

Figure 4.12 shows a box blade attachment mounted on the rear of a tractor. The ripper teeth inside the box are raised. This is probably the most universally used piece of equipment for finish grading and contouring. It is typically the last piece of equipment on site prior to landscaping. Inside the box are ripper teeth for disturbing the soil. As the ripper teeth dig into the soil, the soil boils up into the box where it is broken apart as the tractor moves forward. The operator can regulate the depth of the ripper teeth, as well as the bottom of the box. As the tractor moves forward, the box is raised and the soil is evenly spread or the soil fills voids as the tractor drags the box over the surface. The outside rear of the box can be used to push soil around like a bulldozer as well. Obviously, this equipment is not suitable for hard or rocky soils.

4.4.4 Scrapers

Scrapers are designed to load, haul, and dump loose material. The greatest advantage is their versatility. They can be used for a wide variety of material types and are economical for a range of haul distances and conditions. They are a compromise between a bulldozer, an

FIGURE 4.12 Box blade.

excavator, and a dump truck. Scrapers are articulated, tractor powered, and pull a bowl that holds the soil. A blade is mounted on the bottom of the bowl that cuts into the travel surface and the disturbed soil flows into the bowl as the scraper moves forward. Figure 4.13 shows the tractor, bowl, and chain in operation. Scrapers can self-load or be assisted by another scraper or a bulldozer.

Scrapers are classified in the following categories:

1. *Single engine*: A tractor pulling a bowl that can operate under its own power or be push-assisted. This is the most common type of scraper on large earthmoving jobs.
2. *Tandem or twin engine*: This type has a second engine mounted in the rear and can develop greater power. This is ideal for steeper hauls at greater speeds. Typically cost about 30% more than a conventional scraper.
3. *Push–pull scraper*: This type is designed with a push block mounted on the rear and a bail mounted on the front to assist other scrapers or be pushed by other scrapers. They are ideal for dense soil-excavating projects when a dozer is not utilized for pushing.
4. *Elevating*: These are self-contained loading and hauling units. The chain elevator serves as a loading mechanism. The extra weight of the loading mechanism is a disadvantage during the haul cycle, but this type is ideal for short-haul situations where the ratio of haul time to load time is low. These are used generally for utility work, dressing up behind high-production spreads, or shifting material during fine-grading operations. The chain breaks the soil as it enters the bowl and is easier to discharge. These units can be push-assisted.

Wheel-type scrapers have potential for high-travel speeds on favorable haul roads and can go up to 30 mph. When digging in hard clay, once the bowl of the scraper starts filling and getting weighted down, the demand on the scraper's power is the greatest. The operator wants to set the blade just deep enough so that when the pass through the hole is complete, the bowl is full. Typically, these scrapers need bulldozer support to provide the extra tractive effort needed for economical and efficient loading. To reduce the effort that the scraper must exert to load and get out of the hole, a bulldozer is an economical and efficient pusher.

Figure 4.14 shows three techniques typically used for push assisting a scraper through the hole, backtrack loading, chain loading, and shuttle loading. The technique used should be determined based on the quantity of work and specific site considerations. Avoiding repositioning and keeping the scraper traveling forward will optimize production time.

FIGURE 4.13 Elevating scraper.

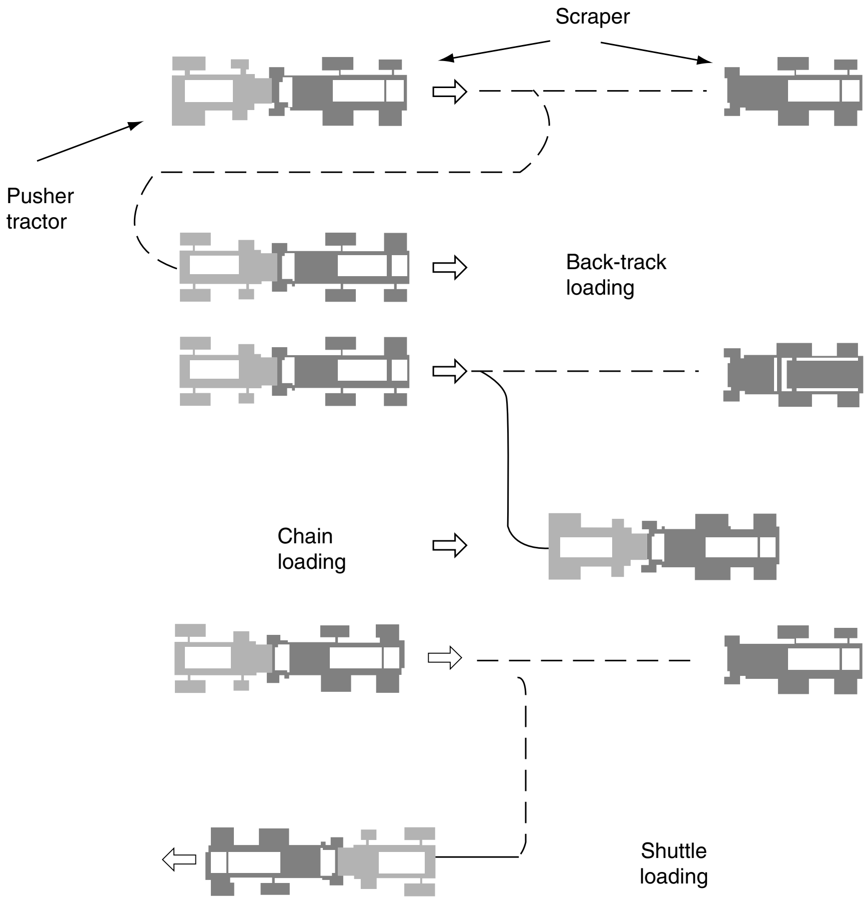


FIGURE 4.14 Scraper loading techniques.

Backtrack loading is the most common type of technique for multiple scrapers and a single pusher.

Heaped scraper capacities range from about 15 to 44 cy. Load ratings range from about 18 to 52 tons. Maximum depth of cut ranges from over 13″ to 17″. Maximum depths of spread range from about 14″ to over 22″.

4.4.4.1 Scraper Production

To load the scraper, the front end of the bowl (nearest the cab) is lowered until the attached cutting edge penetrates the travel surface. As the scraper moves forward, the front apron of the bowl is raised so that a strip of excavated earth can flow into the bowl. The amount of excavated soil depends on the depth of penetration of the cutting edge. The scraper moves forward until the bowl is full. The blade is lifted and the apron closes. Ripping (bulldozer with ripper shanks) or tilling (tractor pulling a plow) the soil lift to be excavated prior to the scraper making a pass can increase scraper production. Sometimes applying water will loosen soil also.

To dump the scraper load, the cutting edge is set above the discharged material, raising the apron. The material is forced out by means of a movable ejector mounted at the rear of the bowl. The size of the apron opening regulates the amount of material discharged and the material lift depth.

The capacity of the scraper bowl can be measured by volume or weight. When the capacity or the weight is exceeded, operating efficiency decreases. Scraper volume is measured in two ways in loose cubic yards. Struck volume is the loose cubic yards that a scraper would hold if the top of the material were struck off even at the top of the bowl. Heaped volume is the loose cubic yards that a scraper would hold with the material heaped and sloping above the sides of the bowl. The heaped volume takes into account the fill factor.

The cycle time for a scraper is estimated by adding the fixed times to load, dump, turn around, and spot for the next cut, and the variable or travel times to haul full and return empty. Scraper rimpull, speed, and gradability performance can be verified by referring to the rimpull, speed, and gradability curves for the model. The expected performance of the scraper can be compared to these operating requirements of the work. Load times vary based on power, bowl capacity, and site conditions and range from 0.4 to 1.0 min typically. Maneuver and spread or maneuver and dump times range from 0.6 to 0.7 min. Additional maneuvering (spotting) when approaching the cut might be required and should be added if necessary.

Dozer-assisted means that the dozer makes contact with the back bale of the scraper as it starts into the hole. The dozer is actually providing most of the pushing power to not only make the cut, but also to transport the full bowl through and out (boost) of the cut. This greatly optimizes what a bulldozer is designed to do and greatly reduces the power needed by the scraper to excavate and start hauling when fully loaded. It is an ideal pairing of equipment to optimize the capabilities of both.

To determine the number of scrapers that can be matched to one pusher or dozer, the pusher cycle time must be determined. This cycle time includes match up and to contact with the rear of the scraper, push through the hole, boost out of the hole, and maneuver to match up to the next scraper coming through the hole.

Example 4.6 A Cat D631E Series II wheel tractor scraper assisted with a D9R bulldozer is to be used to move dirt about 4200′ to build a detention pond at the entry of subdivision. The D9 has ripped the soil in the area to be excavated about 18″ deep. The D9 is to push the scraper until it is out of the hole. Once full, the scraper's average haul speed will be around 10 mph. The return route is about 4400′ and the average return speed will be around 14 mph. The rated heaped capacity of the D631 is 311 cy. The estimated load time according to the performance manual is 0.6 min. The estimated dump time is about 0.7 min. The Cat estimated hourly O&O for moderate conditions for the D9 is \$86/h and for the D631 is \$87/h. The projected O&O cost includes the operator for this calculation.

1. What is the work hour productivity if the operator works 50 min per 60-min hour?

$$\text{Work hour production} = [(\text{rated capacity}) \times (\text{operational efficiency})]/\text{cycletime}$$

$$\text{Haul time} = 4200'/[(10\,\text{mph})(88'/\text{min/mph})] = 4.77\,\text{min}$$

$$\text{Backtrack(return)time} = 4400'/[(14\,\text{mph})(88'/\text{min/mph}) = 3.57\ \text{min}$$

$$\begin{aligned}\text{Cycletime} &= \text{load} + \text{haul} + \text{dump} + \text{return}\\ &= 0.6\,\text{min} + 4.77\,\text{min} + 0.7\,\text{min} + 3.57\ \text{min} = 9.64\,\text{min/cycle}\end{aligned}$$

$$\text{Production} = [(31\,\text{lcy})(50\,\text{min/h})]/9.64\,\text{min/cycle} = 160.8\,\text{lcy/h}$$

2. How many scrapers will the D9 support?

$$
\begin{aligned}
&\text{Pusher cycle time} = 1.4L_s + 0.25\,\text{min}\\
&L_s = \text{the load time of the scraper} = 0.6\ \text{min}\\
&\text{Boost time} = 0.1\,\text{min; maneuver time} = 0.15\,\text{min; boost} + \text{maneuver} = 0.25\,\text{min}\\
&\text{Return time} = 40\%\ \text{of the load time}\\
&\text{Pusher cycle time} = 1.4(0.6) + 0.25\ \text{min} = 1.09\,\text{min/pusher cycle}\\
&\text{Number of assisted scrapers} = (9.64\,\text{min/scraper cycle})/(1.09\,\text{min/pusher cycle})\\
&\qquad = 8.8\ \text{scrapers}
\end{aligned}
$$

If this is rounded up to nine scrapers working with this D9, occasionally a scraper might have to wait for a short time before hitting the hole. If it is rounded down to eight scrapers, there should be no delay for any scraper to hit the hole. It is probably advisable to round down and use eight scrapers.

3. How many hours will it take to excavate and haul 20,600 bcy of soil with swell factor of 15% using the D9 and 8 D631 scrapers?

$$
\begin{aligned}
\text{Amount of soil excavated per hour} &= 8\ \text{scrapers}\ (160.8\,\text{lcy/h})\\
&= 1286.4\,\text{lcy/h}\\
&\quad [(20{,}600\,\text{bcy})(1.15\%\text{swell})] = 23{,}690\text{lcy}\\
&= 23{,}690\,\text{lcy}/1286\,\text{lcy/h}\\
&= 18.5\,\text{h}
\end{aligned}
$$

4. How much will it cost to excavate and move this dirt?

$$[(18.5\ \text{h})(1\ \text{dozer})(\$\,86/\text{h})] + [(18.5\,\text{h})(8\ \text{scrapers})(\$\,87/\text{h})] = \$\,14{,}467$$

5. What is the unit cost for the work?

$$\$\,14{,}467/20{,}600\,\text{bcy} = \$\,0.702/\text{bcy}.$$

4.4.5 Trucks

Trucks are an extremely important part of the earthmoving and material-moving process. They are basically a tractor and a trailer with sides. Like the rest of the equipment categories, there are a wide range of trucks based on hauling conditions and need. Typically trucks are sized by trailer volume. Obviously, the larger and heavier the load, the larger a tractor you need to pull the trailer. Trucks are typically used with excavators and loaders for excavation and soil haul off or delivery. Compared to other earthmoving equipment, they can obtain high travel speeds. Rough terrain trucks have frames, suspension systems, and motors designed to traverse rough surfaces and radical travel grades. Trucks designed for hauling on the highway are designed for less rigorous conditions.

Two basic considerations for choosing a truck trailer are the method of dumping and the class of material hauled. Trucks may dump from the rear (the most common), from the bottom (belly dump), or from the side depending on the type of material and work activity. Common rear dump trucks are typically not articulated, but larger rough terrain trucks are

FIGURE 4.15 Belly dump truck.

typically articulated for greater maneuverability. Figure 4.15 shows a bottom or belly dump truck. When the gate is opened at the bottom of the bed, the load is spread in an even windrow as the truck moves forward. The windrows spread easier than a pile. A grader will typically follow to spread the material for compaction.

Topsoil, select fill, clay, sand, and aggregate are typical building materials transported by truck. Material considerations include size and shape of the material pieces and cohesiveness of the material. The size to weight relationship will influence the volume of the trailer matched to the tractor. Size and shape will influence how the material will pack in the trailer. If the material is cohesive, the trailer shape should be conducive for the material to be easily discharged when dumped. Rounded edges keep material from compacting in corners. Capacities of construction-hauling trucks range from 6 lcy to gigantic trucks used in mass earthmoving or mining. Typical rear dump trucks used on construction sites are 9 or 12 lcy.

4.4.5.1 Truck Production

Dump truck production is similar to the other earthmoving equipment cycles. Trucks however are typically dependent on another piece of equipment for loading. Truckloads are rated by volume and weight. Trucks must be permitted to operate on public highways and streets. Production cycles have fixed and variable times. Typical cycle fixed times include loading, dumping, and required spotting times. It should be noted that the loading time is the time required by the piece of equipment loading the truck. The loading time equals number of cycles required to load the truck times the estimated cycle time. The number of loader cycles to fill a truck equals volume of the truck divided by the volume of the loader bucket per cycle. Trucks are usually loaded by front-end loaders or excavators. Spotting to load or dump and wait or delay times are influenced by job conditions, work setup, and management of the process.

Turn and dump time in moderate conditions for end-dump trucks are about 1.3 min. Spotting time is about 0.3 min. Turn and dump time in moderate conditions for belly or bottom dump trucks are about 0.7 min. Spotting time is about 0.5 min. Note that belly dumping takes less time to turn and dump, because the placement is more precise than rear dumping, but the spotting takes a bit longer. A load from a rear dump truck must be followed by a dozer or a loader to knock it down for the grader to spread. A windrow discharged from a belly dump truck can be followed by the grader, making spreading and compacting faster.

The variable times include hauling and return. If the travel route is on the construction site, delays will probably be minimal. If hauling is done on public roads, then delays become much less predictable. Traffic in a metropolitan area can drastically influence production cycle time. Driver time management can also greatly influence production.

Example 4.7 A Cat 950G wheel loader equipped with a 2.3 lcy bucket and a 0.2 min cycle time is to be used to load a Cat D30D articulated truck with a heaped capacity of 21.6 lcy. It takes about 1.3 min to dump the load.

1. How long does it take to load the truck?

$$21.6\,\text{lcy}/2.3\,\text{lcy} = 9.4\,\text{cycles/truck load} = \text{round off to 9 cycles/load}$$
$$= (9\text{ cycles})(2.3\,\text{lcy/cycle}) = 20.7\,\text{lcy/load}$$
$$(9\text{ cycles})(0.2\text{ min/cycle}) = 1.8\,\text{min to load the truck}$$

2. How much dirt can be hauled in 1 work hour by the D30D?

$$\text{Work hour production} = [(\text{ratedcapacity})(\text{operational efficiency})]/\text{cycle time}$$
$$\text{Haul time} = 9200'/[(25\text{ mph})(88'/\text{min/mph})] = 4.18\,\text{min}$$
$$\text{Return time} = 9200'/[(30\text{ mph})(88'/\text{min/mph}) = 3.48\,\text{min}$$
$$\text{Cycle time} = \text{load} + \text{haul} + \text{dump} + \text{return}$$
$$= 1.8\,\text{min} + 4.18\,\text{min} + 1.3\,\text{min} + 3.48\,\text{min} = 10.76\,\text{min/cycle}$$
$$\text{Hourly production} = [(20.7\,\text{lcy})(50\,\text{min/h})]/10.76\,\text{min/cycle} = 96.2\,\text{lcy/h}$$

3. How many trucks will the 950G support?

$$\text{Number of trucks or haulers} = \text{hauler cycle time/hauler time at the load site (spotting and loading)}$$
$$\text{Number of D30D trucks supported by the 950G} = 10.76\,\text{min/cycle}/1.8\,\text{min to load} = 5.97\text{ or 6 haulers}$$

This assumes no delay for positioning to be loaded.

4.5 EXCAVATING EQUIPMENT SELECTION

Excavating equipment included in this discussion are:

- Excavators
- Backhoes
- Front shovels

4.5.1 Excavators

The excavator combines digging and lifting abilities. Excavators come in a wide range of sizes. Bucket size, boom length, and operating speed are primary considerations for choosing the proper excavator. Typically, the faster the operating speed, the faster the machine can load, swing, dump, return, and dig (the normal excavator production cycle). Excavators are ideal for digging and dumping into a dump truck or a pile.

Excavators are ideal for underground utility construction. For trenching, the operator fills the bucket and dumps to the side above grade. With the excavator in the same path, the operator can also use the bucket side and bottom to scrape the dirt back into the trench and compact it after the work is done. Another reason that the excavator is ideal for underground utility construction is its lifting ability. Most buckets have an ''eye'' for securing rigging. Pipe can be easily rigged and placed in the trench. If necessary, the load can be picked up and ''walked'' to the placement point. Obviously, the excavator should be rated for the load.

Excavators can accommodate numerous attachments such as pinchers for lifting logs or pipes, a jackhammer for busting up concrete or compacted soil, or a magnet for metal material moving. Excavator attachments are similar to backhoe attachments and are run by hydraulics. Along with the many attachments, excavators can be equipped with long reach booms, demolition arrangements, different shoe selections, and different quick coupler systems. Bottom dump buckets permit more accurate loading of narrow trucks and reduce spillage.

Heaped bucket capacities range from very small (0.1 cy), to extremely large for mass excavation (over 7 cy). Most excavators accommodate a range of bucket sizes. Maximum digging depths range from about 7′ to 34′, depending on the boom and stick lengths and combinations. Lifting capacities over the front of the excavator range from about 1300 lbs to over 64,000 lbs.

4.5.1.1 Excavator Production

Excavators are ideal for mass rough excavation below grade. Small excavators can be used for small shallow holes and big excavators for big deep holes. The proficiency of the operator will greatly affect production (perhaps more so than with other earthmoving equipment). Excavators are mobile, and can run at peak speed of about 3.5 mph. The travel path or work surface must be relatively stable and flat. Small rubber tracked or tire equipped excavators are ideal to work in areas of limited space and height. Most excavators will support different combinations of stick, boom, and attachments. Obviously, they have to fit the machine and match the power that can be generated to dig, lift, or run the attachment.

The weight of the soil in the bucket can sometimes make the excavator unstable. The rated load should not exceed 75% of the tipping load. Attention to setup and load weight is essential. If the bucket of soil is too heavy, the bucket pass should not be so deep and less soil excavated per production cycle. Bank weights for common earth materials as per the 30th edition of the *Caterpillar Performance Handbook* are shown in Table 4.6 [1].

An excavator can be used to dig into a vertical face of dirt, but because of the downward motion is not ideal for scooping. This technique can be used to knock dirt loose from the face to the travel surface and then be scooped and hauled by a loader. They are ideal for demo as the reach of the stick and boom keeps the machine a safe distance from falling or shifting debris above grade. Excavators can also be used for material handling. A typical excavator production cycle is as follows: fill the bucket (load), raise load above grade or to the necessary height, swing the load to the dump point, dump the load, swing the empty bucket back to the excavation point, drop the bucket, and start the cycle over.

Figure 4.16 shows the basic parts of an excavator. As per the 30th edition of the *Caterpillar Performance Handbook*, ideal excavator setup for truck loading should consider the following [1]:

TABLE 4.6
Common Earth Material Bank Weights

Material	Bank Weight (lbs/bcy)
Dry clay	3100
Wet clay	3500
Dry clay and gravel	2800
Wet clay and gravel	3100
Loam earth	2600
Dry gravel	2850
Dry, loose sand	2700
Wet sand	3500
Shale	2800

1. The bench height or distance from bucket insertion to the surface on which the excavator sits should equal about the stick length for stable material. This is the optimal height and allows the excavator to be above the dump truck while loading, minimizes lifting the bucket, reducing cycle time and wear.
2. The truck should be positioned where the truck rail (edge of the bed) is below the boom stick hinge pin (connection of the boom to the stick).
3. The truck should position as close to the centerline of the excavator as possible when aligning for loading.
4. The excavator should position for digging so that the stick is vertical when the bucket is full and curled with the load.
5. It is recommended that the operator boom up when the bucket is 75% through the curl (digging motion to the machine) cycle.

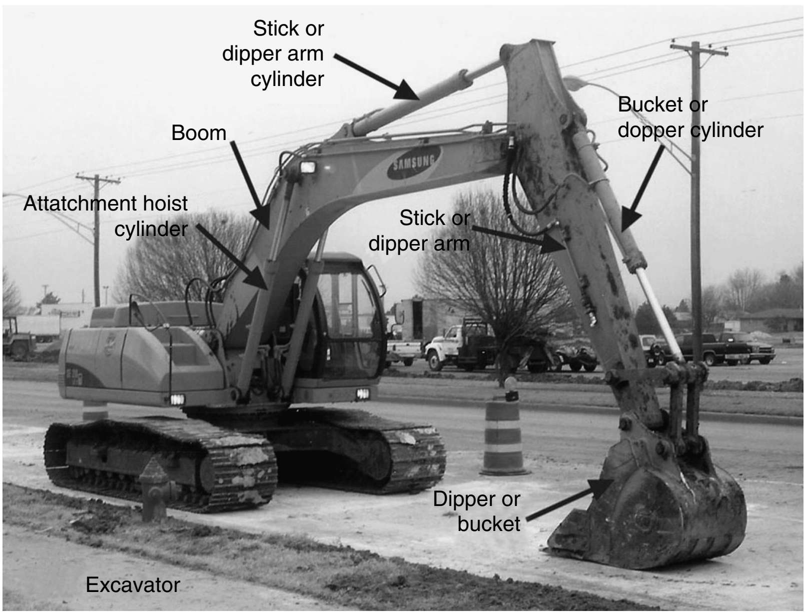


FIGURE 4.16 Excavator parts.

The loading time is the time required by the piece of equipment to load the hauling unit.

Trucks are usually loaded by front-end loaders or excavators. Spotting to load or dump and having to wait is a delay time influenced by job conditions, work setup, and management of the process.

$$\text{Loading time} = \text{number of cycles required to load the truck (the estimated cycle time)}$$

$$\text{Number of loader cycles to fill a truck} = \frac{\text{volume of the truck (lcy)}}{\text{volume of the loader (lcy)/cycle.}}$$

Example 4.8 A Cat 320C excavator equipped with a 1.96 lcy heaped bucket is used to dig in sandy clay soil. It takes about 0.33 min per bucket load dumped into a fleet of Cat D30D articulated trucks. Each truck carries a heaped capacity of 21.6 lcy. It takes about 5 min to haul and dump the load, return and position for reloading.

1. How long does it take to load one D30D? (Assume the bucket fill factor for the sandy clay is approximately 1.0.)

$$\begin{aligned}
(21.6\,\text{lcy/truck load})/(1.96\,\text{lcy/bucket load}) &= 11.02\ \text{cycles/truck load}\\
&= \text{round off to 11 cycles/truck load}\\
&= (11\ \text{cycles})(1.96\,\text{lcy/cycle})\\
&= 21.56\,\text{lcy/truck load}\\
(11\ \text{cycles})(0.33\,\text{min/cycle}) &= 3.63\,\text{min to load the truck}
\end{aligned}$$

2. How much dirt can be hauled in 1 work hour by one D30D?

$$\text{Work hour production} = [(\text{rated capacity})\ (\text{operational efficiency})]/\text{cycle time}$$

$$\begin{aligned}
\text{Cycle time} &= \text{load} + (\text{haul} + \text{dump} + \text{return})\\
&= 3.63\,\text{min} + 5\ \text{min} = 8.63\,\text{min/cycle}
\end{aligned}$$

$$\begin{aligned}
\text{Estimated hourly production} &= [(21.6\,\text{lcy})(50\,\text{min/h})]/8.63\,\text{min/cycle}\\
&= 125.1\,\text{lcy/h/D30D}
\end{aligned}$$

3. How many D30Ds will the 320C support?

$$\text{Number of trucks or haulers} = \text{hauler cycle time/hauler time at the load site (spotting and loading)}$$

$$\begin{aligned}
\text{Number of D30D trucks supported by the 320C} &= \frac{(8.63\,\text{min/hauling cycle})}{(3.63\,\text{min/loading cycle})}\\
&= 2.37\ \text{haulers}
\end{aligned}$$

Three haulers would mean there is a good chance that one hauler will be waiting to be loaded most of the time. With two haulers, the excavator will be idle for sometime. Based on the time available for the excavation, a larger excavator might be considered to better accommodate three D30Ds. When determining whether to round up or down the number of supporting equipment, it is best to keep the most expensive pieces of equipment working. It is more cost-effective to have the less expensive piece of equipment idle. Because of the small amount of excavation use 2 D30D trucks to haul the 1500 bcy of soil that must be excavated.

4. What is the 320C's hourly production?

$$\text{Hourly production} = [(1.96\,\text{lcy/bucket})(50\,\text{min/h})]/0.33\,\text{min/cycle} = 297\,\text{lcy/h}$$

It should be noted that with this scenario the number of D30Ds determines the hourly production, and not the excavator. Two trucks can load and haul 250 lcy/h.

5. How long will it take to complete the excavation?

$$\text{Convert the 1500 bcy to lcy: } 1500\ \text{bcy}(1.15\%\ \text{swell}) = 1725\ \text{lcy to be moved}$$
$$1725\ \text{lcy}/250\ \text{lcy/h} = 6.9\ \text{h} = 7\ \text{h}$$

6. What is the unit cost for excavating and hauling the dirt to another location?

$$\text{O\&OHourly cost for a 320C working in moderate conditions} = \$22/\text{h}$$
$$\text{O\&OHourly cost for a D30D working in moderate conditions} = \$\,42/\text{h}$$
$$\text{Operators are paid \$23/h including contractor outlay}$$
$$(3\ \text{operators})(\$23/\text{h}) = \$69/\text{h}$$
$$\text{Hourly O\&O cost for this equipment package} = \$22 + [2\ \text{trucks}(\$42/\text{h})] = \$106/\text{h}$$
$$(\$106/\text{h} + \$69/\text{h})7\,\text{h} = \$1225\ \text{cost}$$
$$\$1225/1500\ \text{bcy} = \$\,0.817/\text{bcy}$$

4.5.2 Backhoes

Backhoes are probably the most common piece of construction equipment found on commercial construction projects. They come in many sizes and are ideal for light excavation, trenching, material moving, and loading. Backhoes can be used as a hoe or a loader and can accommodate many different accessories and attachments for different operations. One of the backhoe's greatest strengths is that many attachments can be used to increase its versatility on a job site. Simple efficient systems are designed for easy connection of most attachments. If the contractor does not need the attachment all of the time, it can be rented as needed. Figure 4.17 shows the hoe part is located on the back of the machine (backhoe).

The operator drives and operates the loader bucket from the front seat and operates the hoe from the rear seat. Backhoes are designed to operate using outriggers for stability. Outriggers are spread on the digging end (excavator). The scooping bucket supports the front end. All four wheels are off the ground when digging. The backhoe is ideal for light underground utility construction. The hoe can be used for trenching and lifting like the excavator. The bucket can be used for hauling material and backfill. For a large backhoe, maximum digging depth is about 16′, loader bucket capacity is about 1.5 cy, and maximum lifting capacity is over 4 tons.

Figure 4.18 shows JCB's backhoe demonstration at Conexpo in Las Vegas in 2001. It is a choreographed show called the "dancing diggers." Conexpo is the largest equipment show in the world. Most heavy construction equipment is showcased there. Contractors and suppliers come from all over the world. It is acres and acres of the latest and greatest construction

FIGURE 4.17 Backhoe.

equipment. Most manufacturers showcase their greatest capacity equipment, from buckets to cranes, to engine parts to attachments of every kind.

4.5.2.1 Backhoe Production

If a loader bucket is used to move material, production is figured like a front-end loader. If the excavator bucket is used, production is figured like an excavator. Cycle components are the same. Times may be slightly less because of the maneuverability and size difference of the backhoe compared to a larger loader or excavator. Backhoes are made for lighter work than typical loaders or excavators. They are purchased for many times their multiuse

FIGURE 4.18 Dancing diggers.

capacity. They need a fairly level and stable work surface and enough area for proper outrigger placement.

4.5.3 Front Shovels

Front shovels operate very similarly to front-end loaders as stated earlier in this chapter. They are designed to dig above grade into the face of the excavation, not to scoop at ground level. These shovels typically operate on tracks for better traction when pushing the bucket into the face to be excavated. The work typically entails filling the bucket, backtracking or positioning and dumping the bucket contents into a pile or a truck. Front shovels are typically not very mobile and travel distance minimized. The typical production cycle is like a front end loader and production is calculated similarly. Bucket sizes range from over 6 to 36 cy and the vertical digging envelope can reach almost 50′. Some shovels are equipped with bottom dump buckets to reduce wear on the machine and provide greater dumping and loading accuracy.

4.6 LIFTING CONSIDERATIONS

The Power Crane and Shovel Association (PCSA) is responsible for establishing many of the operating and lifting criteria for this heavy construction equipment. Published technical bulletins and other information are available through this organization. An excellent resource for mobile crane information is the *Mobile Crane Manual* published by the Construction Safety Association of Ontario [2].

Manufacturers publish model-specific tables to be used for checking lifts. These tables are not interchangeable for different models of the equipments. Crane failure can result from stability failure (proper setup) or from structural failure (components of the crane). It is extremely important that tables published for a specific model of crane are used only for checking lifts by that crane. Both stability and structural capacities must be verified. As the size of the equipment increases, typically the lifting capacity, the cost and the need for a competent and experienced operator also increases.

4.6.1 Placing a Load

Figure 4.19 graphically shows the variables and forces when placing a load with a lattice boom crane. For most lifting, the same loading principles apply to all types of cranes regardless of the type, boom configuration, or size. Lifting variables include the load weight and shape, boom length, horizontal distance from the centerline of the crane to the placement point, angle of boom, and the lifting quadrant for picking and placing the load. Forces determined by these variable forces when a lift is made include the tipping moment and the stabilizing moment. The physical location of instability related to the crane's body is called the tipping axis. This is also the center of gravity when the crane is loaded and swinging. The tipping axis location varies with the load and the counterweight relationship. The crane is stable when the stabilizing moment exceeds the tipping moment.

It is necessary to know the rated lift or load capacity of the equipment prior to making a lift. This is basically how much a crane can lift (lbs) with a certain length boom (ft) setup, located at located at a certain horizontal distance from the placement point (ft), creating a specific angle of the boom to the ground (degrees). For a vertical mast forklift, the load capacity is determined by how much the forklift (lbs) can lift to a certain height (ft). This type of forklift can only tilt the mast a very short distance so that they are assumed to be stable within this range. This information can be found in manufacturer's lifting capacity tables and should be consulted prior to crane or forklift selection.

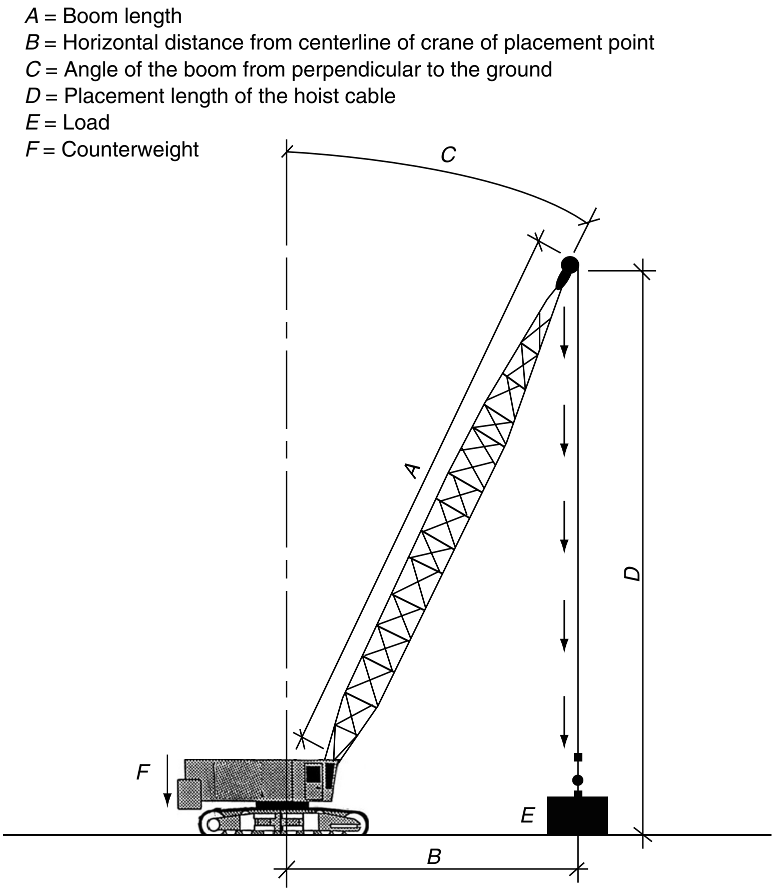


FIGURE 4.19 Loading forces.

The tipping condition is the point of tipping for a particular crane and setup when the overturning moment of the load (the load is too heavy or too dynamic in the air) becomes greater than the stabilizing moment of the machine (machine weight and counterweights). The tipping load is the load that produces this condition. The crane operator must avoid this condition and consult load charts and weight tables to ensure a safe lift if necessary. The crane's leverage must be greater than the load's leverage. Stability failure is caused by trying to lift too heavy load or extending the boom too far or at too much of an angle with the load, causing the machine to tip over in the direction of the load or in the direction the load takes it.

Table 4.7 lists common building materials found on a commercial construction project, weights of each piece, and if applicable pallet or bundle weights. The proper amount of counterweight and the balanced transference of the load weight to the ground via tracks, outriggers, or stabilizers provide the machine stability. It should be noted that the boom and crane components (pendants, attachments, pulleys) have a limited amount of structural strength to accommodate the load. Loading greater than this amount might cause structural failure before the machine becomes unstable.

The sweep area is the total area the crane can cover or swing over. This area is divided into parts called quadrants determined with respect to the position of the boom. Load

TABLE 4.7
Common Material Weights

Material	Unit Weight (Each)	Pallet/Bundle Weight
#5 Rebar	20 lbs	2000 lbs
CY 3500 psi concrete	4000 lbs	N/A[a]
Light 8 × 16 concrete block	28 lbs	2015 lbs
Heavy 8 × 16 concrete block	32 lbs	2305 lbs
3° × 7° Metal door frame	45 lbs	N/A
4 × 8 × 1/2″ Sheetrock	45 lbs	3150 lbs
4 × 8 × 3/4″ Sheetrock	55 lbs	3300 lbs
2 × 4 × 8′ 25 Gauge metal stud	2 lbs	200 lbs
Composite shingles	85 lbs/bundle	2040 lbs
Roof felt	90 lbs/roll	1440 lbs
8′ × 8′ × 3/4″ Glass	1250 lbs	N/A

[a]N/A, not available.

capacity varies depending on the quadrant position of the boom and the load with respect to the machine's undercarriage. Typically one quadrant of the four will sustain the greatest lifting capacity. Crawler crane quadrants are usually defined by the longitudinal centerline of the machine's crawlers — over the side over the drive end of the tracks, or over the idler end of the tracks, (the ideal lifting position). Wheel-mounted crane quadrants are usually defined by the configuration of the outrigger locations — over the side, over the rear, or over the front.

The rated load is typically based on the direction of minimum stability for the mounting. The minimum stability condition restricts the rated load because usually the crane must lift and swing the load. Swinging the load causes the boom to move through various quadrants, changing the load's effect on the crane as it moves. Additionally, rated loads are based on the assumption that the crane is level for a full 360° swing. If the crane is not level, the effect is greater as the boom length increases. Load tables are based on static conditions. Cranes operate in dynamic conditions including wind forces, swinging the load, the hoisting speed, hoist-line braking, and the efficiency of the operator. The load includes the weight of the item that is lifted, plus the weights of the hooks, blocks, slings, and any other items used in hoisting the load. This must be considered in the lifting capacity.

The working range or lifting radius is important once a crane is selected based upon rated load capacity. The working range (the horizontal distance from the axis of rotation of the crane to the center of the vertical hoist line or the tackle with the load applied) considers the boom length necessary to lift the load along with required rigging, the required height at a certain distance from the center of rotation. At a certain boom length, as the distance from center of rotation increases, the angle of the boom decreases. As this angle of the boom decreases, the lifting capacity also decreases (tipping moment increases). Because of this condition, the placement of the crane prior to the lift is extremely important. The lifting equipment should be placed as close to the lifting and placement points as possible. By getting as close as possible, the lifting radius is reduced and the lifting capacity is increased. If this cannot be done, then perhaps a larger capacity crane may be needed or if the lifting capacity is adequate a longer boom may be required.

Lifting capacities should not exceed the following percentages of the tipping loads assuming the crane is properly set up [2].

- Crawler track — 75%
- Rubber tire mounted — 85%
- Machines on outriggers — 85%

4.6.2 The Operator

As with any heavy construction equipment, having a qualified and competent operator is a primary consideration for equipment selection and operation. Risks incurred during lifting are different from risks incurred during excavating or earthmoving. Lift failure often results in great damage to workers and the built project. If an accident occurs, the operator and the condition of the equipment will be investigated. For this reason, it is so important to have a qualified and competent operator, especially if the lift is unique or the job conditions are undesirable.

It should be noted that the crane or lift operator is ultimately responsible for coordination and execution of everything that happens during a lift. The operator determines whether a successful lift can be made or not. Operators must be certified to operate certain types of lifting equipment. The operator should be able to do the following:

- Verify the equipment capacity
- Verify the rigging capacity
- Inspect the condition of the equipment
- Coordinate the lift
- Execute the lift

4.6.3 Mobilization and Setup

Mobilization is the process of transporting and getting the equipment ready for use at the desired location. Whether a forklift or a crane, typically equipment is transported by a semitruck and trailer to the project. The number of trucks needed is determined by the size and number of equipment components to be transported. As the size of the lifting equipment increases, the time and cost to dismantle, load, evaluate haul routes, and reassemble the equipment increases. Sometimes special permits must be obtained to transport oversized equipment loads on public highways. This must be done prior to transport. When planning a lift, these items and any support equipment such as a forklift or mobile crane necessary for assembly should be incorporated into the schedule and budget. For rental equipment, transport and setup costs are usually included in the cost.

Before hoisting a load, the equipment should be leveled. If the crane is not set up level, the lifting capacity is affected and reduced in the direction of the unlevel surface. Setup should be on firm stable ground or timber mats to resist settling as the load is lifted and maneuvered. If the machine uses outriggers for stabilization, they should be fully extended and leveled. The load of the machine should be transferred to the ground through the outriggers only. Figure 4.20 shows the outrigger foot on a timber mat reinforced with a metal plate. Several layers of plywood secured together or timbers are used many times under outriggers. Equipment should be set up as close to the placement point as possible and clearance for the boom should be checked from every point. Any hindrances, especially electrical lines, should be noted and avoided. The travel surfaces must be stabilized and level if the crane must move with the boom extended or up. Many times timber pads must be placed in front of the crane by support lifting equipment to provide a stable level travel surface as they move forward.

FIGURE 4.20 Outrigger setup.

4.6.4 Booms

A lattice boom resembles pipe pieces connected together. It is cable suspended and acts as a compression member. The structure is lightweight, which means extra lifting capacity. This boom is usually transported in sections that are assembled at the site. Crawler and tower cranes typically have lattice booms. Most heavy lifting is done with lattice booms. Figure 4.21 looks up a lattice boom. Figure 4.22 shows common boom ends available for Manitowoc cranes. Each is designed for a specific purpose.

Hammerhead booms are most typically found for heavy lifting such as tilt-up concrete construction. Offset or tapered ends are usually found on lighter lifting cranes such as steel erection or material stocking. Figure 4.23 shows that a telescoping boom works in the same manner as a retractable telescope. As lift height is needed, the boom is telescoped or extended. This boom acts a bending member when lifting. Typically, the boom comes ready for lifting when it arrives at the site. Mobile hydraulic cranes, sky track type lifters, and some man lifts use telescoping booms. Moderate to medium lifting can be done with telescoping booms. A less expensive lattice boom crane has the same lifting capacity as a larger more expensive telescoping boom crane but typically must be assembled.

4.6.5 Forks

Figure 4.24 shows a lifting apparatus attached to a boom that is ideal for fitting under a pallet with material stacked on it or for picking up material stacked on runners. Vertical mast forklifts have limited ability to place the load as once the boom is extended vertically, it can only be tilted slightly for load placement. Forks are rated for loads and usually matched specifically with the machine's load and lifting height capacities.

FIGURE 4.21 Lattice boom.

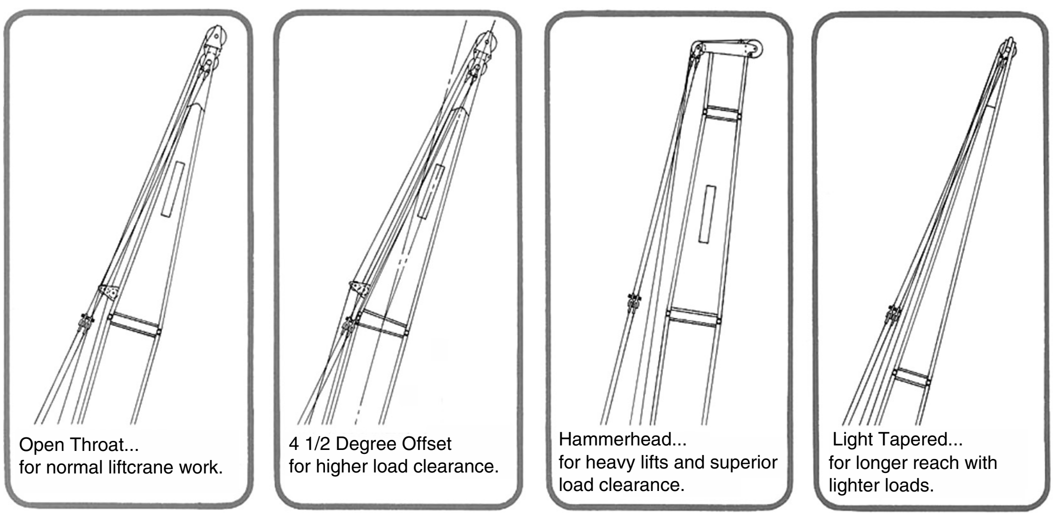


FIGURE 4.22 Common lattice boom tips (Manitowoc Crane Group).

FIGURE 4.23 Telescoping boom.

FIGURE 4.24 Forks.

FIGURE 4.25 Sheetrock attachment.

Forklifts or lift trucks do not require leveling typically, however the loading and travel surfaces should be level as possible and stable enough to support the equipment and load. It is essential that the loading area and the travel route are clear of debris or obstructions and the route is marked for worker traffic in the area. It is very easy with all of the noise, people, and movement on a project for moving forklifts not to be noticed, creating a potential hazard. Loads should be positioned and packed sufficiently so that the forks on a lift can be inserted under the load easily without disturbing the packing or damaging the load. If the load is not positioned correctly, the load can be pushed over while the operator is trying to get the forks in place for the lift. Then someone has to repack or reload, causing loss of time and sometimes requiring cleanup.

Several types of lifting apparatus designed specifically for handling a specific type of building material are available. Figure 4.25 shows a lift truck with an attachment designed for placing sheetrock so that it is positioned for easy unloading through a window or building opening.

4.6.6 Rigging

Rigging is the apparatus used to attach the load to the crane cable so that it can be picked up and moved. "Riggers" are a craft and essential on a project where loads have to be lifted above grade and placed. Most heavy or industrial construction will have this trade on site. For a successful lift, the choice of proper rigging and applying it correctly is just as important as the choice of a crane with adequate lifting capacity. The rigging must be rated for the load just like the crane. The rigging should also be included in the weight of the load. Important field considerations for rigging are as follows:

- Inspect rigging visually prior to every use
- Store rigging properly
- Use qualified personnel to rig loads, especially loads to be transported over other workers or the structure
- Use common sense
- Lift the load slowly a few feet off of the ground to tighten the rigging. Make sure the load is not going to shift once it is in the air

Prior to a lift, the following rules should be observed:

- Know the weight of the load (check material weight tables or get with manufacturer).
- Determine the center of gravity of the load. Not rigging to the center of gravity can imbalance the crane when the load is lifted.
- Protect the load from the rigging with padding or other material if necessary.
- Attach tag lines if necessary while the load is on the ground. These are ropes attached to the load so that it can be maneuvered from the ground at lift and maneuvered from the placement position while it is still in the air when lowered.

Once the load is rigged, lift the load a few inches and check the crane stability and the rigging to make sure the load is stable. When the lift starts, swing the boom slowly and steadily. Avoid jerky starts and stops to avoid swinging the suspended load. Hoist the cable slowly and steadily as the lift is made to avoid swinging the load. Four lift factors for rigging that should be evaluated prior to a lift:

1. The size, weight, and center of gravity of the load
2. The number of legs and the angle the sling makes with the horizontal line when attached to the load
3. The rated capacity of the rigging
4. The history of care and previous use of the rigging

Typical rigging apparatus includes a length of material with connecting devices on the ends. This is called a sling. Types of common sling materials include [4]:

- *Alloy steel chains*: Preferable for lifting hot materials
- *Wire rope*: Economical, readily available, resistant to abrasion, and flexible. Defined by the lay or way in which the wire strands are woven together. Field lubrication is necessary to prevent rusting
- *Natural and synthetic fiber rope*: Inexpensive, pliant, grips the load, typically does not mar the load surface. Not suitable for heavy loads.
- *Synthetic webbing*: Typically does not mar the load surface, straps typically have end pieces designed for easy connection to the load
  - *Nylon*: Used for loads in alkaline or greasy conditions and is resistant to chemicals

- *Dacron*: Used for loads with high concentrations of acid or high-temperature bleach
- *Polyester*: Used for loads with bleaching agents or when minimum stretching is required

How a load is bundled or packaged will influence the type of sling used. Square edges on a load should be protected to avoid damage as the load is lifted using a chain or a wire as the sling. Many types of connectors are available. Hooks and shackles are very common and typically connected to wire rope or the crane cable for easy connection of load rigging. These are rated for capacity just like all other lifting equipment.

For a crane (typically not on a forklift) a hoisting cable is run through the boom, whether the boom is lattice or telescoping. One end typically is wound around a drum behind the crane cab. As cable is needed, it is reeled off of this drum. On the other end of the cable is a ball or hook. The ‘‘headache ball’’ keeps the lifting cable taut so that it is minimally affected by the wind. Rigging is secured around the load and attached to the hook. All hooks are required to have a safety latch. It is an OSHA violation to use a hook without the safety latch. Should the load shift, the hoist be stopped suddenly or the load be struck, the closed latch keeps the rigging from slipping off the hook releasing the load [4].

Figure 4.26 shows a ‘‘spreader bar’’ attached to the hook at the end of the hoist line. Note the end of the hammerhead boom. The rigging attached to the tilt-up panel is attached to the spreader bar at the pulleys. As the crane lifting cable is retracted, it lifts the spreader bar and the panel. The wire rope rigging loop connected to the panel is run over the pulleys on the bottom of the bar. If necessary, the rigging can reposition over the pulley as the panel is lifted.

FIGURE 4.26 Crane using a spreader bar.

The panel is desinged with enough strength so that it can be tilted up and moved to its proper location. By distributing or spreading the load symmetrically, there is less stress on the panel when it is hoisted. Not only must the integrity of the rigging be checked, but the integrity of the spreader bar or any apparatus used to attach to the load should be inspected prior to the lift.

4.6.7 Jibs

Many cranes use jibs bolted to the end of the boom to increase the working range. Jibs come in many lengths and configurations and are assembled like booms. Jibs can be attached to both lattice and telescoping booms. The advantage of the jib is that it can be operated independently from the boom without having to increase the angle of the boom (lower the boom). The jib is like an extra boom that is hinged to the main boom. The same lift forces that are placed on the boom are placed on the jib. Instead of transferring to the crane cab and counterweights, they are transferred to the boom end. The jib weight should be included when evaluating the boom capacity.

As shown in Figure 4.27, most jibs have a gantry and backstay and forestay pendants just like the main boom. These pendants raise or lower the jib as needed (jib offset). In most of the jibs, a secondary hoist cable runs through the end of the jib and has a ball and a hook on the end just like the main hoist cable. The same lifting variables and ultimate forces that apply to booms also apply to jibs. The structural capacity of the jib should be verified using the manufacturer's load tables based on the specific crane to which it is attached and the setup. Jib lengths can reach over 220′. Length and configuration will vary with the capacity of the boom and size of the crane.

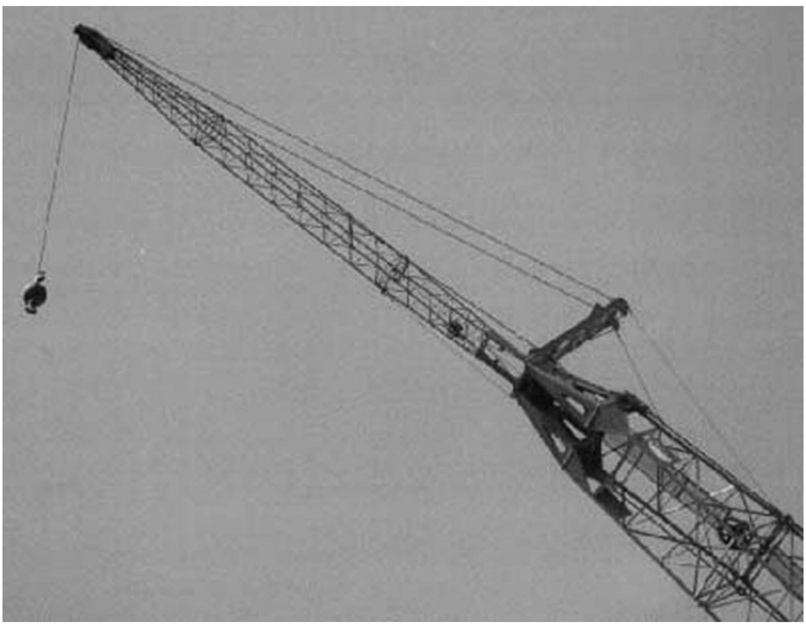


FIGURE 4.27 Common jib.

4.6.8 Hoist Speed

The hoist speed is how fast the hoist cable can be extended or retracted. The capacity of the crane's motor to turn the drum on which the hoist cable is coiled dictates this speed. Raising or lowering the cable with a load creates a dynamic condition that is compounded by the speed with which it is done. Raising the load as the boom is swung or extended adds to the dynamic conditions. The shape and compactness of the load and wind conditions also influence how fast the cable can be reeled in or out.

For high production work activities where the placement height is high, fast hoist speed will decrease the production cycle time. The placement height distance influences the hoist time the same way the travel distance affects the travel time for a groundmoving machine. The manufacturer's specifications for the specific crane used should be consulted for hoist speed capacities.

4.7 LIFTING EQUIPMENT SELECTION

Lifting equipment included in this discussion are:

- *Hoisting*: Mobile, crawler, and tower cranes
- *Material moving*: Forklifts, concrete pumps
- *People moving*: Personnel lifts

4.7.1 Cranes

Cranes discussed in this section are considered typical and found on most construction jobs that require hoisting. Other special types of cranes and many different combinations of booms and jibs are not discussed.

4.7.1.1 Telescoping Boom Mobile Cranes

Telescoping boom mobile cranes are very economical for making one lift or a limited number of lifts in a short period of time. Most of the time mobile cranes are rented. They can be driven assembled to the job or the lift site on public roads. This greatly reduces the setup time and cost. Lifting capacities and work ranges can be quite large if necessary, but most lifting is light to medium.

Example 4.9 Conduct a "lift check" for the following condition. The placement point for a load is 52′ above the ground. The load is 2′ tall. The rigging is 6′ and the vertical boom clearance is about 10′. The height from the ground should be about 70′. The operating radius from axis of rotation is 50′.

Use the Grove RT600E series — 105 ft. Main boom "working range table" is included in Appendix B to determine the boom length for the lift (how much the boom will need to be extended). To use the table, extend a horizontal line from the 70′ height from the ground point across the table. Extend a vertical line from the 50′ point on the operating radius from axis of rotation axis. The two lines intersect between the curved 70′ and 80′ boom lengths. To be safe and to provide enough working range use at least an 80′ of boom for this lift. The boom angle is about 44°.

Use the Grove RT650E series — 105 ft. Main boom "load chart" included in Appendix B to determine the lift capacity in pounds for this crane. Find the 80′ boom length (horizontal top axis) — drop down this column. Find the 50′ radius (vertical left axis) — go horizontally across the table. Where the boom length column and line from the radius axis intersect is the maximum capacity for this setup, for this crane, with this boom. The 650 will pick about 14,200 lbs or 7.1 tons.

Note that this is the maximum capacity. If the weight of the load exceeds this amount, then recheck with a closer radius (move the crane closer so there is less boom angle). If you cannot get closer, then you might have to use a larger capacity crane.

4.7.1.2 Lattice Boom Crawler Cranes

Lattice boom crawler cranes are very common on most types of construction projects. They are versatile in that many attachments to perform many different types of work such as draglines and clamshells for excavation, pile drivers, dynamic compactors, "wrecking" balls for demolition, augers for drilling holes, and magnets for moving metal objects can be easily attached and used. There are several boom configurations that can be used.

A guy derrick crane uses a back boom as a derrick that can be anchored temporarily to other structures to counterweight the load as it is lifted and placed. The lifting cable comes from the back of the cab of the crane, over the derrick boom and then through the lifting boom to the load, thus transferring the compressive force of the load to the derrick. This crane can boost capacity 800% over a basic crawler crane.

A crawler tower crane is less costly than a true tower crane. The main boom is vertical with a luffing boom attachment. The compressive load is transferred to the crane cab and counterweights down this vertical boom. Maximum boom and jib combination are approximately 480′.

The sky horse configuration is similar to the guy derrick, except the back boom is shorter than the lifting boom. It is not temporarily secured during the lift. This crane can approximately triple the capacity of a standard crane.

A ringer lift attachment at the base of a crawler crane is used for heavy lifting. The ring helps to stabilize the crane to the lifting surface. The crane can have a sky horse boom configuration with a luffing jib attachment. Typically a great amount of counterweight is attached for balance. The counterweight is supported on the structural ring. Ringer lift cranes can lift and swing mega-heavy loads.

Figure 4.28 is adapted from an illustration in the *Mobile Crane Manual* [2] published by the Construction Safety Association of Ontario and shows the basic parts of a lattice boom crane.

Because of the crawler tracks and the instability caused by the moment created at the end of the boom by the load, these cranes move slowly and must travel on a level stable surface. If necessary, the crane can build its own road as it moves forward. This portable surface must be level and stable enough to support the crane's weight and also the weight of its load. When planning a lift, how and where the crane travels to its lifting position with its load must be planned. Provision for avoiding obstacles and having a stable travel surface must be made.

Example 4.10 Conduct a "lift check" on the following situation. The placement point for a load is 130′ above the ground. The load is 6′ tall. The rigging is 8′ and the vertical boom clearance is about 16′. The height above ground should be about 160′. The distance from centerline of rotation is 100′.

Use the Manitowoc Model 777 with No. 78 Main boom "heavy-lift boom diagram" included in Appendix B to determine a minimum boom length for the lift. To use the table extend a horizontal line from the 160′ height above ground point across the table. Extend a

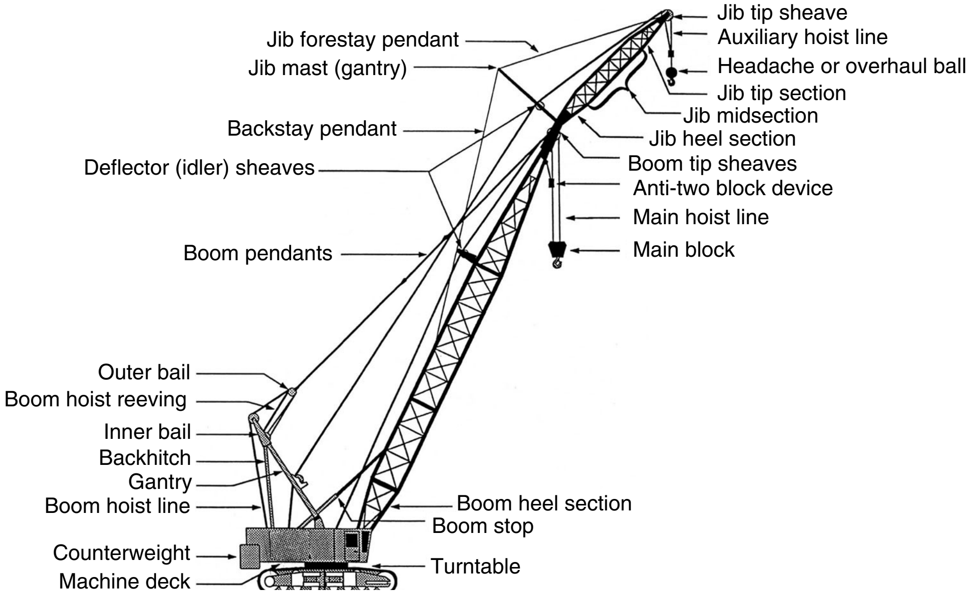


FIGURE 4.28 Parts of a lattice boom crane.

vertical line from the 100′ point on the distance from centerline of rotation axis. The two lines intersect almost right on the curved 180′ line. To be safe and to provide enough working range use at least a 190′ boom for this lift. The boom angle is about 57°.

Use the Manitowoc Model 777 with No. 78. Main boom "heavy-lift load charts" included in Appendix B to determine the lift capacity in pounds for this crane. Find the 190′ boom length (horizontal top axis) — drop down this column. Find the 100′ radius (vertical left axis) — go horizontally across the table. Where the boom length column and line from the radius axis intersect is the maximum capacity for this setup, for this crane, with this boom. The model 777 will pick about 27,600 lbs or 13.8 tons.

Note that this is the maximum capacity. If the weight of the load exceeds this amount, then recheck with a closer radius (move the crane closer so there is less boom angle). If you cannot get closer, then you might have to use a larger capacity crane.

4.7.1.3 Tower Cranes

Tower cranes are one of the greatest construction equipment achievements. They are designed to work in congested areas. These cranes are a lifting device on top of a tower or mast. When a pick is made, the same lifting forces occur as for any other crane. Counterweight must be provided to balance the load. Compression is transferred down to the ground by the tower instead of outriggers, tires, or tracks. Lifting from up in the air can be a lot more demanding and complicated than lifting while sitting on the ground.

Manufacturers classify tower cranes as top slewing, bottom slewing, self-erecting, and special application. Slewing means turning about a fixed point. Cranes can be bottom slewing or top slewing. Only the boom rotates on top slewing cranes. The tower and boom rotate on bottom slewing cranes. The most common type of top slewing tower crane is the horizontal boom. This boom provides optimum coverage. These cranes use a trolley system that positions the hoist line and load by rolling on the bottom of the boom. The longer the boom, the greater the coverage, however the lifting capacity decreases as the load placement (trolley) nears the end of the boom.

All tower cranes have the same basic parts:

- A power source
- A base that is fixed (concrete) or movable (rail tracks)
- A tower or mast
- A boom or jib combination
- A hoist cable and motor system
- A pendant cable system
- A gantry system (tower top or intermediate)
- A turntable mounting for the boom and operator's cab
- A counterweight system
- An operator's cab

Horizontal, luffing, and articulated luffing boom configurations are common for tower cranes. Figure 4.29 shows a Liebherr 390HC horizontal jib tower crane located in Las Vegas, Nevada on the Stratosphere (tallest structure in Nevada). The final hook height was 1120′.

FIGURE 4.29 Liebherr 390HC. (Manitowoc Crane Group)

The crane was used to construct the roller coaster and "straight shot" ride on the top of the restaurant. The crane configuration has a forward jib and a rear jib with a trolley running on the forward jib controlling the hoisting cable. Sheedy Crane Service erected this crane. Another prominent crane supplier and erector is Morrow Equipment Company, L.L.C.

Figure 4.30 shows a Liebherr 112HC-K articulated jib tower crane. Note the pivot point between the first boom and the second boom or jib. Note the configuration of the pendant cables. Also note the lifting cable is on a trolley like a horizontal jib crane; the bottom boom can be moved in and out at an angle — the top boom can be raised or lowered for load clearance as the trolley is manipulated (by repositioning the jib excess hook reach can be converted to added hook height). While this is happening, the crane can also be rotated 360° if necessary. These cranes are primarily used for tower construction or restricted job sites and this is the "luffed" position. The articulated jib crane can also be operated in the horizontal position for maximum working range (like a horizontal jib crane).

Figure 4.31 shows two Liebherr 500HC-L luffing boom tower cranes used during construction of the Luxor Hotel and Casino in Las Vegas, Nevada. The advantage of using the luffing boom cranes is obvious when compared to using horizontal boom cranes. This setup is like a lattice boom crane on the ground, except the crane is on a tower. Luffing cranes are considered as special application tower cranes. These types of cranes are excellent for restricted working areas.

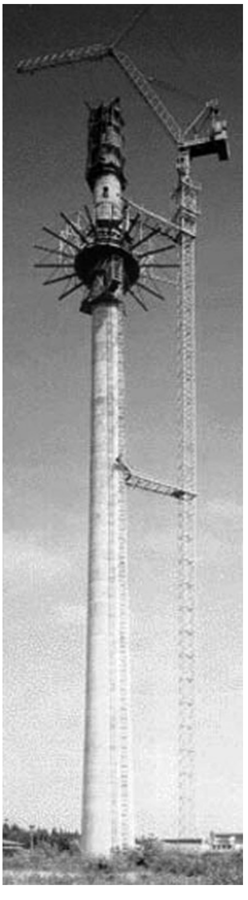


FIGURE 4.30 Liebherr 112HC-K. (Manitowoc Crane Group)

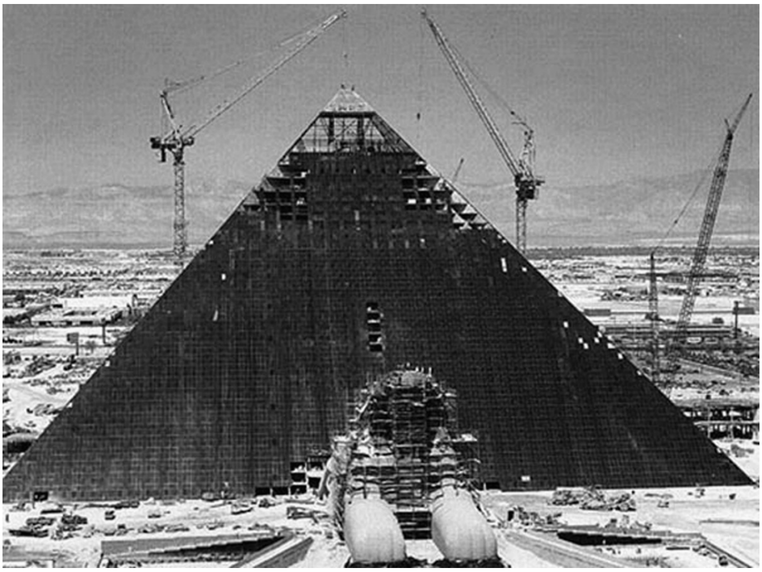


FIGURE 4.31 Liebherr 500HC-L. (Manitowoc Crane Group)

Tower cranes typically are placed in a concrete foundation, but can be mounted on the structure or on rails. A professional engineer must certify the foundation or any bracing or connections to an existing structure supporting the tower crane. If a service is erecting the crane, they will usually provide the base construction details. Since tower cranes typically do not move, the tower location and boom length determine the covered area. Typically, an electrical power source must be run to the crane base and up the tower. Provision for security of crane access and the electrical service must be made.

Counterweight elements must be accurately weighed and the weight clearly and durably marked on each element and entered in the equipment record system or on the erector's checklist. This checklist must then be available at the workplace. Erection, climbing or self-erecting, and dismantling must be part of the tower crane strategy. Towers have a maximum freestanding height. The tower crane may be attached temporarily to the structure, decreasing the moment at the top of the tower when a load is hoisted. This gives the crane greater stability and the tower can be built higher.

An access ladder must be provided and fixed in position on the mast of the tower crane. Each tower crane jib must have a continuous catwalk with a handline from the mast to the tip. An anemometer (wind-measuring device) must be mounted on the crown, apex or operator's cab of each tower crane. Typically a mobile crane is used to assemble the jib, machinery section, and counterweights.

Erecting a tower crane is a substantial construction process that requires other equipment such as forklifts, crawler cranes, or most likely, mobile cranes. Pieces are typically hauled to the job site by 18-wheel trailers and then unloaded for erection. If the crane base is not part of a structure, a concrete base must be constructed prior to erection. One of the considerations in the tower crane strategy is what to do with the crane base after the crane is dismantled. If the base is large, it could be quite costly to remove and haul off the concrete. The size and depth of the base or the necessary structural accommodations if the crane is located on an existing structure are determined by how much compression and moment resistance are needed to support the crane and its maximum load. If the crane is secured to the structure, the operator should check the connections regularly. Manufacturer performance specifications should be followed.

The maximum unsupported jib height is 265 ft (80 m). The crane can have a total height much greater than 265 ft if it is tied into the building as the building rises around the crane. The closer the load to the tower, the more weight the crane can lift safely. The further the load is from the tower, the less weight the crane can lift safely.

The area of coverage based on the lift capacity must be detailed for the whole site by reviewing the site plan. Sometimes multiple towers are necessary to get adequate coverage. Using tower cranes is typically safer and more efficient than having to move crawler cranes many times. Economy for the combination of crane capacity, coverage, and number of cranes should be worked out when the site is planned. Crane requirements for heavy one-time lifts are somewhat different from the requirements for everyday lifting performed by most tower cranes. It is cheaper to have a tower crane that can lift 90% of the loads on hand every day for an extended period of time and pay a rental fee for having a larger capacity crane on the job for a short time to make the other 10% of lifts. These percentages should be determined and may change based on project needs. Most project lifting strategies use a combination of crane types. The superintendent should be involved with the crane supplier or company crane supervisor in deciding locations, capacities, heights, and numbers of tower cranes. Locations must be able to accommodate delivery, staging, and rigging.

Most construction companies lease tower cranes for the erection of the structure and the roof. Tower cranes are usually leased monthly. Normal use tower cranes on high-rise buildings will run between $7000 to $15,000/month. Obviously larger capacity cranes or specialty cranes cost more. The erection and dismantling costs may be included as cost in the contractor's budget or in the supplier's mobilization costs.

The rental/erection company ships the crane to the site, assembles it, and charges a monthly fee while the crane is on the site. Depending on the size of the crane, the typical fee for installation and disassembly amounts to around $60,000. This price includes shipping the crane to the site, renting the mobile crane used to assemble the tower crane, the cost of the crew that handles the assembly, and other associated costs. A typical monthly fee for a 150-ft tall average capacity tower crane is approximately $15,000, with an additional charge to rent the climbing frame and extra mast sections if required.

Example 4.11 Conduct a "lift check" for the following situation. The placement point for a load is 130′ above the ground. The load is 6′ tall. The rigging is 8′ and the vertical boom clearance is about 16′. The height above ground should be about 160′. The hook radius is 100′.

Use the Potain MD 485B-M20 — maximum capacity is 44,092 lbs, "working range diagram" included in Appendix B to determine the required jib/boom length for the lift. It should be noted that this P850A has a maximum freestanding hook height (HH) of 286′1″. The hook height or tower can be adjusted based on the highest placement point to be serviced. Obviously, there is no need to have more than an adequate amount of tower as higher the tower the more moment created by the lift. The 286′1″ HH is more than enough to reach the 160′ height above ground. The jib selected is the 246′1″ long L75.

Use the Potain MD 485B-M20 — maximum capacity = 44,092 lbs, "rated load chart" SM-DM Trolley included in Appendix C to determine the lift capacity in pounds for this crane. Find the 246′1″ jib length (horizontal top axis) — drop down this column. Find the 100′ hook radius (vertical left axis) — go horizontally across the table. Where the jib length column and line from the hook radius axis intersect is the maximum capacity for this setup, for this crane, with this jib. The 485 will pick about 25,836 lbs or 12.9 tons.

4.7.2 Forklifts

Forklifts are ideal for loading and unloading delivery trucks and moving material around the job site on the ground. They are ideal for placing material on the structure or on scaffold up to three stories. Above that height a crane is typically required. Instead of securing the load to a hoist line using rigging, the load rests on forks maneuvered securely under the load on the ground. Paths should be made and controlled around the job site for material movement by forklifts. There are two basic types of forklifts. One has a vertical mast and the other has a telescoping boom. Both types are rated for capacity and the manufacturers specifications should be consulted prior to use.

For both types of forklifts, the basic lifting considerations discussed previously must be determined prior to selection and use. Load weight, lift height and distance, and setup location must match the forklift's structural capacity and stability. As with other lifting equipment, as size increases, so does lifting capacity. For telescoping boom forklifts, as size increases so does the vertical reach and horizontal operating range.

Vertical mast forklifts require a relatively stable and flat lifting surface. Basically the boom goes straight up with little tilting ability. Because of limited tilting range, the forklift must be able to get up close to the structure on which the load is to be placed. The forklift positions perpendicular to the building after transporting the load to the placement location. The load is raised with the mast tilted back to the cab slightly. When the load is high enough to be set down, the mast is tilted forward or the forklift is pulled closer to the placement surface and the mast tilted forward. When positioned the load is lowered and placed. Typically, wood runners or shims are placed under the load so that the forks can be removed when the load is secure. Once the load is clear, the mast is tilted back to the cab and the forklift backs up while continuing to lower the mast. The cage over the operator should be adequate to deflect a load shift or fall.

Telescoping boom forklifts are typically designed for more irregular terrain and greater lifting distances. The load placement process is very similar to a telescoping boom crane. The boom can extend horizontally while lifting. The fork apparatus can tilt and push forward when in placing position. A major advantage is that this lift does not have to be up next to the structure in order to place the load. Some models of telescoping boom forklifts have outriggers or stabilizers.

Forklift production is determined by how long it takes to secure, transport, and unload the load at the placement location. This is influenced by the distance and the speed of transport. The speed of transport is influenced by congestion, the travel surface, and the amount of maneuvering that is required.

4.7.3 Personnel Lifts

Personnel lifts play a supporting role and are ideal for hoisting men, tools, and equipment into position to secure structural components or materials in locations unreachable by a ladder or other means. They are typically tire equipped and self-propelled and require a stable operating surface. Personnel lifts come in many operation types and lifting and height capacities. Most of them have the operation controls on the work platform, so height and platform location can be adjusted while in use. There are two basic types of personnel lifts found on most construction jobs. One has a scissor-type lifting mechanism and a work

FIGURE 4.32 Scissor and telescoping boom personnel lifts.

platform and the other has a telescoping or retractable boom and a work platform. The same lifting limitations that are applied to cranes can be applied to these lifts as well. A tipping condition will result in case of too much weight, whether people, materials, or tools. Lift users should be aware of these operating restrictions prior to use. Both types are rated for capacity and the manufacturers specifications should be consulted prior to use. Figure 4.32 shows two scissor lifts and a telescoping boom lift working together. The name scissor lift comes from the configuration of the lifting apparatus. This lift is typically used for interior work on a flat stable work surface. They are ideal for MEP rough in and trim out and sheetrock, ceiling, or soffit installation. Scissor lifts can reach up to 60′ and accommodate a load up to 1 ton. Larger work platforms require larger and more powerful base units. As the required work height increases, the less stable the scissor lift becomes. This is their greatest limitation.

The lifting mechanism for telescoping/retractable boom man lift works in the same way as a telescoping boom crane. Work platforms used on these types of lifts are typically smaller than those that can be used on scissor lifts, however the reach can be much greater. Telescoping boom man lifts can reach up to 150′. The work platform swivels and levels as the boom positions. These lifts are ideal as support equipment for securing structural steel components together, exterior caulking and cleaning.

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[2] D.E. Dickie. *Mobile Crane Manual*. Ontario, CA: Construction Safety Association of Ontario, 1982.
[3] J.E. Schaufelberger. *Construction Equipment Management*. New York: Prentice Hall, 1999.
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5 Advanced Methods in Estimating and Optimizing Construction Equipment System Productivity

5.1 INTRODUCTION

The past four decades have been an era of accelerating technology. Much advancement has been made in the development of larger, faster, more productive construction machinery. Increased machine productivity has resulted in an increase in the overall project size. These two factors have combined to produce a very capital-intensive environment in which the equipment managers must operate. The risk they must bear is further increased by inflation. As a result, the members of the construction industry have been forced to search for methods to reduce a high level of risk. Historically, the least cost method for reducing risk has been used to provide detailed estimating and planning before undertaking an equipment-intensive project and solid management throughout the course of the project. Estimating and planning involves the judicious selection of equipment, the careful scheduling of time and resources, and the accurate determination of expected system productivity and cost. Management involves putting the plan into action. The key management ingredient is having predetermined standards by which actual system outputs can be measured and upon which future decisions can be based.

Even a seemingly straightforward operation such as earthmoving is a highly dynamic system. A hauling operation contains several components that interact in a very complex manner. Analytical methods, based on engineering fundamentals, have been developed to solve the problem of bringing these components together in a logical manner. These methods mathematically model hauling systems. Their solutions are numerical results that may be used in the decision-making process of estimating, planning, and managing an equipment-intensive project.

5.2 BACKGROUND

Early methods made the somewhat naive assumption that optimizing productivity based on physical constraints of the environment would in turn minimize the overall production cost. Therefore, no effort was made to include cost or profit variables in those mathematical models. The models developed by Gates and Scarpa [1] were the first to recognize the importance of the cost function in the overall system optimization. Many methods currently in use do not adequately model physical conditions. They rely on the judgment and experience of the user, which may be very good or very bad with corresponding outputs from the models.

5.3 PEURIFOY'S METHOD OF OPTIMIZING PRODUCTIVITY

The first author to propose a method to optimize the productivity of construction equipment systems was Peurifoy [2]. His method involves determining all the physical constraints on the hauling system and evaluating them to determine the system's ultimate performance. The constraints are as follows:

1. *Haul road rolling resistance*: The haul road is broken down to segments like road materials (i.e., asphalt, rutted earth, etc.) and rolling resistance in pounds per ton is assigned to each segment. These assigned values are then used as part of an equation to determine the maximum velocities of haul units.
2. *Haul road grades*: The route is evaluated to determine the grade of the haul road for use in the velocity calculation.
3. *Haul unit horsepower*: This value is used to determine the maximum amount of rimpull, which can be developed by the haul unit. It is then used to determine the maximum velocity attainable by the haul unit in a loaded and an unloaded condition.
4. *Haul unit loaded and empty weight*: The weights are used to determine whether sufficient power is available to move the vehicle and then in the velocity calculation.
5. *Haul unit transmission characteristics*: These characteristics are used to determine the amount of time required to accelerate to top speed.
6. *Haul unit loading time*: The loading time is necessary to determine both cycle time and the optimum number of haul units.
7. *Haul unit travel time*: Travel time is one of the parts of cycle time.
8. *Haul unit delay time*: This consists of all times encountered in the cycle time except travel and loading times.
9. *Altitude of the project site*: Altitude affects engine performance and thereby alters the engine's ability to produce rimpull.

5.3.1 RIMPULL

The first concept that must be understood is rimpull. Rimpull is defined as the tractive force between the driving wheels and the surface on which they travel. If the coefficient of traction is high enough that the tires do not slip, maximum rimpull is a function of the power of the engine and the gear ratio between the engine and the driving wheels. The following equation can be used to determine maximum rimpull:

$$\mathrm{RP} = \frac{375\,(\mathrm{HP})(e)}{V} \tag{5.1}$$

where RP is the maximum rimpull (lbs), HP the horsepower of the engine, e the efficiency of the engine (decimals), and V the velocity (miles per hour, mph).

The rimpull required to overcome grade and rolling resistances is given by the following formula:

$$\mathrm{RP_R} = W(\mathrm{RR} + 20(\pm S)) \tag{5.2}$$

where RP_R is the rimpull required (lbs), W the weight of vehicle (tons), RR the rolling resistance (lbs/ton), and S the slope of grade (%).

The difference between the maximum rimpull and the required rimpull equals the amount of force available to accelerate the vehicle to top speed. The acceleration in miles per hour per minute is as follows:

$$a = \frac{0.66(\mathrm{RP_a})}{W} \tag{5.3}$$

where a is the acceleration (mph/min) and RP_a the available rimpull (i.e., $RP_a = RP - RP_R$).

Thus if maximum speeds in each gear are known, the time to accelerate to top speed can be determined.

Example 5.1 If a truck with a 150 horsepower engine with an efficiency of 0.81* weighs 38,000 lbs fully loaded and has maximum speeds of 3.0, 5.2, 9.2, 16.8, and 27.7 mph in 1st through 5th gears, respectively, the top speed and time to reach that speed on a level road with a rolling resistance of 60 lbs/ton can be found as follows.

Subtracting Equation 5.2 from Equation 5.1 yields:

$$\begin{aligned} \text{In 1st gear: } \mathrm{RP_a} &= \frac{375(\mathrm{HP})(e)}{V} - W(\mathrm{RR} + 20(\pm S)) \\ &= \frac{375(150)(0.81)}{3.0} - \frac{38{,}000\,(60 + 20(0))}{2000} \\ &= 15{,}187.5 - 1{,}140 = 14{,}047.5 \text{ lbs} \end{aligned}$$

$$\text{Maximum available rimpull per ton} = \frac{\mathrm{RP_a}}{W} = \frac{14{,}047.5}{(38{,}000/2{,}000)} = 739.34 \text{ lbs/ton}$$

As the maximum rimpull is often not reached due to lack of driver courage and mechanical losses in the gears, this value is reduced to 300 lbs/ton, the maximum achievable value cited by Peurifoy and Schexnayder [2].

Then from Equation 5.3:

$$a = 0.66(300) = 198 \text{ mph/min}$$

And the time to accelerate from 0 to 3 mph will equal

$$time = \frac{3.0}{198} = 0.015 \text{ min}$$

The same set of calculations is then made for each of the five gears keeping the 300 lbs/ton as the maximum in mind. The results are as follows:

$$\begin{aligned} \text{Acceleration time for 2nd gear} &= 0.011 \text{ min} \\ \text{Acceleration time for 3rd gear} &= 0.030 \text{ min} \\ \text{Acceleration time for 4th gear} &= 0.139 \text{ min} \\ \text{Acceleration time for 5th gear} &= 0.622 \text{ min} \end{aligned}$$

*Note: $e = 0.81$ is an average value for engine efficiency. This can vary from 0.60 when a truck is cruising empty in high gear to 0.92 when a loaded truck is climbing a grade in low gear.

Assuming 4 s per gear change, the total time to accelerate to a top speed of 27.7 mph equals 1.069 min.

5.3.2 Cycle Time and Optimum Number of Units

At this point, the foregoing calculations must be made for the empty weight of the truck so that the time for the return trip may also be determined. Once this is done, the top speeds found are used to determine the travel times. The time to load and discharge the material must also be estimated. The total cycle time (C, in min)can now be calculated:

$$C = L + T + D \tag{5.4}$$

where L is the loading time (min), T the travel time (min), and D the discharge time plus time for other delays for turns, maneuvering, acceleration, etc. (min).

The optimum number of haul units (N) is determined as follows:

$$N = \frac{C}{L} \tag{5.5}$$

The productivity can be estimated with the following equation:

$$P = \frac{60N(S_{\mathrm{H}})}{C} \tag{5.6}$$

where P is the productivity (tons or cubic yards per hour), S_{H} the size of hauling unit (tons or cubic yards), and 60 the conversion factor from minutes to hours.

Example 5.2 An 18–cubic yard dump truck has a loading time of 3 min, a travel time of 7 min, and the dumping and delay times of 5 min. Calculate the cycle time, optimum number of hauling units, and productivity.

$$C = 3 + 7 + 5 = 15 \text{ min}$$

Therefore, $N = 15/3 = 5$ units

$$\text{and} \quad P = \frac{60(5)(18)}{15} = 30 \text{ cubic yards per hour}$$

Peurifoy's techniques allow the engineer to relate the hauling process to engineering fundamentals and make estimates of system productivity based on these fundamentals. The primary weakness of this model is that it does not include cost factors, and the estimates are based on instantaneous production rather than sustained production. Instantaneous production is the maximum theoretical production achievable at any given instant. Sustained production is the average realistic production achievable throughout the course of the project that considers hard-to-quantify factors for human frailty, equipment reliability, and environmental instability. Peurifoy's calculations tend to become rather complex and have provided a basis upon which subsequent authors have expanded.

5.4 PHELPS' METHOD

Phelps [3] takes Peurifoy's method and carries it a step further by introducing a factor of realism into the computations. This method strives to estimate the production that can realistically be achieved in a given period of time. Phelps defines this as sustained production. To do this, the amount of time that is wasted due to human weakness and imperfect management is apportioned to each cycle. In industry, equipment managers sometimes try to compensate for the human factor by using a 45 to 50-min productive hour. This does not give an accurate estimate because operations that have long cycle times allow less opportunity to waste time than ones with short cycle times. For example, the average truck driver is more likely to waste time using the restroom or getting a drink when the truck is loaded or waiting to be loaded than when engaged in the haul, dump, and return portion of the cycle. Thus, on projects with longer haul distances, the total amount of time wasted is less than the shorter hauls because a greater portion of the cycle time is spent actively engaged in operating the vehicle.

5.4.1 Fixed Time

Phelps breaks the cycle into three parts: fixed time, variable time, and loading time. The fixed time consists of the delays that are built into the system due to mechanical constraints and the human factors. These include times to accelerate, decelerate, turn, dump, and waste (i.e., nonproductive times). The acceleration and deceleration can be estimated by using empirical values [3]:

$$\text{Total acceleration time} = 0.3x + 0.2y \tag{5.7}$$

$$\text{Total deceleration time} = 0.02(x + y) \tag{5.8}$$

where x is the number of accelerations while loaded and y the number of accelerations while empty.

The total fixed time (F) can be estimated by using the following empirical values shown in Table 5.1, which were established from actual project information.

5.4.2 Variable Time

The loading time (L) is estimated from the production characteristics of the loader given by the manufacturer. The variable time (V) is calculated using the following equations:

TABLE 5.1
Phelps Method Fixed Time (F) Values When Loading Time (L) Is Given [3]

Haul Type	Distance (ft)	Fixed Time Formula
Short haul	200′–1200′	$F = 4.5 \text{ min} + L$
Medium haul	1200′–5000′	$F = 4.0 \text{ min} + L$
Long haul	5000′–9600′	$F = 3.5 \text{ min} + L$

Note: These values contain one acceleration and deceleration for each haul and return trip. Therefore, if intermediate stops occur, this value should be increased appropriately.

$$V_H = \frac{375(\text{HP})(e)}{W_F(\text{RR} + 20(\pm S))} \quad (5.9)$$

$$V_R = \frac{375(\text{HP})(e)}{W_E(\text{RR} + 20(\pm S))} \quad (5.10)$$

$$V = \frac{60d}{V_H} + \frac{60d}{V_R} \quad (5.11)$$

where V_H is the velocity of haul direction (i.e., while loaded) (mph), V_R the velocity of return direction (i.e., while empty) (mph), W_F the weight when fully loaded (tons), W_E the weight when empty (tons), V the variable time (min), and d the haul distance (miles).

5.4.3 Instantaneous and Sustained Cycle Times

With the above information, the instantaneous cycle time (C) can be calculated:

$$C = F_i + V + L \quad (5.12)$$

where F_i is the instantaneous fixed time (min) (i.e., the sum of all fixed time components except waste time (W)) or

$$F_i = F - W \quad (5.12a)$$

The number of units can be calculated using Equation 5.5. The total wasted time for the entire project is estimated and apportioned to each cycle to determine the waste time per cycle (W). With this, the sustained cycle time (C_s) is calculated. The sustained productivity (P_s) can also be computed:

$$C_s = C + W \quad (5.13)$$

$$P_s = \frac{60(N)(S_H)(H)}{C_s} \quad (5.14)$$

where S_H is the capacity of haul unit (tons or cubic yards) and H the shift length (hours).

Example 5.3 Given a haul length of 1300 ft, a loading time (L) of 3.0 min, a variable time (V) of 4.0 min, compute the sustained cycle time, the optimum number of hauling units (N), and sustained production rate. The hauler has a capacity of 20 bank cubic yards. The shift is 8 h long and waste time (W) is 2.0 min per cycle.

Using the empirical estimates for fixed time (F) shown in Table 5.1:

$$F = 4.0 + L = 4.0 + 3 = 7.0 \text{ min}$$

and from Equation 5.12a

$$F_i = 7.0 - 2.0 = 5.0 \text{ min}$$

From Equation 5.12 and Equation 5.5, respectively,

$$C = 5.0 + 4.0 + 3.0 = 12 \text{ min}$$

and

$$N = \frac{12.0}{3.0} = 4 \text{ units}$$

From Equation 5.13:

$$C_s = 12 + 2 = 14 \text{ min}$$

From Equation 5.14:

$$P_s = \frac{60(4)(20)(8)}{14} = 2743 \text{ cubic yards per shift}$$

It should be noted that Phelps' method does not fix the physical constraints, which can be varied. For instance, the poor haul road maintenance can cause the rolling resistance to markedly increase, which decreases the achievable speeds. This causes an increase in the variable times of the hauling units. As any component of the sustained cycle time increases, the optimum number of hauling units changes, and the system's ability to maintain the calculated sustained productivity begins to fail. Therefore, the use of this method should include an analysis of changing physical constraints to determine the most economical situation. Thus, the maximum achievable production can be determined in context with the appropriate equipment mix, inherent physical conditions, and ancillary requirements such as haul road maintenance. The final result is a fully optimized system within the physical constraints of the project environment.

5.5 OPTIMIZING THE HAULING SYSTEM BASED ON LOADING FACILITY CHARACTERISTICS

Arriving at an optimum equipment fleet for a given hauling task necessarily involves relating the two major types of equipment in the system to one another. This can be done by mathematically characterizing the operational characteristics of the loading facility to the mathematical description of the hauling unit through the use of a load growth curve.

5.5.1 LOAD GROWTH CURVE CONSTRUCTION

An earthmoving system's productivity is limited by the production of the loading facility. In other words, regardless of the size, number, and speeds of the hauling units, the ability of the loading facility to load the haul units will determine the maximum productivity of the system. As a result, the loading facility characteristics must be carefully considered in the planning and in subsequent steps of a hauling operation. Most models do include some function describing the loading facility such as loading time or loader productivity. Generally, loading time is derived by dividing the haul unit capacity by the equipment manufacturer's figure for loader productivity. This does not consider the fact that the size of the haul unit may not be an even multiple of the loader bucket capacity. For example, if a front loader with a 1.5 cubic yard bucket is loading a 10.0 cubic yard dump truck, it would require 6.67 buckets to fill the truck. As it takes virtually the same amount of time for a loader to load two thirds of a bucket as it does to load a full bucket, the theoretical productivity is not achieved. Additionally, legal haul restrictions and material weight must play a part in the selection of an optimum mix of loader and hauling unit. Therefore, improvements to existing methods must be made to more adequately consider the characteristics of a loading facility.

The *Caterpillar Performance Handbook* [4] contains a number of load growth curves for bottom-loaded earthmovers. Experience with this management tool in the field has shown it to be extremely valuable in modeling actual occurrences. The same concept can be applied to top-loading operations. To construct a load growth curve, the unit of hauler capacity is plotted against the loading time. A given loading facility equal to loading cycle must first be separated into its various elements. These elements are then divided into productive and nonproductive categories. The physical act of placing material into a haul unit is considered productive. Other elements such as filling the bucket, maneuvering, and movement are considered nonproductive in this application. Productive elements are plotted as sloping vertical deflections, and nonproductive elements are plotted as horizontal displacements.

Example 5.4 A front loader with a 1.5 bank cubic yard bucket has the following cycle elements:

Move to stockpile	0.05 min
Fill bucket	0.10 min
Move to truck and maneuver to load	0.15 min
Dump loaded bucket	0.10 min
Total cycle time	0.40 min

The constructed load growth curve is shown in Figure 5.1. Note that there are a total of 0.3 min of nonproductive time and 0.1 min of productive time.

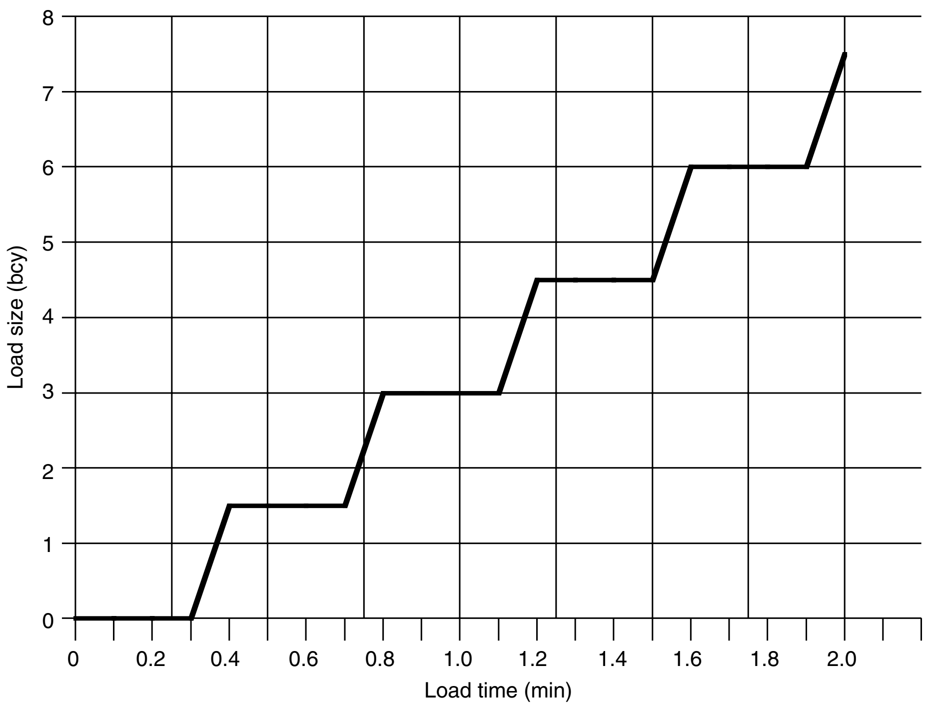

FIGURE 5.1 Load growth curve for bucket loader.

5.5.2 Belt Conveyor Load Growth Curve

The same theory can be applied to all types of loading facilities. It should be noted that the load growth curve for a belt conveyor is parabolic until it reaches its top operating speed where it then becomes a straight line. Thus it has two elements of cycle time: accelerate to operating speed and operate at that speed until the haul unit is full. Both these elements are productive. This can be simplified as a straight line by decreasing the slope of the steady-state line to compensate for the initial acceleration time. The next set of examples illustrates the construction of load growth curves for a belt conveyor and a discharge hopper.

Example 5.5 A belt conveyor has a theoretical productivity of 2000 tons per hour. The time to accelerate to operating speed is 0.1 min. Construct a simplified load growth curve for this machine.

$$\text{Steady-state slope} = \frac{2000 \text{ tons per hour}}{60 \text{ min/h}} = 33.33 \text{ tons/min}$$

Assume average loading duration = 3.0 min
Therefore, percent slope reduction = 0.1/3.0 = 0.03 or 3.0%
Thus the slope for design purposes = (1.0 – 0.03)(33.33) = 32.33 tons/min

The load growth curve is shown in Figure 5.2.

Example 5.6 A 10.0 bank cubic yard discharge hopper is filled by a belt conveyor, which is loaded by a 5 bcy bucket loader. The productivity of the conveyor is greater than the productivity of the loader. Therefore, as the conveyor's productivity is limited by the

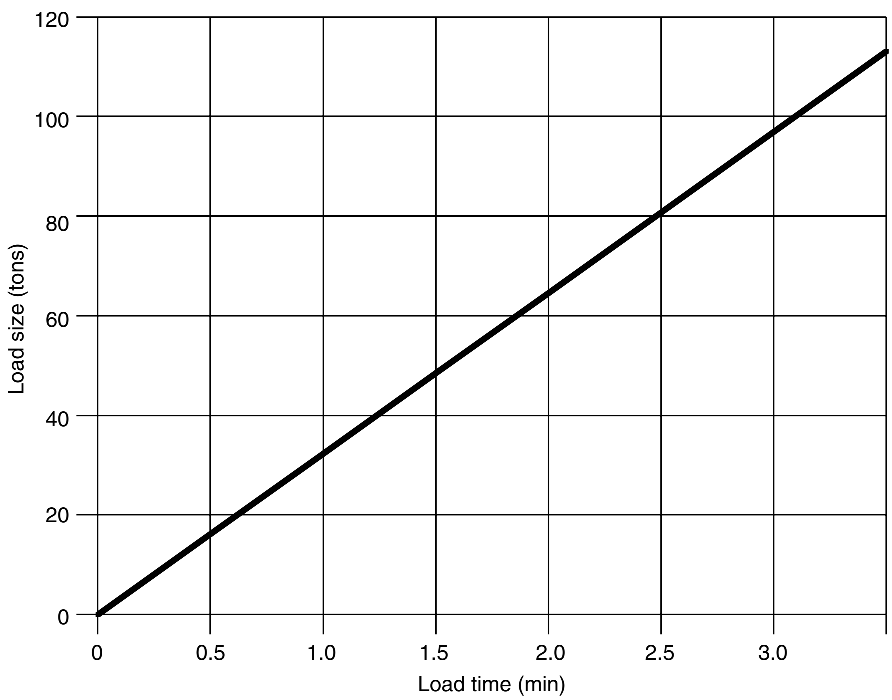

FIGURE 5.2 Belt conveyor load growth curve for Example 5.5.

productivity of its loading facility, its theoretical productivity is of no significance. The hopper's loading cycle can be broken into two elements:

Fill hopper = 0.7 min and
Discharge load into haul units = 0.1 min

Figure 5.3 illustrates the load growth curve for this situation. It looks much like the bucket loader load growth curve shown in Figure 5.1. This is because the bucket loader in this example is controlling the system productivity.

5.5.3 Determining Optimum Number of Haul Units

The next model takes the best characteristics from the Phelps method and combines them with load growth curve information to determine the optimum number of haul units. A comparison of five optimization methods with actual data gathered in the field found the Phelps method to be the most consistent [5]. Therefore, an improved model was devised that utilizes many of the same concepts as Phelps. It also adds parameters for cost. As costs vary by location, it is important to remember that the ultimate goal of optimizing a hauling system is to maximize productivity while minimizing cost. Therefore, it is conceivable that an optimum equipment mix, which is based on physical factors alone, may not minimize the cost in every location. Thus, cost factors must be considered equally important to engineering fundamentals.

The analysis starts with determining the maximum velocity using Equation 5.9 and Equation 5.10. These velocities are then compared to the maximum allowable velocity (i.e., the legal speed limit or other restriction) to determine the actual velocities to be used in the travel time (T) calculation:

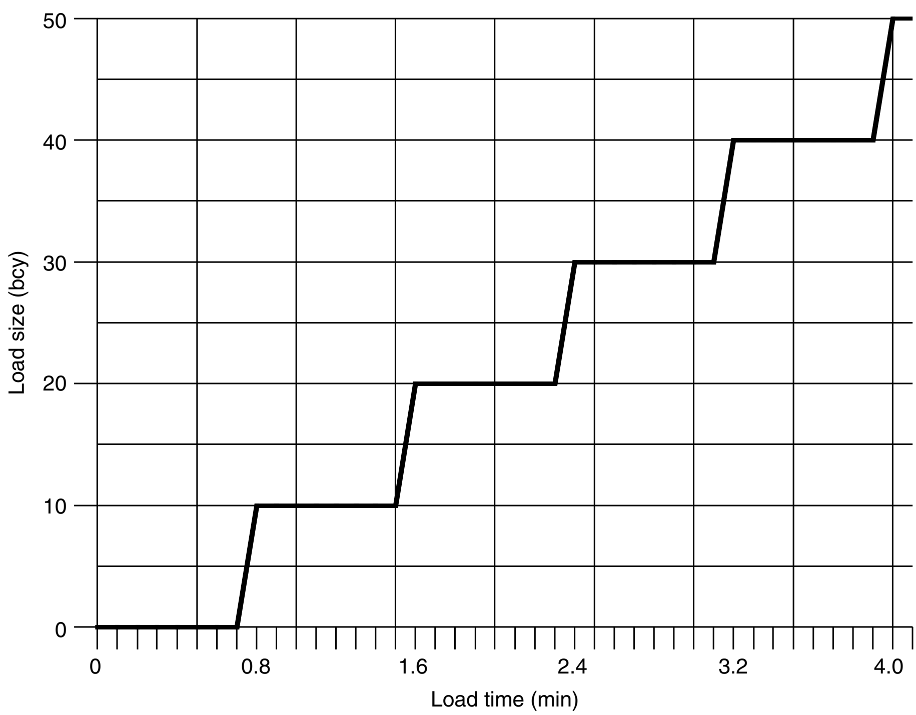

FIGURE 5.3 Load growth curve for discharge hopper for Example 5.6.

$$T = \frac{d}{88}\left(\frac{1}{V_{\mathrm{H}}} + \frac{1}{V_{\mathrm{R}}}\right) \quad (5.15)$$

The loading time (L) is then taken off the load growth curve constructed for the given loading facility. The delay time (D) along the route is estimated. These are then added to the travel time to calculate the instantaneous cycle time from Equation 5.4 and the optimum numbers of haul units from Equation 5.5:

$$C = L + T + D \quad (5.4)$$

$$N = \frac{C}{L} \quad (5.5)$$

N is usually not a whole number and must therefore be rounded. The rounding decision is of great import because it will ultimately determine the maximum productivity of the hauling system. Two analytical methods are available to make this decision.

5.5.4 Rounding Based on Productivity

The decision whether to round the optimum number of haul units up or down can have a marked effect on the system's productivity. Rounding the number up maximizes the loading facility's productivity. Rounding the number down maximizes haul unit productivity. Therefore, it is logical to check both productivities and select the higher of the two. This process is best shown by example.

Example 5.7 A 1.5 cubic yard front-end loader is going to load dump trucks with a capacity of 9.0 cubic yards. The loader takes 0.4 min to fill and load one bucket. The travel time in the haul is 4.0 min. Dump and delay times are 2.5 min combined:

$$L = \frac{9(0.4)}{1.5} = 2.4 \text{ min}$$

$$C = 4.0 + 2.5 + 2.4 = 8.9 \text{ min}$$

and

$$N = \frac{8.9}{2.4} = 3.71 \text{ haul units}$$

Rounding down will maximize haul unit productivity. In other words, the haul units will not have to wait to be loaded, but the loader will be idle during a portion of each cycle. Therefore

$$\text{Productivity of 3 haul units} = \frac{9(3)(60)}{8.9} = 182 \text{ cubic yards per hour}$$

Rounding up will maximize loader productivity with the haul units having to wait for a portion of each cycle. This assumes that there will always be a truck waiting to be loaded as the loader finishes loading the previous truck. Therefore,

$$\text{Loader productivity} = \frac{1.5(60)}{0.4} = 225 \text{ cubic yards per hour}$$

This number can be checked by calculating the productivity of 4 haul units. The additional time each truck spends waiting to be loaded (A) can be calculated as follows:

$$A = N(L) - C \tag{5.16}$$

In this case, $A = 4(2.4) - 8.9 = 0.7$ min per cycle.

Thus, actual cycle time = 8.9 + 0.7 = 9.6 min per cycle

and

$$\text{Productivity of 4 haul units} = \frac{9(4)(60)}{9.6} = 224 \text{ cubic yards per hour}$$

This is equal to productivity of the loader. Therefore it checks. When comparing the two possible productivities it appears that it is best to round up in this case. Thus 4 haul units are selected. This decision also makes intuitive sense. No matter how many trucks were added to the system, they could never haul more material than the loader could load. The only way that a higher level of productivity could be achieved in this example is to add another loader or use a larger loader.

5.5.5 Rounding Based on Profit Differential

Another philosophy on rounding the optimum number of haul units involves analyzing both cases to determine which would yield the greatest amount of profit. The aim is to find the best trade-off between the added cost of an extra vehicle and the benefit of having or not having that vehicle.

Example 5.8 A 1.5 cubic yard front-end loader has an hourly cost (C_L) of \$150.00 with operator. This figure includes jobsite fixed costs such as supervision. The hourly cost of a dump truck (C_t) is \$50.00/h with a driver. The instantaneous cycle time (C) is 8.0 min and the loading time (L) is 1.5 min per truck. The size of the truck (S_H) is 10 cubic yards. The project quantity (M) is a total of 10,000 cubic yards of material that requires hauling and the bid unit price is \$2.00 per cubic yard:

$$N = \frac{8.0}{1.5} = 5.33 \text{ haul units}$$

The total cost (TC) to complete the project can be described by the following equation:

$$\text{TC} = \frac{M(C)(C_t)(N) + C_L)}{N(S_H)(60)} \tag{5.17}$$

Therefore, the total cost if N is rounded down to 5 units is

$$\text{TC}_5 = \frac{10{,}000(8)(50(5) + 150)}{5(10)(60)} = \$10{,}667$$

The total cost if N is rounded up to 6 units is

$$\text{TC}_6 = \frac{10{,}000(9)(50(6) + 150)}{6(10)(60)} = \$11{,}250$$

The total revenue for the project = 2.00(10,000) = \$20,000
Then, profit with 5 trucks = \$9,333
Profit with 6 trucks = \$8,750

In this case it is better to round down, as greater profit is realized.

In practice, an old rule of thumb should be considered when making rounding decisions: "Always round down, as it is easier to add another truck when necessary than to delete one that is not required." The simple logic of this rule speaks for itself. The manager should never make this decision arbitrarily. Factors such as time, equipment, and labor constraints must be considered before the decision is made. Finally, the experience of the decision maker must ultimately be relied upon to determine the most advantageous situation.

5.5.6 Optimizing with Cost Index Number

Once the rounding decision has been made, the sustained cycle time (C_s) can be calculated. If N is rounded down, C_s is found directly from Equation 5.13 because the productivity of the haul units is controlling system productivity. If N is rounded up to allow the productivity of the loading facility to control, C_s is found by adding Equation 5.13 to Equation 5.16. The result is shown below:

$$C_s = C + W + A \tag{5.18}$$

The total time (TT) to complete the haul of a given amount of material and the system's cost index number (CIN) can be computed as follows:

$$\text{TT} = \frac{M(C_s)}{60(N)(S_H)} \tag{5.19}$$

$$\text{CIN} = \frac{\text{TT}(N(\text{EOC} + \text{MOC} + \text{OC}) + \text{IC})}{M} \tag{5.20}$$

where TT is the total time to complete haul (h), S_H the size of haul unit (tons or cubic yards), M the amount of material (tons or cubic yards to match S_H), N the optimum number of haul units, CIN the cost index number, EOC the equipment ownership cost (\$/h), MOC the maintenance and operating cost (\$/h), and OC operator cost (\$/h).

5.5.7 Selecting Optimum Haul Unit Size

In most situations, a construction contractor will not be constrained by the size of haul unit that must be used before bidding on a project. In many cases, trucks will be rented for the duration of the project either directly or via a subcontract. Therefore, it is very important to select the equipment mix that best satisfies the physical constraints of the actual project environment. The above model can be used to do just that. The process is illustrated by the next example.

Example 5.9 The front-end loader from Example 5.4 with a bucket size of 1.5 loose cubic yards will be used to load material from a stockpile. Its load growth curve is shown in Figure 5.1. To complete this project, 10,000 loose cubic yards of materials are to be hauled. Three sizes of haul units are available to the equipment manager. Their details are shown in Table 5.2. Projects costs, which are independent of haul unit size selection, are estimated to be \$300/h. The material must be hauled over a haul road that has a one-way length of 5000 ft, 60 lbs/ton rolling

TABLE 5.2
Specifications for Haul Units in Example 5.9

Item	Haul Unit A	Haul Unit B	Haul Unit C
Capacity (lcy)	6–8	12–14	15–17
Horsepower	109	260	260
Efficiency	0.80	0.80	0.80
Weight empty (tons)	8.7	18.4	18.7
Weight full (tons)	17.7	36.4	41.2
EOC ($/h)	8.96	11.18	13.52
MOC ($/h)	6.04	6.20	7.94
Labor ($/h)	15.00	15.00	15.00

resistance, and an average slope of +2.0% in the haul direction. The unit weight of the material is 3000 lbs per loose cubic yard. The speed limit of the haul road is 35 mph, and the cost for a truck driver is $15/h.

From Equation 5.9 and Equation 5.10 for haul unit A:

$$V_H = \frac{375(109)(0.8)}{17.7(60 + 20(+2))} = 18.47 \text{ mph}$$

and

$$V_R = \frac{375(109)(0.8)}{8.7(60 + 20(-2))} = 187.93 \text{ mph}$$

Then comparing $V_{max} = 35$ mph
$V_H = 18$ mph
$V_R = 35$ mph

From Equation 5.15:

$$T = \frac{5000}{88}\left(\frac{1}{18} + \frac{1}{35}\right) = 4.78 \text{ min; use } 4.8 \text{ min}$$

From Figure 5.1: Entering the load growth curve on the Y-axis at 6.0 cubic yards, the loading time (L) for haul unit A is found to be 1.6 min.

The delay times are estimated as follows [3]:

Accelerate after load	0.3 min per cycle
Decelerate to dump	0.2 min per cycle
Maneuver and dump	1.0 min per cycle
Accelerate empty	0.2 min per cycle
Decelerate	0.2 min per cycle
Total	1.9 min per cycle

Therefore, $D = 1.9$ min.
Then from Equation 5.4:

$$C = 1.6 + 4.8 + 1.9 = 8.3 \text{ min}$$

From Equation 5.5:

$$N = \frac{8.3}{1.6} = 5.19 \text{ units}$$

As the maximum achievable system productivity is the productivity of the loader, this number will be rounded up to 6 units. Thus, each truck will have an additional time waiting to load each cycle. From Equation 5.16:

$$A = 6(1.6) - 8.3 = 1.3 \text{ min}$$

and

Driver waste time (W) is estimated to be 2.0 min per cycle.
Therefore, from Equation 5.13:

$$C_s = 8.3 + 1.3 + 2.0 = 11.6 \text{ min per cycle}$$

From Equation 5.19 and Equation 5.20, respectively,

$$\text{TT} = \frac{10{,}000(11.6)}{60(6)(6)} = 53.7 \text{ h of hauling}$$

and

$$\text{CIN} = \frac{53.7((8.96 + 6.04 + 15)(6) + 300)}{10{,}000} = 2.58$$

Repeating the above calculations for haul units B and C yields the following numbers:

$$N_B = 3 \text{ and } \text{CIN}_B = 2.13; \qquad N_C = 3 \text{ and } \text{CIN}_C = 2.12$$

Assuming that the addition of sideboards would allow one more bucket of material to be loaded per cycle, the following numbers of haul units and CINs are found:

N'_A(optimum number of type A haul units with sideboards, 7.5 loose cubic yards) = 5
$\text{CIN}'_A = 2.40$
$N'_B(13.5 \text{ lcy}) = 3$
$\text{CIN}'_B = 2.09$
$N'_C(16.5 \text{ lcy}) = 2$
$\text{CIN}'_C = 2.47$

Plotting CIN vs. size in loose cubic yards yields Figure 5.4. This shows that the use of three (3) Type B (12 lcy basic size) with sideboards provides the minimum CIN, and therefore, this is the optimum size and number of hauling units for this project.

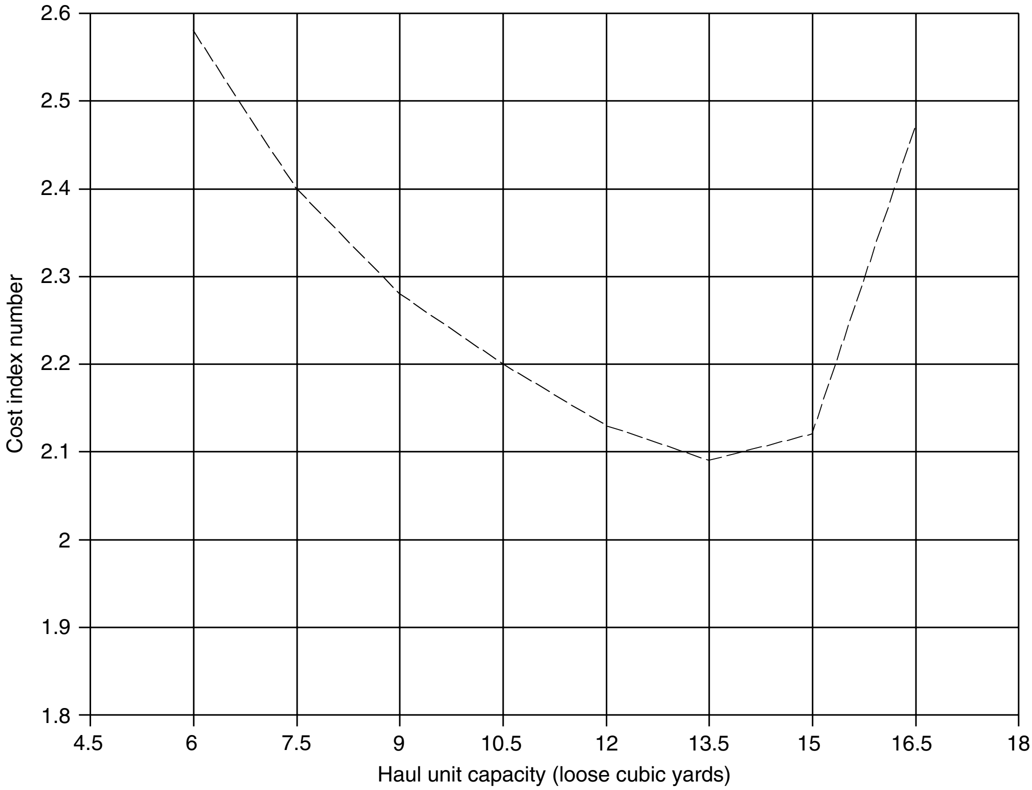

FIGURE 5.4 Cost index number (CIN) comparison for Example 5.9.

5.5.8 Optimizing the System with a Belt Conveyor

As previously mentioned, the logic shown in Example 5.9 can be used for any type of loading facility. The next example demonstrates the use of this model with a belt conveyor. This type of loading facility has the advantage of allowing a variable amount of material to be loaded. Thus the project manager can analyze several differently sized loads for each available type of haul unit. This allows the project manager to more closely optimize the load in relation to rolling resistance and horsepower.

Example 5.10 The project used in Example 5.9 will be accomplished using a belt conveyor that is buried in a stockpile. Therefore, the conveyor can be assumed to be continuously loaded so that its productivity will control system productivity. The conveyor has a theoretical productivity of 1000 tons per hour. Its load growth curve is shown in Figure 5.5. After performing the same set of calculations as in Example 5.9, the results of the nine possible combinations of loads on the three different haul units are as follows:

Load haul unit A with:	6 lcy:	$N = 12$ and CIN $= 1.09$
	7 lcy:	$N = 11$ and CIN $= 1.03$
	8 lcy:	$N = 10$ and CIN $= 0.98$

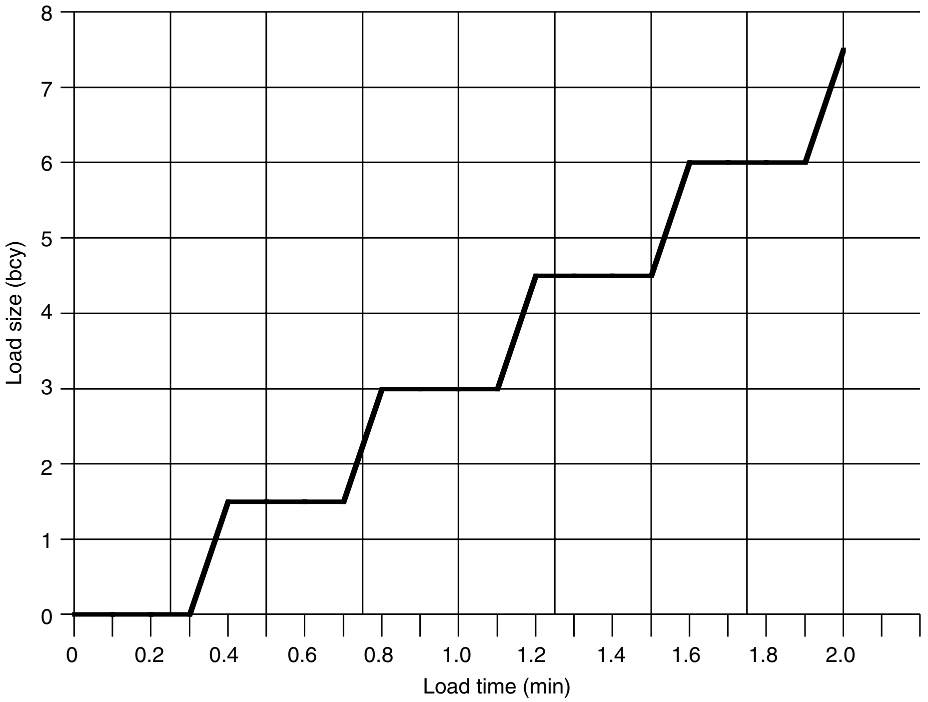

FIGURE 5.5 Load growth curve for Example 5.10.

Load haul unit B with:	12 lcy:	$N = 6$ and CIN $= 0.84$
	13 lcy:	$N = 6$ and CIN $= 0.79$
	14 lcy:	$N = 5$ and CIN $= 0.85$
Load haul unit C with:	15 lcy:	$N = 5$ and CIN $= 0.86$
	16 lcy:	$N = 5$ and CIN $= 0.82$
	17 lcy:	$N = 5$ and CIN $= 0.80$

Comparing CINs, it is found that using six Type B haul units loaded to 13 loose cubic yards minimizes the CIN. The use of five Type C haul units loaded to 17 loose cubic yards yields a CIN very close to the optimum. However, the problem of vehicle reliability should be considered in the final decision. If one of the six Type B units breaks down, there would be a 17% loss in production until it is returned to service. On the other hand, if one of the five Type C units is lost, the system suffers a 20% production drop. Therefore, the use of six Type B haul units is the best solution.

5.5.9 Selecting the Optimum Size-Loading Facility

All the discussions to this point have centered on selecting the optimum size and number of haul units given for a particular loading facility. There are times when just the opposite decision must be made. The previous model can be adapted to pick the optimum size-loading facility, when the size and maximum number of haul units are fixed.

Example 5.11 Using the project information from Example 5.9, a project manager has ten Type C haul units available and a choice of three bucket loaders to rent. The characteristics of each loader are shown in Table 5.3.

The load growth curve for Loader I is shown in Figure 5.1. Corresponding load growth curves would be constructed for Loaders II and III. It is poor practice to load less than a full bucket. Therefore, each loader should be analyzed before loading the given haul unit with all feasible combinations of full buckets. In other words, Loader I can load the Type C haul unit with either a 15 loose cubic yards (10 full buckets) or 16.5 loose cubic yards (11 full buckets).

The results of the calculations are shown below:

Loader I: 15.0 lcy load: $N = 2$ and CIN $= 2.18$
16.5 lcy load: $N = 2$ and CIN $= 2.09$
Loader II: 16.0 lcy load: $N = 2$ and CIN $= 2.00$
Loader III: 15.0 lcy load: $N = 3$ and CIN $= 1.48$

From these calculations, Loader III with the 2.5 loose cubic yard bucket should be chosen. It should load 15 loose cubic yards (6 full buckets) on the Type C haul unit.

5.6 COMMENTS ON OPTIMIZING EQUIPMENT FLEETS

The examples discussed in this chapter clearly demonstrate the relative ease and objectivity with which construction equipment fleet composition decisions can be made using the salient physical parameters of a given project. The great danger that is faced by both project managers and estimators is the bias toward using equipment that is currently in the company's inventory without regard to the potential impact on project productivity. As a minimum, the option of renting an optimized equipment mix should be evaluated against using current equipment. In this analysis, the cost of idle equipment should be factored into the final result to allow the management to select the least cost solution. If renting an optimized equipment mix is selected, the bid price should include the cost of idle equipment to allow the organization to recover those costs as well as the actual rental costs.

Rounding is another decision that has been shown to be very important. One option not analyzed in this chapter is to round the number of haul units up and use one of the units as a standby vehicle. In other words, if the optimum number of haul units was rounded up to six, five of the trucks would be put into production with drivers and the sixth vehicle would be

TABLE 5.3
Loader Characteristics for Example 5.11

Loader	I	II	III
Bucket size (lcy)	1.5	2.0	2.5
Cycle elements			
Move to pile (min)	0.05	0.05	0.05
Fill bucket (min)	0.10	0.13	0.17
Maneuver to load (min)	0.15	0.15	0.15
Load truck (min)	0.10	0.13	0.17
Total load time (min)	0.40	0.46	0.54

brought on site for use, if a production vehicle were to break down. The broken unit would then become the standby unit once it is repaired. Another method would be to rotate the standby unit every day and utilize the time a vehicle is out of production to perform preventive maintenance. Fluids level can be checked. Wornout tires can be replaced, and minor adjustments to major assemblies such as clutches and brakes can be made. This management technique not only maximizes equipment availability but also reduces the overall maintenance and repair costs as well adjusted and lubricated assemblies fail at a much lower rate. Additionally, unquantifiable savings due to the psychological attitude of the operator result. Those who have worked in the construction industry can verify that an operator who is sitting in a clean, well-maintained vehicle tends to operate the vehicle with more confidence and care and thereby achieves higher production. Thus a program of regular rotation of operational vehicle for on-site preventive maintenance reduces the amount of equipment time lost to unscheduled breakdowns.

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6 Stochastic Methods for Estimating Productivity

6.1 INTRODUCTION

Chapter 5 furnished a number of different methods for calculating the productivity of a given piece of equipment. Each of these methods relied on fixed estimates of time and cost. The concept of a sustained cycle time vs. an instantaneous cycle time was introduced, and this concept allows the estimator to compensate for the unforeseen interruptions in a typical equipment production cycle. The sustained cycle time, which might also be called the average daily cycle time, recognizes that equipment production systems are indeed variable even though the mathematical model that was used to estimate production is deterministic.

6.2 BACKGROUND

The next step is to recognize that each input variable in the production rate estimate has its own characteristic variability. For instance, in a wheel-loader or dump-truck production system, the variability of the loader's cycle time is normally less than that of the trucks for no other reason than there is typically only one loader and hence one operator. Whereas if there is more than one dump truck, and the truck drivers will have their own individual abilities to safely operate the machine. Thus, while the loader will cycle within a fairly tight range of instantaneous cycle times, the trucks' times will experience greater variability across the course of the workday. If the haul is over a public highway, variation in cycle times will increase by another increment as the truck drivers have to deal with different traffic situations on each cycle, some of which will cause big delays, such as a traffic jam, and others that will improve the cycle time for a given cycle where the truck happened to hit all the green lights as it proceeded down the road without having to stop.

Accounting for this variation would seem to be an impossibly complex mathematical situation as the influence of traffic on a public road is infinitely random and infinitely variable. It would be according to the discussed deterministic models illustrated in Chapter 5. However, the laws of probability and statistics were developed to specifically give the analyst tools to be able to account for systems that encounter a measurable degree of variation in their normal circumstances. Thus, given some background information about the inherent variation in each input variable, equipment production can be estimated using a stochastic model that includes all the normal variation and furnishes output that shows the expected range of productivity that can be achieved by the equipment package under analysis. Typically this range will be displayed as a best possible case, a worst possible case, or a most likely case.

Given this type of information, the estimator can then get a better feeling for what is realistically achievable under the project's conditions and can adjust the final estimated production rate for a given crew accordingly. Thus, the accuracy of the final estimate should be enhanced. Additionally, the project manager can then take the information to the field and be able to better manage the actual construction, ensuring that the actual production rates do not leave the range in the estimate. As a result, stochastic estimates of productivity furnish not only a more precise preproject estimate but also a mechanism that can transcend the office and take the estimating assumptions to the field and enact them.

This chapter will discuss the simple rules of probability and statistics that are used to develop a stochastic mathematical model of a typical equipment production system, building on the deterministic models shown in Chapter 5. It will discuss the use of standard commercial simulation software packages for solving equipment production problems. Finally, some time will be spent on discussing the elements required to validate a simulation model to ensure that it is adequately predictive.

6.3 DEVELOPING MATHEMATICAL MODELS

Chapter 3 discussed the development of a mathematical model for determining optimum equipment replacement timing and strategy. The rules shown for that problem are not different from the rules for modeling equipment production on a stochastic basis. Essentially, there are three major rules. First, the analyst must be able to mathematically describe the system under analysis in terms of interrelated equations based on the physical constraints of the given system. Next, the variables used in the equations must have values that can be used to solve them. In the deterministic model, each variable has a single "best" value that is used. In a stochastic model, a range of possible values for each variable is used and each value range has an associated probability distribution function (PDF). Finally, there must be a clearly defined decision criterion that mathematically describes the final solution (i.e., "maximize earthmoving crew production").

With these in hand, a model can be developed. Often the model starts out as a deterministic one and is then modified to permit a range of input variable values rather than the single value. Thus, the equations that describe the deterministic model can be transferred to a computer program, which in many cases is merely a standard commercial spreadsheet program. There are other modeling programs available, which interact with the model expressed in the spreadsheet that add the stochastic dimension to the process and change the output from deterministic to stochastic. Several of these will be discussed and demonstrated in this section.

At this point, a short discussion about the application of probability and statistics for calculating the equipment productivity is warranted. The following sections will merely highlight the important concepts as applied to equipment production models. For further details, the reader can consult the references at the end of the chapter.

6.3.1 Probability Theory

In construction equipment production system analysis, probability theory is used to account for the fact that the real cycle times will vary from cycle to cycle depending on many circumstances that are far too complex for the estimator to model. For instance, the cycle time of a push-loaded scraper is dependent on the cycle time of the pusher dozer. In a given cycle, if the dozer operator takes a short break between scrapers to drink water or use the bathroom, the next scraper will probably end up waiting for several seconds or minutes longer than the normal time to begin loading. These types of delays are predictable and the deterministic production model accounts for them using the concept of sustained cycle time rather than making all the calculations using the instantaneous cycle time.

Nevertheless, there are other delays that are not included in the sustained cycle time. An example of this type would be the production time lost for the pusher dozer to refuel at mid-morning because the operator forgot to top off the machine's fuel tank the night before. On the other hand, there will be cycles during the normal day that take less than the sustained cycle time because the system can actually achieve its computed instantaneous cycle times. Thus, using the sustained cycle time as a sort of an average, an observer with a stop watch who recorded the actual cycle time of a given scraper would record times that are both less than and greater than the sustained cycle time that was used in the estimate. A table or graph of these times would be called as "frequency distribution" because it shows how many times a specific cycle time was observed in a given period.

Example 5.3 computed the sustained cycle time for the loader-truck hauling system to be 14 min per cycle. Figure 6.1 is a graphical depiction of a hypothetical frequency distribution of actual cycle times on 30-sec increments for that system. One can see that this system's cycle times ranged from a low of 10 min to a high of 20 min with the 14-min sustained cycle time, the time that was observed most often. Also looking at this chart, one can see that there seem to be a greater number of actual cycle times that are more than the sustained cycle time of 14 min than there are times less than 14 min. In fact, the average observed cycle time is 14.9 min, nearly a full minute greater than that computed by the estimator in this example. This indicates that the actual production is going to be less than the estimated production. Rerunning that example with a 15-min sustained cycle time gives a production rate of 2560 cubic yards per day, which is roughly nine truckloads of less than estimated. So, one can see that if the estimator had known how the actual cycle times would be distributed in relation to the computed sustained cycle time, the bid could have been adjusted to account for the variation in the field. This is exactly what a stochastic production estimating model provides.

So for the next project, Example 5.3 estimator now has a historical record of actual cycle times and could develop a stochastic model to estimate future production rates based on this data. The software that is used to run the stochastic model usually requires the estimator to identify the type of frequency distribution that applies to a given variable. This can be done in one of the two ways. First, if the estimator does not have any historical data like that shown in Figure 6.1, an assumption for the type of distribution can be made. The second way, which requires historical data, is to use curve-fitting software to actually assist in defining the appropriate distribution based on the available data. There are quite a large number of frequency distributions that are used in statistics. However, the four most common

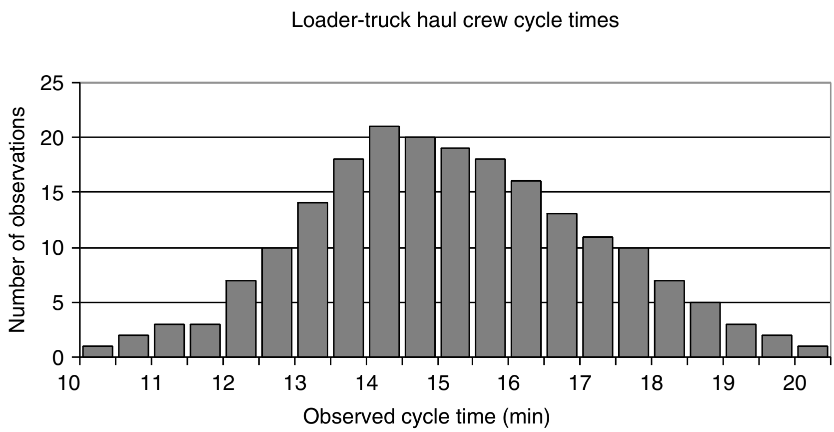

FIGURE 6.1 Hypothetical frequency distribution for Example 5.3, loader-truck haul crew.

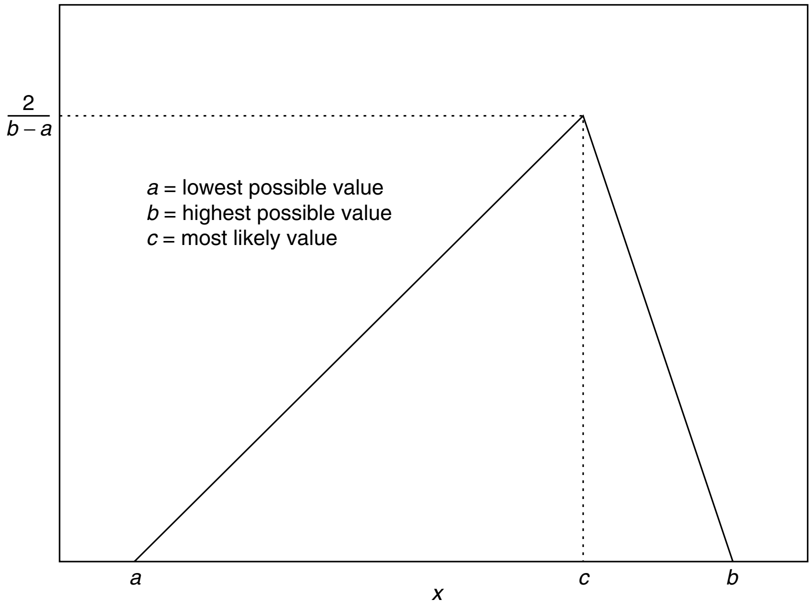

FIGURE 6.2 Triangular probability frequency distribution.

distributions for the types of simulations that are used in equipment production modeling are the following:

- Triangular distribution (Figure 6.2): This distribution is selected when the estimator can only estimate the lowest possible value, the highest possible value, and the most likely value.
- Poisson distribution (Figure 6.3): This distribution is appropriate when the variations in values under analysis are random, such as the arrival of public traffic at a construction work zone. Four conditions must be present to permit the selection of this distribution for the stochastic model [1]:
  - "Events can happen at any of a large number of places within the unit of measurement and along a continuum.
  - At any specific point, the probability of an event is small.
  - Events happen independently of other events.
  - The average number of events over a unit of measure is constant." [1]
- Normal distribution (Figure 6.4): This is the classic "bell curve." This is used when an uncertain value is subject to "many different sources of uncertainty or error" [1]. Some notable qualities of the normal distribution:
  - The density function is symmetric about its mean value.
  - The mean is also its mode and median.
  - 68.27% of the area under the curve is within one standard deviation of the mean. 95.45% of the area is within two standard deviations. 99.73% of the area is within three standard deviations.
- Uniform distribution (Figure 6.5): This is used when the high and low values are known and the chance of observing any value whose range is equal to all other chances.

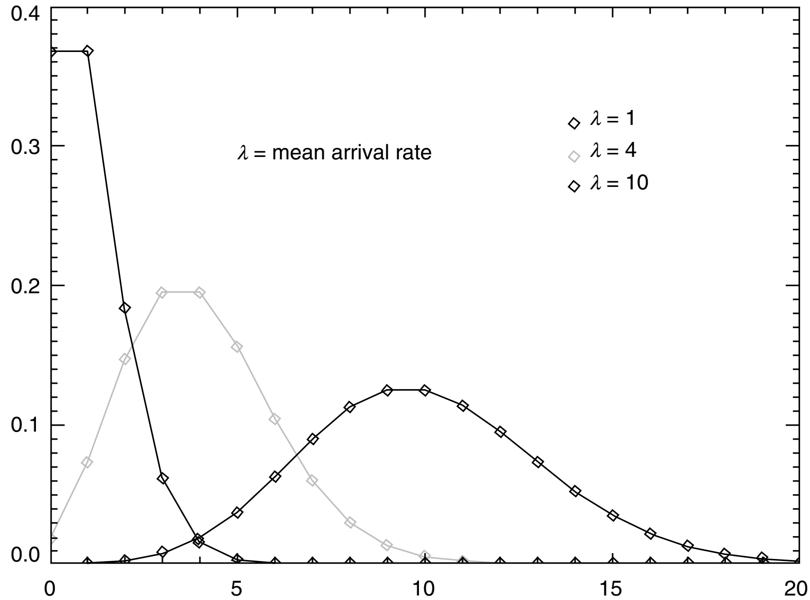

FIGURE 6.3 Poisson probability frequency distribution.

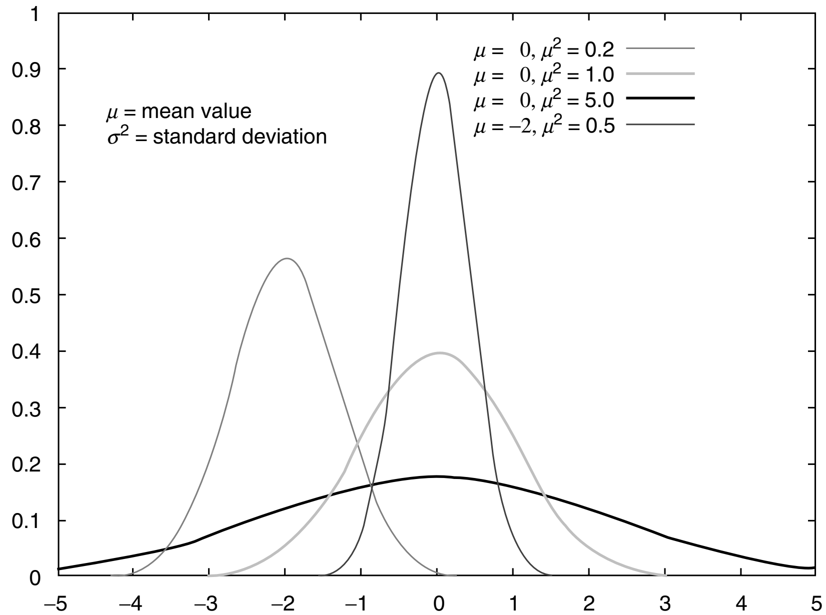

FIGURE 6.4 Normal probability frequency distribution.

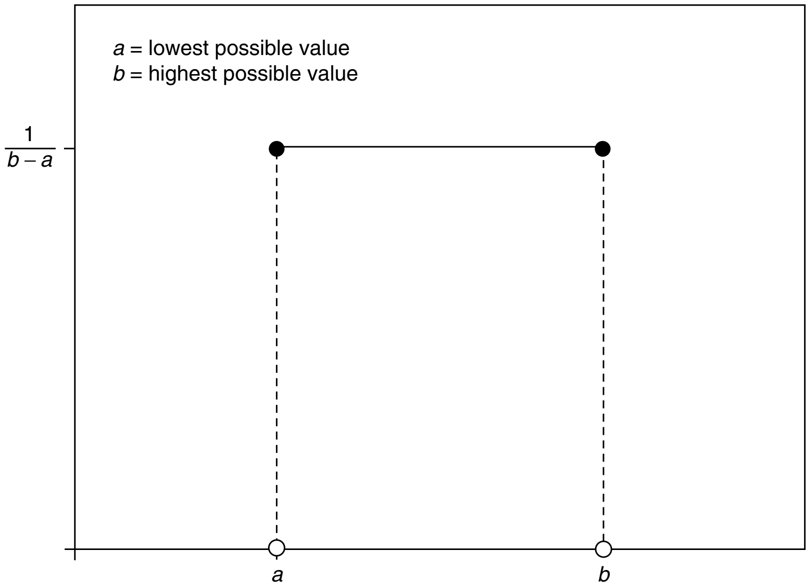

FIGURE 6.5 Uniform probability frequency distribution.

Thus, to move from a deterministic equipment production model to a stochastic one, the estimator will need to do the following:

- Assemble the variables that are going to be part of the model.
- Develop the mathematical relationships for each variable.
- Identify the possible range in values for each variable.
- Associate a probability frequency distribution with each variable that is going to be allowed to vary in the impending simulation.
- Develop the remaining input that is required by the simulation software that will be used.

6.3.2 Statistical Analysis

Statistical analysis goes hand-in-hand with the above discussion. In estimating equipment productivity, it is common to use the "average" times or loads. The mathematical average is a statistical measure. It is more properly called the "mean." Along with the mean comes the "median," which is literally the middle value without regard to frequency, and the "mode," which is the most frequent value in the population. These are all called measures of "central tendency," which means that they describe the axis about which the actual observed values are oriented. The next concept that must be understood to utilize a stochastic equipment production model is the idea of variation within a given sample population.

Figure 6.1 shows the variation of cycle times for the hypothetical haul crew. The mean was 14.9 min, but the range was from 10 to 20 min. The standard deviation of the data is 2.0 min. If the cycle time was assumed to be normally distributed and there is a 68.27% probability that any given actual cycle time will be somewhere between 12.9 (one standard deviation less than the mean) and 16.9 min (one standard deviation more than the mean). So, roughly two thirds of the time the haul crew will be achieving actual cycle times that are within 2 min of the mean. This helps to define the natural variation in this particular parameter. Knowing this, the estimator can now associate a distribution with the historical data for use in the stochastic model.

Taking the data shown in Figure 6.1 and running it through a software package that compares the actual shape of the data's distribution to the shapes of standard distributions with the same mean and standard deviation, the software recommended that a triangular distribution with the low value of 10 min, a high value of 20 min, and a most likely value of 14.5 min be used. Figure 6.6 shows how the distribution was fit to the data from Figure 6.1. Thus, the estimator now has a distribution to associate with the haul crew's cycle times and can then use this in a simulation to fine-tune both the production estimates and eventually the unit price that will be bid for the pay item that this particular crew will perform.

Getting back to the subject of variation inside a given population, the estimators can also utilize the statistical analysis of construction functions to temper their judgment regarding how conservative the estimated production rates should be to cover the unknowns discussed in the first paragraph of this section. Given a mean and a standard deviation for a particular parameter like haul cycle time, the measures of central tendency and dispersion about the mean allow one to make the following judgments:

- If the standard deviation is relatively small as compared to the mean, then it indicates that variation in this particular parameter value will be correspondingly small. Thus, this situation would allow the estimator to use the mean as the predicted value for the parameter with good confidence.
- If the standard deviation is relatively large as compared to the mean, then it indicates that variation in this particular parameter value will be correspondingly great, and the estimator will need to use a value that is greater than the mean as the predicted value for the parameter in order to increase the confidence that the actual average value will be less than or equal to the value used in the estimate.

6.3.3 Historical Data

To conduct the types of statistical analyses discussed above, one must have historical data on which to operate. Obtaining, reducing, and maintaining historical data is a difficult and time-consuming process. As a result, many equipment managers and estimators merely use the information from the last project and assume that it will be close enough to the upcoming project that no difference will be made. This is not always the case. The heart of good estimating is a robust database that is based on the actual costs and production rates that

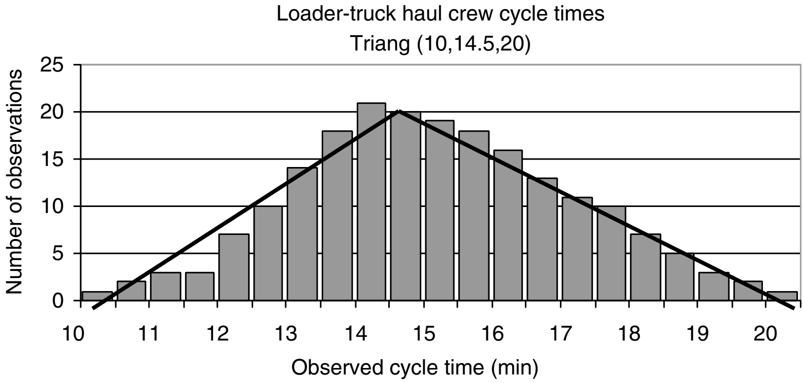

FIGURE 6.6 Triangular distribution fit to Figure 6.1 data.

were achieved on a representative sample of the past projects. The term ''representative sample'' is very important to understand.

Using all the past projects in an organization's files would mean including projects that had anomalies in them. For instance, a given project might have achieved high weekly production rates because there was no adverse weather during the entire job. On the other hand, a project that was plagued with bad weather and muddy working conditions would experience below normal production rates. Therefore, it is important to eliminate data from projects that were not typical from the production-estimating database.

In statistical terms, this is called ''removing outliers'' and is one of the most controversial phases of a rigorous engineering research methodology. There are accepted statistical methods for doing this, but they were designed for use on large sample sizes and would probably not be usable in this particular application. This is because construction projects for the average organization come in populations of tens rather than hundreds or thousands that the research community is used to working with. Because the construction industry does not have a huge population in which to sample, it becomes even more important that those projects that are atypical be removed from the estimating database.

There are a number of types of historical data that are important to the equipment manager, project manager, estimator, and scheduler. These are generally as follows:

- Cost performance data
- Production performance data
- Maintenance failure data
- Labor performance data

6.3.3.1 Cost Performance Data

Cost performance data is different from purely cost data in that it not only records the actual costs that were incurred but it also relates the actual costs to the estimated costs. It can be expressed as a ratio and described by the following equation:

$$\text{Cost performance} = \frac{\text{Actual cost for a given item}}{\text{Estimated cost for that item}} \quad (6.1)$$

Ideally, the ratio will be unity. However, if the ratio is greater than one, the estimator should investigate to find out what was different and adjust the estimating factors for future projects if necessary. The same thing should happen if the ratio is less than one because this indicates that the estimate was too conservative and bidding too high. This often leads to not winning the project. In reality, there will be a range, say 0.95 to 1.05 in which the estimator will feel comfortable leaving the estimating factors alone.

The difference between cost performance data and cost data is an important distinction because cost estimates can be impacted by many different factors. Some of the factors can be controlled during project execution through diligent project management, but some of the factors are totally outside the ability of the project personnel to influence. A controllable factor would be the amount of overtime that has been allowed during the course of a project. Whereas an uncontrollable factor would be an unexpected raise in the rate of the overtime premium pay during project execution due to a newly negotiated union labor agreement. In the first case, the cost performance can be controlled by estimating a given amount of overtime work as a means of controlling cost risk and putting that cost in the bid. Whereas in the second case, a change in the overtime premium rate is impossible to predict and therefore, it cannot be accounted for in the bid. Thus, in the first case, the estimator can check the performance of labor costs vs. the estimate and determine if the amount of overtime estimated for that project was adequate and adjust that rate if it was too high or too low. In the second case, the estimator can only change the formulas for estimating total labor costs to reflect the newly negotiated labor rate. The cost performance in the second case becomes an anomaly and should be eliminated from the estimating database, as it is clearly atypical.

The second issue related to cost performance is the impact of inflation on the actual costs of labor and materials. A prudent estimator will normally factor in some inflation, particularly if the period of performance is quite long. Nevertheless, the market is full of surprises and those contractors who had bid the 2003 structural steel prices for projects to be constructed in 2004 got the surprise of their lives, when steel prices inflated by 40 to 60% [2]. Obviously, this was an unexpected development and caused so much pain in the construction industry that many public owners actually negotiated price increases to critical construction contracts rather than bankrupting their contractors and have their projects go unfinished. Nevertheless, this is a useful example on cost performance. Projects that were underway when the steel price hike happened become anomalies because their ratio of actual costs to estimated costs will be quite high and not representative of future projects that will be bid using the higher steel prices.

The final issue with cost performance data is the age of the data in the database. At some point in time, the prices of old projects are no longer valid and only serve to arithmetically reduce the average values, which leads to cost performance ratios that are greater than one and worse, to reduced profitability. Thus, some mechanism for defining when a project's data has become outdated and needs to be removed should be in place. A common system is to use a 24- to 36-month moving average, which automatically drops projects from the database when they become outdated. When making these adjustments, the estimator must remember that cost performance is a direct function of production performance and ensure that the production rates achieved are reflected in the cost data, which are both reasonable and representative of expectations for the given project environment.

6.3.3.2 Production Performance Data

Understanding how the actual production related to the estimated production is absolutely essential for any equipment-intensive project. These projects are by definition production driven. The reader will understand the importance of production performance data while reading Chapter 7 on scheduling. Thus, capturing production performance data is essential and more important than capturing the cost performance data because the production data is related to the physical conditions in which the project was undertaken. The price of diesel fuel could double on a project, as happened in the summer of 2005, making the cost performance look awful. But if the production performance was close to unity, the estimator would know that the unexpected change in the price of fuel was the cause for missing the target profit and not the ability of the crews to construct the project as planned. Production performance can be expressed in an equation similar to cost performance:

$$\text{Production performance} = \frac{\text{Actual production for a given item}}{\text{Estimated production for that item}} \tag{6.2}$$

Typical production data should be collected for every major crew or equipment resource package. Tracking the actual production achieved during construction furnishes a good project control metric and assists the project manager in identifying those crews that require assistance or need to work extra hours early in the game. One of the major drawbacks of production performance data is that the estimator often assumes that all the machinery will be available all the time during the project. This is a poor assumption. Construction equipment gets hard use and requires an aggressive preventive maintenance and repair program to maximize its availability. Thus, it is equally important to collect maintenance failure data.

6.3.3.3 Maintenance Failure Data

This data needs to be collected for each type of machine that is used in the construction projects for the given organization. The purpose of this data is to give the necessary information for the estimator and the scheduler to adjust production assumptions to deal with this reality. This idea is best explained by the following example.

Example 6.1 A bulldozer is used normally for five 10-h shifts per week for 50 weeks each year. In the past three years, it has been unavailable because of breakdown, routine maintenance, and servicing 44 h in year 1, 150 h in year 2, and 163 h in year 3. The earthmoving crew to which it is assigned has a sustained production rate of 2000 cubic yards per day assuming 100% availability. Find the estimated production rate for a project that will last for 1 year based on the data in this problem.

$$\text{Maximum availability} = 10\ \text{h/day}(5\ \text{days/week})(50\ \text{weeks/year}) = 2500\ \text{h}$$

$$\text{Average yearly down time} = (44 + 150 + 163\ \text{h/year})/3\ \text{years} = 119\ \text{h/year}$$

$$\text{Adjusted production rate} = (1 - (119/2500))(2000\ \text{cy/day}) = 1905\ \text{cy/day}$$

At this point, having collected all the data that is required, the estimator can move on and develop the simulation model to allow the stochastic calculation of equipment production rates. It must be remembered that the purpose for taking this analysis to the next level is to get a better handle on the risks due to uncertainty. Understanding the credible range in possible production rates for every equipment-resourced crew in the project increases the amount of analytic information available to the estimator and to the individual, which will be responsible for making the final business decision of exactly how much the final bid price will be for the equipment-intensive project, or if the organization is a public agency, exactly how much funding will be authorized to self-perform the equipment-intensive project with inhouse construction resources.

6.4 SIMULATIONS

Twenty years ago, simulations were only used by academics who had easy access to great amounts of computing power. As a result, the technique was not useful for the construction industry as a tool, adding value only to academic research. That stigma needs to be removed as the power of the personal computer has increased and the availability of inexpensive simulation software packages that operate from the standard commercial spreadsheets are ubiquitous throughout the construction industry. As a result, the power of enhanced information that can be obtained through the use of simulations is readily available to the average project manager, estimator, or scheduler if they are willing to take a few hours to learn how to make the simulation software operate with the spreadsheet program that they already know well.

In the use of simulations for equipment-intensive projects, there are a number of well-known simulations that have been used specifically for the purpose of analyzing equipment production. The major benefit derived is the ability to compare the possible alternatives inexpensively to see which one furnishes the maximum production or the minimum unit cost. Riggs and West state: "Computer simulation is an effective way to deal with complex economic relations without suffering the penalties of real trial-and-error experiences" [3]. For example, making the decision as to how many dozer–scraper teams to use on a given earthmoving project can determine the ultimate profitability of that job. It is economically impossible to go out to the field and actually perform experiments with real equipment teams to determine which one optimizes the team's production. However, using a computer simulation, the estimator can "try" all the permutations and combinations of dozers and scrapers that make sense for a given task and compare their outcomes mathematically. A paper by Ioannou describes the use of a simulation to optimize the equipment fleet used for loading, hauling, and placement of riprap for dam embankment [4]. If the computer simulation is run thousands of times, the picture of the expected outcomes becomes more clear and the level of uncertainty that is associated with using a deterministic value for the parameters in the model is greatly reduced because eventually all possible outcomes will be found. The graph for the set of simulation outcomes becomes an approximation of the probability distribution for the different alternatives that can guide the decision-maker to the final decisions.

6.4.1 Monte Carlo Simulation Theory

The most common commercial simulation software programs are based on Monte Carlo game theory [3]. This type of simulation essentially uses a random-number generator to randomly select the possible values for each of the variables in the model that have an associated probability distribution and then it calculates the outcome. It then repeats this sequence as many times as required and then accumulates each iteration's output to form an approximate probability distribution for the expected outcome. In equipment production simulation, those outcomes could be an expected daily production rate, an expected unit cost, or an expected length of schedule for the project. The estimator or project manager can then take the output and use it to adjust the bid pricing, which is based on the deterministic solution to the same problem.

6.4.1.1 Developing Monte Carlo Simulation Input

Input for a standard Monte Carlo simulation is described in detail above. Developing the input is mainly a function for satisfying the input requirements of the simulation software that is used. This will be shown by example using a commercial software package called @Risk® [5]. The information from Example 5.3 will be used.

Example 6.2 A 1.5 cubic yard front-end loader is going to load dump trucks with a capacity of 9.0 cubic yards. The loader takes 0.4 min to fill and load one bucket. The travel time in the haul is 4.0 min. Dump and delay times are 2.5 min combined.

$$L = 2.4 \text{ min},\ C = 8.9 \text{ min, and } N = \frac{8.9}{2.4} = 3.71 \text{ haul units}$$

Rounding the number of haul units down will maximize haul unit productivity. In other words, the haul units will not have to wait to be loaded, but the loader will be idle during a portion of each cycle. Rounding the number of haul unit up will maximize loader productivity with the haul units having to wait for a portion of each cycle. This assumes that there will always be a truck waiting to be loaded as the loader finishes loading the previous truck.

Productivity of 3 haul units = 182 cy/h

Productivity of 4 haul units = Loader productivity = 225 cy/h

The above is the deterministic solution to the problem of estimating the haul crew's production rates and making the decision of how many trucks should be assigned to this crew. Based on the assumption, the project manager would want to maximize production, then the crew would have a loader and four trucks assigned to it.

However, when the estimator collected the cycle time data, it was found that three of the variables actually had substantial ranges of actual times rather than specifically achieve the same time in every observation. First, the time taken for the loader to load a single bucket actually varied between 0.3 and 0.5 min with 0.4 min, the most likely time. Because the haul was over a public road, the trucks' travel time also varied due to interference of public traffic as follows: 3.5 min if there was no traffic interference to 5.0 min if the truck got stuck behind a slow-moving vehicle and the average time observed was 4.0 min. Finally, the delay time was a function of the truck's ability to pass through a traffic light and make a left turn across traffic. It then varied between 1.5 and 3.0 min with each 0.5-min increment as likely as the other because both possible delays were essentially random.

Based on the equations given in Chapter 5 for Example 5.3, a computer spreadsheet was developed based on the deterministic values given in the original problem statement. The @Risk software was then activated and three input variables were designated along with their associated probability distributions, which are shown in Figure 6.7:

- Loader load time: Assigned a triangular distribution with 0.3 min as the lowest possible value, 0.5 min as the highest possible value, and 0.4 min as the most likely time. Triang(0.3,0.4,0.5)
- Truck travel time: Also assigned a triangular distribution with 3.5 min as the lowest possible value, 5.0 min as the highest possible value, and 4.0 min as the most likely time. Triang(3.5,4.0,5.0)

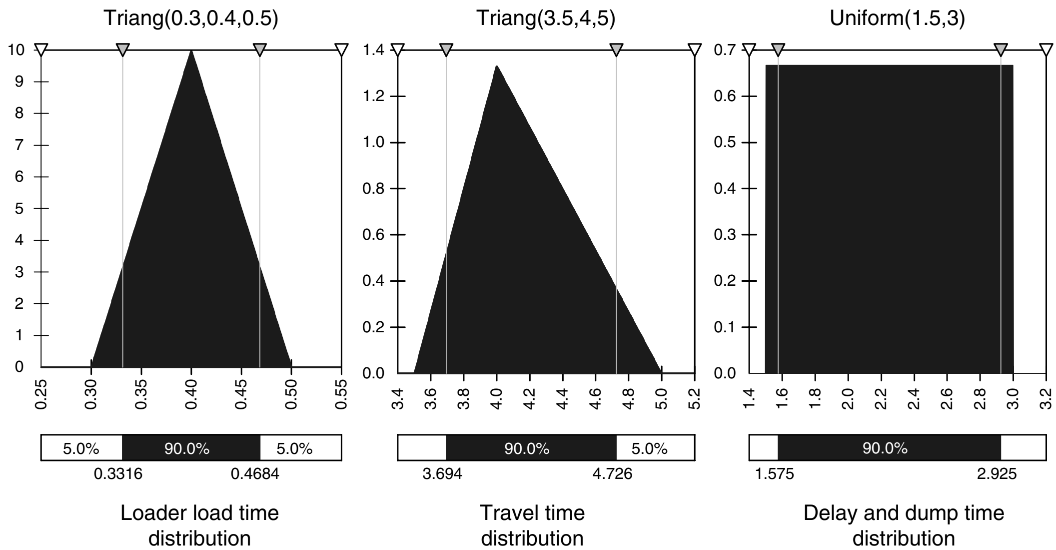

FIGURE 6.7 Probability distributions for three input variables in Example 6.2.

- Delay and dump times: As this variable had the same probability for all possible times, it was assigned a uniform distribution with 1.5 min as the lowest possible value and 3.0 min as the highest possible value. Uniform(1.5,3.0).

Once all the inputs have been properly recorded in the simulation software, the simulation is ready to be run and its output can be analyzed.

6.4.1.2 Analyzing Monte Carlo Simulation Output

The process of simulation output analysis will also be described using the example stated in the previous section. After running 100 iterations of the Monte Carlo simulation, the output shown in Table 6.1 was produced. These numbers can be easily interpreted to assist the production-based equipment fleet size and composition decisions.

Looking at Table 6.1, two alternatives are shown. The first alternative shown as simulation output 1 is the predicted hourly production rates if the crew is resourced with a 1.5-cubic yard front-end loader and four 9-cubic yard dump trucks. The second alternative shown as simulation output 2 is the predicted rates if the crew is given only three trucks. As in the deterministic solution to this problem, the 4-truck crew has the higher predicted productivity. However, when one compares the mean predicted values to the values calculated using the deterministic model, it can be seen that both are higher and the 3-truck crew is predicted to produce 13 cubic yards per hour more than the calculated values using the deterministic model. This is a 7% increase in the average production for that crew.

One can also see that the ranges in production for the two alternative crews overlap, indicating that it is possible to achieve production rates greater than or equal to a 4-truck crew with a 3-truck crew itself. Thus, the potential for using three instead of four trucks and saving the cost of a truck and a driver for the entire length of the project should be investigated. Whereas in the deterministic analysis, it was immediately rejected as the estimated

TABLE 6.1
Example 6.2 Simulation Output

Simulation Value	Variable Name	Deterministic Value	Minimum Value	Mean Value	Maximum Value	5th Percentile Value	95th Percentile Value
Output 1	Production *N* rounded up to four trucks (cy/h)	225	180	227	288	192	269
Output 2	Production *N* rounded down to three trucks (cy/h)	182	130	195	265	164	245
Input 1	Loader load time (min)	0.4	0.3	0.4	0.5	0.3	0.5
Input 2	Travel time (min)	4.0	3.5	4.2	4.9	3.7	4.7
Input 3	Delay and dump time (min)	2.5	1.5	2.2	3.0	1.6	2.9

production of the 3-truck crew was substantially less than the 4-truck crew. To assist in making this decision, another function of the simulation output can be consulted. Probability distributions for the output variables can be drawn and manipulated to gain additional information about each alternative. Figure 6.8 is the distribution for the 3- and 4-truck crews.

Making the assumption that the project manager believes that the crew needs to have a minimum hourly production rate of at least the 225 cubic yards per hour that was selected in Example 5.3, one can enter Figure 6.8 and find that there is a 15% probability that three trucks will produce at least 225 cubic yards per hour. Thus, there is an 85% chance that on any given hour that production quota will be missed. Comparing this with the 4-truck crew, which has a probability of roughly 50% of meeting or exceeding the 225 cubic yards per hour production target. This gives the decision-maker a way to quantify the risk of using only three trucks on this job rather than the four trucks that would have been determined from the deterministic analysis.

6.4.2 Other Simulations

There are two main simulation strategies: "process interaction" and "activity scanning." A third approach called "event scheduling" is sometimes combined with process interaction [6]. Those software packages that utilize these simulation strategies generally require that their users be able to perform computer programming functions to input model characteristics and mathematics. These programs are very powerful and produce very specific information based on the quality of the input.

There are a number of these equipment simulations available in both the industry and the academia. STROBOSCOPE (an acronym for STate and ResOurce-Based Simulation of Construction ProcEsses) was designed specifically for the modeling of construction operations [7]. It is a simulation programming language based on the activity scanning simulation paradigm and activity cycle diagrams. CYCLONE is another general construction simulation program that is probably the oldest simulation program in use. CYCLONE is an activity

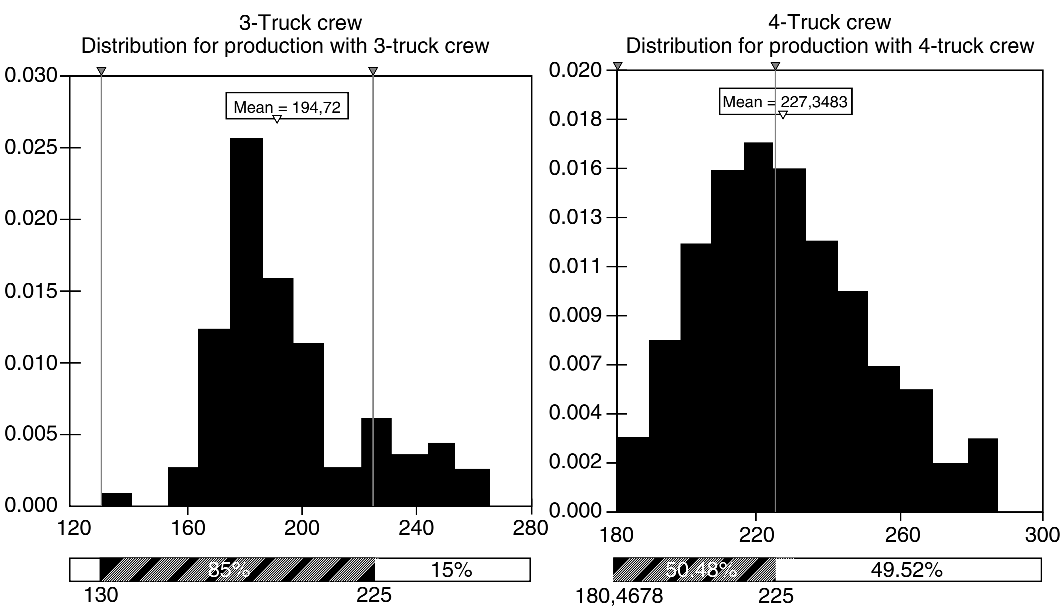

FIGURE 6.8 Probability distribution for 3-truck and 4-truck crews in Example 6.2.

scanning-based simulation where the activity cycle diagram is actually the simulation model itself and not just a plan for a simulation program. The reader is directed to an excellent paper by Martinez and Ioannou [6] that contains a detailed description of these two construction simulation packages and also compares and contrasts the attributes of each.

Another type of simulation program that is generally applicable to construction equipment simulations is based on "queuing theory." In French, the word "queue" means a line. Queuing theory deals with the formation and operation of lines. By using the fundamental laws of probability and statistics, the planner can model almost any system in which a line is formed by using queuing theory. The typical construction equipment project involves the loading and unloading of bulk materials like earth, sand, and gravel. The lines of equipment waiting to be loaded and unloaded are an integral part of the operational environment that makes queuing theory a valuable tool to estimate the system's productivity. The rate at which bulk construction material is transferred is the prime item of interest in optimal construction equipment analysis. The three basic components of a queuing system are:

1. The arrival of customers (haul units, trucks, scrapers)
2. The queue discipline
3. The service of customers (the productivity of the loading facility)

In some cases, these components are independent of each other, and in other cases they are not. For purposes of analysis and illustration, the components are assumed to be independent. Random arrivals and scheduled arrivals are the two primary types of arrival patterns. Scheduled arrivals include patterns in which some customers arrive early and others late. Random arrival patterns are assumed to conform to a Poisson distribution [8]. Both patterns use the mean arrival rate of customers as the salient parameter. This is normally described using customers per unit time as a dimension. It is generally possible to solve queuing problems that involve random arrivals. On the other hand, it is generally impossible to solve scheduled arrival problems by exact methods [9]. However, the computation can be simplified in case of a construction hauling system by assuming that the haul units will arrive one at a time and the time interval between arrivals will be a function of cycle time plus delays.

One simple software package available for this type of analysis is QUEUE.XLA [10]. This is a discreet event simulation and uses queuing theory to simulate the motion of customers through lines and predicts the estimated waiting times for different combinations of customer service facilities. In construction, the service facilities would be the piece of equipment responsible for loading another piece of equipment, which in turn would haul, dump, and return to enter the queue and be serviced once again. Thus, this type of simulation software would be useful to compare alternative hauling crew sizes to reach a point where the waiting time is minimized. This is important because when a piece of construction equipment, be it loader or hauler, if not productive, is costing money for the equipment and its operator to wait for its turn to become productive. General formulae for these answers shown below for single channel systems are as follows:

$$W_{\mathrm{q}} = \frac{\lambda}{\mu(\mu - \lambda)} \tag{6.3}$$

$$P_{\mathrm{o}} = 1 - \frac{\lambda}{\mu} \tag{6.4}$$

where W_{q} is the mean waiting time, P_{o} the probability that the facility is idle, λ the mean arrival rate (haul units/unit time), and μ the mean service rate (haul units/unit time).

Example 6.3 shows how the simulation software, based on this theory, operates on a typical construction problem. The deterministic method in the example will obviously need to be developed for input into the stochastic simulation in much the same way as the Monte Carlo simulation example of the previous section.

Example 6.3 A ready-mix concrete company is going to replace its fleet of mixer trucks and seeking to select the optimum number of trucks in relation to the service rate of its batch plant and the rate at which orders are received. The concrete batch plant loads mixer trucks with a maximum capacity of 12 cubic yards. Orders are filled on a first come, first served basis, and are received on a random basis throughout the day. Some orders are placed in advance (i.e., scheduled), but the time of day at which concrete is required on an advance order is sufficiently spread across the course of an average day that all orders can be assumed to be random and conform to a Poisson distribution. On an average day, the company will fill orders totaling 480 cubic yards of concrete with the average load of 9 cubic yards. The batch plant can discharge concrete into the mixer trucks at a rate of 2 cubic yards per min. The total ownership and operating cost of the batch plant including labor and overhead is \$1500/h. The same cost for the trucks is \$80/h. As the batch plant is the loading facility, this situation can be modeled as a single channel queuing problem with $N' = 1$.

$$\text{The arrival rate, } \lambda = \frac{480 \text{ cy/day}}{9 \text{ cy/load } (8\,\text{h/day})} = 6.67 \text{ loads/h or } 53.33 \text{ loads/day}$$

$$\text{The service rate, } \mu = \frac{2 \text{ cy/min } (60 \text{ min/h})}{9 \text{ cy/load}} = 13.3 \text{ loads/h}$$

From Equation 6.3,

$$W_\text{q} = \frac{6.67}{13.3(13.3 - 6.67)} = 0.08 \text{ h/load} = 4.8 \text{ min/load}$$

and from Equation 6.4,

$$P_\text{o} = 1 - \frac{6.67}{13.3} = 0.50$$

Average total daily waiting time for the fleet = 0.08 h/load (53.33 loads/day) = 4.26 h/day

$$\text{Average daily loading facility idle time} = 0.50(8) = 4 \text{ h/day}$$

At the optimum number of trucks:

$$\text{The cost of waiting trucks} = \text{cost of facility idle time [11]}$$

Therefore,

$$\text{Cost of waiting trucks} = 4.26 \text{ h/day } (\$80/\text{h})\ (N)$$

and

$$\text{Cost of idle facility} = 4 \text{ h/day } (\$1500/\text{h})(1)$$

Setting these equations equal to each other and solving for N, the optimum number of trucks is 17.6. Obviously, now a rounding decision must be made. If the number is rounded up to 18, each truck will load an average of three loads per day. It is easy to see how queuing simulations could then be developed into stochastic simulations to enhance the amount of information available to the equipment manager.

6.4.2.1 Developing Input

Input development for each of these other simulations will be specific to the software package itself. As a result, it is difficult to generalize the requirements in this discussion. Nevertheless, the estimator will need to come prepared with sufficient historical data on the possible operations that are to be modeled. As a minimum, the probable range of potential values for each variable and parameter in the model must be known to give the simulation program the ability to use realistic numbers. The old "Garbage In, Garbage Out" cliché is very applicable to the subject of equipment simulations.

6.4.2.2 Analyzing Output

Again the output will be specific to the program used. To analyze its meaning, the estimator should have a set of clearly written decision criteria that can be used to measure the relative success or failure of each alternative under analysis to satisfy the specific objectives of the simulation. Such criteria may look as follows:

- Minimize waiting time of haul units
- Maximize daily production rate
- Minimize unit costs

6.5 EXPECTED PRODUCTION

The whole purpose of a stochastic equipment production simulation is to compute expected production rates based on the constraints inherent to the project itself. The expected production output from these simulations is then utilized in two different ways. First, these rates are adjusted as required using the estimator's professional judgment and used to compute the unit costs of equipment-intensive tasks on the project for use in bid preparation. In this application, the simulation gives the estimator the ability to quantify the uncertainty associated with each possible alternative and allows a decision as what each crew will cost based on their ability to produce. Secondly, the expected production rates that are used in the estimate become project control metrics that the project manager can use in the field to manage the job and measure project progress.

6.5.1 Cost Estimating Factors

To develop the estimating factors from the simulation output, the estimator will take the following steps:

- Select the crew size and composition
- Select the expected production rate that flows from the crew size and composition
- Gather equipment ownership and operating costs data including labor rates for the given crew
- Apply those to the crew's expected production rate to arrive at an hourly crew cost
- Given the hourly crew costs and the quantity of work to be performed by the crew, develop a unit cost for each pay item that the crew will accomplish

This process will be illustrated by continuing with the haul crew developed in Example 6.2 with associated cost data.

Example 6.4 Calculate the unit cost for the crew given that the cost of the 4-truck haul crew is as follows:

Loader with operator = \$77.45/h
Truck with operator = \$83.75/h
Hourly crew cost = \$77.45 + 4(83.75) = \$412.45/h

From Table 6.1, the expected production = 227 cy/h

$$\text{Therefore, unit cost} = \frac{\$412.45/\text{h}}{227\ \text{cy/h}} = \$1.82/\text{cy}$$

It should be noted that this figure includes only the direct cost of labor and equipment and would then be marked up as appropriate to cover indirect costs, overhead, and profit, if applicable.

6.5.2 Production Management Factors

Production management factors are project control metrics that can be used in the field to make routine daily equipment management decisions and also to measure project progress. For the haul crew in the above example, the expected production rate was 227 cubic yards per hour. By definition, this rate must be understood as an average *sustained* production rate. Therefore, it serves as a basis to be expanded to a series of larger units of time to allow the project manager to measure the crew's actual productivity against its planned productivity and when the project is in progress to measure the minimum required productivity. The following is an example of how these are used.

Example 6.4 The project that the 4-truck haul crew will work on has a total of 175,000 cubic yards of aggregate to be hauled by the crew. The crew will work for a standard 40-h workweek. Calculate the daily and weekly minimum production rate based on the expected production rate from the simulation and determine how many weeks this project should last.

Expected daily production = 227 cy/h (8 h/day) = 1,816 cy/day
Expected weekly production = 227 cy/h (40 h/week) = 9,080 cy/week
Expected project duration = 175,000 cy/9,080 cy/week = 19.3 weeks

Given the above production factors, the project manager can now measure the actual production against planned production and use the comparison to make equipment management decisions. For instance, if actual daily production has been exceeding the expected daily production and one of the trucks breaks down, the project manager can look at the accumulated excess production and determine whether or not to schedule the haul crew to work overtime to make up for the loss of one truck for a given period of time.

6.6 VALIDATING SIMULATION MODELS

The final requirement in utilizing a simulation model is validating its accuracy and determining how close to reality it is actually coming. To do this a validation data collection plan must be developed, so that field personnel can obtain the necessary information that will allow the estimator to refine the model's assumptions and mathematical relationships. Each simulated project, based on the historical data, will be somewhat different from the projects from which the historical data was drawn. Thus, recalibrating the simulation model is essential to preserving its authority for future estimates. The validation process essentially consists of verifying the model's assumptions and fundamental input data and then a sensitivity analysis is conducted to identify those input parameters that have the greatest effect on the model's output.

6.6.1 Verifying Assumptions and Inputs

A good estimator always documents the assumptions that were used in the estimate. This rule applies to equipment-intensive project estimates as well as for other projects. Once the simulations have been run and the estimating factors have been determined, it is worthwhile to review the initial set of assumptions that were used to develop the model to ensure that they have not been unintentionally changed during the analysis. One good method for doing this is the use of a trial set of input values that correspond with the assumptions, which were checked and for which the estimator already knows the answer. These are fed into a fresh copy of the simulation, run through the model, and the output derived from this exercise is checked against the known values. If the answers are roughly the same, then the model development process did not unintentionally alter the initial set of assumptions.

The reader should remember that since most of the simulations use random values taken from the probability distribution of each variable, it is unlikely that the answers will be exactly the same as each simulation will use a somewhat different set of random values. If the output of the known sample does not match, then the estimator needs to thoroughly check the simulation model and identify where the error lies and correct it before moving on with the estimate using the simulation-derived factors.

The next check could be best described as the "reality check." Regardless of the level of experience that the estimator has in the construction industry, all the salient assumptions and input values for production rates, crew sizes, and other issues that will eventually drive the bid's bottom-line should be presented to another knowledgeable and experienced member of the organization to see if they seem realistic at face value. This individual should preferably be the one who will be responsible for eventually building the project for the amount of money that is bid for. Any changes or adjustments that come out of this process should be made, and then the final simulation can be run to produce the production-estimating factors.

6.6.2 Sensitivity Analysis

The type of sensitivity analysis that was described in Section 6.3.3 is also applicable to simulations as well. In essence, a sensitivity analysis is performed as the simulation is run with the software randomly selecting possible values from within the specified range of the probability distribution for each variable. Commercial simulation software packages like @Risk often conduct the sensitivity analysis in conjunction with the simulation and report the results in various forms in the simulation output. For Example 6.2 simulation, tornado diagrams were produced for both alternatives and the one for the 4-truck haul crew that was selected is shown in Figure 6.9.

Looking at this figure, it shows that the production rate of the crew is extremely sensitive to the time it takes for the loader to load a single bucket. The reader will remember that the range of possible times for the loader was 0.3 to 0.5 min per bucket (18 to 30 s). That is a very narrow range. Each truck will require six buckets to fill it before it can leave for to complete the haul. Thus, knowing this information, the project manager needs to set up the area in

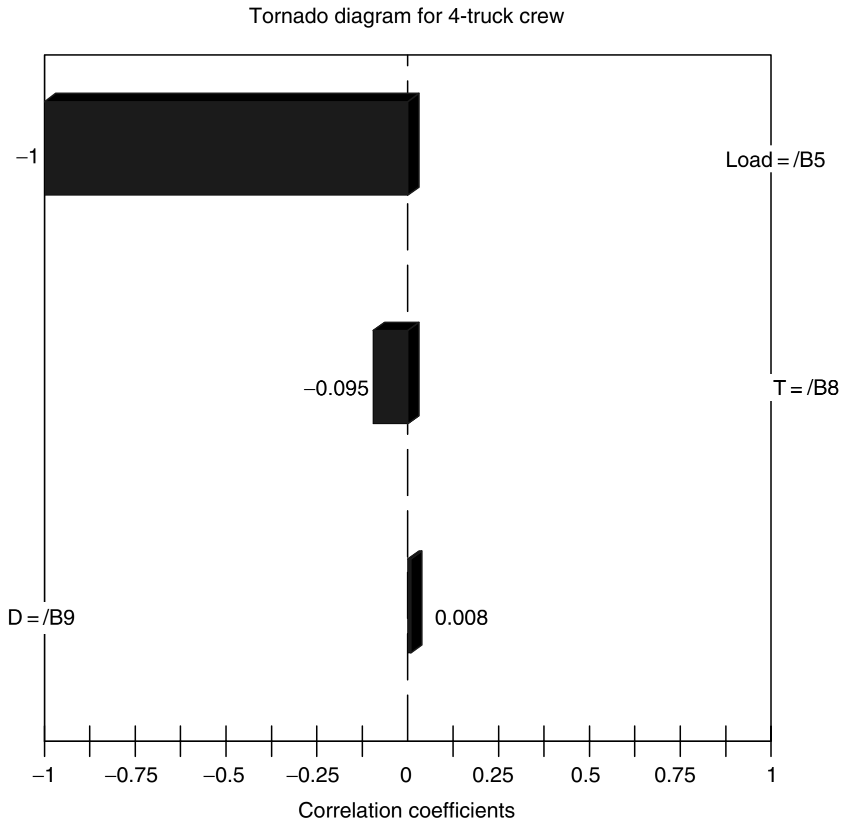

FIGURE 6.9 Tornado diagram for 4-truck haul crew sensitivity analysis.

which the loader will load the trucks in a fashion that will minimize if not eliminate any and all distractions to the loader operator. Other managers who will be on the project will need to be told to leave the loader alone and not ask for it to be pulled off the material haul for short periods of time to accomplish other minor tasks. Indeed, the success of this particular work item is dependent on the loader's ability to maintain the cycle time that is going into the estimate. In fact, due to the model's extreme sensitivity to this one variable, the range of values should probably be physically checked in the field if possible, and hopefully before the bid is submitted.

This example furnishes an excellent illustration of how much additional valuable information can be derived at a very little cost from a simple Monte Carlo simulation. When equipment simulations first came on the scene in the days of the mainframe computer, they were merely an interesting academic exercise that took too long and added cost without adding value to the estimator on an equipment-intensive project. However, with the advent of powerful personal computers combined with commercial simulation software packages that work hand-in-hand with most common spreadsheet programs, they have become a mechanism for quantifying the uncertainty that is inherent to the estimating and bidding process. Simulation can give information to the estimator and the project manager that cannot be determined through simple deterministic spreadsheet calculations. Their greatest benefit is in their ability to more closely model the reality of a construction project where not every cycle is equal to or less than the cycle time used in the bid. By allowing experienced construction management professionals to see things in a different quantitative fashion, simulations allow those persons to temper their professional judgment with hard facts and numbers, creating a means to better manage the risks inherent to any equipment-intensive project. This factor alone argues for their increased use throughout the industry.

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7 Scheduling Equipment-Intensive Horizontal Construction Projects

7.1 INTRODUCTION

Projects that require large numbers of machines present their own challenges to construction schedulers. Activities such as preventive maintenance, standby vehicles, and multiple shift operation require special knowledge to integrate into the normal project schedule. Most, if not all, construction projects have contractual completion dates that if missed, significantly alter the financial profitability of the project through either liquidated damages or late-completion penalties. Even in the absence of these, it hurts the contractor's overall profitability because keeping equipment committed to a given project longer than originally planned prevents it from working on other projects where it could have earned the company additional profit in that fiscal year. Thus, understanding the scheduling dynamics of an equipment-intensive project is the key to achieving target profit margins for the equipment's owner.

From a scheduling point of view, equipment-intensive projects are defined as those projects where the production of the equipment is significantly more important than the production of the labor. For instance, a highway construction project may have 30 employees working on it each day in a variety of trades. However, the great majority of those people will be operating pieces of construction machinery with only a few people assigned jobs as common laborers using hand tools. Conversely, labor-intensive projects typically have few pieces of equipment that are used for localized tasks and the majority of the workers are in trades that require hand tools like cement finishers, carpenters, and common laborers. Thus, the scheduler of an equipment-intensive project is primarily concerned with managing the work site in a manner that eliminates conflicts between the equipment, whereas the scheduler of a labor-intensive project is primarily concerned with managing the work site in a manner that eliminates conflicts between the trades. The scheduler of an equipment-intensive project establishes the durations of each activity in the schedule based on shift length and equipment package production rates, and the scheduler of a labor-intensive project establishes the durations of each activity in the schedule based on shift length and trade crew production rates.

In each case, the scheduler's task is to devise a sequence of work that permits the project to be finished before its contract completion date. However, in the equipment-intensive project, the scheduler typically is dealing with large quantities of materials that must be moved, processed, and installed and a minor error in the assumed production rate of a given equipment package can be translated into a major time or cost problem. As a result, scheduling an equipment-intensive project requires an in-depth understanding of how production rates of interdependent equipment packages impact the schedule.

7.2 BACKGROUND

At this point, the reader should note that the following is a brief description of the mechanics of schedule development and is intended as a "refresher" for a reader who has knowledge of the subject that may have not been used for a period of time. It is not intended to be a comprehensive review of scheduling methods. If the reader needs further detail on this subject, the references listed at the end of this chapter should be consulted [1–4].

There are two different methods that are used to mathematically model the construction schedule and deconflict the schedule for simultaneous activities, which in turn produces a schedule that reasonably estimates whether or not the project can be completed in the allotted time. The first method is called critical path method (CPM). The two different CPM models are activity-on-arrow (AOA) and activity-on-node (AON) [1]. Figure 7.1 shows notional concepts of each CPM model. AOA only permits a relationship between activities (called a precedence relationship) where one activity must finish before subsequent activities can start (called a finish-to-start (FS) relationship). As a result, it is very cumbersome when modeling large projects with thousands of activities. AON on the other hand allows four different precedent relationships to be modeled, which are shown in Figure 7.2:

1. Finish-to-Start (FS): The preceding activity must finish before subsequent activities can start.
2. Start-to-Start (SS): The preceding activity must start before subsequent activities can start.
3. Finish-to-Finish (FF): The preceding activity must finish before subsequent activities can finish.
4. Start-to-Finish (SF): The preceding activity must start before subsequent activities can finish.

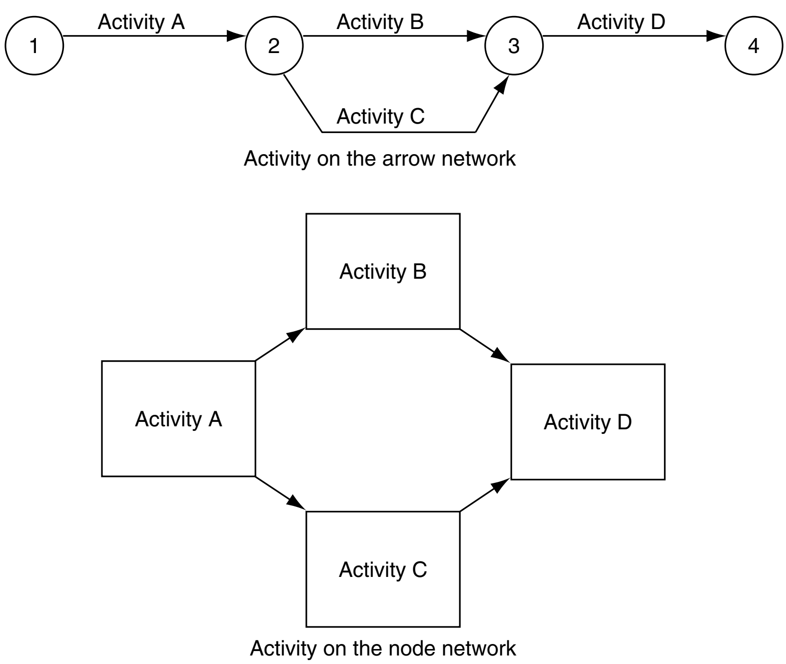

FIGURE 7.1 Notional concepts of the AOA and AON networking methods.

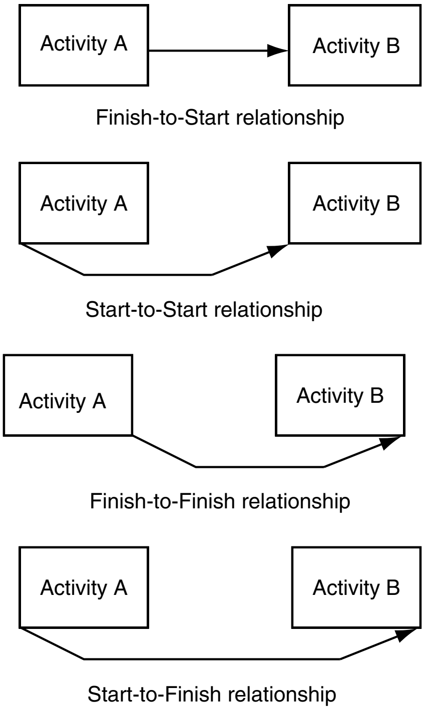

FIGURE 7.2 PDM precedence relationships.

The AON method has been adopted by most current commercial computer scheduling packages. So this book will devote the next section to briefly describe the AON network as described as the precedence diagramming method (PDM). CPM's primary goal is to identify the sequence of work that is most critical to completing the project on time and it is called as the "critical path." All other related work sequences have float or slack time in their path, and thus the scheduler can concentrate on managing the work sequences that are critical.

The second common scheduling technique is called linear scheduling (LS). LS is production based rather than activity based like PDM. Although some writers have described ways to determine the critical path of a linear schedule, its primary goal is to maximize the production of all equipment resource packages (more commonly called "crews") by ensuring that one activity's production rate does not unintentionally control the production of another one. This is done using a graphical approach rather than the networking approach used in CPM. The graph has two axes: time is on the y-axis and location is on the x-axis. Thus, LS not only tracks the project in time but also ensures that there are no conflicts between crews on the actual ground. Section 7.4 explains how this is accomplished.

The remainder of this chapter will briefly describe the internal algorithms of each scheduling method and then show how LS can be used to plan the work sequence for the major features of work and then converted to a PDM schedule where all other activities can be added in a comprehensive schedule for the entire project.

7.3 PRECEDENCE DIAGRAMMING METHOD

PDM is nothing more than AON with a few extra rules to provide continuity in the process of developing a logic diagram. This diagram takes the form of a network that logically lays out the sequence of work based on the technical constraints that define the precedence relationships between all the activities that make up the project. A precedence relationship is a technical constraint that describes the relationships between either the start or finish of the activity in question and all other activities in the project that are related to it.

For example, in a typical equipment-intensive utility project, the contractor must dig the utility trench before utility line can be installed, and the utility line must be installed before the trench can be backfilled. Thus, the project can be described as three linear activities where one must be completed before the next can start using FS relationships. The activities have the following durations:

- Trenching: 3 days
- Installation: 5 days
- Backfill: 2 days

With this information, the precedence diagram shown in the upper portion of Figure 7.3 can be drawn. The reader should also note the convention illustrated in this figure for displaying the early and late event times on the network. Adding the cumulative durations, the scheduler can see that this project will take 10 working days.

Obviously, this is a conservative schedule as it assumes that no activity can start before the preceding one is completed. This is not necessarily true in this case. After discussions with the field superintendent, the scheduler finds out that installation of the utility line can actually begin after 1 day's worth of trench has been dug, and that the backfilling can begin 3 days after the installation has started. Installation still cannot finish until the trenching is completed and the same finish relationship holds true between installation and backfilling. Thus, the scheduler can revise the schedule as shown in the lower part of Figure 7.3 and sequence the activities in parallel. In other words, the diagram now shows that on the second day of the project both the trenching and installation crews will be working. The scheduler does this by using SS and FF relationships and showing the delay between the start of trenching and the start of installation by the small box on that arrow with a number showing how many days of "lag" exists on that path. In other words, the start relationship between the two activities can now be articulated as follows: Installation cannot start until 1 day *after* trenching starts. Thus, this is a SS relationship with 1 day of lag.

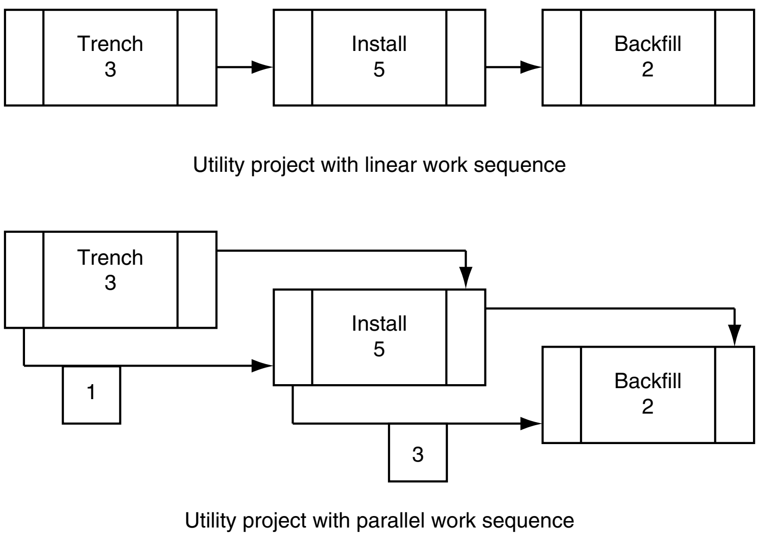

FIGURE 7.3 PDM for linear and parallel work sequences.

7.3.1 Determining the Critical Path

To determine how long a project will take, a series of calculations must be made on the PDM network. There are three discreet sets of calculations as follows:

- *Forward pass calculation*: This process determines the early event times (the earliest activity can begin and end) for the project.
- *Backward pass calculation*: This process determines the late event times (the latest activity can begin and end) for the project.
- *Determination of float*: Float is the amount of time an activity can start after its early start time without creating a delay for the entire project.

These calculations are best described through the use of an example. The two networks shown in Figure 7.3 will furnish the input for this example.

7.3.1.1 Forward Pass Calculation

Looking first at the network describing the linear work sequence, one can conduct the forward pass calculations using the following formulas:

$$\mathrm{EF} = \mathrm{ES} + d \tag{7.1}$$

where EF is the early finish time, ES the early start time, and d the duration of the activity and

$$\mathrm{ES(succeeding\ activity)} = \mathrm{EF(preceding\ activity)} \tag{7.2}$$

Thus, looking at the first activity "trench" with its duration of 3 days, its ES would be 0, then

$$\mathrm{EF_{Trench}} = 0 + 3 = 3 \text{ days}$$

Moving on to the next activity, "install," it cannot start until "trench" is finished so the ES for "install" (the succeeding activity) would equal the EF of "trench" (the preceding activity) or 3 days. Next adding its 5-day duration to its ES, we get

$$\mathrm{EF_{Install}} = 3 + 5 = 8 \text{ days}$$

Using the same calculation, we can then calculate the EF of "backfill" to be 10 days, and this concludes the forward pass for this network. The results are displayed in Figure 7.4 for both networks. Finally, if more than one arrow leads into a start of an activity from two or more preceding activities, the highest of the EF values of the preceding activities should be selected as ES for the activity in question.

Next, one can see that the parallel work sequence allows the contractor to complete the project 4 days earlier than the linear work sequence.

7.3.1.2 Backward Pass Calculation

Next the late event times need to be calculated using the backward pass that is based on the following equations:

$$\mathrm{LS} = \mathrm{LF} - d \tag{7.3}$$

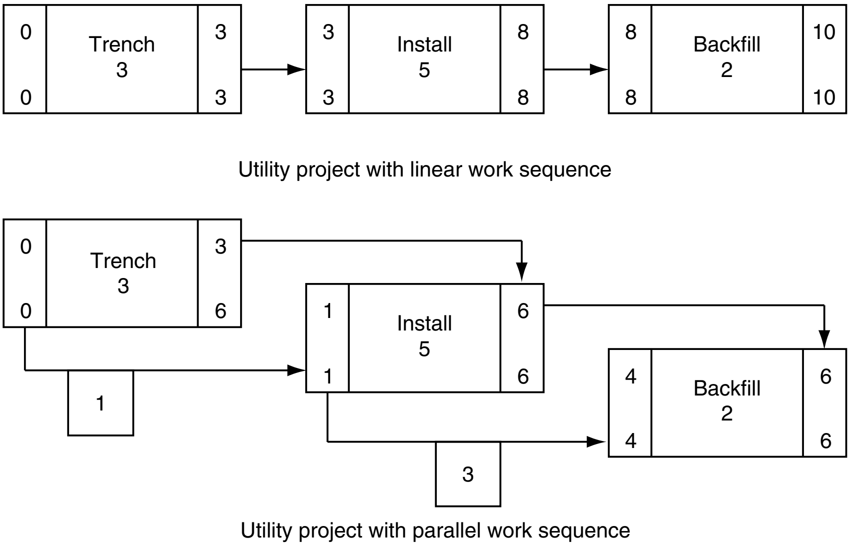

FIGURE 7.4 PDM forward and backward pass calculations.

where LS is the late start time, LF the late finish time, and *d* the duration of the activity and

$$\text{LF(preceding activity)} = \text{LS(succeeding activity)} \quad \text{if FS} \tag{7.4a}$$

or

$$\text{LF(preceding activity)} = \text{LF(succeeding activity)} \quad \text{if FF} \tag{7.4b}$$

If both FS and FF exist, then

$$\text{LF(preceding activity)} = \text{the lowest value of all relationships} \tag{7.4c}$$

As the linear work sequence network contains only FS relationships and there is only one path through the network from beginning to end, the late event times found in the backward pass calculation are equal to the early event times for every activity. Therefore, the backward pass will be illustrated using the parallel work sequence network shown in Figure 7.4. Starting with the last activity "backfill" and assuming that the project must be completed as quickly as possible, the LF will equal the EF or 6. We then execute the calculations shown in Table 7.1 and can arrive at the late event times for each activity.

With the early and late event times calculated, the scheduler can now calculate the float for the two networks.

7.3.1.3 Calculating Float

In PDM, there are three types of float and the equations for calculating each are as follows:

- Start Float (SF): Float associated with an activity's start

$$\text{SF} = \text{EF} - \text{ES} \tag{7.5}$$

TABLE 7.1
Backward Pass Calculations

Act	Duration (days)	LF	Calculation	LS
Backfill	2	6	LS = 6 − 2	4
Install	5	LF(backfill) = 6	LS = 6 − 5 = 1	
		or	LS = LS(backfill) − lag	1
			= 4 − 3 = 1	
Trench	3	LF(install) = 6	LS = 6 − 3 = 3	
		or	LS = LS(install) − lag	Select the smaller of 3 or 0
			= 1 − 1 = 0	Therefore LS = 0

- Finish Float (FnF): Float associated with an activity's finish

$$\text{FnF} = \text{LF} - \text{LS} \tag{7.6}$$

- Total Float (TF): Float associated with the path in which an activity falls

$$\text{TF} = \text{LF} - \text{ES} - d \tag{7.7}$$

It is possible for an activity to have zero SF or FF and still have a quantity of TF. This means quite literally that only the start or finish of that activity has no float but the path (sequence of work) in which it falls has float. The scheduler must calculate the float for every path in the network to determine the critical path. The critical path is the longest path through the network and is determined by the sequence of activities in which the float is zero. Table 7.2 is the matrix associated with the parallel work sequence shown in Figure 7.4 with the associated float calculations completed.

Looking at the float in the network, one can see that everything except the finish of "trench" has no float and is therefore critical. Table 7.2 shows us that we must start "trench" on its early start date but could actually finish it 3 days late and still be able to finish the project by the end of Day 6. However, this is not the case with the other two activities, which must start and finish on their early dates. Any increase in their actual durations will cause the project to finish later than the end of Day 6. Thus, it is important to ensure that those two activities are assigned sufficient resources to ensure their timely start and completion. This then leads to the discussion of critical resource identification.

7.3.2 Critical Resource Identification

It is imperative that the project manager knows which resources assigned to the project can directly impact on the project's timely completion. It is also essential that the estimator who bids the job has a pretty good idea as to which resources will become critical.

There are two common ways to identify critical resources. The first is to look at the float available in each activity in the schedule and declare that the resources associated with each critical activity automatically become critical resources. Thus, in the above example, if the "install" activity required a backhoe, a pipe truck, and an air compressor plus the workers to operate them, these machines with their operators and any other associated labor would

TABLE 7.2
Float Calculations for Parallel Work Sequence

Activity	Duration (days)	ES	EF	LS	LF	SF	FnF	TF
Trench	3	0	3	0	6	0	3	3
Install	5	1	6	1	6	0	0	0
Backfill	2	4	6	4	6	0	0	0

be coded as critical resources. Measures would then be taken to ensure that these resources would be assigned to the critical activities as prescribed by the schedule before allowing them to be used on other less critical tasks. This is a good project control technique and highlights the connection between the estimated time of performance and the labor and equipment costs outlined in the cost estimate because it links crews to the production activities on which they will be used.

The second method takes a less theoretical and more pragmatic approach to this issue. It recognizes that the schedule is just an estimate of the time it will take to complete the project and sees the activity durations as targets rather than absolute values. The durations are a function of the production rates that the estimator applied to each crew and can be changed by adding or subtracting resources as required to meet the activity completion targets (also referred to as ‘‘milestones’’). Thus, it looks at the project manager’s ability to acquire more equipment and labor on short notice to differentiate between critical and noncritical resources. This method then defines a critical resource as one that physically or technically cannot be increased within a specific period of time and then seeks to ‘‘hand-manage’’ all critical resources, letting the noncritical ones rise and fall based on the needs of the project. The best example of a critical resource in this approach is a tower crane on a building project. Typically, the project will erect one tower crane to service the project from the beginning to the end. Thus, the scheduler must ensure that if there is only a single crane on a given project that no two activities that require the crane are scheduled to happen at the same time. Often, this will put activities that require the critical resource on the critical path because they must be scheduled in series as they cannot be scheduled in parallel.

The major advantage to the second approach is that it greatly reduces the number of critical resources that must be managed during project execution. This allows the project manager to maintain a keen focus on those resources that greatly affect the actual duration of the project. The danger that comes from selecting this approach over the first one is that it tends to uncouple the equipment resource package assumptions and their planned production rates that were made during the estimate from the actual execution of the project by allowing the project manager to increase the allocation of noncritical resources to accommodate the short-term needs of the project. If this is done with great discipline, its attendant increase in actual cost can be controlled. However, one must be careful not to give in to the temptation to retain the larger size equipment resource package as insurance against unknown future delays. Thus, to mitigate the risk that the actual cost of production will exceed the estimated cost, the scheduler needs to resource load the schedule.

7.3.3 Resource Loading the Schedule

Resource-loaded schedules are typically done using commercial construction scheduling software [4]. They can be quite arcane and complicated. The aim of resource loading is to ensure that the schedule is indeed realistic within the constraints of the available resources and their associated production rates. The purpose of this section is not to ''teach'' the reader the mathematical mechanics of resource-loaded schedules. It is rather to highlight the benefits that can be achieved by utilizing this powerful project control tool, and show through a simple example how this technique can be used to increase the accuracy of the estimate for an equipment-intensive project.

Resource loading has two objectives:

- To permit the accumulation of resource requirement data across the life of the project, which then permits the project manager to plan the hiring of labor and the acquisition of equipment for the project
- To ensure that the durations for those resources that have been designated as critical are realistic for the production rates that can reasonably be achieved by the given crew

Resource loading is accomplished by filling out a ''resource dictionary'' [4] in the software package that is used by the scheduler. This task essentially consists of identifying the equipment and labor requirements need for each crew and then associating them with the activities to which they will be assigned. The software then produces a histogram for each individual trade and specific piece of the equipment, which then allows the project manager to procure these resources, as they are needed in the project. The following is a simple example of happenings inside the software when a project's schedule is resource loaded using the information present in Table 7.3.

Figure 7.5 shows the resource histograms for the backhoe requirements of the two potential work sequences shown in the example of Figure 7.4. One can see by choosing a schedule to complete each activity before starting the next activity, the project can be completed with only one backhoe at a cost of 10 days worth of backhoe rental. However, if the parallel work sequence is selected the project will need two backhoes on Days 2, 3, 5, and 6. Because the second backhoe will be idle on Day 4, the estimator will need to include 11 days of backhoe cost to the estimate unless the project manager has the flexibility to return the backhoe for 1 day to the rental company or use it on another project. This simple example shows how important it is to plan the details of the construction equipment utilization during the bidding process to ensure that the final cost estimate reflects the actual work sequence that will be used on the job, which quite naturally leads to the discussion of cost loading the schedule.

7.3.4 Cost Loading the Schedule

Cost-loaded schedules are commonplace in the commercial building construction industry. The American Institute of Architects standard contract between the owner and the general

TABLE 7.3
Resource Requirements for Utility Project

Act	Duration (days)	Backhoe	Pipe Truck	Air Compressor	Tamping Machine	Operator	Laborer
Trench	3	1				1	1
Install	5	1	1	1		1	5
Backfill	2	1			1	1	2

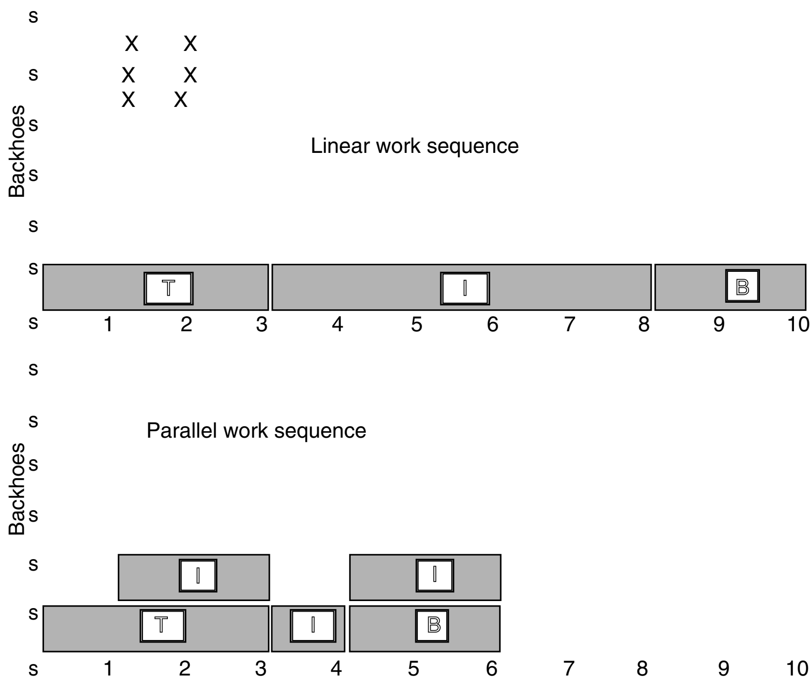

FIGURE 7.5 Resource histogram for utility project options.

contractor [5] contains a provision requiring the submission of a "schedule of values" against which the contractor will be paid for satisfactory progress during each pay period. To do so, this requires the estimator to accumulate all the direct costs associated with each feature of the work that is listed in the project schedule of values, assign indirect costs and profit margins, and furnish a lump sum value for each feature of the work. After this, the owner would pay a portion of that lump sum commensurate with the item's current completion percentage. In other words, if a work item has a value of $100,000 and is 50% complete, then the owner would pay $50,000 less any retainage that might be appropriate.

Many, if not most, equipment-intensive projects utilize unit price rather than lump sum contracts [5]. Thus, the unit price for each pay item reflects its individual cost and markups. Some unit price contracts have hundreds of individual pay items, making them difficult to use the pay items themselves as a cost control measure during construction as it is extremely complicated to relate them directly to an activity-based schedule. Thus, the estimator must roll up the various pay items and precisely synchronize them with the work described for each activity in the schedule. This creates a schedule of values for the project and the necessary input to allow the project manager to cost load the schedule. Table 7.4 shows the costs associated with the example utility project.

Figure 7.6 shows the utility project parallel work sequence schedule as a cost-loaded bar chart. One can see that when displayed in this manner, it shows the expected cash flow for the life of the project. This is sometimes called "earned value" because once the contractor has completed an activity, the activity's value has been "earned" or in other words, the contractor can apply for the payment for that activity. For instance, by the end of Day 3, the contractor would have expected to earn $96,000 because activity "trench" would be completed and 2 days worth of "install pipe" would also have been finished. Cost-loaded

TABLE 7.4
Cost Loading Input for Utility Project

Activity	Duration (days)	Cost ($)	Daily Cost ($/day)
Trench	3	36,000	12,000
Install	5	150,000	30,000
Backfill	2	28,000	14,000

Note: The above costs were contrived for example purposes only and do not reflect any attempt to achieve realism.

schedules allow one to track the financial completion of the project along with its physical completion.

Figure 7.7 shows the daily cost histogram and the cumulative cost curve for the project. These two graphics can be very useful project control measures. Looking at this at a more global level than shown by this extremely simple example, in order to finish as planned a project must be properly financed, and inadequate cash flow is one of the major causes of contractor bankruptcy [5]. Thus, taking the project plan consisting of the estimate and the schedule and reducing it to the visual form illustrated in Figure 7.7 can give the project manager a very powerful tool to develop the project's finance plan.

For instance, if the example utility project could only receive $35,000 per day of financing, the daily cost histogram shows that there are 4 days where this plan will exceed that limit and therefore, even though there seems to be no technical reason why the project cannot be finished in 6 days, the financial constraints will make it impossible. This would force the project manager to seek a different schedule that fits the financial constraint just described.

To briefly summarize, the PDM of scheduling is an activity-based methodology that permits the scheduling of equipment-intensive projects. Its output can be structured to furnish powerful project control tools that are useful in executing the project plan in a manner that fits both cost and time constraints. The major assumption that the estimator must make in using this method is that the durations derived from the production rates for the crews associated with each activity will not be hindered or conflicted by the work going in other parallel activities. This is because this scheduling method has no inherent algorithmic mechanism to manage both space and time simultaneously. Thus, the danger in the field

	Day	1	2	3	4	5	6
Activity	duration (day)						
Trench	3	12K	12K	12K			
Install pipe	5		30K	30K	30K	30K	30K
Backfill	2					14K	14K
Daily cost		12K	42K	42K	30K	34K	34K
Cumulative cost		12K	54K	96K	126K	170K	214K

FIGURE 7.6 Cost-loaded bar chart for utility project.

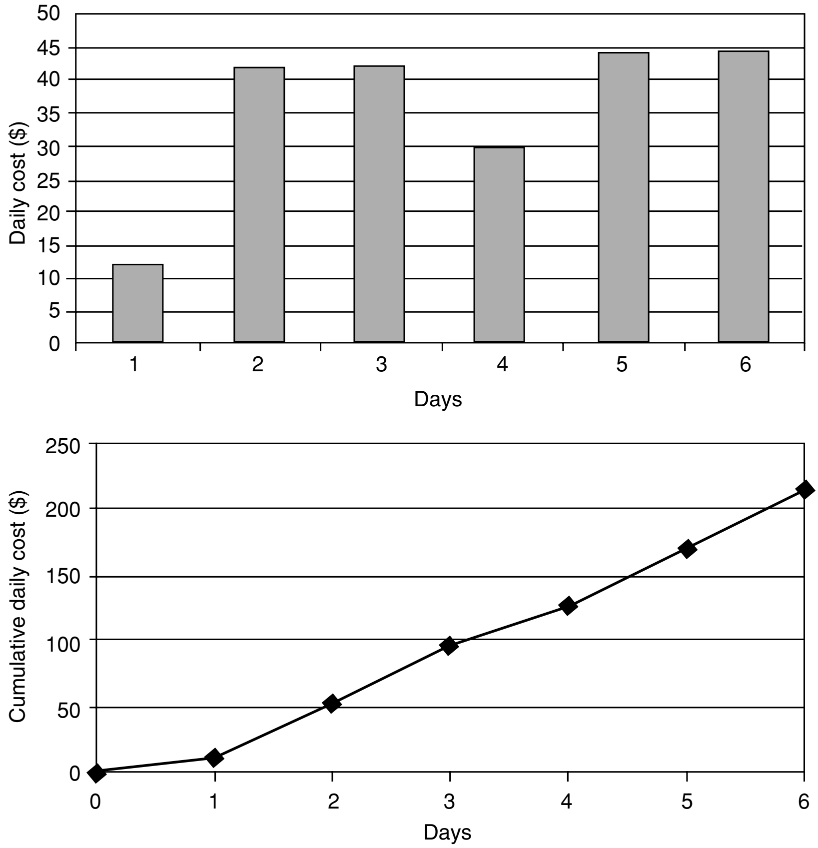

FIGURE 7.7 Daily cost histogram and cumulative daily cost curve for utility project.

is that two sets of equipments and their crews will converge on the ground and need to use the same space in order to maintain their target production rates. When this happens, one process will inevitably delay the other until the space conflict is over. While these disruptions occur on a labor-intensive project, the cost is not nearly as high to have a crew of painters wait for half-a-day for the drywall crew to finish than it is for a paving train to wait half-a-day for the base on which they will pave to be completed. Thus, it is very important to develop equipment-intensive schedules with this issue in mind. Fortunately, a scheduling method exists that can manage both time and space in a single stroke, and it is called linear scheduling (LS).

7.4 LINEAR SCHEDULING METHOD

Linear schedules graphically represent both time and space on the same chart and thus allow the scheduler to ensure that two crews are not in conflict with each other. Additionally, instead of time based, they are production based and allow the scheduler to precisely synchronize the schedule to the production assumptions that were used in the estimate, providing a seamless transition from project planning to project execution. Thus the purpose of this section will be to provide the reader with a simple overview of this technique. Once again, the reader can consult the references listed at the end of the chapter for a detailed explanations of LS. A great synopsis on LS was published in the notes that accompany a training course for the personnel of Peter Kiewit & Sons Inc., a large and heavy-civil construction company. It is shown as follows:

> Linear schedules are simple charts that show both when and where a given work activity will take place. Because they put time and space together on one chart, linear schedules allow us to see how the pieces of the project fit together. Enhanced with color, varying shades, or patterns they also communicate types of work and crew movement. This is something neither bar charts nor CPM schedules can do . . . [6].

To track both time and space, the LS method utilizes a standard graph where location is on the *x*-axis and time is on the *y*-axis. Thus, it is best used on linear projects such as highways, pipelines, and railways. Figure 7.8 shows the concept for a road project that is 1000 ft (10 stations) long. In this example, there are three activities:

1. Subgrade preparation
2. Install stabilized base
3. Place asphalt pavement

In this figure, the contractor has decided to start in the east end of the project (STA 10+00) where he has an area to store his equipment and then work on the westbound lane toward the west (STA 0+00), completing the subgrade preparation and the stabilized base. The contractor will then perform the same activities on the eastbound lane working back to the east end (STA 10+00). Because the asphalt batch plant is located west of the project, the contractor will reverse the work process and pave from west to east and back. Figure 7.8

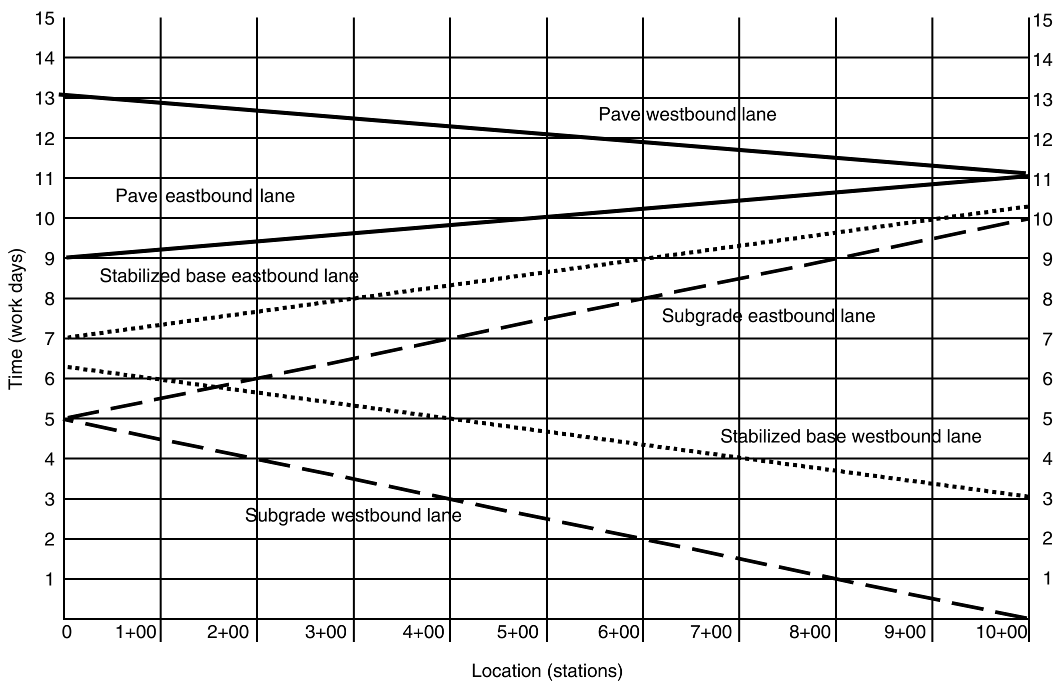

FIGURE 7.8 Example linear schedule for rural highway rehabilitation project.

shows the final schedule for this project. The steps used to arrive at this will be explained in the upcoming sections of this chapter. This scenario was selected to demonstrate the flexibility inherent in LS.

LS is best used in the planning process of the project [6]. While it is possible to display every single feature of work on the chart, it is often not valuable to do so. Thus, most practitioners who use this technique use it to plan the ''big items of work'' and then convert the result to a PDM network, adding the remainder of the project's less important activities at that stage. This approach has three advantages. First, it allows the scheduler to utilize the estimator's cardinal production rates for the major features of construction to ensure that those items that are critical to project profitability are scheduled in a manner where the planned production rates can be realistically achieved. Next, it creates a focus on those activities that will generate the majority of the cash flow and keeps them from becoming lost in the minutiae of the complete construction schedule for a major project. It does this by forcing the scheduler to ''plug'' the minor items of work into the schedule around the major items and prevents them from unintentionally controlling the overall pace of construction as could happen when PDM is used alone. Finally, as many owners require the use of a construction schedule configured in a specified commercial PDM-based scheduling software package, converting the linear schedule for the major items of work to PDM and then inserting the remaining project activities also helps ensuring that the schedule still used for making progress payments conforms to the project's original plan as reflected by the cost estimate and bidding documents.

7.4.1 Identifying Production-Driven Activities

Production-driven activities are those activities whose estimated production rate must be met or exceeded for the project to finish on time and achieve its target profit margin. Typically, these consist of activities where the lion's share of the cost lies and along whose path the critical path belongs. For instance, a typical rural highway project may include earthwork, base, paving, signage, striping, drainage structures like culverts and curb, and gutter, as well as miscellaneous items like driveways, moving and resetting post boxes, etc.

From that list, it is easy to see that those features of work that are directly associated with the roadway itself are the major cost items. In this case, it would be earthwork, base, and paving. However, in those areas where the culverts cross the road, they will need to be installed before the final earthwork, base, and paving can be placed over them. Thus, from this list, we have the following four production-driven activities:

- Earthwork
- Base
- Paving
- Culverts

The remainder of the work can be scheduled as required in a manner that will not interfere with the production-driven activities. Additionally, depending on the project site, it may be possible to construct the culverts at the same time as roadway activities are underway as long as the culverts are completed before the other crews physically reach the locations of the culverts. Thus, the initial focus of the linear schedule will be to deconflict the space between the culvert construction crews and the other three roadway construction crews in a manner that permits all the four crews to achieve the production rates assumed in the project estimate. Once the production-driven activities are identified, their requisite production rates can be calculated.

7.4.2 Establishing Production Rates

As discussed in Chapter 5, there are two forms in which production can be expressed:

- *Instantaneous production*: The production rate of a single cycle
- *Sustained production*: The average rate of multiple cycles over a protracted period of time

To this list, the required production rate should be added. This particular rate has little to do with the numbers or sizes of equipment in the resource package. It is project-dependent and is the number of units of work that must be accomplished divided by the duration of time the contract allows for that work to be completed. It can be expressed by the following equation:

$$P_r = \frac{M}{\text{CT}} \tag{7.8}$$

where P_r is the required daily production rate (units per day), M the total units that need to be processed or moved (units), and CT the contract time allowed (days).

This is the starting point for the production rate calculations that are made in conjunction with the development of the linear schedule. The idea is to ensure that adequate resources can be allocated to each crew to ensure that the project's contractual requirements are met. This is best explained by the following example.

Example 7.1 A project involves hauling 100,000 cy of aggregate to a stockpile at an asphalt batch plant. The contract allows 10 working days to build the stockpile. Using the 18-cy dump truck and the production rate of 360 cy/h shown in Example 5.3, calculate how many trucks will be required to ensure that the project will be completed on time.

$$P_r = \frac{100{,}000\ \text{cy}}{10\ \text{days}} = 10{,}000\ \text{cy/day}$$

$$N_r = \frac{10{,}000\ \text{cy/day}}{360\ \text{cy/h}(8\ \text{h/day})} = 3.5 = 4\ \text{trucks}$$

Thus, one can understand from the above example that irrespective of the equipment selected, the crew must have a minimum sustained production rate of at least 10,000 cy/day. Thus, all the crews are assembled and optimized with the required production rate for each in mind.

In order to utilize the LS method, the estimator/scheduler must convert the standard rates of production that are in material units over time to time over units of space. In Figure 7.8, the unit of space was stations (STA). (By way of review, 1 station equals 100 linear feet.) Therefore, all the crews must have their production rates converted to the unit days per station to be able to put into the linear schedule. Again, this can easily be illustrated by the following example.

Example 7.2 For the project in Figure 7.8, the subgrade preparation work involves scarifying, compacting, and shaping the existing subgrade to grade. The road will consist of two 12-ft lanes and a 4-ft shoulder on each side. The project is 10 stations long. The crew for this feature of work has a sustained production rate of 356 sy/day. Determine the production rate in days per station for the activity. The contractor will do one lane plus its shoulder at a time.

$$\text{Roadbed width} = 1\ \text{lane}(12\ \text{ft}) + 1\ \text{shoulder}(4\ \text{ft}) = 16\ \text{ft}$$

$$\text{Area/station} = \frac{16\ \text{ft}(100\ \text{ft/STA})}{9\ \text{sf/sy}} = 177.8\ \text{sy/STA}$$

$$P_s = \frac{177.8\ \text{sy/STA}}{356\ \text{sy/day}} = 0.5\ \text{days/STA/lane}$$

$$\text{Total time} = (0.5\ \text{days/STA/lane})(10\ \text{STA})(2\ \text{lanes}) = 10\ \text{days}$$

Looking at the slopes of the lines shown in Figure 7.8, one can see that the crew assigned to installing the stabilized base has a production rate of 0.33 days per station and the paving crew has a production rate of 0.2 days per station.

7.4.3 Lines, Bars, and Blocks

Linear schedules consist of the following elements:

- *Lines*: Lines are used to represent activities that are in continuous movement. The line literally tracks the progress of the crew in time across the project site. The slope of the line represents the crew's production rate. As the line's slope increases, the crew's production rate decreases. Thus, a fairly flat slope indicates a very fast production rate. Figure 7.8 shows three activities that are all represented by lines.
- *Bars*: A vertical line that indicates a crew working in a single location for a long period of time is called a bar. Often bars are used to represent a series of interrelated activities. In PDM, this would be termed as a "hammock activity" [4]. For instance, the construction of a culvert at a particular station would involve a number of separate activities including preparing the pipe's bed, laying the pipe, construction of headwalls, etc. A single bar covering all the activities involved in the culvert for the entire period of its construction can be used on the linear schedule.
- *Blocks*: A block is typically a rectangle that literally "blocks" out an area of the project for a specified period of time. These are used when an activity, like grading, will move back and forth over a specific area rather than through it from one end to the other (a line). Blocks are used if the activity will occupy the space for a relatively long period of time. Thus, other activities shown as lines cannot progress through the block until its duration is completed.

Once again this process is best explained to the reader through an example problem for this type of schedule.

Example 7.3 A small highway rehabilitation project is awarded and the contractor decides to use LS to plan the construction sequence and make sure that none of the crews conflict with each other or the other constraints imposed on the project. The project description is as follows:

- Mobilization will occur between STA 9+00 and STA 10+00. It will take 2 days.
- The first task is to demolish 1900 LF of existing pavement, which has a sustained production rate of 300 LF/day.

- After the pavement is demolished, the next activity is to install cement-treated subbase (CTSB). This crew will have a sustained production rate of 267 LF/day.
- On top of the CTSB, asphalt-stabilized base (ASB) must be installed and that crew has a sustained production rate of 200 LF/day.
- Finally, Type A hot-mix asphalt paving will be laid on the completed ASB at a sustained production rate of 400 LF/day.
- A series of small concrete box culverts must be built between STA 9+00 and STA 11+00. The group will take 8 working days. The specifications restrict putting equipment loads on the new culverts until 3 days after last culvert is poured. This work is accomplished by a concrete subcontractor and includes excavation, backfill, and final grading for the culverts.
- The last activity in the project is cleanup and demobilization, and it will take 2 days.

The linear schedule will be done using working days and to simplify this example, the assumption will be made that this project will involve all the 7 days per week until it is finished and that the contractor can work the entire width of the roadway without traffic control or detour considerations. Thus, Figure 7.9 shows the first step in assembling the linear schedule for this project. The time is shown on the vertical axis and the location in stations is shown on the horizontal axis. All the respective crews have had their sustained production rates converted to linear feet per day, which will allow them to be quickly converted to days per station and plotted on the linear schedule as needed. As mobilization will occur in the vicinity of the area between STA 9+00 and STA 10+00, it is shown as a bar, 1 station long and 2 days, in duration.

Next, one must step back and think about the technical sequence of work. Obviously, the first activity will necessarily be the demolition of the existing pavement, which is followed by the CTSB, ASB, and Type A pavement. However, from STA 9+00 to STA 11+00, the series of box culverts will need to be built *before* the new subbase, base, and pavement can be constructed. Therefore, the pavement should be removed in that area first to allow the concrete subcontractor to go to work and get those structures built. Therefore, the demolition of existing pavement activity is scheduled to start at STA 9+00 and proceed to STA 19+00 as shown in Figure 7.9. This allows the concrete subcontractor to get into the area in which it needs to work at the start of Day 4 as shown in Figure 7.10.

The "build culverts" activity is shown as a bar extending from STA 9+00 to STA 11+00 and 9 days tall. Additionally, the constraint imposed by the contract specifications that no construction wheel loads may be placed on the new culverts until 3 days after the last one is completed is shown in this figure as a block 2 stations wide and 3 days high. Once the culvert activity is placed on the graph, the remaining pavement demolition can be added. It can be seen that the pavement demolition at STA 19+00 is completed at the end of Day 5. The contractor then moves his crew back to STA 9+00 and completes the pavement demolition from STA 9+00 to STA 0+00. Note that when this activity is complete, the CTSB activity can be added to the linear schedule.

Technically, in the areas where there are no culverts, the CTSB can be started as soon as the pavement demolition is completed. However, from STA 9+00 to STA 11+00, the culverts must also be complete. Therefore, there are two options possible for scheduling this particular activity and the linear schedule greatly assists in visualizing both. The first option is to start the CTSB crew at STA 19+00 as soon as the demolition crew is clear of that area and work back toward the beginning of the project. When the CTSB crew gets to STA 11+00, it will have to move around the culvert construction area and pick up at STA 9+00. Then, it will need to go back as soon as the load restriction block is over and put the CTSB over and between the culverts.

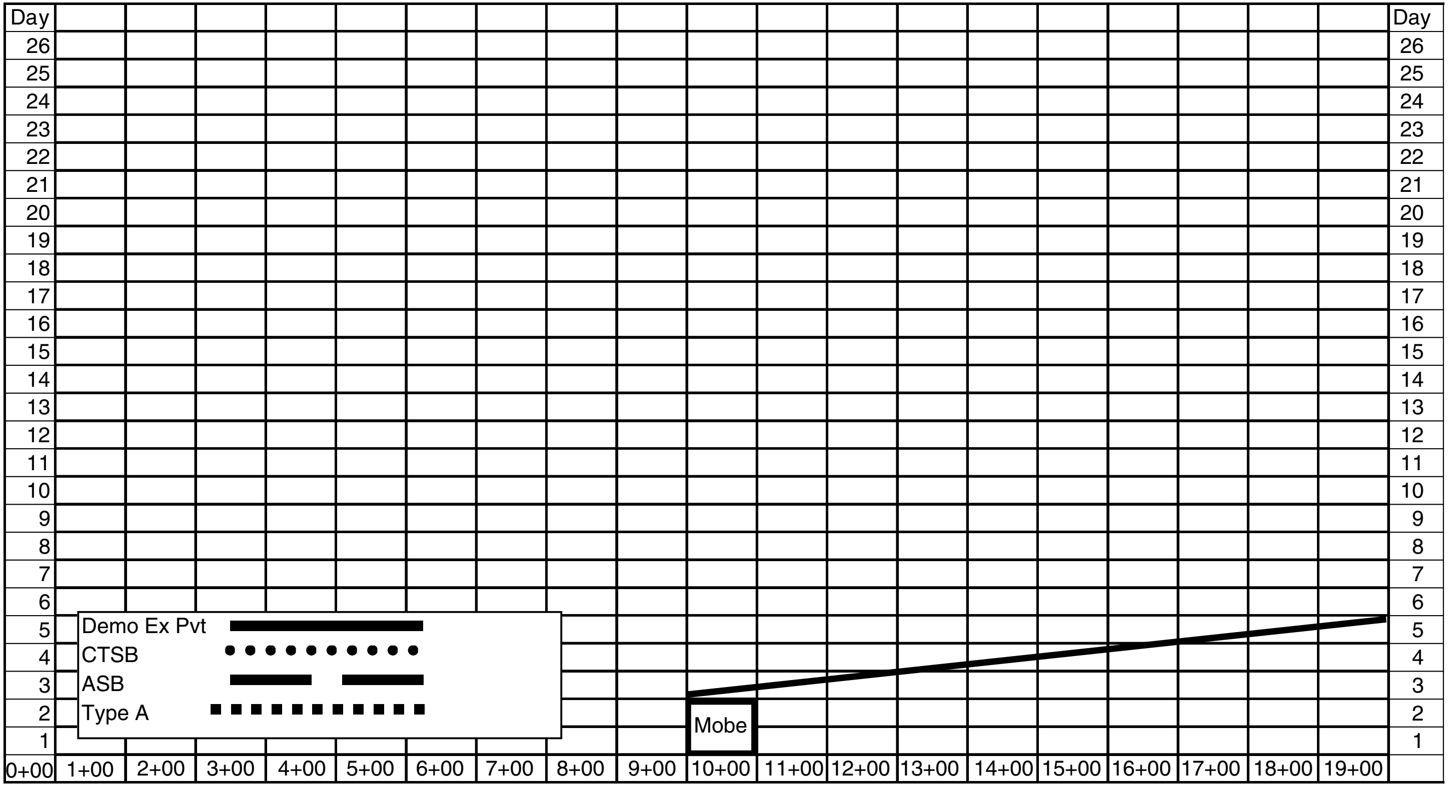

FIGURE 7.9 Linear scheduling example Step 1.

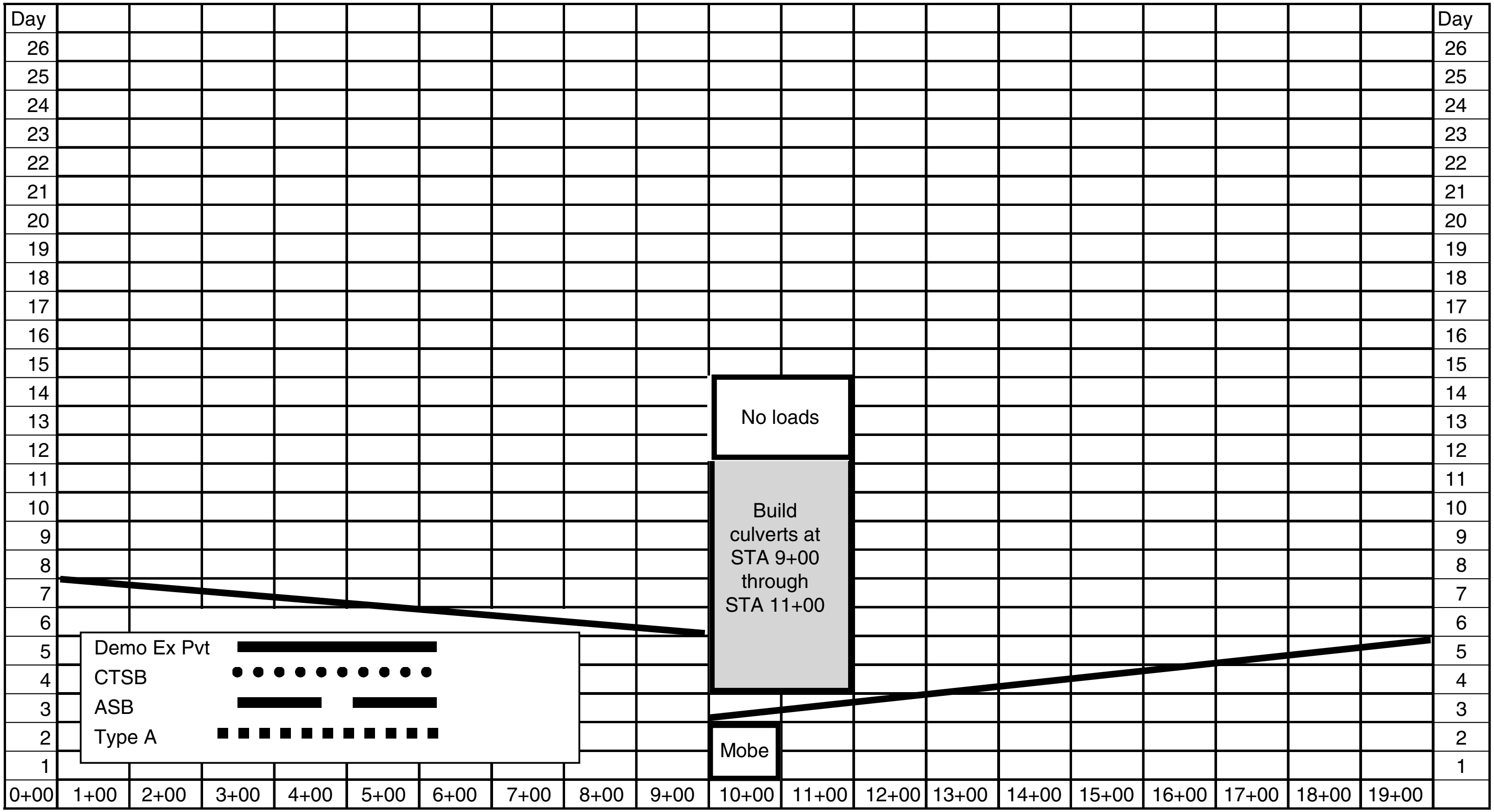

FIGURE 7.10 Linear scheduling example Step 2.

Looking at Figure 7.11, the lightly dotted line called as the ''early start CTSB'' schedule shows this option. As the load restriction block does not end until Day 14, the early start option forces the CTSB to stand down on Day 12 and wait for 2.5 days for the load restrictions to be lifted. This is not satisfactory. It would be better to bring the crew on later and have it work continuously until the activity is complete. So the final schedule for the CTSB crew, shown by the heavy dotted line, is to have it start on Day 8 rather than on Day 6, which gives it half-a-day of float to move back to the culvert area and finish the CTSB between those 2 stations. Note that when scheduler converts the linear schedule from working days shown in the figure to actual calendar days, every effort should be made to schedule the work so that the ''no loads'' block falls on a weekend or holiday to minimize the loss of production due to this restriction. If this can be done, the scheduler may choose to start the CTSB earlier to take advantage of allowing the culverts to cure over a nonwork period.

This is an excellent example of how the visual format furnished by a linear schedule assists the scheduler or the estimator to make good work-sequencing decisions that might not be discovered using a PDM network. It is likely, if this project had been scheduled using PDM only, that the project manager would have brought the CTSB crew onto the job on its early start date (Day 6), then they would have been nonproductive for that 2.5-day period before the load restrictions on the new culverts were lifted. This would have caused the contractor to pay for 2.5 days worth of crew standby cost and exceed the amount estimated in the bid for this activity.

With the CTSB scheduled, the remaining two production-driven activities can be added to the linear schedule. ASB is scheduled in such a manner that it does not conflict with the CTSB at STA 11+00, which is completed on the afternoon of Day 15. Figure 7.12 shows that ASB will not reach this station until the morning of Day 16, and this gives the ASB a start date of Day 12. Finally the Type A paving can be done in 4.75 days. Therefore, to avoid a possible conflict at the end of the job between the ASB and the Type A crews, the latter is scheduled to end 1 day after the ASB ends. The final activity of cleanup and demobilization is added and the linear schedule shown in Figure 7.12 is complete.

It should be noted that there are other solutions for this particular problem. The reader should not be distracted by this fact. This particular solution was chosen to illustrate the various capabilities of LS.

7.4.4 Converting to PDM

Many owners require that their construction contractors utilize a commercial project scheduling software package to facilitate the process of controlling the project's schedule. Most of these software packages are based on CPM using PDM as the network analysis algorithm. Thus, it is quite important to take the output derived from a linear schedule and convert it to PDM so that it can be used directly in contract-mandated computer scheduling and project control software. Again, it is important to state that combining the two methods is an excellent way of developing a construction schedule. As previously discussed, using LS techniques to plan the work sequence of production-driven activities as the first step in the development of the final construction schedule has many advantages.

As could be seen in Example 7.3, a number of production-related decisions were made as a result of the visual representation that the linear schedule provides. Thus, with those important decisions made on the major activities that are associated with ensuring the project's profitability, the scheduler can then convert the linear schedule into a PDM to complete the detailed scheduling task using the following steps:

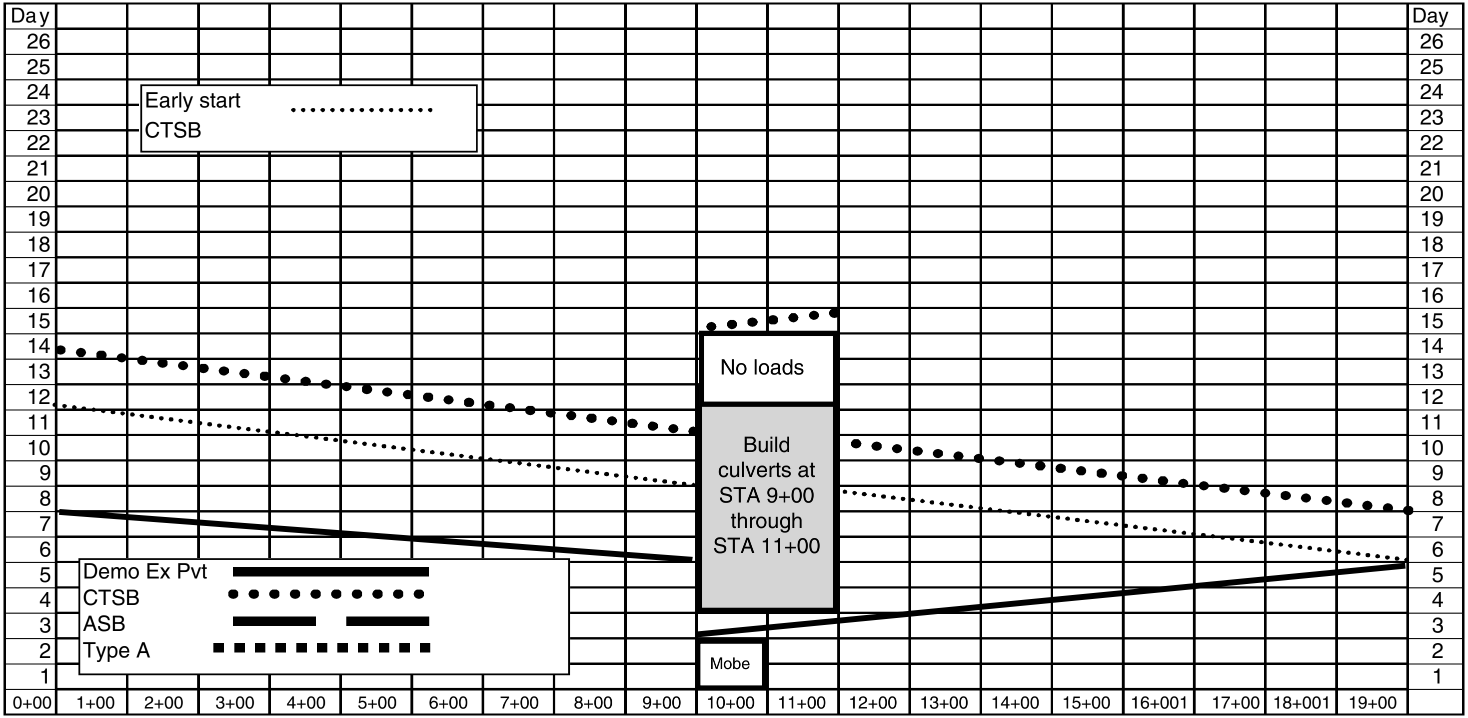

FIGURE 7.11 Linear scheduling example Step 3.

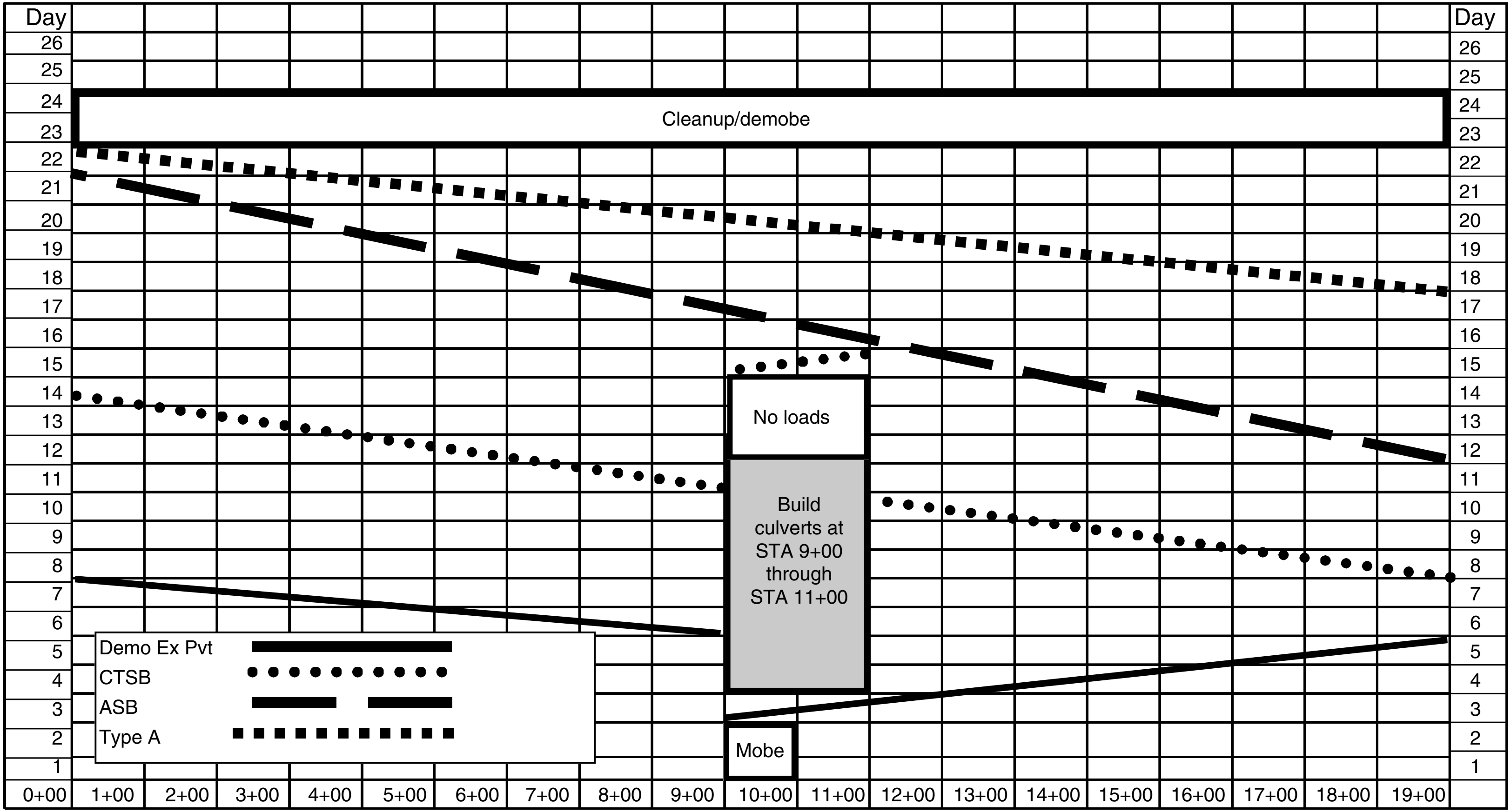

FIGURE 7.12 Linear scheduling example Step 4.

1. List all the activities shown in the linear schedule, their durations rounding partial days up to the next highest whole day, and their precedence relationships.
2. For each line, determine if the activity will be shown in the PDM as a single activity or if it would be more appropriate to break it down into several activities. If it is broken down, the sum of the durations of the series of new activities cannot exceed the duration of the line they represent in the linear schedule.
3. For each bar, break down the series of activities that make up the bar and distribute the total duration associated with the bar in the linear schedule to each of the activities. The total duration of the activities that make up the hammock represented by the bar cannot exceed the duration assigned to the bar in the linear schedule.
4. Similarly, for each block, determine if it will be shown in the PDM as a single activity or if it would be more appropriate to break it down into several activities. If it is broken down, the sum of the durations of the series of new activities cannot exceed the duration of the block they represent in the linear schedule. Additionally, some blocks, like the one in the previous example, represent a constraint rather than a production activity, decide whether to show the block as an activity that has duration but no resources or as a lag on the finish of a related activity.
5. Assemble the final list of activities to be developed into a PDM network, including those minor activities that were not shown on the linear schedule with their associated durations and precedence relationships and develop the network in the scheduling-designated software package.

Note: When setting up the initial data project in the software, *do not* input the contract completion date at this point. Some software will default to making the network start on the designated start date and finish on the designated finish date. Thus, the scheduler may be faced with trying to flush out negative float if the initial network is longer than the period available in which to complete the project, or there will be no critical path (i.e. all activities will have float) if the opposite is true.

6. Check the project completion date computed by the software against the contractual completion date. If the initial schedule is longer than the time allowed, then if possible adjust the logic used in the network to reduce the overall duration. If this does not work, go to those activities where the durations were rounded up and reduce their durations by rounding down.
7. The final product should conform to the contract specifications and fall within the contract period.

To demonstrate how this conversion methodology works, Example 7.3 will be converted to a PDM.

Example 7.4 Figure 7.12 shows that the project can be completed in a total of 24 working days. Table 7.5 shows a list of the activities and their respective durations taken directly from the linear schedule in Figure 7.12.

This completes both Step 1, i.e., the list of activities from the linear schedule, and Step 2, i.e., the determination of how the lines on the linear schedule will be broken up. One can see that the scheduler has chosen to break each of the production-driven activities represented by lines into separate activities as they break up on the linear schedule. This allows them to be related to the "build culverts" hammock activity and the "no loads" bar. Additionally, one can see that the work-sequencing decisions made on the linear schedule are represented by precedence relationships and lag to ensure that the PDM preserves the logic that went into making those decisions.

The next step will be to break down the "build culverts" hammock activity into individual activities and replace the single activity shown in Table 7.5. To do this, a list of the activities and durations for a single culvert is generated as follows:

- Excavate and prepare bed, 4 h
- Form box culvert, 8 h
- Pour and finish concrete, 4 h
- Backfill, 3 h
- Final grading, 1 h

Looking at this list, the scheduler decides to simplify the process by combining the "backfill" and "final grading" for all four culverts into a single activity "backfill and final grading culverts A–D" and assigns it a duration of 2 days. Next, the excavation and bed preparation activity is broken into two activities, "excavate and prepare bed culverts A and B" and "excavate and prepare bed culverts C and D" of 1-day duration each. Similarly, the decision is made to pour the concrete for two culverts per day, creating the activities "pour concrete culverts A and B" and "pour concrete culverts C and D" of 1-day duration each. Finally, each culvert is assigned a separate "form culvert" activity with a 1-day duration. The resulting

TABLE 7.5
PDM Activities and Durations from Figure 7.12

Activity Code	Activity	Linear Schedule Type	Duration (days)	Precedence
010	Mobilize	Bar	2	None
020	Demolish existing pavement STA 9+00 to 19+00	Line	3	FS 010
025	Demolish existing pavement STA 9+00 to 0+00	Line	2	FS 020
030	Build culverts STA 9+00 to 11+00	Bar	8	FS 010 Consists of four individual box culverts including excavation, backfill, formwork, concrete, and final grading
040	Install CTSB STA 19+00 to 11+00	Line	3	FS 020 with 2 days lag
045	Install CTSB STA 9+00 to 0+00	Line	4	FS 040
047	Install CTSB STA 9+00 to 11+00	Line	2	FS 045, FS 030, and FS 050
050	Cure culverts/no loads	Block	3	FS 030
060	Install ASB STA 19+00 to 0+00	Line	10	SS 040 with 4 days lag and FF 047
070	Install Type A STA 19+00 to 0+00	Line	5	SS 060 with 6 days lag and FF 060
080	Cleanup/demobilize	Bar	2	FS 070

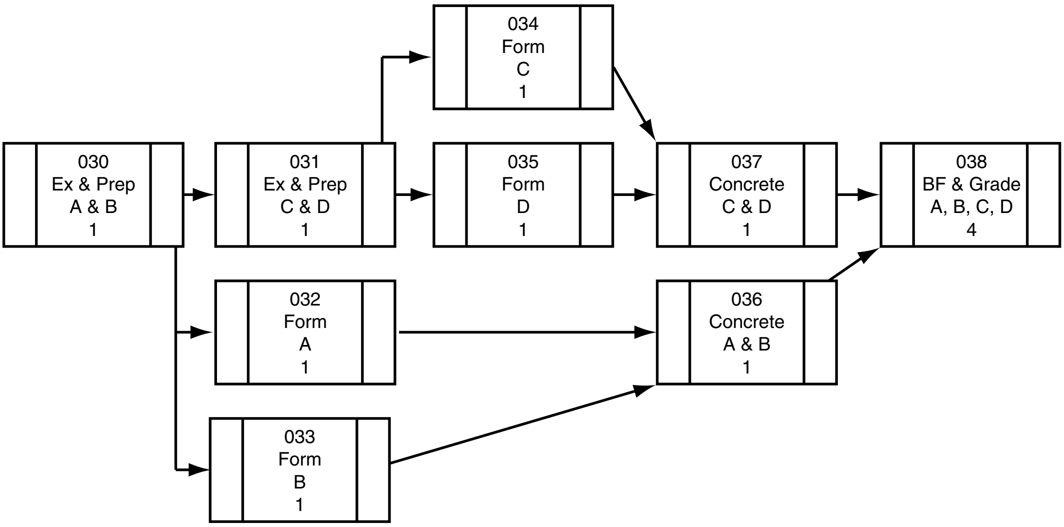

FIGURE 7.13 PDM fragmentary network for "build culvert" work sequence.

output is shown in Table 7.6 and the fragmentary network (fragnet) for this series of activities is shown in Figure 7.13.

This project has some miscellaneous activities that were not included in the linear schedule. The activities, their durations, and precedence relationships are as follows:

- Guardrail must be built between STA 9+00 and STA 11+00. It will take 2 days and can begin as soon as the paving is completed in that area.
- Striping of the road will take 2 days and can begin when the pavement is ready.
- Signs at STA 4+00, STA 7+50, STA 9+85, and STA 11+00 can be emplaced after the paving is finished at that location. All the signs can be installed in 1 working day.

Adding these activities to the activities given in Table 7.5 and Table 7.6 completes the activity list for the PDM in Table 7.7 and is shown in Figure 7.14.

Thus, it has been demonstrated that the two scheduling methods, PDM and LS, can be employed work together to assist the estimator or the scheduler or the project manager to establish the project's sequence of work in a logical manner that permits the control of the project throughout the construction cycle. To briefly summarize, the following points have been made:

- LS furnishes a methodology to focus the scheduling process on those production-driven activities whose successful execution drives an equipment-intensive project's profitability. It does so by reducing the schedule to its most essential portions and graphically manages both time and space on the project site.
- PDM furnishes a methodology for organizing the great amount of detail that attends most construction projects. Its concepts are both well understood and well accepted by both owners and construction contractors, and its use is often required as a part of the construction contract.
- The benefits of both methodologies can be leveraged by using LS to plan the sequence and timing of work for the major items and then converting that output into PDM. Next, all the remaining items of work can be added to the PDM to produce the final construction schedule for an equipment-intensive project.

TABLE 7.6
Detailed List of Build Culverts Activities

Activity Code	Activity	Duration (days)	Precedence
030	Excavate and prepare bed culverts A and B	1	FS 010
031	Excavate and prepare bed culverts C and D	1	FS 030
032	Form culvert A	1	FS 030
033	Form culvert B	1	FS 030
034	Form culvert C	1	FS 031
035	Form culvert D	1	FS 031
036	Pour concrete culverts A and B	1	FS 033
037	Pour concrete culverts C and D	1	FS 035
038	Backfill and final grading culverts A, B, C, and D	4	FS 036 and FS 037

TABLE 7.7
Final List of Activities for Converting Figure 7.12 to PDM

Activity Code	Activity	Duration (days)	Precedence
010	Mobilize	2	None
020	Demolish existing pavement STA 9+00 to 19+00	3	FS 010
025	Demolish existing pavement STA 9+00 to 0+00	2	FS 020
030	Excavate and prepare bed culverts A and B	1	FS 010
031	Excavate and prepare bed culverts C and D	1	FS 030
032	Form culvert A	1	FS 030
033	Form culvert B	1	FS 030
034	Form culvert C	1	FS 031
035	Form culvert D	1	FS 031
036	Pour concrete culverts A and B	1	FS 033
037	Pour concrete culverts C and D	1	FS 035
038	Backfill and final grading culverts A, B, C, and D	4	FS 036 and FS 037
040	Install CTSB STA 19+00 to 11+00	3	FS 020 with 2 days lag
045	Install CTSB STA 9+00 to 0+00	4	FS 040
047	Install CTSB STA 9+00 to 11+00	2	FS 045 and FS 050
050	Cure culverts/no loads	3	FS 038
060	Install ASB STA 19+00 to 0+00	10	SS 040 with 4 days lag and FF 047
070	Install Type A STA 19+00 to 0+00	5	SS 060 with 6 days lag and FF 060
072	Build guardrail STA 9+00 to 11+00	2	SS 070 with 2 days lag
074	Striping STA 19+00 to 0+00	2	SS 070 with 3 days lag and FF 070
076	Install signs	1	SS 070 with 4 days lag
080	Cleanup/demobilize	2	FS 070, FS 072, FS 076

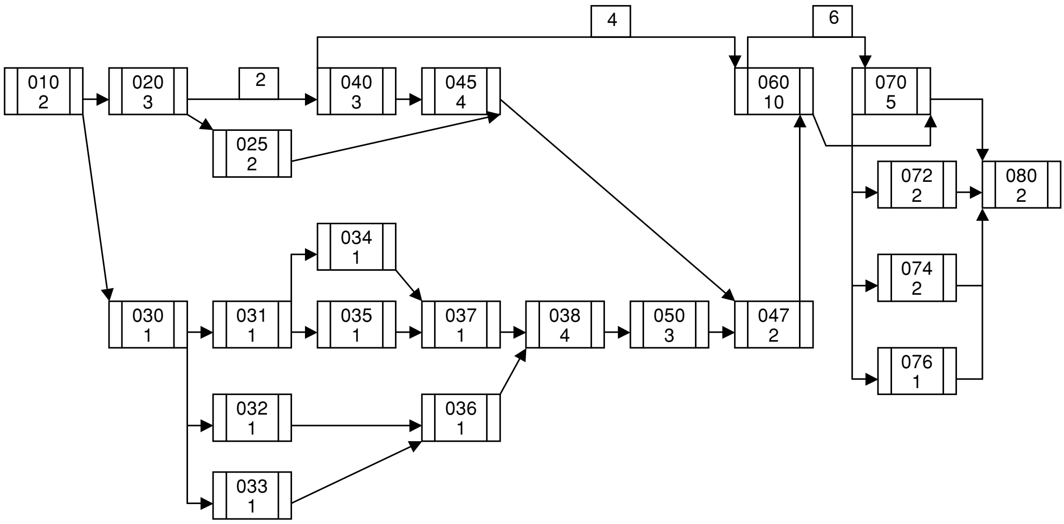

FIGURE 7.14 Example linear schedule converted to PDM network.

7.5 DEVELOPING EQUIPMENT RESOURCE PACKAGES (CREWS)

The heart of a scheduling equipment-intensive project is the equipment itself. Previous chapters have shown the reader how to select and then optimize various pieces of equipment to maximize the system's production. The next step is to take the production calculated by the estimator for various sets of equipments and their operators and create a crew. The definition of a crew is as follows:

> A self-contained grouping of machines, operators, and other support resources that has been designed to complete a specific item or type of work.

In its simplest form, a crew could consist of a single worker with the appropriate tools. On the other end of the spectrum, the crew can contain a multitude of different pieces of machinery along with operators, laborers, supervisors, support vehicles, and maintenance staff. The makeup of an individual crew is often the prerogative of the estimator who must make certain assumptions to complete the cost estimate for a project. If the project is awarded on a price that was based on the estimator's assumptions, the project manager must ensure that all the field personnel know what those assumptions are and only change them if they are wrong or if there is a better, less costly way to complete the project. To be sure, most estimators are intimately familiar with how their respective companies tend to do business and generally base their crew composition assumptions based on past success.

Example 5.3 illustrates the thought process that goes behind developing a crew designed to haul material a specified distance from one point to another on the project. The final outcome of that problem was that the machinery assigned to the haul crew was a 1.5 cy front-end loader and three 12 cy end dump trucks with sideboards. Once the equipment has been determined, the labor that must go with the equipment must be assigned. In this case, as a minimum there would be a bucket loader operator and three truck drivers. Depending on the reason for the haul, there might also be a laborer who would act as a spotter for the dump trucks showing where the next load should be dumped. There also might be a supervisor who would be assigned a pick-up truck. Thus, the total equipment resource package would look like the one shown in Table 7.8.

TABLE 7.8
Equipment Resource Package for Example 5.3

	Granular Material Haul Crew			
Crew Number Equipment	**Number**	**Labor Classification**	**Number**	**Other**
1.5 cy Wheeled front-end loader	1	Loader operator	1	
12 cy End dump truck	3	Truck driver	3	With sideboards
0.5-ton Pick-up truck	1	Supervisor	1	Transit
N/A[a]		Laborer (dump spotter)	1	Hand level and rod

[a]N/A, not applicable.

7.5.1 Rules for Developing Crew Sizes

Thus, the remainder of the crews for a given project would be assembled to permit the estimator to determine the total amount of direct equipment and labor costs that need to be allocated to this particular job. Several rules should be remembered as one develops equipment resource packages into crews for a given project as follows:

1. Develop the crews for the production-driven activities first. These are the items of work that make up the major financial portion of the contract. Therefore, these activities should be given the first priority for resources at all times.
2. Never plan to "borrow" a piece of equipment or resource from a crew assigned to a production-driven activity as a short-term savings measure. This could cause that activity to miss its required production and threaten project profitability. It is better to estimate the cost of renting of a similar piece of equipment for that limited period of time than to potentially "rob Peter to pay Paul."
3. Consider the impact on required production of losing a piece of equipment due to maintenance failure when deciding whether to round up or round down to optimize the size of the equipment spread. If the crew is allocated to a production-driven critical activity, it is better to round up and have an additional piece of equipment in the spread to cover those unavoidable periods of reduced production due to maintenance.
4. For noncritical activities, attempt to develop crews that are sized to be flexible enough to be able to assign to more than one specific type of work. In these cases, it is always easier to add workers and equipment to a crew than it is to remove them once they have been used on the job site. So start with the minimum requirement and increase the size of the crew as required.

7.5.2 Developing Crew Costs

Once the crews have been developed for a given project, the next step is to calculate the cost of the crew in two different ways by composite crew hour and by unit cost. The first step in developing a crew cost is to assign the appropriate equipment rental rates and labor rates to each resource in the crew. Table 7.9 shows how this was done for the crew created for Example 5.3.

TABLE 7.9
Crew Cost Table for Example 5.3[a]

	Granular Material Haul Crew					
Crew Number Equipment	**Number**	**Rate ($/h)**	**Labor**	**Number**	**Rate ($/h)**	**Total ($/h)**
1.5 cy Wheeled front-end loader	1	32.95	Loader operator	1	31.20	64.15
12 cy End dump truck	3	58.83	Truck driver	3	25.00	251.49
0.5-ton Pick-up truck	1	11.28	Supervisor	1	37.50	48.78
N/A[b]			Laborer (dump spotter)	1	18.90	18.90
Total hourly crew cost						383.32

[a]The calculation is based on 2743 cy/shift.
[b]N/A, not applicable.

Example 5.3 calculated that this particular equipment spread could produce 2743 cy/8-h shift. Thus, the direct unit cost for hauling this material can be calculated as shown:

$$\text{Crew cost/shift} = \$383.32/\text{h}(8\ \text{h/shift}) = \$3066.56/\text{shift}$$

$$\text{Direct unit cost} = \frac{\$3066.56/\text{shift}}{2743\ \text{cy/shift}} = \$1.12/\text{cy}$$

Thus, the estimator now has three different cost factors with which to estimate the total cost of this particular activity:

1. Hourly crew cost = $383.32/h
2. Daily crew cost = $3066.56 per shift or per day
3. Direct unit cost of hauling the material = $1.12/cy

More importantly, these cost and production factors can be translated after contract award to project control metrics that can be used by the project manager to ensure that the project achieves its target profit.

7.6 ESTABLISHING PROJECT MANAGEMENT ASSESSMENT PARAMETERS

If the project manager does not fully understand the rationale used by the estimator to assemble the bid, completing that project at a cost that guarantees the margins contained in the bid becomes very difficult. Thus, it is important that the estimator on an equipment-intensive project captures his or her logic in a manner that is easy for the project manager to translate into project control mechanisms. As such, there are two parameters that are generally tracked to determine if the project is progressing satisfactorily. These are cost performance and time performance. Cost performance metrics assist the project manager in understanding how the project is proceeding on a financial basis. Time performance metrics are used to track the project's actual progress with respect to its schedule. Both are interrelated and equally important. Thus, it is vital that the numbers used in the estimate flow out to the project in the form of project performance metrics.

The three types of project performance metrics are relative, static, and dynamic [7]. Relative metrics are expressed as a percentage and as a result are independent of the size of a project. This allows the project manager to directly compare the performance of small projects with the performance of large projects. The cost and time growth metrics shown below are typical examples of relative metrics:

$$\text{Time growth} = \frac{\text{final contract time} - \text{original contract time}}{\text{original contract time}} \tag{7.9}$$

where time growth is denoted in percent and final contract time and original contract time in days.

$$\text{Cost growth} = \frac{\text{final contract cost} - \text{original contract cost}}{\text{original contract cost}} \tag{7.10}$$

where cost growth is denoted in percent, original contract cost in \$, and final contract cost in \$.

The second type is static metrics. These metrics are discreet numerical measures that do not change with time. As a result, they are project size dependent, and the project manager can only use them to compare projects that are roughly the same size. Cost per square foot of constructed area and charge days per lane-mile of highway are examples of static metrics. Finally, dynamic metrics are those that vary with time. Dynamic metrics also depend on size of the project. These metrics are generally a function of both cost and time. Some include cost, time, and a function of physical size. As a result of their mathematical complexity, project managers must understand the limitations of each and every metric they choose to measure project performance. An example of a typical dynamic metric is construction placement as calculated in the following equation:

$$\text{Construction placement} = \frac{\text{construction cost}}{\text{construction time}} \tag{7.11}$$

where construction placement is denoted in \$/day, construction cost in \$, and construction time in days.

The details mentioned earlier are project performance metrics that can be used as project control assessment measures on any construction project. On equipment-intensive projects, the focus must remain on production and as such, the project management assessment measures should also be developed with a strong production focus.

7.6.1 Minimum Required Daily Production

Equation 7.8 for required daily production can be used as a control measure as well as an estimating tool. This is an elegant use of a very simple equation in that the equation calculates a number that is independent of the resources that have been assigned to a given item of work, both the quantity of work and the time allowed in which to accomplish it come from the construction contract. Thus, it can serve as a "floor" requirement that must be met or exceeded each day if the project is going to be completed on time as shown by the following example.

Example 7.5 A project requires 100,000 cy of aggregate be moved to a stockpile to support an asphalt batch plant. The contractor has 40 working days to build the stockpile. The granular material haul crew shown in Table 7.9 is allocated to this task. Calculate the minimum required daily production and compare it with the crew's sustained production.

$$P_r = \frac{100{,}000 \text{ cy}}{40 \text{ days}} = 2500 \text{ cy/day}$$

$$\text{Granular material haul crew, } P_s = 2743 \text{ cy/day}$$

$$P_s \geq P_r$$

Therefore, this crew will be adequate. However, if the crew loses one of its dump trucks to a maintenance break down, its production will drop by 33% to 1860 cy/day. This would cause the actual production to be less than the minimum required daily production. Thus, the project manager might make the decision to regain that daily total by requiring the crew to work roughly 2 h and 45 min of overtime or until the daily total is over 2500 cy. Thus, it can be seen that this project assessment parameter can assist the project manager in making day-to-day decisions regarding the control of the project.

7.6.2 Expected Daily Production

Expected daily production differs from minimum daily production in that it relates the actual level of resources assigned to a given task to the production that can realistically be achieved. In the above example, the granular material haul crew had a sustained production rate of 2743 cy/day. Thus, it could be expected to be able to finish the job in 37 days or 3 days earlier. Realistically, there will be daily variations both up and down from the expected daily production rate. So the project manager should use it more as an average value rather than an absolute value to gauge the actual production achieved by a given crew.

7.6.3 Allowable Cycle Time Variation

Allowable cycle time variation goes back to the calculation of sustained production itself. This metric furnishes a microscopic measure to assess the ability of a given crew to achieve the production rates around which the estimate was based. As noted in Chapter 5, the estimator does a lot of rounding as the equipment resource allocation is developed and the production rates for each crew are estimated. For a haul item, the process starts by looking at the round-trip cycle time of the crew. Cycle times are inherently variable in that any number of factors can arise that either increase or decrease the actual cycle time from the cycle time used in the production calculations. Therefore the project manager needs to know not only the planned cycle time used in the estimate to arrive at the sustained production rate but also the cycle time that is associated with arriving the minimum daily production rate to know what the allowable variation in actual cycle times should be. This can be computed by reorganizing Equation 5.14 as follows:

$$P_s = \frac{60(N)(S_H)(H)}{C_s}$$

where C_s is the sustained cycle time associated with the sustained production P_s. Substituting the minimum required daily production P_r for P_s and maximum allowable cycle time C_{max} for C_s yields the following equation:

$$C_{max} = \frac{60(N)(S_H)(H)}{P_r} \quad (7.12)$$

where C_{max} is the maximum allowable cycle time.

Thus, by using $C_s = 14$ min from the earlier example, the maximum allowable cycle time would be calculated as follows:

$$C_{max} = \frac{60(4)(20)(8)}{2500}$$

$$C_{max} = 15.4 \text{ min}$$

Therefore, the allowable variation in cycle time would be about 1 min and 30 s. Knowing this, the project manager could ask the foreman for the crew to spot check the cycle time throughout the day to ensure that the crew would hit its minimum required daily production and its expected daily production each day. This metric furnishes an early warning system that allows the project supervisors to immediately recognize that something is wrong and take action to rectify the problem before a substantial amount of time and production are lost.

7.6.4 Cost and Unit Targets

Cost and unit targets are project assessment parameters that furnish a historical perspective and lag rather than lead the actual observed progress on a given project. Cost targets seek to measure how closely actual project costs are tracking the assumptions made in the estimate. Unit targets seek to measure how closely actual project production track the production rate assumptions made in the estimate.

The most common and widely used tool for tracking the cost target is called the earned value. Essentially, earned value assumes that once a unit of work is complete, the contractor has "earned" the value of that unit and can subsequently submit an application for payment. Earned value basically creates a graph of project cash flow versus time. To use this concept as a project control measure, the project manager must strip out all markups and any unbalancing that has been done with the unit prices quoted in the bid documents. A cost target seeks to allow the project manager to control cost without taking profit into account. Therefore, to develop a cost target value, the numbers used in the estimate that account for all the costs associated with an item of work must be identified and included in the target value. To arrive at a target cost metric, a specific period of time must be chosen. As many companies do their payroll on a weekly basis, the weekly target cost becomes a convenient project assessment parameter. The target cost value then becomes the value of payroll and equipment ownership costs and rental rates that are associated with a given item of work accomplished using the specified shift length used in the estimate as the basis. Once this value is determined, it can then be compared on a periodic basis with the actual cost value computed using the actual payrolls and equipment hours in the given period.

Using the example shown in Table 7.9, the project manager can compute the weekly cost target value as follows:

$$\text{Weekly target cost} = (5 \text{ days/week})(8 \text{ h/day})(\$383.22/\text{h})$$

$$\text{Weekly target cost} = \$15{,}328.80$$

This value can then be used to compare with the actual total for each week to give the project manager an idea of how well the project is performing against the plan formed by the project cost estimate.

Unit targets are computed much in the same manner, substituting the quantities of work for the costs. Continuing the example, the granular material haul crew had a minimum production of 2500 cy/day. That can then be extended across a week for a minimum unit target of 12,500 cy/week. It can also be used with the expected production of 2743 cy/day to get a second expected unit target value of 13,715 cy/week. Thus, the project manager now has a range of 12,500 to 13,715 cy/week against which to judge the actual progress and make decisions for future weeks.

It is always valuable to use both cost targets and unit targets together. Equipment management decisions made on the job site are normally centered on recovering lost production and bringing actual production back into the range as discussed in the previous paragraph. However, in Example 7.5, the project manager decided to work overtime to recover the production lost by a maintenance problem with one of the dump trucks. The hourly costs of the crew shown in Table 7.9 is based on an 8-h shift with the labor that is computed based on straight time. Once the crew is required to work overtime in this example the cost of an overtime hour jumps up to $439.62 assuming all the workers will be paid at a rate of 1.5 times their straight time hourly wage. The actual daily cost becomes $4272.72 instead of $3065.76, an increase of over $1200. Thus, while the project manager would have achieved his or her unit target for the week, the cost target would have been exceeded and the project's actual profit margin would have been reduced from the target profit that was built into the bid.

7.7 SUMMARY

The old cliché that "time equals money" was never more appropriate than in the scheduling of equipment-intensive projects. The scale and complexity of these types of construction projects drives the requirement to not only accurately estimate the production rates of various crews but also schedule them in a fashion where the production achieved in critical activities is not interrupted by noncritical activities. This production can only be achieved if those features of work are allocated sufficient equipment and labor to realistically allow those crews to produce at rates that equal or exceed the assumptions used in the estimate. Thus, understanding of the dynamics of each particular project is essential to its financial and technical success. Good scheduling practices assist the project manager as well as the estimator in gaining that understanding and ensuring that the bid has not created a "mission impossible" situation for the actual execution of the equipment-intensive project.

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8 Scheduling Lifting Equipment for Vertical Construction

8.1 INTRODUCTION

The jobsite lifting strategy is a very influential consideration when determining the approach to construction, the budget, and the schedule. Simply put, if you cannot get the necessary material and pieces on the structure, you cannot put them in place. That sums up how critical the lifting plan is for the success of the project.

Lifting is one of the most critical planning issues for scheduling a vertical or a high-rise construction. Without heavy lifting equipment, meeting our needs today for bridge, industrial, petrochemical, and tower constructions would be almost impossible. Lifting equipment is used to move, hoist and place workers, material, and equipment onto the structure as it goes up. The strategy must focus on safety due to the many dangers lifting poses. Types, numbers, and locations of lifting equipment on the jobsite dictate field productivity. Productivity will many times be dependent on how fast the material can be delivered, staged, hoisted, and placed on the structure. Construction cannot occur if material, manpower, or building components cannot be placed.

8.2 LIFTING AND VERTICAL CONSTRUCTIONS

Cranes make "on-time" delivery scheduling possible. This delivery and erection strategy usually entails a large precast concrete or steel section or part of the building cladding arriving at the site at a predetermined time. Deliveries may be scheduled during off-traffic times. The truck pulls into an area that can be reached by the tower crane. The load is rigged and unloaded off the trailer. Without setting down, the load is hoisted and positioned on the structure. The load is secured to the structure and the rigging is released. The crane positions to unload and lift the next load. Delivery timing can be staggered to allow time for loads to be hoisted and secured. This approach demands great attention to the work scheduled on a day-to-day basis. How and when the work will be performed is the basis for scheduling. Efficient and effective communication with suppliers or manufacturers is critical because of the importance of meeting the schedule. If the operation is to run smoothly, the truck must arrive at about the time the crane is ready to lift. The truck cannot leave until it is unloaded, therefore possibly causing traffic congestion or having to wait at a remote location.

Though harder to coordinate, this process is efficient and has productivity benefits. Most loads however, have to be stored, staged, and rigged before erection. By not setting the load down, it only has to be rigged once, and does not have to be moved twice, minimizing the chance of damage, no surface space is consumed for storage, and no protection or security has to be supplied. These are great benefits when building on restricted sites in metropolitan areas where surface area is limited and minimal disruption to traffic and people is required.

To lift safely, choosing the right equipment and rigging is mandatory. Risks of high-rise construction are greatly compounded due to the work occurring off the ground and the lifting typically occurring over part of the built structure. Government and company regulations typically mandate safe lifting practices that must be followed in the field. The cost incurred by this lifting strategy must be estimated and included in the project budget at the time of bidding. The strategy has to minimize the much greater risk that all the people working on the structure face as the height of construction increases. This is a huge responsibility for all the parties involved in vertical construction.

8.3 LIFTING PRODUCTIVITY

The lifting strategy and ultimate economy of lifting (using the most economical equipment to do lifting) required to erect the project should be considered in the design. Designing a structure using components that can be hoisted and placed using readily available lifting equipment will influence the construction budget. Typically erection productivity will be greater, erection time more efficient, and unit costs less.

The steps for making a "pick" are similar for all types of lifting equipments. The production cycle time can be calculated by adding together how long each of the steps takes. The largest variable in the cycle time is the placement height. Obviously the higher the placement, the longer it takes to get the load to the height. Instead of horizontal travel time used to calculate the cycle time for earthmoving equipment, vertical hoist time is used. How fast the load can be hoisted is influenced by the crane capacity and the physical characteristics of the load. An oversized crane can lift a load faster than a crane that is near its maximum lifting capacity. A concentrated packaged load can be lifted faster than a long or irregularly shaped load.

Typical lifting equipment production steps are:

1. Prepare the load — secure or band, position so it can be rigged and lifted
2. Rig the load (gripping)
3. Hoist the load for movement or placement
4. Walk the load — carry the load on the ground to the placement location
5. Place the load — the boom tip is swung to a vertical point above the placement point and the load is lowered
6. Unload the load or release the rigging (un-gripping)
7. Return for the next load

The time spent for performing steps 1, 2, 5, and 6 varies based on several factors. Support workers and riggers on the ground perform steps 1 and 2. Riggers, ironworkers, or carpenters on the structure typically perform steps 5 and 6. The work efficiency of these crews has a primary influence on cycle time. Along with worker efficiency, load characteristics, work complexity, amount of manpower required to place and secure the load, weather, and required support material or equipment greatly influence cycle or use time. For most vertical construction activities, the time spent holding the load until it is safely secured is much longer than the actual hoist time. Steps 3 and 4 are a function of the crane's capability; lift capacity, boom length, and hoist speed.

A perfect example of the lifting production cycle is bucket-pouring concrete columns on a high-rise in a metropolitan area. A bucket is rigged on the hoisting cable of a tower crane. The bucket is filled with concrete from a delivery truck at ground level. The boom is swung near the face of the building as the full bucket is raised. The bucket is hoisted to a height that is slightly above the placement point at the top of the structure. The boom is swung over the structure and the boom tip is positioned over the placement location. The bucket is lowered to the appropriate column form on the structure. The bucket is positioned and opened by the workers at the form. When the concrete is all released, the bucket is raised and swung back over the ground loading point. The bucket is lowered to the ground level and positioned to be filled again. For this type of production cycle, as the vertical hoist height increases with each floor that is poured, so does the cycle time. The economy of this type of redundant production is to find a tower crane that will safely lift the loaded bucket as quickly as possible.

Walking a load with a crane or cranes and forklift production has these similar steps, except that ground travel time is included. The distance the load must be carried and the speed of travel influence the cycle time. The farther the load is transported, the longer the cycle time, unless the speed is increased. The distance from where material-delivery trucks can be unloaded, to where material is stored, to where it is erected, influences the cycle time for material moving. These locations and travel routes should be considered when setting up the jobsite.

8.4 SCHEDULING LIFTING FOR HIGH-RISE WORK

Lifting equipment economy for high-rise work is reached when the cost for lifting equipment is balanced with the desired productivity. Doing this correctly entails evaluating the jobsite layout, the sequence of the work, and the construction schedule to select the right type, capacity, and the number of cranes. Lifting must be considered in the construction schedule, not only on a daily basis, but for critical lifts that might affect work on the whole jobsite. Many times critical path activities are dependent on a crane for completion.

8.4.1 Lifting Strategy

In the preconstruction stage, when the construction schedule is prepared, items requiring lifting equipment for erection should be determined by reviewing the plans and developing a strategy for how the structure will go together. These items are typically grouped by work package or jobsite location. Items requiring special lifting equipment due to size, weight, location, or sequence of construction should be determined. Equipment to place these items is likely to be brought in only for the duration of the lift or to perform that specific work. Scheduling large-capacity one-time lift cranes demands extra attention due to availability, lead time required to get the crane on-site and setup and planning the lift. Most items that require lifting will probably be placed using equipment on-site for the duration of the major work.

When a crane has to be moved and reset, this is nonproductive time and typically requires special surface stabilization and preparation for travel and setup areas. Even if the crane is on tires, outriggers must be set and the crane leveled. Moving a crane with the boom up is time-consuming and creates a hazard because of the nature of the task. If lifting is limited, the site is stable, unobstructed, and the schedule can be met, one crane might be the best alternative. From a safety perspective if the crane is going to have to be moved many times, multiple cranes might be a better alternative to minimize crane moving. If work can proceed simultaneously in multiple locations, then having multiple cranes is probably the best alternative. Simply, the more lifting equipment used, the more expensive the cost for lifting, but the greater the productivity.

Idle time for a crane is expensive. Most of the times it cannot be avoided, but ample work should be planned to take advantage of the crane setup. Ample workers should be available to rig and place loads. "Hook time" should be sequenced with craft users so that when one crew does not need the crane, another crew can use it. This demands management of day-to-day activities and coordination with all crews utilizing the crane.

It is a good idea to have a field manager, the superintendent or general foreman, coordinate daily lifting instead of the crane operator. Try not to put the crane operator in the position of having to prioritize "hook time" for different crews. Meet with crew foreman at the start of the day to schedule "hook time," so workers and support equipment can be coordinated. It is a good idea to schedule activities requiring the crane in advance so these times can be coordinated and communicated to all crane users. Schedule stocking activities early in the day or at the first of the day before production lifting is started so materials can be available on the structure for workers. Avoid idle time for workers waiting for material by reviewing all needs on a daily basis.

When the number of cranes and possible setup locations are determined, the heaviest load and longest placement reach required for each setup should be determined. Ranges of load sizes, configurations, and compositions should be evaluated. This information is used to select the appropriate type and capacity crane or cranes for each setup.

Dual crane lifting requires special attention for scheduling. This is not everyday lifting and must be planned ahead of time. Typically the lift setup is more involved due to the load sharing. All lifting factors should be determined and crane capacity verified for all conditions and quadrants required for the lift. This is always required in a critical lift evaluation whether for one crane or multiple cranes. More experienced operators and greater communication are required during the lift and the load weight, size or shape is typically large, cumbersome, or both. Figure 8.1 shows a dual crane lift of an elevated highway ramp beam. Rigging

FIGURE 8.1 Dual lifting.

attachment points are determined by the center of gravity of the load and the proportion of the total weight that can be lifted by each crane.

The weight and length of the beam makes a dual lift more efficient and cost effective than finding and setting up one crane with the necessary capacity to make this lift. Note the setup of the mobile telescoping boom cranes so that they are lifting and placing over the front. When two cranes must travel with a large load, it is advisable to use cranes with the same length booms. Overloading could occur if the lift capacity of either crane is close to its maximum and one hoists faster than the other or repositions the boom independently without coordination of changes to the other crane setup. Ends of beams, such as heavy dense concrete girders like the one hoisted in Figure 8.1, should be set simultaneously to avoid a "shock load" effect, resulting in a $33\frac{1}{3}\%$ increase in loading on the crane holding the unset end. The *Mobile Crane Manual* lists and explains formulas to perform these calculations [1].

When deciding what equipment to use to set a 200-ton vessel on an industrial site, two choices are available for crane selection. A 500-ton mobile crane can be used for the setup and boom length required. This crane must be shipped from two states away and assembled on the jobsite. It will take 10 days to get the crane ready for the lift. Another alternative is to use two 250-ton mobile cranes available in the closest metropolitan area. It will take 3 days to get these cranes ready to lift. Meeting the desired schedule and budget of getting the 500-ton crane on-site and setup for the lift must be compared to getting two 250-ton cranes on-site sooner at a lesser cost. If the two smaller cranes can safely perform the lift, this may be the most economical and a timely alternative. Lifting capacity for either crane should not exceed 75% of the rated lifting capacity. It should be noted that lifting concerns are greatly increased using two cranes.

8.4.2 Typical Lifting Activities for High-Rise Construction

Crane lifting is most intense on a typical high-rise construction project during below-grade foundation construction and erection of the structure. The size of the foundation hole, the height of the structure, and the type and composition of the building components will dictate lifting requirements, equipment, work sequence, and scheduling. Most jobs will have forklifts, tire equipped a mobile light to moderate lifting crane, a heavy lifting crane, and personnel lifts on-site for most of the major construction projects (until the building exterior is complete). Periodically most jobs will have concrete pump trucks, other lifting equipment, and many types of support equipment on-site as it is needed.

Durations for lifting activities will vary based on the load size and configuration, complexity of the connection or placement and supporting manpower or equipment required. The actual time to hoist a load is fairly predictable based on height and the speed of hoist line. Once hoisted, many loads require positioning, aligning, and securing on the structure. Loads such as steel or precast concrete beams must be placed precisely and held in place until the proper connections can be made on each end. Most of the times this takes much longer than the time required to hoist the load. The number and locations of connections influence the type and number of support equipment needed. This dictates the number of equipment operators and erection personnel needed. Typically welding takes longer than bolting and each method requires different personnel to perform the connection. The skill and proficiency of the erection crew will greatly influence the amount of "hook time" required to hold a load until it is secure. These activities might be scheduled by area of the jobsite, part of the structure, or area covered by the crane. Pricing catalogs can be consulted for estimated times and costs for specific work activities such as steel structure erection or concrete placement.

Using a crane or building an earth ramp are two ways to get forms, material, and equipment into a foundation hole. Both are used most of the times. The power and stability of earthmoving, excavating, and compacting equipment makes use of the earthen ramp for entrance and exit safe and fairly predictable. Lifting equipment using the ramp is not as predictable as the other equipment. A forklift carrying a load of rebar on forks and negotiating an incline is not as predictable. Obviously the length, grade, and stability of the earthen ramp will influence the use by different equipment. Concrete trucks might use the ramp to go into the hole and chute pour accessible foundation parts, but most material deliveries will be made at the ground level and then placed in the hole by a crane. This is much safer than delivery traffic down in the hole. Many times forms or materials are too large or heavy to be placed using manpower or smaller mobile lifting equipment and require hoisting and holding by a crane setup on the ground level. Layout and organization of the foundation hole should be considered in the construction strategy. A safety strategy should be detailed and communicated to those working in the hole. Many considerations are similar to working on grade.

Typical high-rise construction is very redundant once the foundation and common areas on the first few bottom floors are complete. Many times the shell of the building is completed and the area within each floor is completed based on what is to be occupied. Lifting activities are typically redundant floor after floor because the structure and materials to be placed are the same.

This section lists activities or parts of high-rise work requiring lifting. Not all jobs will have all of these activities. The list is not intended to be comprehensive. Many of the activities listed must be defined further to be communicated effectively on the construction schedule. Typically high-rise scheduling is done by floor or location on the job (north wall, column lines, or specific part of the project). The level of detail should be determined by the needs of the field personnel to coordinate the work. The order in which they are listed is based on building from the groundup, but several activities will occur as they are needed and will be done simultaneously with others. Some activities are ongoing and require daily coordination by the superintendent or management staff with crane operators and foreman. This level of coordination may be too detailed to include in the comprehensive construction schedule. Items requiring support equipment that must be brought from off-site, such as concrete pumping, require special attention due to the extra coordination needed. Table 8.1 lists typical commercial construction activities requiring lifting listed by the phase of construction in which they typically occur.

8.5 CONCRETE-PLACING

Bucket pouring and pumping are two methods commonly used for placing concrete in a vertical construction. The selected method must take into account the volume of concrete to be placed, the location of the pour, the expertise of the placement crew, and the desired production.

8.5.1 Bucket Pouring

As previously stated, tower cranes are typically used when operating space is limited. This usually means that lay down and staging space is limited too. Tower cranes are ideal for bucket-pouring concrete in high-rise cast-in-place construction. Figure 8.2 shows a bucket being lowered to the placement point. The bar at the bottom of the bucket is used to release the load when the bucket is in the right location. Bucket pouring, especially for flatwork, is very redundant and done at a higher speed typically than normal crane operation. High-speed repetitive lifting production is called ‘‘duty cycle’’ operation. When pumping the concrete is not an option due to height, mix, or location, bucket pouring using a crane is the best solution. If amounts to place are small and not spread out, bucket pouring is the best option (columns and beams).

TABLE 8.1
Typical Commercial Construction Hoisting Activities

Job Start-Up
Stabilize crane setup location(s) or area(s)
Procure and setup support equipment to assemble crane(s)
Mobilize, assemble, and setup jobsite crane(s)
Unload delivered heavy materials, building components, and equipment during site mobilization

Demolition
Demo structure — taking down a structure swinging a wrecking ball or some kind of wrecking weight attached to the hoist line into the structure face
Demo flatwork — breaking concrete flatwork by dropping a wrecking ball vertically onto the surface

Tower Crane Setup
Secure required permits and airport clearance
Place tower crane foundation
Run power to the tower crane foundation
Erect the tower crane
Secure necessary rigging
Tower crane maintenance
Dismantle the tower crane
Load the tower crane for transport

Foundation Earthmoving and Excavation
Site mass excavate with a dragline or clamshell
Foundation hole excavation with a dragline or clamshell
Dynamic compaction — extreme compacting method utilizing a weight on the end of the hoist line, dropped repeatedly to the surface of the area requiring compaction
Place site shoring
Pile driving
Place piers, caps, footings, and grade beams — forms, rebar, concrete bucket pouring, or pumping
Material and equipment movement/placement/removal in the foundation hole

Structural Work
Place foundation flatwork — forms, rebar, concrete bucket pouring, and pumping
Place foundation walls — forms, rebar, concrete bucket pouring, and pumping
Place vertical structural components for each floor — steel, cast-in-place (forms, rebar, concrete) or precast concrete columns, precast panels, and bracing
Place horizontal structural components for each floor — steel, cast-in-place (forms, rebar, concrete) or precast concrete beams, precast panels, open web steel joists, metal decking, and bracing
Stock floor shoring materials
Place floor flatwork — pan or plywood formwork, bracing materials, rebar, sleeves, miscellaneous floor components, bucket pouring small areas
Pump floor flatwork — large areas
Stock and place roof structural components — beams, ridges, rafters, decking
Stock and place miscellaneous structural components — metal stairways, special bracing

Stocking
Stock assembly and erection equipment on the structure — welding machines, on-structure material moving machines, generators
Stock interior structural materials — metal stud or wood framing material, block, other materials
Stock miscellaneous materials — mortar, nails, fasteners, insulation, welding supplies
Stock MEP rough-in materials — pipe, fittings, supports, hangers, and pre-made plumbing assemblies, conduit, fittings, wire and power, security and communication assemblies and components, ductwork, hangers, controls, and mechanical components

Continued

TABLE 8.1 (Continued)
Typical Commercial Construction Hoisting Activities

Stock and place exterior structural or accent components — awnings, decorations, manufactured pieces, walkways, skylights, signage
Stock and place exterior curtain wall materials or components — masonry pieces, brick, glass, stone, metal, pre-cast panels, other materials
Stock interior finish materials — sheetrock, metal doors, insulation, many other materials
Stock and place roof materials — shingles, metal panels, tiles
Stock and place flashing
Stock and place windows
Place rooftop mechanical, electrical, or communication components
Exterior painting, surface preparation, or finishing
Exterior caulking

Support Work
Place temporary facilities on the structure — porta-johns, plan reading booths, tool and material storage boxes
Remove trash containers
Raise the self-erecting tower crane/extend the boom of the on-site crane
Erect personnel/material moving equipment — personnel elevators, conveyors, trash chutes

FIGURE 8.2 Concrete bucket in air.

Tower crane bucket pouring production is based on several considerations:

- Setup for ''chuting'' the concrete into the bucket should be free of encumbrances and accessible to the crane and the concrete delivery truck with enough space to accommodate both.
- Ease of rigging or unrigging the bucket. Typically the bucket will stay rigged to the hoist line until the pour is complete. Bucket capacity typically run about 1.5–3 cubic yards. One cubic yard of standard mix concrete weighs approximately 3900 lbs.
- The speed at which the hoist line is raised or lowered and the speed of the boom swing are variable production cycle times. The faster the hoist line is raised or lowered, the shorter the vertical hoist time. The line and boom can be operated faster if the load is undersized for the crane capacity. Typically the closer the load gets to the tipping condition, the slower the operation. The less cumbersome or irregular the load, the faster the boom can be swung. The time increases with the lift height increase or the amount of placement positioning required. Hoisting a concentrated load must be done steadily with attention to slowing and stopping of the hoist line or boom to avoid swinging or spinning the load.
- Unloading the bucket is a variable time in the production cycle. How much concrete is dumped depends on the location, rate of the pour, size, and shape of the forms filled and the amount of times the bucket has to be repositioned. Pouring into beam or column forms demands precise attention to placement location, rate, and amount. Concrete must be vibrated after a certain amount is placed before more can be dumped. The bucket may need to be moved after it has only been partially placed.

Example 8.1 A free standing, top slewing, standard configuration, two-part standard line Liebherr tower crane secured in a concrete foundation base is hoisting a 1.75 cy bucket to pour concrete columns on a high-rise office building. The pour is a 10th floor column. Each floor is about 11′6″ floor surface to floor surface. The top of this column form is 6′ off the 10th floor surface. The crane capacity is verified for the lifting radius of 90′ and the setup. Normal concrete weighs about 150 lbs/cf.

$$150 \text{ lbs/cf}(27 \text{ cf/cy}) = 4050 \text{ lbs/cy} = \text{slightly more than 2 tons/cy}$$

A bucket load for this setup weighs about 1.75 cy (4050 lbs/cy) = 7088 lbs.
What is the hourly production for the crane to make this pour?

First the cycle components and their appropriate times must be determined:

1. The loading time on the street = 0.5 min. The bucket is about 30′ from the tower base when loading.
2. Hoist time = lift height/line speed.
   The lift height = 10 stories (11.5′/story + 6′ + 10′) to clear the load over the placement point = approximately 131′.
   Line speed average = 120′/min (see manufacturer's specifications for this information).
   Hoist time = 131′/(120′/min) = 1.1 min.
3. Once the load reaches approximately 131′ the boom is positioned and the load is moved along the trolley 60′ to above the placement point. This takes about 0.4 min.
4. It takes about 0.1 min to lower and position the bucket.
5. It takes about 0.6 min to dump the load.

6. It takes about 1.4 min to raise the bucket, retract the trolley 60′, lower the bucket to the street, and position for another load.

Cycle time = 0.5 min + 1.1 min + 0.4 min + 0.1 min + 0.6 min + 1.4 min = 4.1 min
Use a 50-min work hour for production calculation.

$$\text{Hourly production} = \frac{50\ \text{min}}{4.1\ \text{min/cycle}} = 12\ \text{cycles/h}(1.75\ \text{cy/cycle}) = 21\ \text{cy/h.}$$

8.5.2 Pumping

Concrete pumping is used whenever the concrete cannot be unloaded directly from the truck down a chute to the placement location. The concrete mix must also be suitable for pumping. The pour could be out into the middle of a large slab on grade or over 250′ up a high rise. The distance to push the concrete, the diameter of the hose or pipe, the type of concrete mix, and the desired output determine the amount of pressure that has to be developed by the pump to place the concrete. The amount of pressure needed is proportionate to the diameter of the pipe through which the mix is pumped and the boom configuration and height. As the pump height or distance or the diameter of the line increases, typically the larger the capacity of the pump unit required. Once the setup location is determined, boom and pump specs should be reviewed to verify adequate capacity. When pumping is not an alternative, bucket pouring is used. For small pour amounts this may be more cost efficient than using a pump truck. However for large pours and pouring efficiency, pumping is faster and more efficient. The pump boom can be attached to a fixed base on the pour floor. It is much easier to move the boom and hold the hose than drag the hose over a large pour area.

The pump supplier should be consulted for the selection of a proper unit prior to the pour. For more information about concrete pumping equipment and related resources, refer to Schwing's *Pumping Concrete and Concrete Pumps — A Concrete Placing Manual* [2].

Space for the pump truck and delivery trucks should be marked off using ribbon, cones, or temporary barricades. This area should be stable and level with room for the pump truck to fully extend, set, and level outriggers. The setup should be clear of overhead encumbrances or utility lines. There should be plenty of area for the concrete delivery trucks to position for unloading in the hopper and then exit to a designated clean-out or wash area. There should be a signaler or flagman to direct traffic or delivery trucks. There should be space for trucks to wait if they cannot pull directly to the hopper. Communication should be set up between the ground crew and the crew pouring on the structure.

Figure 8.3 shows the concrete delivery truck "chuting" the concrete into the hopper of the pump truck. Figure 8.4 and Figure 8.5 show pump trucks pouring flatwork for a slab and second floor, respectively.

Example 8.2 A Putzmeister 58M truck mounted concrete boom pump is to be used to pour flatwork on a 10-story classroom building. It is assumed that the pump can sufficiently push the concrete mix. The vertical reach of the 58M is about 188′. It has a horizontal reach of about 174′. The pour is at about 96′ floor level and most of the boom will be needed to cover the pour surface. The 58M can pump about 200 cy/h. The concrete company has promised between five and seven 9 cy trucks/h. Two pours of 12,500 sf (25,000 sf total) 4″-thick 3500-psi light mix concrete are planned on consecutive days. The truck setup and priming is $900. There is a $125/h charge for the truck, operator, and helper. There is a $2/pumped cy charge. There is no minimum time charge used in this problem, though most pumping services have a minimum time charge per setup. This example illustrates the importance of uninterrupted and adequate concrete delivery.

FIGURE 8.3 Chuting concrete into the pump hopper.

How much will the pump truck and setup cost to pump the concrete for the 25,000 sf floor? What is the unit cost for the pump truck?

$$[25{,}000\ \text{sf}(0.33')]/27\ \text{cf/cy} = 306\ \text{cy of concrete for the whole floor (assume no waste)}$$

$$[12{,}500\ \text{sf}(0.33')]/27\ \text{cf/cy} = 153\ \text{cy of concrete/pour}$$

$$5\ \text{trucks/h}(9\ \text{cy/truck}) = 45\ \text{cy/h}$$

FIGURE 8.4 Pumping a slab on-grade.

FIGURE 8.5 Pumping elevated flatwork.

$$7 \text{ trucks/h}(9 \text{ cy/truck}) = 63 \text{ cy/h}$$

$$153 \text{ cy to be pumped}/45 \text{ cy/h} = 3.4 \text{ h thus, charge time} = 4 \text{ h}$$

$$153 \text{ cy to be pumped}/63 \text{ cy/h} = 2.5 \text{ h thus, charge time} = 3 \text{ h}$$

Daily cost for the pump truck and operator = setup + hourly charge + per yard pumped charge

$$\text{Total hourly charge for 5 trucks/h} = 4 \text{ h} \times \$125/\text{h} = \$500$$

$$\text{Total hourly charge for 7 trucks/h} = 3 \text{ h} \times \$125/\text{h} = \$375$$

$$\text{Per yard pumped charge} = 153 \text{ cy} \times \$2/\text{cy} = \$306$$

$$\text{Daily cost for 5 trucks/h} = \$900 + \$500 + \$306 = \$1706$$

$$\text{Daily cost for 7 trucks/h} = \$900 + \$375 + \$306 = \$1581$$

$$\text{Total cost for pumping the 25,000 sf for 5 trucks/h} = 2 \text{ setups}(\$1706) = \$3412$$

$$\text{Total cost for pumping the 25,000 sf for 7 trucks/h} = 2 \text{ setups}(\$1581) = \$3162$$

Unit cost range:

$$\text{Unit cost for pumping for 5 trucks/h} = \$3412/25{,}000 \text{ sf} = \$0.136/\text{sf}$$

$$\text{Unit cost for pumping for 7 trucks/h} = \$3162/25{,}000 \text{ sf} = \$0.126/\text{sf}$$

8.5.3 Scheduling and Ordering Concrete

Use the following guidelines for communicating with the concrete plant dispatcher when ordering concrete over the telephone. The dispatcher typically coordinates orders and deliveries.

Order at least a day ahead of time; put concrete on "will call" at least 12 h before it is needed. "Will call" means that someone will call to verify the order prior to the pour.

Typically if there is no ''will call,'' then the concrete will be delivered as per the instructions at the time the order is placed. The following list includes suggestions for ordering concrete:

- Order the and mix and batch (strength) and any admixtures needed
- Order the desired quantity needed
- State the date and time when the concrete is needed
- State the location of the pour. State delivery directions or special instructions, if necessary
- Detail how quickly the concrete is needed once the pour begins
- State who will be making the pour and how many workers will be available
- State that pumping equipment will be used. The delivery time and quantity must be coordinated with the pump truck and the concrete crew making the pour. State who is supplying the pump truck and their schedule
- Describe any potential jobsite problems or special conditions for entry, pouring, cleaning, or exit.

The following list includes jobsite conditions that should be considered prior to making a pour:

- Designate a clean-out area
- Verify truck access to chute pouring setups
- Allow room for truck positioning, maneuvering, and turning
- Make sure soil is stable for haul route and exit
- If the site surface is questionable for travel, make provision for towing or pulling
- Remove trash and debris that might be in the way of the trucks
- Make sure the necessary placement crew is present
- Make sure someone is designated to direct trucks or traffic if necessary
- Verify pumping equipment schedule and operation
- Provide a tire wash pit, if necessary

Trucks should be scheduled to avoid more than a 20-min pause in pumping during warm weather. If this happens, the pump line may have to be cleaned and the truck re-primed.

Figure 8.6 labels the parts of a typical rear-dump concrete truck. The dumping chute will extend approximately 10′–12′.

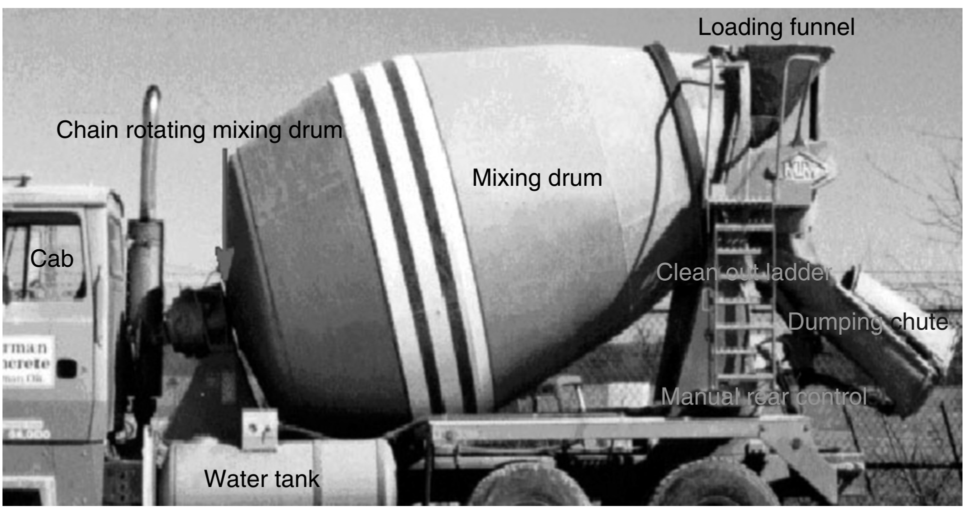

FIGURE 8.6 Concrete truck parts.

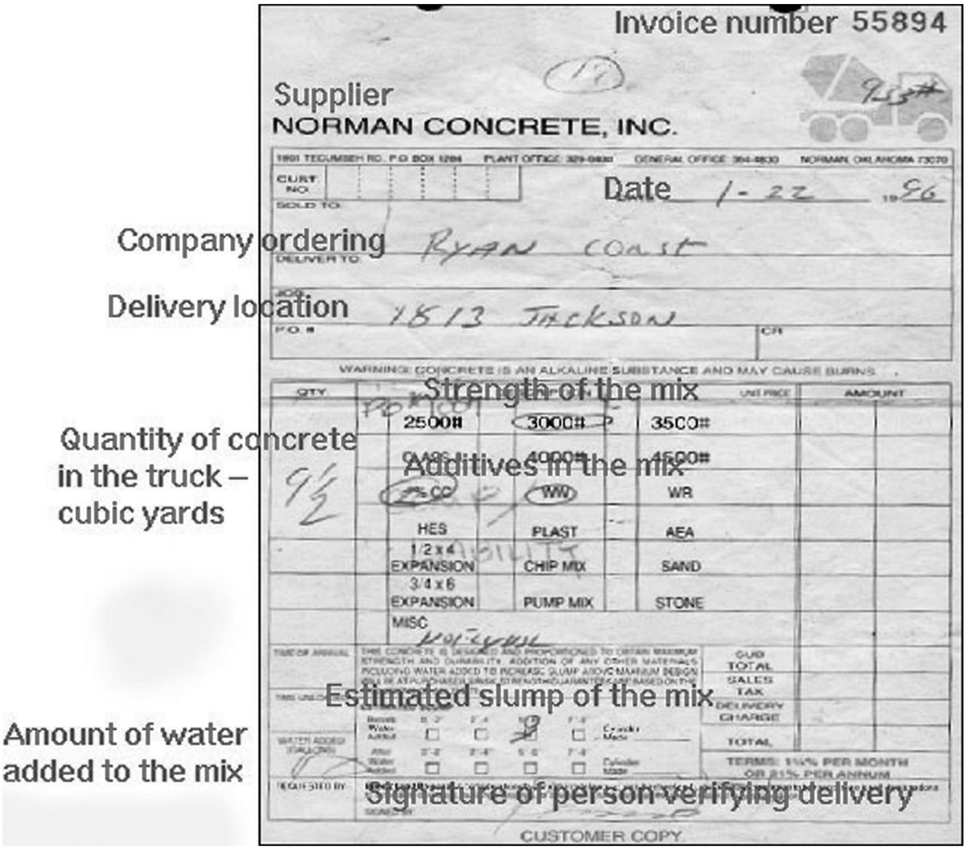

FIGURE 8.7 Concrete delivery invoice.

Figure 8.7 shows a typical concrete invoice. The truck driver retains a signed copy to verify the composition of the batch, how much water was added, and that the load was received. The field person monitoring the pour should keep copies of the delivery slips to verify the batch design and billing.

8.6 TOWER CRANE ERECTION AND DISMANTLING

A configuration of cranes with different capacities, heights, and radiuses may be used depending on the size of the buildings under construction and the desired lifting production. Most construction companies lease tower cranes from suppliers and erectors. This reduces the contractor's liability and provides expertise necessary for erection, maintenance, and dismantling. Personnel are typically certified by the crane erection company and they handle most erections and dismantling done by the company. The crane is usually transported to the site using semitrucks and trailers. Delivery, unloading, and storage of the crane parts during erection should be in close proximity to the crane location. The supplier unloads, erects, tests, and certifies the crane erection and readiness. Figure 8.8 shows concrete block used to test load and calibrate a tower crane.

If maintenance or testing is required, the supplier typically does this during the lease period. An engineer employed or retained by the crane erection company typically certifies

FIGURE 8.8 Test blocks.

the crane foundation or structural connection required for the selected crane. Site restrictions such as electric power lines, air space, public access areas, or other hazardous systems must be recorded and considered. An anemometer must be mounted on the crane and readable by the operator from the cab. Tower crane operations typically stop if the wind is over 23–25 mph.

Average installation and dismantling can cost up to $60,000 depending on the size of the crane and transport requirements. This price includes shipping the crane to the site, providing the mobile crane used to assemble the tower crane, the erection crew, and testing and certifications. A typical monthly fee for a 150-ft-tall tower crane is approximately $15,000. Lease cost will vary depending on the supplier, crane type, size, and capacity.

The erecting order for a tower crane is the opposite of the dismantling order shown in the included series of figures. The time to assemble is about the same as the time to dismantle. Tower crane erection and dismantling takes about 10 to 16 h. The height of the tower and length of the jib determine how many pieces must be erected and dismantled. Typically the more pieces, the greater the time required. How much space is available for lay down of dismantled parts will determine how many times riggers have to come down off the tower to load components on semis for transport from the jobsite. If there is minimal lay down space, the process will be slower or two crews may be required — one on the crane and one on the ground. A typical erection and dismantling crew will have five to eight riggers depending on the type of crane, support equipment, and working conditions.

Time required to hook-up electrical power to the crane is variable. Rough-in should be done so that minimal hook-up time at the base is necessary during erection. Running power cables on the crane is dependent on crane type, size, configuration, and how the pieces come prepared.

Figure 8.9 shows steel beam sections welded together to the base of the first tower section. This section is positioned and leveled on a footing as shown in Figure 8.10 and then concrete is poured around embeds to secure the base of the tower. Base foundation preparation should be complete when the first tower section arrives so that it can be installed. Depending on the complexity of the base required, time should be allocated for excavation, pier or footing installation, tower base preparation, rebar, and concrete placement.

Figure 8.11 shows a tower crane with the first tower section embedded in concrete. The base is protected by a 2×4 wood rail. The ladder that the operator must take up or down the tower is surrounded by a cage starting about 3′ off of the ground and running up the middle of the tower.

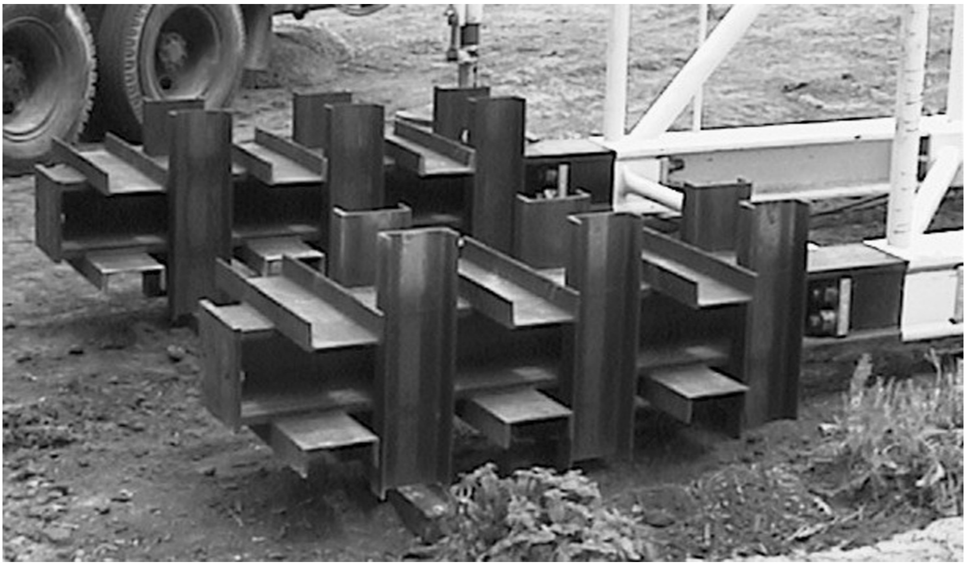

FIGURE 8.9 Embeds.

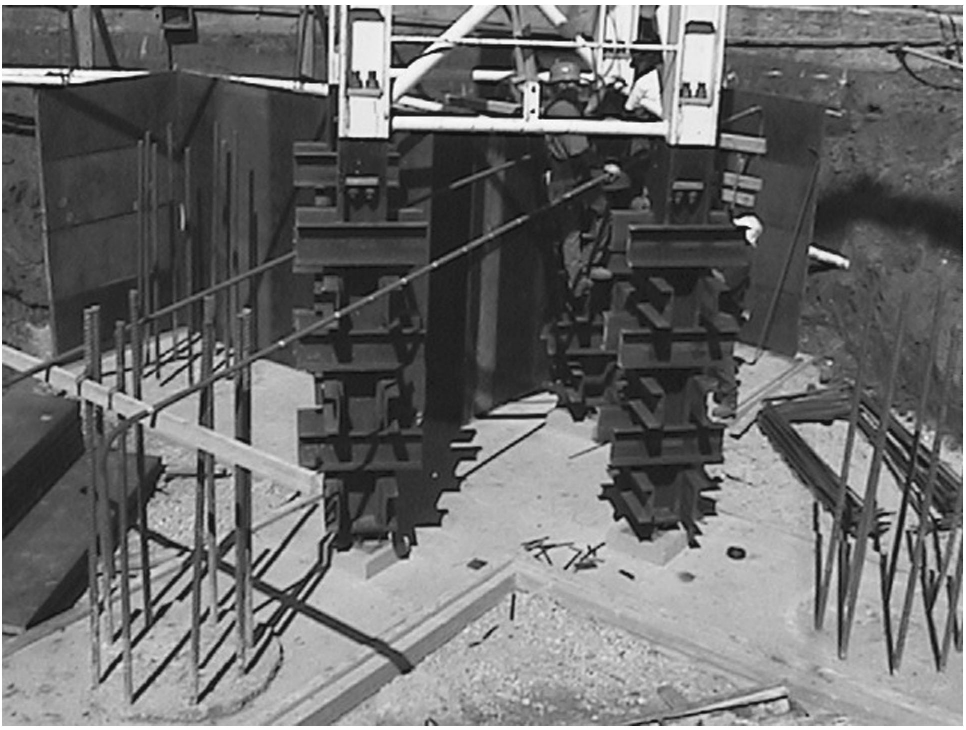

FIGURE 8.10 Tower base prior to pour.

FIGURE 8.11 Tower base.

Typically prior to erecting or dismantling a meeting is held at the jobsite. The representative or inspector from the crane owner or supplier is present along with the Project Superintendent, the crew of riggers, and other required personnel and equipment operators. Personnel responsibilities such as rigging points, the erection or dismantle sequence, required support equipment, and site considerations are discussed. All riggers are typically trained and certified by the crane supplier to work on their cranes.

The support crane capacity, ground location, condition of the setup points, and number of setups is critical in the strategy. Typically this crane is used for unloading, lifting, and holding parts until they are secured. The same must be done for dismantling parts for haul-off. Each support crane setup (extending outriggers, placing pads, and leveling the crane) takes approximately 45 to 60 min. Tractor trailer access and spotting for haul-off in relationship to the cranes working radius must be determined. Ground locations for setting detached components must be determined relative to the support crane location and loading. The horizontal jib tower crane in Figure 8.12 was used to construct a campus building. This crane had a hook height of 180′4″ and a jib length of about 140′.

The first time the riggers are on the crane to start the dismantling process, the following work is done:

- The hoist cable and trolley are disassembled and stowed.
- The counterweights are removed.
- The pendants holding the jib tip sections are released and collapsed (those supported by the intermediate gantry).
- The intermediate gantry is removed.
- The first four jib tip sections are removed (typically two at a time).

FIGURE 8.12 Horizontal jib tower crane.

During erecting and dismantling, while the crane is operable, the tower crane operator positions the jib or counterdeck at the most convenient angle for rigging, disconnection, and removal. The best orientation is determined by the location and coverage area of the support crane.

FIGURE 8.13 First semiload.

Figure 8.13 shows the first semiload to be hauled from the site. Typically this load will include cables, pendants, counterweights, and part of the jib. Note the use of an adjacent dead end street that could be barricaded as the loading area. Trucks can back into position, be loaded by the support crane, and pull straight out of the site. Sometimes the pieces of the tower crane might be set on the ground temporarily until the support crane can be moved closer to the trucks hauling the parts.

Figure 8.14 shows a 200-ton, 260′ boom support crawler crane beside the tower. The riggers are off the tower and loading the truck with the removed jib sections, counterweights, and other parts. The tower is still able to slew. The crawler must be moved to reach the rest of the tower.

Figure 8.15 shows the remaining sections after the first two jib sections are removed. The crane has rotated into position for continued dismantling. Figure 8.16 shows the support crawler moved closer to reduce the operating radius. It must be on a stable surface. The forklift is used to move the outrigger pallets into position. Outriggers are then extended on the each side and the crane is leveled. Figure 8.17 shows the riggers back up on the crane (at top of towertop). They are releasing and collapsing the pendants on the jib side.

The pendants are collapsed and secured on the last jib section after the rigging is secured. Figure 8.18 shows the jib section disconnected from the towertop. The jib section (actually two sections) is released from the tower, swung away, and lowered to the ground. The tower crane is still operable. Figure 8.19 shows the counterdeck section rotated into position so it is

FIGURE 8.14 Support crane.

FIGURE 8.15 Two jib sections dismantled.

FIGURE 8.16 Support crane move.

FIGURE 8.17 Riggers on the crane.

FIGURE 8.18 Disconnecting the remaining jib.

FIGURE 8.19 Positioning the counterdeck.

at the best location for rigging and hoisting by the support crane. Figure 8.20 shows riggers unbolting the power supply and motor. They are then rigged, lifted, and lowered to the ground.

After this step, the crane is no longer operable. As shown in Figure 8.21 the counterdeck is rigged, unbolted, swung clear of the tower, and lowered to the ground. As shown in Figure 8.22, the counterdeck is lowered to the ground. Note the rigger on the end of the tag line. The towertop is unbolted, swung clear, and lowered to the ground as shown in Figure 8.23.

Figure 8.24 shows the remaining cab, turntable, and tower. The cab and turntable are the heaviest part of this crane weighing about 35,000 lbs. As shown in Figure 8.25 the cab is disconnected, swung free, and lowered to the ground, leaving the tower standing in Figure 8.26.

Due to limited lay down area, the riggers come down off the tower to load the dismantled components on the ground onto waiting trucks. When this is complete they mount the tower for the last time, rig the first two sections from the top and release the connectors. The sections are swung free and lowered to the ground. This is done until the tower base section is all that is

FIGURE 8.20 Removing the motor.

FIGURE 8.21 Dismantling the counterdeck.

FIGURE 8.22 Lowering the counterdeck.

FIGURE 8.23 Flying the towertop.

FIGURE 8.24 Tower and cab.

FIGURE 8.25 Flying the cab.

FIGURE 8.26 Cab on ground.

left. If the tower base is embedded in concrete, the section is cut free and scrapped. The concrete tower base is typically covered by new construction or in some cases must be removed, resulting in extra expense. Foundation removal is typically done by the project contractor.

REFERENCES

1. D.E. Dickie. *Mobile Crane Manual*. Toronto: Construction Safety Association of Ontario, 1982.
2. K.E. Eckardstein. *Pumping Concrete and Concrete Pumps*. Schwing, Ed. Herne, Germany: GmbH, 1983.

9 The Buy, Lease, or Rent Decision

9.1 INTRODUCTION

When commercial manufacturing of heavy construction equipment began, the primary way to acquire a new piece of equipment was outright purchase. Players in the construction industry typically were wealthy and filled all of the primary roles — owner, designer, and contractor. Without credit and financing, heavy equipment purchase probably would be limited today, much like it was in the late 1800s. The proliferation of diverse equipment manufacturers around the world has spawned great competition, not just for the purchase price of the equipment, but financing, terms of use, and method of payment.

9.2 ACQUIRING HEAVY EQUIPMENT

In the current construction marketplace, equipment manufacturers, used equipment brokers, and rental companies provide a means for a user with proper credentials and competence to acquire just about any heavy construction machine available on a temporary or permanent basis. There are numerous options to consider when deciding on heavy equipment acquisition and financing. Traditionally, the equipment purchase process was complete when the contractor selected a specific make and model of machine from a dealer. The buyer received financing with a down payment, often the trade-in of an older piece of equipment. The new piece of equipment was the loan security. If the contractor defaulted on loan, then the lender could repossess the equipment. This acquisition process today includes numerous financing options and scenarios that banks, finance companies, leasing agencies, and manufacturers offer. All major heavy construction equipment manufacturers offer a number of creative leasing, renting, and installment loan products.

The equipment rental industry has leveled the playing field for contractors by minimizing the risk associated with equipment purchase and utilization. Renting or leasing appropriate equipment greatly increases the type and size of the projects that contractors and subcontractors can bid and execute. Contractors bid jobs today knowing they will rent every piece of heavy equipment used on the project or subcontract any work requiring heavy equipment.

The used equipment in the industry also provides a convenient means for equipment to be acquired. The use of the Internet for advertising and procurement is growing. Online equipment procurement sites are gaining popularity among contractors. E-mails are "used" for equipment advertisements, which include operating specifications, work history, operating condition, and pictures of the actual piece of the equipment. This is an easy and economical way to reach a large audience of potential equipment buyers.

The primary consideration in the buy, lease, or rent decision is the amount of risk the equipment user wishes to assume. This risk is typically associated with financial considerations.

The evaluation of this risk makes equipment acquisition an important managerial concern. It is advisable to consult an accountant prior to purchase of equipment to evaluate cash flow and tax implications. Along with these financial considerations, how much the equipment is to be utilized is the most important consideration for return on investment. Future work volume, production needs, project-specific or client requirements, long-term company goals, acquisition time, and equipment availability must be considered when developing a utilization strategy for a piece or fleet of the equipment.

For this reason, subcontracting small parts of the work that are equipment intensive minimizes risk and is typically most efficient. Ownership of a particular type or types of equipment, combined with expertise and experience, makes specialty subcontractors cost-efficient and minimizes the risk for the contractor. Specialty subcontractors such as dirt work, excavation or demolition and hauling, concrete pumping, and soil and concrete boring are common today. Subcontracting the work removes most equipment responsibilities from the contractor.

In the 30th Annual CIT Group Construction Industry forecast for the year 2006, contractors polled favouring their own equipment but expect to meet 16% of their 2006 equipment needs with leased or rented equipment [3]. Whether renting, leasing, or owning, the equipment must pay for itself by earning more money than it costs. The ability to do this is greatly influenced by keeping the piece or group of equipment busy. Sustained profitability using standard equipment typically demands continual equipment utilization. The ability to do this is typically market driven and influenced by the overall business strategy of the company. Simply stated, equipment that is not operating is not making money. This places a tremendous responsibility on the equipment-intensive civil or road building contractors who own large fleets of equipment to stay busy. To further compound the risk, heavy construction equipment typically does not appreciate in value, but requires more maintenance with age and wear and has a limited useful life.

9.3 FINANCING METHODS

In today's marketplace, there are four primary methods used to finance the purchase of construction equipment: conventional financing purchase, the financial lease agreement, the tax lease agreement, and the rental purchase (rent-to-own) agreement. It is a good idea to explore all the financing options to determine which is most suitable. It simply may not make sense to purchase equipment with large amounts of cash that can be used for other opportunities. If the best solution cannot be determined with the help of the equipment dealer's financial representative, then a financial professional should be consulted. An analysis should be done, taking into account a number of company-specific variables to compare leasing and purchasing scenarios. In order to perform this analysis, the consultant will need to make certain assumptions or projections concerning company operating guidelines or desired financial goals. This analysis will typically include, but is not limited to:

- Working capital constraints — actual and desired
- Desired tax benefits — actual and desired
- Balance sheet objectives or financial goals — actual and desired
- Cash flow requirements — actual and desired
- Equipment obsolescence and ultimate replacement strategy
- Equipment utilization — actual and desired
- Opportunity cost
- Investment strategy goals

9.3.1 Outright Cash Purchase

Putting tax and other considerations aside, an outright cash purchase with funds provided from working capital is the least cost method of acquiring needed equipment when funds are available. Service fees, finance charges, and interest expense are eliminated for the buyer. Ownership is immediate, and equipment cost is shown on the balance sheet subject to the depreciation methods used by the customer. Although outright purchase may provide the lowest total cost, other factors should also be considered. The reason most contractors choose to finance their equipment purchases is that outright purchasing is not necessarily a good decision. There is a financial impact of increasing the assets on the contractor's balance sheet. Outright purchase converts a liquid asset (cash) into a fixed asset (equipment). Large "out-of-pocket" purchases can be detrimental to cash flow, dramatically reduce working capital, and increase opportunity cost.

9.3.2 Conventional Financing Purchase

Most contractors are not able to own construction equipment without debt and build equity in it over time. Most times, financial constraints make outright cash purchase of equipment impossible or impractical. Conventional purchase financing provides the contractor with the capital required to make the purchase through loan arrangements secured by accounts receivable, own equity in the equipment, and use the equipment to collateralize the loan. Trade-ins or down payments are included in the financial agreement for most of the cases. Installment sales contracts allow the contractor to purchase the equipment and pay for it over a period of time. Installment loans offer many of the same general advantages offered by other financing instruments, primarily in terms of cash flow advantages and lower payments than with outright purchase. However, installment loan financing provides the depreciation and tax benefits of ownership. Installment loans are ideal for users desiring immediate equipment ownership with payment extending over a period of time. Most heavy equipment dealers will finance new equipment up to 60 months, with longer terms available under special conditions. Finance terms for used equipment usually run up to 48 months, depending on the equipment and work conditions. Contractors who prefer paying for equipment using installment loans generally have a more stable predictable work load than those who lease. A general rule of thumb for fleets that utilize equipment over a longer life (more than 7 years) is to purchase equipment rather than exercise lease or rental alternatives.

Another consideration for ownership relates to a contractor's working conditions and maintenance program. Leased or rented equipment must be maintained to certain standards that may be difficult for the contractor utilizing equipment in harsh working conditions. The contractor may have to pay for extensive overhauls of major components or cosmetic repairs (paint, glass, tires, etc.) when leased or rented equipment is returned. According to Cudworth, the following features may make purchasing an attractive alternative [5]:

1. *Use and possession*: The owner has absolute control of the use and disposition of the equipment.
2. *Flexibility*: The owner can sell the equipment, trade it, or use it until it is not economical to repair without having to respond to any creditor. Ownership gives the user complete flexibility regarding servicing, maintaining, and insuring the equipment.
3. *Price*: The buyer with cash is usually able to get better discounts due to a stronger financial position in the deal.
4. *Tax benefits*: The owner can take advantage of depreciation and interest tax benefits associated with equipment ownership.
5. *Pride of ownership*: Ownership can lead to better care and maintenance.

The purchase option for equipment acquisition generally becomes more economically attractive if there is a high utilization rate throughout the useful life of the equipment. This point is extremely important, because the inability to use the machine enough to pay for its cost is the greatest risk and disadvantage of purchasing. Whether the equipment is working or not, the owner's financial obligation to the lender continues. Borrowing large sums of money is sometimes necessary to purchase large heavy equipment tieing up company capital and borrowing power. If the machine's working capabilities are limited, the types of work activities that can be undertaken by the machine are limited. This is not necessarily a disadvantage, but a limitation. Many construction activities are redundant and similar each time therefore the same machine can be used. Other responsibilities (not necessarily disadvantages, unless mismanaged) of owning include licenses, proper registration, all associated paperwork, insurance, maintenance, transport, storage, and provision of a qualified operator. All of these requirements of equipment ownership have to be managed, tracked, and controlled. The administration of equipment management costs should be included in the charge for use of the equipment.

9.3.3 Leasing

Over the past several years there has been an increasing trend toward leasing as a way to finance construction equipment. It is usually easier to gain financial approval for equipment under a lease program than through conventional purchase financing. In its simplest form, an equipment lease is simply a rental agreement. Rent is paid for the equipment during the rental period. Once the agreement is over, the equipment is returned to the owner. In a true lease, the lease payments are considered an expense of the lessee. The lessee does not own the equipment and it is not shown as an asset on financial statements. The most significant factor that affects the decision of renting or leasing is the duration of time the equipment will be required. Leasing is often considered more favorable when the equipment is needed for more than 6 months. Most leases run from 18 to 24 months. For large expensive equipment, leases can run as long as 84 months.

Leasing arrangements are a form of finance in which an asset is acquired by a third party, usually a bank, finance company, or dealer and then leased to the end user for a predetermined agreed upon period of time. This arrangement means the leasing party never actually has title to the asset for the term of the lease, although it is allowed to use the asset during that time. In the usual capital equipment lease, the term of the lease will equal the operating life of the asset and the repayments will be geared to the cost of the asset spread over that time, plus a profit margin for the lessor. Leasing does not have an impact on a company's current or debt-to-worth ratios, thus showing a more positive financial condition for bonding purposes. Leasing encourages a more orderly planned equipment replacement strategy, minimizing maintenance costs before they become excessive. Leasing also eliminates used equipment disposal or resale for the user.

Construction equipment leasing allows for more flexibility dealing with cyclical and regional fluctuations at a work level. Many leasing companies offer seasonal leases called skip leases that allow the user to schedule payments during busiest months, thus reducing cash flow concerns during seasonal periods when work is low. Step-up leases start with smaller payments that increase over time, allowing the user to generate revenue while initial payments are lower. Deferred payment leases allow the user to defer initial payments until cash flow is started.

There are two types of common equipment leases offered by most equipment dealers. The finance lease is a lease that allows the contractor to make lease payments over a period of time and purchase the machine for a bargain purchase or mandatory amount at the end of the lease term. The lessee typically retains the tax benefits. The term for new equipment ranges between 12 and 60 months.

With Caterpillar's "Finance Lease Option Plan (FLOP)" the lessee can obtain 100% financing with a fixed finance rate. The lessee has the option of purchasing the piece of equipment for a predetermined amount or returning the piece of equipment at the end of the lease. Payments can be made monthly, quarterly, semiannually, or annually depending on the qualifications of the lessee. Monthly payments can be set up lower than traditional financing. [2].

The tax lease typically offers a lower monthly payment than a finance lease. At the end of the lease term, the contractor has three options: buy the equipment at a fair market value, extend the lease for a new fixed term or month-to-month basis, or return the equipment to the dealer.

Caterpillar has two tax lease options available. The "Tax Lease — Long Term Rental" or "Fair Market Value (FMV) Lease" can provide the lowest payments to the lessee. This lease generally qualifies for off-balance sheet financing, freeing the working capital for operating needs. Typically the lessee plans to return the equipment to the dealer at the end of the lease. With this approach at the end of the lease term the machine may be purchased for fair market value. The FMV is indirectly influenced by the condition of the market at the end of the lease term along with the machine specification, usage, and finance term. If demand for equipment is high, the FMV will be higher than if there is not strong demand [2].

The "Cat Value Option (CVO) Lease" is similar to the FMV option with most of the same advantages and considerations. The major difference is that at the end of the lease term the lessee may purchase the equipment at a predetermined FMV or return it to the dealer. This approach removes market uncertainty, but can be unfavorable if the market is weak and the predetermined value if higher than current FMV [2].

Lease pricing varies among lessors. Pricing is influenced by the lessor's ability to acquire equipment at discounts, financing, calculation of risk factors, assignment of residual value, desired rate of return based on the market and expenses to carry out the lease transaction and operation. All of these factors are driven by market supply and demand.

According to Fetridge and MacManamy, many factors make leasing an attractive financing solution for the lessee. The following are advantages of leasing [6, 7]:

1. *Lower rates and lessee cannot claim tax benefits*. When the lessee cannot take advantage of tax benefits associated with equipment ownership, such as depreciation and interest, the leasing is more attractive. The lessor can purchase the equipment, claim the tax benefits, and lease the equipment to the lessee. The tax benefits are passed to the lessee in the form of lower lease rates.
2. *Cash flow improvement*. Compared with a loan, a lease typically gives the lessee a more favorable cash flow, especially during the first years of use.
3. *Carry on off-balance sheet for financial accounting purposes*. The lessor assumes title to the equipment with interest expense capitalized into the lease when the equipment is delivered and accepted by the lessee.
4. *Impact on lessee's income*. During the early years of a properly structured lease usually there is less effect on income depreciation and interest payments related to the purchase of the equipment.
5. *Fixed-rate lease payments*. The lessee can know the exact amount of future payments and avoid the risks inherent in fluctuations in the cost of funds. By knowing this amount information, the lessee can predict future financing equipment costs and cash needs more accurately.

6. *Faster amortization of the equipment*. The lessee under an operating lease may be able to amortize the cost of the equipment faster through tax-deductible rentals than through depreciation and after tax cash flow.
7. *Hedge against inflation*. Future lease rentals are paid in inflated currency. The lessor (bank) can borrow long to minimize the effect of inflation and pass on this protection to the lessee in the form of long-term level lease payments.
8. *Payments coordinated with lessee's cash flow*. Payment schedules can be coordinated with earnings generated from the use of the equipment by the lessee. This flexibility may not be available with other financing methods.
9. *Long-term financial availability*. Leases can be structured for most of the useful life of the equipment. The lease contract can exceed the period of time normally available on a term loan. Lessors can offer lease terms due to faster return of capital from cash flow generated by tax benefits.
10. *Convenience*. For leasing contracts below $5 million, documentation may be simpler and more flexible than other sources of financing.
11. *Full financing*. Leasing can provide the lessee 100% financing. The amount can include shipping and installation charges. A typical equipment loan may require an initial down payment.
12. *Earnings from the retained capital*. A lease allows retentions of lessee's capital that can be used elsewhere in the lessee's business.
13. *Obsolescence*. Leasing avoids equipment obsolescence for the lessee. If equipment becomes obsolete faster than its depreciation life, leasing may be more attractive.
14. *Uncertain residual value*. The more risk associated with the residual value of the equipment, the more attractive leasing becomes.

Leasing is ideal for acquisition of equipment for long-term use and ultimate purchase. Disadvantages are limited. The reputation and the reliability of the lessor and terms of the lease agreement should be verified prior to entering into a lease. There are many types of leases and conditions can vary based on the market or the lessor. In some instances the total sum of all leasing rates can reach a total amount greater than the cost of the new equipment.

9.3.4 Renting

Renting is gaining popularity as an option for contractors when it comes to acquiring equipment. In CIT's 2006 Construction Industry Forecast, respondents as in the past, cited limited need for the equipment as the primary reason for renting [3]. The forecast highlights that as equipment fleets grow older, more contractors are finding it necessary to use rental equipment to back up the equipment they own.

The most obvious disadvantage of straight-out equipment rental is that there is no option for accruing equity. Equipment rental has no impact on the balance sheet. It does, however, impact cash out-of-pocket. Rental payments reduce the company's earnings as an operating expense and since the equipment is not owned, there is no impact on depreciation. Dealer equipment rental programs offer many of the same advantages or benefits of lease programs. The contract period for rental provides complete flexibility, with contract periods as brief as a day or a week or as long as a month or a year.

One of the greatest risks any business can incur is that of having a large portion of its capital tied up in nonproductive assets. Construction equipment sitting idle in a yard or warehouse still demands outlays for insurance and maintenance, and depreciation may continue just about as fast as if the equipment were working. Most contractors rent approximately 25% of their total equipment requirements. This follows an 80/20 balance for equipment specification and purchase. A contractor purchases or leases equipment that is appropriate for 80% of the work performed and rent for the other 20% of the work.

Most rental companies calculate their rates on a monthly basis. Weekly rates are usually about three times the daily rates. Similarly, monthly rates equal about three times the weekly rates. To have some idea of the prevailing rates, there are several sources of rate information.

- *Associated Equipment Distributors (AED) Green Book*. The AED is the trade association of leading distributors and manufacturers of the construction equipment. Average rental rates for the equipment are listed according to their general characteristics and function.
- *Rental Rate Blue Book for Construction Equipment*. This book lists the average rental rate for equipment and tools nationwide. Equipment is listed by function and model. The book also has a correlation index to adjust for location and equipment age.
- R.S. Means' *Building Construction Cost Data*.
- Rates from local equipment suppliers and rental services.

On an hourly basis, renting is typically the most expensive of the three acquisition solutions. However, it is ideal for work activities not performed on a regular the basis, because it minimizes idle time for seldom-used equipment. Renting is the best solution when equipment will be utilized for a short duration. The American Rental Association [1] suggests the following advantages for renting equipment:

1. *Minimum equipment for the job*. Equipment ownership becomes particularly expensive when the equipment is idle and not utilized. When ownership of the basic equipment is combined with rental as needed, idle time is minimized.
2. *Right equipment for the job*. Ownership encourages inefficiency through use of wrong size or type of equipment for a given job. Renting can minimize this hidden cost.
3. *Warehousing or storage*. Warehousing facilities are seldom needed for rental equipment, thus reducing overhead.
4. *Breakdowns*. The rental service will typically replace equipment if there is a breakdown, thus minimizing downtime due to repairs.
5. *Maintenance*. Full maintenance is covered on a day-to-day basis. The user needs no repair shop, no spare parts supply, no mechanics, and no maintenance records.
6. *Equipment obsolescence*. The rental service may provide the latest types and models of equipment that are faster and more productive than the older models.
7. *Disposal cost*. Selling used and obsolete equipment is not required.
8. *Cost control*. Cost is easier to monitor and control with rented equipment. The true cost of an owned equipment is often difficult to determine.
9. *Inventory control*. Contractors have less inventory loss when equipment is rented. The presence of continuous billing on any rented item tends to establish accountability for that item.
10. *Taxes and licenses*. Personal property taxes and license costs are eliminated on rented equipment. Leasing cost is 100% deductible.
11. *Conservation of capital*. The lessees' capital is available for other uses or investment. Contractors should analyze cash requirements and consider renting equipment as a method of conserving working capital.
12. *Increase in borrowing capacity*. Rented equipment does not result in a liability on the balance sheet. Debt ratios will improve, making the lessee firm seem stronger financially.

13. *Cost estimating and bid preparation*. Renting can increase estimating accuracy because all repair and downtime costs become more predictable.
14. *Short-term jobs*. Renting is the most economical solution for short-term and specialty jobs.
15. *Transportation costs*. Renting is the best way to avoid transporting equipment from project to project, thus reducing transportation costs. This is especially beneficial when dealing with heavy equipment requiring special hauling equipment.
16. *Equipment testing*. Allows use of equipment in the field without purchase, leading to a better understanding of equipment capabilities and suitability for the work.

The greatest disadvantage of renting is the resultant higher unit cost to perform the work. Typically the hourly rental rate is more than the lease or ownership rate. Higher unit cost will typically result in a less competitive estimate when bidding against someone who owns their equipment.

9.3.5 Rent-to-Own (Rental Purchase)

Rent-to-own for 1- to 2-year projects with high equipment utilization is a good approach if the user is uncertain about the need for the equipment after the completion of the project. The rent-to-own option can be an attractive alternative to an outright purchase for several reasons. Rent-to-own gives the contractor the opportunity to build a down payment via the application of rental payments toward the purchase price of the equipment. This allows the equipment to begin generating cash toward its purchase. It gives the contractor a trial period to see how the equipment works and a chance to verify its need for future work.

9.4 EQUIPMENT FINANCING COMPARISON

Table 9.1 and Table 9.2 compare the four basic means of equipment financing. The tables are adapted from the information provided by Caterpillar Financial Services Corporation [2].

9.4.1 Acquisition Comparison

The following comparison is based on a discussion with a financial representative from one of the Caterpillar dealers [10]. It is assumed that the user has evaluated all the work and company considerations prior to seeking acquisition. Typically the potential user will meet with a salesman prior to meeting the financial representative. It is the job of the financial representative to verify the user's needs and match them to the best acquisition option. In this

TABLE 9.1
Comparison of Financial Methods

Finance Method	Ownership	Tax Benefits	Equity Accumulation	Payment	Payout at Lease Termination
Installment sale	Immediate	Contractor	Fastest	Highest	N/A[a]
Finance lease	Payout at lease termination	Contractor	Slower	Low	Discounted cost
Tax lease	Payout at lease termination	Financier	None	Lower	Premium cost
Rent-to-own	Payout at lease termination	Financier	None	Lowest	Fair market value

[a]N/A, not applicable.

TABLE 9.2
Advantages of Financial Methods

Installment sale	Contractor owns and depreciates Contractor builds equity fastest Contractor has contractual flexibility
Finance lease	Predetermined purchase amount Monthly payments lower than purchase financing Lessee has rights to the depreciation Slow equity accumulation
Tax lease	Optional ownership Low flexible monthly payments No equity accumulation
Rent-to-own	Optional ownership Lowest monthly payments Lessee treats unit as a rental

example, a contractor needs a Caterpillar D6R bulldozer. The finance amount for the D6 is $290,000. The contractor estimates about 1500 h of use each year. The interest rate is 7.85% and the term is 60 months. Insurance for the D6 is adjusted for the option plan. Table 9.3 shows projected financial amounts for different finance options available through Caterpillar. Based on this situation, the FMV and CVO plans are very close and yield the lowest monthly payment. The primary difference between these two alternatives is the purchase option at the end of the lease term [10].

9.5 RENTAL AND LEASE CONTRACT CONSIDERATIONS

Typically the rental terms are agreed upon, documented, and signed prior to delivery and use of the machine. The following discussion is based on the general characteristics found in the construction equipment rental industry. These issues and corresponding values will vary according to the terms of the particular rental agreement. According to Park and Dale, the general characteristics or clauses that are included in every rental contract are as follows [9]:

1. *Time basis of the rate*. The basis for rental rates is usually a single shift of 8 h per day, 40 h per week, or 176 h per month for a consecutive 30-day period. Many distributors

TABLE 9.3
Acquisition Options and Dollar Amounts

Acquisition Option	Finance Amount	Rate	Payment	Insurance/ Month	Purchase Option
Rent	N/A[a]	N/A[a]	7,500	N/A[a]	N/A[a]
Installment sale	290,000	7.85%	5,859	352	N/A[a]
Finance lease — FLOP	290,000	7.85%	4,917	352	68,960
Tax lease — FMV	290,000	7.85%	4,544	346	FMV
Tax lease — CVO	290,000	7.85%	4,590	348	87,924

[a]N/A, not applicable.

do not rent their equipment by the day or the week, particularly for large equipment. If the equipment will work more than one shift per term, the rate usually increases by 50% for each additional shift.

2. *Rental period*. The rental period usually begins when the equipment leaves the equipment owner's warehouse and ends when it is returned to the same location. For out-of-town shipments, the rental period starts on the date of the bill of lading (a list of goods received for transportation) of shipment and ends on the return date of bill of lading.
3. *Payment procedures and insurance*. Rental payments may be payable in advance or in instalments depending upon the terms and conditions of the rental agreement. The contractor's credit history and bargaining power can have a considerable impact on the payment requirements. It is common for the lessee to provide all insurance coverage.
4. *Normal wear and tear*. Normal wear and tear is defined as the deterioration resulting from the use of equipment under normal circumstances, provided that the equipment is properly maintained and serviced. This clause considers who is responsible for repair and maintenance of the equipment and payment for those services. This issue should be addressed at the time of rental in order to prevent misunderstanding and problems.
5. *Fuel and lubricants*. The lessee usually provides all wearable supplies, such as fuel and lubricants.
6. *Operators*. Operators and field specialists are generally not included in the rental rate. Their salaries and expenses are typically extra. If provided by the equipment owner, the operator should be trained and certified to operate the equipment if necessary.
7. *Freight charges*. The common practice is that the lessee pays for the freight charges from the shipping point to the destination and return. The lessee generally pays the additional charge when loading, unloading, dismantling, or assembling is required. Many suppliers add a surcharge based on the current price of fuel.
8. *Condition of equipment*. The equipment is to be returned in the same condition it was in at the time of delivery except for normal wear and tear. The lessee usually is responsible to pay clean up charges for excessively dirty equipment.
9. *Cancellation and extension of contracts*. These clauses outline the user's privilege to cancel the contract, term extensions, and the result of late payment.

The basic agreement between lessor and lessee may include many different conditions and provisions. The variation of these provisions depends on the capacity of the parties and the potential implications for tax treatment. The following is a detailed checklist of items that should be addressed in a rental or lease agreement. This information was extracted from the publication titled *Equipment Leasing for Commercial Bankers* and represents the basic considerations regarding lease documentation from a bank officer's point of view [8].

1. Identification of both lessee and lessor
2. Identification of equipment, attachments, or accessories by make, model, serial number, and hour meter reading if appropriate
3. Lease or rental period, including the start and end dates, duration, use location, and any rental or lease period extension provisions
4. Payment or rate including the actual dollar rate per unit of time, date of initial, and periodic payments, payment location, deferred payment, deposits, nonpayment periods, payment for partial periods, and penalties or interest
5. Loading, unloading, and transportation responsibilities, inspections, compliance, and special provisions

6. Assumption of operation, repair and maintenance responsibilities, and payment, including notification of the lessor and field inspections for major repairs or component replacement
7. Proof of required permits, insurance and bonds for transport, assembly, and use
8. Indemnity and "hold harmless" clauses and provisions
9. Specification of ownership or title to the equipment or terms for transfer
10. Subletting, use by other parties or movement of equipment from the authorized location without the expressed permission of the lessor
11. Damage or misuse of definitions, repair provisions, "normal wear and tear" limitations, and return provisions and expectations for the equipment, tires and tracks, attachments, or accessories
12. Fuel, oil, grease, and filter replacement
13. Purchase option provisions such as time, deadlines, amount or rate, options, discounts, required paperwork, warranties, and other conditions if applicable
15. Arbitration rights and responsibilities
16. Termination of agreement conditions and financial obligations
17. Miscellaneous legal provisions or conditions regarding the contract

9.6 THE BUY, LEASE, OR RENT DECISION

Table 9.4 is adapted from Coombs and Palmer's book, *Construction Accounting and Financial Management* [4]. The table suggests the optimal approach for equipment acquisition based on customer needs or criteria.

As stated before, the buy, lease, or rent decision is most influenced by how long the equipment is needed. A short period of utilization favors renting and a longer period favors

TABLE 9.4
Customer Criteria for Equipment Acquisition

Customer Criteria	Cash Purchase	Finance Purchase	Lease	Rent
Wants ownership	×	×		
Optional ownership			×	
Use and return only				×
Off-balance sheet accounting			×	×
100% Financing		×	×	
Trade-in value	×	×		
Expense 100% of payments			×	×
Need tax write-off	×	×		
Lowest total cost (ownership)	×			
Lowest monthly payment (use)			×	
Uncertain future work			×	×
Avoid debt			×	×
Try out equipment			×	×
Improve cash flow			×	
Plan equipment replacement		×	×	×
Minimize equipment disposal concerns			×	×

leasing or purchase. Along with the discussed financial analysis and comparison there are many nonquantitative areas to be considered prior to the decision:

- Work volume
- Nature and types of construction projects
- Client requirements and expectations
- Reputation and company perception to potential clients
- Funding capabilities
- Long-term financial goals
- Relationship with equipment supplier
- Company ownership policy

A study of the acquisition and finance alternatives comes after identification of the need for a piece of equipment. This evaluation is a key component in the financial planning of the construction firm.

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10 Construction Equipment Maintenance

10.1 INTRODUCTION

One can accomplish all the detailed analysis that has been covered in the book so far to ensure that the right equipment is selected, the system has been optimized for production, and the appropriate estimating factors have been used, but when the machine breaks down, the production drops to zero and the equipment starts costing money to its owner rather than making money. Construction equipment maintenance programs generally consist of three major components: preventive maintenance, routine maintenance, and major repairs. If the first two programs are both aggressively applied and well managed, the major repair program is minimized, and even more importantly, the first two programs occur as scheduled under the owners' control whereas major repairs occur randomly and usually at times when they seem to create the most distress to the project. Thus, to understand effective construction equipment management, one must also understand effective construction equipment maintenance.

10.2 NEED FOR A MAINTENANCE PROGRAM

As would be expected in equipment-intensive projects, the major capital investment is for the equipment needed in the field. It constitutes a big percentage of the total project cost and as a consequence, the effectiveness of equipment management during project execution is a very important factor in project profitability [1]. Many factors affect the productivity of a machine. Weather, operator efficiency, and operating site conditions all have an impact and are often not possible for the project manager to control. However, the one truly controllable factor is machine availability. For this reason, equipment availability management, which is the primary goal of equipment maintenance, must be aggressively pursued based on a detailed maintenance program developed by the project managers. The specific details of an equipment maintenance program depend on various factors such as the size of the fleet, the type of the project, location, climatic conditions, and other factors, and each program must be customized for the project on which it will be used. However, the absence of a properly implemented maintenance program leads to premature equipment failure, potential cost overruns, and increased crew idle time due to the equipment awaiting repairs. Moreover, the percentage of the total operating cost used for repairs can reach 25% or more [1]. As a consequence, the quality of maintenance management is a significant factor affecting actual construction equipment ownership costs. Implementation of a detailed maintenance program can consistently lower the cost of operating the equipment contemplated in the estimate.

10.2.1 Types of Maintenance Programs

For purposes of this discussion, two types of equipment maintenance programs will be considered: unscheduled maintenance and planned or preventive maintenance. Unscheduled maintenance is performed to get the construction equipment that breaks down during the scheduled shift back to its working condition. The aim of this type of maintenance is to minimize equipment downtime after failure. This type of maintenance is not predictable. As a consequence, it is difficult to implement a rational unscheduled maintenance program. The equipment manager must trade off the cost of idle time for mechanics on the job waiting for a piece of equipment to repair versus the cost of an idle crew waiting for the mechanics to arrive at the job site. This type of maintenance is often called "reactive maintenance" because the manager must react to unprogrammed maintenance requirements, attempting to bring the tools, repair parts, and expertise together in a fashion which gets the broken machine up and running as quickly as possible. The alternative to constantly reacting to unpredictable equipment failure is to reduce them by implementing a sound preventive maintenance program on the job site.

The main objective of preventive maintenance (PM) main objective is to minimize unplanned equipment failure by devoting a regular period of time to inspecting the equipment and ensuring that minor problems are fixed before they can become major failures. It typically involves periodic inspection, lubrication, and replacement of worn parts, filters, oil as well as other equipment engine fluids. It is done with the view to extend the life of the engine parts by reducing wear, reducing incidents of equipment breakdown, and increasing the overall productivity of the equipment and associated crews by maximizing equipment availability. The term predictive maintenance has been used more recently to describe this type of approach. Predictive maintenance attempts to schedule maintenance tasks based on the past performance of engine parts so that parts are replaced just before they fail or begin to adversely influence engine performance. It is assumed that the future performance will be similar to past performance. It must be noted that the main goal of preventive and predictive maintenance is to reduce time and money spent on unscheduled maintenance.

10.3 DESIGNING THE MAINTENANCE PROGRAM

There are many factors involved in designing an effective maintenance program. They include the following:

- Clearly defining program objectives and goals
- Developing a good communication system
- Furnishing the proper maintenance organization
- Providing precise clarification of the maintenance procedures
- Maintaining complete control of the maintenance performance
- Active evaluation of maintenance results
- Strong upper management support

The most frequent cause of poor maintenance program execution is the failure to define the program effectively and to communicate goals to both consolidated maintenance facility and field mechanics. This section will consider six major factors that relate to designing a maintenance program:

1. Define objectives and goals
2. Establish responsibility and authority
3. Define actions to be taken
4. Establish control procedures

5. Establish financial control procedures
6. Provide feedback and performance indexes

10.3.1 Define Objectives and Goals

Maintenance objectives fall in two categories: the primary objective and the secondary objective [1, 2]. The primary objective of maintenance is the repair and upkeep of production equipment to ensure that it is kept in a safe and effective operating condition so that production targets can be met on time, in budget, and in good quality. The secondary objective of maintenance is to perform approved maintenance and repair work to the extent that such maintenance work does not reduce the planned operating hours per year upon which the equipments' hourly rental rates are predicated. Objectives help to ensure that the intended maintenance program can be carried out effectively. The fundamental objectives of a good planned maintenance program are as follows [1]:

- Eliminate unnecessary maintenance
- Reduce work cost
- Reduce overall maintenance cost
- Reduce repair parts inventory
- Reduce lost production caused by failure during normal shift
- Increase productivity
- Extend the operating life of construction equipment
- Increase overall profit generated by equipment

10.3.2 Establish Responsibility and Authority

The method of establishing responsibility and authority depends on the objectives of maintenance program. The four major types of organizational patterns for construction companies are the traditional organization, functional organization, disciplinary organization, and matrix organization. The responsibility and authority of personnel in the maintenance division are established based on the overall organization of the private construction company or the public agency. However, the organization structure should encourage working efficiency while facilitating communication and interaction. Its size depends on the characteristics of the project and the size of the company.

A small construction company or public agency requires only a few mechanics to be responsible for all the construction equipment because it has a small equipment fleet (up to 20) [3]. Figure 10.1 shows maintenance organization of small type. Rapp and George [3] call this a "function-grouped" maintenance organization because the equipment manager furnishes maintenance services to all the equipment used by the various trades in the organization. This makes sense in that the size of the organization and the types of projects it will undertake do not justify dedicated maintenance support on a project-by-project basis.

In a medium-sized construction company or public construction agency, there are increased types and sizes of equipment [3]. It is necessary to have an adequate number of mechanics to support specific production divisions within that organization. A production division will typically be led in the field by an area superintendent whose technical expertise is specific to the type of work the division is assigned. The equipment used in the division will tend to be similar, and thus the mechanics will be more specialized than in the small organization. Figure 10.2 shows an example of a maintenance department of a medium-sized contractor or public agency. This maintenance organization is termed as the "product-grouped" organization by Rapp and George [3].

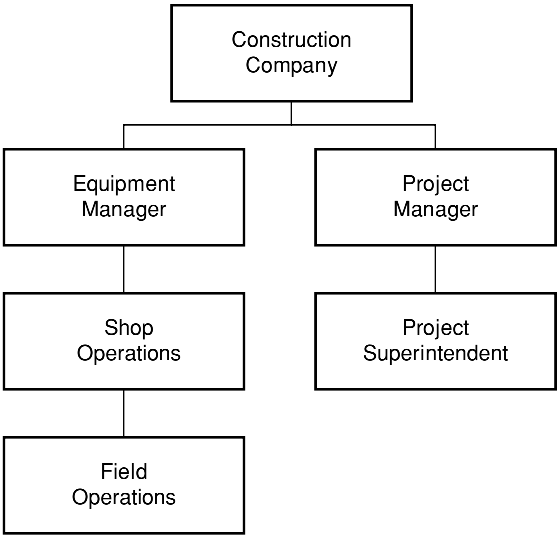

FIGURE 10.1 Function-grouped maintenance organization. (From R. Rapp and B. George. Maintenance management concepts in construction equipment. In *Proceedings of the 33rd Annual Conference of the Associated Schools of Construction*. Seattle, WA, 1997, pp. 53–66. With permission.)

Finally, a large construction company or public construction agency will have many large projects underway at any given point in time. Thus, each project will need to have a dedicated maintenance group for its large fleet of equipment [3]. The equipment manager will be included in the matrix of operational requirements and hence, this type of organization

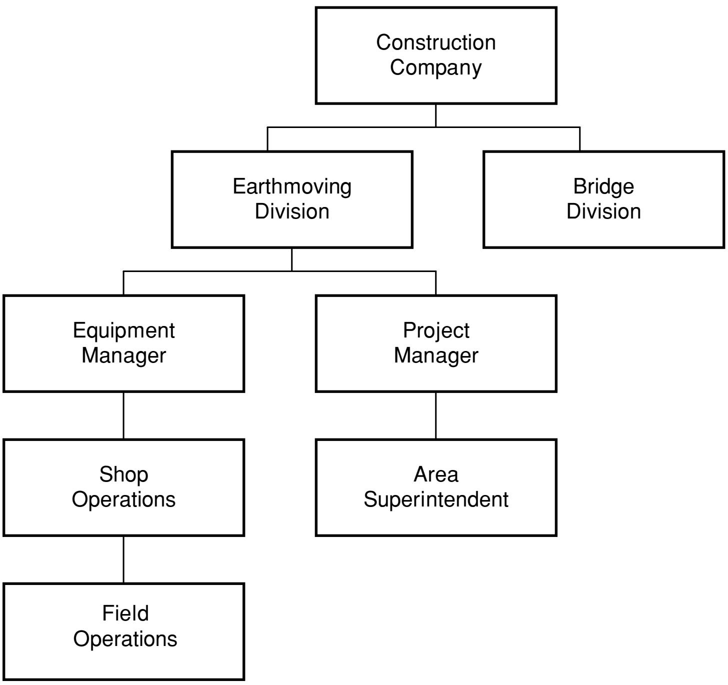

FIGURE 10.2 Product-grouped maintenance organization. (From R. Rapp and B. George Maintenance management concepts in construction equipment. In *Proceedings of the 33rd Annual Conference of the Associated Schools of Construction*. Seattle, WA, 1997, pp. 53–66. With permission.)

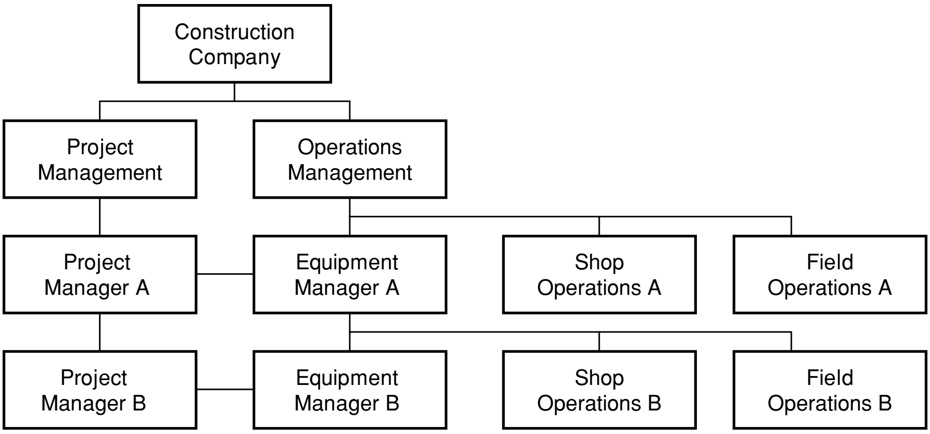

FIGURE 10.3 Matrix-structured maintenance organization. (From R. Rapp and B. George. Maintenance management concepts in construction equipment. In *Proceedings of the 33rd Annual Conference of the Associated Schools of Construction*. Seattle, WA, 1997, pp. 53–66. With permission.)

is called a "matrix-structured maintenance organization" by Rapp and George [3]. Figure 10.3 shows the maintenance organizational structure for a large company or public agency. The advantage of this organization is that it is a self-contained unit that can be reassigned to another project as soon as the current project is complete. Additionally, these units can be combined as required to handle multiple projects in the same general location.

10.3.3 Actions and Controls

After defining the goals and the responsibilities of the maintenance organization, management further defines the steps the maintenance organization should follow. These include activities such as:

- Initiating repair work orders
- Equipment preventive maintenance schedule
- Estimating the resources required for a repair work order
- Estimating the resources required for a preventive maintenance service
- Ordering materials and parts not on hand [4]

Furthermore, like every other activity on a construction job site, equipment maintenance activities must be financially controlled. These types of service-oriented activities can be controlled in much the same manner as the production-oriented activities that they support using a cost breakdown structure (CBS) that relates to the production work breakdown structure (WBS). The CBS must include all the expenditure required to fulfill the needs of both the accounting and the maintenance functions. Next, a financial system that feeds cost data into the maintenance budgeting system must be implemented. Short-range, intermediate, and long-range budgets should be developed and controlled [4]. These types of maintenance budgets contain the following information:

- *Short-range maintenance budget*: A budget for repair, service, and lubrication items that are necessary to support the project on which the equipment included in the budget is currently working.

- *Intermediate-range maintenance budget*: A budget for repair and replacement of worn items that will be necessary to prepare the equipment for the next project to which it will be assigned.
- *Long-range maintenance budget*: A budget for periodic upgrade and replacement of major end items such as engines, transmissions, etc. necessary to achieve the useful life of given pieces of equipment in the fleet.

To implement such a control system, it is necessary to get feedback from field activities. This is possible by controlling completed work, labor, productivity, safety, etc. (see Section 10.5). For instance, a periodic report that lists the status of every piece of equipment within the fleet is helpful. This type of report would furnish information for equipment that is "idle" and the reason for its nonproductive time that may require attention from the management. Additionally, performance indices can be calculated in order to evaluate the effectiveness and efficiency of maintenance [3].

10.4 PREVENTIVE AND PREDICTIVE MAINTENANCE MANAGEMENT

Various maintenance tasks have to be performed on each piece of equipment at various intervals. The maintenance checklist for each piece of equipment is typically found in the manufacturer's service manual for each piece of equipment. Thus, it is possible to consolidate these for the entire fleet and coordinate the fleet's master maintenance schedule. Doing this not only helps scheduling the maintenance resources assigned to the fleet but also assists in developing the intermediate and long-term budgets previously discussed.

10.4.1 Preventive Maintenance

The equipment manager's major task is to ensure that the equipment is scheduled for maintenance in such a manner that the maintenance department does not become overloaded and that production for ongoing projects is not adversely impacted. To do this, a list of all equipments and their maintenance schedules is prepared. A system of priority is then established such that primary production units whose failure would cause a breakdown in operations are given top priority for early preventive maintenance procedures. Realistically, not all equipment can be maintained strictly on their maintenance schedule as maintenance in such a manner might result in higher cost due to lost production than the expenses that would be incurred due to unscheduled equipment failure. Care should be taken to ensure that preventive maintenance of equipment lower on the priority list is not ignored altogether as this may result in the increased cost of unscheduled maintenance. Other factors to be considered in preventive maintenance scheduling include the operating conditions, the age of the equipment, and the past history of similar equipment.

Mann [4] proposed an objective method to determining the appropriate maintenance approach on a piece-by-piece basis for the typical construction project. Essentially, he identified three possible maintenance strategies:

- *First breakdown approach*: The equipment is never pulled out of production for preventive maintenance. Preventive maintenance is conducted after a piece of equipment breaks down in conjunction with its repair.
- *No alternative approach*: The equipment is pulled out of production for preventive maintenance in accordance with its manufacturer's recommended schedule. Production is incrementally sacrificed to maximize equipment availability throughout the project.

- *Breakdown-dollar versus inspection-dollar approach*: A rational comparison of the cost of lost production against the cost of maintenance inspection is made and the lower cost option is selected utilizing a mathematical algorithm based on a calculated preventive maintenance factor discussed later.

An example of the decision process for establishing job priority utilizing the three approaches of equipment maintenance is illustrated in Figure 10.4. In the "first breakdown approach," equipment is operated until it breaks down with nominal maintenance. Then, while repairs are carried out after a breakdown, the machine is inspected for potential maintenance problems and preventive maintenance, lubrication, services, and replacement of minor parts is also done to get simultaneously with the repair or while waiting to get the repair parts. The thrust of this approach is based on the fact that a backup piece of equipment can be put in service while the given piece is in repair and that no unacceptable loss in production will be sustained. Thus, it is more economical to wait for a specific reason to put the equipment in maintenance and then perform preventive maintenance than to take it out of service and lose its productive potential.

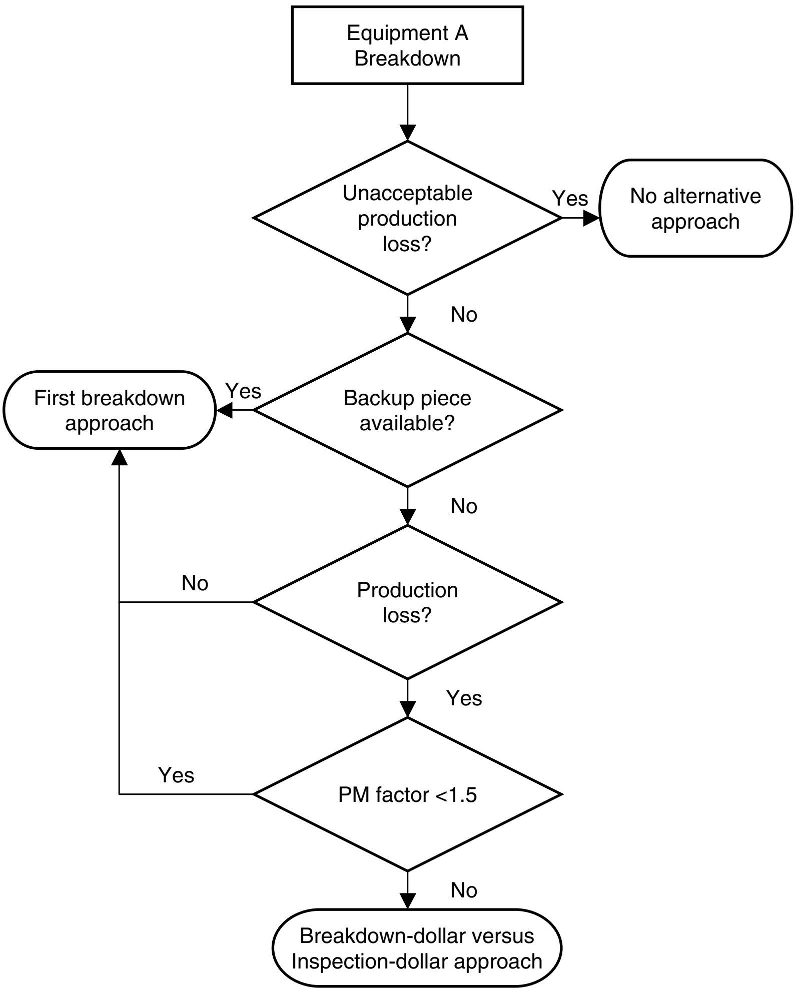

FIGURE 10.4 Rational preventive maintenance program decision tree. (From L. Mann, Jr. *Maintenance Management*. Lanham, MD: Lexington Books, 1983, pp. 141–165. With permission.)

Contrasting the first breakdown is the "no alternative approach," which is applied to those items of equipment that must be operational in order for the project to maintain a long-term production objective. This method's idea is that it is better to schedule short periods of inactivity to perform preventive maintenance than to suffer the consequences of an unscheduled breakdown. These items are the most critical ones for the project whose failure would cause production to cease in other areas as well as the area that directly services the equipment. A tower crane on a multistory-building project furnishes a good example. An asphalt batch plant on a highway-paving project is another example. In both cases, the unscheduled loss of a single item of equipment causes an unacceptable production loss in all the trades assigned to the project, and thus their maintenance should be the top priority [1].

For items of equipment that fall somewhere between the above two methods, the "breakdown-dollar versus inspection-dollar" approach can be used to design the appropriate preventive maintenance plan. In this approach, the machines are ranked in the order of importance, which is determined by a preventive maintenance factor (PM factor) [1]. This approach compares the cost of repairs due to breakdown with the expenses incurred due to preventive maintenance and is shown in Equation 10.1. Equipment having a preventive maintenance factor of more than 1.5 requires preventive maintenance and should be taken out of service periodically to perform those checks and services. The higher the preventive maintenance factor, the more important and critical the equipment is

$$\text{PMF} = \frac{C(A)(B)}{D(E)} \tag{10.1}$$

where PMF is the preventive maintenance factor, C the number of breakdowns per year (based on past experience), A the cost of repairs caused by the breakdown, B the cost of repairs to the other equipment damaged by the breakdown, D the number of planned preventive activities per year, and E the average cost of preventive maintenance activity.

Once the preventive maintenance approach to maximize equipment availability is determined, statistical measures for assessing how successful the preventive maintenance program is should be developed. These measures assist the equipment manager in adjusting the equipment maintenance schedule and budget as well as acting as performance indicators.

10.4.2 Availability and Reliability

The two major statistical measures of maintenance program's success are the availability and reliability of each piece of construction equipment and are used as inputs for maintenance program scheduling and budgeting. These values should be used simultaneously and in tandem. Typically, availability provides statistical information that is most useful for maintenance scheduling. Reliability provides the necessary information for maintenance budget development and monitoring.

10.4.2.1 Availability

The equipment manager can use some simple statistical tools to calculate the availability of the different types of equipment in the fleet for purposes of scheduling maintenance and evaluating cost. These tools can also serve as performance control measures for equipment assigned to specific jobs. Statistical availability is calculated using records for the following two metrics for each piece of equipment on previous or current projects:

- *Downtime*: The period of time during which equipment cannot be operated.
- *Uptime*: The period of time during which equipment can be operated.

The accuracy of these measures is directly related to the size of the database for each piece of equipment. Thus, the reader should note that the equipment manager should be very careful in how these measures are applied and that the relative strength of the organization's historical maintenance record base will directly reflect the effectiveness of using these statistical control measures.

10.4.2.1.1 Downtime

Downtime is defined as the period of time during which equipment cannot be operated and is broken into two components:

- *Active downtime*: The period of time spent in performing inspection, testing, repair, replacement, and related support activities.
- *Delay downtime*: The periods of equipment inoperability attributed to the administration of maintenance, which include periods due to unavailability of tools, test equipment, and spare parts as well as delays not directly attributable to active corrective or preventive maintenance action.

Repair time is the period of active downtime required to return a failed equipment to its normal operation. Also referred to as corrective action time, it is the period needed to locate, isolate, and correct the fault. The U.S. Army Logistics Support Activity, the proponent for the Army's equipment preventive maintenance program [5], has developed the theoretical basis for quantifying equipment availability for equipment maintenance scheduling and performance evaluation. The system is based on a primary statistical measure called the mean time to repair (MTTR). The commercial term mean corrective-action time (MCT) is a synonym of MTTR. MTTR is the statistical mean of the time required to repair an item, and as such, represents the total elapsed time (clock hours) for corrective maintenance divided by the total number of corrective maintenance actions during a given period [5]. It can be defined by the following equation:

$$\mathrm{MTTR} = \frac{\sum_{i=1}^{N} R(i)}{N} \tag{10.2}$$

where MTTR is the mean time to repair, $R(i)$ the time to repair for the failure number (i), and N the number of failures.

Another useful statistical measure is the mean time for preventive maintenance (MTPM) and is shown in Equation 10.3. This is the statistical mean of the time required to maintain an item, and as such, represents the total elapsed time (clock hours) for preventive maintenance divided by the total number of preventive maintenance actions during a given period [5]:

$$\mathrm{MTPM} = \frac{\sum_{i=1}^{N} P(i)}{N} \tag{10.3}$$

where MTPM is the mean time for preventive maintenance, $P(i)$ the time to preventive maintenance for the failure number (i), and N the number of failures.

Continuing with useful maintenance metrics, the mean active maintenance downtime (MAMDT) is the statistical mean of the individual elapsed times for all maintenance tasks during a specified period of time (clock hours). It results from both mean preventive and corrective maintenance actions: weighted average of the MTTR and mean preventive maintenance action time [5]. For the calculation in the following equation, the number of corrective maintenance actions and the number of preventive maintenance actions must be determined:

$$\mathrm{MAMDT} = \frac{\mathrm{MTTR}(N_c) + \mathrm{MTPM}(N_p)}{N_c + N_p} \tag{10.4}$$

where MAMDT is the mean active maintenance downtime, MTTR the mean time to repair, N_c the number of corrective actions, MTPM the mean time for preventive maintenance, and N_p the number of preventive maintenance actions.

Mean downtime (MDT) is the statistical mean of the individual elapsed times for all downtime (clock hours). It results from the mean corrective maintenance actions and the mean time to diagnose the presence of fault (MTDF) [5] and is shown in the following equation:

$$\mathrm{MDT} = \mathrm{MTTR} + \mathrm{MTDF} \tag{10.5}$$

where MDT is the mean downtime, MTTR the mean time to repair, and MTDF the mean time to diagnose the presence of fault.

10.4.2.1.2 Uptime

Many different types of uptimes can be calculated, but the two most commonly used are the following:

- *Mean time between failures* (MTBF): The statistical mean time a piece of equipment is expected to work without failing.
- *Mean time between maintenance* (MTBM): The statistical mean time a piece of equipment is expected to work between two maintenance actions.

MTBF accounts only for downtime due to failures, while MTBM includes all corrective and preventive actions. These metrics are shown in the following equations:

$$\mathrm{MTBF} = \frac{L}{N_c} \tag{10.6}$$

where L is the useful life of the equipment and N_c the number of corrective failures.

$$\mathrm{MTBM} = \frac{L}{N_c + N_p} \tag{10.7}$$

where L is the useful life of the equipment, N_c the number of corrective actions, and N_p the number of preventive maintenance actions.

10.4.2.1.3 Availability Calculation

Once the components of uptime and downtime are known, the equipment manager can then make several types of equipment availability calculations. The purpose of calculating availability is to quantify equipment usage time. As the cost of equipment has huge repercussions on the total project cost, it is very important to understand the statistical availability of the equipment to validate the assumptions made in the cost estimate and the project schedule. Situations when an activity must be delayed because an essential piece of equipment is broken down must be avoided as much as possible (especially when this activity is critical). Availability (A) is basically the ratio of the uptime to the sum of uptime and downtime and can be expressed in the following equation [6]:

$$A = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}} \tag{10.8}$$

Three types of availability can be distinguished [5, 6]:

- Inherent availability
- Achieved availability
- Operational availability

Inherent availability (A_i) looks at availability from a design perspective [6]. It is much like instantaneous production discussed in Chapter 5. Essentially, it is the probability that a piece of equipment, when used under stated conditions, without consideration for any scheduled or preventive maintenance in an ideal support environment will operate satisfactorily at any given time. It excludes ready time, preventive maintenance downtime, and waiting or administrative downtime [5], as these variables cannot be accurately determined in an ideal environment. A_i is calculated using the following equation:

$$A_i = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \tag{10.9}$$

where MTBF is the mean time between failure and MTTR the mean time to repair.

The next availability metric is achieved availability (A_a). This is the "probability that a piece of equipment, when used under stated conditions and in an ideal support environment (available tools, parts, manpower, manuals, etc.), will operate satisfactorily at any given time. It excludes supply downtime, and waiting or administrative downtime" [5]. The following equation shows how to calculate this metric:

$$A_a = \frac{\text{MTBF}}{\text{MTBF} + \text{MAMDT}} \tag{10.10}$$

where A_a is the achieved availability, MTBF the mean time between failure, and MAMDT the mean active maintenance downtime.

The final availability metric is operational availability (A_o), and it looks at availability by accumulating all the time lost in a typical maintenance program. It is the "probability that a piece of equipment, when used under stated conditions in an actual support environment, will operate satisfactorily at any given time" [5] and can be calculated using the following equation:

$$A_o = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}} \tag{10.11}$$

where A_o is the operational availability, MTBM the mean time between maintenance, and MDT the mean downtime.

Example 10.1 A given piece of construction equipment has the following maintenance uptime and downtime hours associated with it:

- Expected operating time 2000 h/year
- Useful life is five years

- Historical records show two major breakdowns per year
- It takes four h to diagnose the reason for the repair need
- It takes a total of five working days to complete the repair
- Current policy is to schedule two preventive maintenance services each year and it takes one working day to complete each preventive maintenance service

This piece of equipment is the primary production maker on which the bid was based. The equipment manager is preparing to resource this large equipment-intensive project that will use a number of these pieces of equipment and wants to know whether it would be better to increase the preventive maintenance service schedule to one service per quarter (four per year) with an anticipated reduction in major breakdowns to one per year. Using the availability metrics, calculate the availability, inherent availability, achieved availability, and operational availability.

Based on the given information, the variables in the required availability equations are as follows:

$$\text{MTDR} = 4\ \text{h}$$

$$L = 2000\ \text{h/year}(5\ \text{year}) = 10{,}000\ \text{h}$$

$$N_c = 2\ \text{breakdown/year}(5\ \text{year}) = 10\ \text{corrective failures}$$

$$N_p = 2\ \text{PM services/year}(5\ \text{year}) = 10\ \text{PM actions}$$

$$N = N_c + N_p = 20\ \text{total maintenance periods}$$

$$\text{MTBF} = 10{,}000\ \text{h}/20\ \text{maintenance periods} = 1000\ \text{h}$$

$$\sum R_i = 2\ \text{repairs/year}(5\ \text{days/repair})(8\ \text{working hours/day}) = 80\ \text{h/year}$$

$$\text{MTTR} = 80\ \text{h}/2\ \text{repairs/year} = 40\ \text{h/year}$$

$$\sum P_i = 2\ \text{PM services/year}(1\ \text{day/PM/year})(8\ \text{working hours/day}) = 16\ \text{h/year}$$

$$\text{MTPM} = 16\ \text{h}/2\ \text{PM services/year} = 8\ \text{h/year}$$

$$\text{MAMDT} = 40\ \text{h/year}(10\ \text{corrective failure})/20\ \text{total maintenance periods} = 24\ \text{h/year}$$

$$\text{MDT} = 40\ \text{h/year} + 4\ \text{h/year} = 44\ \text{h/year}$$

Table 10.1 provides the different values of availabilities calculated using the previously described formulas. First, it can be seen that implementing the more aggressive preventive maintenance will increase availability if the number of major repairs is indeed reduced. The one possible exception is in operational availability where the extra preventive maintenance services cause the comparison to be in favor of the current program.

Operational availability is the most pragmatic of the three component measures. It uses the sum of the mean time between maintenance for any reason and adds the average downtime for a given instance as the denominator in the availability equation. Thus, it does not seek to differentiate between scheduled and unscheduled maintenance. As a result, the comparison is between the current programs with four maintenance periods (two unscheduled breakdowns and two scheduled preventive maintenance periods) and compares that to the proposed program with five maintenance periods (one unscheduled breakdown and four scheduled preventive maintenance periods). So it is intuitive that the program that has the

TABLE 10.1
Equipment Availability Output (Example 10.1)

Annual Total Scheduled Hours	Uptime Hours	Downtime Hours	Availability (%)	Inherent Availability (A_i) (%)	Achieved Availability (A_a) (%)	Operational Availability (A_o) (%)
2000	1904	96	95.2	96.2	97.7	91.9
2000	1928	72	96.4	98.0	99.3	90.1

lowest number of unavailable periods should have the better operational availability. Obviously, operational availability does not account for the potential impact on other equipment resource packages and the potentially higher cost of corrective repairs versus preventive maintenance services and replacements.

Thus, this example would seem to support implementing the proposed program of scheduling quarterly preventive maintenance services for this critical type of equipment. This will enhance the overall availability and the probability that the project can be built as bid and as scheduled. However, a check should be made to ensure that both the estimator and the scheduler could support the loss of each one of these critical pieces of equipment for 72 working hours each year, which translates into nearly two full weeks.

10.4.2.2 Reliability

Reliability is not a different term for availability. Availability relates how the maintenance will be scheduled and in effect is a measure of equipment time usage. Reliability on the other hand measures the interval of time when the piece of equipment is failure-free [6]. Thus, a highly reliable piece of equipment could have a low availability due to a very aggressive preventive maintenance program that takes it out of use more than it needs to be. Equipment reliability is also important for management decisions. Thus it furnishes quantitative information that can be used either for maintenance scheduling or for predicting failures as a means for determining the optimum size and composition of maintenance resources. It is articulated as a percentage. As maintenance failures are not governed by any particular schedule, the reliability equation assumes that they are random and uses the one that is defined by Lusser's equation, an exponential distribution describing random failures [6]. The following is the equation using the previously defined terminology:

$$R = e^{-\lambda t} = e^{-t/\Theta} = e^{-t/\mathrm{MTBF}} \tag{10.12}$$

where R is the reliability, t the mission time (one day, one week, one month, one year), λ the failure rate, and $\Theta = 1/\lambda = \mathrm{MTBF}$ (or MTBM according to the available data).

Mission time is the period of time the equipment in question will be utilized on a given project. The reader must be careful not to automatically define this as the project duration. For instance, a 3-year highway construction project may start with a 6-month period of earthwork that is critical to the overall project completion, but the mission time for the earthmoving equipment is six months, not the 36-month project duration.

Reliability is a relative term that increases as compared to the mean time between failures. If the period defined by the MTBF is long compared to the mission time, the chances for failure will be few and therefore, the reliability will increase. For example, if the MTBF is 350 days and the mission time is 30 days, the chance that the equipment will fail during that mission period will be low. The opposite is true. If MTBF is 30 days and the mission time is 350 days, the equipment's reliability will be low, as the chances that it will fail at least once during the project have become high.

These factors become highly interrelated. As reliability drops (i.e., MTBF becomes smaller), the equipment manager must furnish additional maintenance resources to ensure that better maintainability (i.e., shorter MTTR) is realized if the project is to achieve the same level of required availability for a given piece of equipment. When equipment with high levels of reliability is selected, maintenance becomes less critical in achieving the required levels of availability. Thus, a comparative analysis can be made between the reliability and the cost of maintenance resource levels to achieve the same availability [6]. This information can be built into the equipment selection procedure described in Chapter 4.

10.4.3 Oil Sample Analysis

Preventive maintenance can use a number of analytical techniques to determine the optimum level of maintenance time and cost based on historical records of maintenance failures versus equipment usage. Adding an oil analysis program to the other preventive maintenance checks and services creates a very effective means to identify mechanical problems before they occur. One of the most cost-effective methods of monitoring wear of engine parts is the scheduled oil sampling analysis (SOS). In this program, samples of used oils are collected at regular intervals and tested to determine the remaining lubricating, cooling, and cleaning capabilities of the oil. The difference between the properties of used and unused oil is used to recommend required preventive maintenance as well as pinpoint existing engine malfunctions. It must however be noted that the results of oil analysis are subjective and it is hence important to select a good oil analysis firm and to have it perform all the analysis for a particular piece of equipment [7–9]. It should be noted that oil analysis is a predictive maintenance procedure since its purpose is to detect a failure before it occurs.

The Caterpillar company breaks down its recommended SOS program into four categories [9]:

- *Wear rate analysis*: This test monitors engine wear by detecting and measuring the quantity and type of metal particles that are in the used engineer oil for a given piece of equipment. As these tests are taken at regular intervals over time, the rate at which wear metal particles increase from sample to sample can be measured and used to predict future component failure. The amount of particle in a given sample then furnishes an idea of how much wear is taking place. Thus, wear rate trends for each oil-lubricated compartment can be developed using the results of sampling at specified intervals.
- *Oil cleanliness analysis*: This consists of a particle content analysis on nonengine oil like that used in hydraulics and the power train and permits a comprehensive assessment of the overall equipment's condition.
- *Oil condition analysis*: This analysis focuses on quantifying the loss of the engine oil's lubricating properties. It uses an infrared analysis instrument to compare the properties of a used oil sample to that of a sample of unused oil.
- *Oil contamination analysis*: This test detects the presence of foreign substances such as fuel, water, and glycol. Their presence indicates problems with engine components that will require immediate correction.

10.4.4 Preventive Maintenance Reporting Systems

With the variety of specialized software now available, many large organizations use computer-based systems to schedule maintenance, manage parts inventory stock, and to prepare operating cost reports. However, there are also manual reporting systems in use. The ''Caterpillar Time and Cost Record'' is one such system [9]. It consists of the following paper record forms:

- *Daily work and cost record*: A report filed at the end of each working day or shift that details fuel and other fluids consumption, job, and production data like downtime, operator hours, and repairs accomplished during the period as well a report of the equipment's requirements for adjustments, repairs, and other maintenance [9].
- Repair backlogs on which faults indicated on the daily work and cost records are recorded. The faults are classified into three categories:
  (1) *Type A*: Repairs that must be performed immediately because they either relate to safety or could result in machine breakdown.
  (2) *Type B*: Repairs that are not urgent but should be done as soon as convenient. These may include faults that affect machine productivity such as a worn cutting edge or a sticky dump gate.
  (3) *Type C*: Repairs that can be postponed until the next scheduled maintenance period. These might be the replacement of a cracked seat cushion or a faulty fuel gauge [9]. The information from the repair backlogs as well as the equipment maintenance history file are used to generate a maintenance work order, which is given to the mechanic charged with the maintenance for that item of equipment. When the repair is completed, the repair backlog is updated [9].
- *Service record*: This record gives a comprehensive picture of the maintenance cost of each piece of equipment. It has three major components including the availability record, which details daily planned and actual equipment usage and daily idle and downtime. This information can be used to calculate various factors such as MTTR, MTBF, availability, and reliability. The maintenance schedule and fuel expenses section details upcoming scheduled maintenance as well as fuel-consumption rates. The engine record gives details of oil, grease, and filter replacement. The repair backlog is updated as well as records for the oil analysis schedule. Service record information is obtained from operators' daily report and used to prepare the periodic cost summary reports. It can be used in conjunction with the repair backlog to prepare preventive maintenance work orders [9].

Computer-based reporting systems vary with the limitations of the software. However, comprehensive systems such as the maintenance control system developed by Caterpillar [9] can be used in combination with the manual paper methods for scheduling, inventory and equipment performance, and cost monitoring. The computer-based systems can generate a number of helpful products such as repair work orders, service parts lists, and periodic preventive maintenance checklists.

10.5 MAINTENANCE PERFORMANCE CONTROL

Construction projects require control systems to give their managers real-time feedback on progress and costs. By the same token, construction equipment maintenance performance must also be evaluated to measure the effectiveness of the maintenance support program. When maintenance performance is poor, construction costs will likely exceed estimates and unscheduled downtime will unhorse efforts to meet project production objectives and stay on schedule. Like all objective evaluation programs, maintenance evaluation often meets with resistance from maintenance personnel who are unwilling to allow the assessment of their performance efficiency. To overcome this attitude, the equipment manager needs to counter resistance with education, clearly explaining both the content of the evaluation and its benefits to the project. Moreover, an overall strategy is necessary which identifies actions to organize and conduct evaluation and convert the results into improvements [1]. The strategy should include the following:

- Develop a cogent policy on maintenance evaluation
- Provide advance notification and training for maintenance personnel
- Schedule the evaluation
- Publicize its content
- Use the most appropriate evaluation technique
- Announce evaluation results
- Take appropriate action
- Announce the improvements since last evaluation
- Specify the date of the next evaluation

10.5.1 Maintenance Labor Productivity Control

Productivity measurement is the most effective way to verify the efficiency of labor. The measurement can identify the factors that inhibit productivity. Measuring maintenance program productivity requires a thorough understanding of the program's objectives and benefits by both management and labor. Well-defined objectives have to be established and production information obtained directly from the people performing the maintenance. Some of the factors involved in the loss of productivity are time spent in identifying parts, waiting for tools or parts, poorly communicated or incorrect repair instructions, waiting for other crafts, and lack of proper tools or test equipment. Productivity control should include the following items:

- Check the time spent by each crew on each maintenance action and compare it to some standards from organizational records
- Develop an index that compares the cost of labor to the cost of material. This index is based on the hypothesis that the material cost is more stable than the labor cost. Thus, a change from normal ratios will indicate a change in performance
- Control the quality of maintenance by monitoring unscheduled maintenance records. An increase in the amount of unscheduled maintenance can indicate poor preventive maintenance quality

10.6 PREVENTIVE MAINTENANCE PROGRAMS

To accrue the benefits associated with preventive maintenance, the organization must implement a proper preventive maintenance program. A comprehensive program includes the following components:

- Operator training
- Published guidelines
- Cost control metrics that measure preventive maintenance effectiveness

10.6.1 Operator Training

Training is an important factor for improving productivity and reducing the maintenance activities [1]. For example, if an operator does not know the physical limitations of the machine, damage due to improper use by overloading may result in increasing the maintenance cost. This can cause safety problems that may lead to serious accidents. Training essentially involves the equipment operators and the maintenance craftsman. Additionally, when new equipment is added to the equipment fleet, training must be immediately provided to the operators and maintenance personnel.

Once the activities requiring the training program have been recognized, the next step is to determine the number of personnel to be trained. Thereafter a training method has to be designed. The method could be as simple as ensuring that a trained shop foreman demonstrates the operation of equipment and maintenance procedures in the shop. If a larger group requires, training then formal classes are probably in order. Vocational training school might be a good place for training instructors. At the end of the training program, hands-on performance tests must be conducted to evaluate the performance of the employees taking the course.

10.6.2 Maintenance Guidelines

Successful equipment management is founded on aggressive preventive maintenance. The first stage of preventive maintenance is the operator's daily visual inspection. When something wrong is noticed, the operator should be trained to bring it to the attention of the appropriate authority utilizing the administrative procedures set forth in the guidelines to schedule the action required. Preventive maintenance is everyone's responsibility and should be performed using a written checklist to ensure that nothing is missed and that the inspection is conducted the same way every time. There are maintenance software programs that can generate these operators' checklists [10].

A good set of maintenance guidelines should be comprehensive and tailored to the types of equipment and the operating environments in which the equipment will be used. A solid set of cogent guidelines enhances the probability that both operators and mechanics will be able to standardize their procedures and be able to effectively communicate preventive maintenance issues. A set of guidelines should set policy and include the following:

- Responsibilities of operators
- Responsibilities of maintenance personnel
- Administrative procedures for reporting and tracking maintenance issues
- Frequency of preventive maintenance services
- Standards for maintenance response time
- Procedures for ordering and installing repair parts

10.6.3 Maintenance Cost Control Metrics

The total maintenance cost over equipment lifetime often exceeds the acquisition cost. Maintenance cost is controllable through a well-designed maintenance program and maintenance cost analysis. To maintain the equipment, a contractor has two choices, first is to build his own maintenance shops on the job site, employ mechanics and the management staff. The other is to let an equipment dealer handle machinery repair. After performing the detailed cost analysis for the two choices, the choice that gives the minimum cost should be selected.

The costs associated with a maintenance shop should be broken down into three categories: direct labor cost, job overhead, and office overhead. To estimate direct labor costs, total hours worked by all repair and maintenance personnel are determined. These labor hours can be obtained from payroll records. There are some items that have to be deducted from these total labor hours. These items include nonproductive time and rework order time. Nonproductive time is the period of time spent in cleanup, travel waiting, etc. and sometimes is up to 35% for total worked hours. Rework order losses vary depending upon the mechanic's skill, the complexity of the job, and the type of equipment. After deducting of these items from the total labor hours, the net hours are multiplied by the wage rates to obtain the labor costs for 1 year.

Job overhead costs are the expenses incurred for managing the maintenance program. It includes items such as supervisor and management staff salaries, total employee benefits like insurance and pension, transportation expenses as well as expenses for tools and supplies. Every equipment maintenance organization has a certain fixed expense that must be paid regardless of the amount of work done, and this is called office overhead. This includes such items as office rent, fuel, lights, telephone and telegraph, stationary, office supplies, advertising, trade journals and magazines, donations, legal and accounting expenses not directly chargeable to any one job, fire and liability insurance for the office, club and association dues, and office employees such as bookkeeper, stenographer, and clerks. By adding these items, the total cost associated with maintenance is obtained.

10.7 FIELD MAINTENANCE

Job site equipment maintenance is essential to the success of any equipment-intensive project. However, the resources required to accomplish this task will always vary on a project-by-project basis. On many projects, the resource requirement may only consist of a mechanic who visits the site on a periodic basis to conduct inspections and replaces consumable parts with major maintenance tasks that are performed at the organization's home base maintenance facility or by maintenance personnel from an equipment dealership. Other projects will justify a dedicated temporary maintenance facility on site and an aggressive preventive maintenance program performed by mechanics assigned to the temporary facility. The bottom line is simple. Every project must be analyzed to determine its field maintenance requirements, and the equipment manager should furnish the results of that analysis to the estimator so that an appropriate cost can be allocated to the project bid. For public agencies, the same analysis should be undertaken and the costs of field maintenance are included in the budget for the in-house project. Failure to consider field maintenance will directly affect the ability of the equipment group to meet its budget and can in fact be deleterious to the project schedule as poorly maintained equipments miss production targets due to breakdowns and the unscheduled maintenance required in some situations.

10.7.1 Field Maintenance Personnel and Support Facilities

The City of Los Angeles, California furnishes an excellent job description for the types of duties that will be undertaken by a field maintenance person [11]. This is quoted in its entirety to furnish an example and checklist for conducting the analysis described in the previous paragraph. While on the construction site, a construction equipment service worker necessarily performs the following tasks:

- Lubricates construction and transportation equipment
- Drains, flushes and refills transmissions, differentials, and similar systems
- Inspects and replaces oil and gas filters
- Checks and dispenses oil, fuel, and water when needed and is responsible for the efficient use of such supplies

- Inspects and services air- and water-filled tires by inflating, patching, or replacing
- Takes oil samples for analysis, removes, retaps, and replaces broken grease fittings, tests, services, and replaces batteries and battery accessories
- Flushes radiators and blocks
- Checks and replaces thermostats and radiator hoses when needed
- Checks and adds fluid to hydraulic brake systems
- Steam cleans vehicles and equipment, cleans, washes, and polishes vehicles and glass parts; cleans grease from engines with detergent solution
- Services steam cleaning, lubrication, air compressing, and fuel dispensing equipment, maintains wash racks, wash rack sumps, lubrication racks, and grease pits, checks and maintains tools
- Maintains shop and work area clean, inspects fire extinguishers
- Keeps records on equipment serviced and time spent servicing the equipment
- Balances daily report of oil and gas used
- Visually inspects construction and transportation equipment and makes written and oral reports on obvious repairs needed
- Maintains stock and inventory records and prepares requisitions for needed parts and supplies
- Drives various types of service trucks and operates construction and transportation equipment to facilitate servicing
- Acts for dispatcher in dispatcher's absence and may occasionally be assigned to other duties to meet technological changes or emergencies

An option to furnishing the resources for field maintenance with in-house resources is to contract that out to a specialized company that performs equipment maintenance on site installing their temporary maintenance facility. One such company advertises the following services [12]:

- All preventive maintenance on fleet equipment (tractors, trucks, trailers, etc.)
- All preventive maintenance on material handling equipment
- Provide the staff for the on-site maintenance facility with all required maintenance technicians, clerical support, and management required for the fleet operation
- Over the road emergency service
- All heavy maintenance required on the fleet and material handling equipment
- Equip the maintenance facility with all the tools and shop equipment required for the fleet operation
- Parts and tires required for the fleet operation
- Periodic fleet management reports
- Day-to-day care of the maintenance facility
- Licensing and vehicle administration support
- Compliance with all federal and state fleet regulations

There are a number of benefits of hiring an on-site maintenance facility subcontractor, and they include allowing the operations manger to focus on project production, leaving the logistics of field maintenance to the subcontractor. It may cost less in the long term in that the organization does not need to increase its staff and pay for their initial training. It definitely frees capital associated with maintaining shop inventories of tools, repair parts, and consumable supplies. Finally, it transfers the risk of maintenance contractually to another party and thereby increases cost certainty for the project.

10.7.2 Design Features for Field Maintenance Facilities

A maintenance shop that is on site must have several design features in order to enable the maintenance personnel to perform the previously mentioned tasks and operate the required machinery on time and effectively. Some of the critical features are "the accessibility to the parts and tool storage facilities, in terms of convenient location, easy approach, and size of doors, the size of storage rooms for bulk materials and spare parts, ventilation, including necessary temperature adjustments; the demand in power supply and its adequacy for all rotating and welding equipment, needs of lighting, the need of utilities apart of water and oil; drainage and of course safety while performing all the maintenance tasks" [1].

10.7.3 Specialized Maintenance Tools

Some traditional maintenance equipment is used on a daily basis on construction sites such as generators, welding machines, calibration machines, pressure-drop measuring equipment, lubrication, and sand blasting machines. Other maintenance equipment that can monitor the equipment condition and provide useful information in order to perform on time preventive or predictive maintenance includes electronics such as pressure gages, strain gages, transducers, sensors, steady-state torque measurement, temperature-resistance detectors, and portable lubrication pump. Moreover, maintenance systems have improved, including the adoption of centralized lubrication, standardization of bolt size, improved parts interchangeability, and replacement of major components in each unit [1]. Many construction equipment companies have also added sophisticated electronic systems in the operator's cab, which may be equipped with monitor panel, on which the operator can confirm at a glance items that need to be checked.

The problem with listing all special maintenance equipment is the fact that they depend on technology improvement, and although the basic needs remain the same, the equipment may be out of date very fast. Focusing on examples on the traditional lubrication equipment, the technology today can provide alternative solutions with automated systems instead of a manual system. In this application of specialized maintenance equipment, "all lubrication points are connected to one or more lubricant metering devices that can be centrally and easily supplied with grease. Lube points which are normally difficult to access can now be serviced quickly and efficiently — guaranteeing the right quantity of lubrication for every point" [13]. Proper lubrication increases uptime and renders the maintenance routines simple. Automated lubrication systems constitute only one of many new interesting solutions available for equipment maintenance. As already said, new and even more improved solutions may be available in the market in the future.

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11 Construction Equipment Site Safety

11.1 INTRODUCTION

The construction industry has long recognized that construction is a high-risk series of activities requiring active safety measures everyday. The accident frequency and severity rates in this industry are well above the averages of all other industries. In the United States, there are two major published sources of work accident statistics, the National Safety Council and the U.S. Department of Labor.

11.2 SAFETY AS A PROFIT CENTER

It is easy to understand why construction is so dangerous, since it involves large, heavy materials, and equipment that often works at heights, in holes, underground, and in highly hazardous locations. "More than 100 people each year are killed by mobile heavy equipment on construction sites. The main causes of death are: workers on foot being struck by equipment that is backing up or changing direction; operators being crushed when equipment rolls over while on a slope or when equipment is loaded/unloaded from a flatbed/lowboy truck; operators or mechanics being run over or caught in between when the brakes are not set, equipment is left in gear, wheel chocks are not used, or the equipment and controls are not locked out; and workers on foot or in a trench being crushed by falling equipment loads, backhoe buckets or other moving parts." [3].

In 1927 the General Building Contractors' Association of America published its first edition of the *Manual of Accident Prevention* to persuade construction executives to take more interest in safety. The manual states the following reasons for placing emphasis on safety [2]:

- Humanitarianism
- Direct cost of previous accidents
- Increased insurance premiums and company experience modifier
- Enforcement of mandatory accident prevention measures
- Increased record keeping and addition of safety personnel
- Direct cost of each accident occurrence
- Delay to the project
- Uninsured damages
- Lost production
- Indirect cost of each accident occurrence
- Loss of management and worker time for investigation
- Loss of morale
- Loss of skilled workers
- Loss of equipment

TABLE 11.1
Average Insurance and Wage Rates

Classification of Work	Worker's Compensation and Employer's Liability Average (%)	Average Hourly Wages ($/hr)
Equipment operators (crane or shovel)	10.4	35.90
Equipment operators (medium equipment)	10.4	34.65
Equipment operators (light equipment)	10.4	33.05
Oiler	10.4	30.10
Master mechanics	10.4	36.20
Truck drivers (light)	15.2	26.80
Truck drivers (heavy)	15.2	27.55

The reasons to focus on safety have not changed since the first edition in 1927. Most construction companies consider safety a "profit center" today. Saving on property damage, bodily injury, and workers' compensation insurance premiums is a great financial incentive for companies to avoid accidents. Property and bodily injury are direct costs, but based on the accident severity and impact, indirect costs can be several times greater than the direct costs. Insurance covers only direct costs of accidents and not the indirect costs, such as reduced productivity, schedule delays, added administrative duties, worker replacement and possibly fines or penalties. Incorporating a safety plan into jobsite management is essential for a successful profitable project.

Workers' compensation is typically the most expensive insurance carried by the contractor or the subcontractor. Table 11.1 lists worker-related insurance rates for equipment operators based on rates in the *2005 Means Building Construction Cost Data Book* [5]. Workers' compensation rates represent the national average of states rates established for each trade. Listed wage rates represent the national average base rate including frenges for each craft.

11.3 THE JOB SAFETY PLAN

All general contractors and subcontractors should have effective and ongoing safety programs. AIA Document A201, General Conditions of the Contract for Construction, Section 3.3.1 states that the contractor "shall be fully and solely responsible for the jobsite safety." Section 3.4.3 further states that "The Contractor shall enforce strict discipline and good order among the Contractor's employees and other persons carrying out the Contract. The Contractor shall not permit employment of unfit persons or persons not skilled in tasks assigned to them." [1]. Federal project contracts refer to Federal Acquisition Regulations (FAR) clause 52.236–13, Accident Prevention.

One of the first actions when a job begins is to create and record a job safety plan. Evidence of this plan and all related components will be one of the items an OSHA inspector will look for if they come for job inspection. A copy of the plan should be kept in the job trailer or on-site. The possible components of the general safety plan might include the following.

- Evidence of compliance with all federal, state, and owner safety and health standards and regulations. It is good practice to keep an OSHA manual in the job trailer in an accessible location. Post safety announcements and regulations in an accessible location for all workers to see.

- Posted project safety and health rules (safe work practice training or postings, toolbox talks, posted safety warnings, pretask meeting reports, job safety analysis [JSA] reports).
- Posted and accessible crisis management plan (emergency response plan, evacuation plan). The emergency response plan should have designated company contact persons with current telephone numbers, emergency telephone numbers for ambulance service, the nearest hospital or law enforcement, and a map showing the route with directions to the nearest hospital or emergency room.
- Posted and accessible hazard communication program (MSDS log, evidence of field notification, and postings).

The job safety plan can be supported in many ways. Safe working habits can be reinforced through the use of craft safety representatives. Include representatives from each appropriate project craft along with supervisory personnel at regular safety meetings to discuss safety and health issues:

- Conduct daily safety audits using checklists (can be developed based on company or craft specific needs) to help craft safety representatives carry out this process. Communicate these with equipment operators and associated personnel.
- On-sites where there is a lot of heavy equipment traffic, dust, and noise require personnel on the ground to wear orange or colored vests for greater visibility.
- Use the schedule to insure that all the required safety materials, such as shoring, trench boxes, barricades or fall protection equipment are on-site prior to work commencement.
- Investigate any accident, incident, or near miss to determine causes and develop, document, and implement corrective action to eliminate reoccurrence. This can be time-consuming and it is advisable to assign a specific person to gather required information.
- Use weekly toolbox meetings. The Associated General Contractors has many packaged talks that can be easily integrated into these meetings. Plan safety into the work and use a developed promotion, awareness, and recognition process that gives renewed weekly and monthly emphasis on the company's safety commitment.
- Make project safety goals an integral part of your company's safety strategy. A possible ultimate safety goal is "lost time injuries = 0." This is an attainable goal, but is dependent on the commitment to safety of the management team, field personnel, subcontractors, and building trades. The commitment must be companywide and part of the recognized work culture.
- Have a recognition or safety incentive program to help achieve the overall objective of the safety program. Recognition is intended to emphasize the importance of safety to the entire company and to meet objectives by actively involving craft and field supervision in hazard awareness, accident prevention, and safe performance practices.
- Identify all major job phases on the schedule. Conduct hazard analysis or JSA for each phase and train the employees involved to carry out that portion of the job with safety procedures in advance of start-up. It is very important that this analysis occurs proactively.
- Communicate the safety plan appropriately to non-English-speaking workers, operators, and field management personnel. Most general safety material and rules and regulations are published in Spanish. This information is important, but the daily and hourly specific work strategy and associated safety considerations must be communicated as needed. This requires greater effort when language is a barrier to effective communication. Identify bilingual operators or craft workers to help communicate the plan to all workers involved.

11.4 HEAVY CONSTRUCTION EQUIPMENT SITE SAFETY CONSIDERATIONS

Before the actual construction begins these steps should be taken to formulate a project site safety plan:

- Identify the work activities, locations, and quantities
- Define work processes
- Relate the schedule and required productivity to the defined work activities
- Identify required equipment
- Identify locations for operating equipment
- Identify equipment travel routes and work areas
- Define and document the project plan

Site safety management for operation of heavy construction equipment should be part of the overall job safety plan. The site includes not only where the construction is occurring, but the area needed for support activities such as equipment travel, storage, or staging. Mobile heavy machines designed for speed and movement, while carrying a load, create hazards that must be controlled and managed like any other aspect of safety on the job. Machines working together and traveling at the same time compound the safety considerations and require greater coordination.

Subcontractors and equipment operators employed by the contractor typically assume the responsibility for daily site safety management. It is the job of the contractor to coordinate these users to make sure the site management plan is implemented successfully. The amount of required coordination and communication will depend on the size and complexity of the work to be accomplished. On a per job basis the following considerations should be evaluated by the contractor, subcontractors, and equipment operators and communicated to all involved in use of and working around heavy equipment.

Only qualified, drug- and alcohol-free, focused operators should be allowed to operate the equipment. All employees who operate construction equipment should be trained in the proper procedures of the equipment and should be given a physical examination to ensure that they can physically operate the equipment. At a minimum, the examination should require passing the following:

- Proper vision with or without eyeglasses
- Ability to distinguish colors
- Adequate hearing
- No physical defects to impair performance
- No proneness seizures or loss of physical control
- Sufficient strength, endurance, agility, coordination, and reaction to meet equipment demand

If drug testing is required there are many companies that offer this service. Once a person has been physically qualified to operate the equipment, training and instruction can begin. The prospective operators should be able to read and understand the signs, signals, and operating instructions for each type of equipment they will operate. The contractor should develop a training program to ensure that the operator has been given instructions for the safe operation of the equipment and the ability to demonstrate proficiency in the operation of the equipment. Many operator certification programs on all types of heavy equipment are commercially available today. Prior to permitting the employee to operate equipment independently, instruction and testing should be done by a qualified representative. After qualifying, for insurance purposes, the employee's record should be documented as to which types of equipment the employee is qualified to operate. The operator is the "final front" for safety on the jobsite. The operator makes the final call as to whether the work can be done safely with the equipment or not.

On a congested equipment-intensive jobsite, communication with operators is one of the most important site safety considerations. Going over the daily scheduled work activities, where equipment will be operating and noting possible areas, times, and specific locations of congestion should be part of this daily communication. There should be a procedure, whether orally, using hand signals, or radios to communicate with in-cab operators during the work. Oral communication is usually very limited due to the noise level when equipment is operating. There should be a means of communication with operators in case an emergency situation occurs.

The operator should make a daily inspection of equipment for proper operation and wear and tear. Checking warning devices should be part of each operator's daily duties. Requiring documentation of this inspection in a formal safety strategy with associated record keeping is an appropriate way to ensure that operators do this everyday. Equipment, attachments, or accessories should not be modified or changed without proper inspection and certification by a competent person representing the company or equipment manufacturer.

Mark the equipment work areas with tape or barricades to warn workers on-foot of operating machinery that may be swinging or backing in their production cycle. Swinging equipment, such as excavators digging and swinging to dump, pose a hazard because the operator cannot see directly behind the machine. Special attention should be paid to limiting access to areas where bidirectional equipment (forward moving and then backtracking to reposition to move forward again) such as bulldozers, compactors, or loaders are working. Marking a limited access area will minimize operator concern for pedestrian traffic. Excavating equipment should not be positioned too close to the excavation as soil will give way and the machine can become unstable and turn over or fall into the hole. When working around the excavating equipment in open holes or in trench boxes, there should be a communicated evacuation plan for workers to exit from the hole in case of cave-in or the equipment falls into the hole. Working at odd angles with the machine on a descending incline or in unstable dirt should be avoided or extra measures must be taken to minimize the hazard. Equipment should be set up to avoid any encumbrances such as overhead power lines or trees.

Any underground utilities, pipelines, or other possible underground feature should be marked prior to the start of excavation. It is critical that time be allocated in the work schedule for this to be done. Telephone, power, and gas companies provide this service. Operators should be warned about what is below the surface. If these locations are tentative, operators should be informed so that work proceeds with caution until underground lines or features are physically located and visible. Most of the times locations on the surface can be determined, but depths are irregular and not consistent with the information in plans or provided by utility companies.

In order to avoid congestion and unsafe conditions in a hole or below-grade work area, prepare and communicate a plan with the excavator equipment and hauling unit operators to sequence and time arrival of multiple units loading and dumping. Load, haul, dump, and return cycle times should be determined and used to sequence haulers and time arrival in the hole. To achieve optimal production, correct placement of hauling units and when they should advance into loading position should be determined and communicated to hauling unit operators. The path into the hole should be marked and stabilized if necessary. Units should not pull into position until the previous unit is exiting or the excavator operator signals for advancement. The more equipment operating in a confined area, the more control and communication are typically required. As the excavating equipment moves, new setup locations and positions should be communicated to hauler operators. The excavator operator should monitor and control hauling unit arrival timing and positioning.

Along with grade and surface conditions the travel routes should be set up to avoid intersections or blind areas, which result from sharp turns around piles of dirt or structures. Scrapers should have the right-of-way if possible. They are the hardest piece of equipment to slow and require the most effort to accelerate. Routes can be marked with ribbons to warn workers on-foot.

When trucks delivering equipment to the jobsite are slowing or positioning for entry or to exit and merge into oncoming traffic, site access and egress should be set up to minimize disruption of street or highway traffic. Entry and exit turning radii should be wide enough for long trailers to turn and maneuver conveniently and quickly. For security purposes entrances or exits should be set up in view of the job trailer. If this is not possible, gatekeepers or guard shacks may be necessary at remote points. When traffic disruption is inevitable, qualified personnel to direct traffic should be provided. The number and location of access and exit points should be determined after review of delivery–unloading and loading–transport needs. The only way to control dust is to sprinkle travel surfaces. If the site is muddy, tire wash pits may be necessary to minimize tracking of mud onto streets. Separate entrance and exit gates can be advantageous on a jobsite with high delivery traffic. Allowing trucks to pull in and continue forward for unloading and then exit is more efficient and safer.

On large construction sites the haul route is a primary consideration for equipment wear and tear and production. The grade of the haul route should be evaluated for optimum equipment production. The job layout should be reviewed and grades established if necessary. An engine going downhill does not work as hard as an engine going uphill. Therefore equipment should load going downhill and dump prior to going uphill if possible. Flat travel routes have less grade resistance and require less demand on engines and brakes. Steep routes demand more powerful equipment and are harder on brake systems. Turnouts may need to be provided depending on the length of the routes. The longer the travel distance the more time required for a production cycle. For long travel distances, higher speed machines may be necessary. Haul routes should be set up so that the equipment is always moving forward.

The bearing capacity of the haul route must be great enough to efficiently carry the equipment and loads. The condition of the surface of the haul route will influence the amount of maintenance that equipment will require and how fast equipment can travel. If equipment tires or tracks sink into the haul surface, the equipment has to work harder to overcome the resistance to move forward or backward. Heavily used routes should be groomed and scraped to provide an optimal surface for equipment movement. Deeply rutted, wash-boarded, or muddy surfaces require a much greater burden on the engine and frame than a groomed surface. Maintaining the surface minimizes the resistance to tires or tracks traveling over the surface. Equipment traveling on dusty surfaces will spread silt onto and into everything. This will affect the whole jobsite. Equipment air filters should be changed more frequently (so should the air conditioning filters in the job trailers). Water could be spread on the travel surfaces to reduce the amount of dust. This is very helpful, but promotes rutting as the surface dries out and is compacted by equipment movement. The surface must then be re-graded and compacted. If the surface is not adequate, a temporary topping may be required, such as limestone, crushed concrete, or ground asphalt.

For equipment-intensive projects, such as mass excavation or road projects, the contractor will typically have an on-site fuel tank to which the equipment operator will pull up and fill the equipment in the same manner as a gas station. It should be noted that OSHA has specific guidelines for setup and maintenance of on-site fueling facilities. As shown in Figure 11.1 the tank must be secured to a stand or stabilized on the ground.

To minimize spillage an earthen berm is usually constructed around the tank and the pit is lined with a vapor barrier. The equipment pulls up to the tank and is fueled using a hose like

FIGURE 11.1 On-site fuel facility.

in a regular gasoline filling station. Fire extinguishers should be available on each side of the pit in case of a fire. The pump should be disabled or locked at night when no one is on the jobsite. The fueling facility should be set up away from major travel routes with easy access and departure so that equipment is always moving forward. Portable self-contained fueling units require minimal site preparation and can be ready for use upon delivery.

Large fleet operators must monitor fuel consumption. A log should be kept accessible in the fueling area or in the cab of the equipment. For each fill-up the operators should enter their name, equipment identification, date, time, and quantity of fuel. It is a good practice for the operator to keep a log as well with them. Tracking fuel consumption is important for comparison of estimated and actual production and costs. Proper documentation, such as operating manuals, maintenance records, or work logs, for each piece of equipment should be kept updated and accessible on-site and possibly in the appropriate machine.

11.5 A JOB SAFETY ANALYSIS FOR EARTHMOVING

A JSA is the systematic identification of potential hazards in the work place by qualified personnel as a first step for controlling the possible risks involved. Another name is a pretask safety analysis. Lifts or special construction activities with high risk should be the focus of these evaluations. The superintendent should help identify activities with high risk that should be analyzed.

A hazard is anything that has the potential to cause harm. A risk is the likelihood of someone exposed to that hazard and harmed as a result. The JSA should assess the risks that may be present in all work activities and may identify particular areas for more detailed assessments. Essentially, individuals who are familiar with the working area and working practices should be involved with the JSA process. It is important to carry out the JSA in a practical and systematic way. The superintendent is responsible for assigning and monitoring the completion of this analysis. Follow these suggested steps to perform a JSA:

1. Identify the focus for the assessment
2. Identify the included work activities and required equipment
3. Identify the potential hazards
4. Identify who is at risk
5. Evaluate the perceived risk
6. Review the required controls
7. Produce a JSA report recording the findings and details of the required action
8. Review and revise the results with appropriate parties to the work
9. Prepare and document the work strategy plan
10. Communicate the plan and have participants "sign-off" that they understand the plan and their responsibilities for execution of the work and safety

This JSA example will outline considerations through step 6. Once controls are determined then the report can be written. Figure 11.2 to Figure 11.4 are pictures of the site for this example. The site in this figure is already in operation, but it should be noted that a safety evaluation should be done prior to job setup and when work commences as necessary.

The process follows the following steps:

1. The focus of this assessment is to develop a safety plan for simultaneous excavation of a building foundation hole and delivery and spreading of select fill for pavement base.
2. Work activities and equipment:
   - Foundation excavation: an excavator (critical piece of equipment) digging the hole on the southwest end of the project and three rear-end dump trucks transporting the spoil to a dump location on the northwest corner of the site (see Figure 11.4).
   - Select fill delivery on the east side of the project and spreading: rear dump trucks as available and a bulldozer used to spread the loads after dumping.
3. Potential hazards:
   - The north and south road adjoining the site is under construction
   - There is only one site entry and exit from the adjoining north and south road
   - Two on-site travel routes are required
   - Excavator setup
   - Bulldozer backtracking into the path of a loaded truck exiting the hole going east
   - Points of congestion on the haul and return paths going east
   - Proximity of northwest dump area to the public road
   - Proximity of south haul route (for fill) to public road (see Figure 11.3)
   - Delivery route options for dumping select fill
   - Timing and sequencing haulers into the hole to be loaded.
4. All equipment operators and on-site pedestrians are at risk.
5. Evaluate perceived risks:
   - Traffic on the entry road is sporadic. Entry is probably best from the south going north so that oncoming traffic does not have to be negotiated.

FIGURE 11.2 Building site.

FIGURE 11.3 South side of site.

FIGURE 11.4 North side of site.

- Delivery drivers must be aware of entering and exiting trucks when approaching the access.
- A route is required for haul trucks loaded by the excavator. This route runs from the hole to the east and then around the spoil pile and west to the dump area on the northwest side of the site.
- Another route is required for delivery trucks. Once entering the site, they can go south around the excavator to dump on the south end of the pile or east (straight into the site) to dump on the north end of the pile. Dumping on the north end requires additional positioning and backing into dump position.
- The excavator must have a suitable stable surface on which to set up. It can set at grade level with the trucks pulling into the pit below grade at the ideal position for loading.
- When trucks are exiting the hole, there is a possibility that the bulldozer may backtrack into their path. The trucks have a somewhat restricted view coming out of the hole.
- Several points of congestion might possibly exist when all trucks are running. Trucks returning to the hole to be loaded by the excavator cross the site entrance path. Trucks exiting the hole and turning north on the east side of the site follow the same path as trucks dumping select fill. Trucks entering the site to dump on the north end of the select fill pile or exiting after dumping there follow the same path as trucks traveling west to dump soil from the hole in the spoil pile on the northwest corner of the site.
- Site access should be limited to avoid pedestrians entering the site along the north and south road and the highway feeder road running parallel to the south end of the site.
- Trucks to be loaded by the excavator should be sequenced and timed to avoid congestion or crowding in the hole.

6. Review the required controls:
   - A flagman should be provided if entry and exit is limited due to traffic.
   - Delivery trucks should enter going north to minimize traffic disruption.
   - Fencing along the site perimeter near operating roads should be installed limiting pedestrian access to areas where trucks are traveling or backing to dump.
   - Flagging should be installed around the excavator swing area, creating a limited access area.
   - Trucks should use horns to warn operating equipment that they are approaching.
   - Backup buzzers should be tested and operating for all equipments (especially trucks).
   - Paths where possible congestion might develop are wide enough for trucks to travel without impeding each other. It should be suggested that trucks traveling to the dump area on the northwest corner stay to the right when traveling from the pit, allowing room for other delivery trucks to pass either direction.
   - The bulldozer operator should minimize backtracking across the pit exit path when trucks are operating. Due to the limited line of sight of truck operators coming out of the hole, the dozer operator should assume the greatest responsibility for avoiding a truck to stop when accelerating to come out of the hole.
   - Trucks to be loaded by the excavator should not enter the pit for positioning until the preceding truck is out of the pit.
   - The excavator operator should signal truck operators when they are loaded and ready to exit.
   - The plan should be communicated to all operators working on-site. Delivery truck operators should be informed of the strategy before coming on-site with the first load.

11.6 LIFTING SAFETY

The superintendent, in conjunction with the craft foremen and crane operator, typically oversees the coordination and execution of the lifting on a day-to-day basis. Being able to efficiently and safely place materials, workers, building components or equipment on the structure is a primary project goal, making crane selection and use a vital part of the project plan.

11.6.1 Safety Considerations

A part of the project start-up process is to procure and set up necessary lifting equipment. This might entail special site preparation or construction of special support structures or foundations. Availability must be considered, especially if you need a crane immediately without prior arrangements. The complexity of this part of the process will change with each job and the cranes chosen. Trying to operate in a limited metropolitan work area has different considerations than building in an open space, however the concepts that must be considered do not change. Whether the lift is small or large, involving one crane or multiple cranes with support lifting equipment, these safety parameters should be considered prior to commencing the work.

The following information is from the U.S. Department of Energy Standard 1090-99, Hoisting and Rigging:

"All hoisting operations are inherently dangerous. Planning is a crucial factor in successfully completing a critical lift. The following steps will help to ensure your next critical lift is properly planned and safely completed.

- First, the operating organization must appoint a person-in-charge for the entire lifting operation. This person must meet the definitions of "appointed," "designated," and "qualified" as described in the manual. Also, this person must be present at the lift site during the entire lifting operation.
- The person-in-charge ensures that a prelift plan is prepared; it defines the operation and includes the following information:
  - A list of items to be moved, including a description of each item's weight, dimensions, center of gravity, and presence of hazardous or toxic materials.
  - List and description of the type and rated capacity of operating equipment, such as cranes or forklifts, that are needed to perform the pick or move.
  - Rigging sketches that serve as a guide or blueprint of what will happen. The sketches may include lifting points, methods of attachment, sling angles, load vectors, boom and swing angles, crane orientations, rated capacities, and other factors affecting equipment operation.
  - Step-by-step operating procedures that include applicable rigging precautions and safety measures are noted.
- The person-in-charge ensures that experienced operators and signalers assigned to the lift are trained and qualified to operate the specific equipment and give required signals.
- Next, the person-in-charge ensures that *manual* sections addressing the specific equipment used are followed. This includes activities such as inspections and operating practices.
- Before carrying out the lift, the procedure and rigging sketches must be reviewed and approved by the responsible manager or designee and the responsible oversight organization such as Safety and Quality Assurance or Quality Control.

- Finally, a prelift meeting must be held before actually making the lift. All personnel involved in the lift must attend, including operators, signalers, person-in-charge, and others as required. During the meeting, the critical lift plan is reviewed and questions resolved.
- Critical lift plans, when implemented by trained and knowledgeable personnel, are the most effective way to identify potentially unsafe conditions and prevent accidents" [6].

Refer to the following sections of the *OSHA Standards for the Construction Industry Part 1926 — Safety and Health Regulations for Construction* for important regulations about cranes and lifting:

- "1926.550(a)(2): Rated load capacities and recommended operating speeds, special hazard warnings, or instruction, shall be conspicuously posted on all equipment. Instructions or warnings shall be visible to the operator while he is at his control station.
- 1926.550(a)(4): Hand signals to crane and derrick operators shall be those prescribed by the applicable ANSI standard for the type of crane in use. An illustration of the signals shall be posted at the job site.
- 1926.550(a)(5): The employer shall designate a competent person who shall inspect all machinery and equipment prior to each use, and during use, to make sure it is in safe operating condition. Any deficiencies shall be repaired, or defective parts replaced, before continued use.
- 1926.550(a)(9): Accessible areas within the swing radius of the rotating superstructure of the crane, either permanently or temporarily mounted, shall be barricaded in such a manner as to prevent an employee from striking or crushing by the crane. A rope with ribbons on stakes in the ground around the crane can be used or some cranes are equipped with permanent markings that move as it moves.
- 1926.550(a)(14)(i): An accessible fire extinguisher of 5BC rating or higher, shall be available at all operator stations or cabs of equipment" [4].

For more information about lifting safety, the U.S. Department of Labor's OSHA web site titled, "Construction: Crane, Derrick, and Hoist Safety" www.osha-skc.gae/SLTC/cranehoistsafetyindex.html offers a great resource for lifting safety information.

Hand signals are a form of visual communication used by riggers, spotters, and crane operators to guide the operator when lifting. Visual signals might be required because equipment noise makes oral communication unreliable. It is a good idea to have hand signals posted in the lifting equipment cab and in an accessible location for all workers to review. Workers involved directly with lifting should be trained to use appropriate hand signals.

11.6.2 Prelift Meetings

The following discussion focuses on more specific considerations to be included in the prelift meeting and strategy.

- Define and document the project lifting needs (mobility, operating radius, lift capacity, type, and number of cranes) based on the construction schedule.
- Define and determine crane duties and crane locations. If there is only one crane on the job, selection and capacity will be based on heaviest load and farthest reach required of the crane to perform the required work activities.

- Coverage of all parts of the site requiring lifting might entail the use of several cranes. Each crane must be selected individually based on the lifting needs for the part of the project it is covering. Cranes working together demand even more attention due to heightened need for coordination and communication. Safe coverage of the whole project requires defining individual coverage areas and travel paths. Critical lift studies are required for heavy lifting, such as highway girders or petrochemical vessels, due to the magnitude and risk of the lift. These studies require detailed evaluation of all facets of the lift.
- Have a communication plan involving the crane operator, "person-in-charge," ground crew, and placement crew simultaneously. The plan includes the means of communication — primarily radio and hand signals. Lines of sight must be considered if visual signaling is used.
- Stabilize and level the setup location and travel areas and paths. Make sure crane selection considers unloading, staging, and lifting locations. These areas must be stable and unencumbered too.
- Set up and communicate a priority of use schedule for each crane. Establishing a plan scheduling who uses the crane will make the work more efficient. If not managed and communicated properly, this can be quite frustrating on a busy job if multiple crews or subs are using the crane to place materials.
- Establish, communicate, and post an emergency plan to all personnel in case there is a crane failure or accident.
- Determine required clearance or permits required by local governing bodies. Incorporate procurement into the construction schedule.
- Make sure all safety requirements are met. Give special consideration to lighting and electrical installation on tower cranes.
- Schedule crane maintenance, inspection, or downtimes into the project construction schedule.
- Hold mandatory prelift or critical lift meetings as required. Depending on the needs of the project, hold daily coordination meetings or include lifting strategy discussion in progress meetings if appropriate.
- Coordinate preparing and locating material for rigging and hoisting.
- Coordinate all supporting crafts and equipment.
- Make lifting safety a primary influence on the project construction plan.

Example 11.1 The following is an example lifting work activity that might require a prelift or pretask meeting. A crew will be installing 60′ glue-lamp beams weighing 80 lbs per linear foot in a training and high bay roof structure. The floor has been poured and is usable. They will be using a 60-ton Grove telescoping boom mobile crane to hoist the beams into position at an approximate 30′ height. A Skytrak will be used to move the beams to the crane to be rigged and swung into place. When in position, one end is fastened in a hanger on the exterior wall and the other end is secured on a girder running perpendicular and down the middle of the bay. Personnel will use a Genie telescoping boom platform lift and a JLG scissor platform lift to get in position to fasten the beam-ends.

The list of considerations below is not comprehensive and is offered as the basis for a JSA. Exact details should be included in the JSA. The communication solution might include a brief meeting of all personnel involved in the lifting for the day before work commences. In this meeting the following might be discussed by the person in charge of the lifting:

- Personnel responsibilities and assignments
- Issues or problems from the day before
- Required support equipment
- Required support tools or material
- Condition of equipment
- Schedule and production needs
- Weather conditions
- Other possible considerations:
  - The work sequence — movement of beams to staging, staging, lifting, placement, and securing (when work platforms are extended for securing ends)
  - Communications
    - Methods — radio, hand signals, yelling
    - Line of sight — make sure all can see the necessary signaler
    - Signaler competency
- Rigging — check rating, condition, and coordinate use of taglines
- Notation and provision made for avoidance of all encumbrances — remove trash if necessary
- Operators qualifications — crane and personnel lifts
- Equipment condition and operation
- Use and marking of work area
- A competent and qualified person monitoring the lifting and the area
- Proper crane setup — level, stable, and marked-off
- Possible sketch of work sequence and area

11.7 OSHA ACCIDENT REPORTING AND RECORD KEEPING

Compliance with federal safety regulations requires attention to documentation. Records should be complete and up-to-date, and support required safety reports. Failure to keep good safety records can result in disciplinary action after an inspection, and hinder ability to track equipment safety program progress and effectiveness.

11.7.1 Reporting

Only certain work-related incidents are required to be reported to OSHA. Reporting of nonwork-related incidents is not required. Reportable injuries or illnesses are considered work-related, a new case or meets one or more of OSHA general recording criteria. Work-related injuries or illnesses are "an event or exposure in the work environment either caused or contributed to the resulting condition or significantly aggravated a preexisting injury or illness" [4]. According to *OSHA 29 CFR 1926 OSHA Construction Industry Regulations* an injury or illness is recordable if it meets these general recording criteria. Suggested paperwork and notification time frames are listed after each injury or illness category [4].

- Death — OSHA 300 Log — report orally or in person to OSHA within 8 h
- Hospitalization of three or more employees as a result of a work-related incident — OSHA 300 Log — report orally or in person to OSHA within 8 h
- Days away from work — OSHA 300 Log and OSHA Form 301 — report to OSHA within seven days
- Restricted work — OSHA 300 Log and OSHA Form 301 — report to OSHA within seven days

- Transfer to another job — OSHA 300 Log and OSHA Form 301 — report to OSHA within seven days
- Medical treatment beyond first aid — OSHA 300 Log and OSHA Form 301 — report to OSHA within seven days
- Loss of consciousness — OSHA 300 Log and OSHA Form 301 — report to OSHA within seven days
- Diagnosis by a physician or health professional — OSHA 300 Log and OSHA Form 301 — within seven days.

Medical treatment includes treatment administered by a physician or by a registered professional personnel under the standing orders of a physician. Medical treatment does not include first aid treatment (one-time treatment and subsequent observation of minor scratches, cuts, burns, splinters, etc. that do not ordinarily require medical care) even though provided by a physician or registered personnel.

11.7.2 Record Keeping

Every employer who currently has or has had ten or more employees at any one time during the calendar year immediately preceding the current calendar year must maintain three basic OSHA records:

- OSHA Form 300 (Log of Work-Related Injuries and Illnesses)
- OSHA Form 300A (Summary of Work-Related Injuries and Illnesses)
- OSHA Form 301 (Injury and Illness Incident Report).

These records should be up-to-date and accessible at the jobsite for examination by appropriate governmental representatives of the Department of Labor or Department of Health, Education, and Welfare. The records must be maintained for a period of five years following the end of the calendar year to which they relate. All records are the employer's records. Submission of records to any federal agency or other parties is not required unless specifically requested. Required forms may be obtained at the nearest OSHA office or from the OSHA website. Instructions accompany each form. Each form should have the year to which it relates noted on the form.

- OSHA Form 300 is a log of all work-related injuries and illnesses that are required to be recorded. The log is required to be maintained at each of the employer's establishments and kept readily available. Entries include the case no., employee's name, job title, date of injury or illness, location of occurrence, description of the injury or illness, and a classification of the case. All entries should have a corresponding Form 301.
- OSHA Form 300A must be completed from the Form 300 log entries. It must be certified by the highest ranking company official at the site. The form reports the total annual number of cases, total number of days away from work, and all injury and illness types reported. This report should be available to employees, former employees, and their representatives.
- OSHA Form 301 must be filed for all injuries or illnesses within seven days after occurrence. There should be a corresponding form for each Form 300 entry. Entries on this form include information about the employee, information about the physician or other health care professional, and information about the case.

TABLE 11.2
Safety Requirements for Earthmoving, Excavating, and Lifting Equipment

Safety Equipment	Mid-Size Cranes	Motor Graders	Scrapers	Tractor	Off Road Haulers	Trucks	Wheel Loaders	Crawler Tractors	Excavators
Audible alarm		×	×	×	×	×	×		×
Backup alarm		×	×	×	×	×	×	×	×
Barricade	×								×
Body prop						×			
Boom stop	×								
Brake lights						×			
Brakes		×	×	×	×	×	×	×	
Brush screen		×	×					×	
Cab glass		×	×	×		×	×	×	×
Cab shield						×			
Exhaust guards		×	×	×	×		×	×	×
Fenders		×	×	×	×	×	×		
Fire extinguisher	×			×	×	×	×		×
Headlights		×	×	×			×		
Rating chart	×								×
Reflectors	×	×	×	×	×	×	×	×	×
Rollover protective structure (ROPS)		×	×	×	×		×	×	
Scissor-point guard				×			×		
Seat belt		×	×	×	×	×	×	×	×
Slow-moving vehicle warning		×	×	×			×		
Walkways	×								
Warning tags	×			×	×		×	×	
Window glass	×								
Windshield					×	×			

11.8 SAFETY REQUIREMENTS FOR CONSTRUCTION EQUIPMENT

Table 11.2 shows various equipment safety requirements for earthmoving, excavating, and lifting equipment. Most are specified in the OSHA standards for these types of common heavy equipment.

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12 Construction Equipment Security

12.1 INTRODUCTION

The loss of materials and equipment due to theft and vandalism is currently a massive problem within the construction industry. It is estimated that industry losses resulting from material and equipment theft exceed $1 billion annually. A study conducted by *Construction Equipment* magazine in the year 2000 found that 73% of the participants within construction industry listed construction equipment theft as a critical issue [1]. While theft and vandalism may be an unavoidable reality on construction sites throughout the country, much more can be done to reduce their damaging effects. This chapter will address how and why of theft within the industry, and offer numerous techniques to mitigate this troublesome issue.

Theft and vandalism of heavy construction equipment, tools, and materials are extremely common within the industry, and occur at alarming rates. The Insurance Services Offices Inc., (ISO) estimates that since 2000 there has been over $1 billion in insurance claims on construction equipment annually. In addition, since 1996, the theft value of equipment has increased as much as 20% each year. Perhaps, the most disturbing fact is that ISO estimates that only 10–15% of stolen equipment is ever recovered in the United States [2].

According to *Construction Equipment* magazine, $14,600 is the average value of a piece of stolen equipment. Independent of the cost of the piece of equipment, an estimated $53,000 is incurred in downtime and administrative delays for each loss. In addition, the average deductible payment for stolen equipment is $1500. These two figures total nearly $55,000 for each stolen piece of equipment. This $55,000 seems even more damaging when compared to the average present-day value of an individual piece of stolen equipment of $15,000 [1]. Considering the narrow profit margins in the construction industry, it is easy to understand how several major equipment losses can quickly erase the profitability of any project.

12.2 SECURITY ISSUES

Theft and vandalism can be significantly reduced through proactive management techniques that emphasize the implementation of rigorous project-specific security programs. There are currently numerous organized theft prevention programs available within the industry. Unfortunately, no standardized theft prevention program exists in the United States [3]. Despite the lack of a standardized construction security program, there are many things construction equipment owners can do to reduce the negative impacts of theft and vandalism.

Security programs can be broken down into two basic categories:

- Theft prevention
- Equipment recovery

Effectively planning and implementing a security program ultimately accomplishes these two objectives. Establishing a good security plan is the basis for eliminating theft and vandalism for a contractor. However, a plan is only as good as its implementation. Fortunately, in recent years many new technologies and organizations have been created in order to help construction equipment owners combat the problem of equipment theft and vandalism.

Insurance is the key way for a construction equipment owner to get protection from theft and vandalism on a construction project. Insurance protects the construction equipment owner from the inherent risks associated with using construction equipment. The larger and more complex a piece of equipment is, the higher the risk in using, and the more the insurance will cost. The common method of insuring construction equipment for construction equipment owners is with a contractor's equipment floater. The rising cost of insurance is also a major concern of the construction industry. In a recent study by CIT Equipment Rental and Finance of Tempe, Arizona, 87% of construction equipment owners viewed the rising cost of insurance as a critical industry issue [4]. This rising cost adds to the cost of all projects. It also cuts into the profitability of a construction equipment owner.

12.3 THEFT AND VANDALISM

Theft and vandalism are issues that affect every construction project. The continual rise in theft and vandalism of construction equipment greatly affects individual projects and the industry as a whole. The Inland Marine Underwriters Association (IMUA) echoes ISO's estimate of $1 billion in annual insurance claims on construction equipment. Construction groups also report alarming figures as well. In 1994, a study by the Associated General Contractors (AGC) from 1971 to 1984 found that its members, who represent only a portion of the entire industry within the United States, suffered $2.9 billion in losses from stolen equipment [5]. The key to understanding theft and vandalism lies in fully understanding the definitions, causes, and statistics of these problems.

Theft is defined as the unauthorized removal of any material or equipment from a job site. The most common form of theft on a construction site consists of materials and small handheld tools. These items are the most pilferable and easiest to resell. Heavy construction equipment, however, is the greatest concern since it generates the largest recovery, insurance claims, lost productivity, and future procurement costs.

Vandalism is the willful or malicious destruction or defacement of property on the job site. The goal of vandalism on a construction site is to disrupt the flow of normal work. Common examples of vandalism include destruction of completed work, damage to machines and equipment, and damage to materials. All of these actions cause the equipment owner to waste time and money correcting the deficiencies. Most notably, vandalism of construction equipment often causes costly time delays to the project. Loss of productivity ultimately leads to significant problems in completing the project on schedule and within budget.

Different groups of people steal and vandalize construction equipment for their own personal reasons. Motivations ranging from simple greed to complex political and social statements lead individuals to commit these crimes on construction projects. Thefts are most commonly committed for personal profit. Groups indulge in vandalism for various reasons by groups that range from disgruntled workers getting revenge to social activists trying to make a political statement.

Law enforcement reports estimate that the employees who work directly on the construction site commit most construction thefts [6]. This figure includes all thefts on projects including materials and small tools. According to the AGC, the top four groups associated with construction equipment theft are amateurs, employees, rival contractors, and professional thieves [5]. The reason that numerous groups are associated with these major thefts is that the rewards outweigh the risks. Compounding the problem is the frequent lack of an organized equipment marking and tracking system within a construction company, making equipment theft identification and recovery even more difficult [1].

Crime rings are more likely to be involved with heavy equipment theft, because of the amount of money involved compared with the limited risk. These groups are often fairly sophisticated and capable of quickly moving heavy equipment off a job site. They are also able to replace all identification tags, plates, or markings and ship the equipment to a designated seller. Selling these pieces of equipment can be very easy once all identification has been replaced and the selling location is outside the area of the theft [7].

Vandalism is credited to three main groups: disgruntled workers, social activists, and petty criminals [8]. Petty criminals, such as juveniles, are mostly likely to damage a small quantity of equipment and cause minor defacement such as graffiti. Social activists often indulge in vandalism as a means to promote their cause. The cause may involve the project site directly or indirectly. Activists use a variety of tactics including sit-down strikes, hindering normal project activities, and actual destruction of machinery or completed work. All of these actions cause time delays and additional cost for repair or replacement. Disgruntled workers make up the final category of vandals. Disgruntled workers can be the most dangerous to the site because they can effectively slow down or stop all work on the project. These people may include striking union workers, a group of disloyal or dissatisfied personnel, or a single employee who decides to take action against the company. All of these can lead to disastrous situations for a project [8].

Traditionally, Texas leads the nation in theft of construction equipment. The National Equipment Register (NER) annually produces a list of the top ten states for equipment thefts. Texas has been at the top of this list since 1998. In addition, Florida, Georgia, North Carolina, and Illinois have all consistently been in the top five since 1998. Table 12.1 shows the top ten states for equipment thefts from 1998 through 2001. In 2004, the top five states accounted for 38% of the theft statistics in the nation [9].

Typically, the majority of construction-related thefts occur on the job site itself. For instance, in 2003, 68% of all thefts occurred at locations other than the equipment owners' home office equipment yards. Thus, it can be concluded that the greatest danger lies on the project site. Consequently, 28% of thefts occurred within home office equipment yards and only 4% occurred in transit between the sites. These figures represent the total number of thefts that were reported by insurance companies [9].

TABLE 12.1
Equipment Theft Frequency by State

Rank	2001	2000	1999	1998
1	Texas	Texas	Texas	Texas
2	Florida	Florida	North Carolina	North Carolina
3	North Carolina	North Carolina	Georgia	Georgia
4	Georgia	Georgia	Illinois	Florida
5	Illinois	Illinois	Florida	California
6	Missouri	Indiana	Missouri	Illinois
7	California	Minnesota	Indiana	Ohio
8	Pennsylvania	Pennsylvania	Ohio	Oklahoma
9	Tennessee	Michigan	Oregon	Indiana
10	Indiana	South Carolina	Pennsylvania	South Carolina

Source: National Equipment Register *2004 Equipment Theft Report*. New York: National Equipment Register Inc., 2005, pp. 4–9. With permission.

The *Construction Equipment* magazine study conducted in April 2000 surveyed subscribers in the construction industry on the problem of equipment theft and vandalism. This study concluded that the average contractor lost five pieces of light equipment and nearly three pieces of heavy equipment annually. The contractors with fleets valued at over $25 million reported the highest number of annual losses, with nearly eight pieces of light and over three pieces of heavy equipment lost annually. The study also calculated the average number of days that construction projects owners were delayed due to vandalism on construction equipment. The industry average due to vandalism was nearly 3 days annually. Construction equipment owners with fleets valued over $25 million had the highest rates with nearly 5 days of delays annually [1].

According to the NER, the top five most frequently stolen pieces of equipment account for 75% of all heavy construction equipment thefts within the United States. Skid-steer loaders are listed as the most common pieces stolen in 2004, accounting for 31% of all construction equipment thefts. Tractors, backhoes, generator or compressors, and excavators are shown as the other four major categories of construction equipment thefts [9]. Table 12.2 shows the total breakdown of equipment thefts. The NER sums up the key conclusions reached from this study that equipment owners should consider when developing their theft prevention program:

> The two key factors in the type of equipment most likely to be stolen are value and mobility — the higher the value of an item and the easier it is to transport, the greater the chance of theft. Value is the primary factor until an item becomes too large to move on a small trailer — i.e. mechanical cranes are very valuable but are seldom, if ever, stolen as they are difficult to move [9].

Once a thief has stolen a piece of equipment, the most important goal is to quickly move that piece to an area where all identification can be altered, replaced, or removed. In general, most equipment stays within a 500-mile radius of the crime. However, southern border states such as Texas, New Mexico, Arizona, and California may experience a larger number of stolen pieces crossing the border into Mexico [10]. The next step for a thief is to find a way to sell the piece of equipment. If identification has been replaced, the individual may easily sell the piece at any auction for used equipment. A significant black market also exists for the stolen construction equipment.

TABLE 12.2
Equipment Theft Frequency by Type

Equipment Type	2004	2003
Skid-steer loader	31%	23%
Tractor	21%	26%
Backhoe	16%	20%
Generator/compressor	5%	*
Excavator	4%	4%
Bulldozer	3%	3%
Loader	2%	12%
Forklift	2%	*
Roller	1%	*
Trencher	1%	*
Other	14%	12%

*Included in "Other" in 2003 data.
Source: National Equipment Register *2004 Equipment Theft Report*. New York: National Equipment Register Inc., 2005, pp. 4–9. With permission.

12.4 SECURITY PROGRAMS

Although security programs can be expensive to initiate, their benefits accrued through avoiding the costs of unscheduled production losses can be used to amortize the initial costs. Case studies show that organizations that have established formal equipment security programs experience far less theft, vandalism, and associated work stoppages than those who meekly accept robbery as an inevitable occurrence on the work site. The following section will focus on both theft prevention techniques and formal procedures to follow after a theft occurs. An effective security program consists of both planning and implementation phases.

12.4.1 Security Planning

The first step in formulating an effective security program is an initial assessment of current security risk factors that exist within the organization's purview. Security plans must be customized for the specific locations where they will be implemented, taking into consideration project-site specifics such as location, local crime rates, local labor crime history, and law enforcement availability and effectiveness. This type of risk analysis allows the implementator to address the differences of each job in the planning phase. Cost–benefit analysis should be used to decide in which areas the company wishes to assume risk. Based on these considerations, a written organization security policy should be formally adopted and promulgated throughout the organization.

A formal security policy does not need to be a large complex document. It should take a global approach and be flexible enough to be applicable to a range of construction jobs typically undertaken by the organization. The policy should be posted and readily accessible to all workers. Most importantly the policy must be followed and enforced. An effective security policy should include these basic elements:

- Organization security practices and objectives
- Written roles and responsibilities for each level in the organizational hierarchy starting with the equipment operator and moving up the chain of command
- Equipment security checklists and procedures for each major class of construction equipment
- Incentives for reporting internal thieves in the form of a confidential reward system
- Clear enforcement standards

The following is an example of a global job-site security checklist developed by the AGC of Washington [11]. Much of what it contains is common sense, and it can be used as the basis for a similar one customized for any given public or private equipment-owning organization:

- Visit the site after dark to evaluate lighting. Lighting can be a wise investment in the protection against theft
- Place your tool storage area where it can be seen by law enforcement, neighbors, and others who can report unusual activity
- Alert neighbors and nearby businesses that you are working in the area. Ask them to keep a watch on unusual activities. Provide a contact person and phone number to call when suspicious activity is observed
- Notify your local law enforcement agency that you have begun construction in the area Provide them with the name of a company contact and phone number
- Install adequate perimeter fencing. Check and maintain weekly
- Close fences

- Close locks during the day
- Develop a key control system and use it consistently
- Remove the tires off small equipment
- Perform regularly inventory of tools and equipment to ensure that all items are marked with the company name and the driver's license number of the company.
- Be sure you know what tools and equipment will be used on the job and that you have a current working list of items and their model and serial numbers
- Develop a tool-loan policy
- Remember: engage employees in these prevention techniques. Be sure all tools and equipment are locked up at the end of each work day

Prepare for long holiday weekends by [11]:

- Removing high cost equipment from the site
- Removing vehicle and equipment batteries
- Installing theft prevention devices to disable fuel, hydraulic, and electrical systems
- Removing wheels from job trailers, compressors, and generators
- Taking the tongue off equipment (if removable), if bolted, remove from site
- Removing and securing large amounts of metals, especially copper wire (if it must be left on site, spray paint it black, stack it where it is difficult to load, use case hardened chain to secure, and surround it with heavy objects)
- If you recently installed copper or aluminum, consider hiring a guard service
- Parking heavy equipment camp wagon style heel to toe, with generators and compressors inside the circle
- Posting no trespassing signs
- Removing valuable items from job trailer. Locking down computers and backing-up information on disks. Storing disks away from site
- Considering having someone stay on site over the long weekend
- Remember: begin planning on the Tuesday prior to a long weekend. Give specific tasks to employees and expect site to be secured by mid-day Friday

This checklist is not inclusive, but it serves to illustrate the importance of making job-site security a daily occurrence and not an afterthought.

Another important aspect of an organizational security policy is the establishment of financial incentives and a reward system. It is advisable for an equipment-owning organization to become a member of a local or national "hotline" reward program, which can provide funding for the rewards, and posters that explain the program. Establishing year-end incentive programs for all employees can serve as an effective means of motivating the entire company to prevent crime, by raising its level of perceived importance. Employees working on the site are most likely to have information regarding equipment theft; as a result, it is advisable to implement a confidential reward system for employees who provide information, leading to the recovery of stolen equipment. A confidential reward system is often the most effective way to stop "inside" robberies. Details of all these policies should be posted and made well known to all employees if they are to act as an effective deterrent to internal theft.

Like planning, security-program implementation requires front-loaded cost and effort. The decision on what type and how many systems to implement should be based upon a security-risk assessment and cost–benefit analysis. Security alone, however, should not be the only consideration. The implementation of various security systems often provides an organization with the additional benefits of increased accountability and provides management tools to better utilize its available assets.

Considering that most of construction-related thefts are committed by on-site employees, background checks should be conducted on all employees [2]. Companies should conduct basic background checks for criminal records, and contact former employers to identify personnel with potential risk. Drug tests should be administered to all employees, as drug abuse is often tied to theft. Many employers urge the use of pre-employment drug testing, which is also important from a safety standpoint. Credit checks, when possible, can also serve to identify potential problems with employees. It is important to note that maintaining good relations with employees can often be the most effective form of construction-site theft prevention.

Due to the large volume of equipment present at a job site at one point of time, construction equipment owners are often unaware for some time that equipment is missing or stolen. Unorganized or inadequately monitored equipment lends itself to easy theft. The problem of recovering stolen equipment is often exacerbated by the inability to accurately identify it. The AGC indicates that 66% of all stolen items were not marked [12]. All of these problems can be mitigated by a comprehensive and standardized equipment accountability system. An effective equipment accountability system includes:

- Detailed equipment records
- Equipment storage standards
- Regular inventories
- Standardized equipment marking systems
- Key control
- Equipment tracking systems

It is important to keep an accurate inventory of all equipment on each work site. This inventory should include equipment location, assignment, and the dates of delivery and anticipated return. The model number, manufacturer, year, make, and any specific model names should be recorded. It is important to not generalize equipment such as "tractor" or "dozer." It is recommended that a company register all equipment with a national database that works with law enforcement, such as the NER, or the AGC's Company Identification Number (CIN) system. National database systems such as the NER or CIN have proven to both help construction equipment owners more effectively manage their equipment and improve the likelihood of recovering the equipment in the event of theft.

Equipment should be stored in clearly designated and established areas. Heavy equipment should be parked in the designated parking areas, preferably those in highly visible locations. Vehicles and equipment should be stored in such a manner, like a single row, that a missing unit is readily apparent. Larger pieces of equipment should be positioned in a circular or a wagon-train pattern, with generators, compressors, and other smaller items inside the ring. The use of anti lift devices and various wheel and hitch locks should also be considered [13]. Tool rooms should be established, along with a standardized check-in and check-out procedures and accountability systems. Well-organized equipment not only improves work place efficiency, but also reduces the likelihood of theft. It is important to assign a supervisor the duty of inspecting stored equipment, particularly equipment that is not used for an extended period of time.

12.4.2 Security Inventories and Markings

As part of an organization's security plan, standards for equipment inventories should be established. Routine inventories not only improve equipment accountability, they also establish work-site conditions that discourage theft. Employees are far less likely to steal organizational equipment if it is regularly inventoried. At a minimum, an organization should inventory 100% of its equipment annually. To minimize work disruption, the inventories should be spread throughout the year. Periodic unannounced inventories are also a good idea to maintain accountability of high-risk items like air compressors and power tools. A supervisor should be assigned the duty of managing the inventories. It is also good practice to sporadically change the personnel conducting the inventories.

All organizational equipment should be clearly marked with a standardized logo or marking pattern. As part of the NER or CIN systems, standardized marking colors, sizes, codes, and locations are provided. Both of these systems provided extensive instructions on how to properly mark equipment, helping to both prevent equipment theft and aid in its recovery. A comprehensive marking system will also help distinguish a general contractor's equipment from subcontractor equipment or public agency's equipmen. In addition to utilizing a marking system, maintaining a photograph file of vehicles and equipment can aid in the recovery process.

There are numerous means of marking equipment, tools, and materials. A few of the more common and effective include [13]:

- Crime Prevention Decals, which provide some theft and pilferage deterrence.
- Use of a hardened steel punch to impress identification numbers into the metal. This is one of the most indelible methods of marking available. Even if the marking is ground down, police have the means to detect the original marking number through the use of sophisticated chemicals, which can identify the crystalline structure of the original marking.
- Use of electric engravers to etch markings and numbers. The deeper the etching, the more difficult it is to remove.
- Branding irons are an effective means to mark wooden, plastic, and rubber materials. If the spot for marking is properly selected, it is very difficult to remove or obliterate the mark without making the alteration very obvious.
- Welding number plates to the equipment is another excellent permanent marking method.
- Ink stamps are good for identifying and marking high-risk materials. If marked in several locations, the markings become difficult to remove or conceal.
- Distinctive paint jobs on vehicles, equipment, and tools help differentiate and distinguish equipment. To aid in recovery, it is a good idea to have patterns, symbols, or markings on vehicles and equipment that are easily identifiable from the air.

The decals mentioned above deserve more mention here. Organizations like the AGC and NER provide a series of decals that can easily be placed on all vehicles, equipment, gates, and doors. These decals not only clearly mark the equipment, but also serve as an effective deterrent by demonstrating that a comprehensive crime prevention system is in place.

On many job sites, keys are frequently left in vehicles and access to keys is often unregulated. A company policy should be established detailing the control and accountability of keys. At a minimum, keys should be removed from vehicles and turned into a central point prior to the end of the workday. It is advisable to have a centrally-controlled key check-out point, for instance colocated with the tool room. Keys should be signed in and out, and a comprehensive inventory of all keys should be maintained. A supervisor should be appointed to monitor and enforce proper key control.

In many cases manufacturer's keys are universal, working on more than one piece of equipment. Electronic keys are now available that can help owners manage machine access and deter theft. The machine security system (MSS), from Caterpillar Inc., for instance, uses electronic keys with unique digital IDs. These digital keys can be used as conventional keys that can work with all existing Caterpillar machines. However, if the key is used on a machine that has been equipped with an MSS system, only the keys programmed into that machine's system would start the equipment. Owners can program the keys to manage access to equipment and can preset time frames, such as nights, weekends, and holidays, during which the machines cannot be started. Systems like these can be a factory-installed option, or retrofitted with a dealer-installed kit. Although more expensive and involved than standard keys, a digital key system clearly offers impressive theft prevention and protection opportunities [14].

Recent technological advances in equipment tracking have now been extended to the world of heavy construction equipment. Tracking systems, like those produced by the LoJack Corporation, once reserved to the world of privately-owned vehicles, now offer coverage for heavy construction equipment. These systems are tied indirectly with local law enforcement agencies and can significantly improve the likelihood of recovering stolen equipment. The LoJack system uses a small radiotransmitter attached to the vehicle or piece of equipment, which can be tracked by local law enforcement in the event of theft. The LoJack system currently maintains a 90% recovery rate for stolen vehicles and equipment and costs approximately $700 per transmitter [15]. LoJack is a nationwide system; however, it is primarily confined to large residential areas. Other tracking systems make use of global positioning system (GPS) and cellular network technology to locate stolen equipment. GPS systems can track equipment anywhere in the world; however, the signal can sometimes be blocked if the piece of equipment is moved indoors. All tracking systems rely upon the attached transmitter to facilitate recovery. Transmitters can be broken during routine equipment use, and can be removed by knowledgeable thieves. In addition to providing theft deterrence and increasing the probability of recovery, GPS systems have the added benefit of providing the equipment owner with better control of his the equipment. A simple computer console can continuously display the updated location of all the equipment, providing the owner with a better understanding of where and how his equipment is used. A GPS system, for instance, can significantly reduce the unauthorized use of company vehicles [17].

12.4.3 Job-Site Security

A properly organized and laid-out construction site can provide a significant degree of theft deterrence. Conversely, a poorly organized site lends itself to easy robbery and pilferage. The majority of field security can be performed easily and at a relatively low cost. Again, the advantages of up-front security costs should be weighed against the perceived risk and potential cost–benefit payoff. Field security can be broken down into the following areas:

- Warning signs and postings
- Site perimeter protection
- Lighting and motion detectors
- Alarm systems
- Security personnel and guard dogs
- Police patrol requests

Warning signs and postings are some of the simplest and most cost-effective means of deterrence, and should be considered as the first step in establishing site security. While signs will not inhibit the determined criminal, they will help discourage random vandalism. At a minimum "warning" and "no trespassing" signs should be posted around the perimeter of the work site. The signs should also indicate what laws would be in violation, and the penalty associated if disregarded. The AGC, CIN, and NER warning signs should be posted, indicating that a comprehensive accountability system is in place.

At a minimum, some kind of barrier should delineate the boundaries of the construction site. Depending upon the site and level of security deemed appropriate, the most substantial barrier possible should be put in place. Chain-link fencing is a common barrier and offers affordable protection. Chain-link fencing has the added benefit of allowing thieves to be seen by patrolling law enforcement or security. Chain-link fencing should be a minimum of 8-ft high, with posts set no wider than the narrowest construction vehicle; the posts should be set in concrete. If allowable, barbed wire or razor wire atop the fence adds a significant deterrence to potential scaling. When fencing is not feasible, earthen berms, trenches, or steel pipe and picket fences can be used. Earthen walls or berms should be no higher than 3 ft to allow viewing into the site by law enforcement personnel. Trenches should be 3- to 4-ft deep so that most wheeled vehicles cannot be driven across. If possible steel pipe or picket fences should be 3 to 4 ft from the ground, spaced no more than 2 ft apart, and sunken 4 to 6 ft underground in concrete [13].

Regardless of which barrier method is chosen, all work-site entrances should have a well-secured gate. If possible, a site should have only one entrance and exit gate. Gates should be of heavy construction with spot-welded pins to prevent easy removal. Gate-locking hardware should consist of case-hardened chain and a high-security permanently attached lock. Shielded or blind locking devices are also recommended. Key control is an important aspect of perimeter security, and the access to gate keys should be closely monitored.

Lighting is a valuable deterrent to the construction equipment the theft of because the majority of the thefts occurs during the night. Thieves often depend upon darkness for concealment. Properly placed lighting will not only deter potential theft but assists law enforcement and security personnel in patrolling the site. Lights should be placed at the perimeter of the site and face inward, in order to avoid distracting glares for the patrolling law enforcement or security personnel. Lights should be far enough from the perimeter to keep potential thieves from tampering with them. It is important to install adequate lighting to illuminate the entire site, specifically areas with high-value items. Low-cost motion sensors can be installed on smaller sites, but should cover the entire compound and all approaches. Motion sensors may also be appropriate for specific areas of larger sites, such as at entrance and exit gates and around high-value items [13].

A myriad of electronic alarm systems are now available to increase the security of a job site. The applicability of a specific system is site- and condition-dependent. The most significant limiting factor of a security alarm system is not the availability of technology, but the availability of funding for a system. Cameras, lights, and alarms can be triggered by a variety of sensors. Numerous systems can be tied directly to local law enforcement communication systems. Television monitors and video-recording cameras have become much more affordable in the past decade, and provide a multitude of sophisticated security options. The present availability of alarm system affords a construction company the ability to be creative and flexible in its alarm system choice.

Properly trained security personnel with adequate resources can provide the highest level of security for a job site. The decision to hire security guards should be dependent upon several factors, including the sensitivity of a project, its location, and overall budget. The quality rendered by security companies varies greatly with the price. Some secutiry companies offer excellent services with highly-trained personnel. In some instances, one unarmed night watchman may be sufficient to deter theft. Thus it is important to clearly define security goals before hiring any security personnel. Another important issue to consider is whether the security guards will be armed or guard dogs will be used. Local law enforcement, as well as the FBI and insurance carriers, should be consulted when making decisions of this type and magnitude. Again, the level of risk a construction company is prepared to assume should be weighed against the cost benefit of paid professional security personnel.

A more economic alternative to on-site security is to make use of local law enforcement personnel. By maintaining good relations with the local police department, arrangements can be made to have regular police patrols of your job site. Police patrols should be frequently requested for high-risk times, such as early evenings and Friday nights before weekends and holidays.

12.4.4 Heavy Equipment Protection

There are several techniques available to help prevent the theft of heavy equipment. Parking formations can make theft more difficult, protect smaller equipment, and allow for rapid identification of a stolen piece of equipment. All loose equipment should be anchored with chains or cables. In addition to controlling the keys of vehicles, or using digital keys, owners can institute standard end-of-day practices that will make theft much more difficult. Distributor caps can be removed, or battery terminals be disconnected, at the end of each workday for instance. Blades and buckets on heavy construction equipment should be lowered. Tires can be removed from equipment, like trailers, that are not frequently used. Trailer hitches can be removed from items like heavy generators. Anti-theft devices, which disable the hydraulic, fuel, and electrical systems, can be installed. Numerous locking mechanisms are now available that can be applied to virtually every piece of construction equipment. Wheel and axle locks are relatively inexpensive and very effective. Locks can also be installed on fuel-filler caps and hood side plates. Supervisors must ensure that workers comply with security policies and utilize provided security equipment. This is by no means an all-inclusive list of equipment and techniques available to increase the protection of a company's heavy equipment. What is important is to recognize that numerous solutions are available to help reduce the risk of heavy equipment theft.

The great majority of heavy equipment theft occurs in the hours of darkness. In particular Friday evenings, or any workday prior to a holiday, are the most likely times for a theft to occur. Quite simply, committing a theft on a Friday evening gives a thief a 2- to 3-day lead before the theft is even identified. While it is impossible to accurately predict when a theft will occur, planning for a potential theft by increasing security on these times of risk, with police patrols for example, can greatly increase the chances of thwarting a robbery.

Thefts should be reported as soon as possible to the appropriate local authorities. The more time a thief is given to transport, disassemble, or sell a piece of stolen equipment, the better chance he has of not being caught. If equipment is registered with a national database, like the AGC or NER, the appropriate agency should be notified immediately. These agencies can rapidly notify local, state, and national law enforcement authorities. Port authorities are also notified to pay special attention to equipment shipments. The NER and AGC also notify local and state rental agencies. It is quite common for stolen equipment to be stripped down, repainted, and then resold at a local auction. Accurate records and standardized markings assist law enforcement agencies in locating and retrieving stolen equipment and greatly increase the probability of equipment recovery. After notifying law enforcement authorities and the NER and AGC, insurance providers should be contacted. It is important to note that insurance claims are not valid unless an official report is filed with the appropriate law enforcement agency. If a construction company is affiliated with other construction-related companies, through an organization like the AGC for example, they should pass along the details of the theft to these fellow companies as well. Several agencies, like the Construction Crime Information Center (CCIC), exist on state and national levels, which can assist companies in recovering stolen property. A company should consider offering a reward for the recovery of the stolen equipment, if it does not already have a reward system in place. Following a theft, the management of the company should conduct an internal investigation, with the aid of law enforcement personnel, to identify possible reasons why the theft occurred and take corrective actions to prevent a similar type of theft from occurring again [13, 18].

If and when stolen equipment is recovered, it is very important that the company conduct necessary report follow-up procedures. If a company utilized a national organization like the NER, AGC, or CCIC, it should notify the organization and complete the necessary paper work. Most importantly, a company should fulfill its legal obligations and pursue full prosecution of the criminal element. Far too many construction firms opt to forego the legal hassles of prosecution. While this may seem financially beneficial in the short term, it establishes a dangerous precedent, making it difficult for the legal system to establish future deterrence.

12.5 INSURANCE

Insurance is the main method that construction equipment owners use to protect themselves from the risk of construction equipment theft and vandalism. The broad area of insurance that construction equipment falls within is called inland marine insurance. The term inland marine derives from the days when all materials insured were associated with the ships used to transport goods from port to port. Inland marine items were all items not associated directly with ships [19].

12.5.1 Policy Information

The standard inland marine insurance policy applicable to a owner's construction equipment, other than vehicles used regularly on public highways, is called a "contractor's equipment floater." This name applies to materials of a mobile or "floating" nature. Almost anything movable from a power shovel to a toolbox can be insured [20]. However, under this policy, most of all construction equipment larger than a simple tools is insured.

The "floater" is a general policy that is tailored to meet the specific requirements under which the equipment is insured. This includes all types of equipment used in construction such as cranes, truck loaders, concrete batch mixers, crushers, bulldozers, and small items like jackhammers and power tools. The exception, as stated above, is equipment that operates regularly on public roads. The floater protects equipment on the job site, in transit or when it is idle in storage. Large units with high values are covered best when specifically scheduled on policies, while a blanket amount can take care of smaller items.

The criteria that the construction equipment owner must follow to qualify for coverage include [20]:

- The equipment to be insured must be mobile in nature, that is to be able to be transported from one location to another
- The equipment must not be located so as to remain at one location permanently
- Each piece of equipment must be listed on a schedule
- The policy must cover and include any transportation risks to or from temporary locations

Sometimes, it is necessary to hire an independent consultant to verify and establish the physical characteristics of the equipment. Some of the more important aspects of this investigation include [16]:

- *Security analysis*: A complete breakdown of factors that affect the security of the equipment such as equipment locks, storage procedures, posted guards, guard dogs, alarms, and fences
- *Equipment data*: This includes information such as model number, mileage, list of attachments, minor damage, engine and chassis numbers, paint scheme, and company's identification numbers
- *Equipment usage*: Included here are the nature of the work to be performed, and site investigation and inspection data to determine the conditions in which the equipment will work
- *Operator's experience*: This includes operator's experience with similar model equipment and previous accident history
- *Transportation data*: This includes the carrier, route to be followed, premove and postmove inspections

The following is a checklist prepared by William Derk in his text *Insurance for Contractors* and used by construction-equipment owners for standard equipment floaters [20]:

- Broad perils in lieu of specific coverage
- Complete and accurate inventory of equipment
- Provision for newly acquired equipment
- Automatic coverage for rented equipment
- Protection of lessor's interest, including loss of use
- Automatic coverage
- On premises coverage
- Equipment in transit
- Equipment at job sites
- Deductibles applicable — consideration of alternative deductible levels and premiums
- Report of value requirements, if any
- Territorial coverage limits
- Foreign operations
- Coverage for newly acquired entities
- Joint ventures
- Advance notice of cancellation by carrier

Additionally, the following items are applicable as a crime coverage checklist [20]:

- Blanket crime coverage
- Consideration of limits and deductibles
- Complete and accurate name insured
- Advance notice of cancellation by carrier

Coverage should be tailored to fit exposure. To get reasonable premium levels and protection, a reasonable deductible amount should be set. In general, self-insurance of petty pilferage claims is better than full coverage because any insurance company is going to charge more than a dollar in premiums for every dollar in routine loss they must pay [20]. Small losses are better chalked up as an expected business expense. Most experts agree that property insurance should be "all risk of physical loss" [21]. In general, a construction company should buy the broadest protection available, in order to preclude having inadequate coverage in the future.

Insurance rates on construction equipment have risen 15–25% since 2001. The increase in rates has resulted for several reasons. The slowed economy, fear of terrorism, and the tightening insurance market are all contributors to the steep increase in rates. Rates have not raised this drastically since mid-1980 when some insurance premium renewals jumped nearly 1000% in 2 years [21].

When renewing policies, the construction equipment owner should start research and negotiations as early as possible. One suggestion is to send the current carrier a request-for-proposal (RFP) for the renewal. The construction equipment owner can then use this RFP to negotiate a fair and equitable premium with that carrier. By starting research early, the construction-equipment owner can readily identify what the current market rate for insurance will be for this particular situation. The construction equipment owner can save up to 25% on premium costs by starting research 90–120 days earlier [21]. The key to negotiating a rate with the insurer is to understand the system and having accurate information. It is important to realize that the rates are modified. The most important factor influencing the insurance rate is the construction equipment owners' past track record.

The experience rating is a calculation of individual credits or debits applied to a base rate. It is based upon the ratio of premiums to losses over a number of years. By using a formula, a comparison is made of actual losses incurred over 3 years compared with anticipated loss levels [22]. This is used to minimize wide swings and prevent a small construction equipment owner from paying a very high premium in the event of a serious loss. It is important to note that the frequency of claims will raise premiums more significantly than the severity (i.e., dollar value) of claims [23].

Another example of modification of premiums for burglary insurance was provided in the *Complete Insurance Guide for Contractors* [24]. It lists modification factors for burglary insurance as:

- Management attitude toward the insurance company's safety and security policies
- Wages paid to employees, their ages and responsibilities
- Condition of equipment and repair facilities
- Location and condition of premises

Debits and credits of 5–10% may be used to modify any of these factors with a total modification generally limited to 25%.

12.5.2 Types of Policies

There are two main types of policies, as discussed earlier. They differ over the type and nature of "covered risk." An "all risk" policy covers against direct loss or damage to the equipment resulting from any external cause. The "named-risk" policy covers only certain specified risks such as fire, explosion, earthquake, or overturning of equipment. Some exceptions might be included in the policy. The rate for "named-risk" policies is the lowest and is chosen by the construction equipment owner seeking the lowest cost [23, 24]. Choosing the least expensive policy, however, is not always the most prudent decision.

The next function is to determine the most critical risks. The experience of the construction equipment owner should indicate the need for any special coverage associated with a critical risk. The construction equipment owner should compare rate considerations against recognized or assumed risks, and determine the best combination of insurance coverage. Often construction equipment owners utilize a combination of "all risk," "named risk," and self-insurance. Business needs and financial status will often drive these decisions.

A well-written policy should address the following [21]:

- Coverage for all agreed and recognized risks applicable to the particular equipment
- Specific equipment descriptions

- Stipulated insured value
- List of all risks not covered under the policy
- Date the policy will take effect
- Agent and the company underwriting the equipment
- Any special conditions or exclusions

In an "all risk" policy, the two basic functions are to reimburse the construction equipment owner for damage or loss of equipment and to provide legal defense and payment for injuries or damage resulting from the operation of the equipment [23]. The "all risk" policy, however, often excludes mysterious disappearances, flood, earthquake, and roof collapse in mine damages. Mysterious disappearance is the loss of equipment with no sign of force used to steal the piece of equipment.

12.5.3 Rates and Deductibles

Policy compensation rates for a construction equipment owner's equipment can vary, depending on the competition among insurance companies. The lowest rate can be 0.5% of the total coverage, with a high deductible. The normal range is between 0.25 and 2.25% of the total coverage [24]. The underwriter will check into the reputation of the construction equipment owner. Initially, this will be a simple report or questionnaire, and if necessary will confirm financial and business references [24]. The most favorable rates for the coverage will be awarded to the construction equipment owners with the best reputation. The rates are influenced by inflation (tendency toward increase) and interest rates. Premiums for physical damage to equipment depend on its age, gross weight, the territory where it is normally operated, usage, the type of materials handled, and the replacement cost of the vehicle [23]. The construction equipment owner should consider the trade-off between its ability to pay the deductible and the benefits of a lower rate.

The value of the equipment can be determined in several ways [16]. The more common methods are:

- *Bank loan amount*: In most cases, for heavy equipment the lender will insist that the equipment is insured to the full-loan value
- *Independent evaluation*: The value is determined by an independent consultant or equipment value manual. This is mostly applicable to a new or used piece of equipment based upon the actual market value
- *Declared value*: This is determined by the construction equipment owner. In this case, the construction equipment owner is willing to take risks by declaring a value less than the equipment's actual worth. This lowers the premium, but will also lower the overall coverage of the equipment
- *Bill of sale*: This method is mostly used for newly-acquired equipment

If the construction equipment owners control too much equipment, they may wish to combine insurance. A fleet discount can be negotiated for each piece of equipment above a designated amount. More appropriately, there are premium discounts based on the total amount of premium paid. If the equipment is valued at more than $100,000, an annual adjustment policy should be considered. Coverage is provided for all equipment without requiring a schedule.

Insurance companies have developed what is called "binder" to cover a short period of time. This covers the period just before a policy takes effect, usually 10 to 30 days maximum. The binder is a short-written policy that outlines basic coverages for the equipment. Coverage before the binder takes effect can be handled with a verbal binder. The verbal binder is followed up with a letter of agreement confirming the arrangements [24].

While insurance policies provide construction companies a degree of protection from theft and vandalism, they are not the best solution from an economic standpoint. Deductibles and premiums continue to rise as a result of increased equipment thefts. As discussed earlier, insurance rates are expected to rise throughout the next decade. The expected increases will greatly affect the way that construction equipment owners choose to protect their equipment against risk. In a recent survey by CIT Equipment Rental and Finance, 87% of contractors said that rising insurance rates were a critical concern in the construction equipment industry [4]. The bottom-line factors that affect a policy and the rates are:

- Past loss experience
- Reputation
- Previous contract experience
- Dispersion of risk

12.6 SUMMARY

Construction equipment security is a key aspect to any construction site. The loss of construction equipment due to theft and vandalism is nearing epidemic proportions within the industry. The most effective way for a construction equipment owner to combat this problem is through proactive management and implementation of good security programs. There are many new organizations and technologies available to construction equipment owners that aid in establishing effective security programs. Additionally, construction equipment owners should insure equipment to control risk of equipment loss. Construction equipment losses cost the construction industry an estimated $1 billion annually. Implementing efficient security programs and adequately insuring equipment can greatly decrease the risk of theft and vandalism.

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13 Inventory Procedures and Practices

13.1 INTRODUCTION

The control and maintenance of construction equipment inventories is a problem that continues to plague the construction industry. The total investment in construction equipments nationwide is immense. Careful planning of equipment and spare parts inventories is required to realize a decent return on investment. The dictionary defines the term inventory as "a complete listing of merchandise or stock on hand, work in progress, raw materials, etc., made each year by a business" [1]. In the context of construction equipment, inventory means an accurate listing of resources available in order to ensure that they will be readily available if the situation demands. The problem is not simply confined to the stock of equipments, spare parts, and related consumable items, but can be tied to the fluctuating production and capacity needed to do several projects simultaneously.

13.2 OBJECTIVES OF INVENTORY CONTROL

Unfortunately, construction equipment inventory management often does not hold an important role in an organization's overall policy. To ensure that this vital component is given the proper visibility, the organization must have a clearly defined objective for inventory control. The purpose of the inventory control function in supporting business activities is to optimize four targets:

- Maximizing equipment availability during planned operating hours
- Reducing spare parts inventory levels
- Reducing operating costs
- Guaranteeing productivity in the field

The general objective of the inventory control is to minimize the total cost of keeping the inventory while making trade-offs among the four major categories of costs:

- Purchase costs
- Ordering costs
- Capital costs of maintaining an inventory
- Impact costs due to the unavailability of parts and support equipment

These are interrelated since reducing cost in one category may increase cost in others. The costs in all categories are generally subject to considerable uncertainty. For these reasons computerized models are needed and can be obtained commercially.

The primary function of inventory management is to ensure the proper balance between production requirements and available assets that provide the most effective and efficient support of construction operations. Inventory management controls are required to implement and monitor organization-owned support equipment and levels of spare parts in the warehouse to realize a profit. Inventory management includes periodically analyzing spare part stock levels, processing requisitions, effecting transfers between organizations, and completing the disposition of obsolete or long-term idle support equipment.

Inventory management, as in all functions, must have predefined and approved objectives. A goal should be established for meeting the demands from immediate spare parts stock levels. Contingency procedures are required in order for the system to respond to possible stock-out conditions. The equipment fleet size dictates the warehouses' locations and the levels of spare parts inventory. An effective inventory management program depends on several factors:

- Articulating management objectives and goals
- Identifying demand fluctuation levels
- Forecasting the needs for new equipment and spare parts
- Gathering, analyzing, and reporting field performance data
- Establishing contingency procedures to deal with catastrophic failure or lack of parts
- Developing effective, timely cost, and service level controls

Gathering, analyzing, and reporting information is necessary to keep the equipment manager informed for timely decision-making. For this reason, the most important aspect of inventory management system is the task of follow-up and feedback. A new product will have dynamic changes, as the equipment is refined, modifications incorporated, information obtained on usage rates in the operational environment, and vendor and supplier problems identified.

Inventory managers should be aware of scheduled, interval replacement of parts so that they can have sufficient inventory on hand in case of a failure during planned operation. The information resulting from an inventory management system is only as good as the accuracy of the information in the system. The most important criterion for any inventory system is its timeliness. This creates an environment where the necessary information can be easily understood and accrues benefits for the organization [2–5].

13.3 EQUIPMENT AND PARTS IDENTIFICATION

A logical methodology for assigning unique identification numbers to construction equipment and at a lower level to repair parts and service items is the backbone to a robust equipment inventory system. There is no specific "school solution" for this requirement. However, the literature is rife with examples that have demonstrated their utility in equipment-owning organizations as large as the U.S. Department of Defense to the small construction contractor. These systems can be paper-based with manual data entry or computer-based with automated input utilizing high technology. Irrespective of the platform, the systems are based on a method that systematically creates meaningful individual identification numbers that allow the equipment manager and its staff to rapidly associate the performance input with inventory records.

13.3.1 Equipment Identification

Each piece of construction equipment must have individual identification so that it can be accurately and easily noted on the inventory records. James Douglas, in his seminal work *Construction Equipment Policy* [6], details a system of equipment numbers that consists of five

TABLE 13.1
Identification Number Groups and Types for a Hypothetical Equipment-Owning Organization

Group	Description	Type	Description
0	Administrative vehicles	0	Wheeled
1	Excavation equipment	1	Tracked
2	Earthmoving equipment	2	Towed
3	Grading equipment	3	Skid-mounted
4	Compaction equipment	4	Stationary
5	Loading equipment		
6	Lifting equipment		
7	Paving equipment		
8	Batch/screening plant equipment		
9	Power generation equipment		

or six digits. The system starts with three numbers that denote the equipment classification code and followed by two or three digits to designate the machine. The equipment classification code breaks the equipment down into groups, types, and classes, each being a subdivision of the next higher order. Table 13.1 shows a hypothetical example for a typical equipment-owning organization. This organization has ten different groups of equipment and within those groups, there are five different types of equipment. It can be seen that the group in this example is logically organized by the equipment's general purpose and the type is set up around the means of locomotion. Thus, this can be easily adapted for use in estimating and scheduling as each of these inventory identification numbers can be assigned in a WBS to a specific crew for a given task.

The type codes should be broken down further by the user to reflect the classes of equipment in the inventory. For example, type code 10 (1-"excavation equipment" + 0-"wheeled" = 10) backhoes might be broken down into the six class codes shown in Table 13.2. Thus, all wheeled backhoes with 1.0 cubic yard buckets would be coded "102."

Finally in Douglas' system, each individual piece of equipment would be assigned a two- or three-digit equipment serial number. Therefore, if the organization's fleet included three wheeled backhoes with 1.0 cubic yard buckets, they would be inventory coded: 10201, 10202, and 10203. To recap that would be:

- 1 (Group) Excavation equipment
- 0 (Type) Wheeled

TABLE 13.2
Identification Number Classes for a Hypothetical Equipment-Owning Organization

Group	Type	Class	Description
1	0	0	Wheeled backhoe 0.5 cy bucket with 0.5 cy front-loader bucket
		1	Wheeled backhoe 0.75 cy bucket with 0.5 cy front-loader bucket
		2	Wheeled backhoe 1.0 cy bucket with 0.5 cy front-loader bucket
		3	Wheeled backhoe 1.5 cy bucket with 0.5 cy front-loader bucket
		4	Wheeled backhoe 2.0 cy bucket with 0.5 cy front-loader bucket
		5	Wheeled backhoe 2.5 cy bucket with 0.5 cy front-loader bucket

- 2 (Class) Backhoe 1.0 cy bucket with 0.5 cy front-loader bucket
- 01, 02, or 03 (Equipment serial number)

Equipment registration numbers should be painted on each machine in numerals in a color that contrasts with the basic color of the machine and large enough to permit easy identification. They should be easily visible while the machine is working or in motion. These numbers are best located on the engine compartment or cab door of a machine. Where ever useful, they may also be located on the front or rear of a vehicle as well as on top to make them visible from the air. If the equipment is operated during the hours of darkness, reflector paint can be used for the registration numbers to augment other safety markings and enhance the visibility of the number. Decals, reflector or not, may be used for both insignia and numerals [6].

13.3.2 Parts Identification

The acquisition process for spare parts should be as effective as possible. Obviously, acquisition improvements will vary with individual circumstances. On one side, there are parts with temporary acquisition-method suffix codes that require vigorous follow-through action; on the other there are parts with codes, suggesting a relatively small degree of performance.

An example of a large public agency that has a sophisticated repair parts inventory system is the U.S. Department of Defense (DOD) and their specific guidelines are covered in documents, Defense Acquisition Regulation, Supplement No. 6, DOD Spare Parts Breakout Program [7]. This example should give the equipment manager an idea of the logic that lies behind this immense public agency's repair parts inventory policy and perhaps can be adapted for use on a smaller scale.

Breakout codes are needed to identify, select, and screen parts. They are also used to ensure that appropriate stockage levels are maintained. Three types of codes are used in the breakout program. "The codes, assigned by DOD activities, describe the results of parts screening reviews and apply to various, competitive, acquisition conditions. They are:

- Acquisition-method codes (AMC). These codes are assigned by DOD activities to decide the acquisition method for the part. The following codes are applied:
  - AMC 1 (Suitable for competitive acquisition)
  - AMC 2 (Suitable for acquisition for the first time)
  - AMC 3 (Acquire directly from the actual manufacturer, eventhough the prime contractor is not the actual manufacturer)
  - AMC 4 (Acquire, for the first time, directly from the actual manufacturer rather than the prime contractor who is not the actual manufacturer)
  - AMC 5 (Acquire only from the prime contractor although the engineering data identifies the federal supply code for manufacturers (FSCM) and the part number of a source other than the prime contractor)
- Acquisition-method suffix codes (AMSC). These codes are assigned by DOD activities to further describe the AMC. The following codes are applied:
  - AMSC A (The government's right to use data in its possession is questionable. This code is only applicable to parts under immediate buy requirements and only as long as data rights are still under review for resolution and appropriate recording)
  - AMSC B (Acquisition of this part is restricted to source specified on the source control, altered item, or selected item drawings/documents)
  - AMSC C (This part requires engineering source approval by the design control activity to maintain the quality of the part. An alternate source must qualify with the design control activity's procedures as approved by the government engineering activity)

- Contractor technical information codes (CTIC). These codes are used by contractors when contractor assistance is requested. [7]"

13.4 INVENTORY RECORD KEEPING AND MANAGEMENT SYSTEMS

Establishing an equipment inventory system means registration (establishment of a numbering system), keeping inventory records, and making periodic inventories of all eligible equipment, maintaining proper storage of the equipment, guaranteeing security, and assigning custody. On the other hand, an inventory management system requires more than just computers and technology. It requires people and systems, and even more than the sum of those critical parts. A basic inventory management platform contains management philosophy, methodology, suggested reports, and systems. All the above must be considered and agreed upon before commencement of any system design. With that agreement and system foundation, an equipment manager can then lead the development of a culture of inventory control in the organization. It is unfortunate that many owners consider these items of insufficient importance to merit top-level attention. The result is a gradual but sustained loss of value and materials that could be saved.

13.4.1 Paper-Based Record Keeping

The first step required in developing a responsible inventory of equipment is to adopt a registration system by which permanent identification numbers can be assigned to each machine as it is acquired. A system of this sort not only serves to identify each machine but also aids in recording the history of the machine as it passes through its working life, and in collecting costs and operating statistics that are so important in analyzing its performance.

At the time of inspection on receipt, a permanent identification number should be given to the piece of equipment. This number should be permanently affixed to the machine and its records are not changed during possession by the purchaser. The eligibility of equipment that will receive these numbers should be determined when the registration system is first established. An equipment-owning organization will usually find that about 75% of its capital investment in equipment is about 25% of its machines. These are the first and most important machines to get into the system. Thereafter, some limit should be set on the minimum value of a machine to be registered.

An inventory data card must be filled out for each eligible machine on the inspection when it is received. At this time it will receive its permanent registration number in accordance with the numbering system chosen. Douglas proposes a manual record keeping method that is based on a standard form [6]. The purpose of keeping the information should be made clear so as to teach the record keeper the necessity of accurate data. The information that needs to be contained on that form is as follows:

- The description of the equipment as found in the classification code
- The name of the original equipment manufacturer
- The year of manufacture of the basic machine
- The model number and serial number
- The name of the manufacturer of the engine
- Information regarding the engine. If there are two engines, as in a twin-engine wheel tractor–scraper, then both should be listed here with the front engine at the left followed by a slash and then rear engine
- Accessories and attachments including a short description of the items and their name of the manufacturer, year of manufacturer, model number of each of the accessories, the cost of the particular item. All major accessory items should be listed

here including radio equipment, power control units, dozer blades, and the other optional equipment other than special tires included in the purchase price

- Information on tires for wheeled equipment including the axles from front to rear with spaces for one to five axles, the number of tires (wheels), and the size and ply rating, and the total cost of tires on a particular axle
- The market value of the machine in order to obtain a capital-cost curve for analytical purposes. Month and year of the appraisal should be recorded.
- The purchase-order number, the name of the seller, and the delivery date of the machine when purchased.
- The date of disposal and the life in months. The estimated life is recorded when the machine is purchased and put into service. The actual life is recorded on the date of disposal
- A summary of the capital costs of the machine, accessories, and tires. The acquisition costs are broken down into cost, freight, and taxes
- The weights are useful in figuring freight and shipping costs. All costs should be recorded in dollars of that year [6]

13.4.2 Electronic Record Keeping

This category of software provides the equipment manager with a comprehensive vehicle maintenance management package for planning, controlling, and monitoring all of the fleets' operational activities. Some packages have been specifically designed to help organizations to achieve increased productivity, reduce unscheduled downtime, and extend equipment life. They take advantage of computer-based technology and operate in an open environment, which allow the use of aggressive mobile facilities, as well as the ability to interface with other applications. Electronic record keeping systems are designed to operate in real time, facilitating the collection of all data when and where it takes place. The key to success in this type of system is accurate and timely data input. These systems are operational in both public and private fleets of all different sizes.

The most important features for an electronic record keeping system are:

- *Computer platform*: The platform should be user-friendly and compatible with existing organizational hardware
- *Scheduling*: The scheduling function should include the ability to generate work orders for scheduled preventive maintenance as well as repair orders
- *Fluids tracking*: The software should support the organization's oil and fluids analysis program without modification
- *Tire tracking*: The software should maintain a complete tire history, including tire repair and costs per mile according to their equipment identification number, tire type, manufacturer, or vehicle code
- *Inventory*: The software should support the real-time change in equipment and repair parts inventories, relating each transaction with a cost code
- *Purchasing*: The software should create both purchase orders and purchase requests.
- *Security*: The software should be secure down to the form level

It needs to be noted that equipment record keeping software packages can also be found that are Web-based. These systems furnish the ability to move large amounts of data anywhere in the world in real time. As the use of the Internet has become pervasive, equipment-owning organizations should be looking to implement a system that leverages the power of the World Wide Web.

13.5 EQUIPMENT LOCATION AND UTILIZATION

The choice of the right equipment is strictly connected with the jobsite requirements. Typically, construction equipment is used to perform essentially repetitive operations, and can be broadly classified according to two basic categories:

- Equipment such as cranes or graders that stay within the general confines of the construction site while working
- Equipment such as dump trucks or ready-mixed concrete trucks that transport materials to and from the site

In both cases, the cycle of a piece of equipment is a sequence of tasks that is repeated to produce a unit of output. In order to increase jobsite productivity, the equipment manager selects equipment with proper characteristics and a size most suitable for the work conditions at a construction site and to achieve field production objectives, the equipment manager needs to know where each piece of equipment is at all times.

Real-time systems with a connection between accountability, cost control, and jobsite productivity factors have been developed, leveraging the capabilities of computer-based technology and satellite and cellular phone communication linkages. Organizations with large equipment fleets use data on equipment location to optimize the utilization of these expensive and critical resources. Moreover, the data can be transmitted almost anywhere on the face of the planet giving equipment manager real-time status of their fleets, facilitating routine, and crisis decision-making.

13.5.1 Geographic Information System Applications

A geographic information system (GIS) (also referred to as a spatial information system) is a system composed of software, hardware, and data. It must also have trained personnel to help manipulate, analyze, and present information that is tied to a spatial location. It uses computer technology for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data related to positions on the earth's surface. Typically, a GIS is used for processing various types of mapping products that are represented as different informational layers. Each layer contains information about a specific type of feature. Each feature is linked to a position on the graphical image of a map. Layers of data are organized in a manner that permits easy study and statistical analysis. Users are primarily government related, town planning, local authority, and public utility management, environmental, resource management, engineering, business, marketing, and distribution [8].

Equipment inventory management systems using GIS permit the real-time monitoring of actual equipment locations. This allows improved data collection, fleet management, and accountability. It also permits the inventory of every piece of equipment that carries a GIS transmitter to be accomplished remotely utilizing Web-based applications that link to the organization's inventory control software. GIS systems come in two types:

- Fleet management systems (FMS)
- Automatic vehicle location (AVL) systems, which are really just specialized FMSs

In fact, an AVL is an automated system and related technology of tracking vehicle locations. AVL systems utilize GPS technology coupled with wireless communication systems to provide a vast array of data to the home station and fleet operator.

In the information technology market there are systems that are complete, turnkey equipment management packages, which include hardware, network services, and data integration capabilities. These systems help to:

- Improve equipment maintenance and service costs by allowing the schedule for preventive maintenance to be developed with real-time knowledge of equipment location
- Reduce equipment downtime by allowing maintenance personnel to be able to better plan their work routines
- Reduce equipment theft and misuse by furnishing a means by which the equipment fleet owner can track the movements of every piece in the fleet
- Increase equipment utilization and sharing across jobsites by identifying idle equipment on a real-time basis as well as showing individual equipment proximity radii

Data from these systems can be integrated with mobile communication systems for maintenance service and delivery trucks using portable computer and cellular telephone technology. These systems are composed of a software package that does the data processing, a communication system to detect and transmit the position of the equipment and positioning integrator that communicates with some positioning system. The software can be based on the Internet to provide fast access to critical equipment information from any Web connection. Moreover, systems integrated with the organization's other computer record keeping and accounting systems permit a seamless integration of critical equipment operating data with more complex financial and scheduling systems, which allows equipment owner to update all aspects of their operation with real-time information. The most common functions of a FMS system are as follows:

- *Vehicle tracking*: Providing real-time location data on each piece of equipment in the fleet
- *Geocoding*: Furnishing address information to operators and managers to develop efficient route planning
- *Network topology*: Developing and scheduling vehicle route information
- *Route logging*: Recording the routes that were actually followed as well as mileage for things like fuel tax mileage reporting
- *Accessibility*: Selecting the administrative sites that are best for project support locations
- *Order fulfillment*: Historical record of customer service job fulfillment

13.5.2 Global Positioning System Equipment Fleet Management Systems

The global positioning system (GPS) is a location-based technology which relies on a network of 24 active NAVSTAR satellites orbiting the Earth and constantly transmitting radio signals to ground-based stations and GPS receivers on Earth. The U.S. military originally designed and fielded it for global navigation and precision weapons system guidance. In 1982, GPS satellite technology was finally adapted for use by commercial ventures. A GPS satellite transmits to its own location on the Earth, and the precise time of transmission using synchronized atomic clock data. Given this data, the receiver calculates its latitude and longitude based on the signal strength and location of the satellite. This is accurate to within 10 m and uses a geometric method called "triangulation," which relies on the signal information from at least three satellites to determine the receiver's location on the planet. The signals are line-of-sight and as the number of satellites within the range of the receiver increases, the accuracy of the location data also gets greater. With permutations of the same data, the GPS receiver can calculate the vehicle's speed and direction in addition to just latitude and longitude. When GPS is combined with analysis and mapping software, it furnishes a global view of the equipment fleet's activity, locations, and graphic annotation of key events like service stops, route tracking, and variations from route.

Commercial fleet management systems provide the equipment manager with real-time access to this type data, and detailed analysis tools to measure operator efficiency, vehicle maintenance history, fuel usage, and the ability to identify anomalies like speeding, unauthorized usage, and equipment stops that are inconsistent with planned operations. The bottom-line is a fact-based management information system that measures equipment operational efficiency, operator safety, route effectiveness, and automates vehicle record keeping, mileage logs, service records, and other data that may be desired by the equipment manager. Thus, this technology promises potentially large benefits to those equipment managers who can adapt it to their specific requirements for equipment inventory and control.

13.5.3 Comparing GPS Systems

There are four principal categories of GPS-enabled fleet management systems on the market today:

- Passive systems
- Active systems
- Hybrid systems
- Low-earth-orbit (LEO) satellite systems

This section will give a general overview of each category and discuss the advantages and disadvantages of each [9–11].

Passive systems are based on onboard device records GPS signal data during the vehicle operations. Information is stored for retrieval and uploads to the principal fleet management computer when the vehicle returns to home base. Alternatively, removable memory modules can be exchanged in the field, away from the office, by mail, or during scheduled meetings. The "passive" GPS system shown in Figure 13.1 is often the best solution for data collection on vehicles that are on the road away from the home office for weeks or months at a time.

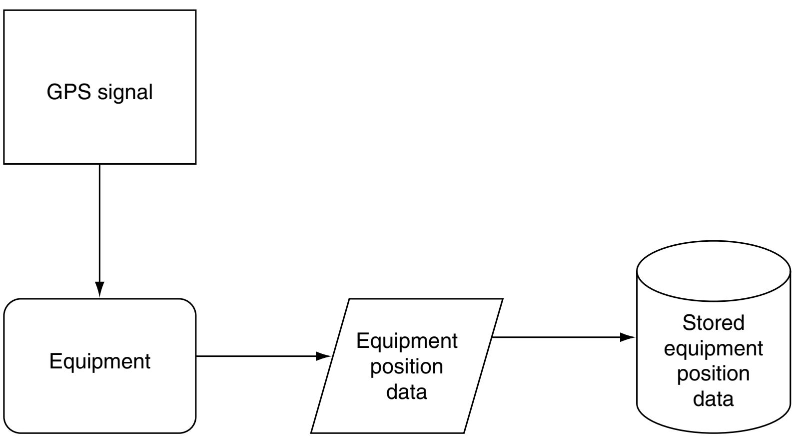

FIGURE 13.1 Passive GPS system flowchart.

Passive GPS systems are called "passive" because the GPS system installed in the equipment merely records its location on an onboard database receiving the signal from the GPS satellites. It has several advantages. First, it provides a simple solution for fleets that do not routinely return to a central equipment storage facility at the end of everyday. It gives specialized staff, such as supervisory personnel, the ability to distinguish between personal and company business vehicle use. It is usually the lowest cost option. Conversely, its disadvantage includes the need for a removable and exchangeable data module, which retrieves the vehicle information, and most importantly, it does not allow for real-time location or remote accountability because the data is stored on the data module and not transmitted to a central location [9–11].

Active systems rely on a vehicle-mounted GPS receiver and a wireless communication system such as a cellular data line built into the device. At specific time intervals, the system transmits latitude and longitude location data, speed, and direction of travel over the wireless network to a central data collection point. This data can be subsequently transmitted to the fleet home office or compiled for transfer to an Internet site where the subscribing company can view its fleet activity. Figure 13.2 is the flow chart for this type of system.

Active GPS systems have a number of advantages. First, they provide vehicle locations at regular intervals which allows equipment managers to track vehicle activity remotely and in real time. They facilitate route adjustments "on the fly" to accommodate changing service vehicle assignments based on location or to reroute equipment around traffic congestion or dangerous situations. Often, active systems may actually require additional people to track and deal with fleet status updates throughout the day. Depending on the data transmission interval, monthly access costs can be large. Finally, data stored on the Internet is often perishable making it difficult to perform trend analysis over a long period of time [9–11].

As might be expected, hybrid systems combine the functions of both passive and active systems into a single package that provides real-time equipment location data as well as the long-term information storage of a stored data system. By combining the features of each system, the hybrid GPS fleet management system gives equipment managers real-time vehicle locations, status updates, and data logging. Figure 13.3 is the flow chart for this type of system.

Hybrid systems have many advantages. They give equipment managers access to comprehensive vehicle data as they need it, in real time from central locations, and in stored data from the data storage devices. If communications are interrupted, equipment

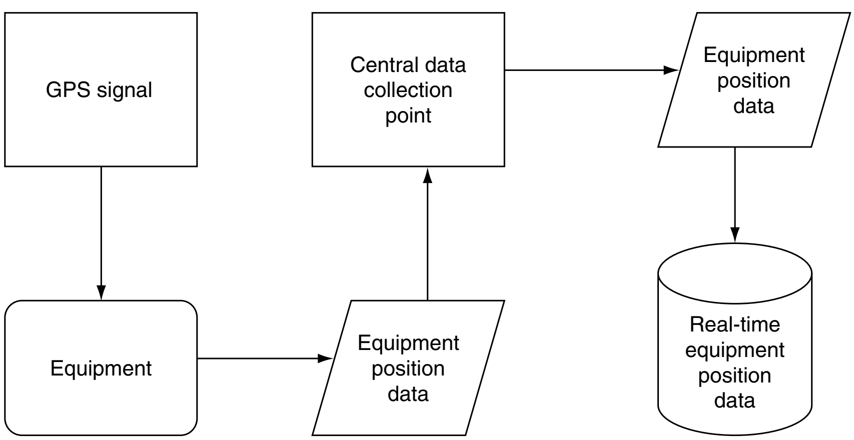

FIGURE 13.2 Active GPS system flowchart.

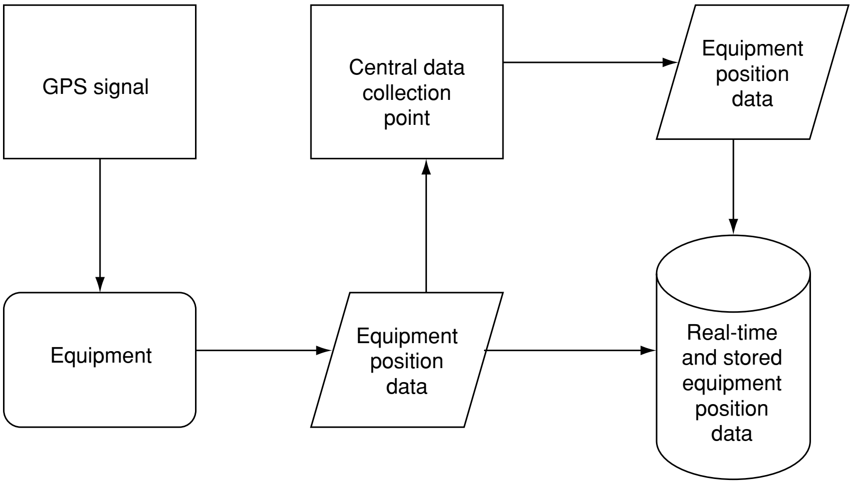

FIGURE 13.3 Hybrid GPS system flowchart.

positional and other data is stored in the onboard device and not lost. Hybrid systems provide the most flexibility and adaptability to most organizational requirements and needs. As for their disadvantages, the hybrid system's communication features demands an active Internet connection and may also require a dedicated computer. Costs are higher because service contracts, connectivity, and transmission charges apply when using the active part of the system [9–11].

The LEO system uses a dedicated LEO satellite constellation. This is a two-way mobile satellite tracking system and allows for instant digital communications between equipment operators and their bases. LEO systems are favored by over-the-road trucking companies and constitute the most expensive approach to GPS fleet management. They provide the most comprehensive system in terms of both connectivity and range. LEO-based systems are able to provide service where conventional cellular communications are not available, such as rural areas as well as remote areas of the world. Figure 13.4 shows that this is also the most complex form of GPS-based equipment management.

Thus, it demands a staff who have the technical acumen and experience to manage it [9–11].

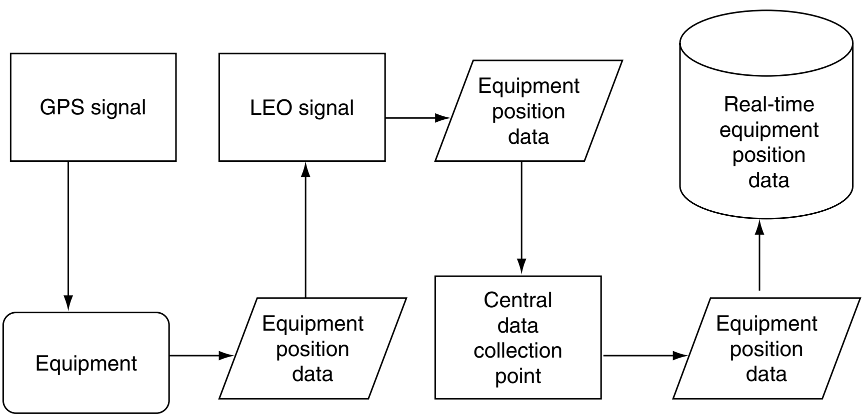

FIGURE 13.4 Low-earth-orbit (LEO) GPS system flowchart.

13.6 SUMMARY

Recently, the application of sophisticated inventory procedures into equipment-owning organizations are becoming more widespread, especially in large organizations. The purpose is to optimize services and costs through real-time knowledge of the equipment situation and utilization. The primary objective of inventory control is to minimize the cost of keeping the equipment inventory. For this reason, equipment inventory control can be decisive in an organization's overall effort to reduce equipment costs, and thus enhance its competitiveness if it is a private company or to maximize the utilization of its annual budget if it is a public agency. Inventory control can become the best source of data for making management decisions on whether to rent or own construction equipment because it gives the manager the real information on fleet performance, cost, and utilization.

The input of the actual equipment usage data from automated systems reduces uncertainty in the equipment decision-making process. The utilization of GPS applications in the equipment inventory control enhances the effectiveness of equipment operations and when combined with GIS, furnishes a comprehensive approach to equipment management. These systems are becoming very common, and their benefits will increase their adoption by both public and private equipment-owning organizations. Equipment managers who know all the equipment locations and its current status because of an aggressive inventory control program will be integral to the success of their organization.

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Appendix A: Corps of Engineers Construction Equipment Ownership and Operating Expense Schedule

This appendix contains an extract from the U.S. Army Corps of Engineers 2003 Construction Equipment Ownership and Operating Expense Schedule, Region VI; Document EP 1110-1-8 for use in solving the types of problems described in chapter 2.

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A10	**AGGREGATE/CHIP SPREADERS**												
	SUBCATEGORY 0.10		**SELF-PROPELLED**										
			ROSCO MANUFACTURING CO.										
	A10RS003	SPR-H	CHIP SPREADER, SELF PROPELLED, 10.0 FT, 1.70 CY	152 HP	D-off		$89,436	26.98	5.67	8.73	1.30	7.28	149
	A10RS004	SPR-H	CHIP SPREADER, SELF PROPELLED, 11.0 FT, 1.80 CY	152 HP	D-off		$92,408	27.57	5.86	9.03	1.34	7.28	150
	A10RS005	SPR-H	CHIP SPREADER, SELF PROPELLED, 12.0 FT, 2.03 CY	152 HP	D-off		$96,073	28.32	6.10	9.40	1.40	7.28	152
	A10RS006	SPR-H-H	CHIP SPREADER, SELF PROPELLED, 13.0 FT, 2.28 CY	152 HP	D-off		$99,658	29.03	6.33	9.75	1.45	7.28	153
	A10RS007	SPR-H	CHIP SPREADER, SELF PROPELLED, 15.0 FT, 2.53 CY	152 HP	D-off		$91,317	27.36	5.79	8.92	1.33	7.28	156
	A10RS008	SPREADPRO	CHIP SPREADER, SELF PROPELLED, 16.5 FT, 4.50 CY	215 HP	D-off		$165,148	45.91	10.49	16.18	2.40	10.29	158
	SUBCATEGORY 0.20		**TOWED & TAILGATE**										
			AMERICAN ROAD MACHINERY, INC.										
	A10AR001	TG-505C	CHIP SPREADER, TAILGATE, 8′ WIDE (ADD DUMP TRUCK)				$3,838	0.92	0.32	0.51	0.06	0.00	5
	A10AR002	ODELL 900	CHIP SPREADER, TOWED, 8′ WIDE (ADD DUMP TRUCK)				$9,541	2.49	0.78	1.27	0.14	0.00	22
A15	**AIR COMPRESSORS, PORTABLE**												
	SUBCATEGORY 0.10		**ROTARY SCREW**										
			INGERSOLL RAND CO.										
	A15IA001	P175WJD	AIR COMPRESSOR, 175 CFM, 100 PSI (ADD HOSE)	56 HP	D-off		$20,478	6.99	1.10	1.62	0.29	2.90	21

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A15		***INGERSOLL RAND CO. (continued)***										
	A15IA002	HP300WCU	AIR COMPRESSOR, 300 CFM, 150 PSI (ADD HOSE)	110 HP D-off		$44,244	14.37	2.39	3.52	0.63	5.71	38
	A15IA003	VHP400WCU	AIR COMPRESSOR, 400 CFM, 200 PSI (ADD HOSE)	174 HP D-off		$52,954	19.97	2.85	4.19	0.75	9.03	53
	A15IA004	HP450WCU	AIR COMPRESSOR, 450 CFM, 150 PSI (ADD HOSE)	174 HP D-off		$52,954	19.97	2.85	4.19	0.75	9.03	53
	A15IA005	XP525WCU	AIR COMPRESSOR, 525 CFM, 125 PSI (ADD HOSE)	174 HP D-off		$52,954	19.97	2.85	4.19	0.75	9.03	53
	A15IA006	XHP650WCAT	AIR COMPRESSOR, 650 CFM, 350 PSI (ADD HOSE)	300 HP D-off		$116,808	38.55	6.29	9.25	1.66	15.56	136
	A15IA007	XHP750WCAT	AIR COMPRESSOR, 750 CFM, 300 PSI (ADD HOSE)	300 HP D-off		$122,525	39.48	6.60	9.71	1.74	15.56	136
	A15IA008	VHP825WCU	AIR COMPRESSOR, 825 CFM, 200 PSI (ADD HOSE)	335 HP D-off		$92,613	36.94	4.97	7.32	1.31	17.38	96
	A15IA009	XP1000WCAT	AIR COMPRESSOR, 1000 CFM, 125 PSI (ADD HOSE)	310 HP D-off		$92,657	35.31	4.98	7.32	1.32	16.08	104
	A15IA010	XHP1070WCAT	AIR COMPRESSOR, 1070 CFM, 350 PSI (ADD HOSE)	400 HP D-off		$165,343	52.95	8.92	13.13	2.35	20.75	152
		SULLAIR CORPORATION										
	A15SR006	125DPQJD	AIR COMPRESSOR, 125 CFM, 100 PSI (ADD HOSE)	76 HP D-off		$13,307	7.13	0.71	1.04	0.19	3.94	24
	A15SR007	130DPQJD	AIR COMPRESSOR, 130 CFM, 100 PSI (ADD HOSE)	77 HP D-off		$13,318	7.21	0.72	1.05	0.19	3.99	26
	A15SR004	185	AIR COMPRESSOR, 185 CFM, 100 PSI (ADD HOSE)	78 HP D-off		$14,278	7.43	0.76	1.12	0.20	4.05	24
	A15SR005	250	AIR COMPRESSOR, 250 CFM, 100 PSI (ADD HOSE)	80 HP D-off		$17,818	8.13	0.96	1.41	0.25	4.15	26
	A15SR008	375HDPQJD	AIR COMPRESSOR, 375 CFM, 150 PSI (ADD HOSE)	123 HP D-off		$29,231	12.80	1.57	2.29	0.42	6.38	42
	A15SR009	425DPQJD	AIR COMPRESSOR, 425 CFM, 100 PSI (ADD HOSE)	124 HP D-off		$29,231	12.86	1.57	2.29	0.42	6.43	42
	A15SR010	600HDTQCA	AIR COMPRESSOR, 600 CFM, 150 PSI (ADD HOSE)	230 HP D-off		$54,083	23.84	2.89	4.23	0.77	11.93	100
	A15SR011	750HHDTQCA	AIR COMPRESSOR, 750 CFM, 175 PSI (ADD HOSE)	300 HP D-off		$62,992	29.85	3.37	4.95	0.89	15.56	103

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A15		***SULLAIR CORPORATION (continued)***										
	A15SR002	900XH	AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)	440 HP D-off		$124,399	48.98	6.68	9.81	1.77	22.82	157
	A15SR012	1050DTQCA	AIR COMPRESSOR, 1050 CFM, 100 PSI (ADD HOSE)	300 HP D-off		$61,958	29.68	3.31	4.86	0.88	15.56	105
	A15SR013	1200HDTQCA	AIR COMPRESSOR, 1200 CFM, 150 PSI (ADD HOSE)	440 HP D-off		$115,146	47.44	6.19	9.12	1.63	22.82	166
	A15SR014	1500DTQCA	AIR COMPRESSOR, 1500 CFM, 100 PSI (ADD HOSE)	440 HP D-off		$115,383	47.55	6.17	9.05	1.64	22.82	172
	A15SR015	1900DTQCA	AIR COMPRESSOR, 1900 CFM, 100 PSI (ADD HOSE)	525 HP D-off		$124,487	54.58	6.66	9.78	1.77	27.23	164
		NO SPECIFIC MANUFACTURER										
	A15XX019	85G	AIR COMPRESSOR, 85 CFM, 100 PSI (ADD HOSE)	30 HP G		$8,962	5.98	0.48	0.70	0.13	3.47	14
	A15XX020	85D	AIR COMPRESSOR, 85 CFM, 100 PSI (ADD HOSE)	30 HP D-off		$12,473	4.01	0.67	0.98	0.18	1.56	24
	A15XX021	100G	AIR COMPRESSOR, 100 CFM, 100 PSI (ADD HOSE)	50 HP G		$11,934	9.46	0.64	0.94	0.17	5.78	16
	A15XX022	100D	AIR COMPRESSOR, 100 CFM, 125 PSI (ADD HOSE)	35 HP D-off		$13,903	4.57	0.75	1.09	0.20	1.82	15
	A15XX023	125G	AIR COMPRESSOR, 125 CFM, 100 PSI (ADD HOSE)	65 HP G		$12,697	11.82	0.68	1.00	0.18	7.51	20
	A15XX024	125D	AIR COMPRESSOR, 125 CFM, 125 PSI (ADD HOSE)	50 HP D-off		$14,663	5.66	0.79	1.15	0.21	2.59	23
	A15XX025	160G	AIR COMPRESSOR, 160 CFM, 125 PSI (ADD HOSE)	60 HP G		$13,454	11.19	0.72	1.06	0.19	6.93	23
	A15XX026	175D	AIR COMPRESSOR, 175 CFM, 100 PSI (ADD HOSE)	70 HP D-off		$17,919	7.49	0.96	1.41	0.25	3.63	27
	A15XX027	175G	AIR COMPRESSOR, 175 CFM, 125 PSI (ADD HOSE)	90 HP G		$14,447	15.86	0.78	1.14	0.21	10.40	24
	A15XX028	185D	AIR COMPRESSOR, 185 CFM, 100 PSI (ADD HOSE)	75 HP D-off		$18,412	7.90	0.99	1.45	0.26	3.89	27
	A15XX029	185G	AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)	70 HP G		$15,428	13.01	0.83	1.21	0.22	8.09	23
	A15XX030	250	AIR COMPRESSOR, 250 CFM, 100 PSI (ADD HOSE)	95 HP D-off		$27,319	10.65	1.47	2.16	0.39	4.93	31

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A15	***NO SPECIFIC MANUFACTURER (continued)***												
	A15XX031	300	AIR COMPRESSOR, 300 CFM, 125 PSI (ADD HOSE)	110 HP	D-off		$31,777	12.35	1.71	2.52	0.45	5.71	34
	A15XX032	375	AIR COMPRESSOR, 375 CFM, 125 PSI (ADD HOSE)	112 HP	D-off		$33,314	12.74	1.78	2.62	0.47	5.81	44
	A15XX033	450	AIR COMPRESSOR, 450 CFM, 125 PSI (ADD HOSE)	150 HP	D-off		$40,969	16.47	2.17	3.18	0.58	7.78	89
	A15XX034	600	AIR COMPRESSOR, 600 CFM, 100 PSI (ADD HOSE)	200 HP	D-off		$59,780	22.79	3.20	4.69	0.85	10.37	99
	A15XX035	750	AIR COMPRESSOR, 750 CFM, 125 PSI (ADD HOSE)	250 HP	D-off		$63,740	26.72	3.42	5.01	0.91	12.97	101
	A15XX036	825	AIR COMPRESSOR, 825 CFM, 125 PSI (ADD HOSE)	310 HP	D-off		$68,737	31.44	3.68	5.40	0.98	16.08	112
	A15XX037	900	AIR COMPRESSOR, 900 CFM, 125 PSI (ADD HOSE)	260 HP	D-off		$75,574	29.27	4.05	5.95	1.07	13.49	99
	A15XX038	1200	AIR COMPRESSOR, 1200 CFM, 125 PSI (ADD HOSE)	325 HP	D-off		$112,382	39.48	6.05	8.90	1.60	16.86	150
	A15XX039	1300	AIR COMPRESSOR, 1400 CFM, 125 PSI (ADD HOSE)	395 HP	D-off		$117,485	44.91	6.31	9.28	1.67	20.49	180
	A15XX040	1600	AIR COMPRESSOR, 1600 CFM, 100 PSI (ADD HOSE)	425 HP	D-off		$124,395	47.98	6.69	9.83	1.77	22.04	180
	SUBCATEGORY 0.20		**SHOP TYPE**										
	NO SPECIFIC MANUFACTURER												
	A15XX041	80/15	AIR COMPRESSOR, 15 CFM, 80 GAL (ADD HOSE)	5 HP	E		$5,986	1.13	0.29	0.42	0.08	0.24	3
	A15XX042	80/25	AIR COMPRESSOR, 25 CFM, 80 GAL (ADD HOSE)	7 HP	E		$6,330	1.33	0.32	0.45	0.09	0.34	3
	A15XX043	120/35	AIR COMPRESSOR, 35 CFM, 120 GAL (ADD HOSE)	10 HP	E		$6,367	1.53	0.32	0.45	0.09	0.48	4
	A15XX044	120/55	AIR COMPRESSOR, 55 CFM, 120 GAL (ADD HOSE)	15 HP	E		$7,828	2.06	0.39	0.55	0.11	0.72	4
	A15XX045	120/90	AIR COMPRESSOR, 90 CFM, 120 GAL (ADD HOSE)	25 HP	E		$10,140	3.05	0.50	0.72	0.14	1.20	4
	A15XX046	120/112	AIR COMPRESSOR, 112 CFM, 120 GAL (ADD HOSE)	30 HP	E		$11,276	3.54	0.55	0.80	0.15	1.44	5

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A20	**AIR HOSE, TOOLS & EQUIPMENT**											
	SUBCATEGORY 0.10		**AIR DRILL HOSE**									
		NO SPECIFIC MANUFACTURER										
	A20XX001		AIR HOSE, 0.75″, 100′, HARDROCK			$1,213	0.82	0.19	0.33	0.02	0.00	1
	A20XX002		AIR HOSE, 1.00″, 100′, HARDROCK			$1,406	0.94	0.21	0.38	0.02	0.00	1
	A20XX003		AIR HOSE, 1.25″, 100′, HARDROCK			$1,753	1.19	0.27	0.48	0.03	0.00	1
	A20XX004		AIR HOSE, 1.50″, 100′, HARDROCK			$2,289	1.54	0.35	0.62	0.04	0.00	1
	A20XX005		AIR HOSE, 2.00″, 100′, HARDROCK			$3,236	2.18	0.49	0.88	0.05	0.00	2
	A20XX006		AIR HOSE, 2.50″, 100′, HARDROCK			$3,962	2.67	0.60	1.08	0.06	0.00	3
	A20XX007		AIR HOSE, 3.00″, 100′, HARDROCK			$4,891	3.30	0.75	1.33	0.08	0.00	4
	A20XX008		AIR HOSE, 4.00″, 100′, HARDROCK			$6,529	4.39	0.99	1.77	0.10	0.00	6
	SUBCATEGORY 0.20		**SANDBLAST HOSE**									
		CLEMCO INDUSTRIES CORPORATION										
	A20CM017		SANDBLAST HOSE, 0.75″ID, 100′ LONG USE AS SAND BLASTING ACCESSORY			$496	0.35	0.08	0.13	0.01	0.00	1
	A20CM018		SANDBLAST HOSE, 1.00″ID, 100′ LONG USE AS SAND BLASTING ACCESSORY			$658	0.47	0.10	0.18	0.01	0.00	1
	A20CM020		SANDBLAST HOSE, 1.25″ID, 100′ LONG USE AS SAND BLASTING ACCESSORY			$717	0.50	0.11	0.19	0.01	0.00	1
	A20CM019		SANDBLAST HOSE, 1.50″ID, 100′ LONG USE AS SAND BLASTING ACCESSORY			$813	0.57	0.12	0.22	0.01	0.00	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.30		SANDBLASTERS, BREAKERS, & MISC. AIR TOOLS										
		CHICAGO PNEUMATIC TOOL CO.											
	A20CK002	CP-0009F	ROTARY/CHIP HAMMER, 8 LB, AIR (ADD 30 PSI COMPRESSOR & BIT COSTS)	20 CFM	A		$928	0.36	0.08	0.14	0.01	0.00	1
	A20CK001	CP-0014RR	ROTARY/CHIP HAMMER, 15 LB, AIR (ADD 30 PSI COMPRESSOR & BIT COSTS)	32 CFM	A		$1,686	0.65	0.15	0.25	0.02	0.00	1
	A20CK003	CP-0022	ROCK DRILL, 30 LB, AIR (ADD 50 CFM COMPRESSOR & BIT COSTS)	56 CFM	A		$1,851	0.73	0.17	0.28	0.03	0.00	1
	A20CK005	CP-0069	ROCK DRILL, 55 LB, AIR (ADD 140 CFM COMPRESSOR & BIT COSTS)	130 CFM	A		$2,200	0.85	0.20	0.33	0.03	0.00	1
	A20CK006	CP-0111-THLA	BREAKER-FOUR BOLT, 25 LB (ADD 50 CFM COMPRESSOR & BIT COSTS)	45 CFM	A		$1,314	0.52	0.12	0.20	0.02	0.00	1
	A20CK008	CP-1230-S1.25	BREAKERS-FOUR BOLT, 60 LB (ADD 65 CFM COMPRESSOR & BIT COSTS)	63 CFM	A		$1,351	0.52	0.12	0.20	0.02	0.00	1
	A20CK010	CP-1240-S1.25	BREAKER-FOUR BOLT, 90 LB (ADD 90 CFM COMPRESSOR & BIT COSTS)	81 CFM	A		$1,491	0.58	0.13	0.22	0.02	0.00	1
		CLEMCO INDUSTRIES CORPORATION											
	A20CM010	PACKAGE TWO	SANDBLASTER, 2 CF CAP, W/ 0.50″ × 25′ HOSE (ADD 100 CFM COMPRESSOR & NOZZLE COST)	100 CFM	A		$3,184	1.31	0.29	0.48	0.05	0.00	4
	A20CM011	PACKAGE FOUR	SANDBLASTER, 4 CF CAP, W/ 1.00″ × 25′ HOSE (ADD 170 CFM COMPRESSOR & NOZZLE COST)	170 CFM	A		$3,542	1.44	0.32	0.53	0.05	0.00	5
	A20CM012	PACKAGE SIX	SANDBLASTER, 6 CF CAP, W/ 1.25″ × 25′ HOSE (ADD 200 CFM COMPRESSOR & NOZZLE COST)	200 CFM	A		$3,849	1.64	0.35	0.58	0.06	0.00	6

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A20	***CLEMCO INDUSTRIES CORPORATION (continued)***												
	A20CM013		SANDBLASTER, 60CF CAP, W/ 1.25″D × 50′L HOSE (ADD 450 CFM COMPRESSOR & NOZZLE COST)	450 CFM	A		$16,325	6.51	1.40	2.33	0.23	0.00	30
	A20CM014		SANDBLASTER, 120CF CAP, W/ 1.25″D × 50′L HOSE (ADD 700 CFM COMPRESSOR & NOZZLE COST)	700 CFM	A		$19,319	7.67	1.60	2.64	0.28	0.00	35
	A20CM015		SANDBLASTER, 160CF CAP, W/ 1.25″D × 50′L HOSE (ADD 900 CFM COMPRESSOR & NOZZLE COST)	900 CFM	A		$20,682	8.35	1.75	2.90	0.30	0.00	45
	A20CM016		SANDBLAST ABRASIVE STORAGE HOPPER, 700 CF, 8′ DEEP, 10′ WIDE & 23′HIGH (ADD SAND BLASTER & ACCESSORIES)				$13,054	5.38	1.17	1.96	0.19	0.00	69
	WACKER CORPORATION												
	A20WC002	EHB 10/110	BREAKER/DRILL, 40 LB, ELECTRIC (ADD 2 KW GENERATOR & BIT COSTS)	2 HP	E		$1,404	0.80	0.13	0.21	0.02	0.08	1
	A20WC004	BHF 30S	BREAKER/DRIVER, 85 LB, W/ POWER UNIT (ADD BIT COSTS)	4 HP	G		$3,847	2.02	0.35	0.58	0.06	0.40	1
	NO SPECIFIC MANUFACTURER												
	A20XX021	STANDARD 25–30 LBS	PAVEMENT BREAKER, 25–30 LB, HAND HELD	100 CFM	A		$1,024	0.39	0.09	0.15	0.01	0.00	1
	A20XX022	SILENCED 35–45 LBS	PAVEMENT BREAKER, 35–45 LB, HAND HELD	100 CFM	A		$1,274	0.50	0.12	0.19	0.02	0.00	1
	A20XX023	SILENCED 60–65 LBS	PAVEMENT BREAKER, 60–65 LB, HAND HELD	100 CFM	A		$1,631	0.63	0.14	0.24	0.02	0.00	1
	A20XX024	SILENCED 80–90 LBS	PAVEMENT BREAKER, 80–90 LB, HAND HELD	100 CFM	A		$1,707	0.66	0.15	0.26	0.02	0.00	1
	A20XX025	55DRY	ROCK DRILL, DRY, 55 LB, HAND HELD	100 CFM	A		$2,309	0.90	0.21	0.35	0.03	0.00	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A25	**ASPHALT PAVING DISTRIBUTORS**											
	SUBCATEGORY 0.00		**ASPHALT PAVING DISTRIBUTORS**									
			ROSCO MANUFACTURING CO.									
	A25RS006	MAXIMIZER 11	ASPHALT DISTRIBUTOR, 2000 GAL, FOR TRUCK MTD (ADD 32,000 GVW TRUCK)			$43,697	14.02	3.91	6.55	0.63	0.00	70
	A25RS008	MAXIMIZER 11	ASPHALT DISTRIBUTOR, 3100 GAL, FOR TRUCK MTD (ADD 42,000 GVW TRUCK)			$50,319	16.61	4.50	7.55	0.72	0.00	97
			NO SPECIFIC MANUFACTURER									
	A25XX001	1100G	ASPHALT DISTRIBUTOR, 1100 GAL, 400 GPM, FOR TRUCK MTD (ADD 32,000 GVW TRUCK)			$43,670	13.49	3.90	6.55	0.62	0.00	64
	A25XX002	2600G	ASPHALT DISTRIBUTOR, 2600 GAL, 400 GPM, FOR TRUCK MTD (ADD 32,000 GVW TRUCK)			$51,002	16.52	4.56	7.65	0.73	0.00	89
	A25XX003	3600G	ASPHALT DISTRIBUTOR, 3600 GAL, 400 GPM, FOR TRUCK MTD (ADD 42,000 GVW TRUCK)			$55,730	18.49	4.98	8.36	0.80	0.00	104
A30	**ASPHALT PAVERS & MISCELLANEOUS ROAD EQUIPMENT**											
	SUBCATEGORY 0.10		**SELF PROPELLED**									
			BARBER-GREENE COMPANY									
	A30BG008	BG210B	ASPHALT PAVER, 8′ WIDE SCREED, WHEEL, W/15′6″ SCREED EXTENSION	107 HP	D-off	$210,215	56.18	13.94	21.95	2.96	5.12	224
	A30BG007	BG230	ASPHALT FINISHER, 8′ WIDE SCREED, WHEEL, W/15′ 6″ SCREED EXTENSION	107 HP	D-off	$265,605	70.70	17.66	27.84	3.74	5.12	335

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A30		*BARBER-GREENE COMPANY (continued)*										
	A30BG004	BG225C	ASPHALT FINISHER, 8′ WIDE SCREED, CRAWLER, W/15′ 6″ SCREED EXTENSION	121 HP D-off		$277,291	73.99	18.64	29.46	3.91	5.79	360
	A30BG009	BG240C	ASPHALT PAVER, 10′ WIDE SCREED, CRAWLER, W/19′6″ SCREED EXTENSION	153 HP D-off		$297,092	79.76	19.66	30.93	4.19	7.33	449
	A30BG005	BG245C	ASPHALT FINISHER, 10′ WIDE SCREED, CRAWLER, W/19′ 6″ SCREED EXTENSION	173 HP D-off		$333,990	90.47	22.46	35.49	4.71	8.28	396
	A30BG003	BG260C	ASPHALT FINISHER, 10′ WIDE SCREED, WHEEL, W/19′ 6″ SCREED EXTENSION	174 HP D-off		$312,376	86.12	20.52	32.24	4.40	8.33	323
		BLAW KNOX CONSTRUCTION EQUIPMENT CORP.										
	A30BK010	PF-150	ASPHALT PAVER/FINISHER, 8′ WIDE SCREED, WHEEL	47 HP D-off		$135,976	35.11	9.01	14.18	1.92	2.25	154
	A30BK011	PF-161	ASPHALT PAVER/FINISHER, 8′ WIDE SCREED, WHEEL	107 HP D-off		$219,508	58.37	14.56	22.94	3.09	5.12	210
	A30BK013	PF-3172	ASPHALT PAVER/FINISHER, 10′ WIDE SCREED, WHEEL	145 HP D-off		$262,540	70.99	17.41	27.42	3.70	6.94	299
	A30BK015	PF-3200	ASPHALT PAVER/FINISHER, 10′ WIDE SCREED, WHEEL	184 HP D-off		$302,304	82.79	20.02	31.51	4.26	8.81	340
	A30BK017	PF-5500	ASPHALT PAVER/FINISHER, 10′ WIDE SCREED, CRAWLER	184 HP D-off		$319,221	86.16	21.46	33.92	4.50	8.81	340
	A30BK018	PF-5510	ASPHALT PAVER/FINISHER, 10′ WIDE SCREED, CRAWLER	184 HP D-off		$324,446	87.38	21.81	34.47	4.57	8.81	320
	A30BK019	RW 100 A	ASPHALT PAVER, SHOULDER PAVING MACHINE, 1′–10′ WIDE, BITUMINOUS & AGGREGATE, WHEEL	105 HP D-off		$194,952	52.23	12.99	20.47	2.75	5.03	245
	A30BK020	RW 195 D	ASPHALT PAVER, SHOULDER PAVING MACHINE, 2′–10′ WIDE, BITUMINOUS & AGGREGATE, WHEEL	173 HP D-off		$251,381	69.66	16.78	26.47	3.54	8.28	330
	A30BK021	TITAN 325 EPM	ASPHALT PAVER, 32.8′ WIDE, CRAWLER W/DUAL TAMPER SCREED	176 HP D-off		$574,221	145.62	38.60	61.01	8.09	8.43	399

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A30	***BLAW KNOX CONSTRUCTION EQUIPMENT CORP. (continued)***											
	A30BK022	PF-2181	ASPHALT PAVER, 8′ WIDE SCREED, WHEEL, 2 WHEEL DRIVE, 182 CF HOPPER	145 HP D-off		$245,642	67.02	16.28	25.63	3.46	6.94	283
	A30BK023	PF-4410	ASPHALT PAVER, 8′ WIDE SCREED, CRAWLER, 155 CF HOPPER	145 HP D-off		$273,037	72.94	18.36	29.01	3.85	6.94	269
	CATERPILLAR INC. (MACHINE DIVISION)											
	A30CA001	AP-200B	ASPHALT PAVER, 3–12′ WIDE PAVING RANGE, CRAWLER, 6 TON HOPPER	35 HP D-off		$55,168	15.09	3.71	5.86	0.78	1.68	96
	A30CA013	AP-650B	ASPHALT PAVER, 8′ WIDE SCREED, CRAWLER, 177 CF HOPPER	121 HP D-off		$258,828	68.15	17.40	27.50	3.65	5.79	328
	A30CA002	AP-800C	ASPHALT PAVER, 10′ WIDE PAVEMASTER SCREED, WHEEL, 195 CF HOPPER	107 HP D-off		$245,434	64.60	16.27	25.62	3.46	5.12	318
	A30CA014	AP-900B	ASPHALT PAVER, 10′ WIDE SCREED, WHEEL, 215 CF HOPPER	153 HP D-off		$270,170	73.43	17.85	28.07	3.81	7.33	377
	A30CA008	AP-1000B	ASPHALT PAVER, 10′–12′ WIDE PAVEMASTER SCREED, WHEEL, 215 CF HOPPER	174 HP D-off		$293,498	80.14	19.45	30.62	4.14	8.33	414
	A30CA015	AP-1050B	ASPHALT PAVER, 10′ WIDE EXTEND-A-MAT SCREED, CRAWLER, 215 CF HOPPER	174 HP D-off		$342,828	91.11	23.05	36.43	4.83	8.33	415
	A30CA016	AP-1055B	ASPHALT PAVER, 10′ WIDE SCREED, CRAWLER, 215 CF HOPPER	174 HP D-off		$337,238	89.79	22.67	35.83	4.75	8.33	412
	A30CA009	AP-1050B	ASPHALT PAVER, 10′–24′ WIDE PAVEMASTER SCREED, CRAWLER, 215 CF HOPPER	175 HP D-off		$358,887	94.94	24.13	38.13	5.06	8.38	443
	VOGELE AMERICA - PRO-PAV DIV.											
	A30CH001	780WB	ASPHALT PAVER, 8′0″ WIDE SCREED, WHEEL, 190 CF HOPPER	110 HP D-off		$241,234	63.67	16.03	25.25	3.40	5.27	265

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A30	*VOGELE AMERICA - PRO-PAV DIV. (continued)*											
	A30CH002	880WB	ASPHALT PAVER, 8′0″ WIDE SCREED, WHEEL, 190 CF HOPPER	152 HP D-off		$263,124	71.57	17.46	27.49	3.71	7.28	315
	A30CH003	880RTB	ASPHALT PAVER, 8′0″ WIDE SCREED, CRAWLER-RUBBER TRACK, 190 CF HOPPER	152 HP D-off		$264,990	71.48	17.81	28.16	3.73	7.28	282
	A30CH004	1010WB	ASPHALT PAVER, 10′0″ WIDE SCREED, WHEEL, 205 CF HOPPER	152 HP D-off		$277,450	74.93	18.39	28.95	3.91	7.28	305
	A30CH005	1110WB	ASPHALT PAVER, 10′0″ WIDE SCREED, WHEEL, 225 CF HOPPER	173 HP D-off		$302,723	82.29	20.06	31.57	4.27	8.28	343
	A30CH006	1110RTB SWIFTRACK	ASPHALT PAVER, 10′0″ WIDE SCREED, CRAWLER-RUBBER TRACK, 225 CF HOPPER	200 HP D-off		$353,362	95.15	23.75	37.54	4.98	9.58	402
	CEDARAPIDS INC., A TEREX COMPANY											
	A30EJ001	CR351	ASPHALT PAVER, 8′0″ WIDE FASTACH SCREED, WHEEL, 145 CF HOPPER	130 HP D-off		$203,088	55.92	13.45	21.18	2.86	6.22	263
	A30EJ002	CR361	ASPHALT PAVER, 8′0″ WIDE FASTACH SCREED, CRAWLER, 145 CF HOPPER	130 HP D-off		$226,451	61.08	15.22	24.06	3.19	6.22	253
	A30EJ003	CR451	ASPHALT PAVER, 10′0″ WIDE FASTACH SCREED, WHEEL, 229 CF HOPPER	172 HP D-off		$236,922	66.79	15.58	24.48	3.34	8.24	315
	A30EJ004	CR461	ASPHALT PAVER, 10′0″ WIDE FASTACH SCREED, CRAWLER, 219 CF HOPPER	172 HP D-off		$261,386	71.83	17.57	27.77	3.68	8.24	356
	A30EJ005	CR551	ASPHALT PAVER, 10′0″ WIDE FASTACH SCREED, WHEEL, 267 CF HOPPER	172 HP D-off		$265,440	73.38	17.11	26.73	3.74	8.24	341
	A30EJ006	CR561	ASPHALT PAVER, 10′0″ WIDE FASTACH SCREED, CRAWLER, 267 CF HOPPER	172 HP D-off		$289,941	78.56	19.50	30.81	4.09	8.24	389

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
		GEHL COMPANY											
	A30GC001	1438	ASPHALT PAVER, 8′0″ WIDE SCREED, WHEEL	25 HP	G		$29,140	10.38	1.95	3.07	0.41	2.70	64
	A30GC002	1448	ASPHALT PAVER, 8′0″ WIDE SCREED, WHEEL	25 HP	D-off		$32,283	9.11	2.15	3.40	0.45	1.20	67
	A30GC003	1639	ASPHALT PAVER, 9′0″ WIDE SCREED, CRAWLER	25 HP	G		$41,002	13.15	2.76	4.36	0.58	2.70	84
	A30GC004	1649	ASPHALT PAVER, 9′0″ WIDE SCREED, CRAWLER	41 HP	D-off		$44,424	12.92	2.99	4.72	0.63	1.96	85
	SUBCATEGORY 0.20		**TOWED**										
		MIDLAND MANUFACTURING INC.											
	A30MY001	SP-8	ASPHALT PAVER, SHOULDER PAVING MACHINE, 1′–8′ WIDE, BITUMINOUS & AGGREGATE, WHEEL	80 HP	D-off		$119,815	24.51	6.50	9.59	1.70	3.51	185
	A30MY002	SP-10	ASPHALT PAVER, SHOULDER PAVING MACHINE, 1′–10′ WIDE, BITUMINOUS & AGGREGATE, WHEEL	100 HP	D-off		$155,505	31.60	8.43	12.44	2.21	4.39	275
	SUBCATEGORY 0.30		**SLURRY SEAL PAVERS (Cold mix)**										
		NO SPECIFIC MANUFACTURER											
	A30XX001	MINIMAC	ASPHALT PAVER, SLURRY SEAL PAVER 8′ WIDE, SELF PROPELLED	110 HP	D-off		$133,273	22.48	6.23	8.73	1.86	4.54	130
	A30XX002	MACROPAVER 12B	ASPHALT PAVER, SLURRY SEAL PAVER 8′ WIDE (ADD 40,000 GVW TRUCK)	110 HP	D-off		$152,511	24.26	7.22	10.17	2.13	4.54	175

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.40		**MISCELLANEOUS ROAD EQUIPMENT**									
			BLAW KNOX CONSTRUCTION EQUIPMENT CORP.									
	A30BK024	MC-330	ASPHALT PAVER, MOBILE CONVEYOR, 60″ WIDE BELT, WHEEL (ADD ASPHALT PAVER UNIT)	184 HP D-off		$284,406	58.08	15.31	22.53	4.04	8.08	430
			CATERPILLAR INC. (MACHINE DIVISION)									
	A30CA007	BG-650	ASPHALT PAVER, ASPHALT WINDROW ELEVATOR, WHEEL (ADD ASPHALT PAVER UNIT)	107 HP D-off		$109,415	24.40	5.87	8.63	1.55	4.70	171
			LEE-BOY									
	A30LD001	3000	ASPHALT PAVER, ASPHALT FORCE FEED LOADER, 30″ WIDE BELT, WINDROW OR LOOSE, WHEEL (ADD ASPHALT PAVER UNIT)	110 HP D-off		$125,549	27.31	6.73	9.89	1.78	4.83	198
			ROADTEC									
	A30RT001	SB-1500	ASPHALT PAVER, ASPHALT MATERIAL TRANSFER VEHICLE, 15 TON HOPPER, 600 TPH, 65″ WIDE CONVEYOR, WHEEL	275 HP D-off		$459,187	92.20	24.88	36.71	6.52	12.07	600
	A30RT002	SB-2500B	ASPHALT PAVER, ASPHALT MATERIAL TRANSFER VEHICLE, 25 TON HOPPER, 1000 TPH 69″ WIDE CONVEYOR, WHEEL	275 HP D-off		$481,656	96.00	26.08	38.48	6.84	12.07	790

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
A35	**ASPHALT PAVING KETTLES**												
	SUBCATEGORY 0.00		**ASPHALT PAVING KETTLES**										
		AEROIL PRODUCTS COMPANY, INC.											
	A35AE001	KEB-80KE	ASPHALT/PAVEMENT KETTLE, 80 GAL, TRAILER W/PUMP & HOSE	5 HP	G		$9,250	5.09	0.73	1.18	0.14	0.50	9
	A35AE002	KEB-115KE	ASPHALT/PAVEMENT KETTLE, 115 GAL, TRAILER W/PUMP & HOSE	5 HP	G		$9,565	5.87	0.76	1.23	0.14	0.50	11
	A35AE003	KEB-170KE	ASPHALT/PAVEMENT KETTLE, 170 GAL, TRAILER W/PUMP & HOSE	5 HP	G		$10,220	6.41	0.82	1.33	0.15	0.50	15
	A35AE004	KEB-260KE	ASPHALT/PAVEMENT KETTLE, 260 GAL, TRAILER W/PUMP & HOSE	5 HP	G		$11,163	7.57	0.90	1.46	0.17	0.50	19
	A35AE005	KEB-360KE	ASPHALT/PAVEMENT KETTLE, 360 GAL, TRAILER W/PUMP & HOSE	5 HP	G		$12,279	10.06	0.98	1.57	0.19	0.50	20
A40	**ASPHALT & CONCRETE MILLERS/PROFILERS/PLANERS**												
	SUBCATEGORY 0.00		**ASPHALT & CONCRETE MILLERS/PROFILERS/PLANERS**										
		CATERPILLAR INC. (MACHINE DIVISION)											
	A40CA008	PM-465	ASPHALT COLD PLANER, 75″ W × 10.0″ D, CRAWLER (ADD CUTTING TEETH COSTS)	500 HP	D-off		$441,017	174.87	36.06	58.80	6.66	33.25	505
	A40CA009	PM-565B	ASPHALT COLD PLANER, 83″ W × 12.0″ D, CRAWLER (ADD CUTTING TEETH COSTS)	625 HP	D-off		$648,235	247.81	53.01	86.43	9.79	41.56	735

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	CMI CORPORATION - BID-WELL DIVISION												
	A40CW001	PR-1050	ASPHALT PROFILER, MAX 12.5′ W × 12″ D, CRAWLER (ADD CUTTING TEETH COSTS)	1,030 HP	D-off		$777,304	320.69	63.55	103.64	11.73	68.50	1,065
	ROADTEC												
	A40RT001	RX-20B	ASPHALT COLD PLANER, 40″ W × 10″ D, WHEEL (ADD CUTTING TEETH COSTS)	230 HP	D-off		$298,699	109.15	24.19	39.36	4.51	15.30	324
	A40RT002	RX-25	ASPHALT COLD PLANER, 52″ W × 8″ D, CRAWLER (ADD CUTTING TEETH COSTS)	250 HP	D-off		$390,957	138.82	31.97	52.13	5.90	16.63	420
	A40RT003	RX-45B	ASPHALT COLD PLANER, 78″ W × 12″ D, CRAWLER (ADD CUTTING TEETH COSTS)	460 HP	D-off		$483,489	184.32	39.54	64.47	7.30	30.59	617
	A40RT004	RX-60B	ASPHALT COLD PLANER, 86″ W × 12″ D, CRAWLER (ADD CUTTING TEETH COSTS)	800 HP	D-off		$620,475	254.13	50.74	82.73	9.37	53.20	918
	A40RT005	RX-68B	ASPHALT COLD PLANER, 98″ W × 12″ D, CRAWLER (ADD CUTTING TEETH COSTS)	800 HP	D-off		$660,735	266.27	54.03	88.10	9.98	53.20	830
	A40RT006	RX-70B	ASPHALT COLD PLANER, 150″ W × 8″ D, CRAWLER (ADD CUTTING TEETH COSTS)	800 HP	D-off		$731,783	287.68	59.84	97.57	11.05	53.20	920
A45	**ASPHALT RECYCLERS & SEALERS**												
	SUBCATEGORY 0.00		**ASPHALT RECYCLERS & SEALERS**										
	AEROIL PRODUCTS COMPANY, INC.												
	A45AE001	HEPR-52V	ASPHALT RESURFACER-PATCHER, 4′WIDE, 17.3 SF, 600,000 BTU INFRA-RED HEATER, TRAILER MTD				$8,210	9.88	0.78	1.29	0.13	0.00	11

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
A45	***AEROIL PRODUCTS COMPANY, INC. (continued)***												
	A45AE002	HEPR-96V	ASPHALT RESURFACER-PATCHER, 8′WIDE, 32.0 SF, 1,200,000 BTU INFRA-RED HEATER, TRAILER MTD				$16,046	19.70	1.52	2.54	0.25	0.00	16
	A45AE003	HEPR-120V	ASPHALT RESURFACER-PATCHER, 10′WIDE, 40.0 SF, 1,420,000 BTU INFRA-RED HEATER, TRAILER MTD				$18,914	23.27	1.79	3.00	0.29	0.00	17
	ROSCO MANUFACTURING CO.												
	A45RS001	RA-2000	ASPHALT SPRAY PATCHER, TRAILER MTD, 300 GAL	85 HP	D-off		$38,663	18.31	3.65	6.10	0.60	3.73	60
	A45RS002	RA-300	ASPHALT SPRAY PATCHER, TRUCK MTD, 400 GAL	210 HP	D-on		$126,140	57.20	12.05	20.18	1.96	10.88	179
	SEALMASTER, INC.												
	A45SE002	SP200 DUAL	ASPHALT SEALCOATER, 200 GAL, 108″ WIDE DUAL SPRAY, SQUEEGEE	20 HP	G		$25,215	12.43	2.40	4.01	0.39	2.00	28
	A45SE003	SP300 DUAL	ASPHALT SEALCOATER, 300 GAL, 108″ WIDE DUAL SPRAY, SQUEEGEE	30 HP	D-off		$35,285	15.66	3.34	5.58	0.55	1.32	39
	A45SE004	TR-1000	ASPHALT SEALER, 1000 GAL TANK TRAILER	16 HP	G		$18,270	8.73	1.68	2.80	0.28	1.60	52

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
B10	**BATCH PLANTS, ASPHALT & CONCRETE**												
	SUBCATEGORY 0.20		**CONCRETE**										
			CEMEN TECH										
	B10CC007	MCD2-50HT	BATCH PLANT, CONCRETE DISPENSER, 15 CY/HR MAX, W/ TWO AGGREGATE BINS, 2 CY/1 CY CEMENT BIN/7′ LONG SLOPING 8″ DIA SCREW WET MIXER/DELIVERER/250 GAL WATER TANK/& METERING PUMP, 2 CY LOAD, TRAILER MTD	18 HP	G		$32,319	12.75	2.05	3.15	0.47	1.80	80
	B10CC008	MCD5-100H	BATCH PLANT, CONCRETE DISPENSER, 30 CY/HR MAX, W/ TWO AGGREGATE BINS, 5.5 CY/ 1.9 CY CEMENT BIN/9′ LONG SLOPING 9″ DIA SCREW WET MIXER/DELIVERER/250 GAL WATER TANK/& METERING PUMP, 5 CY LOAD, TRUCK MTD	163 HP	G		$72,643	41.76	4.42	6.72	1.06	16.32	132
	B10CC009	MCD8-100H	BATCH PLANT, CONCRETE DISPENSER, 30 CY/HR MAX, W/ TWO AGGREGATE BINS, 9.3 CY/ 3.1 CY CEMENT BIN/9′ LONG SLOPING 12″ DIA SCREW WET MIXER/DELIVERER/250 GAL WATER TANK/& METERING PUMP, 8 CY LOAD, TRUCK MTD	200 HP	G		$98,045	52.91	5.88	8.89	1.43	20.02	194
	B10CC010	MCD8-150H	BATCH PLANT, CONCRETE DISPENSER, 60 CY/HR MAX, W/ TWO AGGREGATE BINS, 9.6 CY/ 3.1 CY CEMENT BIN/9′ LONG SLOPING 12″ DIA SCREW WET MIXER/DELIVERER/250 GAL WATER TANK/& METERING PUMP, 8 CY LOAD, TRUCK MTD	200 HP	G		$107,050	55.22	6.46	9.79	1.56	20.02	204

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
REGION 6													
B10			***CEMEN TECH (continued)***										
	B10CC012	210 BBL	BATCH PLANT, SILO, CEMENT, 830 CF, 210 BARREL (BATCH PLANT ATTACHMENT)	18 HP	G		$19,933	7.66	1.29	1.99	0.29	1.80	35
	B10CC011	HS-240	BATCH PLANT, SILO, CEMENT, 38 TON HORIZONTAL 240 BARREL (BATCH PLANT ATTACHMENT)	20 HP	E		$20,157	6.80	1.30	2.02	0.29	0.83	45
	B10CC013	300 BBL	BATCH PLANT, SILO, CEMENT, 1200 CF, 300 BARRL (BATCH PLANT ATTACHMENT)	18 HP	G		$24,028	8.65	1.55	2.40	0.35	1.80	48
	B10CC014		BATCH PLANT, CEMENT LOADING AUGER, 6″ DIA, 19′ LONG (BATCH PLANT ATTACHMENT)	5 HP	E		$6,253	2.24	0.41	0.63	0.09	0.21	10
			CON-E-CO										
	B10CL025	MTM 12	BATCH PLANT, CONCRETE MIXER, 12 CY, TILT DRUM, 11.67′ DIA, REMOVABLE AXLES, TRAILER MTD (ADD DRY BATCH PLANT)	200 HP	E		$251,993	69.58	16.19	25.05	3.66	8.32	130
	B10CL021	VERSA-PLANT 10	BATCH PLANT, CONCRETE AGGREGATE DRY, 40CY/HR, 10 CY AGGREGATE BATCHER, W/ 30″ × 40′ LOADING CONVEYOR, SCALES & WATER METER INCLUDED, TRAILER MTD (ADD 5 KW GENERATOR, WATER TANK & WET BATCHER)	35 HP	E		$76,433	19.66	4.82	7.42	1.11	1.46	190
	B10CL015	PLP MODEL 12	BATCH PLANT, CONCRETE AGGREGATE DRY, 200 CY/HR, W/TWO AGGREGATE BINS, 81 TON, 60 CY/36″ × 20′ CONVEYOR/3 BIN 12 CY AGGREGATE BATCHER/ 30″ × 33.5′ LOADING CONVEYOR/& 475 BARREL, 88 TON CEMENT SILO, TRAILER MTD (ADD 110 KW GENERATOR)	30 HP	E		$143,345	37.21	9.05	13.94	2.08	1.25	380

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B10		***CON-E-CO (continued)***										
	B10CL005	LO-PRO 10T-CM	BATCH PLANT, CONCRETE AGGREGATE DRY, 275 CY/HR, W/TWO AGGREGATE BINS, 65 TON, 50 CY/36″ × 20′ CONVEYOR/10 CY AGGREGATE BATCHER/36″ × 36′ LOADING CONVEYOR/& 215 BARREL, 35 TON CEMENT SILO, TRAILER MTD (ADD 140 KW GENERATOR)	120 HP E		$169,114	47.94	10.71	16.50	2.46	4.99	410
	B10CL006	LO-PRO 12T-CM	BATCH PLANT, CONCRETE AGGREGATE DRY, 275 CY/HR, W/TWO AGGREGATE BINS, 65 TON, 50 CY/36″ × 20′ CONVEYOR/12 CY AGGREGATE BATCHER/36″ × 36′ LOADING CONVEYOR/& 215 BARREL, 35 TON CEMENT SILO, TRAILER MTD (ADD 140 KW GENERATOR)	120 HP E		$204,849	56.14	13.02	20.07	2.98	4.99	426
	B10CL027		BATCH PLANT, CEMENT SILO, 1910 CF, 475 BARREL (BATCH PLANT ATTACHMENT)			$18,142	4.15	1.17	1.81	0.26	0.00	144
	B10CL042		BATCH PLANT, SCREW CONVEYOR, 6″ DIA, 10′ LONG (CEMENT SILO ATTACHMENT)	5 HP E		$2,901	0.96	0.19	0.29	0.04	0.21	5
	B10CL045		BATCH PLANT, SCREW CONVEYOR, 6″ DIA, 20′ LONG (CEMENT SILO ATTACHMENT)	10 HP E		$3,677	1.44	0.24	0.37	0.05	0.42	11
	B10CL036		BATCH PLANT, SCREW CONVEYOR, 9″ DIA, 10′ LONG (CEMENT SILO ATTACHMENT)	8 HP E		$3,146	1.19	0.21	0.31	0.05	0.33	9
	B10CL040		BATCH PLANT, SCREW CONVEYOR, 9″ DIA, 20′ LONG (CEMENT SILO ATTACHMENT)	20 HP E		$4,324	2.17	0.28	0.43	0.06	0.83	16
	B10CL032		BATCH PLANT, SCREW CONVEYOR, 12″ DIA, 10′ LONG (CEMENT SILO ATTACHMENT)	10 HP E		$3,771	1.46	0.24	0.38	0.05	0.42	10

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B10		***CON-E-CO (continued)***											
	B10CL034		BATCH PLANT, SCREW CONVEYOR, 12″ DIA, 20′ LONG (CEMENT SILO ATTACHMENT)	20 HP	E		$7,542	2.91	0.49	0.75	0.11	0.83	20
		EXCEL MACHINERY LTD.											
	B10EM001	EXCEL PORT-A-PUG	BATCH PLANT, CONCRETE CONTINUOUS PUGG MILL MIXER, 400 CY/HR MAX, W/12 CY AGGREGATE STORAGE BIN/ 48″ × 18′ METERING CONVEYOR/CEMENT SILO, 44 TON, 34.8 CY/30″ × 37′ CONVEYOR, TRAILER MTD (ADD 200 KW GENERATOR)	25 HP	G		$379,194	92.90	24.07	37.12	5.51	2.50	590
	B10EM002		BATCH PLANT, CEMENT SILO, 55 TON HORIZONTAL 350 BARREL (BATCH PLANT ATTACHMENT)	20 HP	E		$6,786	3.74	0.32	0.43	0.10	0.83	45
	B10EM003		BATCH PLANT, CEMENT SILO, 2200 CF (BARREL CAP 550 MAX/ 450 MIN) W/DRIVE-THRU TYPE UNDERSTRUCTURE (BATCH PLANT ATTACHMENT)				$22,353	5.14	1.45	2.24	0.33	0.00	222
		ROSS COMPANY											
	B10RC007	BANDIT 5	BATCH PLANT, CONCRETE AGGREGATE DRY, 100 CY/HR, W/TWO AGGREGATE BINS, 65 TON, 48 CY/36″ × 20′ CONVEYOR/2 BIN 5 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 257 BARREL, 48 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	15 HP	E		$121,462	31.27	7.70	11.85	1.77	0.62	3,000

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B10		***ROSS COMPANY (continued)***											
	B10RC032	RUSTLER III	BATCH PLANT, CONCRETE AGGREGATE DRY, 160 CY/HR, W/TWO AGGREGATE BINS, 28 TON, 21 CY/2 BIN 12 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 400 BARREL, 75 TON CEMENT SILO, TRAILER MTD (ADD 130 KW GENERATOR)	50 HP	E		$191,013	51.28	12.07	18.58	2.78	2.08	536
	B10RC006	RUSTLER II	BATCH PLANT, CONCRETE AGGREGATE DRY, 160 CY/HR, W/3 AGGREGATE BINS, 71 TON, 52 CY/36″ × 20′ CONVEYOR/3 BIN 12 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/375 BARREL, 70 TON CEMENT SILO, TRAILER MTD (ADD 130KW GENERATOR)	46 HP	E		$174,272	47.17	10.99	16.91	2.53	1.89	489
	B10RC008	BANDIT 12 BTR	BATCH PLANT, CONCRETE AGGREGATE DRY, 200 CY/HR, W/THREE AGGREGATE BINS, 65 TON, 48 CY/36″ × 20′ CONVEYOR/3 BIN 12 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 720 BARREL, 134 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	30 HP	E		$146,562	37.91	9.31	14.36	2.13	1.25	250
	B10RC027		BATCH PLANT, CONCRETE MIXER, 4.5 CY, TILT DRUM, SKID MTD (ADD DRY BATCH PLANT)	40 HP	E		$134,639	35.23	8.69	13.46	1.96	1.66	34
	B10RC028		BATCH PLANT, CONCRETE MIXER, 6.0 CY, TILT DRUM, SKID MTD (ADD DRY BATCH PLANT)	60 HP	E		$151,179	40.47	9.76	15.12	2.20	2.50	45
	B10RC029		BATCH PLANT, CONCRETE MIXER, 8.0 CY, TILT DRUM, SKID MTD (ADD DRY BATCH PLANT)	80 HP	E		$170,780	46.39	11.02	17.08	2.48	3.33	60

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	REGION 6 EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
B10			***ROSS COMPANY (continued)***										
	B10RC030		BATCH PLANT, CONCRETE MIXER, 10.0 CY, TILT DRUM, SKID MTD (ADD DRY BATCH PLANT)	100 HP	E		$185,985	52.30	12.00	18.60	2.70	4.16	75
	B10RC031		BATCH PLANT, CONCRETE MIXER, 12.0 CY, TILT DRUM, SKID MTD (ADD DRY BATCH PLANT)	120 HP	E		$196,258	56.08	12.67	19.63	2.85	4.99	90
	B10RC016	MOBILE MIXER	BATCH PLANT, CONCRETE MIXER, 4.5CY, TILT DRUM TYPE, REVOLVING LIFT STAND, TRAILER MTD (ADD DRY BATCH PLANT & POWER)	75 HP	E		$215,410	59.35	13.64	21.02	3.13	3.12	420
			STEPHENS MANUFACTURING CO., INC.										
	B10SN031	DC-12	BATCH PLANT, CONCRETE AGGREGATE DRY, 100 CY/HR, W/2 BIN 12 CY BATCHER/ 24″ × 41′ LOADING CONVEYOR/ & 311 BARREL, 58 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	15 HP	E		$43,540	12.25	2.53	3.80	0.63	0.62	340
	B10SN033	DC COLT	BATCH PLANT, CONCRETE AGGREGATE DRY, 100 CY/HR, W/2 BIN 12 CY BATCHER/ 30″ × 33.5′ LOADING CONVEYOR/& 311 BARREL, 58 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	30 HP	E		$87,135	23.28	5.35	8.16	1.27	1.25	340
	B10SN032	MUSTANG 5	BATCH PLANT, CONCRETE AGGREGATE DRY, 160 CY/HR, W/3 AGGREGATE STORAGE BINS, 29.6 TON, 40 CY/3 BIN 5 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 251 BARREL, 47 TON CEMENT SILO, TRAILER MTD (ADD 115 KW GENERATOR)	30 HP	E		$103,762	27.35	6.42	9.82	1.51	1.25	420

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
B10	***STEPHENS MANUFACTURING CO., INC. (continued)***											
	B10SN034	STALLION	BATCH PLANT, CONCRETE AGGREGATE DRY, 160 CY/HR, W/3 AGGREGATE BIN STORAGE, 65 TON, 48 CY/2 BIN 10 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 374 BARREL, 70 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	20 HP E		$100,660	25.80	6.22	9.51	1.46	0.83	360
	B10SN036	MUSTANG 10	BATCH PLANT, CONCRETE AGGREGATE DRY, 160 CY/HR, W/3 AGGREGATE BIN STORAGE, 75 TON, 55 CY/2 BIN 10 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 351 BARREL, 65 TON CEMENT SILO, TRAILER MTD (ADD 115 KW GENERATOR)	45 HP E		$135,793	35.58	8.48	13.02	1.97	1.87	500
	B10SN035	THOROUGH-BRED	BATCH PLANT, CONCRETE AGGREGATE DRY, 180 CY/HR, W/4 AGGREGATE BIN STORAGE, 65 TON, 48 CY/2 BIN 12 CY BATCHER/30″ × 33.5′ LOADING CONVEYOR/& 374 BARREL, 70 TON CEMENT SILO, TRAILER MTD (ADD 100 KW GENERATOR)	20 HP E		$111,164	28.36	6.90	10.56	1.62	0.83	300
	SUBCATEGORY 0.30		**PUGMILL**									
	KOLBERG - PIONEER, INC											
	B10KB001	52 PORTABLE PUGMILL	BATCH PLANT, PUGMILL, CONTINUOUS MIXER, 48″ DIA TWIN SHAFT × 6′ LONG, W/9 CY FEEDER HOPPER/36″ × 11.5′ BELT FEEDER/30″ × 27′ CONVEYOR/WATER OR	95 HP E		$123,736	28.79	6.62	9.71	1.76	3.95	190

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B10		***KOLBERG - PIONEER, INC (continued)***										
	B10KB002	52S PORTABLE PUGMILL	ASPHALT PUMP & METER (ADD 95 KW GENERATOR & ANY MATERIAL FEEDS) BATCH PLANT, PUGMILL, CONTINUOUS MIXER, 48″ DIA TWIN SHAFT × 8′ LONG, W/13 CY FEEDER HOPPER/TWO - 36″ × 11.5′ BELT FEEDERS/2ND 11 CY FEEDER HOPPER/ 30″ × 27′ CONVEYOR/WATER OR ASPHALT PUMP & METER (ADD 220 KW GENERATOR & ANY MATERIAL FEEDS)	220 HP E		$227,558	55.50	12.23	18.00	3.23	9.15	230
B15	**BROOMS, STREET SWEEPERS & FLUSHERS**											
	SUBCATEGORY 0.00		**BROOMS, STREET SWEEPERS & FLUSHERS**									
		BROCE MANUFACTURING COMPANY										
	B15BM001	RJ-350	BROOM, SELF PROPELLED PAVEMENT, 96″ BROOM LENGTH	80 HP D-off		$26,291	10.15	1.84	2.96	0.36	3.51	45
		ELGIN SWEEPER COMPANY										
	B15EC002	PELICAN P	STREET SWEEPER, 68″ BROOM LENGTH, 36″, 3 CY HOPPER, 180 GAL WATER TANK	100 HP D-off		$92,402	25.70	6.39	10.25	1.26	4.39	128
	B15EC001	EAGLE F	STREET SWEEPER, 280″ BROOM LENGTH, 4 CY HOPPER, 280 GAL WATER TANK, DUAL ENGINE	49 HP D-off	170 HP D-on	$145,520	36.87	10.05	16.12	1.99	4.02	150

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	FIVE STAR MANUFACTURING CO/ELGIN SWEEPER											
	B15FS001	BROOM BEAR FL42H	STREET SWEEPER, 58″ BROOM LENGTH, 44″, 4 CY HOPPER, 350 GAL WATER TANK	230 HP D-off		$149,493	45.27	10.43	16.77	2.04	10.09	213
	JOHNSTON SWEEPER COMPANY											
	B15JS001	2000T	STREET SWEEPER, 33″ BROOM LENGTH, 2 CY HOPPER, 41 GAL WATER TANK	94 HP D-off		$80,245	22.69	5.59	8.98	1.10	4.13	53
	B15JS002	J4000	STREET SWEEPER, 58″ BROOM LENGTH, 44″, 5 CY HOPPER, 220 GAL WATER TANK	190 HP D-off		$145,225	42.21	10.06	16.15	1.98	8.34	150
	M-B COMPANIES, INC.											
	B15MB001	MT	STREET SWEEPER, 7′ BROOM LENGTH, W/SPRINKLER, PTO DRIVE (ADD 45–100HP TRACTOR)			$6,466	1.51	0.46	0.73	0.09	0.00	10
	B15MB002	HT	STREET SWEEPER, 7′ BROOM LENGTH, W/SPRINKLER, PTO DRIVE (ADD 45–100HP TRACTOR)			$8,378	1.96	0.58	0.94	0.11	0.00	14
	B15MB003	53T	STREET SWEEPER, 7′ BROOM LENGTH, W/SPRINKLER, TOWED, HYDRAULIC (ADD TOWING UNIT)			$12,064	2.87	0.82	1.32	0.16	0.00	18
	B15MB004	53MH	STREET SWEEPER, 7′ BROOM LENGTH, W/SPRINKLER, TOWED (ADD TOWING UNIT)	18 HP G		$14,063	5.27	0.97	1.55	0.19	1.80	17
	ROSCO MANUFACTURING CO.											
	B15RS005	CHALLENGER II	STREET SWEEPER, 7′ BROOM LENGTH, SELF PROPELLED, 12 GALLON	80 HP D-off		$42,121	13.62	2.92	4.68	0.58	3.51	75
	B15RS001	RB-48	STREET SWEEPER, 8′ BROOM LENGTH, SELF PROPELLED	80 HP D-off		$32,948	11.62	2.28	3.65	0.45	3.51	52

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	TERRAMITE CONSTRUCTION EQUIPMENT											
	B15TB001	TSS36	STREET SWEEPER, 6′ BROOM LENGTH, SELF PROPELLED	45 HP D-off		$21,146	7.12	1.47	2.35	0.29	1.98	34
	B15TB002	TSS38	STREET SWEEPER, 8′ BROOM LENGTH, SELF PROPELLED	45 HP D-off		$21,297	7.16	1.48	2.37	0.29	1.98	34
	WALDON, INC.											
	B15WD001	SWEEPMASTER 250	BROOM, SELF PROPELLED PAVEMENT, 90″ BROOM LENGTH	80 HP D-off		$30,393	11.07	2.10	3.36	0.42	3.51	48
	B15WD002	SWEEPMASTER 250	BROOM, SELF PROPELLED PAVEMENT, 90″ BROOM LENGTH, 180 GAL WATER TANK	80 HP D-off		$32,416	11.50	2.24	3.59	0.44	3.51	48
B20	**BRUSH CHIPPERS**											
	SUBCATEGORY 0.00		**BRUSH CHIPPERS**									
	BANDIT INDUSTRIES, INC.											
	B20BN001	65	BRUSH CHIPPER, 6″ CAPACITY, DISC TYPE, TRAILER MTD	20 HP G		$9,862	4.85	0.69	1.11	0.13	2.00	18
	B20BN002	90W-XP	BRUSH CHIPPER, 9″ CAPACITY, DISC TYPE, TRAILER MTD	37 HP G		$15,394	8.32	1.08	1.73	0.21	3.70	32
	B20BN003	150XP	BRUSH CHIPPER, 12″ CAPACITY, DISC TYPE, TRAILER MTD	70 HP G		$19,162	13.49	1.34	2.16	0.26	7.01	44
	B20BN004	254	BRUSH CHIPPER, 14″ CAPACITY, DISC TYPE, TRAILER MTD	125 HP D-off		$29,782	13.74	2.09	3.35	0.41	5.49	78
	B20BN005	1290	BRUSH CHIPPER, 12″ CAPACITY, DRUM TYPE, TRAILER MTD	65 HP G		$17,337	12.42	1.22	1.95	0.24	6.51	44
	B20BN006	1690	BRUSH CHIPPER, 16″ CAPACITY, DRUM TYPE, TRAILER MTD	119 HP G		$18,394	19.68	1.29	2.07	0.25	11.91	44

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B20		***BANDIT INDUSTRIES, INC. (continued)***										
	B20BN007	1890	BRUSH CHIPPER, 18″ CAPACITY, DRUM TYPE, TRAILER MTD	125 HP D-off		$33,700	14.63	2.36	3.79	0.46	5.49	78
		MORBARK, INC.										
	B20MQ001	2070XL	BRUSH CHIPPER, 7″ CAPACITY, DISC TYPE, TRAILER MTD	86 HP D-off		$18,516	8.97	1.28	2.06	0.25	3.77	40
	B20MQ003	13	BRUSH CHIPPER, 13″ CAPACITY, DISC TYPE, TRAILER MTD	125 HP D-off		$25,690	12.80	1.78	2.85	0.35	5.49	68
	B20MQ004	2400XL	BRUSH CHIPPER, 15–17″ CAPACITY, DISC TYPE, TRAILER MTD	125 HP D-off		$29,935	13.77	2.05	3.27	0.41	5.49	94
	B20MQ005	22 RXL	BRUSH CHIPPER, LOG CHIPPER, 22″ CAPACITY, TRAILER MTD	650 HP D-off		$329,275	112.84	22.88	36.75	4.50	28.53	700
B25	**BUCKETS, CLAMSHELL**											
	SUBCATEGORY 0.00		**BUCKETS, CLAMSHELL**									
		HAWCO MANUFACTURING COMPANY, LLC										
	B25HB001	HD-050	BUCKET, CLAMSHELL, 0.50 CY, HEAVY DUTY/DIGGING			$15,264	3.20	1.07	1.72	0.21	0.00	30
	B25HB003	HD-100	BUCKET, CLAMSHELL, 1.00 CY, HEAVY DUTY/DIGGING			$24,524	5.14	1.72	2.76	0.34	0.00	48
	B25HB005	HD-150	BUCKET, CLAMSHELL, 1.50 CY, HEAVY DUTY/DIGGING			$31,826	6.66	2.22	3.58	0.43	0.00	66
	B25HB007	HD-200	BUCKET, CLAMSHELL, 2.00 CY, HEAVY DUTY/DIGGING			$37,569	7.86	2.63	4.23	0.51	0.00	78
	B25HB008	HD-250	BUCKET, CLAMSHELL, 2.50 CY, HEAVY DUTY/DIGGING			$43,792	9.17	3.07	4.93	0.60	0.00	91
	B25HB009	HD-300	BUCKET, CLAMSHELL, 3.00 CY, HEAVY DUTY/DIGGING			$48,222	10.09	3.37	5.42	0.66	0.00	103

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B25	***HAWCO MANUFACTURING COMPANY, LLC (continued)***											
	B25HB010	HD-350	BUCKET, CLAMSHELL, 3.50 CY, HEAVY DUTY/DIGGING			$50,602	10.59	3.54	5.69	0.69	0.00	131
	B25HB011	HD-400	BUCKET, CLAMSHELL, 4.00 CY, HEAVY DUTY/DIGGING			$51,888	10.86	3.63	5.84	0.71	0.00	145
	B25HB012	HD-450	BUCKET, CLAMSHELL, 4.50 CY, HEAVY DUTY/DIGGING			$54,795	11.46	3.83	6.16	0.75	0.00	165
	B25HB013	HD-500	BUCKET, CLAMSHELL, 5.00 CY, HEAVY DUTY/DIGGING			$56,570	11.83	3.95	6.36	0.77	0.00	173
	B25HB014	HD-550	BUCKET, CLAMSHELL, 5.50 CY, HEAVY DUTY/DIGGING			$59,120	12.37	4.14	6.65	0.81	0.00	178
	B25HB015	HD-600	BUCKET, CLAMSHELL, 6.00 CY, HEAVY DUTY/DIGGING			$61,137	12.80	4.28	6.88	0.84	0.00	199
	NO SPECIFIC MANUFACTURER											
	B25XX001	1/4SSN	BUCKET, CLAMSHELL, 0.20 CY, SQUARE NOSE, STANDARD			$6,894	1.44	0.48	0.78	0.09	0.00	14
	B25XX002	1/2SSN	BUCKET, CLAMSHELL, 0.50 CY, SQUARE NOSE, STANDARD			$10,166	2.13	0.71	1.14	0.14	0.00	27
	B25XX003	3/4SSN	BUCKET, CLAMSHELL, 0.70 CY, SQUARE NOSE, STANDARD			$12,522	2.62	0.88	1.41	0.17	0.00	35
	B25XX004	1SSN	BUCKET, CLAMSHELL, 1.00 CY, SQUARE NOSE, STANDARD			$13,677	2.87	0.96	1.54	0.19	0.00	43
	B25XX005	1-1/4SSN	BUCKET, CLAMSHELL, 1.20 CY, SQUARE NOSE, STANDARD			$15,942	3.34	1.12	1.79	0.22	0.00	49
	B25XX006	1-1/2SSN	BUCKET, CLAMSHELL, 1.50 CY, SQUARE NOSE, STANDARD			$17,873	3.74	1.25	2.01	0.24	0.00	64
	B25XX007	1-3/4SSN	BUCKET, CLAMSHELL, 1.70 CY, SQUARE NOSE, STANDARD			$19,097	4.00	1.34	2.15	0.26	0.00	67
	B25XX008	2SSN	BUCKET, CLAMSHELL, 2.00 CY, SQUARE NOSE, STANDARD			$22,334	4.68	1.57	2.51	0.31	0.00	76
	B25XX009	2-1/2SSN	BUCKET, CLAMSHELL, 2.50 CY, SQUARE NOSE, STANDARD			$23,361	4.89	1.64	2.63	0.32	0.00	92
	B25XX010	3SSN	BUCKET, CLAMSHELL, 3.00 CY, SQUARE NOSE, STANDARD			$24,879	5.21	1.74	2.80	0.34	0.00	98
	B25XX011	3-1/2SSN	BUCKET, CLAMSHELL, 3.50 CY, SQUARE NOSE, STANDARD			$26,033	5.45	1.83	2.93	0.36	0.00	108
	B25XX012	4SSN	BUCKET, CLAMSHELL, 4.00 CY, SQUARE NOSE, STANDARD			$29,092	6.09	2.04	3.27	0.40	0.00	119

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
B25		***NO SPECIFIC MANUFACTURER (continued)***										
	B25XX013	4-1/2SSN	BUCKET, CLAMSHELL, 4.50 CY, SQUARE NOSE, STANDARD			$39,274	8.22	2.75	4.42	0.54	0.00	145
	B25XX014	5SSN	BUCKET, CLAMSHELL, 5.00 CY, SQUARE NOSE, STANDARD			$41,919	8.77	2.93	4.72	0.57	0.00	154
	B25XX015	5-1/2SSN	BUCKET, CLAMSHELL, 5.50 CY, SQUARE NOSE, STANDARD			$50,875	10.65	3.56	5.72	0.70	0.00	158
	B25XX016	6SSN	BUCKET, CLAMSHELL, 6.00 CY, SQUARE NOSE, STANDARD			$51,246	10.73	3.59	5.77	0.70	0.00	166
	B25XX017	6-1/2SSN	BUCKET, CLAMSHELL, 6.50 CY, SQUARE NOSE, STANDARD			$55,355	11.59	3.88	6.23	0.76	0.00	177
	B25XX018	7SSN	BUCKET, CLAMSHELL, 7.00 CY, SQUARE NOSE, STANDARD			$52,390	10.96	3.67	5.89	0.72	0.00	185
	B25XX019	7-1/2SSN	BUCKET, CLAMSHELL, 7.50 CY, SQUARE NOSE, STANDARD			$58,744	12.29	4.11	6.61	0.80	0.00	192
B30	**BUCKETS, CONCRETE**											
	SUBCATEGORY 0.10		**GENERAL PURPOSE, MANUAL TRIP**									
		GAR-BRO MANUFACTURING COMPANY										
	B30GB001	433-G	BUCKET, CONCRETE, GENERAL PURPOSE, 1.0 CY			$2,940	0.63	0.22	0.35	0.04	0.00	6
	B30GB002	442-G	BUCKET, CONCRETE, GENERAL PURPOSE, 1.5 CY			$3,849	0.83	0.28	0.46	0.05	0.00	8
	B30GB003	462-G	BUCKET, CONCRETE, GENERAL PURPOSE, 2.0 CY			$4,748	1.01	0.34	0.56	0.06	0.00	10
	B30GB004	493-G	BUCKET, CONCRETE, GENERAL PURPOSE, 3.0 CY			$6,886	1.48	0.50	0.82	0.09	0.00	14
	B30GB005	4123-G	BUCKET, CONCRETE, GENERAL PURPOSE, 4.0 CY			$8,202	1.76	0.60	0.97	0.11	0.00	18

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.20		LAYDOWN									
	GAR-BRO MANUFACTURING COMPANY											
	B30GB006	425-A	BUCKET, CONCRETE, LAYDOWN, 1.0 CY, HEAVY DUTY AIR GATE			$15,201	3.36	1.11	1.81	0.20	0.00	26
	B30GB007	465-A	BUCKET, CONCRETE, LAYDOWN, 2.0 CY, HVDY AIR GATE			$16,361	3.62	1.19	1.94	0.22	0.00	32
	B30GB008	495-A	BUCKET, CONCRETE, LAYDOWN, 3.0 CY, HEAVY DUTY AIR GATE			$18,201	4.02	1.32	2.16	0.24	0.00	40
	B30GB009	4125-A	BUCKET, CONCRETE, LAYDOWN, 4.0 CY, HEAVY DUTY AIR GATE			$20,718	4.57	1.50	2.46	0.27	0.00	51
	B30GB010	4155-A	BUCKET, CONCRETE, LAYDOWN, 5.0 CY, HEAVY DUTY AIR GATE			$25,549	5.64	1.86	3.03	0.34	0.00	73
	SUBCATEGORY 0.30		LOWBOY									
	CAMLEVER											
	B30CR001	LB-375	BUCKET, CONCRETE, LOWBOY, 0.38 CY, AIR GATE			$3,947	0.89	0.29	0.47	0.05	0.00	2
	B30CR002	LB-050	BUCKET, CONCRETE, LOWBOY, 0.5 CY, AIR GATE			$4,234	0.96	0.31	0.50	0.06	0.00	2
	B30CR003	LB-075	BUCKET, CONCRETE, LOWBOY, 0.75 CY, AIR GATE			$4,563	1.03	0.33	0.54	0.06	0.00	3
	B30CR004	LB-100	BUCKET, CONCRETE, LOWBOY, 1.0 CY, AIR GATE			$4,699	1.07	0.34	0.56	0.06	0.00	5
	B30CR005	LB-150	BUCKET, CONCRETE, LOWBOY, 1.5 CY, AIR GATE			$5,532	1.26	0.40	0.66	0.07	0.00	6
	B30CR009	LXB-150	BUCKET, CONCRETE, LOWBOY, 1.5 CY, AIR GATE			$5,824	1.32	0.43	0.69	0.08	0.00	6
	B30CR006	LB-200	BUCKET, CONCRETE, LOWBOY, 2.0 CY, AIR GATE			$6,497	1.48	0.48	0.77	0.09	0.00	8

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
B30		*CAMLEVER (continued)*										
	B30CR010	LXB-200	BUCKET, CONCRETE, LOWBOY, 2.0 CY, AIR GATE			$6,803	1.55	0.50	0.81	0.09	0.00	6
	B30CR011	LXB-300	BUCKET, CONCRETE, LOWBOY, 3.0 CY, AIR GATE			$8,073	1.84	0.59	0.96	0.11	0.00	6
	B30CR012	LXB-400	BUCKET, CONCRETE, LOWBOY, 4.0 CY, AIR GATE			$9,333	2.12	0.68	1.11	0.12	0.00	6
	SUBCATEGORY 0.40		**LOW SLUMP**									
		GAR-BRO MANUFACTURING COMPANY										
	B30GB011	440-A	BUCKET, CONCRETE, LOW SLUMP, 1.0 CY, AIR GATE			$12,033	2.73	0.88	1.43	0.16	0.00	20
	B30GB012	450-A	BUCKET, CONCRETE, LOW SLUMP, 1.5 CY, AIR GATE			$12,480	2.84	0.91	1.48	0.17	0.00	21
	B30GB013	460-A	BUCKET, CONCRETE, LOW SLUMP, 2.0 CY, AIR GATE			$12,922	2.93	0.94	1.53	0.17	0.00	24
	B30GB014	493-A	BUCKET, CONCRETE, LOW SLUMP, 3.0 CY, AIR GATE			$16,857	3.82	1.22	2.00	0.22	0.00	49
	B30GB015	4139-A	BUCKET, CONCRETE, LOW SLUMP, 4.0 CY, AIR GATE			$17,457	3.96	1.27	2.07	0.23	0.00	52
	B30GB016	4200-A	BUCKET, CONCRETE, LOW SLUMP, 6.0 CY, AIR GATE			$25,069	5.69	1.82	2.98	0.33	0.00	78
	B30GB017	4250-A	BUCKET, CONCRETE, LOW SLUMP, 8.0 CY, AIR GATE			$30,189	6.85	2.19	3.58	0.40	0.00	90
B35	**BUCKETS, DRAGLINE**											
	SUBCATEGORY 0.10		**LIGHT WEIGHT**									
		HENDRIX MANUFACTURING COMPANY, INC.										
	B35HE001	LS	BUCKET, DRAGLINE, 0.75 CY, LIGHT WEIGHT/PERFORATED			$4,979	1.04	0.35	0.56	0.07	0.00	15
	B35HE002	LS	BUCKET, DRAGLINE, 1.0 CY, LIGHT WEIGHT/PERFORATED			$5,901	1.23	0.41	0.66	0.08	0.00	18

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B35	***HENDRIX MANUFACTURING COMPANY, INC. (continued)***											
	B35HE003	LS	BUCKET, DRAGLINE, 1.5 CY, LIGHT WEIGHT/PERFORATED			$7,786	1.64	0.55	0.88	0.11	0.00	26
	B35HE004	LS	BUCKET, DRAGLINE, 2.0 CY, LIGHT WEIGHT/PERFORATED			$9,177	1.92	0.65	1.03	0.13	0.00	32
	B35HE005	LS	BUCKET, DRAGLINE, 2.5 CY, LIGHT WEIGHT/PERFORATED			$10,790	2.26	0.76	1.21	0.15	0.00	37
	B35HE006	LS	BUCKET, DRAGLINE, 3.0 CY, LIGHT WEIGHT/PERFORATED			$13,302	2.79	0.93	1.50	0.18	0.00	46
	B35HE007	LS	BUCKET, DRAGLINE, 3.5 CY, LIGHT WEIGHT/PERFORATED			$14,702	3.07	1.03	1.65	0.20	0.00	50
	B35HE008	LS	BUCKET, DRAGLINE, 4.0 CY, LIGHT WEIGHT/PERFORATED			$17,899	3.74	1.25	2.01	0.24	0.00	65
	B35HE009	LS	BUCKET, DRAGLINE, 4.5 CY, LIGHT WEIGHT/PERFORATED			$19,006	3.98	1.33	2.14	0.26	0.00	69
	B35HE010	LS	BUCKET, DRAGLINE, 5.0 CY, LIGHT WEIGHT/PERFORATED			$22,925	4.80	1.60	2.58	0.31	0.00	85
	B35HE011	LS	BUCKET, DRAGLINE, 6.0 CY, LIGHT WEIGHT/PERFORATED			$24,870	5.21	1.74	2.80	0.34	0.00	92
	B35HE012	LS	BUCKET, DRAGLINE, 7.0 CY, LIGHT WEIGHT/PERFORATED			$27,155	5.68	1.90	3.05	0.37	0.00	101
	B35HE013	LS	BUCKET, DRAGLINE, 8.0 CY, LIGHT WEIGHT/PERFORATED			$30,113	6.30	2.11	3.39	0.41	0.00	112
	B35HE014	LS	BUCKET, DRAGLINE, 9.0 CY, LIGHT WEIGHT/PERFORATED			$34,787	7.28	2.44	3.91	0.48	0.00	128
	B35HE015	LS	BUCKET, DRAGLINE, 10.0 CY, LIGHT WEIGHT/PERFORATED			$37,801	7.91	2.65	4.25	0.52	0.00	139
	B35HE016	LS	BUCKET, DRAGLINE, 12.0 CY, LIGHT WEIGHT/PERFORATED			$46,507	9.74	3.26	5.23	0.64	0.00	166
	B35HE017	LS	BUCKET, DRAGLINE, 14.0 CY, LIGHT WEIGHT/PERFORATED			$53,458	11.18	3.74	6.01	0.73	0.00	191
	SAUERMAN											
	B35SA001	SC-1050-K	BUCKET, DRAGLINE, 1.0 CY, CRESCENT			$15,885	3.33	1.12	1.79	0.22	0.00	15
	B35SA003	SC-1070-K	BUCKET, DRAGLINE, 2.0 CY, CRESCENT			$23,792	4.99	1.67	2.68	0.33	0.00	25
	B35SA004	SC-1090-K	BUCKET, DRAGLINE, 3.0 CY, CRESCENT			$32,610	6.83	2.29	3.67	0.45	0.00	36

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B35		***SAUERMAN (continued)***										
	B35SA005	SC-1100-K	BUCKET, DRAGLINE, 4.0 CY, CRESCENT			$40,835	8.54	2.86	4.59	0.56	0.00	49
	B35SA006	SC-1110-K	BUCKET, DRAGLINE, 5.0 CY, CRESCENT			$48,132	10.07	3.37	5.41	0.66	0.00	58
	B35SA007	SC-1120-K	BUCKET, DRAGLINE, 6.0 CY, CRESCENT			$54,126	11.33	3.79	6.09	0.74	0.00	68
	B35SA008	SC-1130-K	BUCKET, DRAGLINE, 8.0 CY, CRESCENT			$63,799	13.35	4.46	7.18	0.87	0.00	88
	B35SA009	SC-1140-K	BUCKET, DRAGLINE, 10.0 CY, CRESCENT			$81,010	16.95	5.67	9.11	1.11	0.00	106
	B35SA010	SC-1150-K	BUCKET, DRAGLINE, 12.0 CY, CRESCENT			$98,870	20.69	6.91	11.12	1.35	0.00	132
		NO SPECIFIC MANUFACTURER										
	B35XX001	6-1/2L	BUCKET, DRAGLINE, 6.5 CY, LIGHT WEIGHT			$24,578	5.15	1.73	2.77	0.34	0.00	94
	B35XX002	7-1/2L	BUCKET, DRAGLINE, 7.5 CY, LIGHT WEIGHT			$27,637	5.79	1.94	3.11	0.38	0.00	106
	B35XX003	8-1/2L	BUCKET, DRAGLINE, 8.5 CY, LIGHT WEIGHT			$30,569	6.40	2.14	3.44	0.42	0.00	116
	B35XX004	9-1/2L	BUCKET, DRAGLINE, 9.5 CY, LIGHT WEIGHT			$34,864	7.30	2.44	3.92	0.48	0.00	132
	B35XX005	11L	BUCKET, DRAGLINE, 11.0 CY, LIGHT WEIGHT			$39,146	8.18	2.73	4.40	0.53	0.00	148
	B35XX006	13L	BUCKET, DRAGLINE, 13.0 CY, LIGHT WEIGHT			$48,191	10.09	3.37	5.42	0.66	0.00	178
	SUBCATEGORY 0.20		**MEDIUM WEIGHT**									
		HENDRIX MANUFACTURING COMPANY, INC.										
	B35HE018	TS	BUCKET, DRAGLINE, 0.75 CY, MEDIUM WEIGHT			$5,707	1.07	0.37	0.57	0.08	0.00	17
	B35HE019	TS	BUCKET, DRAGLINE, 1.0 CY, MEDIUM WEIGHT			$6,567	1.24	0.42	0.66	0.09	0.00	19
	B35HE020	TS	BUCKET, DRAGLINE, 1.5 CY, MEDIUM WEIGHT			$8,910	1.67	0.57	0.89	0.12	0.00	28

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B25	***HENDRIX MANUFACTURING COMPANY, INC. (continued)***											
	B35HE021	TS	BUCKET, DRAGLINE, 2.0 CY, MEDIUM WEIGHT			$10,596	1.98	0.67	1.06	0.14	0.00	36
	B35HE022	TS	BUCKET, DRAGLINE, 2.5 CY, MEDIUM WEIGHT			$12,416	2.33	0.79	1.24	0.17	0.00	41
	B35HE023	TS	BUCKET, DRAGLINE, 3.0 CY, MEDIUM WEIGHT			$14,611	2.74	0.93	1.46	0.20	0.00	49
	B35HE024	TS	BUCKET, DRAGLINE, 3.5 CY, MEDIUM WEIGHT			$16,139	3.02	1.03	1.61	0.22	0.00	54
	B35HE025	TS	BUCKET, DRAGLINE, 4.0 CY, MEDIUM WEIGHT			$19,342	3.62	1.23	1.93	0.26	0.00	70
	B35HE026	TS	BUCKET, DRAGLINE, 4.5 CY, MEDIUM WEIGHT			$20,702	3.88	1.32	2.07	0.28	0.00	72
	B35HE027	TS	BUCKET, DRAGLINE, 5.0 CY, MEDIUM WEIGHT			$26,526	4.97	1.69	2.65	0.36	0.00	93
	B35HE028	TS	BUCKET, DRAGLINE, 6.0 CY, MEDIUM WEIGHT			$27,401	5.13	1.74	2.74	0.37	0.00	96
	B35HE029	TS	BUCKET, DRAGLINE, 7.0 CY, MEDIUM WEIGHT			$31,277	5.86	1.99	3.13	0.42	0.00	111
	B35HE030	TS	BUCKET, DRAGLINE, 8.0 CY, MEDIUM WEIGHT			$34,432	6.44	2.18	3.44	0.46	0.00	122
	B35HE031	TS	BUCKET, DRAGLINE, 9.0 CY, MEDIUM WEIGHT			$41,196	7.71	2.61	4.12	0.55	0.00	149
	B35HE032	TS	BUCKET, DRAGLINE, 10.0 CY, MEDIUM WEIGHT			$43,874	8.22	2.79	4.39	0.59	0.00	159
	B35HE033	TS	BUCKET, DRAGLINE, 12.0 CY, MEDIUM WEIGHT			$56,641	10.61	3.59	5.66	0.76	0.00	202
	B35HE034	TS	BUCKET, DRAGLINE, 14.0 CY, MEDIUM WEIGHT			$63,090	11.82	4.01	6.31	0.85	0.00	225
	NO SPECIFIC MANUFACTURER											
	B35XX007	6-1/2M	BUCKET, DRAGLINE, 6.5 CY, MEDIUM WEIGHT			$27,824	5.21	1.76	2.78	0.37	0.00	101
	B35XX008	7-1/2M	BUCKET, DRAGLINE, 7.5 CY, MEDIUM WEIGHT			$31,800	5.96	2.02	3.18	0.43	0.00	117
	B35XX009	8-1/2M	BUCKET, DRAGLINE, 8.5 CY, MEDIUM WEIGHT			$34,241	6.41	2.17	3.42	0.46	0.00	126
	B35XX010	9-1/2M	BUCKET, DRAGLINE, 9.5 CY, MEDIUM WEIGHT			$40,718	7.63	2.59	4.07	0.55	0.00	152

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
B25	***NO SPECIFIC MANUFACTURER (continued)***											
	B35XX011	11M	BUCKET, DRAGLINE, 11.0 CY, MEDIUM WEIGHT			$45,020	8.44	2.86	4.50	0.61	0.00	169
	B35XX012	13M	BUCKET, DRAGLINE, 13.0 CY, MEDIUM WEIGHT			$57,079	10.70	3.63	5.71	0.77	0.00	211
	SUBCATEGORY 0.30		**HEAVY WEIGHT**									
	HENDRIX MANUFACTURING COMPANY, INC.											
	B35HE035	MH-S	BUCKET, DRAGLINE, 2.75 CY, HEAVY WEIGHT			$21,458	3.65	1.26	1.93	0.29	0.00	69
	B35HE036	MH-S	BUCKET, DRAGLINE, 3.0 CY, HEAVY WEIGHT			$22,390	3.81	1.31	2.02	0.30	0.00	72
	B35HE037	MH-S	BUCKET, DRAGLINE, 3.5 CY, HEAVY WEIGHT			$25,185	4.27	1.47	2.27	0.33	0.00	81
	B35HE038	MH-S	BUCKET, DRAGLINE, 4.0 CY, HEAVY WEIGHT			$34,205	5.80	1.99	3.08	0.45	0.00	110
	B35HE039	MH-S	BUCKET, DRAGLINE, 4.5 CY, HEAVY WEIGHT			$38,249	6.49	2.23	3.44	0.51	0.00	123
	B35HE040	MH-S	BUCKET, DRAGLINE, 5.0 CY, HEAVY WEIGHT			$39,488	6.71	2.31	3.55	0.53	0.00	127
	B35HE041	MH-S	BUCKET, DRAGLINE, 6.0 CY, HEAVY WEIGHT			$42,293	7.18	2.47	3.81	0.56	0.00	136
	B35HE042	MH-S	BUCKET, DRAGLINE, 7.0 CY, HEAVY WEIGHT			$53,519	9.09	3.12	4.82	0.71	0.00	175
	B35HE043	MH-S	BUCKET, DRAGLINE, 8.0 CY, HEAVY WEIGHT			$55,047	9.34	3.21	4.95	0.73	0.00	180
	B35HE044	MH-S	BUCKET, DRAGLINE, 9.0 CY, HEAVY WEIGHT			$69,979	11.88	4.08	6.30	0.93	0.00	234
	B35HE045	MH-S	BUCKET, DRAGLINE, 10.0 CY, HEAVY WEIGHT			$72,540	12.31	4.23	6.53	0.96	0.00	243
	B35HE046	MH-S	BUCKET, DRAGLINE, 12.0 CY, HEAVY WEIGHT			$86,270	14.65	5.03	7.76	1.15	0.00	289
	B35HE047	MH-S	BUCKET, DRAGLINE, 14.0 CY, HEAVY WEIGHT			$92,081	15.63	5.37	8.29	1.22	0.00	309

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
			NO SPECIFIC MANUFACTURER									
	B35XX013	3/4H	BUCKET, DRAGLINE, 0.75 CY, HEAVY WEIGHT			$7,060	1.20	0.41	0.64	0.09	0.00	20
	B35XX014	1H	BUCKET, DRAGLINE, 1.0 CY, HEAVY WEIGHT			$7,926	1.35	0.47	0.71	0.11	0.00	23
	B35XX015	1-1/2H	BUCKET, DRAGLINE, 1.5 CY, HEAVY WEIGHT			$11,780	2.00	0.69	1.06	0.16	0.00	35
	B35XX016	2H	BUCKET, DRAGLINE, 2.0 CY, HEAVY WEIGHT			$13,431	2.28	0.79	1.21	0.18	0.00	42
	B35XX017	2-1/2H	BUCKET, DRAGLINE, 2.5 CY, HEAVY WEIGHT			$14,654	2.48	0.85	1.32	0.19	0.00	48
	B35XX018	5-1/2H	BUCKET, DRAGLINE, 5.5 CY, HEAVY WEIGHT			$31,247	5.31	1.83	2.81	0.42	0.00	113
	B35XX019	6-1/2H	BUCKET, DRAGLINE, 6.5 CY, HEAVY WEIGHT			$33,325	5.66	1.94	3.00	0.44	0.00	125
	B35XX020	7-1/2H	BUCKET, DRAGLINE, 7.5 CY, HEAVY WEIGHT			$37,652	6.39	2.20	3.39	0.50	0.00	135
	B35XX021	8-1/2H	BUCKET, DRAGLINE, 8.5 CY, HEAVY WEIGHT			$40,897	6.94	2.38	3.68	0.54	0.00	159
	B35XX022	9-1/2H	BUCKET, DRAGLINE, 9.5 CY, HEAVY WEIGHT			$51,764	8.79	3.02	4.66	0.69	0.00	181
	B35XX023	11H	BUCKET, DRAGLINE, 11.0 CY, HEAVY WEIGHT			$55,431	9.42	3.24	4.99	0.74	0.00	198
C05	**CHAIN SAWS**											
	SUBCATEGORY 0.00		**CHAIN SAWS**									
			OLYMPYK CHAIN SAWS									
	C05OL001	941	CHAIN SAW, 16″-18″ BAR	2 HP G		$286	0.89	0.08	0.13	0.01	0.32	1
	C05OL002	962	CHAIN SAW, 16″-24″ BAR	5 HP G		$456	1.58	0.12	0.21	0.01	0.65	1
	C05OL003	970	CHAIN SAW, 16″-36″ BAR	5 HP G		$557	1.83	0.14	0.25	0.01	0.72	1
	C05OL004	980	CHAIN SAW, 16″-42″ BAR	6 HP G		$607	2.00	0.15	0.27	0.01	0.79	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C10	**COMPACTORS, WALK-BEHIND OR REMOTE CONTROLLER**											
	SUBCATEGORY 0.10		**COMPACTORS, RAMMERS/TAMPERS & VIBRATORY PLATES**									
			COMPACTION AMERICA									
	C10BO001	BT 50	COMPACTOR, RAMMER, TAMPER, 9″ × 13.8″ SHOE	3 HP G		$3,216	2.20	0.43	0.76	0.05	0.42	1
	C10BO003	BP 10/36	COMPACTOR, VIBROPLATE, 14.2″ × 21.5″ PLATE	4 HP G		$2,224	1.84	0.30	0.53	0.03	0.55	2
	C10BO004	BP 15/45	COMPACTOR, VIBROPLATE, 17.7″ × 21.5″ PLATE	6 HP G		$2,494	2.33	0.34	0.59	0.04	0.83	2
	C10BO007	BPR 35/38D	COMPACTOR, VIBROPLATE, 22.8″ × 31.1″ PLATE, REVERSIBLE	5 HP D-off		$6,665	3.89	0.89	1.58	0.10	0.31	5
	C10BO008	BPR 55/52D	COMPACTOR, VIBROPLATE, 32.3″ × 35″ PLATE, REVERSIBLE	8 HP D-off		$12,815	7.35	1.72	3.04	0.20	0.49	10
			WACKER CORPORATION									
	C10WC003	BS 65Y	COMPACTOR, RAMMER, 11″ × 13″ SHOE, 3640 LBS IMPACT	4 HP G		$4,467	3.02	0.60	1.06	0.07	0.55	2
	C10WC006	BPS 2550 A	COMPACTOR, VIBROPLATE, 19.5″ × 25.5″ PLATE, 5600 LBS IMPACT	8 HP G		$3,041	2.96	0.41	0.72	0.05	1.11	3
	C10WC007	BPU 3345A	COMPACTOR, VIBROPLATE, 23.5″ × 35.5″ PLATE, 7550 LBS IMPACT	9 HP G		$10,010	6.80	1.34	2.38	0.15	1.25	7
	C10WC008	DPU 4045H	COMPACTOR, VIBROPLATE, 23.5″ × 35.5″ PLATE, 9000 LBS IMPACT	6 HP D-off		$13,357	7.48	1.79	3.17	0.20	0.37	7
	C10WC015	DPU 7060	COMPACTOR, VIBROPLATE, 31.5″ × 42″ PLATE, 15600 LBS IMPACT	14 HP D-off		$23,847	13.60	3.19	5.66	0.36	0.86	15

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.20		ROLLERS, VIBRATORY										
		COMPACTION AMERICA											
	C10BO009	BW 55E	COMPACTOR, ROLLER, VIBRATORY, 22″ × 15.7″, 0.17 TON SINGLE SMOOTH DRUM, WALK BEHIND, 1×1	4 HP	G		$5,894	3.62	0.72	1.25	0.09	0.55	3
	C10BO010	BW 35	COMPACTOR, TRENCH ROLLER, VIBRATORY, 15.4″W × 13.8″, 0.5T DOUBLE TAMPING FOOT DRUMS, WALK BEHIND, 2×1	4 HP	D-off		$13,761	7.20	1.68	2.92	0.22	0.24	10
	C10BO014	BW60S	COMPACTOR, ROLLER, 23.6″W, DOUBLE SMOOTH DRUMS	7 HP	D-off		$16,549	8.84	2.02	3.52	0.26	0.43	18
	C10BO015	BW65S	COMPACTOR, ROLLER, 25.6″W, DOUBLE SMOOTH DRUMS	5 HP	D-off		$12,767	6.79	1.56	2.71	0.20	0.31	13
	C10BO011	BW 60HG	COMPACTOR, ROLLER, VIBRATORY, 29.9″W × 19.7″, 0.9 TON DOUBLE SMOOTH DRUMS, WALK BEHIND, 2×2	8 HP	D-off		$10,394	5.83	1.28	2.21	0.17	0.49	26
	C10BO016	BW75S-2	COMPACTOR, ROLLER, 29.5″W, DOUBLE SMOOTH DRUMS	9 HP	D-off		$18,642	10.04	2.28	3.96	0.30	0.55	20
	C10BO013	BMP851	COMPACTOR, TRENCH ROLLER, VIBRATORY, 33.5″W, 6.2 TON DOUBLE TAMPING FOOT DRUMS, WALK BEHIND, 2×1	16 HP	D-off		$36,913	19.74	4.51	7.84	0.59	0.98	34
		RAMMAX MACHINERY CO.											
	C10RX001	P23/16F	COMPACTOR, TRENCH ROLLER, PADFOOT, 23″W, QUAD PADFOOT DRUMS	8 HP	D-off		$27,447	14.39	3.36	5.83	0.44	0.49	20
	C10RX002	P33/24FMR	COMPACTOR, TRENCH ROLLER, PADFOOT, 24″W/33″W, QUAD PADFOOT DRUMS	14 HP	D-off		$38,978	20.63	4.76	8.28	0.62	0.86	30
	C10RX003	P47/40KM	COMPACTOR, TRENCH ROLLER, PADFOOT, 40″W/47″W, QUAD PADFOOT DRUMS	33 HP	D-off		$66,349	35.81	8.11	14.10	1.06	2.02	66

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
			WACKER CORPORATION									
	C10WC010	RSS800A	COMPACTOR, ROLLER, VIBRATORY, 28″W, 2.3 TON SINGLE SMOOTH DRUM, WALK BEHIND, 2×1	11 HP G		$12,675	8.22	1.55	2.69	0.20	1.52	11
	C10WC017	RD7H	COMPACTOR, ROLLER, VIBRATORY, 16.5″W, 2.0 TON DOUBLE SMOOTH DRUM, WALK BEHIND, 2×1	9 HP D-off		$15,352	8.38	1.87	3.26	0.24	0.55	16
	C10WC019	RT560	COMPACTOR, ROLLER, VIBRATORY, 22″W, 4.2 TON DOUBLE SMOOTH DRUM, WALK BEHIND, 2×1	20 HP D-off		$39,008	21.09	4.77	8.29	0.62	1.22	31
	C10WC016	RT820	COMPACTOR, TRENCH ROLLER, VIBRATORY, 32″W, 4.3 TON DOUBLE TAMPING FOOT DRUMS, WALK BEHIND, 2×1	20 HP D-off		$39,531	21.35	4.83	8.40	0.63	1.22	33
C15	**CONCRETE CLEANERS/BLASTERS**											
	SUBCATEGORY 0.00		**CONCRETE CLEANERS/BLASTERS**									
			US FILTER/BLASTRAC									
	C15BL001	1-8 & TURBO VAC	CONCRETE BLASTER CLEANING SYSTEM, 8″ PATH (ADD 4 KVA GENERATOR & BLAST MEDIA COST)	2 HP E		$8,604	4.26	1.00	1.72	0.14	0.09	2
	C15BL003	1-10D & 6-54 DC	CONCRETE BLASTER CLEANING SYSTEM, 10″ PATH (ADD 30 KVA GENERATOR & BLAST MEDIA COST)	10 HP E		$41,251	19.56	4.80	8.25	0.67	0.45	7
	C15BL004	1-15D & 6-54-DC	CONCRETE BLASTER CLEANING SYSTEM, 15″ PATH (ADD 30 KVA GENERATOR & BLAST MEDIA COST)	15 HP E		$48,275	23.09	5.61	9.66	0.78	0.67	8

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C15		***US FILTER/BLASTRAC (continued)***										
	C15BL005	2-20D & 8-54-DC	CONCRETE BLASTER CLEANING SYSTEM, 20″ PATH (ADD 75 KVA GENERATOR & BLAST MEDIA COST)	30 HP E		$70,759	33.81	8.23	14.15	1.15	1.34	12
C20	**CONCRETE BUGGIES**											
	SUBCATEGORY 0.00		**CONCRETE BUGGIES**									
		WACKER CORPORATION										
	C20WC002	WB 16A	CONCRETE BUGGY, 16 CF BUCKET, 1.25 TON, WALK & RIDE, 4×2	13 HP G		$9,816	5.41	1.06	1.79	0.16	1.40	12
		NO SPECIFIC MANUFACTURER										
	C20XX001	10G	CONCRETE BUGGY, 10 CF, 1500 LBS	8 HP G		$6,881	3.64	0.74	1.26	0.11	0.86	10
C25	**CONCRETE FINISHERS/SCREEDS/SPREADERS**											
	SUBCATEGORY 0.10		**FINISHERS/TROWELS**									
		ALLEN ENGINEERING CORP.										
	C25AJ015	PRO 900	CONCRETE TROWEL, RIDING, 2 – 36″ DIA ROTORS	20 HP G		$10,561	6.19	1.01	1.69	0.16	2.16	7
	C25AJ016	PRO 1050	CONCRETE TROWEL, RIDING, 2 – 42″ DIA ROTORS	20 HP G		$11,068	6.36	1.06	1.77	0.17	2.16	8
	C25AJ018	PRO 1200	CONCRETE TROWEL, RIDING, 2 – 46″ DIA ROTORS	25 HP G		$12,833	7.64	1.23	2.05	0.20	2.70	10
	C25AJ019	SUPER PRO 400	CONCRETE TROWEL, RIDING, 2 – 46″ DIA ROTORS	28 HP G		$18,612	9.91	1.78	2.98	0.29	3.02	13

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	STOW MANUFACTURING, INC.												
	C25ST001	SCT36H80	CONCRETE FINISHER, 36″ DIA, ROTO TROWEL	8 HP	G		$2,390	1.89	0.23	0.38	0.04	0.86	3
	C25ST002	SCT46H80	CONCRETE FINISHER, 46″ DIA, ROTO TROWEL	9 HP	G		$2,596	2.10	0.25	0.42	0.04	0.97	3
	WACKER CORPORATION												
	C25WC002	CT48A	CONCRETE FINISHER, POWER TROWEL, 48″ DIA, 4 BLADES	8 HP	G		$3,142	2.13	0.30	0.50	0.05	0.86	3
	C25WC003	CT46A	CONCRETE FINISHER, POWER TROWEL, 2 SETS OF 4 – 48″ DIA BLADES	20 HP	G		$11,720	6.57	1.12	1.88	0.18	2.16	8
	SUBCATEGORY 0.20		**VIBRATORY SCREED**										
	ALLEN ENGINEERING CORP.												
	C25AJ003	12HED	CONCRETE, VIBRATORY SCREED, 12.5′ WIDE	9 HP	G		$5,594	3.07	0.54	0.90	0.09	0.97	5
	C25AJ001	12 HD	CONCRETE, VIBRATORY SCREED, 20′ WIDE	8 HP	G		$3,955	2.39	0.38	0.63	0.06	0.86	4
	C25AJ004	12 HED	CONCRETE, VIBRATORY SCREED, 30′ WIDE	9 HP	G		$7,991	3.83	0.76	1.28	0.12	0.97	8
	C25AJ005	12 HED	CONCRETE, VIBRATORY SCREED, 40′ WIDE	11 HP	G		$9,380	4.57	0.90	1.50	0.15	1.19	10
	C25AJ006	12HED	CONCRETE, VIBRATORY SCREED, 50′ WIDE	11 HP	G		$11,140	5.13	1.06	1.78	0.17	1.19	12
	C25AJ007	12HED	CONCRETE, VIBRATORY SCREED, 55′ WIDE	11 HP	G		$11,847	5.36	1.13	1.90	0.18	1.19	13
	SUBCATEGORY 0.25		**VIBRATORY LASER SCREED**										
	SOMERO ENTERPRISES, INC.												
	C25SV003	S-100	CONCRETE, VIBRATORY LASER SCREED, 8′ WIDE × 12′ BOOM	30 HP	D-off		$138,266	25.52	8.14	12.01	2.13	1.32	72

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C25	***SOMERO ENTERPRISES, INC. (continued)***												
	C25SV002	S-160	CONCRETE, VIBRATORY LASER SCREED, 8′ WIDE × 20′ BOOM	65 HP	D-off		$228,816	43.12	13.49	19.94	3.52	2.85	126
	C25SV001	S-240	CONCRETE, VIBRATORY LASER SCREED, 12′ WIDE × 20′ BOOM	65 HP	D-off		$284,734	52.71	16.78	24.80	4.38	2.85	151
	SUBCATEGORY 0.30		**MATERIAL/TOPPING SPREADERS**										
	ALLEN ENGINEERING CORP.												
	C25AJ008	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 12.5′ WIDE	6 HP	G		$13,495	3.08	0.80	1.18	0.21	0.55	11
	C25AJ009	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 20′ WIDE	6 HP	G		$14,327	3.22	0.85	1.25	0.22	0.55	12
	C25AJ010	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 30′ WIDE	6 HP	G		$15,310	3.40	0.91	1.34	0.24	0.55	13
	C25AJ011	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 40′ WIDE	6 HP	G		$16,398	3.57	0.97	1.43	0.25	0.55	14
	C25AJ012	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 50′ WIDE	6 HP	G		$17,405	3.75	1.03	1.52	0.27	0.55	15
	C25AJ013	SP23H	CONCRETE, MATERIAL/ TOPPING SPREADER, 60′ WIDE	6 HP	G		$18,419	3.92	1.09	1.61	0.28	0.55	17
C35	**CONCRETE GUNITERS/SHOTCRETERS**												
	SUBCATEGORY 0.00		**CONCRETE GUNITERS/ SHOTCRETERS**										
	AIRPLACO EQUIPMENT CO., INC.												
	C35AF002	C-7A	CONCRETE GUNITER/ SHOTCRETER, DRY/SEMI-WET, HOPPER/PUMP/SPRAY, 12 CY/ HR, 2″ HOSE & 1 GUN (ADD 600 CFM COMPRESSOR)	600 CFM	A		$11,361	4.72	0.77	1.19	0.17	0.00	6

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C35	***AIRPLACO EQUIPMENT CO., INC. (continued)***												
	C35AF001	1900 HD NUCRETOR	CONCRETE GUNITER/ SHOTCRETER, DRY MIX, 2 – 15 CY/HR, W/2 PRESSURIZED TANKS/100′-2″ DIA HOSE (ADD 600 CFM COMPRESSOR)	600 CFM	A		$23,334	5.89	1.59	2.47	0.35	0.00	11
	C35AF004	640 Mix Elevator	CONCRETE GUNITER/ SHOTCRETER, DRY BATCH MIXER, 13 CY/HR, W/2 FEEDED (ADD SHOTCRETE MACHINE)	30 HP	G		$39,957	16.09	2.74	4.25	0.61	3.47	45
	C35AF005	734 Mix Elevator	CONCRETE GUNITER/ SHOTCRETER, DRY BATCH MIXER, W/20 CY/HR ELEVATOR FEEDER/45 CF SAND HOPPER/4 CF CEMENT HOPPER/& PREDAMPENING SPRAY BAR (ADD SHOTCRETE MACHINE)	54 HP	D-off		$57,585	19.31	3.92	6.10	0.87	2.80	81
	ALLENTOWN EQUIPMENT												
	C35AL003	GRH-610 ROTARY GUN	CONCRETE GUNITER/ SHOTCRETER, ROTARY PUMP, WET/DRY, 1 – 6 CY/HR, TRAILER MTD, W/HOPPER/100′-1.5″ DIA HOSE/& NOZZLE (ADD 250 – 600 CFM COMPRESSOR)	5 HP	E		$11,903	3.34	0.75	1.14	0.18	0.24	11
	C35AL013	AG-15 AUTOMATIC GUN	CONCRETE GUNITER/ SHOTCRETER, ROTARY PUMP, WET/DRY, 3 – 15 CY/HR, W/ HOPPER/100′ - 1.5″ DIA HOSE/& NOZZLE (ADD 300 – 900 CFM COMPRESSOR)	900 CFM	A		$10,943	3.01	0.73	1.11	0.17	0.00	15
	C35AL008	N-2 PNEUMATIC GUN	CONCRETE GUNITER/ SHOTCRETER, DRY MIX, 2 – 8 CY/HR, W/2 PRESSURIZED TANKS/100′ - 1.5″ DIA HOSE/& NOZZLE (ADD 200 – 900 CFM COMPRESSOR)	900 CFM	A		$23,927	6.03	1.64	2.56	0.36	0.00	13

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C35		***ALLENTOWN EQUIPMENT (continued)***										
	C35AL002	R-900 BATCH MIX RIG	CONCRETE GUNITER/ SHOTCRETER, DRY BATCH MIXER, 10 TON/HR, W/ ELEVATOR FEEDER/20 CF CEMENT HOPPER/8 CF MIXER/& PREDAMPENING SPRAY BAR (ADD SHOTCRETE MACHINE OR ROTARY PUMP)	26 HP D-off		$33,066	10.58	2.21	3.41	0.50	1.35	47
	C35AL014	POWER CRETER 10	CONCRETE GUNITER/ SHOTCRETER, GROUT/MUD JACK/SHOTCRETE, 10 CY/HR, 400 PSI, TRAILER MTD, W/30 GAL HOPPER/74 GAL MIXER (ADD 3″ HOSE LINE)	53 HP D-off		$54,500	17.04	3.74	5.81	0.83	2.75	30
		ALIVA LTD.										
	C35AV008	AL 246	CONCRETE GUNITER/ SHOTCRETER, DRY/SEMI-WET, 1.4 – 2.3 CY/HR, W/1 GAL HOPPER/ROTARY PUMP/100′ - 1.5″ DIA HOSE/NOZZLE/& AIR COMPRESSOR	7 HP E		$24,091	8.26	1.66	2.58	0.37	0.34	9
	C35AV009	AL 252	CONCRETE GUNITER/ SHOTCRETER, DRY/SEMI-WET, 5 – 10 CY/HR, W/4.2 GAL HOPPER/ROTARY PUMP/100′ - 2.36″ DIA HOSE/NOZZLE/& AIR COMPRESSOR	16 HP E		$29,277	10.11	2.01	3.14	0.44	0.77	18
	C35AV010	AL 262	CONCRETE GUNITER/ SHOTCRETER, WET/DRY, 9 - 13 CY/HR, W/4.2 GAL HOPPER/ ROTARY PUMP/100′ - 2.36″ DIA HOSE/NOZZLE/& AIR COMPRESSOR	26 HP E		$52,842	16.44	3.63	5.66	0.80	1.25	27

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C35		*ALIVA LTD. (continued)*										
	C35AV006	AL 285	CONCRETE GUNITER/ SHOTCRETER, WET/DRY, 11 – 27.5 CY/HR, W/6.6 GAL HOPPER/ ROTARY PUMP/100′ - 2.55″ DIA HOSE/NOZZLE/& AIR COMPRESSOR	20 HP E		$80,831	22.75	5.53	8.60	1.23	0.96	33
	C35AV011	AL 302	CONCRETE GUNITER/ SHOTCRETER, SHOTCRETE HYDRAULIC SPRAYER ARM, 25.6′ HIGH (ADD TRUCK OR SMALL TRAILER & SHOTCRETE UNIT)	12 HP E		$40,406	12.50	2.78	4.33	0.61	0.58	50
	C35AV012	AL 307	CONCRETE GUNITERS/ SHOTCRETERS, SHOTCRETE HYDRAULIC SPRAYER ARM, 52.5′ HIGH (ADD TRUCK OR SMALL TRAILER & SHOTCRETE UNIT)	20 HP E		$121,075	32.89	8.33	12.97	1.84	0.96	68
C40	**CONCRETE MIXING UNITS**											
	SUBCATEGORY 0.00		**CONCRETE MIXING UNITS**									
		CEMEN TECH										
	C40CC001	SCD2-50H	CONCRETE MIXERS, STATIONARY CONCRETE DISPENSER, 15 CY/HR, 2 - 4.5 CY MATERIAL CAPACITY	10 HP E		$22,360	7.86	2.14	3.58	0.35	0.45	23
		MULTIQUIP, INC.										
	C40MU001	WM 700SH8	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 6 CF	8 HP G		$2,540	1.92	0.23	0.38	0.04	0.86	8
	C40MU002	WM 120SH	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 12 CF	13 HP G		$5,571	3.59	0.52	0.86	0.09	1.40	11

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C40			***MULTIQUIP, INC. (continued)***										
	C40MU003	MC 62SH8	CONCRETE MIXERS, MIXER, CONCRETE, 6 CF	8 HP	G		$2,722	1.97	0.24	0.40	0.04	0.86	7
	C40MU004	MC 92SH8	CONCRETE MIXERS, MIXER, CONCRETE, 9 CF	8 HP	G		$3,301	2.16	0.30	0.50	0.05	0.86	8
			ROSS COMPANY										
	C40RC005		CONCRETE MIXERS, MIXER, CONCRETE, 12.0 CY, TILT DRUM (ADD DRY BATCH PLANT)	120 HP	E		$198,614	75.63	18.84	31.50	3.09	5.38	90
			STOW MANUFACTURING, INC.										
	C40ST001	CMS4E	CONCRETE MIXERS, MIXER, CONCRETE, 4 CF, PORTABLE	1 HP	E		$1,786	0.79	0.16	0.26	0.03	0.02	5
	C40ST002	CMS4H	CONCRETE MIXERS, MIXER, CONCRETE, 4 CF, PORTABLE	6 HP	G		$1,997	1.39	0.18	0.29	0.03	0.59	5
	C40ST003	CMS6E	CONCRETE MIXERS, MIXER, CONCRETE, 6 CF, PORTABLE	1 HP	E		$2,449	1.08	0.22	0.36	0.04	0.04	7
	C40ST005	CMS9E	CONCRETE MIXERS, MIXER, CONCRETE, 9 CF, PORTABLE	2 HP	E		$3,336	1.45	0.30	0.50	0.05	0.07	8
			NO SPECIFIC MANUFACTURER										
	C40XX001	8E	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 8 CF, ELECTRIC, PORTABLE	2 HP	E		$2,931	1.28	0.29	0.47	0.05	0.09	7
	C40XX002	8G	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 8 CF, GAS, PORTABLE	7 HP	G		$3,138	1.98	0.30	0.50	0.05	0.75	7
	C40XX003	10E	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 10 CF, ELECTRIC, PORTABLE	3 HP	E		$4,486	1.84	0.43	0.72	0.07	0.13	9
	C40XX004	10G	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 10 CF, GAS, PORTABLE	8 HP	G		$4,512	2.57	0.43	0.72	0.07	0.86	10
	C40XX005	12E	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 12 CF, ELECTRIC, PORTABLE	5 HP	E		$5,912	2.47	0.57	0.95	0.09	0.22	11

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C40	***NO SPECIFIC MANUFACTURER (continued)***												
	C40XX006	16E	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 16 CF, ELECTRIC, PORTABLE	5 HP	E		$8,244	3.23	0.79	1.32	0.13	0.22	12
	C40XX007	16G	CONCRETE MIXERS, MIXER, PLASTER/MORTAR, 16 CF, GAS, PORTABLE	9 HP	G		$7,671	3.73	0.74	1.23	0.12	0.97	13
C45	**CONCRETE PAVING MACHINES**												
	SUBCATEGORY 0.00		**CONCRETE PAVING MACHINES**										
	GOMACO CORPORATION												
	C45GO013	GT-3200	CONCRETE PAVING MACHINES, CURB/GUTTER SLIPFORM PAVER, 36″ WIDE	70 HP	D-off		$109,707	37.66	8.98	14.63	1.66	3.63	120
	C45GO010	COMMANDER II	CONCRETE PAVING MACHINES, CURB/GUTTER SLIPFORM PAVER, 2-TRACK	92 HP	D-off		$122,615	42.98	10.03	16.35	1.85	4.77	200
	C45GO014	GT-3600	CONCRETE PAVING MACHINES, CURB/GUTTER SLIPFORM PAVER, 3-TRACK	92 HP	D-off		$146,556	50.19	11.98	19.54	2.21	4.77	210
	C45GO011	COMMANDER III	CONCRETE PAVING MACHINES, CURB/GUTTER SLIPFORM PAVER, 3-TRACK	169 HP	D-off		$167,665	61.60	13.71	22.36	2.53	8.77	300
	C45GO012	COMMANDER III	CONCRETE PAVING MACHINES, CURB/GUTTER SLIPFORM PAVER, 12′, 4-TRACK	169 HP	D-off		$287,236	97.65	23.49	38.30	4.34	8.77	369
	C45GO016	GP-2600	CONCRETE PAVING MACHINES, PAVER, 28′ WIDE, 4-TRACK	230 HP	D-off		$345,429	119.17	28.24	46.06	5.21	11.93	750
	C45GO018	GHP-2800	CONCRETE PAVING MACHINES, PAVER, 28′ WIDE, 4-TRACK	250 HP	D-off		$496,188	165.93	40.57	66.16	7.49	12.97	800
	C45GO020	G-4000	CONCRETE PAVING MACHINES, PAVER, 28′ WIDE, SLIPFORM, CRAWLER, 4-TRACK	325 HP	D-off		$538,348	183.54	44.02	71.78	8.13	16.86	1,150

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	REGION 6 EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C45		***GOMACO CORPORATION (continued)***											
	C45GO025	C-700	CONCRETE PAVING MACHINES, CYLINDER FINISHER, DOUBLE DRUM, 60′ WIDE	48 HP	G		$67,806	27.62	5.54	9.04	1.02	5.54	55
	C45GO031	9500	CONCRETE PAVING MACHINES, TRIMMER/PLACER, W/16′ HEAD	325 HP	D-off		$345,120	125.29	28.22	46.02	5.21	16.86	669
		MILLER SPREADER CO.											
	C45MJ001	MC 650	CONCRETE PAVING MACHINES, CURB BUILDER, 3.7 CF HOPPER 6″ AUGER	15 HP	G		$7,117	4.40	0.59	0.95	0.11	1.73	8
		M-B-W, INC.											
	C45MW001	C100	CONCRETE PAVING MACHINES, RUBBER TIRED, CURB ONLY, 12″	20 HP	D-off		$42,125	13.84	3.24	5.20	0.64	1.04	26
	C45MW002	C101	CONCRETE PAVING MACHINES, RUBBER TIRED, CURB ONLY, 12″	20 HP	D-off		$45,284	14.85	3.47	5.57	0.68	1.04	27
	C45MW003	CG200	CONCRETE PAVING MACHINES, RUBBER TIRED, CURB & GUTTER, 48″	20 HP	D-off		$55,178	17.80	4.19	6.71	0.83	1.04	38
C55	**CONCRETE PUMPS**												
	SUBCATEGORY 0.00		**CONCRETE PUMPS**										
		MAYCO PUMP - MULTIQUIP INC.											
	C55M3001	C-30HD	CONCRETE PUMPS, 25 CY/HR, SINGLE, TRAILER MTD	30 HP	G		$18,500	8.64	1.28	2.06	0.25	3.23	27
	C55M3002	ST-45	CONCRETE PUMPS, 45 CY/HR, SINGLE, TRAILER MTD	57 HP	D-off		$46,212	14.54	3.23	5.20	0.63	2.73	42
	C55M3003	ST-70	CONCRETE PUMPS, 70 CY/HR, SINGLE, TRAILER MTD	106 HP	D-off		$59,027	20.60	4.13	6.64	0.81	5.08	47

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
		MORGEN MANUFACTURING CO.										
	C55MO001	MUSTANG 25, 210-295	CONCRETE PUMPS, 25 CY/HR, TRAILER MTD	30 HP G		$31,355	11.72	2.17	3.47	0.43	3.23	29
	C55MO019	MUSTANG 30	CONCRETE PUMPS, 30 CY/HR, TRAILER MTD	73 HP D-off		$41,681	14.42	2.89	4.63	0.57	3.50	40
	C55MO003	MUSTANG 9-50,213-185	CONCRETE PUMPS, 50 CY/HR, TRAILER MTD	110 HP D-off		$58,315	20.65	4.05	6.50	0.80	5.27	65
	C55MO018	106-115SV	CONCRETE PUMPS, 115 CY/HR, 106′ BOOM (ADD 50,000 GVW TRUCK)			$447,003	107.56	31.08	49.93	6.11	0.00	40
		OLIN ENGINEERING, INC.										
	C55OE006	10 22	CONCRETE PUMP, 22 CY/HR, TRAILER MTD	74 HP D-off		$41,760	14.48	2.89	4.64	0.57	3.54	44
	C55OE009	20 80	CONCRETE PUMP, 76 CY/HR, TRAILER MTD TANDEM	127 HP D-off		$82,279	27.42	5.69	9.14	1.12	6.08	72
	C55OE011	15 95	CONCRETE PUMP, 100 CY/HR, TRAILER MTD TANDEM	181 HP D-off		$73,504	28.58	5.08	8.16	1.00	8.67	70
	C55OE012	20 100	CONCRETE PUMP, 100 CY/HR, TRAILER MTD TANDEM	181 HP D-off		$96,701	34.15	6.71	10.77	1.32	8.67	81
	C55OE001	4Z 26X	CONCRETE PUMPS, PUMP & BOOM, 130 CY/HR, REACH: 72′0″ HORIZONTAL/85′0″ VERTICAL (ADD TRUCK)			$231,917	55.73	16.22	26.09	3.17	0.00	100
	C55OE002	4Z 36X	CONCRETE PUMPS, PUMP & BOOM, 182 CY/HR, REACH: 104′0″ HORIZONTAL/118′0″ VERTICAL (ADD TRUCK)			$298,020	71.61	20.84	33.53	4.07	0.00	100
	C55OE003	5RZ 47I	CONCRETE PUMPS, PUMP & BOOM, 182 CY/HR, REACH: 134′0″ HORIZONTAL/152′0″ VERTICAL (ADD TRUCK)			$454,263	109.15	31.76	51.10	6.21	0.00	100
		SCHWING AMERICA INC.										
	C55SC001	WP750 D-18X	CONCRETE PUMP, 70 CY/HR, 1100 PSI, TRAILER MTD	80 HP D-off		$66,866	20.90	4.66	7.50	0.91	3.83	69
	C55SC002	BPA 2000HDD-20R	CONCRETE PUMP, 67 CY/HR, 1565 PSI, TRAILER MTD	177 HP D-off		$146,114	45.77	10.16	16.32	2.00	8.47	115

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
C55			*SCHWING AMERICA INC. (continued)*										
	C55SC005	BPL 900/KVM 23	CONCRETE PUMP, 117 CY/HR, 75′ BOOM, TRUCK MTD	210 HP	D-on		$210,189	65.63	14.51	23.27	2.87	11.87	359
	C55SC006	BPL 900/KVM 28	CONCRETE PUMP, 117 CY/HR, 92′ BOOM, TRUCK MTD	210 HP	D-on		$274,915	81.18	19.04	30.55	3.76	11.87	470
C60	**CONCRETE SAWS (Add cost for sawblade wear)**												
	SUBCATEGORY 0.00		**CONCRETE SAWS (Add cost for sawblade wear)**										
			CUSHION CUT, INC.										
	C60CQ011	FS 6500/14	CONCRETE SAW, 4.625″ DEPTH, 14″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	65 HP	G		$15,122	16.49	1.36	2.27	0.22	9.01	13
	C60CQ002	FS 9B	CONCRETE SAW, 5.625″ DEPTH, MANUAL 16″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	9 HP	G		$2,458	2.40	0.23	0.37	0.04	1.25	2
	C60CQ003	FS 13BUC	CONCRETE SAW, 5.625″ DEPTH, MANUAL 16″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	13 HP	G		$2,647	3.18	0.24	0.40	0.04	1.80	2
	C60CQ001	FS 3500/20	CONCRETE SAW, 7.75″ DEPTH, SELF-PROPELLED, 20″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	35 HP	G		$11,858	10.05	1.06	1.78	0.17	4.85	10
	C60CQ014	FS 3000/26E	CONCRETE SAW, 10.625″ DEPTH, 6″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	30 HP	E		$12,989	6.58	1.17	1.95	0.19	1.73	13
	C60CQ012	FS 6500/26	CONCRETE SAW, 10.625″ DEPTH, 26″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	65 HP	G		$15,224	16.52	1.36	2.28	0.22	9.01	13

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C60			***CUSHION CUT, INC. (continued)***									
	C60CQ010	FS 3500/30	CONCRETE SAW, 12.125″ DEPTH, SELF PROPELLED, 30″ BLADE, W/TRANSAXLE (ADD COST FOR SAWBLADE WEAR & WATER)	35 HP D-off		$11,909	6.67	1.07	1.79	0.17	2.14	10
	C60CQ013	FS 6500/36	CONCRETE SAW, 14.875″ DEPTH, 36″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	65 HP G		$15,327	16.55	1.37	2.30	0.22	9.01	13
	C60CQ016	FS 7800/36DLS	CONCRETE SAW, 14.875″ DEPTH, 36″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	75 HP D-off		$22,226	13.25	1.99	3.33	0.32	4.59	20
			FELKER									
	C60FE002	S80/14Z	CONCRETE SAW, 5.00″ DEPTH, HAND HELD 14″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	2 HP G		$1,269	0.76	0.12	0.19	0.02	0.28	1
	C60FE006	ES 1409	CONCRETE SAW, 4.625″ DEPTH, WALK BEHIND, 14″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	9 HP G		$2,650	2.46	0.24	0.40	0.04	1.25	2
	C60FE007	ES 1413	CONCRETE SAW, 4.625″ DEPTH, WALK BEHIND, 14″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	13 HP G		$2,775	3.22	0.25	0.42	0.04	1.80	2
	C60FE009	ECII20H	CONCRETE SAW, 7.50″ DEPTH, WALK BEHIND, 20″ BLADE (ADD COST FOR SAWBLADE WEAR & WATER)	20 HP G		$8,867	6.41	0.80	1.33	0.13	2.77	6
			BOART LONG YEAR COMPANY									
	C60LY005	FS 13B	CONCRETE SAW, 7.00″ DEPTH, WALK BEHIND(ADD COST FOR SAWBLADE WEAR & WATER)	13 HP G		$2,602	3.17	0.24	0.39	0.04	1.80	2
	C60LY001	360-10AP	CONCRETE SAW, RAIL SAW, 15.50″ DEPTH, WALL (ADD COMPRESSOR & COST FOR SAWBLADE WEAR & WATER)	10 HP G		$23,479	9.23	2.10	3.52	0.34	1.39	2

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C60	***BOART LONG YEAR COMPANY (continued)***											
	C60LY002	360-35HM	CONCRETE SAW, RAIL SAW, 24.50″ DEPTH, WALL(ADD COST FOR SAWBLADE WEAR & WATER)	35 HP G		$29,691	15.69	2.65	4.45	0.42	4.85	2
	C60LY011	WR-400	CONCRETE SAW, WIRE SAW SYSTEM, HEAVY DUTY (ADD COST FOR WEAR & WATER)	32 HP D-off		$65,086	23.24	5.81	9.76	0.93	1.96	15
C65	**CONCRETE VIBRATORS**											
	SUBCATEGORY 0.00		**CONCRETE VIBRATORS**									
	STOW MANUFACTURING, INC.											
	C65ST007	SV-1 115V	CONCRETE VIBRATOR, 1.375″ HEAD, 21′ SHAFT (ADD GENERATOR)	1 HP E		$908	0.78	0.11	0.20	0.01	0.04	1
	C65ST008	SV-2 115V	CONCRETE VIBRATOR, 2.375″ HEAD, 21′ SHAFT (ADD GENERATOR)	2 HP E		$1,017	0.93	0.14	0.23	0.02	0.08	1
	C65ST009	SV-3 115V	CONCRETE VIBRATOR, 2.625″ HEAD, 21′ SHAFT (ADD GENERATOR)	3 HP E		$1,137	1.09	0.15	0.26	0.02	0.12	1
	C65ST013	G550HC	CONCRETE VIBRATOR, 2.325″ HEAD, W/GAS MOTOR ON CART	6 HP G		$1,920	2.25	0.25	0.43	0.03	0.55	2
	WACKER CORPORATION											
	C65WC005	B 5000	CONCRETE VIBRATOR, 1.75″ DIA, W/GAS MOTOR ON CART	5 HP G		$1,560	1.90	0.20	0.35	0.02	0.50	1
	C65WC004	M 3000	CONCRETE VIBRATOR, 1.75″ DIA, HI-FREQ INTERNAL (ADD 2KV GENERATOR)	3 HP E		$1,239	1.31	0.16	0.28	0.02	0.12	1
	C65WC003	IREN 57	CONCRETE VIBRATOR, 2.50″ DIA, HI-FREQ INTERNAL (ADD 2KV GENERATOR)	2 HP E		$2,332	2.12	0.30	0.52	0.04	0.08	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C75	**CRANES, HYDRAULIC, SELF-PROPELLED**												
	SUBCATEGORY 0.00		**CRANES, HYDRAULIC, SELF-PROPELLED**										
	BRODERSON MANUFACTURING CORPORATION												
	C75BD007	IC-20-1F	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 2.5 TON, 15.0 FT, 4×2	38 HP	G		$48,904	12.06	2.11	2.92	0.65	4.39	61
	C75BD008	IC-35-2C	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 4.0 TON, 19.2 FT, 4×2	42 HP	G		$59,032	13.97	2.56	3.54	0.79	4.85	74
	C75BD004	IC-35	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 4.0 TON/19′ BOOM, 4×2, NON-ROTATING OPERATOR’S CAB	42 HP	G		$66,766	14.99	2.89	3.99	0.89	4.85	74
	C75BD009	IC-80-3F	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 8.5 TON, 30.0 FT, 4×2	66 HP	G		$76,806	19.90	3.31	4.58	1.02	7.62	160
	C75BD005	IC-80-F	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 9.0 TON/30′ BOOM, 4×2, NON-ROTATING OPERATOR’S CAB	66 HP	G		$85,826	21.05	3.70	5.12	1.14	7.62	144
	C75BD006	IC-200-3D	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 15.0 TON/ 50′ BOOM, 4×2, NON-ROTATING OPERATOR’S CAB	110 HP	G		$125,417	32.89	5.40	7.45	1.67	12.71	297
	C75BD010	RT-200-3A	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 15.0 TON, 49.0 FT, 4×4,	85 HP	D-off		$129,207	22.85	5.57	7.70	1.72	4.41	300
	C75BD011	RT-300-2BO	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 15.0 TON, 60.0 FT, 4×4, 20′0″ OFFSET	120 HP	D-off		$233,687	38.93	10.10	13.97	3.11	6.22	473
	GROVE CRANES												
	C75GV026	S4000	CRANES, HYDRAULIC, SELF-PROPELLED, 2.0 TON, 18.0′ BOOM, 4×2×2	18 HP	G		$46,572	8.70	2.03	2.81	0.62	2.08	56

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
C75		***GROVE CRANES (continued)***										
	C75GV027	YB4210	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 10.0 TON, 24.0′ BOOM, 4×2×2	62 HP G		$103,435	22.73	4.48	6.19	1.38	7.16	165
	C75GV021	YB4410	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 10.0 TON/ 30′ BOOM, 4×4, NON-ROTATING OPERATOR'S CAB	62 HP G		$100,963	22.45	4.37	6.04	1.35	7.16	173
	C75GV022	YB4415XT	CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 15 TON/52′ BOOM, 4×4, NON-ROTATING OPERATOR'S CAB	110 HP D-off		$120,760	23.18	5.19	7.16	1.61	5.71	313
	C75GV006	RT58D	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 20 TON/60′ BOOM, 4×4, NON-ROTATING OPERATOR'S CAB	130 HP D-off		$237,645	40.11	10.28	14.21	3.17	6.74	441
	C75GV028	RT525E	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 25.0 TON, 75.0′ BOOM, 4×4×4	145 HP D-off		$243,346	42.38	10.45	14.42	3.24	7.52	500
	C75GV023	RT530E	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 30 TON/95′ BOOM, 4×4	152 HP D-off		$291,396	52.00	12.30	16.84	3.88	7.88	580
	C75GV024	RT640C	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 40 TON/105′ BOOM, 4×4	152 HP D-off		$414,686	67.81	17.68	24.32	5.52	7.88	650
	C75GV019	RT750	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 50 TON/110′ BOOM, 4×4	177 HP D-off		$572,575	89.88	24.57	33.88	7.63	9.18	876
	C75GV014	RT760	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 60TON/110′ BOOM, 4×4, W/ HOOK BLOCK & BALL	198 HP D-off		$613,558	96.33	26.38	36.41	8.17	10.27	909
	C75GV025	RT870	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 70 TON/110′ BOOM, 4×4	198 HP D-off		$687,932	105.87	29.62	40.92	9.16	10.27	1,038
	C75GV020	RT890	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 90 TON/114′ BOOM, 4×4	250 HP D-off		$721,167	113.80	31.06	42.90	9.61	12.97	1,119

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C75			***GROVE CRANES (continued)***										
	C75GV016	RT9100	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 100 TON/114′ BOOM, 4×4, W/ HOOK BLOCK & BALL	250 HP	D-off		$906,862	139.95	38.95	53.74	12.08	12.97	1,364
			PETTIBONE MICHIGAN LLC										
	C75PB001	36MK	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 18.0 TON, 64.1′ BOOM, 4×4×4	127 HP	D-off		$308,930	49.42	13.35	18.45	4.12	6.59	492
	C75PB002	40MK	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 20.0 TON, 64.1′ BOOM, 4×4×4	127 HP	D-off		$319,667	50.79	13.81	19.10	4.26	6.59	492
			TADANO AMERICA CORPORATION										
	C75TD003	TR-300XL-3	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 30 TON/112′ BOOM, 4×4	180 HP	D-off		$315,953	54.64	13.60	18.78	4.21	9.34	537
	C75TD006	TR-350XL-3	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 35 TON/155′ BOOM, 4×4	247 HP	D-off		$370,605	66.48	15.95	22.02	4.94	12.81	621
	C75TD007	TR-500XL-3	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 50 TON/175′ BOOM, 4×4	247 HP	D-off		$597,513	95.57	25.53	35.13	7.96	12.81	882
	C75TD008	TR-650XL-3	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 65 TON/180′ BOOM, 4×4	247 HP	D-off		$553,625	92.44	23.72	32.67	7.38	12.81	945
			TEREX CORPORATION										
	C75TE001	RT230	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 30 TON/94′ BOOM, 4×4	130 HP	D-off		$297,180	48.12	12.83	17.73	3.96	6.74	563
	C75TE002	RT335/40	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 40 TON/94′ BOOM, 4×4	152 HP	D-off		$408,922	64.44	17.65	24.40	5.45	7.88	634

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
C75		***TEREX CORPORATION (continued)***										
	C75TE003	RT450	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 50 TON/105′ BOOM, 4×4	174 HP D-off		$391,389	65.31	16.76	23.09	5.21	9.03	767
	C75TE004	RT160	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 60 TON/115′ BOOM, 4×4	215 HP D-off		$475,035	76.34	19.96	27.26	6.33	11.15	905
	C75TE005	RT175	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 75 TON/126′ BOOM, 4×4	260 HP D-off		$645,089	101.15	27.38	37.58	8.59	13.49	982
	C75TE006	RT190	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 90 TON/124′ BOOM, 4×4	260 HP D-off		$697,497	107.88	29.68	40.77	9.29	13.49	1,106
	C75TE007	RT110	CRANES, HYDRAULIC, SELF-PROPELLED, ROUGH TERRAIN, 100 TON/149′ BOOM, 4×4	260 HP D-off		$799,910	125.71	34.40	47.47	10.66	13.49	1,230
C80	**CRANES, HYDRAULIC, TRUCK MOUNTED**											
	SUBCATEGORY 0.01		**UNDER 26 TON**									
		LINK BELT CONSTRUCTION EQUIPMENT CO.										
	C80LB006	HTC-814	CRANES, HYDRAULIC, TRUCK MTD, 14 TON/80′ BOOM, 6×4	200 HP D-off		$331,889	50.40	14.34	19.83	4.42	8.78	486
	C80LB005	ATC-822	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 22 TON/70′ BOOM, 4×4	190 HP D-off		$286,219	44.57	12.35	17.08	3.81	8.34	392
		TEREX CORPORATION										
	C80TE005	T 220	CRANES, HYDRAULIC, TRUCK MTD, 20 TON, 94′ BOOM, 6×4×2	242 HP D-off		$248,229	43.29	10.68	14.74	3.31	10.62	472
	C80TE006	T 225	CRANES, HYDRAULIC, TRUCK MTD, 25 TON, 94′ BOOM, 6×4×2	242 HP D-off		$248,229	43.29	10.68	14.74	3.31	10.62	472

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.02		**26 TON THRU 65 TON**									
			GROVE CRANES									
	C80GV025	TMS-540	CRANES, HYDRAULIC, TRUCK MTD, 40 TON/90′ BOOM, 6×4	300 HP D-off		$430,777	63.24	17.03	22.69	5.68	13.17	540
	C80GV027	TMS640	CRANES, HYDRAULIC, TRUCK MTD, 40 TON, 105′ BOOM, 8×4×4	250 HP D-off		$472,802	65.40	18.62	24.75	6.24	10.97	743
	C80GV006	TMS-700B	CRANES, HYDRAULIC, TRUCK MTD, 50 TON/110′ BOOM, 8×4	400 HP D-off		$527,246	79.18	20.84	27.76	6.96	17.56	771
	C80GV029	TMS750E	CRANES, HYDRAULIC, TRUCK MTD, 50 TON, 110′ BOOM, 8×4×4	400 HP D-off		$607,344	88.25	23.93	31.83	8.01	17.56	947
	C80GV028	AT700D	CRANES, HYDRAULIC, TRUCK MTD, 50 TON, 110′ BOOM, 8×8×8	400 HP D-off		$605,856	88.09	23.87	31.75	7.99	17.56	856
	C80GV026	GMK 3050	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 55 TON/125′ BOOM, 8×4	349 HP D-off		$581,413	82.52	22.93	30.51	7.67	15.32	745
	C80GV030	TMS760E	CRANES, HYDRAULIC, TRUCK MTD, 60 TON, 110′ BOOM, 8×4×4	400 HP D-off		$608,074	88.33	23.96	31.87	8.02	17.56	949
			LINK BELT CONSTRUCTION EQUIPMENT CO.									
	C80LB007	HTC-830	CRANES, HYDRAULIC, TRUCK MTD, 30 TON/80′ BOOM, 6×4	200 HP D-off		$333,290	47.48	13.11	17.42	4.40	8.78	486
	C80LB004	HTC-8640	CRANES, HYDRAULIC, TRUCK MTD, 40 TON/105′ BOOM, 6×4	350 HP D-off		$392,974	62.10	15.48	20.59	5.18	15.36	595
	C80LB003	HTC-8650	CRANES, HYDRAULIC, TRUCK MTD, 50 TON/110′ BOOM, 8×4	365 HP D-off		$473,898	71.91	18.63	24.76	6.25	16.02	818
			LINK-BELT CONSTRUCTION EQUIPMENT COMPANY									
	C80LI009	HTC-8640	CRANES, HYDRAULIC, TRUCK MTD, 40 TON, 105′ BOOM, 6×4×2	350 HP D-off		$383,715	61.15	15.10	20.08	5.06	15.36	575

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C80	*LINK-BELT CONSTRUCTION EQUIPMENT COMPANY (continued)*											
	C80LI010	HTC-8650	CRANES, HYDRAULIC, TRUCK MTD, 50 TON, 110′ BOOM, 8×4×4	315 HP D-off		$457,247	67.30	17.99	23.91	6.03	13.83	757
	C80LI011	HTC-8660	CRANES, HYDRAULIC, TRUCK MTD, 60 TON, 110′ BOOM, 8×4×4	365 HP D-off		$482,021	72.86	18.94	25.16	6.36	16.02	825
	TEREX CORPORATION											
	C80TE001	T230	CRANES, HYDRAULIC, TRUCK MTD, 30 TON/94′ BOOM, 6×4	250 HP D-off		$374,213	54.51	14.77	19.65	4.94	10.97	506
	C80TE002	T335/40	CRANES, HYDRAULIC, TRUCK MTD, 40 TON/94′ BOOM, 6×4	250 HP D-off		$300,135	46.60	11.80	15.68	3.96	10.97	493
	C80TE003	T 500	CRANES, HYDRAULIC, TRUCK MTD, 50 TON/110′ BOOM, 8×4	370 HP D-off		$399,063	64.12	15.67	20.79	5.27	16.24	806
	C80TE007	T 560	CRANES, HYDRAULIC, TRUCK MTD, 60 TON, 110′ BOOM, 8×4×4, 32 FT	316 HP D-off		$394,362	60.56	15.49	20.57	5.20	13.87	736
	SUBCATEGORY 0.03		**66 TON THRU 125 TON**									
	GROVE CRANES											
	C80GV020	TMS-870	CRANES, HYDRAULIC, TRUCK MTD, 70 TON/110′ BOOM, 8×4	400 HP D-off		$689,345	93.27	25.16	32.24	9.04	17.56	9,161
	C80GV031	TMS875C	CRANES, HYDRAULIC, TRUCK MTD, 75 TON, 110′ BOOM, 8×4×4	400 HP D-off		$685,687	93.10	24.99	31.99	8.99	17.56	817
	C80GV023	GMK 4085B	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 85 TON/125′ BOOM, 8×4	335 HP D-off		$887,683	110.05	32.44	41.60	11.64	14.70	896
	C80GV032	GMK4090	CRANES, HYDRAULIC, TRUCK MTD, 90 TON, 142′ BOOM, 8×6×8	422 HP D-off		$940,720	123.73	34.17	43.67	12.33	18.52	1,184
	C80GV022	TMS-9120	CRANES, HYDRAULIC, TRUCK MTD, 120 TON/110′ BOOM, 8×4	400 HP D-off		$1,199,109	145.54	43.88	56.31	15.72	17.56	1,095

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	LINK BELT CONSTRUCTION EQUIPMENT CO.											
	C80LB001	HTC-8670	CRANES, HYDRAULIC, TRUCK MTD, 70 TON/115′ BOOM, 8×4	365 HP D-off		$543,644	76.58	19.78	25.30	7.13	16.02	936
	C80LB002	HTC-11100	CRANES, HYDRAULIC, TRUCK MTD, 100 TON/115′ BOOM, 8×4	430 HP D-off		$730,629	99.66	26.58	33.99	9.58	18.87	1,139
	TADANO AMERICA CORPORATION											
	C80TD001	ATF-650XL	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 65 TON/132′ BOOM, 8×8	121 HP D-off	349 HP D-on	$607,211	75.18	21.87	27.82	7.96	8.60	1,090
	C80TD002	ATF-1000XL	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 100 TON/ 138′ BOOM, 8×8	158 HP D-off	375 HP D-on	$758,113	92.78	27.42	34.95	9.94	10.46	1,070
	SUBCATEGORY 0.04		**OVER 125 TON**									
	GROVE CRANES											
	C80GV013	GMK 5150B	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON/ 173′ BOOM, 10×8	165 HP D-off	526 HP D-on	$1,262,741	142.34	43.05	53.22	16.44	12.19	1,180
	C80GV014	GMK 5175	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 175 TON/ 173′ BOOM, 10×8	165 HP D-off	526 HP D-on	$1,613,411	176.80	55.07	68.12	21.01	12.19	1,336
	C80GV015	GMK 5210	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 210 TON/ 173′ BOOM, 10×8	165 HP D-off	571 HP D-on	$1,733,248	189.11	59.18	73.22	22.57	12.62	2,348
	C80GV016	GMK 6300B	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 300 TON/ 173′ BOOM, 12×8	269 HP D-off	533 HP D-on	$2,215,200	242.19	75.66	93.61	28.85	16.83	1,425
	TADANO AMERICA CORPORATION											
	C80TD005	ATF-1500XL	CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON/ 162′ BOOM, 10×8	533 HP D-off	503 HP D-on	$909,877	127.10	30.71	37.71	11.85	28.13	1,330

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C85	**CRANES, MECHANICAL, LATTICE BOOM, CRAWLER MOUNTED**												
	SUBCATEGORY 0.12		**DRAGLINE, CLAMSHELL, OVER 1.0 CY THRU 2.5 CY**										
	LINK BELT CONSTRUCTION EQUIPMENT CO.												
	C85LB019	LS-208H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 80 TON/100′ BOOM (ADD BUCKET)	263 HP	D-off		$633,583	85.20	24.51	31.68	8.67	9.79	1,480
	C85LB020	LS-218H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 100 TON/100′BOOM (ADD BUCKET)	263 HP	D-off		$832,932	107.95	32.23	41.65	11.40	9.79	1,773
	TEREX CORPORATION												
	C85TE001	5220	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 50 TON/100′ BOOM (ADD BUCKET)	150 HP	D-off		$540,449	69.04	20.91	27.02	7.40	5.59	831
	C85TE002	7225	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 85 TON/100′ BOOM (ADD BUCKET)	250 HP	D-off		$751,605	98.04	29.08	37.58	10.29	9.31	1,259
	SUBCATEGORY 0.13		**DRAGLINE, CLAMSHELL, OVER 2.5 CY THRU 5.0 CY**										
	LINK BELT CONSTRUCTION EQUIPMENT CO.												
	C85LB021	LS-238H	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 150 TON/100′ BOOM (ADD BUCKET)	207 HP	D-off		$921,141	108.90	32.98	40.94	12.51	7.71	2,435
	C85LB022	LS-248H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 200 TON/120′ BOOM (ADD BUCKET)	248 HP	D-off		$1,232,707	144.44	44.14	54.79	16.74	9.24	3,228

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
		MANITOWOC ENGINEERING CO.										
	C85MA001	3900 VICON	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 3.5 CY/ 80′ BOOM (ADD BUCKET)	335 HP D-off		$946,766	117.42	33.90	42.08	12.86	12.48	1,988
	C85MA002	4100W VICON #1	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 5.0 CY/ 130′ BOOM (ADD BUCKET)	335 HP D-off		$1,526,336	180.10	54.65	67.84	20.73	12.48	3,815
		TEREX CORPORATION										
	C85TE003	9225	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 150 TON/100′ BOOM (ADD BUCKET)	335 HP D-off		$944,876	117.21	33.83	41.99	12.83	12.48	2,482
	SUBCATEGORY 0.14		**DRAGLINE, CLAMSHELL, OVER 5.0 CY**									
		LINK BELT CONSTRUCTION EQUIPMENT CO.										
	C85LB023	LS-278H	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 250 TON/120′ BOOM (ADD BUCKET)	440 HP D-off		$1,500,506	175.16	50.29	60.02	20.28	16.39	4,313
		MANITOWOC ENGINEERING CO.										
	C85MA003	4600 VICON #3	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 7.0 CY/ 140′ BOOM (ADD BUCKET)	680 HP D-off		$1,785,850	215.57	59.85	71.43	24.13	25.32	5,100
	C85MA009	888	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, DRAGLINE/CLAMSHELL, 10 CY/ 70′ BOOM (ADD BUCKET)	330 HP D-off		$1,185,917	137.63	39.75	47.44	16.03	12.29	3,397

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.22		**LIFTING, 26 TON THRU 50 TON**									
		KOBELCO AMERICA INC.										
	C85KC007	CK550	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 50 TON, 30.0′ BOOM, LIFTING	178 HP D-off		$495,961	54.29	17.75	22.04	6.73	4.97	1,001
		LINK BELT CONSTRUCTION EQUIPMENT CO.										
	C85LB018	LS-108H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 50 TON/70′ BOOM, LIFTING	147 HP D-off		$403,961	44.30	14.47	17.95	5.49	4.11	1,040
	SUBCATEGORY 0.23		**LIFTING, 51 TON THRU 150 TON**									
		KOBELCO AMERICA INC.										
	C85KC004	CK550	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 55 TON/160′ BOOM, LIFTING	178 HP D-off		$536,009	57.38	18.37	22.78	6.98	4.97	1,071
	C85KC005	CK850	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 85 TON/180′ BOOM, LIFTING	213 HP D-off		$617,207	66.34	21.16	26.23	8.04	5.95	1,729
	C85KC003	CK1000	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 100 TON/200′ BOOM, LIFTING	265 HP D-off		$848,628	90.28	29.09	36.07	11.05	7.40	1,899
		LINK BELT CONSTRUCTION EQUIPMENT CO.										
	C85LB013	LS-208H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 80 TON/190′ BOOM, LIFTING	263 HP D-off		$667,677	72.87	22.88	28.38	8.69	7.35	1,456
	C85LB014	LS-218H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 110 TON/230′ BOOM, LIFTING	263 HP D-off		$876,105	92.85	30.03	37.23	11.41	7.35	1,906
	C85LB015	LS-238H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 150 TON/240′ BOOM, LIFTING	207 HP D-off		$986,570	101.56	33.82	41.93	12.85	5.78	2,553

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			LINK-BELT CONSTRUCTION EQUIPMENT COMPANY									
	C85LI001	LS-138H SERIES II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 80 TON, 40′ TUBULAR BOOM, LIFTING	207 HP D-off		$590,398	63.57	20.24	25.09	7.69	5.78	1,454
			MANITOWOC ENGINEERING CO.									
	C85MA004	3900 VICON	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 100 TON/210′ BOOM, LIFTING	335 HP D-off		$973,365	104.61	33.37	41.37	12.68	9.36	2,354
	C85MA008	3950 W	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 125 TON/260′ BOOM, LIFTING	335 HP D-off		$1,245,953	130.73	42.71	52.95	16.23	9.36	3,121
	C85MA005	3900W VICON #2	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 140 TON/250′ BOOM, LIFTING	335 HP D-off		$1,112,222	117.91	38.12	47.27	14.48	9.36	2,744
			TEREX CORPORATION									
	C85TE008	HC 80	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 80 TON/200′ BOOM, LIFTING	184 HP D-off		$585,359	62.31	20.06	24.88	7.62	5.14	1,527
	C85TE009	HC 100	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 100 TON/230′ BOOM, LIFTING	230 HP D-off		$728,714	77.60	24.98	30.97	9.49	6.42	2,033
	C85TE010	HC 125	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 125 TON/240′ BOOM, LIFTING	240 HP D-off		$927,007	96.94	31.77	39.40	12.07	6.70	2,128
	SUBCATEGORY 0.24		**LIFTING, OVER 150 TON**									
			AMERICAN CRANE CORPORATION									
	C85AM016	HC 185	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 185 TON, 50′ BOOM, LIFTING	315 HP D-off		$1,056,494	108.60	34.10	40.82	13.69	8.80	2,804
	C85AM017	HC 210	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 210 TON, 50′ BOOM, LIFTING	315 HP D-off		$1,127,804	115.19	36.40	43.57	14.61	8.80	3,344

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	KOBELCO AMERICA INC.											
	C85KC008	CK2000	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 200 TON, 50′ BOOM, LIFTING	316 HP D-off		$1,123,213	114.82	36.26	43.40	14.56	8.83	3,622
	C85KC006	CK2500	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 250 TON/280′ BOOM, LIFTING	279 HP D-off		$1,582,818	156.09	51.09	61.15	20.51	7.79	4,985
	LINK BELT CONSTRUCTION EQUIPMENT CO.											
	C85LB016	LS-248H II	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 200 TON/280′ BOOM, LIFTING	248 HP D-off		$1,284,362	127.40	41.45	49.62	16.64	6.93	3,341
	C85LB017	LS-278H	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 250 TON/330′ BOOM, LIFTING	440 HP D-off		$1,680,060	170.60	54.23	64.91	21.77	12.29	4,309
	MANITOWOC ENGINEERING CO.											
	C85MA006	4100W VICON #1	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 200 TON/260′ BOOM, LIFTING	335 HP D-off		$1,456,503	146.32	47.01	56.27	18.87	9.36	3,929
	C85MA010	888	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 230 TON/300′ BOOM, LIFTING	330 HP D-off		$1,483,718	148.67	47.90	57.33	19.23	9.22	3,697
	C85MA007	4600 VICON #3	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 240 TON/260′ BOOM, LIFTING	431 HP D-off		$2,294,502	227.19	74.06	88.65	29.73	12.04	4,942
	TEREX CORPORATION											
	C85TE014	HC 185	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 185 TON/280′ BOOM, LIFTING	315 HP D-off		$1,248,851	126.40	40.31	48.25	16.18	8.80	3,076
	C85TE011	HC 210	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 210 TON/280′ BOOM, LIFTING	315 HP D-off		$1,367,080	137.36	44.13	52.82	17.72	8.80	3,708
	C85TE012	9310-A	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 225 TON/280′ BOOM, LIFTING	335 HP D-off		$1,371,684	138.47	44.27	53.00	17.77	9.36	3,984

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
C85			***TEREX CORPORATION (continued)***									
	C85TE013	9320	CRANES, MECHANICAL, LATTICE BOOM, CRAWLER, 250 TON/280′ BOOM, LIFTING	335 HP D-off		$1,505,646	150.87	48.60	58.17	19.51	9.36	4,273
C90	**CRANES, MECHANICAL, LATTICE BOOM, TRUCK MOUNTED**											
	SUBCATEGORY 0.04		**OVER 125 TON**									
			LINK BELT CONSTRUCTION EQUIPMENT CO.									
	C90LB001	HC-238H II	CRANES, MECHANICAL, LATTICE BOOM, TRUCK MTD, 150 TON/260′ BOOM, 8×4	207 HP D-off	430 HP D-on	$1,209,836	133.42	40.30	47.90	16.35	10.54	1,913
	C90LB002	HC-248H	CRANES, MECHANICAL, LATTICE BOOM, TRUCK MTD, 200 TON/280′ BOOM, 8×4	248 HP D-off	430 HP D-on	$1,394,296	152.93	46.48	55.27	18.84	11.96	2,476
	C90LB003	HC-278H	CRANES, MECHANICAL, LATTICE BOOM, TRUCK MTD, 300 TON/330′ BOOM, 12×6	360 HP D-off	430 HP D-on	$2,213,678	238.54	73.82	87.80	29.92	15.83	3,385
C95	**CRANES, TOWER**											
	SUBCATEGORY 0.00		**CRANES, TOWER**									
			PECCO AND WOLFF TOWER CRANES									
	C95AP004	SK200	TOWER CRANE, 3.4 TON @ 181′ RADIUS 42.6′ HEIGHT (ADD 95KW GENERATOR & T-SECTION)	128 HP E		$433,787	56.42	15.53	19.28	5.89	5.32	970
	C95AP005	S16-35 TOWER SECTION	TOWER CRANE OPTION, 1.1′ T-TRANSITION S35-S16 (ADD SK 140 - SK 225 TOWER CRANE)			$13,726	1.42	0.50	0.61	0.19	0.00	16

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C95	***PECCO AND WOLFF TOWER CRANES (continued)***											
	C95AP006	S35 TOWER SECTION	TOWER CRANE OPTION, 19.33′ TOWER SECTION (ADD TO SK 140 - SK 400 TOWER CRANE)			$25,516	2.62	0.92	1.13	0.35	0.00	89
	C95AP007	SK400	TOWER CRANE, 3.3 TON @ 245′ RADIUS, 56.7′ HEIGHT (ADD 160 KW GENERATOR & T-SECTION)	213 HP E		$684,686	88.42	24.52	30.43	9.30	8.86	1,783
	C95AP008	S35 CLIMBING UNIT	TOWER CRANE OPTION, 29.2′ CLIMBING UNIT (ADD TO SK 200 - SK 400 TOWER CRANE)			$104,317	11.24	3.74	4.64	1.42	0.00	248
	C95AP009	S35-60 TOWER SECTION	TOWER CRANE OPTION, 19.4′ T-TRANSITION S60 S35 (ADD SK 225 - SK 560 TOWER CRANE)			$34,539	3.56	1.24	1.54	0.47	0.00	99
	C95AP010	SK560	TOWER CRANE, 2.8 TON @ 265′ RADIUS, 76.5′ HEIGHT (ADD 161 KW GENERATOR &T-SECTION)	217 HP E		$916,243	112.48	32.80	40.72	12.44	9.03	1,557
	C95AP011	S60 TOWER SECTION	TOWER CRANE OPTION, 19.33′ TOWER SECTION (ADD TO SK 225 - SK 560 TOWER CRANE)			$32,234	3.32	1.16	1.43	0.44	0.00	99
	C95AP012	S60 CLIMB UNIT	TOWER CRANE OPTION, 32.8′ CLIMBING UNIT (ADD TO SK 225 - SK 560 TOWER CRANE)			$130,444	13.92	4.67	5.80	1.77	0.00	258
	C95AP013	SN355	TOWER CRANE, 3.8 TON @ 197′ RADIUS, 110′ TALL, LUFFING (ADD 300 KW GENERATOR & T-SECTION)	354 HP E		$872,519	116.35	31.24	38.78	11.85	14.73	2,748
	C95AP014	SN35 TOWER SECTION	TOWER CRANE OPTION, 14.75′ TOWER SECTION (ADD TO SN 141 - SN 355 TOWER CRANE)			$29,340	3.02	1.05	1.30	0.40	0.00	89
	C95AP015	SN35 CLIMBING UNIT	TOWER CRANE OPTION, 29.2′ CLIMBING UNIT (ADD TO SN 141 - SN 355 TOWER CRANE)			$113,607	12.18	4.07	5.05	1.54	0.00	248
	C95AP016	S35N-60TOWER SECTION	TOWER CRANE OPTION, 19.4′ T-TRANSITION S60 S35N (ADD SN 141 - SK 355 TOWER CRANE)			$39,571	4.07	1.42	1.76	0.54	0.00	99
	C95AP017	SK140	TOWER CRANE, 3.1 TON @ 151′ RADIUS, 85.0′ HEIGHT (ADD 95KW GENERATOR & T-SECTION)	125 HP E		$368,638	48.55	13.20	16.38	5.01	5.20	1,309

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C95	***PECCO AND WOLFF TOWER CRANES (continued)***											
	C95AP018	S16 TOWER SECTION	TOWER CRANE OPTION, 14.75′ TOWER SECTION (ADD TO SK 140 - SK 200 TOWER CRANE)			$12,132	1.24	0.43	0.54	0.16	0.00	55
	C95AP019	S16 CLIMBING UNIT	TOWER CRANE OPTION, 29.2′ CLIMBING UNIT (ADD TO SK 140 - SK 200 TOWER CRANE)			$70,464	7.75	2.53	3.13	0.96	0.00	165
	C95AP020	SN141	TOWER CRANE, 1.6 TON @ 147′ RADIUS, 89′ TALL, LUFFING (ADD 200 KW GENERATOR & T-SECTION)	223 HP E		$407,421	58.52	14.59	18.11	5.53	9.28	1,082
	C95AP021	SN160-16	TOWER CRANE, 2.8 TON @ 164′ RADIUS, 88′ TALL, LUFFING (ADD 250 KW GENERATOR & T-SECTION)	258 HP E		$638,896	85.45	22.88	28.40	8.68	10.73	1,179
	C95AP022	PH5000-12	TOWER CRANE OPTION, 24 PERSON/2.4 TON MATERIAL ELEVATOR/HOIST (ADD 4.9′ MAST SECTION & 18 KW GENERATOR)	24 HP E		$96,286	12.38	3.45	4.28	1.31	1.00	130
	C95AP023	MAST SECTION	TOWER CRANE OPTION, 4.9′ MAST-> PERSON/MATERIAL ELEVATOR/HOIST (ADD WALL TIE & CABLE GUIDE @30′)			$2,274	0.23	0.08	0.10	0.03	0.00	3
	MORROW EQUIPMENT COMPANY, LLC											
	C95LH022	97K	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 13.2 TON MAX, 1.9 TON @ 148′ RADIUS, 66′ HEIGHT, SELF/ERECTING, W/FIVE - 7′ 10″ TOWER SECTIONS/& ROAD TRANSPORT EQUIPMENT (ADD 40 KW GENERATOR)	35 HP E		$333,966	38.77	11.89	14.71	4.53	1.46	1,593

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
C95	***MORROW EQUIPMENT COMPANY, LLC (continued)***												
	C95LH023	140K	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 11.0 TON MAX, 1.7 TON @ 180′ RAD 146′ HEIGHT, SELF/ERECTING, W/ EIGHT - 9′ 10″ TOWER SECTIONS/& ROAD TRANSPORT EQUIPMENT (ADD 60KW GENERATOR)	65 HP	E		$467,261	55.40	16.64	20.59	6.34	2.70	1,836
	C95LH003	132 HC	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 8.8 TON MAX, 2.4 TON @ 168′ RADIUS, 147.8′ HEIGHT, W/FOURTEEN - 8′ 2″ TOWER SECTIONS (ADD 85 KW GENERATOR)	109 HP	E		$377,668	48.49	13.53	16.79	5.13	4.53	1,156
	C95LH005	200 HC	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 11.0 TON MAX, 2.5 TON @ 201′ RADIUS, 162.7′ HEIGHT, W/NINE - 13′ 7″ TOWER SECTIONS (ADD 110 KW GENERATOR)	148 HP	E		$491,683	63.60	17.61	21.85	6.68	6.16	1,374
	C95LH011	390 HC	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 17.6 TON MAX, 3.3 TON @ 246′ RADIUS, 199.1′ HEIGHT, W/NINE - 19′ 0″ TOWER SECTIONS (ADD 170 KW GENERATOR)	223 HP	E		$918,037	113.04	32.87	40.80	12.47	9.28	2,744
	C95LH013	550 HC20	TOWER CRANE, HORIZONTAL BOOM, JIB CRANE, 22.0 TON MAX, 3.8 TON @ 265′ RADIUS, 237.5′ HEIGHT, W/TWELVE - 19′ 0″ TOWER SECTIONS (ADD 170 KW GENERATOR)	223 HP	E		$1,171,741	139.13	41.95	52.08	15.91	9.28	3,765
	C95LH015	550 HC-L	TOWER CRANE, 26.4 TON MAX, 3/4 TON @ 197′ RADIUS, 210′ HEIGHT, LUFFING, W/SIX 19′ 0″ TOWER SECTIONS (ADD 480 KW GENERATOR)	317 HP	E		$1,561,508	186.95	55.90	69.40	21.20	13.19	5,075

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
D10	**HYDRAULIC TRACK (Add cost for drill steel and bit wear)**											
	SUBCATEGORY 0.10		**AIR TRACK (Add cost for drill steel and bit wear)**									
		INGERSOLL RAND CO.										
	D10IR003	ECM350/VL 140	DRILLS, AIR TRACK, CRAWLER, 2.5-4″ DIA, 12′ FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 750 CFM COMPRESSOR)	750 CFM A		$120,135	17.38	4.94	6.44	1.72	0.00	129
		SULLIVAN INDUSTRIES, INC.										
	D10SU002	RAM EXT, VCR360	DRILLS, AIR TRACK, CRAWLER, 2.5–4″ DIA, 12′ FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 750 CFM COMPRESSOR)	600 CFM A		$148,019	21.22	6.08	7.93	2.11	0.00	152
	D10SU003	RAM EXT, VCR361	DRILLS, AIR TRACK, CRAWLER, 3.0–4″ DIA, 12′ FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)	850 CFM A		$151,322	21.68	6.22	8.11	2.16	0.00	205
	SUBCATEGORY 0.20		**HYDRAULIC TRACK (Add cost for drill steel and bit wear)**									
		INGERSOLL RAND CO.										
	D10IR005	ECM590/YH80A	DRILLS, HYDRAULIC TRACK, CRAWLER, 2.5–4.5″ DIA, 14′ DRIFTER TRAVEL, SELF-CONTAINED (ADD COST FOR DRILL STEEL AND BIT WEAR)	215 HP D-off		$374,891	85.20	19.55	28.12	5.49	11.72	245

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			SULLIVAN INDUSTRIES, INC.										
	D10SU005	SCORPION VCR360	DRILLS, HYDRAULIC TRACK, CRAWLER, 5.25″ DIA, 12′ FEED (ADD COST FOR DRILL STEEL AND BIT WEAR)	260 HP	D-off		$164,246	48.74	8.57	12.32	2.41	14.18	265
	D10SU006	SCORPION VCR361	DRILLS, HYDRAULIC TRACK, CRAWLER, 6.5″ DIA, 12′ FEED (ADD COST FOR DRILL STEEL AND BIT WEAR)	260 HP	D-off		$166,251	49.12	8.68	12.47	2.44	14.18	265
D15	**DRILLS, HORIZONTAL BORING & GROUND PIERCING (Add cost for drill steel and bit wear)**												
	SUBCATEGORY 0.00		**DRILLS, HORIZONTAL BORING & GROUND PIERCING (Add cost for drill steel and bit wear)**										
			BOR-IT MANUFACTURING COMPANY INC.										
	D15BI001	16	DRILL, HORIZONTAL BORING, 16″ DIA, COMBINED HEAD 30,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	16 HP	G		$15,839	5.38	0.83	1.19	0.23	1.97	18
	D15BI002	20	DRILL, HORIZONTAL BORING, 20″ DIA, COMBINED HEAD 44,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	20 HP	D-off		$21,362	5.17	1.11	1.60	0.31	1.09	15
	D15BI003	24	DRILL, HORIZONTAL BORING, 24″ DIA, COMBINED HEAD 84,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	30 HP	D-off		$33,232	7.99	1.74	2.49	0.49	1.64	38
	D15BI004	30	DRILL, HORIZONTAL BORING, 30″ DIA, COMBINED HEAD 170,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	45 HP	D-off		$46,165	11.31	2.41	3.46	0.68	2.45	70

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
D15	***BOR-IT MANUFACTURING COMPANY INC. (continued)***											
	D15BI005	36	DRILL, HORIZONTAL BORING, 36″ DIA, COMBINED HEAD 225,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	68 HP D-off		$70,476	17.23	3.68	5.29	1.03	3.71	90
	D15BI006	48	DRILL, HORIZONTAL BORING, 48″ DIA, COMBINED HEAD 525,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	110 HP D-off		$110,184	27.18	5.74	8.26	1.61	6.00	170
	D15BI008	54	DRILL, HORIZONTAL BORING, 54″ DIA, COMBINED HEAD 32,700,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	171 HP D-off		$134,946	35.78	7.04	10.12	1.98	9.32	250
	D15BI007	60	DRILL, HORIZONTAL BORING, 60″ DIA, COMBINED HEAD 1,100,000# THRUST, W/100′ AUGER TRACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	171 HP D-off		$161,453	40.49	8.42	12.11	2.36	9.32	250
	NO SPECIFIC MANUFACTURER											
	D15XX001	MC-500H	DRILL, HORIZONTAL BORING, 3″ - 6″ DIA, 15,000 # THRUST, HYDRAULIC MOTOR (ADD COST FOR DRILL STEEL AND BIT WEAR)			$6,108	1.09	0.32	0.46	0.09	0.00	10
	D15XX002	H-12/RM-12	DRILL, HORIZONTAL BORING, 4″ - 12″ DIA, 24,000 # THRUST, HYDRAULIC MOTOR (ADD COST FOR DRILL STEEL AND BIT WEAR)			$9,214	1.63	0.48	0.69	0.13	0.00	12

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
D20	**DRILLS, CORE, COLUMN MOUNTED (Add cost for drill steel and bit wear)**												
	SUBCATEGORY 0.00		**DRILLS, CORE, COLUMN MOUNTED (Add cost for drill steel and bit wear)**										
		ACKER DRILL COMPANY INC.											
	D20AD005	630-E	DRILLS, CORE, COLUMN MOUNTED, 4″ DIA MAX CORE HOLE (ADD COST FOR DRILL STEEL AND BIT WEAR)	2 HP	E		$4,243	1.29	0.26	0.40	0.06	0.10	1
	D20AD002	930-E	DRILLS, CORE, COLUMN MOUNTED, 10″ DIA MAX CORE HOLE (ADD COST FOR DRILL STEEL AND BIT WEAR)	2 HP	E		$4,306	1.30	0.26	0.40	0.06	0.10	2
	D20AD006	1040-E	DRILLS, CORE, COLUMN MOUNTED, 10″ DIA MAX CORE HOLE (ADD COST FOR DRILL STEEL AND BIT WEAR)	4 HP	E		$7,026	2.18	0.44	0.66	0.11	0.20	1
	D20AD007	1200-G	DRILLS, CORE, COLUMN MOUNTED, 12″ DIA MAX CORE HOLE (ADD COST FOR DRILL STEEL AND BIT WEAR)	8 HP	E		$11,587	3.85	0.72	1.09	0.17	0.41	3
		CUSHION CUT, INC.											
	D20CQ001	HCD24/12	DRILLS, CORE, COLUMN MOUNTED, 9″–36″ BIT DIA (ADD COST FOR DRILL STEEL AND BIT WEAR)	42 HP	G		$27,177	13.24	1.69	2.55	0.41	5.17	11
		BOART LONGYEAR COMPANY											
	D20LY001	752	DRILLS, CORE, COLUMN MOUNTED, W/E4-230/110 MOTOR (110V) (ADD COST FOR DRILL STEEL AND BIT WEAR)	3 HP	E		$6,247	2.04	0.39	0.59	0.09	0.15	2

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
D20			***BOART LONGYEAR COMPANY (continued)***									
	D20LY002	42N	DRILLS, CORE, COLUMN MOUNTED, W/A4-350 MOTOR (ADD COST FOR DRILL STEEL AND BIT WEAR AND ADD AIR COMPRESSOR)	185 CFM A		$6,455	1.98	0.41	0.61	0.10	0.00	3
D25	**DRILLS, CORE, SKID MOUNTED (Add cost for drill steel and bit wear)**											
	SUBCATEGORY 0.00		**DRILLS, CORE, SKID MOUNTED (Add cost for drill steel and bit wear)**									
			ACKER DRILL COMPANY INC.									
	D25AD004	ACEW	DRILLS, CORE, SKID MTD, 725′ MAX DRILL DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR)	28 HP D-off		$60,268	13.19	3.14	4.52	0.88	1.53	35
	D25AD003	BUSH MASTER	DRILLS, CORE, SKID MTD, NX, 1500′ MAX DRILL DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR)	69 HP D-off		$75,541	18.80	3.95	5.67	1.11	3.76	45
			E-Z DRILL, INC.									
	D25EZ002	210 B	DRILLS, CORE, SKID MTD, HORIZONTAL DOWELLING ASSEMBLY, 18″ DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 100 CFM COMPRESSOR)	100 CFM A		$7,030	1.83	0.35	0.50	0.10	0.00	3
	D25EZ003	210 SRA	DRILLS, CORE, SKID MTD, HORIZONTAL DOWELLING ASSEMBLY, 18″ DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 100 CFM COMPRESSOR)	100 CFM A		$7,497	1.92	0.38	0.54	0.11	0.00	3

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
D25		***E-Z DRILL, INC. (continued)***										
	D25EZ001	210 SR HORIZONTAL	DRILLS, CORE, SKID MTD, HORIZONTAL DOWELLING ASSEMBLY, 18″ DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 100 CFM COMPRESSOR)	100 CFM A		$8,225	2.05	0.43	0.62	0.12	0.00	3
	D25EZ005	210–3 SRA	DRILLS, CORE, DOWELLING MACHINE, SELF PROPELLED, 18″ DEPTH (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 100 CFM COMPRESSOR)	100 CFM A		$27,913	6.50	1.44	2.05	0.41	0.00	12
D30	**DRILLS, EARTH/AUGER (Add cost for drill steel and cutting edge wear)**											
	SUBCATEGORY 0.00		**DRILLS, EARTH/AUGER (Add cost for drill steel and cutting edge wear)**									
		HYDRAULIC POWER SYSTEMS, INC.										
	D30HD001	H-15	DRILL, AUGER, HYDRAULIC, W/60′ 8″ × 21″ LEADS, 15,000 FT-LBS TORQUE (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR AND CRANE)	210 HP D-off		$97,029	34.67	5.06	7.28	1.42	11.45	146
	D30HD002	H-35VT	DRILL, AUGER, HYDRAULIC, W/60′ 8″ × 27″ LEADS, 33,000 FT-LBS TORQUE (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR AND CRANE)	270 HP D-off		$145,772	48.94	7.61	10.93	2.14	14.72	200
	D30HD003	H-50VT	DRILL, AUGER, HYDRAULIC, W/60′ 8″ × 33″ LEADS, 50,000 FT-LBS TORQUE (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR AND CRANE)	335 HP D-off		$189,896	62.71	9.90	14.24	2.78	18.27	269

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	MOBILE DRILLING COMPANY, INC.											
	D30MR001	MINUTEMAN	DRILLS, EARTH/AUGER, W/AUGER KIT, 3″ DIA, 30′ DEPTH, 350 FT-LBS TORQUE, PORTABLE (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)	8 HP G		$8,229	2.84	0.43	0.62	0.12	0.99	4
	D30MR003	B-31	DRILLS, EARTH/AUGER, HYDRAULIC AUGER, 14″ DIA, 30′ DEPTH, 3,500 FT-LBS TORQUE, TRAILER MOUNTED (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)	58 HP D-off		$82,309	19.49	4.27	6.11	1.21	3.16	42
	D30MR005	B-53	DRILLS, EARTH/AUGER, MULTI-PURPOSE, 6″ DIA, 245′ DEPTH, 5,955 FT-LBS TORQUE, W/21,000 GVW TRUCK (W/PTO DRIVE)(ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)	100 HP D-on	2,205 HP D-on	$151,140	62.93	7.79	11.16	2.21	27.21	120
	D30MR006	B-58	DRILLS, EARTH/AUGER, MULTI-PURPOSE, 8″ DIA, 250′ DEPTH, 7,000 FT-LBS TORQUE W/33,000 GVW TRUCK(ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)	115 HP D-off	205 HP D-on	$173,994	43.25	8.99	12.87	2.55	8.20	130
	D30MR007	B-61HDX	DRILLS, EARTH/AUGER, MULTI-PURPOSE, 8″ DIA, 375′ DEPTH, 20,000 FT-LBS TORQUE W/33,000 GVW TRUCK(ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)	115 HP D-off	205 HP D-on	$247,368	57.04	12.81	18.38	3.62	8.20	205

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
D35	**DRILLS, ROTARY BLASTHOLE (Add cost for drill steel and bit wear)**												
	SUBCATEGORY 0.11		**DIESEL, 4.5″ THRU 9.875″ DIAMETER HOLE (Add cost for drill steel and bit wear)**										
		REEDRILL, INC.											
	D35RD001	SK5AD	DRILL, ROTARY BLASTHOLE, 4″-7″ DIA, TRUCK MTD, 148′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	400 HP	D-off	350 HP D-on	$334,226	81.16	14.16	19.10	4.61	25.11	525
	D35RD004	SK40I	DRILL, ROTARY BLASTHOLE, 5″-8″ DIA, CRAWLER, 173′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	430 HP	D-off		$460,586	96.74	19.51	26.32	6.35	23.45	880
	D35RD005	SK45I	DRILL, ROTARY BLASTHOLE, LP, 6″-9″ DIA, CRAWLER, 178′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	430 HP	D-off		$466,034	97.51	19.75	26.63	6.43	23.45	900
	D35RD007	SK50I HP	DRILL, ROTARY BLASTHOLE, HP, 6.5″-9″ DIA, CRAWLER, 178′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	750 HP	D-off		$536,632	131.10	22.73	30.66	7.40	40.90	910
	D35RD006	SK50I	DRILL, ROTARY BLASTHOLE, 7″-9.875″ DIA, CRAWLER, 178′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	430 HP	D-off		$485,966	100.32	20.59	27.77	6.70	23.45	900
	SUBCATEGORY 0.12		**DIESEL, OVER 9.875″ DIAMETER (Add cost for drill steel and bit wear)**										
		INGERSOLL RAND CO.											
	D35IB004	T3W	DRILL, ROTARY BLASTHOLE, WATER WELL 6-24″ DIA, 30,000 LB PULL BACK, TRUCK MTD (ADD COST FOR DRILL STEEL AND BIT WEAR)	465 HP	D-off	380 HP D-on	$470,384	91.83	16.73	20.68	6.39	28.94	660

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
D35		***INGERSOLL RAND CO. (continued)***											
	D35IB003	TH-60	DRILL, ROTARY BLASTHOLE, WATER WELL, 16″ DIA, TRUCK MTD (ADD COST FOR DRILL STEEL AND BIT WEAR)	475 HP	D-off	380 HP D-on	$493,565	94.79	17.59	21.77	6.70	29.48	600
	D35IB005	T3W DEEPHOLE	DRILL, ROTARY BLASTHOLE, WATER WELL 6-18″ DIA, 50,000 LB PULL BACK, TRUCK MTD (ADD COST FOR DRILL STEEL AND BIT WEAR)	575 HP	D-off	380 HP D-on	$545,363	108.06	19.42	24.02	7.41	34.93	688
	D35IB006	T4W	DRILL, ROTARY BLASTHOLE, WATER WELL 6-20″ DIA, 70,000 LB PULL BACK, TRUCK MTD (ADD COST FOR DRILL STEEL AND BIT WEAR)	600 HP	D-off	305 HP D-on	$573,443	112.08	20.42	25.26	7.79	35.59	688
		REEDRILL, INC.											
	D35RD009	SK75I	DRILL, ROTARY BLASTHOLE, 9″-12″ DIA, CRAWLER, 175′ DEEP (ADD COST FOR DRILL STEEL AND BIT WEAR)	750 HP	D-off		$758,861	138.54	27.17	33.73	10.30	40.90	1,530
F10	**FORK LIFTS**												
	SUBCATEGORY 0.00		**FORK LIFTS**										
		CATERPILLAR LIFT TRUCKS,											
	F10C4039	TH-62	FORK LIFT, ROUGH TERRAIN, 3,000# @ 25′ HIGH TELESCOPING MAST, 4 × 4	105 HP	D-off		$74,500	18.26	3.94	5.75	1.06	4.61	178
	F10C4040	TH-63	FORK LIFT, ROUGH TERRAIN, 6,000# @ 41′ HIGH TELESCOPING MAST W/STAB-PADS, 4 × 4	105 HP	D-off		$100,835	22.54	5.36	7.86	1.43	4.61	264

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
F10			***CATERPILLAR LIFT TRUCKS, (continued)***										
	F10C4042	TH-83	FORK LIFT, ROUGH TERRAIN, 8,000# @ 41′ HIGH TELESCOPING MAST W/STAB-PADS, 4 × 4	105 HP	D-off		$111,710	24.18	5.98	8.78	1.59	4.61	278
	F10C4043	TH-103	FORK LIFT, ROUGH TERRAIN, 10,000#@ 44′ HIGH TELESCOPING MAST W/STAB-PADS, 4 × 4	105 HP	D-off		$118,654	25.57	6.29	9.22	1.68	4.61	348
			JCB INC.										
	F10JC001	930-4	FORK LIFT, ROUGH TERRAIN, 6,000# @ 28.00′ HIGH	67 HP	D-off		$56,385	13.05	2.95	4.30	0.80	2.94	150
	F10JC002	940-4	FORK LIFT, ROUGH TERRAIN, 8,000# @ 30.00′ HIGH	67 HP	D-off		$64,230	14.34	3.37	4.92	0.91	2.94	161
			DEERE & COMPANY										
	F10JD001	485E	FORK LIFT, YARD, 5,000# @ 21′ HIGH TELESCOPING-STRAIGHT MAST, 4 × 2	73 HP	D-off		$51,080	12.42	2.67	3.88	0.73	3.20	132
	F10JD002	486E	FORK LIFT, YARD, 6,000# @ 21′ HIGH TELESCOPING-STRAIGHT MAST, 4 × 2	73 HP	D-off		$51,622	12.49	2.69	3.92	0.73	3.20	134
	F10JD003	488E	FORK LIFT, YARD, 8,000# @ 21′ HIGH TELESCOPING-STRAIGHT MAST, 4 × 2	73 HP	D-off		$54,741	13.01	2.87	4.17	0.78	3.20	156
G10	**GENERATOR SETS**												
	SUBCATEGORY 0.10		**PORTABLE**										
			WACKER CORPORATION										
	G10WC001	G 3.7A	GENERATOR SET, PORTABLE, 3.7 KW, 120/240V	8 HP	G		$2,121	1.39	0.15	0.24	0.03	0.80	2

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
G10		***WACKER CORPORATION (continued)***										
	G10WC002	G 5.6A	GENERATOR SET, PORTABLE, 5.6 KW, 120/240V	11 HP G		$2,714	1.88	0.20	0.31	0.04	1.10	2
	G10WC003	GS 8.5A	GENERATOR SET, PORTABLE, 8.5 KW, 120/240V, WITH ELECTRIC START	16 HP G		$3,925	2.71	0.27	0.44	0.05	1.60	2
	G10WC004	GS 9.7A	GENERATOR SET, PORTABLE, 9.7 KW, 120/240V, WITH ELECTRIC START	18 HP G		$4,438	3.06	0.31	0.50	0.06	1.80	2
		NO SPECIFIC MANUFACTURER										
	G10XX001	1000	GENERATOR SET, PORTABLE, 1 KW	1 HP G		$861	0.29	0.06	0.10	0.01	0.10	1
	G10XX004	D4500	GENERATOR SET, PORTABLE, 5 KW	9 HP D-off		$5,129	1.48	0.36	0.58	0.07	0.40	3
	G10XX002	10000	GENERATOR SET, PORTABLE, 10 KW	19 HP G		$5,423	3.37	0.38	0.61	0.07	1.90	6
	G10XX003	10000D	GENERATOR SET, PORTABLE, 10 KW	23 HP D-off		$9,651	3.11	0.68	1.09	0.13	1.01	9
	SUBCATEGORY 0.20		**SKID MOUNTED**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	G10CA020	3304 PKG - P 304DE03	GENERATOR SET, SKID MTD, 113 EKW, 240/480V, 60 HZ PGS PRIME	174 HP D-off		$24,252	13.37	1.41	2.18	0.32	7.64	37
	G10CA012	3306 PKG - 306DE39	GENERATOR SET, SKID MTD, 210 EKW, 240 VOLT, 60 HZ PGS PRIME	314 HP D-off		$30,802	21.98	1.80	2.77	0.41	13.78	52
	G10CA013	3406 PKG - 306DE30	GENERATOR SET, SKID MTD, 275 EKW, 480 VOLT, 60 HZ PGS PRIME	405 HP D-off		$39,083	28.25	2.28	3.52	0.52	17.78	68
	G10CA014	3406 PKG - 406DE30	GENERATOR SET, SKID MTD, 365 EKW, 240/480V, 60 HZ PGS PRIME	536 HP D-off		$50,948	37.26	2.98	4.59	0.68	23.53	72

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
G10	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***												
	G10CA015	3412 PKG - 412DE32	GENERATOR SET, SKID MTD, 455 EKW, 240/480V, 60 HZ PGS PRIME	687 HP	D-off		$70,280	48.57	4.10	6.33	0.93	30.15	93
	G10CA016	3412 PKG - 412DE30	GENERATOR SET, SKID MTD, 545 EKW, 240/480V, 60 HZ PGS PRIME	817 HP	D-off		$87,368	58.39	5.09	7.86	1.16	35.86	100
	G10CA017	3508 PKG - 508DE34	GENERATOR SET, SKID MTD, 725 EKW, 480 VOLT, 60 HZ PGS PRIME	1,089 HP	D-off		$137,018	81.24	7.99	12.33	1.82	47.80	181
	G10CA018	3512 PKG - 512DE1F	GENERATOR SET, SKID MTD, 1000 EKW, 480 VOLT, 60 HZ PGS PRIME	1,443 HP	D-off		$173,955	106.39	10.14	15.66	2.31	63.33	236
	G10CA019	3516 PKG - 516DE35	GENERATOR SET, SKID MTD, 1600 EKW, 480 VOLT, 60 HZ PGS PRIME	2,304 HP	D-off		$292,786	172.36	17.07	26.35	3.89	101.12	291
	NO SPECIFIC MANUFACTURER												
	G10XX005	25G	GENERATOR SET, SKID MTD, 25 KW	36 HP	G		$15,240	6.94	0.89	1.37	0.20	3.60	16
	G10XX006	35G	GENERATOR SET, SKID MTD, 35 KW	50 HP	G		$13,708	8.40	0.80	1.23	0.18	5.01	17
	G10XX007	50G	GENERATOR SET, SKID MTD, 50 KW	70 HP	G		$16,656	11.34	0.97	1.50	0.22	7.01	26
	G10XX008	75D	GENERATOR SET, SKID MTD, 75 KW	107 HP	D-off		$21,024	9.24	1.23	1.89	0.28	4.70	38
	G10XX009	100D	GENERATOR SET, SKID MTD, 100 KW	143 HP	D-off		$21,578	11.27	1.26	1.94	0.29	6.28	42
	G10XX010	125D	GENERATOR SET, SKID MTD, 125 KW	200 HP	D-off		$29,588	15.66	1.72	2.66	0.39	8.78	44
	G10XX011	200D	GENERATOR SET, SKID MTD, 200 KW	375 HP	D-off		$35,715	26.07	2.09	3.21	0.48	16.46	60
	G10XX012	300D	GENERATOR SET, SKID MTD, 300 KW	428 HP	D-off		$51,620	31.56	3.02	4.65	0.69	18.78	105
	G10XX013	400D	GENERATOR SET, SKID MTD, 400 KW	570 HP	D-off		$75,956	43.23	4.43	6.84	1.01	25.02	150
	G10XX014	500D	GENERATOR SET, SKID MTD, 500 KW	713 HP	D-off		$95,625	54.18	5.58	8.61	1.27	31.29	170

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
G10	***NO SPECIFIC MANUFACTURER (continued)***											
	G10XX015	750D	GENERATOR SET, SKID MTD, 750 KW	1,050 HP D-off		$139,934	79.62	8.16	12.59	1.86	46.08	215
	G10XX016	1000D	GENERATOR SET, SKID MTD, 1,000 KW	1,425 HP D-off		$215,701	112.34	12.58	19.41	2.87	62.54	250
G15	**GRADERS, MOTOR**											
	SUBCATEGORY 0.00		**GRADERS, MOTOR**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	G15CA001	120-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 12′ BLADE W/17 TEETH SCARIFIERS	125 HP D-off		$192,540	29.17	7.65	9.82	2.74	5.15	303
	G15CA007	135-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 12′ BLADE W/17 TEETH SCARIFIERS	135 HP D-off		$204,424	31.08	8.13	10.43	2.91	5.57	311
	G15CA003	12-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 12′ BLADE W/17 TEETH SCARIFIERS	140 HP D-off		$226,772	33.87	9.03	11.59	3.23	5.77	349
	G15CA004	140-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 12′ BLADE W/5 RIPPER/SCARIFIERS	165 HP D-off		$241,247	36.94	9.60	12.32	3.44	6.80	353
	G15CA008	143-H	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 12′ BLADE W/5 RIPPER/ SCARIFIERS	185 HP D-off		$278,013	42.26	11.07	14.22	3.96	7.63	349
	G15CA009	160-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 14′ BLADE W/5 RIPPER/SCARIFIERS	185 HP D-off		$259,705	40.14	10.34	13.27	3.70	7.63	380
	G15CA010	163-H	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 14′ BLADE W/5 RIPPER/ SCARIFIERS	200 HP D-off		$300,958	45.69	11.99	15.40	4.29	8.25	404
	G15CA005	14-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 14′ BLADE W/7 SHANK RIPPER	215 HP D-off		$332,024	50.90	13.13	16.79	4.73	8.86	445

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
G15	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	G15CA006	16-H	GRADER, MOTOR, ARTICULATED, 6 × 4, 16′ BLADE W/7 SHANK RIPPER	275 HP D-off		$478,468	72.56	18.85	24.07	6.81	11.34	586
	DEERE & COMPANY											
	G15JD008	670CH	GRADER, MOTOR, ARTICULATED, 6 × 4, AWD, 12′ BLADE W/5 RIPPER/ SCARIFIERS	151 HP D-off		$207,287	33.01	8.15	10.40	2.95	6.23	343
	G15JD009	672CH	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 12′ BLADE W/5 RIPPER/ SCARIFIERS	156 HP D-off		$235,590	36.63	9.30	11.87	3.36	6.43	353
	G15JD010	770CH	GRADER, MOTOR, ARTICULATED, 6 × 4, AWD, 12′ BLADE W/5 RIPPER/ SCARIFIERS	185 HP D-off		$238,201	38.35	9.39	12.00	3.39	7.63	353
	G15JD011	772CH	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 12′ BLADE W/5 RIPPER/ SCARIFIERS	205 HP D-off		$269,884	43.15	10.66	13.64	3.84	8.45	363
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	G15KM006	GD 530A-1	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 13′ BLADE W/11 RIPPER/ SCARIFIERS	144 HP D-off		$239,674	36.43	9.45	12.08	3.41	5.94	303
	G15KM007	GD 650A-1	GRADER, MOTOR, ARTICULATED, 6 × 4, 13′ BLADE W/11 RIPPER/SCARIFIERS	166 HP D-off		$218,125	35.22	8.57	10.92	3.11	6.84	328
	G15KM008	GD 670A-2CY	GRADER, MOTOR, ARTICULATED, 6 × 6, AWD, 14′ BLADE W/7 SHANK RIPPER	204 HP D-off		$279,455	44.39	11.03	14.10	3.98	8.41	346
	G15KM009	GD 750A-1	GRADER, MOTOR, ARTICULATED, 6 × 4, 16′ BLADE W/7 SHANK RIPPER	245 HP D-off		$357,853	55.45	14.16	18.12	5.10	10.10	409

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H10	**HAMMERS, HYDRAULIC (Demolition tool) (Add cost for point wear)**											
	SUBCATEGORY 0.00		**HAMMERS, HYDRAULIC (Demolition tool) (Add cost for point wear)**									
			NPK CONSTRUCTION EQUIPMENT									
	H10NP001	H-06X	HAMMERS, HYDRAULIC, 150 FT-LBS, IMPACT FREQUENCY 700 BPM (ADD 150-250 HP HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			$6,333	2.40	0.52	0.84	0.10	0.00	2
	H10NP002	H-08X	HAMMERS, HYDRAULIC, 200 FT-LBS, IMPACT FREQUENCY 750 BPM (ADD 60-75 HP HYDRAULIC EXCAVATOR L50)(ADD COST FOR POINT WEAR)			$7,035	2.62	0.58	0.94	0.11	0.00	2
	H10NP003	H-1XA	HAMMERS, HYDRAULIC, 300 FT-LBS, IMPACT FREQUENCY 800 BPM (ADD 60-75 HP HYDRAULIC EXCAVATOR L50)(ADD COST FOR POINT WEAR)			$10,523	3.91	0.86	1.40	0.16	0.00	4
	H10NP004	H-2XA	HAMMERS, HYDRAULIC, 500 FT-LBS, IMPACT FREQUENCY 800 BPM (ADD 60-75 HP HYDRAULIC EXCAVATOR L50)(ADD COST FOR POINT WEAR)			$13,544	4.82	1.11	1.81	0.20	0.00	4
	H10NP005	H-3XA	HAMMERS, HYDRAULIC, 750 FT-LBS, IMPACT FREQUENCY 700 BPM (ADD 75-100 HP HYDRAULIC EXCAVATOR L50)(ADD COST FOR POINT WEAR)			$17,931	6.39	1.47	2.39	0.27	0.00	7
	H10NP006	H-4XL	HAMMERS, HYDRAULIC, 1000 FT-LBS, IMPACT FREQUENCY 750 BPM (ADD 95-125 HP HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			$24,100	8.24	1.97	3.21	0.36	0.00	11

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H10	***NPK CONSTRUCTION EQUIPMENT (continued)***											
	H10NP007	H-6XA	HAMMERS, HYDRAULIC, 1250 FT-LBS, IMPACT FREQUENCY 600 BPM (ADD 95-125 HP HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			$33,069	10.94	2.71	4.41	0.50	0.00	16
	H10NP008	H-7X	HAMMERS, HYDRAULIC, 1500 FT-LBS, IMPACT FREQUENCY 550 BPM (ADD 95-125 HP HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			$36,550	12.23	2.99	4.87	0.55	0.00	19
	H10NP009	H-8XA	HAMMERS, HYDRAULIC, 2000 FT-LBS, IMPACT FREQUENCY 550 BPM (ADD 95-125 HP HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			$46,618	15.26	3.81	6.22	0.70	0.00	28
	H10NP015	E-210A	HAMMERS, HYDRAULIC, 3000 FT-LBS, IMPACT FREQUENCY 670 BPM (ADD 20-28 TON HYDRAULIC EXCAVATOR)(ADD COST FOR POINT WEAR)			$56,787	18.32	4.65	7.57	0.86	0.00	34
	H10NP016	E-216	HAMMERS, HYDRAULIC, 5500 FT-LBS, IMPACT FREQUENCY 500 BPM (ADD 28-43 TON HYDRAULIC EXCAVATOR)(ADD COST FOR POINT WEAR)			$78,185	24.75	6.39	10.42	1.18	0.00	56
	H10NP017	E-220	HAMMERS, HYDRAULIC, 8000 FT-LBS, IMPACT FREQUENCY 430 BPM (ADD 33-50 TON HYDRAULIC EXCAVATOR)(ADD COST FOR POINT WEAR)			$102,135	31.95	8.35	13.62	1.54	0.00	68
	H10NP018	E-260A	HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR)(ADD COST FOR POINT WEAR)			$236,974	72.49	19.38	31.60	3.58	0.00	170

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H13	**HAZARDOUS/TOXIC WASTE EQUIPMENT**												
	SUBCATEGORY 0.11		**COMPACTORS (Compression force) 0 THRU 50 TONS**										
			CONSOLIDATED BALING MACHINE COMPANY, INC										
	H13CB001	DOS RAW W1	HAZARDOUS/TOXIC WASTE EQIPMENT, COMPACTOR, RADIOLOGICAL WASTE, 12.5 TON, LOW LEVEL	5 HP	E		$20,472	4.08	1.15	1.74	0.28	0.21	25
	H13CB002	DOS RAW W2	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, RADIOLOGICAL WASTE, 20 TON, LOW LEVEL	10 HP	E		$22,441	4.73	1.27	1.91	0.31	0.42	25
			COMPACTING TECHNOLOGIES INTERNATIONAL										
	H13CO002	8040	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 37 TON HAZARD WASTE IN-DRUM, EXPLOSION PROOF	5 HP	E		$8,129	1.95	0.46	0.69	0.11	0.21	167
			ENVIRO-PAK										
	H13EP001	4000HM	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 30 TON HAZARDOUS WASTE, HAZMAT STORAGE CONTAINER 40″ × 40″ × 40″	5 HP	E		$20,372	4.06	1.15	1.73	0.28	0.21	32
			TEEMARK CORPORATION										
	H13TH001	DPC60-E50	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 30 TON DRUM CRUSHER	5 HP	E		$10,779	2.17	0.61	0.92	0.15	0.21	19
	H13TH002	DPC60-D90	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 30 TON DRUM CRUSHER, TRAILER MOUNTED	9 HP	D-off		$20,270	3.99	1.13	1.69	0.28	0.40	19

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H13		***TEEMARK CORPORATION (continued)***											
	H13TH003	DPC85-D160	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 42.5 TON DRUM CRUSHER, TRAILER MOUNTED	16 HP	D-off		$25,314	5.22	1.41	2.11	0.35	0.70	36
		ADVANCED ENVIRONMENTAL SOLUTIONS											
	H13YB001	CCYC	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 700 PSI OPERATING PRESSURE, FINAL COMPACTED SIZE 39.4″ × 39.4″ × 39.4″	50 HP	E		$316,407	57.42	17.80	26.89	4.35	2.08	320
	H13YB002	CCYC-HD-E	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 1,000 PSI OPERATING PRESSURE, FINAL COMPACTED SIZE 39.4″ × 39.4″ × 39.4″	50 HP	E		$316,407	57.42	17.80	26.89	4.35	2.08	320
	H13YB003	CMC-HD	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 1,200 PSI OPERATING PRESSURE, FINAL COMPACTED SIZE 39.4″ × 39.4″ × 39.4″	50 HP	E		$316,407	57.42	17.80	26.89	4.35	2.08	320
	SUBCATEGORY 0.12		**COMPACTORS (Compression force) OVER 50 TONS**										
		COMPACTING TECHNOLOGIES INTERNATIONAL											
	H13CO003	8550	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 85 TON HAZARD WASTE INDRUM	3 HP	E		$17,071	2.98	0.81	1.14	0.24	0.12	270
	H13CO004	8560-C	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 85 TON HAZARD WASTE INDRUM, W/HEPA FILTER	3 HP	E		$33,669	5.70	1.59	2.24	0.47	0.12	290

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H13	***COMPACTING TECHNOLOGIES INTERNATIONAL (continued)***												
	H13CO006	8560-R	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 85 TON HAZARD WASTE INDRUM, W/HEPA FILTER & SS PLATEN & CHAMBER	3 HP	E		$39,927	6.48	1.89	2.66	0.56	0.12	300
	H13CO005	8560-EXL	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 85 TON HAZARD WASTE IN-DRUM, EXPLOSION PROOF, W/LIQUID REMOVAL SYSTEM	3 HP	E		$54,764	8.84	2.59	3.65	0.76	0.12	310
	ENVIRO-PAK												
	H13EP002	9600HM	HAZARDOUS/TOXIC WASTE EQUIPMENT, COMPACTOR, 250 TON HAZARDOUS WASTE, B-25 METAL STORAGE CONTAINER 4′ × 4′ × 6′	8 HP	E		$32,966	5.67	1.56	2.20	0.46	0.31	100
	SUBCATEGORY 0.21		**FILTER PRESSES, STATIONARY**										
	KOMLINE-SANDERSON ENGINEERING CO												
	H13AY015	L/S 1200/25	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 25 CF MEMBRANE, 1000 MM SQ	50 CFM	A		$51,406	9.07	2.79	4.11	0.73	0.00	112
	H13AY016	K/F 1200/25	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 25 CF CONVENTIONAL, 1000 MM SQ	50 CFM	A		$33,016	5.82	1.79	2.64	0.47	0.00	108
	H13AY013	L/S 1200/50	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 50 CF MEMBRANE, 1200 MM SQ	50 CFM	A		$87,402	15.41	4.74	6.99	1.24	0.00	173

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H13	***KOMLINE-SANDERSON ENGINEERING CO (continued)***											
	H13AY014	K/F 1200/50	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 50 CF CONVENTIONAL, 1200 MM SQ	50 CFM A		$46,317	8.18	2.52	3.71	0.66	0.00	168
	H13AY011	L/S 1200/75	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 75 CF MEMBRANE, 1200 MM SQ	50 CFM A		$109,129	19.25	5.92	8.73	1.55	0.00	194
	H13AY012	K/F 1200/75	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 75 CF CONVENTIONAL, 1200 MM SQ	50 CFM A		$55,072	9.72	2.99	4.41	0.78	0.00	188
	H13AY009	L/S 1200/100	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 100 CF MEMBRANE, 1200 MM SQ	50 CFM A		$130,766	23.07	7.09	10.46	1.86	0.00	199
	H13AY010	K/F 1200/100	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 100 CF CONVENTIONAL, 1200 MM SQ	50 CFM A		$65,893	11.63	3.58	5.27	0.94	0.00	191
	H13AY007	L/S 1200/125	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 125 CF MEMBRANE, 1200 MM SQ	50 CFM A		$147,068	25.95	7.98	11.77	2.09	0.00	216
	H13AY008	K/F 1200/125	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 125 CF CONVENTIONAL, 1200 MM SQ	50 CFM A		$71,385	12.59	3.87	5.71	1.01	0.00	207
	H13AY017	L/S 1200/150	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 150 CF MEMBRANE, 1200 MM SQ	50 CFM A		$162,867	28.73	8.83	13.03	2.31	0.00	235
	H13AY018	K/F 1200/150	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, 150 CF CONVENTIONAL, 1200 MM SQ	50 CFM A		$82,285	14.51	4.46	6.58	1.17	0.00	224

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H13	***KOMLINE-SANDERSON ENGINEERING CO (continued)***											
	H13AY019		HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, FILTER PRESS PLATE SHIFTING UNIT, 1200 MM SQ, MECHANIZED	1 HP E		$10,779	2.21	0.58	0.86	0.15	0.04	5
	H13AY020	SLC-500	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, STATIONARY, PLC CONTROL PANEL - PLATE SHIFTING, COMPUTER AUTOMATED	1 HP E		$14,003	2.78	0.76	1.12	0.20	0.04	2
	SUBCATEGORY 0.22		**FILTER PRESSES, MOBILE**									
	KOMLINE-SANDERSON ENGINEERING CO											
	H13AY031	L/S 1200/25M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 25 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$60,519	10.47	3.32	4.98	0.83	0.00	112
	H13AY032	K/F 1200/25M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 25 CF CONVENTIONAL, 1000 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$42,135	7.31	2.29	3.42	0.58	0.00	109
	H13AY029	L/S 1200/50M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 50 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$96,627	16.68	5.36	8.05	1.33	0.00	193
	H13AY030	K/F 1200/50M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 50 CF CONVENTIONAL, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$55,541	9.61	3.04	4.56	0.76	0.00	188

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H13	***KOMLINE-SANDERSON ENGINEERING CO (continued)***											
	H13AY027	L/S 1200/75M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 75 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$119,356	20.59	6.64	9.99	1.64	0.00	214
	H13AY028	K/F 1200/75M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 75 CF CONVENTIONAL, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$65,299	11.30	3.60	5.39	0.90	0.00	208
	H13AY025	L/S 1200/100M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 100 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$141,995	24.47	7.91	11.91	1.95	0.00	219
	H13AY026	K/F 1200/100M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 100 CF CONVENTIONAL, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$77,122	13.33	4.26	6.40	1.06	0.00	211
	H13AY023	L/S 1200/125M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 125 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$159,298	27.45	8.88	13.38	2.19	0.00	236
	H13AY024	K/F 1200/125M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 125 CF CONVENTIONAL, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM A		$83,615	14.45	4.63	6.95	1.15	0.00	227

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H13	***KOMLINE-SANDERSON ENGINEERING CO (continued)***												
	H13AY021	L/S 1200/150M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 150 CF MEMBRANE, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM	A		$175,474	30.23	9.79	14.76	2.41	0.00	255
	H13AY022	K/F 1200/150M	HAZARDOUS/TOXIC WASTE EQUIPMENT, FILTER PRESS, MOBILE, 150 CF CONVENTIONAL, 1200 MM SQ, TRAILER MOUNTED (ADD COMPR & 60,000 GVW TRUCK)	50 CFM	A		$94,383	16.29	5.23	7.86	1.30	0.00	244
	SUBCATEGORY 0.30		**CENTRIFUGES**										
	BOCK ENGINEERED PRODUCTS, INC.												
	H13BC013	GP 35	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 35 LB DRY WT.	3 HP	E		$12,240	4.79	1.43	2.45	0.20	0.12	9
	H13BC010	305 TX	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 35 LB DRY WT.	3 HP	E		$14,693	5.71	1.71	2.94	0.24	0.12	6
	H13BC012	GP 60	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 60 LB DRY WT.	3 HP	E		$13,550	5.27	1.58	2.71	0.22	0.12	9
	H13BC006	605 TX	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 60 LB DRY WT.	3 HP	E		$19,668	7.57	2.29	3.93	0.32	0.12	9
	H13BC011	GP 100	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 100 LB DRY WT.	5 HP	E		$16,552	6.53	1.93	3.31	0.27	0.21	12

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H13	***BOCK ENGINEERED PRODUCTS, INC. (continued)***												
	H13BC003	GP 130	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, TIMER, 130 LB DRY WT.	5 HP	E		$19,978	7.82	2.32	4.00	0.32	0.21	12
	H13BC009	355	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, MANUAL CONTROL, EXPLOSION PROOF, 35 LB	3 HP	E		$21,092	8.11	2.45	4.22	0.34	0.12	6
	H13BC007	655	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, MANUAL CONTROL, EXPLOSION PROOF, 60 LB	3 HP	E		$25,143	9.64	2.93	5.03	0.41	0.12	9
	H13BC008	755	HAZARDOUS/TOXIC WASTE EQUIPMENT, CENTRIFUGE, FIXED SPEED, MANUAL CONTROL, EXPLOSION PROOF, 100 LB	5 HP	E		$29,811	11.51	3.46	5.96	0.48	0.21	12
	SUBCATEGORY 0.40		**SHREDDERS**										
	MAC CORPORATION												
	H13MN001	52-32HT	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 150 HP, 32″ × 52″ OPENING, TRAILER MTD, W/DIESEL GENERATOR SET/BELT-TYPE INFEED & DISCHARGE CONVEYORS	150 HP	E		$284,596	63.46	15.87	23.91	3.91	6.24	200
	H13MN002	62-40HT	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 200 HP, 38″ × 62″ OPENING, TRAILER MTD, W/DIESEL GENERATOR SET, HOOK-TYPE INFEED FOR TIRES, & DISCHARGE CONVEYOR	200 HP	E		$349,053	79.11	19.46	29.31	4.80	8.32	300

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H13		***MAC CORPORATION (continued)***										
	H13MN003	62-40HT	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 200 HP, 38″ × 62″ OPENING, TRAILER MTD, W/DIESEL GENERATOR SET, CRANE GRAPPLE & DISCHARGE CONVEYOR SYSTEM	200 HP E		$400,503	89.42	22.35	33.68	5.51	8.32	300
	H13MN004	72-46HT	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 300 HP, 45″ × 72″ OPENING, TRAILER MTD, W/DIESEL GENERATOR SET, CRANE GRAPPLE & DISCHARGE CONVEYOR SYSTEM	300 HP E		$462,330	107.51	25.83	38.93	6.36	12.48	400
		SHRED-TECH LIMITED										
	H13SH001	ST-20	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 20 HP, 37″ × 38″ OPENING	20 HP E		$38,248	8.10	2.16	3.25	0.53	0.83	20
	H13SH002	ST-20L	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER 20 HP, 37″ × 46″ OPENING	20 HP E		$35,254	7.56	1.98	3.00	0.48	0.83	23
	H13SH003	ST-50	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 40 HP, 40″ × 55″ OPENING	40 HP E		$70,608	15.13	3.97	6.00	0.97	1.66	45
	H13SH004	ST-50L	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 40 HP, 40″ × 65″ OPENING	40 HP E		$74,520	15.84	4.19	6.33	1.02	1.66	50
	H13SH005	ST-100	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 100 HP, 63″ × 70″ OPENING	100 HP E		$126,188	28.75	7.11	10.73	1.74	4.16	200
	H13SH006	ST-500	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 300 HP, 66″ × 96″ OPENING	300 HP E		$409,336	91.79	23.03	34.79	5.63	12.48	420
	H13SH007	ST-500L	HAZARDOUS/TOXIC WASTE EQUIPMENT, SHREDDER, 600 HP, 66″ × 115″ OPENING	600 HP E		$519,203	129.39	29.21	44.13	7.14	24.96	440

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
	SUBCATEGORY 0.71		**WASTE HANDLING EQUIPMENT, DRUM HANDLING**									
			BASCO									
	H13BB001	T55FLX	HAZARDOUS/TOXIC WASTE EQUIPMENT, WASTE HANDLING EQUIPMENT, DRUM HANDLING, DRUM FILLER, 55 GAL TOP FILL	10 HP E		$27,757	14.03	3.39	5.90	0.44	0.42	3
	H13BB002	MR3	HAZARDOUS/TOXIC WASTE EQUIPMENT, WASTE HANDLING EQUIPMENT, DRUM CLEANER, 60 DRUM/HR CAP INTERIOR	15 HP E		$35,496	18.08	4.33	7.54	0.56	0.62	25
H20	**HOISTS & AIR WINCHES**											
	SUBCATEGORY 0.00		**HOISTS & AIR WINCHES**									
			INGERSOLL RAND MATERIAL HANDLING									
	H20BE002	FA2.5	AIR WINCH (ADD COMPRESSOR) MANUAL BRAKE, 24″ DRUM, 5000 # CAP, 145 FPM	700 CFM A		$18,790	3.67	1.11	1.67	0.27	0.00	10
	H20BE003	FA5	AIR WINCH (ADD COMPRESSOR) MANUAL BRAKE, 24″ DRUM, 10000 # CAP, 65 FPM	700 CFM A		$24,231	4.77	1.43	2.15	0.35	0.00	19
	H20BE004	FA10	AIR WINCH (ADD COMPRESSOR) AUTOMATIC BRAKE, 24″ DRUM, 22000 # CAP, 30 FPM	800 CFM A		$35,945	7.04	2.12	3.20	0.52	0.00	35

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE: MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR): AVERAGE	STANDBY	ADJUSTABLE ELEMENTS: DEPR	FCCM	FUEL	CWT
H25	**HYDRAULIC EXCAVATORS, CRAWLER MOUNTED**											
	SUBCATEGORY 0.10		**0 LBS THRU 12,500 LBS (COMPACT EXCAVATORS)**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	H25CA034	301.8	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 3,800 LBS, 0.04 CY BUCKET, 7.50′ MAX DIGGING DEPTH	17 HP D-off		$30,817	6.93	1.91	2.89	0.46	0.75	37
	H25CA035	303 CR	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 7,500 LBS, 0.11 CY BUCKET, 9.08′ MAX DIGGING DEPTH	25 HP D-off		$39,945	9.15	2.47	3.74	0.60	1.10	73
	H25CA036	305 CR	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 10,800 LBS, 0.17 CY BUCKET, 11.08′ MAX DIGGING DEPTH	42 HP D-off		$67,729	15.48	4.19	6.35	1.01	1.84	109
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	H25KM016	PC03-2	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 2,000 LBS, 0.03 CY BUCKET, 4′11″ MAX DIGGING DEPTH	8 HP D-off		$19,695	4.25	1.22	1.85	0.29	0.35	20
	H25KM017	PC15R-8	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 3,600 LBS, 0.06 CY BUCKET, 7′1″ MAX DIGGING DEPTH	15 HP D-off		$26,568	5.99	1.65	2.49	0.40	0.66	32
	H25KM018	PC20MR-1	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 4,800 LBS, 0.05 CY BUCKET, 8′11″ MAX DIGGING DEPTH	18 HP D-off		$32,201	7.25	1.99	3.02	0.48	0.79	48
	H25KM019	PC27R-8	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 6,000 LBS, 0.10 CY BUCKET, 8′8″ MAX DIGGING DEPTH	26 HP D-off		$34,490	8.16	2.14	3.23	0.52	1.14	62

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25	***KOMATSU AMERICA INTERNATIONAL COMPANY (continued)***											
	H25KM020	PC30MR-1	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 7,200 LBS, 0.07 CY BUCKET, 10′7″ MAX DIGGING DEPTH	28 HP D-off		$38,694	9.10	2.40	3.63	0.58	1.23	73
	H25KM021	PC40MR-1	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 10,000 LBS, 0.18 CY BUCKET, 12′9″ MAX DIGGING DEPTH	37 HP D-off		$47,955	11.40	2.97	4.50	0.72	1.62	99
	H25KM022	PC58UU-3	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 11,400 LBS, 0.29 CY BUCKET, 13′1″ MAX DIGGING DEPTH	40 HP D-off		$64,017	14.66	3.96	6.00	0.96	1.76	115
	H25KM023	PC78US-6	HYDRAULIC EXCAVATOR, CRAWLER, 6,200 LBS, 0.37 CY BUCKET, GENERAL PURPOSE, 12′4″ MAX DIGGING DEPTH	55 HP D-off		$74,211	17.50	4.59	6.96	1.11	2.41	151
	H25KM024	PC75R-2	HYDRAULIC EXCAVATOR, CRAWLER, 6,800 LBS, 0.31 CY BUCKET, GENERAL PURPOSE, 13′3″ MAX DIGGING DEPTH	68 HP D-off		$83,720	20.10	5.18	7.85	1.25	2.98	165
	H25KM025	PC100-6	HYDRAULIC EXCAVATOR, CRAWLER, 9,700 LBS, 0.62 CY BUCKET, GENERAL PURPOSE, 16′7″ MAX DIGGING DEPTH	81 HP D-off		$110,921	26.10	6.86	10.40	1.66	3.56	237
	H25KM026	PC128US-1	HYDRAULIC EXCAVATOR, CRAWLER, 11,500 LBS, 0.62 CY BUCKET, GENERAL PURPOSE, 17′10″ MAX DIGGING DEPTH	86 HP D-off		$134,351	30.89	8.31	12.60	2.01	3.77	280
	MELROE COMPANY/BOBCAT											
	H25ME001	322	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 3,600 LBS, 0.04 CY BUCKET, 7′3″ MAX DIGGING DEPTH	15 HP D-off		$24,653	5.62	1.53	2.31	0.37	0.66	35
	H25ME002	331	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 7,200 LBS, 0.10 CY BUCKET, 10′2″ MAX DIGGING DEPTH	40 HP D-off		$36,624	9.40	2.27	3.43	0.55	1.76	72

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25		***MELROE COMPANY/BOBCAT (continued)***										
	H25ME003	337	HYDRAULIC EXCAVATOR, CRAWLER-RUBBER TRACK, 11,000 LBS, 0.18 CY BUCKET, 12′ MAX DIGGING DEPTH	53 HP D-off		$52,098	13.15	3.22	4.88	0.78	2.33	110
	SUBCATEGORY 0.11		**OVER 12,500 LBS THRU 40,000 LBS**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	H25CA037	307B	HYDRAULIC EXCAVATOR, CRAWLER, 15,200 LBS, 0.40 CY BUCKET, GENERAL PURPOSE, 15.25′ MAX DIGGING DEPTH	54 HP D-off		$79,357	17.60	4.68	7.00	1.18	2.37	153
	H25CA038	307C	HYDRAULIC EXCAVATOR, CRAWLER, 14,310 LBS, 0.48 CY BUCKET, GENERAL PURPOSE, 15.25′ MAX DIGGING DEPTH	54 HP D-off		$96,759	20.76	5.71	8.54	1.44	2.37	182
	H25CA020	311-B	HYDRAULIC EXCAVATOR, CRAWLER, 24,640 LBS, 0.60 CY BUCKET, 16.50′ MAX DIGGING DEPTH	79 HP D-off		$103,659	23.50	6.12	9.15	1.54	3.47	250
	H25CA021	312-B	HYDRAULIC EXCAVATOR, CRAWLER, 26,900 LBS, 0.68 CY BUCKET, 18.16′ MAX DIGGING DEPTH	84 HP D-off		$118,926	26.56	7.02	10.49	1.77	3.69	279
	H25CA039	315B	HYDRAULIC EXCAVATOR, CRAWLER, 35,200 LBS, 0.80 CY BUCKET, GENERAL PURPOSE, 19.83′ MAX DIGGING DEPTH	99 HP D-off		$135,580	30.47	7.99	11.96	2.01	4.35	353
		KOBELCO AMERICA INC.										
	H25KC017	70SR	HYDRAULIC EXCAVATOR, CRAWLER, 16,400 LBS, 0.33 CY BUCKET, 14.75′ MAX DIGGING DEPTH	54 HP D-off		$90,492	19.61	5.33	7.98	1.34	2.37	168

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
H25		***KOBELCO AMERICA INC. (continued)***										
	H25KC016	135SR LC	HYDRAULIC EXCAVATOR, CRAWLER, 30,870 LBS, 0.60 CY BUCKET, 19.58′ MAX DIGGING DEPTH	94 HP D-off		$128,261	28.85	7.57	11.32	1.91	4.13	319
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	H25KM027	PC128UU-2	HYDRAULIC EXCAVATOR, CRAWLER, 12,200 LBS, 0.58 CY BUCKET, 16′ 0″ MAX DIGGING DEPTH, GENERAL PURPOSE	86 HP D-off		$172,847	36.45	10.20	15.25	2.57	3.77	295
	H25KM028	PC150-6	HYDRAULIC EXCAVATOR, CRAWLER, 14,800 LBS, 0.68 CY BUCKET, 19′8″ MAX DIGGING DEPTH	107 HP D-off		$141,728	32.08	8.37	12.51	2.11	4.70	359
	H25KM001	PC 120-6	HYDRAULIC EXCAVATOR, CRAWLER, 26,950 LBS, 0.75 CY BUCKET, 18.08′ MAX DIGGING DEPTH	102 HP D-off		$155,102	34.20	9.16	13.69	2.31	4.48	270
	H25KM003	PC 150LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 39,400 LBS, 1.12 CY BUCKET, 19.58′ MAX DIGGING DEPTH	107 HP D-off		$184,519	39.83	10.88	16.28	2.74	4.70	395
	LINK-BELT CONSTRUCTION EQUIPMENT COMPANY											
	H25LI001	1600 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 15,400 LBS, 0.24 CY BUCKET, 13′7″ MAX DIGGING DEPTH	54 HP D-off		$91,965	19.88	5.43	8.11	1.37	2.37	154
	H25LI003	130 LX	HYDRAULIC EXCAVATOR, CRAWLER, 27,100 LBS, 0.50 CY BUCKET, 18′2″ MAX DIGGING DEPTH	89 HP D-off		$122,254	27.47	7.22	10.79	1.82	3.91	271
	H25LI002	2650 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 14,200 LBS, 0.66 CY BUCKET, 18′3″ MAX DIGGING DEPTH	85 HP D-off		$126,366	27.97	7.46	11.15	1.88	3.73	284

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25	***LINK-BELT CONSTRUCTION EQUIPMENT COMPANY (continued)***											
	H25LI005	160 LX	HYDRAULIC EXCAVATOR, CRAWLER, 35,275 LBS, 0.66 CY BUCKET, 20′1″ MAX DIGGING DEPTH	101 HP D-off		$142,973	31.93	8.43	12.62	2.12	4.43	353
	H25LI004	2700 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 35,275 LBS, 0.66 CY BUCKET, 20′1″ MAX DIGGING DEPTH	100 HP D-off		$148,720	32.92	8.77	13.12	2.21	4.39	352
	SUBCATEGORY 0.12		**OVER 40,000 LBS THRU 100,000 LBS**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	H25CA040	318BL	HYDRAULIC EXCAVATOR, CRAWLER, 40,600 LBS, 1.00 CY BUCKET, HEAVY DUTY, 22.50′ MAX DIGGING DEPTH	115 HP D-off		$147,766	27.15	6.75	9.24	2.13	4.74	405
	H25CA022	320B	HYDRAULIC EXCAVATOR, CRAWLER, 43,800 LBS, 1.50 CY BUCKET, 21.75′ MAX DIGGING DEPTH	128 HP D-off		$193,253	34.26	8.83	12.08	2.79	5.28	438
	H25CA023	320BL	HYDRAULIC EXCAVATOR, CRAWLER, 49,000 LBS, 0.80 CY BUCKET, 39.0′ MAX DIGGING DEPTH, LONG REACH BOOM	128 HP D-off		$223,362	38.48	10.20	13.96	3.22	5.28	490
	H25CA025	325BL	HYDRAULIC EXCAVATOR, CRAWLER, 60,700 LBS, 1.75 CY BUCKET, 23.25′ MAX DIGGING DEPTH	168 HP D-off		$286,961	49.64	13.11	17.94	4.14	6.93	607
	H25CA027	330BL	HYDRAULIC EXCAVATOR, CRAWLER, 75,700 LBS, 2.09 CY BUCKET, 21.58′ MAX DIGGING DEPTH	222 HP D-off		$339,776	60.05	15.52	21.24	4.90	9.15	763
	H25CA032	345BL	HYDRAULIC EXCAVATOR, CRAWLER, 98,600 LBS, 3.00 CY BUCKET, 30.41′ MAX DIGGING DEPTH	290 HP D-off		$458,086	80.45	20.93	28.63	6.61	11.96	988

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
		KOBELCO AMERICA INC.											
	H25KC019	SK210 LC	HYDRAULIC EXCAVATOR, CRAWLER, 48,000 LBS, 1.13 CY BUCKET, 22.00′ MAX DIGGING DEPTH	143 HP	D-off		$194,022	35.21	8.87	12.13	2.80	5.90	480
	H25KC020	SK210 LC	HYDRAULIC EXCAVATOR, CRAWLER, 53,400 LBS, 0.63 CY BUCKET, 39′ MAX DIGGING DEPTH, LONG REACH BOOM	143 HP	D-off		$222,168	39.16	10.16	13.89	3.21	5.90	534
	H25KC021	SK250 LC	HYDRAULIC EXCAVATOR, CRAWLER, 55,100 LBS, 1.875 CY BUCKET, 23.08′ MAX DIGGING DEPTH	176 HP	D-off		$223,446	41.18	10.22	13.97	3.23	7.26	551
	H25KC022	SK250 LC	HYDRAULIC EXCAVATOR, CRAWLER, 59,100 LBS, 0.50 CY BUCKET, 23′ MAX DIGGING DEPTH, LONG LREACH BOOM	176 HP	D-off		$266,280	47.17	12.16	16.64	3.84	7.26	591
	H25KC023	SK330 LC	HYDRAULIC EXCAVATOR, CRAWLER, 77,800 LBS, 2.05 CY BUCKET, 24.58′ MAX DIGGING DEPTH	238 HP	D-off		$321,788	58.42	14.70	20.11	4.64	9.81	778
		KOMATSU AMERICA INTERNATIONAL COMPANY											
	H25KM012	PC 200 LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 46,363 LBS, 1.50 CY BUCKET, 21.75′ MAX DIGGING DEPTH	133 HP	D-off		$240,012	41.08	10.96	15.00	3.46	5.48	464
	H25KM004	PC 220 LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 57,483 LBS, 1.75 CY BUCKET, 22.25′ MAX DIGGING DEPTH	158 HP	D-off		$274,111	47.27	12.53	17.13	3.96	6.51	575
	H25KM005	PC 300 LC-5	HYDRAULIC EXCAVATOR, CRAWLER, 74,803 LBS, 2.50 CY BUCKET, 24.25′ MAX DIGGING DEPTH	232 HP	D-off		$381,710	66.50	17.44	23.86	5.51	9.57	748
	H25KM013	PC 400 LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 99,517 LBS, 2.75 CY BUCKET, 25.50′ MAX DIGGING DEPTH	306 HP	D-off		$500,473	87.29	22.86	31.28	7.22	12.62	995

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	REGION 6 EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	LINK-BELT CONSTRUCTION EQUIPMENT COMPANY											
	H25LI006	2800 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 45,200 LBS, 1.08 CY BUCKET, 21′11″ MAX DIGGING DEPTH	128 HP D-off		$178,470	32.18	8.16	11.15	2.58	5.28	453
	H25LI007	3400 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 53,100 LBS, 1.05 CY BUCKET, 22′10″ MAX DIGGING DEPTH	153 HP D-off		$228,042	40.53	10.42	14.25	3.29	6.31	532
	H25LI008	3900 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 62,800 LBS, 1.32 CY BUCKET, 23′7″ MAX DIGGING DEPTH	178 HP D-off		$250,399	45.06	11.44	15.65	3.61	7.34	629
	H25LI009	4300 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 73,600 LBS, 1.54 CY BUCKET, 24′3″ MAX DIGGING DEPTH	240 HP D-off		$284,254	53.28	12.99	17.77	4.10	9.90	736
	H25LI010	5800 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 99,900 LBS, 2.14 CY, 27′6″ MAX DIGGING DEPTH	300 HP D-off		$421,798	75.91	19.27	26.36	6.09	12.37	998
	SUBCATEGORY 0.13		**OVER 100,000 LBS THRU 160,000 LBS**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	H25CA041	365BL	HYDRAULIC EXCAVATOR, CRAWLER, 149,000 LBS, 3.61 CY BUCKET, 27.58′ MAX DIGGING DEPTH, GENERAL PURPOSE	385 HP D-off		$698,936	104.52	26.27	32.76	9.89	16.90	1,490
	KOBELCO AMERICA INC.											
	H25KC024	SK400 LC	HYDRAULIC EXCAVATOR, CRAWLER, 101,900 LBS 3.06 CY BUCKET, 25.58′ MAX DIGGING DEPTH	306 HP D-off		$419,229	66.66	15.76	19.65	5.93	13.43	1,019

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25		***KOBELCO AMERICA INC. (continued)***										
	H25KC026	SK480LC	HYDRAULIC EXCAVATOR, CRAWLER, 108,000 LBS, 2.25 CY BUCKET, 25.58′ MAX DIGGING DEPTH, HEAVY DUTY	315 HP D-off		$439,182	69.56	16.52	20.59	6.22	13.83	1,080
		KOMATSU AMERICA INTERNATIONAL COMPANY										
	H25KM015	PC 600 LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 133,160 LBS, 4.25 CY BUCKET, 27.83′ MAX DIGGING DEPTH	384 HP D-off		$741,735	109.62	27.89	34.77	10.50	16.85	1,332
	SUBCATEGORY 0.14		**OVER 160,000 LBS**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	H25CA033	365-B	HYDRAULIC EXCAVATOR, CRAWLER, 164,400 LBS, 4.00 CY BUCKET, 31.41′ MAX DIGGING DEPTH	374 HP D-off		$720,331	98.19	24.32	28.43	10.10	16.41	1,644
	H25CA042	375L	HYDRAULIC EXCAVATOR, CRAWLER, 779,900 LBS, 5.00 CY BUCKET, 31.08′ MAX DIGGING DEPTH	428 HP D-off		$873,098	117.66	29.48	34.46	12.25	18.78	1,798
	H25CA030	375	HYDRAULIC EXCAVATOR, CRAWLER, 175,500 LBS, 5.00 CY BUCKET, 34.75′ MAX DIGGING DEPTH	428 HP D-off		$836,396	113.69	28.24	33.02	11.73	18.78	1,750
	H25CA031	375-L	HYDRAULIC EXCAVATOR, CRAWLER, 255,400 LBS, 6.00 CY BUCKET, 26.57′ MAX DIGGING DEPTH	428 HP D-off		$877,634	118.15	29.63	34.64	12.31	18.78	2,554
	H25CA043	385BL	HYDRAULIC EXCAVATOR, CRAWLER, 190,500 LBS, 6.00 CY BUCKET, 27.83′ MAX DIGGING DEPTH, GENERAL PURPOSE	513 HP D-off		$925,903	127.98	31.27	36.55	12.99	22.52	1,920

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	H25KM009	PC 750LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 171,070 LBS, 5.25 CY BUCKET, 27.66′ MAX DIGGING DEPTH	443 HP	D-off		$955,573	127.42	32.26	37.72	13.40	19.44	1,711
	H25KM010	PC 1100-6	HYDRAULIC EXCAVATOR, CRAWLER, 227,100 LBS, 8.50 CY BUCKET, 34.25′ MAX DIGGING DEPTH	611 HP	D-off		$1,324,263	176.43	44.72	52.27	18.58	26.82	2,271
	H25KM011	PC 1100LC-6	HYDRAULIC EXCAVATOR, CRAWLER, 248,060 LBS, 6.50 CY BUCKET, 38.00′ MAX DIGGING DEPTH	611 HP	D-off		$1,392,057	183.79	47.01	54.95	19.53	26.82	2,481
	H25KM033	PC 1800-6	HYDRAULIC EXCAVATOR, CRAWLER, 396,800 LBS, 15.70 CY, 30′5″ MAX DIGGING DEPTH	908 HP	D-off		$1,809,356	244.99	61.09	71.42	25.38	39.85	3,968
	LINK-BELT CONSTRUCTION EQUIPMENT COMPANY												
	H25LI011	8000 QUANTUM	HYDRAULIC EXCAVATOR, CRAWLER, 176,400 LBS, 2.97 CY, 29′6″ MAX DIGGING DEPTH	438 HP	D-off		$733,030	103.02	24.75	28.94	10.28	19.22	1,764
	SUBCATEGORY 0.21		**ATTACHMENTS, MOBILE SHEARS**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	H25CA055	S305	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 9.4″ JAW OPENING (ADD 5 TON HYDRAULIC EXCAVATOR)				$22,945	7.13	1.97	3.25	0.34	0.00	15
	H25CA057	S320	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 15.4″ JAW OPENING (ADD 10 TON HYDRAULIC EXCAVATOR)				$77,944	23.67	6.67	11.04	1.15	0.00	57

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25			***CATERPILLAR INC. (MACHINE DIVISION) (continued)***									
	H25CA052	S230	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 22.0″ JAW OPENING (ADD 17.5 TON HYDARULIC EXCAVATOR)			$88,207	27.38	7.55	12.50	1.30	0.00	84
	H25CA053	S250	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 28.0″ JAW OPENING (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$119,321	36.61	10.21	16.90	1.76	0.00	158
	H25CA054	S280	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 32.0″ JAW OPENING (ADD 50 TON HYDRAULIC EXCAVATOR)			$153,535	48.04	13.14	21.75	2.26	0.00	191
	H25CA056	S2130	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, SCRAP, 43.0″ JAW OPENING (ADD 50 TON HYDRAULIC EXCAVATOR)			$250,895	76.60	21.46	35.54	3.69	0.00	307
			LABOUNTY MANUFACTURING,									
	H25LU001	MSD 7	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 10″ JAW OPENING, 4′7″ REACH (ADD 5 TON HYDRAULIC EXCAVATOR)			$19,148	6.01	1.64	2.71	0.28	0.00	10
	H25LU002	MSD 7R	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 10″ JAW OPENING, 5′0″ REACH (ADD 7 TON HYDRAULIC EXCAVATOR)			$25,886	8.10	2.22	3.67	0.38	0.00	11
	H25LU003	MSD 15	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 18″ JAW OPENING, 6′6″ REACH (ADD 10 TON HYDRAULIC EXCAVATOR)			$40,362	12.64	3.45	5.72	0.59	0.00	30

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25		*LABOUNTY MANUFACTURING, (continued)*										
	H25LU004	MSD 15R	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 18″ JAW OPENING, 8′6″ REACH (ADD 12.5 TON HYDRAULIC EXCAVATOR)			$51,745	16.08	4.43	7.33	0.76	0.00	35
	H25LU005	MSD 30	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 22″ JAW OPENING, 7′0″ REACH (ADD 12.5 TON HYDRAULIC EXCAVATOR)			$58,763	18.33	5.02	8.32	0.86	0.00	50
	H25LU006	MSD 30R	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 22″ JAW OPENING, 10′4″ REACH (ADD 17.5 TON HYDRAULIC EXCAVATOR)			$87,195	27.08	7.46	12.35	1.28	0.00	67
	H25LU007	MSD 40-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 27″ JAW OPENING, 8′6″ REACH (ADD 20 TON HYDRAULIC EXCAVATOR)			$70,129	21.97	6.00	9.93	1.03	0.00	70
	H25LU008	MSD 40R-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 27″ JAW OPENING, 12′6″ REACH (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$96,569	29.93	8.26	13.68	1.42	0.00	90
	H25LU009	MSD 50-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 32″ JAW OPENING, 9′0″ REACH (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$100,594	31.21	8.61	14.25	1.48	0.00	109
	H25LU010	MSD 50R-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 32″ JAW OPENING, 13′4″ REACH (ADD 30 TON HYDRAULIC EXCAVATOR)			$125,587	38.85	10.75	17.79	1.85	0.00	140
	H25LU011	MSD 70-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 35″ JAW OPENING, 10′4″ REACH (ADD 30 TON HYDRAULIC EXCAVATOR)			$113,674	35.34	9.72	16.10	1.67	0.00	130

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	REGION 6 EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H25			***LABOUNTY MANUFACTURING, (continued)***									
	H25LU012	MSD 70R-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 35″ JAW OPENING, 14′4″ REACH (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$151,346	46.90	12.95	21.44	2.23	0.00	164
	H25LU013	MSD 100-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 38″ JAW OPENING, 11′6″ REACH (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$151,569	47.06	12.97	21.47	2.23	0.00	150
	H25LU014	MSD 100R-III	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 38″ JAW OPENING, 16′0″ REACH (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$181,180	56.16	15.51	25.67	2.67	0.00	180
	H25LU015	MSD 140	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 44″ JAW OPENING, 13′10″ REACH (ADD 50 TON HYDRAULIC EXCAVATOR)			$164,884	51.38	14.11	23.36	2.43	0.00	195
	H25LU016	MSD 140R	HYDRAULIC EXCAVATOR, ATTACHMENT, MOBILE SHEARS, 44″ JAW OPENING, 18′6″ REACH (ADD 70 TON HYDRAULIC EXCAVATOR)			$202,010	62.87	17.28	28.62	2.97	0.00	245
	SUBCATEGORY 0.22		**ATTACHMENTS, MATERIAL HANDLING**									
			BALDERSON, INC.									
	H25BS001		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, 0.50 CY BUCKET, W/TIPS (ADD HYDRAULIC EXCAVATOR)			$4,399	1.20	0.37	0.59	0.07	0.00	10

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	REGION 6											
H25		***BALDERSON, INC. (continued)***										
	H25BS002		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, 0.75 CY BUCKET, W/TIPS (ADD HYDRAULIC EXCAVATOR)			$5,038	1.36	0.42	0.67	0.08	0.00	16
	H25BS003		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, 1.25 CY BUCKET, W/TIPS (ADD HYDRAULIC EXCAVATOR)			$5,348	1.44	0.44	0.71	0.08	0.00	30
	H25BS004		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, 1.50 CY BUCKET, W/TIPS (ADD HYDRAULIC EXCAVATOR)			$6,756	1.82	0.55	0.90	0.10	0.00	22
	H25BS005		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, 3.25 CY BUCKET, W/TIPS (ADD HYDRAULIC EXCAVATOR)			$10,315	2.80	0.85	1.38	0.16	0.00	52
		LABOUNTY MANUFACTURING,										
	H25LU023	100 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 1.25CY, 3-TINE/4-TINE (ADD 12.5 TON HYDRAULIC EXCAVATOR)			$10,647	3.13	0.87	1.42	0.16	0.00	18
	H25LU024	110 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 3.50 CY, 3-TINE/4-TINE (ADD 17.5 TON HYDRAULIC EXCAVATOR)			$15,534	4.49	1.27	2.07	0.23	0.00	27
	H25LU025	120 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 3.50CY, 3-TINE/4-TINE (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$19,180	5.59	1.57	2.56	0.29	0.00	35

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H25			***LABOUNTY MANUFACTURING, (continued)***									
	H25LU026	140 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 5.50CY, 3-TINE/4-TINE (ADD 30 TON HYDRAULIC EXCAVATOR)			$21,831	6.40	1.79	2.91	0.33	0.00	49
	H25LU027	160 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 6.50CY, 3-TINE/4-TINE (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$24,465	7.21	2.00	3.26	0.37	0.00	60
	H25LU028	170 TR	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, GRAPPLE, 9.00CY, 3-TINE/4-TINE (ADD 50 TON HYDRAULIC EXCAVATOR)			$31,419	9.19	2.57	4.19	0.47	0.00	80
	H25LU029	RB 80	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING BARREL HANDLER (ADD HYDRAULIC EXCAVATOR)			$25,202	7.21	2.06	3.36	0.38	0.00	17
	H25LU030	RBC 80	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING BARREL HANDLER/CRUSHER (ADD 20 TON HYDRAULIC EXCAVATOR)			$39,014	11.14	3.19	5.20	0.59	0.00	21
	H25LU031	MD 30	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, MATERIAL DENSIFIER, (ADD 25 TON HYDRAULIC EXCAVATOR)			$64,133	18.53	5.25	8.55	0.97	0.00	60
	H25LU032	MD 50	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, MATERIAL DENSIFIER, (ADD 35 TON HYDRAULIC EXCAVATOR)			$76,649	22.12	6.27	10.22	1.16	0.00	90
	H25LU033	R80	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING GRAPPLE, 0.75 CY (ADD 17.5 TON HYDRAULIC EXCAVATOR)			$35,006	10.06	2.87	4.67	0.53	0.00	22

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25	***LABOUNTY MANUFACTURING, (continued)***											
	H25LU034	R100	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING GRAPPLE, 1.00 CY (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$47,043	13.51	3.85	6.27	0.71	0.00	40
	H25LU035	R110	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING GRAPPLE, 1.25 CY (ADD 30 TON HYDRAULIC EXCAVATOR)			$49,749	14.34	4.07	6.63	0.75	0.00	64
	H25LU036	R120	HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, ROTATING GRAPPLE, 2.00 CY (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$52,434	15.17	4.29	6.99	0.79	0.00	84
	WAIN-ROY, INC.											
	H25WN001		HYDRAULIC EXCAVATOR, ATTACHMENT, MATERIAL HANDLING, BUCKET, 36″ PAVEMENT REMOVAL (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$11,384	3.08	0.93	1.52	0.17	0.00	31
	SUBCATEGORY 0.23		**ATTACHMENTS, CONCRETE PULVERIZERS**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	H25CA058	CR3	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRUSHER, 16.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$18,784	6.30	1.61	2.66	0.28	0.00	6

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H25			***CATERPILLAR INC. (MACHINE DIVISION) (continued)***									
	H25CA059	P16	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 30.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$68,289	21.66	5.84	9.67	1.00	0.00	53
	H25CA060	P28	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 34.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$100,501	31.76	8.60	14.24	1.48	0.00	87
	H25CA061	CR28	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRUSHER, 36.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$87,673	27.80	7.50	12.42	1.29	0.00	81
	H25CA062	P60	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 45.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$160,248	50.34	13.71	22.70	2.36	0.00	194
	H25CA063	CR35	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRUSHER, 47.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$114,745	36.31	9.82	16.26	1.69	0.00	111
	H25CA064	CR50	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRUSHER, 63.0″ JAW OPENING (ADD HYDRAULIC EXCAVATOR)			$139,427	44.02	11.93	19.75	2.05	0.00	155
			KENT DEMOLITION TOOLS									
	H25KN001	KHB10G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 2000 LB, W/POINT (ADD 8–12 TON HYDRAULIC EXCAVATOR)			$29,614	9.65	2.54	4.20	0.44	0.00	16

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25		***KENT DEMOLITION TOOLS (continued)***										
	H25KN002	KHB15G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 3000 LB, W/POINT (ADD 13–18 TON HYDRAULIC EXCAVATOR)			$40,895	13.11	3.50	5.79	0.60	0.00	29
	H25KN003	KHB20G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 4000 LB, W/POINT (ADD 18–25 TON HYDRAULIC EXCAVATOR)			$49,939	15.90	4.27	7.07	0.73	0.00	40
	H25KN004	KHB30G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 5000 LB, W/POINT (ADD 25–32 TON HYDRAULIC EXCAVATOR)			$64,867	20.51	5.55	9.19	0.95	0.00	46
	H25KN005	KHB40G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 7000 LB, W/POINT (ADD 32–44 TON HYDRAULIC EXCAVATOR)			$81,543	26.16	6.98	11.55	1.20	0.00	60
	H25KN006	KHB50G 11	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 10,000 LB, W/ POINT (ADD 40 TON HYDRAULIC EXCAVATOR)			$115,612	36.67	9.89	16.38	1.70	0.00	87
		LABOUNTY MANUFACTURING,										
	H25LU045	CP 30	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 14.5″ THICK, (ADD 17.5 TON HYDRAULIC EXCAVATOR)			$21,521	7.14	1.85	3.05	0.32	0.00	21
	H25LU046	CP 40	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 24″ THICK, 16″ WIDE (ADD 20 TON HYDRAULIC EXCAVATOR)			$23,274	7.68	1.99	3.30	0.34	0.00	29

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25			***LABOUNTY MANUFACTURING, (continued)***									
	H25LU047	CP 60	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 30″ THICK, 16″ WIDE (ADD 30 TON HYDRAULIC EXCAVATOR)			$26,796	8.87	2.29	3.80	0.39	0.00	30
	H25LU048	CP 80	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 36″ THICK, 21″ WIDE (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$30,297	10.05	2.60	4.29	0.45	0.00	45
	H25LU049	CP 100	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 42″ THICK, 30″ WIDE (ADD 50 TON HYDRAULIC EXCAVATOR)			$36,722	12.13	3.14	5.20	0.54	0.00	62
	H25LU050	CP 120	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, 48″ THICK, 41″ WIDE (ADD 70 TON HYDRAULIC EXCAVATOR)			$44,767	14.71	3.83	6.34	0.66	0.00	99
	H25LU040	UP 50	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRACKING JAWS, 36.0″ JAW OPENING (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$100,253	31.68	8.57	14.20	1.47	0.00	102
	H25LU041	UP 70	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRACKING JAWS, 48.0″ JAW OPENING (ADD 30 TON HYDRAULIC EXCAVATOR)			$124,973	39.31	10.69	17.70	1.84	0.00	138
	H25LU042	UP 90	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, CRACKING JAWS, 62.0″ JAW OPENING (ADD 37.5 TON HYDRAULIC EXCAVATOR)			$148,471	47.30	12.70	21.03	2.18	0.00	171
	H25LU053	UP 50	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, STEEL JAWS, 41″ JAW OPENING (ADD 22.5 TON HYDRAULIC EXCAVATOR)			$102,614	32.41	8.78	14.54	1.51	0.00	96

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25		***LABOUNTY MANUFACTURING, (continued)***										
	H25LU054	UP 70	HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE PULVERIZER, PLATE SHEAR, 21″ JAW OPENING (ADD 30 TON HYDRAULIC EXCAVATOR)			$126,243	39.70	10.80	17.88	1.86	0.00	126
	SUBCATEGORY 0.24		**ATTACHMENTS, COMPACTORS**									
		ALLIED CONSTRUCTION PRODUCTS										
	H25AU001	4700 W/SWIVEL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 18″ × 12″, 3030 LBS FORCE (ADD HYDRAULIC EXCAVATOR)			$6,043	1.87	0.52	0.86	0.09	0.00	4
	H25AU002	8700C W/ SWIVEL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 34″ × 24″, 6400 LBS FORCE (ADD HYDRAULIC EXCAVATOR)			$6,773	2.09	0.58	0.96	0.10	0.00	9
	H25AU003	9700C W/ SWIVEL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 40″ × 29″, 13500 LBS FORCE (ADD HYDRAULIC EXCAVATOR)			$9,923	3.07	0.86	1.41	0.15	0.00	16
	H25AU004	9800 W/SWIVEL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 44″ × 34″, 20000 LBS FORCE (ADD HYDRAULIC EXCAVATOR)			$15,687	4.84	1.34	2.22	0.23	0.00	23
	H25AU005	9801 W/SWIVEL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 44″ × 34″, 22000 LBS FORCE (ADD HYDRAULIC EXCAVATOR)			$15,998	4.94	1.38	2.27	0.24	0.00	23
		AMERICAN COMPACTION EQUIPMENT, INC.										
	H25AX001	DC-24BL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 23″ WIDE, SHEEPS FOOT, 3 RIMS (ADD 12.5–25 TON HYDRAULIC EXCAVATOR)			$6,286	1.94	0.54	0.89	0.09	0.00	21

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H25	***AMERICAN COMPACTION EQUIPMENT, INC. (continued)***											
	H25AX003	DC-24EX	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 23″ WIDE, SHEEPS FOOT, 3 RIMS (ADD 25–37.5 TON HYDRAULIC EXCAVATOR)			$7,679	2.37	0.66	1.09	0.11	0.00	31
	H25AX005	DC-24EXL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 24″ WIDE, SHEEPS FOOT, 3 RIMS (ADD 37.5–55 TON HYDRAULIC EXCAVATOR)			$8,422	2.59	0.72	1.19	0.12	0.00	35
	H25AX002	DC-36BL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 35″ WIDE, SHEEPS FOOT, 4 RIMS (ADD 12.5–25 TON HYDRAULIC EXCAVATOR)			$6,822	2.11	0.59	0.97	0.10	0.00	25
	H25AX004	DC-36EX	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 35″ WIDE, SHEEPS FOOT, 4 RIMS (ADD 25–37.5 TON HYDRAULIC EXCAVATOR)			$8,742	2.70	0.75	1.24	0.13	0.00	37
	H25AX006	DC-36EXL	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 36″ WIDE, SHEEPS FOOT, 4 RIMS (ADD 37.5–55 TON HYDRAULIC EXCAVATOR)			$9,495	2.93	0.82	1.35	0.14	0.00	43
	KENT DEMOLITION TOOLS											
	H25KN007	KHP-30	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 3000 LB FORCE (ADD HYDRAULIC EXCAVATOR)			$4,142	1.43	0.36	0.59	0.06	0.00	4
	H25KN009	KHP-135	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 13500 LB FORCE (ADD HYDRAULIC EXCAVATOR)			$8,338	2.72	0.71	1.18	0.12	0.00	14
	H25KN010	KHP-210	HYDRAULIC EXCAVATOR, ATTACHMENT, COMPACTOR, 20000 LB FORCE (ADD HYDRAULIC EXCAVATOR)			$12,415	3.98	1.06	1.76	0.18	0.00	23

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
H30	**HYDRAULIC EXCAVATORS, WHEEL MOUNTED**											
	SUBCATEGORY 0.01		**0 THRU 1.0 CY**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	H30CA006	M312	HYDRAULIC EXCAVATORS, WHEEL, 30,400 LBS, 0.70 CY BUCKET, 1-PIECE BOOM, 16′8″ DIGGING DEPTH, 4 × 4 × 2	113 HP D-off		$140,809	30.14	8.50	12.77	2.11	4.66	303
	H30CA007	M315	HYDRAULIC EXCAVATORS, WHEEL, 35,100 LBS, 0.70 CY BUCKET, 1-PIECE, 17′7″ DIGGING DEPTH, 4 × 4 × 2	114 HP D-off		$161,536	33.68	9.78	14.71	2.42	4.70	354
		GRADALL COMPANY										
	H30GA003	G3WD 4 × 2	HYDRAULIC EXCAVATORS, WHEEL, 34,100 LBS, 0.625CY BUCKET, TELESCOPIC BOOM, 4 × 2	173 HP D-off	190 HP D-on	$166,447	40.03	10.15	15.31	2.49	8.92	342
	H30GA006	XL4100	HYDRAULIC EXCAVATORS, WHEEL, 44,851 LBS, 0.75 CY BUCKET, 22′6″ DIGGING DEPTH, TELESCOPIC BOOM, 6 × 4	138 HP D-off	185 HP D-on	$277,779	56.83	16.94	25.56	4.16	7.43	457
	SUBCATEGORY 0.02		**OVER 1.0 CY**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	H30CA005	M318	HYDRAULIC EXCAVATORS, WHEEL, 33,700 LBS, 1.00 CY BUCKET, 19′ DIGGING DEPTH, 30.7′ RAD, 4 × 4	131 HP D-off		$179,515	33.90	9.18	13.09	2.63	5.40	393
	H30CA008	M320	HYDRAULIC EXCAVATORS, WHEEL, 44,800 LBS, 1.060 CY BUCKET, 1-PIECE, 19′ DIGGING DEPTH, 4 × 4 × 2	130 HP D-off		$207,396	38.92	10.60	15.11	3.04	5.36	448

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	GRADALL COMPANY											
	H30GA008	XL 5100	HYDRAULIC EXCAVATORS, WHEEL, 22,800 LBS, 1.25 CY BUCKET, 25′4″ DIGGING DEPTH, 6 × 4	163 HP D-off	230 HP D-on	$326,159	61.44	16.70	23.83	4.78	8.89	553
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	H30KM001	PW170ES-6	HYDRAULIC EXCAVATORS, WHEEL, 37,600 LBS, 1.12 CY BUCKET, 18.67′ DIGGING DEPTH, 29.4′ RAD, 4 × 4	123 HP D-off		$215,222	38.58	11.10	15.89	3.15	5.07	376
H35	**HYDRAULIC SHOVELS, CRAWLER MOUNTED**											
	SUBCATEGORY 0.12		**DIESEL, OVER 5.0 CY**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	H35CA001	5080	HYDRAULIC SHOVEL, CRAWLER, 6.80 CY BUCKET, FRONT SHOVEL, MASS BUCKET, 9′ DIG DEEP	424 HP D-off		$960,777	152.37	37.17	48.04	13.15	18.61	1,848
	HITACHI CONSTRUCTION MACHINERY											
	H35HI004	EX750-5	HYDRAULIC SHOVEL, CRAWLER, 5.23 CY BUCKET	434 HP D-off		$967,379	153.79	37.43	48.37	13.24	19.05	1,666
	H35HI005	EX1100-3	HYDRAULIC SHOVEL, CRAWLER, 7.50 CY BUCKET, ROCK, 235,700 LBS	550 HP D-off		$1,095,705	177.33	42.40	54.79	15.00	24.14	2,356
	H35HI006	EX1200	HYDRAULIC SHOVEL, CRAWLER, 8.5 CY, GENERAL PURPOSE BUCKET, 244,700 LBS	641 HP D-off		$1,107,566	183.81	42.85	55.38	15.16	28.13	2,447

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
H35	***HITACHI CONSTRUCTION MACHINERY (continued)***												
	H35HI002	EX1800-3	HYDRAULIC SHOVEL, CRAWLER, 13.50 CY BUCKET	1,000 HP	D-off		$1,891,612	308.85	73.18	94.58	25.89	43.89	3,896
	H35HI003	EX3500-3	HYDRAULIC SHOVEL, CRAWLER, 23.50 CY BUCKET	1,634 HP	D-off		$3,885,859	611.87	150.33	194.29	53.18	71.72	7,360
	O&K ORENSTEIN & KOPPEL INC.												
	H35OK001	RH 40 E	HYDRAULIC SHOVEL, CRAWLER, 9.20 CY BUCKET	496 HP	D-off		$964,943	156.79	37.34	48.25	13.21	21.77	2,204
	H35OK003	RH 90 C	HYDRAULIC SHOVEL, CRAWLER, 13.10 CY BUCKET	856 HP	D-off		$1,794,531	288.02	69.43	89.73	24.56	37.57	3,484
	H35OK004	RH 120 C	HYDRAULIC SHOVEL, CRAWLER, 17.00 CY BUCKET	1,150 HP	D-off		$2,481,817	396.49	96.01	124.09	33.96	50.47	4,895
	H35OK005	RH 200	HYDRAULIC SHOVEL, CRAWLER, 34.00 CY BUCKET	2,060 HP	D-off		$5,282,062	823.06	204.34	264.10	72.29	90.41	10,582

L10 LAND CLEARING EQUIPMENT

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.00		**LAND CLEARING EQUIPMENT**										
	BALDERSON, INC.												
	L10BS004	BBL7	LAND CLEARING EQUIPMENT, ROCK & ROOT RAKE, 12.0′ WIDE, 9 TEETH (ADD D7 TRACTOR DOZER)				$8,693	1.78	0.47	0.70	0.12	0.00	24
	L10BS005	BRK8	LAND CLEARING EQUIPMENT, ROCK & ROOT RAKE 12.5′ WIDE, 9 TEETH (ADD D8 TRACTOR DOZER)				$22,934	4.33	1.25	1.83	0.33	0.00	72
	L10BS002	BMA8	LAND CLEARING EQUIPMENT, MULTI-APPLICATION RAKE, 12.5′ WIDE, 9 TEETH (ADD D8 TRACTOR DOZER)				$25,202	4.74	1.37	2.02	0.36	0.00	68

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
L10			***BALDERSON, INC. (continued)***									
	L10BS007	988 DTC	LAND CLEARING EQUIPMENT, LOGGING FORK, 92″ TINES (ADD CAT 988 FE LOADER)			$32,373	6.19	1.76	2.59	0.46	0.00	90
	L10BS006	RV8N	LAND CLEARING EQUIPMENT, V-TREE CUTTER (ADD D8 TRACTOR DOZER)			$36,023	6.73	1.95	2.88	0.51	0.00	133
			BUSH HOG									
	L10BU009	FH174	LAND CLEARING EQUIPMENT, FLAIL MOWER, 62″ WIDE, 0.5 - 5″ HEIGHT (ADD FARM 30 - 60 HP TRACTOR)			$4,370	1.67	0.24	0.35	0.06	0.00	10
	L10BU005	SM-60	LAND CLEARING EQUIPMENT, ROTARY CUTTER, 5′ WIDE-SIDE MTD (ADD FARM 50 HP TRACTOR)			$7,129	2.35	0.39	0.57	0.10	0.00	17
	L10BU010	278RP	LAND CLEARING EQUIPMENT, ROTARY CUTTER, 8′ WIDE, 2.5 - 12″ HEIGHT (ADD FARM 40 HP TRACTOR)			$5,716	1.81	0.31	0.46	0.08	0.00	13
	L10BU011	3610	LAND CLEARING EQUIPMENT, ROTARY CUTTER, 10.5′ WIDE, 2 - 14″ HEIGHT (ADD 70 HP FARM TRACTOR)			$11,587	3.54	0.63	0.93	0.16	0.00	46
	L10BU012	3615	LAND CLEARING EQUIPMENT, ROTARY CUTTER, 15′ WIDE, 2 - 14″ HEIGHT (ADD FARM 80 HP TRACTOR)			$14,733	4.59	0.80	1.18	0.21	0.00	51
	L10BU013	2620	LAND CLEARING EQUIPMENT, ROTARY CUTTER, 20′ WIDE, 2 - 14″ HEIGHT (ADD FARM 90 HP TRACTOR)			$17,880	5.64	0.97	1.43	0.25	0.00	63
			VERMEER MANUFACTURING CO.									
	L10VE010	SC 252	LAND CLEARING EQUIPMENT, STUMPER, 16″ DIA WHEEL, TRAILER MTD	25 HP G		$12,237	5.12	0.66	0.97	0.17	2.31	11

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
L10			***VERMEER MANUFACTURING CO. (continued)***										
	L10VE002	SC 630B	LAND CLEARING EQUIPMENT, STUMPER, 18″ DIA WHEEL, TRAILER MTD	34 HP	G		$12,495	6.23	0.67	0.97	0.18	3.14	17
	L10VE009	SC 672A	LAND CLEARING EQUIPMENT, STUMPER, 25″ DIA WHEEL, TRAILER MTD	65 HP	G		$24,930	12.08	1.34	1.97	0.35	6.01	33
	L10VE005	TS-30	LAND CLEARING EQUIPMENT, TREE SPADE, 30″ DIA, 24″ DEPTH, TRAILER MTD	13 HP	G		$8,893	3.12	0.48	0.69	0.13	1.20	38
	L10VE006	TS-44A	LAND CLEARING EQUIPMENT, TREE SPADE, 44″ DIA, 40″ DEPTH, TRAILER MTD	13 HP	G		$21,675	5.36	1.17	1.71	0.31	1.20	66
	L10VE007	TS-50M	LAND CLEARING EQUIPMENT, TREE SPADE, 50″ DIA, 48″ DEPTH (ADD 13,800 GVW TRUCK)				$20,640	5.13	1.12	1.65	0.29	0.00	81
L15	**LANDSCAPING EQUIPMENT**												
	SUBCATEGORY 0.00		**LANDSCAPING EQUIPMENT**										
			BOWIE INDUSTRIES, INC.										
	L15BW001	LANCER 500	LANDSCAPING EQUIPMENT, 500 GAL, HYDROMULCHER, TRAILER MTD	25 HP	G		$12,744	8.68	1.53	2.66	0.20	3.08	25
	L15BW002	VICTOR 800	LANDSCAPING EQUIPMENT, 800 GAL, HYDROMULCHER, TRAILER MTD	35 HP	G		$18,300	12.30	2.19	3.79	0.29	4.31	48
	L15BW003	VICTOR 1100	LANDSCAPING EQUIPMENT, 1,100 GAL, HYDROMULCHER, TRAILER MTD	35 HP	G		$21,621	13.59	2.59	4.50	0.34	4.31	60
	L15BW004	IMPERIAL 3000	LANDSCAPING EQUIPMENT, 3,000 GAL, HYDROMULCHER, TRUCK MTD (ADD 55,000 GVW TRUCK)	90 HP	D-off		$35,749	19.89	4.37	7.60	0.57	4.91	88

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			FINN CORPORATION										
	L15FG001	T330	LANDSCAPING EQUIPMENT, HYDROSEEDER, 3000 GAL, TRUCK MTD (INCLUDES 56,000 GVW TRUCK)	109 HP	D-off	310 HP D-off	$46,625	28.91	5.70	9.91	0.74	8.83	85
			DEERE & COMPANY										
	L15JD001	F725	LANDSCAPING EQUIPMENT, LAWNMOWER, 54″ DECK, SIDE DISCHARGE RIDING, 4 × 2	20 HP	G		$10,732	7.08	1.22	2.09	0.17	2.46	12
	L15JD002	F911	LANDSCAPING EQUIPMENT, LAWNMOWER, 60″ DECK, SIDE DISCHARGE RIDING, 4 × 2	22 HP	G		$14,724	8.93	1.70	2.93	0.23	2.71	15
	L15JD004	F935	LANDSCAPING EQUIPMENT, LAWNMOWER, 72″ DECK, SIDE DISCHARGE RIDING, 4 × 2	22 HP	D-off		$18,412	8.51	2.15	3.71	0.29	1.20	23
	L15JD003	F1145	LANDSCAPING EQUIPMENT, LAWNMOWER, 72″ DECK, SIDE DISCHARGE RIDING, 4 × 4	28 HP	D-off		$22,453	10.47	2.63	4.54	0.36	1.53	26
			TORO										
	L15TO001	SR-21SE	LANDSCAPING EQUIPMENT, LAWNMOWER, 21″ PUSH MOWER, REAR BAGGER	6 HP	G		$890	1.25	0.11	0.19	0.01	0.74	1
	L15TO002	8-25	LANDSCAPING EQUIPMENT, LAWNMOWER, 32″ DECK, RIDING MOWER	8 HP	G		$2,421	2.14	0.28	0.47	0.04	0.99	4
	L15TO003	267-H	LANDSCAPING EQUIPMENT, LAWNMOWER, 48″ DECK W/118 TRACTOR	17 HP	G		$4,740	4.39	0.56	0.96	0.08	2.09	8
	L15TO004	267-H	LANDSCAPING EQUIPMENT, LAWNMOWER, 52″ DECK W/118 TRACTOR	17 HP	G		$4,940	4.46	0.59	1.01	0.08	2.09	8
	L15TO006	30223	LANDSCAPING EQUIPMENT, LAWNMOWER, 62″ DECK W/223 TRACTOR	23 HP	G		$16,459	9.81	1.97	3.41	0.26	2.83	18

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
REGION 6													
L15			***TORO (continued)***										
	L15TO005	30243	LANDSCAPING EQUIPMENT, LAWNMOWER, 62″ DECK W/223D TRACTOR	23 HP	D-off		$20,195	9.33	2.43	4.21	0.32	1.25	20
	L15TO007	30789	LANDSCAPING EQUIPMENT, LAWNMOWER, 72″ DECK	45 HP	G		$18,125	13.78	2.18	3.77	0.29	5.54	20
	L15TO008	30795	LANDSCAPING EQUIPMENT, LAWNMOWER, 72″ DECK W/223D TRACTOR	25 HP	D-off		$22,817	10.47	2.74	4.76	0.36	1.36	25
			WILLMAR EQUIPMENT COMPANY										
	L15WI001	S-200	LANDSCAPING EQUIPMENT, SPREADER, 85 CF DRY CHEMICAL (ADD 55 HP FARM TRACTOR)				$6,074	2.37	0.73	1.25	0.10	0.00	15
L25	**LINE STRIPING EQUIPMENT**												
	SUBCATEGORY 0.00		**LINE STRIPING EQUIPMENT**										
			M-B COMPANIES, INC.										
	L25MB002	5-10A	LINE STRIPING EQUIPMENT, STRIPER, 1 GUN, WALK-BEHIND, SINGLE COLOR	5 HP	G		$3,324	2.64	0.22	0.33	0.05	0.65	6
	L25MB005	5-12	LINE STRIPING EQUIPMENT, STRIPER, 2 GUNS, WALK BEHIND, SINGLE COLOR	10 HP	G		$4,753	3.80	0.31	0.48	0.07	1.31	10
	L25MB003	6-28	LINE STRIPING EQUIPMENT, STRIPER, INTERMEDIATE 2 GUNS, SINGLE COLOR	10 HP	G		$11,035	5.62	0.71	1.10	0.16	1.31	15
	L25MB007	220	LINE STRIPING EQUIPMENT, STRIPER, 3–4 GUNS, SELF PROPELLED	23 HP	G		$36,506	13.86	2.36	3.65	0.53	3.01	30
	L25MB006	245	LINE STRIPING EQUIPMENT, STRIPER, INTERMEDIATE 3 GUNS	60 HP	G		$80,427	31.09	5.19	8.04	1.17	7.85	48

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
L25		***M-B COMPANIES, INC. (continued)***											
	L25MB004	VANMARK 360	LINE STRIPING EQUIPMENT, STRIPER, PAVING, 2-3 LINES, W/ 11,000# GVW TRUCK, TWO COLORS	190 HP	G		$102,603	57.85	6.56	10.13	1.49	24.87	116
	L25MB008	360	LINE STRIPING EQUIPMENT, STRIPER, THERMAL 120 GAL, TRUCK MTD	190 HP	G		$192,830	80.96	12.16	18.72	2.80	24.87	80
L30	**LOADERS, BELT (Conveyor belts) & ACCESSORIES**												
	SUBCATEGORY 0.00		**LOADERS, BELT (Conveyor belts) & ACCESSORIES**										
		HEWITT-ROBINS											
	L30HW015	V-11 6 × 16FT, TD	LOADER, CONVEYOR BELT & ACCESSORIES, SCREENING PLANT, W/6′ × 16′ VIBRATORY SLOPE TRIPLE DECK SCREENS/ 36″ × 16.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER	25 HP	E		$121,755	24.15	6.50	9.53	1.73	1.04	138
		KOLMAN/ATHEY DIV.											
	L30KL003		LOADER, CONVEYOR BELT & ACCESSORIES, BELT FEEDER DOZER TRAP	3 HP	D-off		$11,283	2.25	0.61	0.90	0.16	0.13	33
	L30KL013		LOADER, CONVEYOR BELT & ACCESSORIES, WING WALLS STATIONARY				$1,672	0.30	0.09	0.13	0.02	0.00	9
	L30KL018	XHD	LOADER, CONVEYOR BELT & ACCESSORIES, JACKLEG				$1,286	0.24	0.07	0.10	0.02	0.00	7

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			MORGEN MANUFACTURING CO.										
	L30MO001	303-750	LOADER, CONVEYOR BELT & ACCESSORIES, CONVEYOR, 48′, MOBILE, CONCRETE & AGGREGATE 16″ WIDE	30 HP	G		$37,845	10.81	2.02	2.95	0.54	3.00	57
	L30MO002	303-775	LOADER, CONVEYOR BELT & ACCESSORIES, CONVEYOR, 56′, MOBILE, CONCRETE & AGGREGATE 16″ WIDE	30 HP	G		$39,558	11.13	2.11	3.09	0.56	3.00	62
			METSO MINERALS										
	L30RA001	CV50D	LOADER, CONVEYOR BELT & ACCESSORIES, GRIZZLY SINGLE SCREEN, 40 CY/HR TRAILER MTD	25 HP	D-off		$52,834	11.20	2.82	4.14	0.75	1.10	130
			TELSMITH INC.										
	L30TS001	PTC 24IN × 50FT	LOADER, CONVEYOR BELT & ACCESSORIES, CONVEYOR, TRUSS FRAME, 24″WX 50′L, WHEEL MTD, 750 TPH	10 HP	E		$37,414	7.64	1.97	2.87	0.53	0.42	10
L35	**LOADERS, FRONT END, CRAWLER TYPE**												
	SUBCATEGORY 0.00		**LOADERS, FRONT END, CRAWLER TYPE**										
			CATERPILLAR INC. (MACHINE DIVISION)										
	L35CA011	933-C	LOADER, FRONT END, CRAWLER, 1.30 CY BUCKET	70 HP	D-off		$80,079	20.08	4.35	6.41	1.14	3.35	187
	L35CA012	933-C LGP HYSTAT	LOADER, FRONT END, CRAWLER, 1.30 CY BUCKET - LGP, HYSTAT	70 HP	D-off		$96,608	23.28	5.24	7.73	1.37	3.35	199

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		ENGINE HORSEPOWER FUEL TYPE CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	TOTAL HOURLY RATES ($/HR) STANDBY	ADJUSTABLE ELEMENTS DEPR	ADJUSTABLE ELEMENTS FCCM	ADJUSTABLE ELEMENTS FUEL	CWT
REGION 6													
L35	*CATERPILLAR INC. (MACHINE DIVISION) (continued)*												
	L35CA013	939-C	LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET	90 HP	D-off		$100,162	25.27	5.43	8.01	1.42	4.31	209
	L35CA005	953-C	LOADER, FRONT END, CRAWLER, 2.25 CY BUCKET	121 HP	D-off		$175,309	41.85	9.50	14.02	2.49	5.79	319
	L35CA014	963-C	LOADER, FRONT END, CRAWLER, 3.20 CY BUCKET	160 HP	D-off		$224,523	53.94	12.17	17.96	3.19	7.66	433
	L35CA007	973	LOADER, FRONT END, CRAWLER, 3.70 CY BUCKET	208 HP	D-off		$340,534	79.56	18.46	27.24	4.84	9.96	601
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	L35KM006	D75S-5	LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET, PS	200 HP	D-off		$379,345	86.58	20.57	30.35	5.39	9.58	483
L40	**LOADERS, FRONT END, WHEEL TYPE**												
	SUBCATEGORY 0.11		**ARTICULATED, 0 THRU 225 HP**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	L40CA032	902	LOADER, FRONT END, WHEEL, 0.80 CY BUCKET, GENERAL PURPOSE	45 HP	D-off		$67,659	14.36	3.66	5.31	1.00	1.98	96
	L40CA033	906	LOADER, FRONT END, WHEEL, 1.00 CY BUCKET, GENERAL PURPOSE	60 HP	D-off		$74,577	16.40	4.04	5.87	1.10	2.63	111
	L40CA034	908	LOADER, FRONT END, WHEEL, 1.30 CY BUCKET, GENERAL PURPOSE	82 HP	D-off		$81,995	21.07	4.36	6.29	1.21	3.60	133
	L40CA019	914G	LOADER, FRONT END, WHEEL, 1.70 CY BUCKET, ARTICULATED, 4 × 4	89 HP	D-off		$93,369	21.95	5.06	7.35	1.38	3.91	157
	L40CA022	924GZ	LOADER, FRONT END, WHEEL, 2.20 CY BUCKET, ARTICULATED, 4 × 4	112 HP	D-off		$107,696	25.82	5.84	8.49	1.59	4.92	218

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
L35	*CATERPILLAR INC. (MACHINE DIVISION) (continued)*												
	L40CA015	928G	LOADER, FRONT END, WHEEL, 2.50 CY BUCKET, ARTICULATED, 4 × 4	125 HP	D-off		$128,447	30.02	6.98	10.17	1.89	5.49	257
	L40CA023	938G	LOADER, FRONT END, WHEEL, 3.25 CY BUCKET, ARTICULATED, 4 × 4	160 HP	D-off		$157,954	38.44	8.48	12.30	2.33	7.02	289
	L40CA024	950G	LOADER, FRONT END, WHEEL, 3.50 CY BUCKET, ARTICULATED, 4 × 4	180 HP	D-off		$207,823	48.97	11.13	16.13	3.06	7.90	392
	L40CA025	962G	LOADER, FRONT END, WHEEL, 4.00 CY BUCKET, ARTICULATED, 4 × 4	200 HP	D-off		$216,315	51.59	11.60	16.82	3.19	8.78	405
	CASE CORPORATION												
	L40CS009	621D	LOADER, FRONT END, WHEEL, 2.60 CY BUCKET, 4 × 4, ARTICULATED	134 HP	D-off		$135,864	32.85	7.29	10.57	2.00	5.88	256
	L40CS010	721C	LOADER, FRONT END, WHEEL, 2.75 CY BUCKET, 4 × 4, ARTICULATED	152 HP	D-off		$160,223	37.97	8.64	12.55	2.36	6.67	296
	L40CS011	821C	LOADER, FRONT END, WHEEL, 3.67 CY BUCKET, 4 × 4, ARTICULATED	187 HP	D-off		$213,625	50.17	11.47	16.64	3.15	8.21	379
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	L40KM014	WA65-3	LOADER, FRONT END, WHEEL, 0.92 CY BUCKET, GENERAL PURPOSE	50 HP	D-off		$60,330	13.59	3.23	4.67	0.89	2.19	93
	L40KM015	WA95-3	LOADER, FRONT END, WHEEL, 1.40 CY BUCKET, GENERAL PURPOSE	75 HP	D-off		$74,423	17.63	3.98	5.75	1.10	3.29	128
	L40KM001	WA120-3L3	LOADER, FRONT END, WHEEL, 1.85 CY BUCKET, ARTICULATED, 4 × 4	105 HP	D-off		$117,519	27.17	6.36	9.25	1.73	4.61	181
	L40KM002	WA180-3L	LOADER, FRONT END, WHEEL, 2.25 CY BUCKET, ARTICULATED, 4 × 4	118 HP	D-off		$135,840	30.98	7.37	10.74	2.00	5.18	206

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
L40	***KOMATSU AMERICA INTERNATIONAL COMPANY (continued)***											
	L40KM003	WA250-3MC	LOADER, FRONT END, WHEEL, 2.50 CY BUCKET, ARTICULATED, 4 × 4	135 HP D-off		$164,188	36.69	8.94	13.04	2.42	5.93	248
	L40KM004	WA320-3MC	LOADER, FRONT END, WHEEL, 3.50 CY BUCKET, ARTICULATED, 4 × 4	173 HP D-off		$193,644	45.09	10.45	15.19	2.85	7.59	312
	L40KM005	WA380-3MC	LOADER, FRONT END, WHEEL, 4.25 CY BUCKET, ARTICULATED, 4 × 4	205 HP D-off		$249,755	57.73	13.41	19.46	3.68	9.00	393
	SUBCATEGORY 0.12		**ARTICULATED, OVER 225 HP**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	L40CA026	966G	LOADER, FRONT END, WHEEL, 4.75 CY BUCKET, ARTICULATED, 4 × 4	233 HP D-off		$290,307	53.72	12.28	16.52	4.02	10.23	497
	L40CA027	972G	LOADER, FRONT END, WHEEL, 5.25 CY BUCKET, ARTICULATED, 4 × 4	265 HP D-off		$319,631	58.08	13.61	18.37	4.42	11.63	550
	L40CA007	980G	LOADER, FRONT END, WHEEL, 6.00 CY BUCKET, ARTICULATED, 4 × 4	300 HP D-off		$400,092	72.39	16.95	22.82	5.54	13.17	645
	L40CA008	988F SERIES II	LOADER, FRONT END, WHEEL, 9.00 CY BUCKET, ARTICULATED, 4 × 4	430 HP D-off		$585,293	101.92	24.67	33.13	8.10	18.87	968
	L40CA018	990 SERIES II	LOADER, FRONT END, WHEEL, 11.00 CY BUCKET, ARTICULATED, 4 × 4	625 HP D-off		$977,655	159.22	41.10	55.13	13.53	27.43	1,628
	L40CA009	992-D	LOADER, FRONT END, WHEEL, 15.00 CY BUCKET, ARTICULATED, 4 × 4	800 HP D-off		$1,357,667	216.13	57.31	77.05	18.78	35.11	2,023
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	L40KM006	WA420-3MC	LOADER, FRONT END, WHEEL, 4.80 CY BUCKET, ARTICULATED, 4 × 4	230 HP D-off		$277,592	50.78	11.80	15.91	3.84	10.09	428

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
L40	***KOMATSU AMERICA INTERNATIONAL COMPANY (continued)***												
	L40KM007	WA450-3MC	LOADER, FRONT END, WHEEL, 5.50 CY BUCKET, ARTICULATED, 4 × 4	271 HP	D-off		$330,837	59.07	13.96	18.75	4.58	11.89	502
	L40KM008	WA500-3L	LOADER, FRONT END, WHEEL, 6.50 CY BUCKET, ARTICULATED, 4 × 4	335 HP	D-off		$455,855	78.62	19.29	25.96	6.31	14.70	663
	L40KM009	WA600-3L	LOADER, FRONT END, WHEEL, 8.00 CY BUCKET, ARTICULATED, 4 × 4	490 HP	D-off		$605,951	104.90	25.38	33.99	8.38	21.51	997
	L40KM010	WA700-3L	LOADER, FRONT END, WHEEL, 11.10 CY BUCKET, ARTICULATED, 4 × 4	684 HP	D-off		$1,178,373	185.78	49.99	67.38	16.30	30.02	1,511
	L40KM011	WA800-3LC	LOADER, FRONT END, WHEEL, 13.10 CY BUCKET, ARTICULATED, 4 × 4	853 HP	D-off		$1,518,414	238.80	64.22	86.42	21.01	37.44	2,192
	SUBCATEGORY 0.20		**SKID STEER**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	L40CA028	216	LOADER, FRONT END, WHEEL, SKID-STEER, 13.0 CF, 23 CWT, 60″ BUCKET, 4 × 4	49 HP	D-off		$23,503	8.26	1.48	2.27	0.34	2.35	55
	L40CA029	226	LOADER, FRONT END, WHEEL, SKID-STEER, 13.0 CF, 25 CWT, 60″ BUCKET, 4 × 4	54 HP	D-off		$24,590	8.82	1.55	2.38	0.36	2.59	57
	L40CA030	236	LOADER, FRONT END, WHEEL, SKID-STEER, 14.0 CF, 40 CWT, 66″ BUCKET, 4 × 4	59 HP	D-off		$29,700	10.25	1.86	2.86	0.43	2.82	71
	L40CA031	246	LOADER, FRONT END, WHEEL, SKID-STEER, 15.4 CF, 40 CWT, 72″ BUCKET, 4 × 4	74 HP	D-off		$31,477	11.62	1.98	3.03	0.46	3.54	74
	MELROSE COMPANY/BOBCAT												
	L40ME016	453	LOADER, FRONT END, WHEEL, SKID-STEER, 6.5 CF, 44″ BUCKET	16 HP	D-off		$11,750	3.50	0.74	1.14	0.17	0.75	25

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
L40		***MELROSE COMPANY/BOBCAT (continued)***										
	L40ME017	553	LOADER, FRONT END, WHEEL, SKID-STEER, 6.7 CF, 48″ BUCKET	23 HP D-off		$15,483	4.82	0.98	1.49	0.23	1.08	37
	L40ME012	753	LOADER, FRONT END, WHEEL, SKID-STEER, 13.0 CF, 1,300 LBS, 60″ BUCKET	44 HP D-off		$19,946	7.09	1.27	1.95	0.29	2.08	48
	L40ME018	751	LOADER, FRONT END, WHEEL, SKID-STEER, 14.3 CF, 60″ BUCKET	38 HP D-off		$17,416	6.20	1.10	1.69	0.25	1.82	48
	L40ME019	863	LOADER, FRONT END, WHEEL, SKID-STEER, 16.3 CF, 66″ BUCKET	73 HP D-off		$27,537	10.76	1.72	2.64	0.40	3.50	70
	L40ME020	963	LOADER, FRONT END, WHEEL, SKID-STEER, 23.3 CF, 3,000 LBS, 78″ BUCKET	105 HP D-off		$46,612	17.16	2.87	4.38	0.68	5.03	99
	SUBCATEGORY 0.31		**TOOL CARRIER & TELESCOPIC HANDLERS, 0 THRU 225 HP**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	L40CA013	IT14G	LOADER, WHEEL, INTEGRATED TOOL CARRIER, 1.75 CY LOADER; 6,303 LB @ 12.17′ HIGH, FORK LIFT, OR 1,841 LB @ 22.42′ HIGH, MATERIAL HANDLING ARM	90 HP D-off		$106,247	24.38	5.45	7.77	1.56	3.95	172
	L40CA012	IT28G	LOADER, WHEEL, INTEGRATED TOOL CARRIER, 2.50 CY LOADER; 10,640 LB @ 12.58′ HIGH FORK LIFT, OR 3,195 LB @ 23.25′ HIGH, MATERIAL HANDLING ARM	125 HP D-off		$141,824	32.54	7.29	10.41	2.08	5.49	235
	L40CA014	IT62G	LOADER, WHEEL, INTEGRATED TOOL CARRIER, 4.25 CY LOADER; 13,670 LB @ 12.42′ HIGH, FORK LIFT, OR 5,040 LB @ 22.67′ HIGH, MATERIAL HANDLING ARM	200 HP D-off		$243,340	54.36	12.55	17.97	3.56	8.78	404

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	KOMATSU AMERICA INTERNATIONAL COMPANY											
	L40KM012	WA180-3 PTC	LOADER, WHEEL, INTEGRATED TOOL CARRIER, 2.25 CY LOADER; 4,966 LB @ 12.00′ HIGH, FORK LIFT; OR 2,306 LB @ 18.50′ HIGH, MATERIAL HANDLING ARM	118 HP D-off		$140,348	32.05	7.20	10.27	2.06	5.18	172
	L40KM013	WA250-3 PTC	LOADER, WHEEL, INTEGRATED TOOL CARRIER, 2.50 CY LOADER; 6,068 LB @ 12.25′ HIGH, FORK LIFT; OR 6,669 LB @ 23.17′ HIGH, MATERIAL HANDLING ARM	135 HP D-off		$163,811	38.35	8.30	11.79	2.40	5.93	235
L50	**LOADERS/BACKHOE, WHEEL TYPE**											
	SUBCATEGORY 0.00		**LOADERS/BACKHOE, WHEEL TYPE**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	L50CA001	416C	LOADER/BACKHOE, WHEEL, 1.00 CY FRONT END BUCKET, 24″ DIP, 4.5 CF, 14.5′ DIGGING DEPTH, 4 × 2	80 HP D-off		$76,018	16.22	3.89	5.56	1.11	2.77	145
	L50CA002	426C	LOADER/BACKHOE, WHEEL, 1.25 CY FRONT END BUCKET, 24″ DIP, 7.0 CF, 15.5′ DIGGING DEPTH, 4 × 2	85 HP D-off		$85,087	17.91	4.37	6.24	1.25	2.94	159
	L50CA003	436C	LOADER/BACKHOE, WHEEL, 1.38 CY FRONT END BUCKET, 30″ DIP, 9.5 CF, 16.2′ DIGGING DEPTH, 4 × 2	93 HP D-off		$91,637	19.37	4.70	6.72	1.34	3.22	160
	L50CA004	446B	LOADER/BACKHOE, WHEEL, 1.50 CY FRONT END BUCKET, 36″ DIP, 19 CF, 17.1′ DIGGING DEPTH, 4 × 2	110 HP D-off		$124,714	25.64	6.38	9.10	1.83	3.80	193

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
		CASE CORPORATION										
	L50CS004	580L SERIES 2	LOADER/BACKHOE, WHEEL, 1.00 CY FRONT END BUCKET, 24″ DIP, 4 × 4, EXTENDAHOE	73 HP D-off		$84,812	17.30	4.36	6.23	1.24	2.52	125
	L50CS005	580 SUPER M	LOADER/BACKHOE, WHEEL, 1.00 CY FRONT END BUCKET, 24″ DIP, 4 × 4	90 HP D-off		$92,396	19.34	4.74	6.77	1.35	3.11	163
	L50CS006	590 SUPER M	LOADER/BACKHOE, WHEEL, 1.25 CY FRONT END BUCKET, 24″ DIP, 4 × 4, EXTENDAHOE	99 HP D-off		$105,614	22.09	5.37	7.64	1.55	3.42	169
		JCB INC.										
	L50JC001	210S SERIES 2	LOADER/BACKHOE, WHEEL, 0.80 CY FRONT END BUCKET, 24″ DIPPER, 4WD	60 HP D-off		$58,156	12.64	2.92	4.13	0.85	2.07	106
	L50JC002	214S SERIES 4	LOADER/BACKHOE, WHEEL, 1.25 CY FRONT END BUCKET, 24″ DIPPER, 2WD	72 HP D-off		$55,015	12.55	2.76	3.89	0.81	2.49	132
	L50JC003	214S SERIES 3	LOADER/BACKHOE, WHEEL, 1.40 CY FRONT END BUCKET, 24″ DIPPER, 4WD	92 HP D-off		$79,247	17.48	4.02	5.72	1.16	3.18	164
	L50JC005	215S SERIES 3	LOADER/BACKHOE, WHEEL, 1.40 CY FRONT END BUCKET, 24″ DIPPER, 4WD	92 HP D-off		$87,061	18.76	4.44	6.31	1.28	3.18	176
	L50JC007	217S SERIES 3	LOADER/BACKHOE, WHEEL, 1.60 CY FRONT END BUCKET, 24″ DIPPER, 4WD	92 HP D-off		$111,597	22.72	5.71	8.16	1.63	3.18	178
L55	**LOADER/BACKHOE, ATTACHMENTS**											
	SUBCATEGORY 0.00		**LOADER/BACKHOE, ATTACHMENTS**									
		KENT DEMOLITION TOOLS										
	L55KN001	KB-555	LOADER/BACKHOE, ATTACHMENTS, AIR RAM W/ NARROW CHISEL, 2.5″ DIA, 30″ LONG (ADD 175 CFM COMPRESSOR & LDR/BH)	175 CFM A		$6,879	2.59	0.56	0.92	0.10	0.00	6

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
L55		***KENT DEMOLITION TOOLS (continued)***										
	L55KN002	KB-999	LOADER/BACKHOE, ATTACHMENTS, AIR RAM W/NARROW CHISEL, 3.5″ DIA, 36″ LONG (ADD 250 CFM COMPRESSOR & LDR/BH)	250 CFM A		$14,082	5.29	1.15	1.88	0.21	0.00	10
	L55KN003	KB-2600	LOADER/BACKHOE, ATTACHMENTS, AIR RAM W/NARROW CHISEL, 5.25″ DIA, 48″ LONG (ADD 750 CFM COMPRESSOR & LDR/BH)	750 CFM A		$28,698	10.64	2.35	3.83	0.43	0.00	22
L60	**LOG SKIDDERS**											
	SUBCATEGORY 0.00		**LOG SKIDDERS**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	L60CA014	517 GRAPPLE	LOG SKIDDER, 8 SF GRAPPLE, CABLE 69,200# LINE-PULL & WINCH, CRAWLER	120 HP D-off		$233,862	44.90	13.16	19.88	3.22	5.27	364
	L60CA012	515	LOG SKIDDER, 8 SF GRAPPLE, CABLE 30,000# LINE-PULL & WINCH, WHEEL, 4 × 2	140 HP D-off		$148,382	32.93	8.12	12.15	2.04	6.14	262
	L60CA013	525	LOG SKIDDER, 11 SF GRAPPLE, CABLE 43,000# LINE-PULL & WINCH, WHEEL, 4 × 2	160 HP D-off		$177,828	38.86	9.78	14.65	2.45	7.02	284
	L60CA010	527 CABLE	LOG SKIDDER, CABLE 69,200# LINE-PULL AND WINCH, BLADE, CRAWLER	150 HP D-off		$263,965	51.47	14.85	22.44	3.63	6.58	404
	L60CA011	527 GRAPPLE	LOG SKIDDER, 10 SF GRAPPLE, CABLE 69,200# LINE-PULL & WINCH, CRAWLER	150 HP D-off		$291,510	55.98	16.40	24.78	4.01	6.58	417

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	REGION 6											
		DEERE & COMPANY										
	L60JD001	540G - SKIDDER	LOG SKIDDER, CABLE, 40525# LINE-PULL WINCH AND BLADE, WHEEL, 4 × 4	121 HP D-off		$124,469	28.47	6.76	10.09	1.71	5.31	217
	L60JD003	548G GRAPPLE	LOG SKIDDER, 8.0 SF GRAPPLE WITH BLADE, WHEEL, 4 × 4	121 HP D-off		$127,341	28.95	6.92	10.34	1.75	5.31	251
	L60JD004	648G GRAPPLE	LOG SKIDDER, 10.4 SF GRAPPLE WITH BLADE, WHEEL, 4 × 4	157 HP D-off		$156,543	37.10	8.32	12.34	2.15	6.89	288
	L60JD002	640G SKIDDER	LOG SKIDDER, CABLE, 48767# LINE-PULL WINCH AND BLADE, WHEEL, 4 × 4	157 HP D-off		$183,533	40.12	10.08	15.11	2.52	6.89	239
	L60JD006	643G	LOG SKIDDER, LOG FELLER/ BUNCHER, 18″ DIA TREE SAW CUTTER, WHEEL, 4 × 4	170 HP D-off		$208,022	45.55	11.34	16.95	2.86	7.46	320
	L60JD008	653G	LOG SKIDDER, LOG FELLER/ BUNCHER, 28″ DIA TREE SAW CUTTER, CRAWLER	170 HP D-off		$294,346	57.55	16.56	25.02	4.05	7.46	410
	L60JD007	843G	LOG SKIDDER, LOG FELLER/ BUNCHER, 20″ DIA TREE SAW CUTTER, WHEEL, 4 × 4	200 HP D-off		$221,268	49.37	12.08	18.08	3.04	8.78	323
M10	**MARINE EQUIPMENT (NON DREDGING)**											
	SUBCATEGORY 0.41		WORK FLOATS (NON-DREDGING)									
		MARINE INLAND FABRICATORS										
	M10MZ001		MARINE EQUIPMENT, WORK FLOAT, MEDIUM DUTY, 20′ × 8′ × 2′			$5,710	1.39	0.51	0.86	0.08	0.00	43
	M10MZ003		MARINE EQUIPMENT, WORK FLOAT, MEDIUM DUTY, 20′ × 10′ × 3′			$7,441	1.81	0.67	1.12	0.11	0.00	82

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.42		WORK BARGES (SECTIONAL, NON-DREDGING)									
		MARINE INLAND FABRICATORS										
	M10MZ005	RAKE	MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY', W/ONE BUCKHEAD & SPUDS, 40′ × 12′ × 4′			$20,864	1.28	0.58	0.63	0.26	0.00	193
	M10MZ007		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 50′ × 14′ × 4′			$26,318	1.60	0.72	0.79	0.32	0.00	273
	M10MZ008		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 55′ × 14′ × 5′			$33,132	2.02	0.91	0.99	0.41	0.00	319
	M10MZ009		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 60′ × 16′ × 5′			$39,574	2.42	1.09	1.19	0.49	0.00	388
		NO SPECIFIC MANUFACTURER										
	M10XX001		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, BOW & STERN SECTIONS			$5,178	0.32	0.14	0.16	0.06	0.00	1
	M10XX002		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, LOADING RAMPS			$16,106	0.98	0.44	0.48	0.20	0.00	1
	M10XX003		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MID-SECTION, 20′ × 10′, 5 FT DEPTH			$19,454	1.19	0.53	0.58	0.24	0.00	1
	M10XX004		MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MID-SECTION, 40′ × 10′, 5 FT DEPTH			$31,513	1.93	0.87	0.95	0.39	0.00	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.45		**FLAT-DECK OR CARGO BARGE (NON-DREDGING)**									
		NO SPECIFIC MANUFACTURER										
	M10XX005		MARINE EQUIPMENT, FLAT-DECK CARGO BARGE, 120 FT LENGTH, 30 FT BEAM, 7.25 FT DEPTH, 400 TON			$136,052	3.84	2.27	1.44	1.55	0.00	1
	M10XX006		MARINE EQUIPMENT, FLAT-DECK CARGO BARGE, 120 FT LENGTH, 45 FT BEAM, 7.00 FT DEPTH, 800 TON			$191,494	5.40	3.19	2.02	2.18	0.00	1
	M10XX007		MARINE EQUIPMENT, FLAT-DECK CARGO BARGE, 140 FT LENGTH, 45 FT BEAM, 7.00 FT DEPTH, 900 TON			$242,358	6.84	4.04	2.56	2.76	0.00	1
	M10XX008		MARINE EQUIPMENT, FLAT-DECK CARGO BARGE, 150 FT LENGTH, 45 FT BEAM, 9.00 FT DEPTH, 1,100 TON			$338,053	9.53	5.64	3.57	3.85	0.00	1
	SUBCATEGORY 0.48		**ALL OTHER BARGES (NON-DREDGING)**									
		NO SPECIFIC MANUFACTURER										
	M10XX016	OPEN 195	MARINE EQUIPMENT, ALL OTHER BARGES, HOPPER, 195 FT LENGTH, 35 FT BEAM, 12 FT DEPTH, 1,400 TON			$203,287	13.28	5.61	6.44	2.39	0.00	1
	M10XX017	OPEN 200	MARINE EQUIPMENT, ALL OTHER BARGES, HOPPER, 200 FT LENGTH, 35 FT BEAM, 12 FT DEPTH, 1,600 TON			$214,932	14.05	5.94	6.81	2.53	0.00	1
	M10XX018	CLOSED 195	MARINE EQUIPMENT, ALL OTHER BARGES, HOPPER, 195 FT LENGTH, 35 FT BEAM, 12 FT DEPTH, 1,400 TON			$267,716	17.49	7.39	8.48	3.15	0.00	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
M10		***NO SPECIFIC MANUFACTURER (continued)***											
	M10XX019	CLOSED 200	MARINE EQUIPMENT, ALL OTHER BARGES, HOPPER, 200 FT LENGTH, 35 FT BEAM, 12 FT DEPTH, 1,600 TON				$273,575	17.87	7.55	8.66	3.22	0.00	1
	SUBCATEGORY 0.51		**BOATS & LAUNCHES, 0 THRU 250 HP**										
		MARINE INLAND FABRICATORS											
	M10MZ010	COLT	MARINE EQUIPMENT, BOATS & LAUNCHES, TRUCKABLE WORKBOAT W/PILOT HOUSE & PUSH KNEES, 20′ 3″ × 8′ × 3′	140 HP	D-off		$34,913	12.06	1.39	1.85	0.46	6.14	95
	M10MZ011	MUSTANG	MARINE EQUIPMENT, BOATS & LAUNCHES, TRUCKABLE WORKBOAT W/PILOT HOUSE & PUSH KNEES, 25′ 3″ × 10′ × 3′6″	210 HP	D-off		$45,244	17.35	1.80	2.40	0.60	9.22	190
		SEAARK MARINE											
	M10SM005	18′	MARINE EQUIPMENT, BOATS & LAUNCHES, 18′ RIVER RUNNER, VEE HULL, NO CABIN, CAP 1,350 LBS, OUTBOARD ENGINE	115 HP	G		$20,072	17.10	0.80	1.07	0.26	11.51	15
	M10SM008	19′	MARINE EQUIPMENT, BOATS & LAUNCHES, 19′ ROUSTABOUT, TRI HULL, NO CABIN, CAP 2,600 LBS, OUTBOARD ENGINE	200 HP	G		$37,402	30.02	1.49	1.99	0.49	20.02	17
	M10SM001	17′	MARINE EQUIPMENT, BOATS & LAUNCHES, 17′ LITTLE GIANT, W/CABIN TRI-HULL, CAP 2,000 LBS, OUTBOARD	150 HP	G		$44,528	24.29	1.78	2.37	0.59	15.02	18
	M10SM003	21′	MARINE EQUIPMENT, BOATS & LAUNCHES, 21′ LITTLE GIANT, W/CABIN TRI-HULL, CAP 2,800 LBS, OUTBOARD	200 HP	G		$49,760	31.34	1.98	2.64	0.66	20.02	24

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
M10		***SEAARK MARINE (continued)***											
	M10SM004	23′	MARINE EQUIPMENT, BOATS & LAUNCHES, 23′ LITTLE GIANT, W/CABIN TRI-HULL, CAP 3,400 LBS, STERN DRIVE	250 HP	G		$54,410	38.34	2.17	2.89	0.72	25.03	28
		NO SPECIFIC MANUFACTURER											
	M10XX010	12	MARINE EQUIPMENT, BOATS & LAUNCHES, 12′ TENDER, 7′ BEAM, INBOARD ENGINE, 75 HP	75 HP	D-off		$40,381	8.80	1.61	2.15	0.53	3.29	1
	M10XX009	13	MARINE EQUIPMENT, BOATS & LAUNCHES, 13′ RUNABOUT, 5′ BEAM, OUTBOARD ENGINE, 50 HP	50 HP	G		$11,988	7.80	0.48	0.64	0.16	5.01	13
	M10XX011	14	MARINE EQUIPMENT, BOATS & LAUNCHES, 14′ TENDER, 7′ BEAM, INBOARD ENGINE, 100 HP	100 HP	D-off		$46,307	10.92	1.84	2.46	0.61	4.39	13
	M10XX012	100	MARINE EQUIPMENT, BOATS & LAUNCHES, 16 FT, SHALLOW DRAFT, 100 HP, INLAND TUG	100 HP	D-off		$47,735	11.08	1.90	2.54	0.63	4.39	13
	M10XX013	115	MARINE EQUIPMENT, BOATS & LAUNCHES, 22 FT, SHALLOW DRAFT, 115 HP, INLAND TUG	115 HP	D-off		$61,824	13.48	2.46	3.28	0.82	5.05	23
	M10XX014	175	MARINE EQUIPMENT, BOATS & LAUNCHES, 18 FT, W/STEERING NOZZLE, 175 HP, INLAND TUG	175 HP	D-off		$84,828	19.51	3.38	4.51	1.12	7.68	60
	M10XX015	250	MARINE EQUIPMENT, BOATS & LAUNCHES, 26 FT, W/STEERING NOZZLE, 250 HP, INLAND TUG	250 HP	D-off		$106,326	26.28	4.23	5.65	1.40	10.97	83
	SUBCATEGORY 0.53		**BOATS & LAUNCHES, 251 THRU 500 HP**										
		NO SPECIFIC MANUFACTURER											
	M10XX021	380	MARINE EQUIPMENT, BOATS & LAUNCHES, 40 FT, STANDARD RUDDER, 380 HP, INLAND TUG	380 HP	D-off		$282,941	51.46	10.39	13.36	3.71	16.68	100

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
M10	***NO SPECIFIC MANUFACTURER (continued)***											
	M10XX022	435	MARINE EQUIPMENT, BOATS & LAUNCHES, 45 FT LENGTH, 16 FT BEAM, 5′0″ DRAFT, 435 HP, PUSH BOAT	435 HP D-off		$322,086	58.73	11.83	15.21	4.22	19.09	100
	M10XX023	400	MARINE EQUIPMENT, BOATS & LAUNCHES, 48 FT LENGTH, 20 FT BEAM, 6′6″ DRAFT, 435 HP, PUSH BOAT	400 HP D-off		$431,692	67.84	15.86	20.39	5.66	17.56	100
	M10XX024	435	MARINE EQUIPMENT, BOATS & LAUNCHES, 58 FT LENGTH, 21 FT BEAM, 6′0″ DRAFT, 435 HP, PUSH BOAT	435 HP D-off		$615,618	88.68	22.61	29.07	8.07	19.09	130
	SUBCATEGORY 0.54		**TUGS, 501 THRU 1,000 HP**									
	NO SPECIFIC MANUFACTURER											
	M10XX026	700	MARINE EQUIPMENT, TUGS, 51 FT, TWIN SCREW, 700 HP, INLAND TUG	700 HP D-off		$398,416	61.02	9.28	8.47	5.04	28.86	190
	M10XX027	525	MARINE EQUIPMENT, TUGS, 54 FT LENGTH, 21 FT BEAM, 6′0″ DRAFT, 525 HP, PUSH BOAT	525 HP D-off		$454,381	54.33	10.58	9.66	5.75	21.65	160
	M10XX028	55	MARINE EQUIPMENT, TUGS, 55 FT LENGTH, 20 FT BEAM, 5′0″ DRAFT, 80 T, 870 HP, TOW BOAT	870 HP D-off		$474,989	74.71	11.06	10.09	6.01	35.87	200
	M10XX029	705	MARINE EQUIPMENT, TUGS, 58 FT LENGTH, 24 FT BEAM, 7′6″ DRAFT, 705 HP, PUSH BOAT	705 HP D-off		$625,603	73.80	14.57	13.29	7.92	29.07	190
	M10XX030	62	MARINE EQUIPMENT, TUGS, 62 FT LENGTH, 22 FT BEAM, 5′0″ DRAFT, 80 T, 870 HP, TOW BOAT	870 HP D-off		$661,160	84.97	15.40	14.05	8.37	35.87	200

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
M10		***NO SPECIFIC MANUFACTURER (continued)***										
	M10XX031	870	MARINE EQUIPMENT, TUGS, 64 FT LENGTH, 25 FT BEAM, 8′0″ DRAFT, 870 HP, PUSH BOAT	870 HP D-off		$683,564	86.20	15.92	14.53	8.65	35.87	200
	M10XX032	65	MARINE EQUIPMENT, TUGS, 65 FT LENGTH, 22 FT BEAM, 7′6″ DRAFT, 80 T, 870 HP, TOW BOAT	870 HP D-off		$851,835	95.46	19.83	18.10	10.78	35.87	1
	SUBCATEGORY 0.55		**TUGS, 1,000 THRU 2,000 HP**									
		NO SPECIFIC MANUFACTURER										
	M10XX033	60 21	MARINE EQUIPMENT, TUGS, 60 FT LENGTH, 21 FT BEAM, 5′0″ DRAFT, 80 T, 1050 HP, TOW BOAT	1,050 HP D-off		$566,546	84.17	11.49	8.76	7.11	43.29	1
	M10XX034	70 30	MARINE EQUIPMENT, TUGS, 70 FT LENGTH, 30 FT BEAM, 7′6″ DRAFT, 80 T, 1350 HP, TOW BOAT	1,350 HP D-off		$1,041,305	122.33	21.12	16.09	13.07	55.66	1
	M10XX035	1950	MARINE EQUIPMENT, TUGS, 100 FT LENGTH, 35 FT BEAM, 8′0″ DRAFT, 1950 HP, PUSH BOAT	1,950 HP D-off		$1,322,557	168.52	26.82	20.44	16.60	80.40	1
	M10XX036	120	MARINE EQUIPMENT, TUGS, 120 FT LENGTH, 34 FT BEAM, 8′0″ DRAFT, 80 T, 2000 HP, TOW BOAT	2,000 HP D-off		$2,784,454	237.21	56.47	43.03	34.95	82.46	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
P10	**PILE HAMMER ACCESSORIES - EXTRACTORS & BOX LEADS**											
	SUBCATEGORY 0.00		**PILE HAMMER ACCESSORIES - EXTRACTORS & BOX LEADS**									
		INTERNATIONAL CONSTRUCTION EQUIPMENT, INC										
	P10IC001	216	PILE HAMMER ACCESSORIES, PILE EXTRACTOR, 30 TON LINE PULL (ADD LEADS & CRANE)	175 HP D-off		$99,208	34.42	6.99	10.75	1.61	7.68	130
	P10IC002	416L	PILE HAMMER ACCESSORIES, PILE EXTRACTOR, 40 TON LINE PULL (ADD LEADS & CRANE)	300 HP D-off		$156,171	55.59	11.00	16.92	2.54	13.17	207
	P10IC003	612	PILE HAMMER ACCESSORIES, PILE EXTRACTOR, 40 TON LINE PULL (ADD LEADS & CRANE)	300 HP D-off		$196,222	65.46	13.82	21.26	3.19	13.17	235
	P10IC004	815	PILE HAMMER ACCESSORIES, PILE EXTRACTOR, 50 TON LINE PULL (ADD LEADS & CRANE)	503 HP D-off		$251,010	90.52	17.68	27.19	4.08	22.08	316
	P10IC005	1412B	PILE HAMMER ACCESSORIES, PILE EXTRACTOR, 150 TON LINE PULL (ADD LEADS & CRANE)	800 HP D-off		$401,019	144.42	28.25	43.44	6.53	35.11	525
	P10IC010		PILE HAMMER ACCESSORIES, PILE LEADS, SWING, 26″ × 86′			$20,830	5.14	1.47	2.26	0.34	0.00	101
	P10IC012		PILE HAMMER ACCESSORIES, PILE LEADS, SWING, 32″ × 88′			$25,208	6.21	1.78	2.73	0.41	0.00	155
	P10IC011		PILE HAMMER ACCESSORIES, PILE LEADS, FIXED, 26″ × 86′, W/SPOTTER	13 HP D-off		$40,143	10.63	2.83	4.35	0.65	0.57	134

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P10	***INTERNATIONAL CONSTRUCTION EQUIPMENT, INC (continued)***											
	P10IC013		PILE HAMMER ACCESSORIES, PILE LEADS, FIXED, 32″ × 88′, W/SPOTTER	13 HP G		$43,637	12.45	3.08	4.73	0.71	1.30	193
P20	**PILE HAMMERS, DOUBLE ACTING**											
	SUBCATEGORY 0.10		**DIESEL**									
	INTERNATIONAL CONSTRUCTION EQUIPMENT, INC											
	P20IC001	180	PILE HAMMER, DOUBLE ACTING, DIESEL, 8,100 FT-LBS, MAX STROKE 4′9″ (ADD LEADS & CRANE)			$41,252	13.96	3.22	5.16	0.64	0.00	52
	P20IC002	440	PILE HAMMER, DOUBLE ACTING, DIESEL, 18,100 FT-LBS, MAX STROKE 4′8″ (ADD LEADS & CRANE)			$94,926	31.14	7.41	11.87	1.47	0.00	122
	P20IC003	520	PILE HAMMER, DOUBLE ACTING, DIESEL, 30,000 FT-LBS, MAX STROKE 5′11″ (ADD LEADS & CRANE)			$91,110	30.56	7.11	11.39	1.41	0.00	159
	P20IC004	640	PILE HAMMER, DOUBLE ACTING, DIESEL, 40,000 FT-LBS, MAX STROKE 6′8″ (ADD LEADS & CRANE)			$96,924	33.00	7.56	12.12	1.50	0.00	169
	MKT MANUFACTURING, INC.											
	P20MK001	DA-15C	PILE HAMMER, DOUBLE ACTING, DIESEL, 8,200 FT-LBS, MAX STROKE 10′–6″ (ADD LEADS & CRANE)			$49,095	16.37	3.83	6.14	0.76	0.00	60

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.20		PNUEMATIC (STEAM/AIR)										
		MKT MANUFACTURING, INC.											
	P20MK002	5	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 1,000 FT-LBS, MAX STROKE 7″ (ADD 250 CFM COMPRESSOR, LEADS & CRANE)	250 CFM	A		$21,273	7.22	1.74	2.84	0.32	0.00	17
	P20MK003	6	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 2,500 FT-LBS, MAX STROKE 8.75″ (ADD 400 CFM COMPRESSOR, LEADS & CRANE)	400 CFM	A		$24,799	8.83	2.03	3.31	0.37	0.00	31
	P20MK004	7	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 4,150 FT-LBS, MAX STROKE 9.5″ (ADD 450 CFM COMPRESSOR, LEADS & CRANE)	450 CFM	A		$31,308	11.13	2.56	4.17	0.47	0.00	50
	P20MK005	9B3	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 8,750 FT-LBS, MAX STROKE 17″ (ADD 600 CFM COMPRESSOR, LEADS & CRANE)	600 CFM	A		$49,173	16.79	4.02	6.56	0.74	0.00	74
	P20MK006	10B3	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 13,100 FT-LBS, MAX STROKE 19″ (ADD 750 CFM COMPRESSOR, LEADS & CRANE)	750 CFM	A		$57,375	20.63	4.70	7.65	0.87	0.00	114
	P20MK007	11B3	PILE HAMMER, DOUBLE ACTING, PNUEMATIC (STEAM/ AIR), 19,150 FT-LBS, MAX STROKE 19″ (ADD 900 CFM COMPRESSOR, LEADS & CRANE)	900 CFM	A		$61,367	21.89	5.02	8.18	0.93	0.00	141

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
P25	**PILE HAMMERS, SINGLE ACTING**											
	SUBCATEGORY 0.10		**DIESEL**									
			PILECO, INC.									
	P25DL001	D6-32	PILE HAMMER, SINGLE ACTING, DIESEL, 10,500 FT-LBS (ADD LEADS & CRANE)			$46,836	15.03	3.83	6.24	0.71	0.00	40
	P25DL003	D12-42	PILE HAMMER, SINGLE ACTING, DIESEL, 31,320 FT-LBS (ADD LEADS & CRANE)			$56,007	18.04	4.59	7.47	0.85	0.00	63
	P25DL004	D19-42	PILE HAMMER, SINGLE ACTING, DIESEL, 42,800 FT-LBS (ADD LEADS & CRANE)			$63,889	21.00	5.22	8.52	0.96	0.00	88
	P25DL005	D25-32	PILE HAMMER, SINGLE ACTING, DIESEL, 58,248 FT-LBS (ADD LEADS & CRANE)			$87,853	29.06	7.19	11.71	1.33	0.00	130
	P25DL006	D30-32	PILE HAMMER, SINGLE ACTING, DIESEL, 69,898 FT-LBS (ADD LEADS & CRANE)			$90,949	30.64	7.44	12.13	1.37	0.00	141
	P25DL008	D46-32	PILE HAMMER, SINGLE ACTING, DIESEL, 107,177 FT-LBS (ADD LEADS & CRANE)			$111,629	38.86	9.13	14.88	1.69	0.00	207
	P25DL009	D62-22	PILE HAMMER, SINGLE ACTING, DIESEL, 165,000 FT-LBS (ADD LEADS & CRANE)			$168,590	57.28	13.79	22.48	2.55	0.00	283
	P25DL010	D80-23	PILE HAMMER, SINGLE ACTING, DIESEL, 225,000 FT-LBS (ADD LEADS & CRANE)			$246,505	82.35	20.16	32.87	3.72	0.00	382
	P25DL011	D100-13	PILE HAMMER, SINGLE ACTING, DIESEL, 300,000 FT-LBS (ADD LEADS & CRANE)			$263,499	89.11	21.55	35.13	3.98	0.00	459
			INTERNATIONAL CONSTRUCTION EQUIPMENT, INC									
	P25IC001	30S	PILE HAMMER, SINGLE ACTING, DIESEL, 22,500 FT-LBS (ADD LEADS & CRANE)			$64,020	21.45	5.24	8.54	0.97	0.00	73

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P25	***INTERNATIONAL CONSTRUCTION EQUIPMENT, INC (continued)***											
	P25IC002	42S	PILE HAMMER, SINGLE ACTING, DIESEL, 42,000 FT-LBS (ADD LEADS & CRANE)			$77,575	26.76	6.34	10.34	1.17	0.00	91
	P25IC003	60S	PILE HAMMER, SINGLE ACTING, DIESEL, 60,000 FT-LBS (ADD LEADS & CRANE)			$123,181	41.42	10.07	16.42	1.86	0.00	161
	P25IC004	80S	PILE HAMMER, SINGLE ACTING, DIESEL, 80,000 FT-LBS (ADD LEADS & CRANE)			$144,072	48.61	11.79	19.21	2.18	0.00	175
	P25IC005	100S	PILE HAMMER, SINGLE ACTING, DIESEL, 100,000 FT-LBS (ADD LEADS & CRANE)			$187,375	62.57	15.32	24.98	2.83	0.00	220
	P25IC006	120S	PILE HAMMER, SINGLE ACTING, DIESEL, 120,000 FT-LBS (ADD LEADS & CRANE)			$223,889	74.50	18.31	29.85	3.38	0.00	274
	MKT MANUFACTURING, INC.											
	P25MK002	DA-35C	PILE HAMMER, SINGLE ACTING, DIESEL, 23,800 FT-LBS (ADD LEADS & CRANE)			$64,408	21.86	5.27	8.59	0.97	0.00	113
	P25MK001	DE-33/30/20C	PILE HAMMER, SINGLE ACTING, DIESEL, 33,000 FT-LBS (ADD LEADS & CRANE)			$61,400	20.96	5.03	8.19	0.93	0.00	78
	P25MK003	DE-70/50C	PILE HAMMER, SINGLE ACTING, DIESEL, 70,000 FT-LBS (ADD LEADS & CRANE)			$95,704	32.91	7.82	12.76	1.44	0.00	150
	SUBCATEGORY 0.20		**PNUEMATIC (STEAM/AIR)**									
	VULCAN FOUNDATION EQUIPMENT, INC											
	P25VU002	306	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/ AIR), 18,000 FT-LBS (ADD 750CFM COMPRESSOR, LEADS & CRANE)	750 CFM A		$68,125	23.52	5.83	9.65	1.00	0.00	121

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P25	***VULCAN FOUNDATION EQUIPMENT, INC (continued)***												
	P25VU003	505	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/ AIR), 25,000 FT-LBS (ADD 600CFM COMPRESSOR, LEADS & CRANE)	600 CFM	A		$67,544	23.34	5.78	9.57	0.99	0.00	127
	P25VU004	506	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/ AIR), 32,500 FT-LBS (ADD 900CFM COMPRESSOR, LEADS & CRANE)	900 CFM	A		$68,974	23.78	5.90	9.77	1.01	0.00	140
	P25VU005	508	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/ AIR), 40,000 FT-LBS (ADD 900CFM COMPRESSOR, LEADS & CRANE)	900 CFM	A		$92,641	31.08	7.92	13.12	1.36	0.00	202
	P25VU010	510	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/AIR), 50,000 FT-LBS (ADD 1050CFM COMPRESSOR, LEADS & CRANE)	1,050 CFM	A		$95,133	30.31	8.14	13.48	1.40	0.00	222
	P25VU011	512	PILE HAMMER, SINGLE ACTING, PNUEMATIC (STEAM/ AIR), 60,000 FT-LBS (ADD 1200CFM COMPRESSOR, LEADS & CRANE)	1,200 CFM	A		$96,337	30.90	8.25	13.65	1.42	0.00	242
P30	**PILE HAMMERS, DRIVER/EXTRACTOR, VIBRATORY**												
	SUBCATEGORY 0.00		**PILE HAMMERS, DRIVER/EXTRACTOR, VIBRATORY**										
	MKT MANUFACTURING, INC.												
	P30MK001	V-5C	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 53 TON FORCE DRIVE (ADD LEADS & CRANE)	185 HP	D-off		$88,821	37.24	7.26	11.84	1.34	8.12	118

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
P30			***MKT MANUFACTURING, INC. (continued)***									
	P30MK003	V-20B	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 107 TON FORCE DRIVE (ADD LEADS & CRANE)	325 HP D-off		$154,846	65.07	12.67	20.65	2.34	14.26	211
	P30MK004	V-35	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 180 TON FORCE DRIVE (ADD LEADS & CRANE)	600 HP D-off		$262,592	113.12	21.47	35.01	3.96	26.33	345
			VULCAN FOUNDATION EQUIPMENT, INC									
	P30VU001	400A	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 17 TON	58 HP D-off		$56,667	20.35	4.64	7.56	0.86	2.55	50
	P30VU002	1150A	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 42 TON	155 HP D-off		$121,566	45.38	9.95	16.21	1.84	6.80	138
	P30VU003	2300A	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 84 TON	360 HP D-off		$181,677	75.13	14.85	24.22	2.74	15.80	166
	P30VU004	4600A	PILE HAMMER, DRIVER/ EXTRACTOR, VIBRATORY, 167 TON	560 HP D-off		$258,904	109.75	21.17	34.52	3.91	24.58	246
P35	**PIPELAYERS**											
	SUBCATEGORY 0.00		**PIPELAYERS**									
			CATERPILLAR INC. (MACHINE DIVISION)									
	P35CA001	561M	PIPELAYER, 15′ BOOM, 40,000# CAPACITY	110 HP D-off		$194,515	29.39	8.24	11.12	2.68	2.63	358
	P35CA007	572-H	PIPELAYER, 18′ BOOM, 40,000# CAPACITY	110 HP D-off		$196,790	29.69	8.34	11.25	2.71	2.63	358
	P35CA008	572-R	PIPELAYER, 20′ BOOM, 90,000# CAPACITY	230 HP D-off		$363,166	55.69	15.39	20.75	5.01	5.51	663

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P35	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	P35CA009	583-R	PIPELAYER, 20′ BOOM, 140,000# CAPACITY	305 HP D-off		$466,937	71.89	19.78	26.68	6.44	7.30	984
	P35CA006	589	PIPELAYER, 28′ BOOM, 230,000# CAPACITY	420 HP D-off		$612,775	95.00	25.96	35.02	8.45	10.05	1,450
P40	**PLATFORMS & MAN-LIFTS**											
	SUBCATEGORY 0.00		**PLATFORMS & MAN-LIFTS**									
	BIL-JAX, INC.											
	P40BX001	SKYRIDER 15	MAN-LIFT, 14′10″ HEIGHT, 500 LBS, 24 VOLT DC, RECHARGABLE BATTERIES			$10,797	2.44	0.76	1.21	0.15	0.00	18
	GROVE MANLIFT											
	P40GW020	A33NEJ	MAN-LIFT, ARTICULATED BOOM, 39′ HEIGHT, 500 LBS, 21′ REACH, 4 × 2, SELF PROPELLED, 2.5′ × 4′ PLATFORM	4 HP E	7 HP E	$50,813	12.95	3.27	5.16	0.69	0.35	145
	P40GW021	A45EJ	MAN-LIFT, ARTICULATED BOOM, 51′ HEIGHT, 500 LBS, 25′ REACH, 4 × 2, SELF PROPELLED, 2.5′ × 4′ PLATFORM	5 HP E	7 HP E	$54,641	13.86	3.55	5.59	0.75	0.38	143
	P40GW016	A62J	MAN-LIFT, ARTICULATED BOOM, 68′ HEIGHT, 500 LBS, 64′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	60 HP D-off		$113,189	27.72	7.88	12.65	1.55	2.07	268
	P40GW017	A80J	MAN-LIFT, ARTICULATED BOOM, 86′ HEIGHT, 500 LBS, 64′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	110 HP D-off		$180,820	45.61	12.44	19.94	2.47	3.80	428
	P40GW018	A100J	MAN-LIFT, ARTICULATED BOOM, 106′ HEIGHT, 500 LBS, 54′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	110 HP D-off		$217,877	54.45	14.96	23.95	2.98	3.80	458

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
P40			***GROVE MANLIFT (continued)***									
	P40GW019	A125J	MAN-LIFT, ARTICULATED BOOM, 131′ HEIGHT, 600 LBS, 69′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	110 HP D-off		$270,106	66.00	18.61	29.83	3.69	3.80	479
	P40GW022	T40	MAN-LIFT, STRAIGHT BOOM, 40′ HEIGHT, 500 LBS, 34′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	60 HP D-off		$81,404	20.65	5.66	9.09	1.11	2.07	137
	P40GW023	T66J	MAN-LIFT, STRAIGHT BOOM, 66′ HEIGHT, 500 LBS, 55′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	60 HP D-off		$117,673	28.83	8.10	12.97	1.61	2.07	267
	P40GW024	T80	MAN-LIFT, STRAIGHT BOOM, 86′ HEIGHT, 600 LBS, 70′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	85 HP D-off		$154,103	37.84	10.75	17.27	2.11	2.94	340
	P40GW025	T86J	MAN-LIFT, STRAIGHT BOOM, 92′ HEIGHT, 500 LBS, 76′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	85 HP D-off		$161,595	39.49	11.27	18.11	2.21	2.94	371
	P40GW026	T110	MAN-LIFT, STRAIGHT BOOM, 116′ HEIGHT, 500 LBS, 74′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	110 HP D-off		$222,933	54.29	15.46	24.81	3.05	3.80	397
			TEREX CORPORATION									
	P40TE001	TS25RT	MAN-LIFT, SCISSOR, 25′ HIGH, 1,500 LBS, 4 × 4, SELF PROPELLED, 64 × 124″ PLATFORM	24 HP G		$32,105	9.56	2.20	3.52	0.44	1.85	58
	P40TE002	TS30RT	MAN-LIFT, SCISSOR, 30′HIGH, 2,000 LBS, 4 × 4, SELF PROPELLED, 76 × 160″ PLATFORM	39 HP G		$40,428	12.90	2.78	4.46	0.55	3.00	89
	P40TE003	TA50RT	MAN-LIFT, ARTICULATED BOOM, 55′ HEIGHT, 500 LBS, 29′ REACH, 4 × 4, SELF PROPELLED, 2.2′ × 5′ PLATFORM	32 HP D-off		$70,782	17.20	4.86	7.77	0.97	1.11	143

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	REGION 6 EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P40			***TEREX CORPORATION (continued)***									
	P40TE004	TA60RT	MAN-LIFT, ARTICULATED BOOM, 66′ HEIGHT, 500 LBS, 33′ REACH, 4 × 4, SELF PROPELLED, 3′ × 6′ PLATFORM	44 HP D-off		$83,424	20.62	5.65	9.02	1.14	1.52	241
	P40TE005	TB42	MAN-LIFT, STRAIGHT BOOM, 43′ HEIGHT, 650 LBS, 37′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	66 HP D-off		$54,416	15.05	3.71	5.93	0.74	2.28	131
	P40TE006	TB60	MAN-LIFT, STRAIGHT BOOM, 66′ HEIGHT, 650 LBS, 51′ REACH, 4 × 4, SELF PROPELLED, 3′ × 6′ PLATFORM	66 HP D-off		$86,228	22.17	5.87	9.38	1.18	2.28	230
	P40TE007	TB85	MAN-LIFT, STRAIGHT BOOM, 86′ HEIGHT, 600 LBS, 70′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	66 HP D-off		$139,395	33.93	9.59	15.37	1.90	2.28	370
	P40TE008	TB100	MAN-LIFT, STRAIGHT BOOM, 92′ HEIGHT, 500 LBS, 67′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	76 HP D-off		$159,873	38.90	11.02	17.67	2.18	2.63	393
	P40TE009	TB110	MAN-LIFT, STRAIGHT BOOM, 116′ HT, 500 LBS, 74′ REACH, 4 × 4, SELF PROPELLED, 3′ × 8′ PLATFORM	76 HP D-off		$174,687	42.19	12.06	19.34	2.39	2.63	420
	P40TE010	T-292	MAN-LIFT, LINE-TRUCK, W/ AERIAL 24″ × 30″ PLATFORM, 300 LBS, 34′ HEIGHT, 23′ RAD	210 HP D-off		$61,153	22.75	4.22	6.76	0.84	7.26	115
	P40TE011	T-38P	MAN-LIFT, LINE-TRUCK, W/ AERIAL 24″ × 30″ PLATFORM, 300 LBS, 43′ HEIGHT, 26′ RAD	210 HP D-off		$67,365	24.18	4.60	7.36	0.92	7.26	128
	P40TE012	Digger DerrickC-4045	MAN-LIFT, LINE-TRUCK, W/ 13.7 TON, 45′ HIGH-BOOM TILT POLE CLAWS, & 18″ DIA AUGER	210 HP D-off		$100,432	31.49	6.91	11.08	1.37	7.26	268
	P40TE013	5FC-52	MAN-LIFT, LINE-TRUCK, W/ AERIAL 24″ × 48″ PLATFORM, 700 LBS, 57′ HEIGHT, 35′ RAD	210 HP D-off		$92,039	29.64	6.33	10.14	1.26	7.26	215
	P40TE014	5FC-55	MAN-LIFT, LINE-TRUCK, W/ AERIAL 24″ × 30″ PLATFORM, 500 LBS, 60′ HEIGHT, 38′ RAD	210 HP D-off		$93,720	30.01	6.45	10.33	1.28	7.26	248

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P40		***TEREX CORPORATION (continued)***											
	P40TE015	6H-65	MAN-LIFT, LINE-TRUCK, W/ AERIAL 24″ × 48″ PLATFORM, 750 LBS, 70′ HEIGHT, 39′ RAD	210 HP	D-off		$106,536	32.85	7.35	11.77	1.46	7.26	255
P45	**PUMPS, GROUT**												
	SUBCATEGORY 0.00		**PUMPS, GROUT**										
		AIRPLACO EQUIPMENT CO., INC.											
	P45AF002	HG-5	PUMP, GROUT, HAND PUMP, 12 CF/HR, 0-100 PSI, W/O HOPPER (ADD HOSES)				$802	0.19	0.06	0.09	0.01	0.00	1
	P45AF003	HG-8	PUMP, GROUT, HAND PUMP, 15 CF/HR, 100 PSI, W/5 GAL HOPPER (ADD HOSES)				$1,256	0.29	0.09	0.13	0.02	0.00	1
	P45AF008	HGA-50/GM-30	PUMP, GROUT, 50 CF/HR, 0-250 PSI, SKID MTD, W/5 GAL HOPPER AND 30 GAL MIXER (ADD 50 CFM COMPRESSOR & HOSE)	50 CFM	A		$6,797	1.70	0.46	0.72	0.10	0.00	5
	P45AF005	HJ-15 SG	PUMP, GROUT, HIGH PRESSURE SINGLE CYLINDER GROUT PUMP, 110 CF/HR, 400 PSI, GROUT-MUD JACKING-SHOTCRETE, TRAILER MTD, W/ 30 GAL HOPPER AND 30 GAL MIXER (ADD 200 CFM COMPRESSOR & 2″ HOSE)	11 HP	G		$11,610	4.81	0.77	1.21	0.16	1.61	7
	P45AF009	MP-2J6/GM-70DA	PUMP, GROUT, 160 CF/HR, 1-225 PSI, SKID MTD, W/15 GAL HOPPER/& TWO 70 GAL MIXERS (ADD 350 CFM COMPRESSOR)	350 CFM	A		$22,201	5.30	1.49	2.36	0.31	0.00	5

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
P45	***AIRPLACO EQUIPMENT CO., INC. (continued)***											
	P45AF006	HJ-15 DG	PUMP, GROUT, HIGH PRESSURE DUAL CYLINDER GROUT PUMP, 180 CF/HR, 0-300 PSI, GROUT-MUD JACKING-SHOTCRETE, TRAILER MTD, W/ 30 GAL HOPPER AND 30 GAL MIXER (ADD 200 CFM COMPRESSOR & 2″ HOSE)	11 HP G		$13,204	5.19	0.88	1.38	0.19	1.61	7
	P45AF010	HJ-25	PUMP, GROUT, HIGH PRESSURE DUAL CYLINDER GROUT PUMP, 180 CF/HR, 0-400 PSI, GROUT-MUD JACK-PLASTER, TRAILER MTD, W/100 GAL HOPPER AND 45 GAL MIXER/2″ HOSE	18 HP G		$23,545	8.94	1.57	2.48	0.33	2.63	20
	P45AF011	HJ-36 CRG	PUMP, GROUT, HIGH PRESSURE DUAL CYLINDER GROUT PUMP, 250 CF/HR, 0-250 PSI, GROUT-MUD JACK-SHOTCRETE, TRAILER MTD, W/ 120 GAL HOPPER/90 GAL MIXER/2″ HOSE	35 HP G		$46,191	17.48	3.09	4.88	0.65	5.12	49
	P45AF007	P-280 HD	PUMP, GROUT, 756 CF/HR CONCRETE, 486 CF/HR SHOTCRETE, TRAILER MTD, W/ 6 CY HOPPER (ADD HOSE 2″ - 3″ DIA)	30 HP D-off		$24,453	8.20	1.63	2.57	0.34	1.96	25
	ALLENTOWN EQUIPMENT											
	P45AL015	POWER CRETER PRO	PUMP, GROUT, GROUT-MUD JACK-SHOTCRE, HIGH PRESSURE DUAL CYLINDER GROUT PUMP, 135 CF/HR, 0-1330 PSIE, TRAILER MTD, W/75 GAL HOPPER/82 GAL MIXER/3″ HOSE	23 HP G		$40,956	13.97	2.75	4.33	0.58	3.36	32

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			CHEMGROUT, INC.										
	P45CG001	CG-050	PUMP, GROUT, MINI, AIR, 5 GPM, 100 PSI, PORTABLE (ADD 15 CFM COMPRESSOR)	15 CFM	A		$3,462	0.87	0.24	0.37	0.05	0.00	1
	P45CG002	CG-550P	PUMP, GROUT, MIXER, AIR, 5 GPM, 100 PSI (ADD 85 CFM COMPRESSOR)	85 CFM	A		$5,845	1.47	0.39	0.62	0.08	0.00	3
	P45CG003	CG-500	PUMP, GROUT, MIXER, AIR, 20 GPM, 100 PSI (ADD 230 CFM COMPRESSOR)	230 CFM	A		$14,691	3.60	0.99	1.56	0.21	0.00	12
	P45CG007	CG-570H	PUMP, GROUT, THICK MIX/ SPRAY, 8 GPM, SKID MTD, W/AIR COMPRESSOR	16 HP	G		$16,522	6.92	1.11	1.76	0.23	2.34	13
	P45CG006	CG-575	PUMP, GROUT, THICK MIX/ SPRAY, 8 GPM, TRAILER MTD, W/AIR COMPRESSOR	16 HP	G		$16,800	6.98	1.12	1.76	0.24	2.34	15
			OLIN ENGINEERING, INC.										
	P45OE001	5 25F	GROUT PUMP, 30 CY/HR, TRAILER MTD	42 HP	D-off		$21,291	8.45	1.41	2.21	0.30	2.74	39
	P45OE002	5 40	GROUT PUMP, 42 CY/HR, TRAILER MTD	55 HP	D-off		$29,379	11.40	1.95	3.07	0.41	3.58	42
	P45OE003	5 65	GROUT PUMP, 68 CY/HR, TRAILER MTD	84 HP	D-off		$38,327	15.88	2.55	4.02	0.54	5.47	48
	P45OE004	5 80	GROUT PUMP, 82 CY/HR, TRAILER MTD	120 HP	D-off		$47,577	21.01	3.17	5.00	0.67	7.82	56
	P45OE005	5 140CA	GROUT PUMP, 140 CY/HR, TRAILER MTD TANDEM	181 HP	D-off		$60,651	29.08	4.02	6.33	0.85	11.80	100

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P50	**PUMPS, WATER, CENTRIFUGAL, TRASH**												
	SUBCATEGORY 0.11		**ENGINE DRIVE**										
			WACKER CORPORATION										
	P50WC001	PT 2A	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 2″ DIA, 205 GPM @ 100′ HEAD (ADD HOSES)	10 HP	G		$1,487	2.12	0.10	0.15	0.02	1.39	1
	P50WC002	PT 3A	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 3″ DIA, 425 GPM @ 95′ HEAD (ADD HOSES)	15 HP	D-off		$1,735	1.63	0.12	0.17	0.03	0.92	2
	P50WC003	PTS 4V	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 4″ DIA, 705 GPM @ 106′ HEAD (ADD HOSES)	16 HP	D-off		$3,767	2.15	0.24	0.38	0.05	0.98	3
	P50WC004	PT 6LT	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 6″ DIA, 1300 GPM @ 100′ HEAD, TRAILER MTD (ADD HOSES)	33 HP	D-off		$16,815	6.38	1.07	1.66	0.24	2.02	25
			NO SPECIFIC MANUFACTURER										
	P50XX001	6″ DIESEL	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 6.0″, 1,165 GPM, AIR COOLED (ADD HOSES)	60 HP	D-off		$20,402	9.41	1.32	2.04	0.30	3.67	22
	P50XX002	8″ DIESEL	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 8.0″, 2,085 GPM, WATER COOLED (ADD HOSES)	70 HP	D-off		$37,727	14.00	2.44	3.77	0.55	4.28	35
	P50XX003	10″ DIESEL	PUMP, WATER, CENTRIFUGAL, TRASH, ENGINE DRIVE, 10.0″, 2,665 GPM, WATER COOLED (ADD HOSES)	85 HP	D-off		$40,419	15.82	2.61	4.04	0.59	5.20	43

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION (REGION 6)	ENGINE HORSEPOWER FUEL TYPE MAIN	ENGINE HORSEPOWER FUEL TYPE CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	TOTAL HOURLY RATES ($/HR) STANDBY	ADJUSTABLE ELEMENTS DEPR	ADJUSTABLE ELEMENTS FCCM	ADJUSTABLE ELEMENTS FUEL	CWT
	SUBCATEGORY 0.31		**HOSES, PUMP, SUCTION & DISCHARGE**									
			GORMAN-RUPP COMPANY									
	P50GR001		PUMP, WATER, CENTRIFUGAL, TRASH, HOSE, SUCTION/DISCH, 2″ DIA × 20′ WITH COUPLING (PER SECTION)			$353	0.21	0.05	0.08	0.01	0.00	1
	P50GR002		PUMP, WATER, CENTRIFUGAL, TRASH, HOSE, SUCTION/DISCH, 3″ DIA × 20′ WITH COUPLING (PER SECTION)			$531	0.31	0.07	0.12	0.01	0.00	1
	P50GR003		PUMP, WATER, CENTRIFUGAL, TRASH, HOSE, SUCTION/DISCH, 4″ DIA × 20′ WITH COUPLING (PER SECTION)			$742	0.43	0.10	0.17	0.01	0.00	1
	P50GR004		PUMP, WATER, CENTRIFUGAL, TRASH, HOSE, SUCTION/DISCH, 6″ DIA × 20′ WITH COUPLING (PER SECTION)			$1,519	0.88	0.19	0.34	0.02	0.00	1
P55	**PUMPS, WATER, SUBMERSIBLE**											
	SUBCATEGORY 0.01		**ENGINE DRIVE**									
			GRIFFIN DEWATERING CORP.									
	P55GF001	4MH	PUMP, WATER, SUBMERSIBLE, ENGINE DRIVE, 4″ DIA, 855 GPM @ 20′ HEAD, SKID, INCLUDES POWER UNIT (INCLUDES POWER UNIT MODEL 250)(ADD HOSES)	22 HP D-off		$16,837	5.67	1.08	1.68	0.24	1.35	11
	P55GF002	6M	PUMP, WATER, SUBMERSIBLE, ENGINE DRIVE, 6″ DIA, 1,500 GPM @ 20′ HEAD, JET SKID MTD (INCLUDES POWER UNIT MODEL 400) (ADD HOSES)	22 HP D-off		$21,355	6.72	1.38	2.14	0.31	1.35	12

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.02		ELECTRIC DRIVE										
		GORMAN-RUPP COMPANY											
	P55GR001	S2A1	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 2″ DIA, 138 GPM @ 20′ HEAD (ADD HOSES)	2 HP	E		$2,859	0.71	0.19	0.30	0.04	0.12	2
	P55GR002	S3A1	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 3″ DIA, 278 GPM @ 20′ HEAD (ADD HOSES)	5 HP	E		$3,839	1.13	0.26	0.41	0.05	0.29	3
	P55GR003	S4A1	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 4″ DIA, 860 GPM @ 40′ HEAD (ADD HOSES)	25 HP	E		$13,272	4.55	0.90	1.41	0.19	1.44	12
	P55GR004	S6A1	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 6″ DIA, 1950 GPM @ 40′ HEAD (ADD HOSES)	60 HP	E		$18,025	8.31	1.21	1.92	0.25	3.46	14
		WACKER CORPORATION											
	P55WC001	STP 400	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 2″ DIA, 66 GPM @ 39′ HEAD (ADD HOSES)	1 HP	E		$499	0.18	0.04	0.05	0.01	0.06	1
	P55WC002	STP 750	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 2″ DIA, 100 GPM @ 52′ HEAD (ADD HOSES)	1 HP	E		$892	0.25	0.06	0.09	0.01	0.06	1
P60	**PUMPS, WATER, CENTRIFUGAL, DEWATERING**												
	SUBCATEGORY 0.11		SKID MOUNTED, ENGINE DRIVE										
		HOMELITE, INC. (DEERE & COMPANY)											
	P60HO002	111S2	PUMP, WATER, CENTRIFUGAL, DEWATERING, SKID MOUNTED, ENGINE DRIVE, 2″ DIA, 9,000 GPH AT 22′ HEAD (ADD HOSES)	4 HP	G		$839	0.82	0.05	0.08	0.01	0.49	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
P60	***HOMELITE, INC. (DEERE & COMPANY) (continued)***											
	P60HO003	120S3	PUMP, WATER, CENTRIFUGAL, DEWATERING, SKID MOUNTED, ENGINE DRIVE, 3″ DIA, 17,600 GPH AT 20′ HEAD (ADD HOSES)	8 HP G		$1,374	1.74	0.09	0.14	0.02	1.11	1
	WACKER CORPORATION											
	P60WC001	PG 2	PUMP, WATER, CENTRIFUGAL, DEWATERING, SKID MOUNTED, ENGINE DRIVE, 2″ DIA, 159 GPM AT 98′ HEAD (ADD HOSES)	4 HP G		$585	0.84	0.04	0.06	0.01	0.55	1
	P60WC002	PG 3	PUMP, WATER, CENTRIFUGAL, DEWATERING, SKID MOUNTED, ENGINE DRIVE, 3″ DIA, 264 GPM AT 98′ HEAD (ADD HOSES)	6 HP G		$706	1.23	0.05	0.07	0.01	0.83	1
	SUBCATEGORY 0.21		**WHEEL MOUNTED, ENGINE DRIVE**									
	GRIFFIN DEWATERING CORP.											
	P60GF003	250/4″M	PUMP, WATER, CENTRIFUGAL, DEWATERING, WHEEL, 4″ DIA, 485 GPM @ 60′ HEAD (ADD HOSES)	32 HP D-off		$17,596	6.49	1.13	1.74	0.26	1.96	19
	P60GF008	250/6″T	PUMP, WATER, CENTRIFUGAL, DEWATERING, WHEEL, 6″ DIA, 1040 GPM @ 60′ HEAD (ADD HOSES)	32 HP D-off		$17,871	6.54	1.14	1.76	0.26	1.96	19
	P60GF004	400/8″T	PUMP, WATER, CENTRIFUGAL, DEWATERING, WHEEL, 8″ DIA, 1770 GPM @ 60′ HEAD (ADD HOSES)	61 HP D-off		$22,456	9.94	1.44	2.22	0.33	3.73	31
	P60GF005	600/10″T	PUMP, WATER, CENTRIFUGAL, DEWATERING, WHEEL, 10″ DIA, 3410 GPM @ 60′ HEAD (ADD HOSES)	83 HP D-off		$27,368	12.83	1.76	2.71	0.40	5.08	34

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
P60	***GRIFFIN DEWATERING CORP. (continued)***												
	P60GF006	800/12″T	PUMP, WATER, CENTRIFUGAL, DEWATERING, WHEEL, 12″ DIA, 4410 GPM @ 60′ HEAD (ADD HOSES)	110 HP	D-off		$31,634	15.99	2.02	3.12	0.46	6.73	40
	GORMAN-RUPP COMPANY												
	P60GR001	14C2-F3L	PUMP, WATER, CENTRIFUGAL, DEWATERING, 4″ DIA, 600 GPM @ 80′ HEAD WHEEL (ADD HOSES)	47 HP	D-off		$20,629	8.38	1.32	2.03	0.30	2.88	20
	P60GR002	86A2-F4L	PUMP, WATER, CENTRIFUGAL, DEWATERING, 6″ DIA, 1825 GPM @ 40′ HEAD WHEEL (ADD HOSES)	101 HP	G		$22,656	23.10	1.45	2.24	0.33	14.00	20
P65	**PUMPS, WATER, DIAPHRAGM**												
	SUBCATEGORY 0.11		**SKID MOUNTED, ENGINE DRIVE**										
	HOMELITE, INC. (DEERE & COMPANY)												
	P65HO001	111DP2-1	PUMP, WATER, DIAPHRAGM, SKID MTD, 2″ DIA, 2000 GPH @ 25′ HEAD (ADD HOSES)	4 HP	G		$1,291	0.92	0.09	0.13	0.02	0.49	1
	P65HO002	111DP3-1	PUMP, WATER, DIAPHRAGM, SKID MTD, 3″ DIA, 4800 GPH @ 25′ HEAD (ADD HOSES)	4 HP	G		$1,400	0.94	0.09	0.14	0.02	0.49	2

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.21		WHEEL MOUNTED, ENGINE DRIVE										
			GORMAN-RUPP COMPANY										
	P65GR001	3D-13	PUMP, WATER, DIAPHRAGM, WHEEL, 2″ SUCTION × 3″ DISCHARGE, 3,360 GPH @ 25′ HEAD (ADD HOSES)	5 HP	G		$2,418	1.40	0.15	0.22	0.04	0.69	2
	P65GR002	3D-B	PUMP, WATER, DIAPHRAGM, WHEEL, 3″ DIA, 3,360 GPH @ 25′ HEAD (ADD HOSES)	2 HP	G		$3,072	0.90	0.19	0.29	0.04	0.21	2
	P65GR003	4D-B	PUMP, WATER, DIAPHRAGM, WHEEL, 4″ DIA, 4,440 GPH @ 25′ HEAD (ADD HOSES)	3 HP	G		$7,860	2.16	0.50	0.77	0.11	0.42	3
			WACKER CORPORATION										
	P65WC001	PDT 2A	PUMP, WATER, DIAPHRAGM, WHEEL, 2″ DIA, 50 GPM @ 25′ HEAD (ADD HOSES)	4 HP	G		$1,759	1.08	0.12	0.18	0.03	0.55	1
	P65WC002	PDT 3A	PUMP, WATER, DIAPHRAGM, WHEEL, 3″ DIA, 88 GPM @ 25′ HEAD (ADD HOSES)	4 HP	G		$1,846	1.09	0.12	0.18	0.03	0.55	2
P70	**PUMPS, WATER (For core drills)**												
	SUBCATEGORY 0.01		ENGINE DRIVE										
			NO SPECIFIC MANUFACTURER										
	P70XX001	75–7.6	PUMP, WATER, FOR CORE DRILLS, 7.6 GPM, 75 PSI, MANUAL, SKID (ADD HOSES)	2 HP	G		$2,922	0.94	0.18	0.27	0.04	0.28	1
	P70XX002	225–17.5	PUMP, WATER, FOR CORE DRILLS, 17.5 GPM, 225 PSI, MANUAL, SKID (ADD HOSES)	6 HP	G		$7,635	2.61	0.47	0.72	0.11	0.83	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R10	**RIPPERS & HYDRAULIC BANK SLOPERS (Add cost for point wear)**											
	SUBCATEGORY 0.00		**RIPPERS & HYDRAULIC BANK SLOPERS (Add cost for point wear)**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	R10CA001	D-3	RIPPER, 5-SHANKS & BEAM, HYDRAULIC (ADD D-3 TRACTOR DOZER & COST FOR POINT WEAR)			$5,794	1.33	0.37	0.58	0.08	0.00	8
	R10CA003	D-4C SERIES III	RIPPER, 5-SHANKS & BEAM, HYDRAULIC (ADD D-4 TRACTOR DOZER & COST FOR POINT WEAR)			$5,794	1.33	0.37	0.58	0.08	0.00	8
	R10CA006	D-5C111	RIPPER, SHANK, EACH (ADD D-5 TRACTOR DOZER & RIPPER & COST FOR POINT WEAR)			$237	0.04	0.01	0.02	0.00	0.00	1
	R10CA005	D-5C SERIES III	RIPPER, 5-SHANKS & BEAM, HYDRAULIC (ADD D-5 TRACTOR DOZER & COST FOR POINT WEAR)			$5,794	1.33	0.37	0.58	0.08	0.00	8
	R10CA007	D-6R	RIPPER, 3-SHANKS & BEAM, HYDRAULIC (ADD D-6 TRACTOR DOZER & COST FOR POINT WEAR)			$16,729	3.70	1.08	1.67	0.24	0.00	16
	R10CA010	D-7R	RIPPER, SHANK, EACH (ADD D-7 TRACTOR DOZER & COST FOR POINT WEAR)			$1,769	0.39	0.12	0.18	0.03	0.00	3
	R10CA009	D-7R	RIPPER, 3-SHANKS & BEAM, HYDRAULIC (ADD D-7 TRACTOR DOZER & COST FOR POINT WEAR)			$27,921	6.13	1.81	2.79	0.41	0.00	44
	R10CA013	D-8R	RIPPER, SHANK, EACH (ADD D-8 TRACTOR DOZER & COST FOR POINT WEAR)			$3,661	0.79	0.24	0.37	0.05	0.00	7

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R10	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	R10CA011	D-8R	RIPPER, 1-SHANK & BEAM, HYDRAULIC (ADD D-8 TRACTOR DOZER & COST FOR POINT WEAR)			$30,889	6.79	2.00	3.09	0.45	0.00	38
	R10CA012	D-8R	RIPPER, 3-SHANKS & BEAM, HYDRAULIC (ADD D-8 TRACTOR DOZER & COST FOR POINT WEAR)			$38,846	8.51	2.50	3.88	0.56	0.00	46
	R10CA016	D-9R	RIPPER, SHANK, EACH (ADD D-9 TRACTOR DOZER & COST FOR POINT WEAR)			$3,661	0.79	0.24	0.37	0.05	0.00	7
	R10CA014	D-9R	RIPPER, 1-SHANK & BEAM, HYDRAULIC (ADD D-9 TRACTOR DOZER & COST FOR POINT WEAR)			$40,147	8.85	2.59	4.01	0.58	0.00	7
	R10CA015	D-9R	RIPPER, 3-SHANKS & BEAM, HYDRAULIC (ADD D-9 TRACTOR DOZER & COST FOR POINT WEAR)			$48,074	10.58	3.11	4.81	0.70	0.00	33
	R10CA019	D-10R	RIPPER, SHANK, EACH (ADD D-10 TRACTOR DOZER & COST FOR POINT WEAR)			$6,040	1.55	0.39	0.60	0.09	0.00	12
	R10CA017	D-10R	RIPPER, 1-SHANK & BEAM, HYDRAULIC (ADD D-10 TRACTOR DOZER & COST FOR POINT WEAR)			$68,829	15.12	4.44	6.88	1.00	0.00	63
	R10CA018	D-10R	RIPPER, 3-SHANKS & BEAM, HYDRAULIC (ADD D-10 TRACTOR DOZER & COST FOR POINT WEAR)			$85,009	18.64	5.49	8.50	1.24	0.00	85
	R10CA020	D-11R	RIPPER, 1-SHANK & BEAM (ADD D-11 TRACTOR DOZER & COST FOR POINT WEAR)			$73,620	16.18	4.75	7.36	1.07	0.00	72
	R10CA021	D-11R	RIPPER, 3-SHANKS & BEAM (ADD D-11 TRACTOR DOZER & COST FOR POINT WEAR)			$87,880	19.29	5.68	8.79	1.28	0.00	103

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R15	**ROLLERS, STATIC, TOWED, PNEUMATIC**											
	SUBCATEGORY 0.00		**ROLLERS, STATIC, TOWED, PNEUMATIC**									
	SOUTHWEST CONSTRUCTION EQUIPMENT CO.											
	R15SO001	C-50	ROLLER, STATIC, TOWED, PNEUMATIC, 60 TON, 9.8′ WIDE, 4 TIRE (ADD TOWING UNIT)			$112,652	18.13	5.51	7.82	1.60	0.00	309
	R15SO002	C-75	ROLLER, STATIC, TOWED, PNEUMATIC, 75 TON, 10.5′ WIDE, 4 TIRE (ADD TOWING UNIT)			$124,189	19.88	5.75	7.98	1.76	0.00	347
	R15SO003	C-100XL	ROLLER, STATIC, TOWED, PNEUMATIC, 100 TON, 10.5′ WIDE, 4 TIRE (ADD TOWING UNIT)			$175,449	28.25	8.53	12.08	2.49	0.00	551
R20	**ROLLERS, STATIC, TOWED, STEEL DRUM**											
	SUBCATEGORY 0.00		**ROLLERS, STATIC, TOWED, STEEL DRUM**									
	REYNOLDS INTERNATIONAL, L.P.											
	R20RI001	DD-48 × 40	ROLLER, STATIC, TOWED, 2 STEEL DRUMS, 48″ × 40″, PADFOOT (ADD TOWING UNIT)			$17,991	3.28	0.98	1.44	0.26	0.00	183
	R20RI002	DD-48 × 60	ROLLER, STATIC, TOWED, 2 STEEL DRUMS, 48″ × 60″, PADFOOT (ADD TOWING UNIT)			$24,185	4.31	1.31	1.93	0.34	0.00	243

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SOUTHWEST CONSTRUCTION EQUIPMENT CO.											
	R20SO001	2DH-RR	ROLLER, STATIC, TOWED, TANDEM, 60″ × 60″, SHEEPSFOOT (ADD TOWING UNIT)			$61,942	10.68	3.36	4.96	0.88	0.00	200
R30	**ROLLERS, STATIC, SELF-PROPELLED**											
	SUBCATEGORY 0.01		**PNEUMATIC**									
	COMPACTION AMERICA											
	R30BO004	BW11R	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 13.50 TON, 68″ WIDE, 9 TIRE, ASPHALT COMPACTOR	80 HP D-off		$71,177	20.03	4.55	7.09	1.00	4.36	90
	R30BO003	BW20R	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 30.00 TON, 78″ WIDE, 8 TIRE, ASPHALT COMPACTOR	101 HP D-off		$108,433	28.89	7.08	11.09	1.53	5.51	254
	CATERPILLAR INC. (MACHINE DIVISION)											
	R30CA010	PS-150B	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 14.25 TON, 68″ WIDE, 9 TIRE, ASPHALT COMPACTOR	70 HP D-off		$67,979	18.57	4.47	7.02	0.96	3.82	85
	R30CA011	PS-200B	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 20.00 TON, 68″ WIDE, 9 TIRE, ASPHALT COMPACTOR	105 HP D-off		$82,787	23.87	5.48	8.61	1.17	5.73	87
	R30CA014	PS-360B	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 27.55 TON, 90″ WIDE, 7 TIRE, ASPHALT COMPACTOR	105 HP D-off		$134,316	34.74	8.70	13.61	1.89	5.73	187

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
		ROSCO MANUFACTURING CO.											
	R30RS003	TRU-PAC 915	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 6–15 TON, 68″ WIDE, 9 TIRES, HYDROSTATIC	85 HP	D-off		$52,803	16.43	3.46	5.44	0.74	4.64	115
		SAKAI AMERICA, INC.											
	R30SI002	TS200	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 16.00 TON, 81″ WIDE, 9 TIRE, ASPHALT COMPACTOR	91 HP	D-off		$91,104	24.80	5.87	9.17	1.28	4.96	187
	R30SI003	TS600C	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 16.00 TON, 81″ WIDE, 9 TIRE, ASPHALT COMPACTOR	95 HP	D-off		$113,426	29.57	7.37	11.54	1.60	5.18	187
	R30SI004	TS650C	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 27.00 TON, 82″ WIDE, 7 TIRE, ASPHALT COMPACTOR	108 HP	D-off		$150,258	37.79	9.89	15.53	2.12	5.89	281
	SUBCATEGORY 0.02		**SMOOTH DRUM**										
		COMPACTION AMERICA											
	R30BO005	BW5AS	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, 2 WHEEL, 6 TON, 40″ WIDE ASPHALT COMPACTOR	50 HP	D-off		$63,530	14.32	3.57	5.40	0.87	2.73	94
	R30BO006	BW9AS	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, 2 WHEEL, 10 TON, 50″ WIDE ASPHALT COMPACTOR	80 HP	D-off		$78,452	18.90	4.42	6.67	1.08	4.36	140
	R30BO007	BW11AS	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, 2 WHEEL, 14 TON, 54″ WIDE ASPHALT COMPACTOR	70 HP	D-off		$73,650	17.41	4.14	6.26	1.01	3.82	215

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
			ROSCO MANUFACTURING CO.									
	R30RS001	DLX ROLLPAC III	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, DOUBLE DRUM, 1.5 TON, 34″ WIDE	13 HP G		$8,558	3.44	0.49	0.73	0.12	1.60	17
	R30RS002	STAPAC III	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, DOUBLE DRUM, 2 TON, 40″ WIDE	20 HP G		$11,118	4.93	0.63	0.95	0.15	2.46	26
			SAKAI AMERICA, INC.									
	R30SI005	R2H	ROLLER, STATIC, SELF-PROPELLED, SMOOTH DRUM, 3 WHEEL, 14 TON, 64″ WIDE, ASPHALT COMPACTOR	75 HP D-off		$111,730	24.33	6.29	9.50	1.54	4.09	207
	SUBCATEGORY 0.03		**TAMPING FOOT, LANDFILL & SOIL COMPACTORS**									
			COMPACTION AMERICA									
	R30BO009	BC671RB	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, SHEEPSFOOT, 4 × 4, 35 TON, 63″ DIA, 19.58′ WIDTH PER 2-PASS, W/BLADE	338 HP D-off		$463,508	88.55	21.92	30.90	6.47	18.43	710
	R30BO008	BC771RB	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, SHEEPSFOOT, 4 × 4, 40 TON, 63″ DIA, 19.58′ WIDTH PER 2-PASS, W/BLADE	357 HP D-off		$513,688	96.97	24.30	34.25	7.17	19.47	812
			CATERPILLAR INC. (MACHINE DIVISION)									
	R30CA003	815-F	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, SHEEPSFOOT, 4 × 4, 23 TON, 56″ DIA, 14.25′ WIDTH PER 2-PASS, W/BLADE	220 HP D-off		$300,908	57.53	14.23	20.06	4.20	12.00	456

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R30	*CATERPILLAR INC. (MACHINE DIVISION) (continued)*											
	R30CA012	816-F	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, TAMPING FOOT, CHOPPER, 4 × 4, 25.0 TON, 14.75′ WIDTH PER 2-PASS, W/ BLADE	220 HP D-off		$314,012	59.39	14.85	20.93	4.38	12.00	503
	R30CA006	825-G	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, SHEEPSFOOT, 4 × 4, 35 TON, 51″ DIA, 16.00′ WIDTH PER 2-PASS, W/BLADE	315 HP D-off		$454,240	85.70	21.48	30.28	6.34	17.18	691
	R30CA013	826-G	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, TAMPING FOOT, CHOPPER, 4 × 4, 36.5 TON, 15.66′ WIDTH PER 2-PASS, W/ BLADE	315 HP D-off		$491,016	90.94	23.23	32.73	6.86	17.18	794
	R30CA009	836	ROLLER, STATIC, SELF-PROPELLED, LANDFILL/SOIL COMPACTOR, TAMPING FOOT, CHOPPER, 4 × 4, 50.0 TON, 18.58′ WIDTH PER 2-PASS, W/ BLADE	473 HP D-off		$623,092	120.28	29.47	41.54	8.70	25.79	1,020
R40	**ROLLERS, VIBRATORY, TOWED**											
	SUBCATEGORY 0.00		**ROLLERS, VIBRATORY, TOWED**									
	SOUTHWEST CONSTRUCTION EQUIPMENT CO.											
	R40SO001	566 SHEEPSFT	ROLLER, VIBRATORY, TOWED, SINGLE DRUM, SHEEPSFOOT, 25.5 TON, 72″ WIDE (ADD TOWING UNIT)	50 HP D-off		$86,692	21.93	5.60	8.67	1.26	3.06	165
	R40SO003	572 SMOOTH	ROLLER, VIBRATORY, TOWED, SINGLE DRUM, SMOOTH, 25.5 TON, 72″ WIDE (ADD TOWING UNIT)	50 HP D-off		$83,348	21.23	5.38	8.33	1.21	3.06	169

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
R40	***SOUTHWEST CONSTRUCTION EQUIPMENT CO. (continued)***												
	R40SO002	756 SHEEPSFT	ROLLER, VIBRATORY, TOWED, SINGLE DRUM, SHEEPSFOOT, 23.5 TON, 78″ WIDE (ADD TOWING UNIT)	75 HP	D-off		$113,583	29.49	7.33	11.36	1.65	4.59	240
	R40SO004	786 SMOOTH	ROLLER, VIBRATORY, TOWED, SINGLE DRUM, SMOOTH, 23.5 TON, 78″ WIDE (ADD TOWING UNIT)	75 HP	D-off		$82,859	23.12	5.35	8.29	1.20	4.59	230
R45	**ROLLERS, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM**												
	SUBCATEGORY 0.00		**ROLLERS, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM**										
	COMPACTION AMERICA												
	R45BO004	BW120AD-3	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 2.9 TON, 47.2″ WIDE, 2 × 1, ASPHALT COMPACTOR	33 HP	D-off		$45,855	13.72	2.97	4.59	0.67	2.02	55
	R45BO005	BW138AD	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 4.6 TON, 54.3″ WIDE, 2 × 1, ASPHALT COMPACTOR	46 HP	D-off		$57,312	17.50	3.70	5.73	0.83	2.81	88
	R45BO006	BW151AD-2	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 7.8 TON, 66.1″ WIDE, 2 × 1, ASPHALT COMPACTOR	74 HP	D-off		$111,176	32.77	7.18	11.12	1.62	4.53	146
	R45BO007	BW161AD-2	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 10.4 TON, 66.1″ WIDE, 2 × 1, ASPHALT COMPACTOR	113 HP	D-off		$135,128	41.64	8.72	13.51	1.96	6.91	196
	R45BO008	BW202ADH-2	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 12.6 TON, 84.0″ WIDE, 2 × 1, ASPHALT COMPACTOR	113 HP	D-off		$142,985	43.54	9.23	14.30	2.08	6.91	239

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
		CATERPILLAR INC. (MACHINE DIVISION)											
	R45CA001	CB-214C	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 2.5 TON, 39.4″ WIDE, 2 × 1, ASPHALT COMPACTOR	37 HP	D-off		$38,983	12.36	2.52	3.90	0.57	2.26	44
	R45CA002	CB-224C	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 2.7 TON, 47.2″ WIDE, 2 × 1, ASPHALT COMPACTOR	37 HP	D-off		$45,456	13.92	2.94	4.55	0.66	2.26	44
	R45CA005	CB-434C	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 6.6 TON, 56″ WIDE, 2 × 1, ASPHALT COMPACTOR	70 HP	D-off		$112,619	32.79	7.27	11.26	1.64	4.28	137
	R45CA007	CB-534C	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 10.0 TON, 67″ WIDE, 2 × 1, ASPHALT COMPACTOR	107 HP	D-off		$140,125	42.39	9.05	14.01	2.04	6.55	216
	R45CA010	CB-634C	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 13.2 TON, 84″ WIDE, 2 × 1, ASPHALT COMPACTOR	145 HP	D-off		$167,736	52.07	10.83	16.77	2.44	8.87	269
	R45CA009	CP-563C (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 12.5 TON, 84″ WIDE, SOIL COMPACTOR, PADDED DRUM	145 HP	D-off		$183,909	56.17	11.72	18.10	2.67	8.87	257
		ROSCO MANUFACTURING CO.											
	R45RS001	VIBRASTAT III	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 2.0 TON, 36″ WIDE, ASPHALT COMPACTOR	20 HP	G		$13,535	6.87	0.88	1.35	0.20	2.77	27
		SAKAI AMERICA, INC.											
	R45SI007	SW250	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 1.7 TON, 39.5″ WIDE, 2 × 1, ASPHALT COMPACTOR	14 HP	D-off		$32,181	8.91	2.08	3.22	0.47	0.86	16

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
R45			***SAKAI AMERICA, INC. (continued)***									
	R45SI008	SW350	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 3.0 TON, 47″ WIDE, 2 × 1, ASPHALT COMPACTOR	28 HP D-off		$48,213	13.88	3.11	4.82	0.70	1.71	28
	R45SI009	SW650	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 7.8 TON, 58″ WIDE, 2 × 1, ASPHALT COMPACTOR	37 HP D-off		$92,663	25.34	5.99	9.27	1.35	2.26	157
	R45SI010	SW850	ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 14.0 TON, 79″ WIDE, 2 × 1, ASPHALT COMPACTOR	121 HP D-off		$127,750	40.51	8.25	12.78	1.86	7.40	124
R50	**ROLLERS, VIBRATORY, SELF-PROPELLED, SINGLE DRUM**											
	SUBCATEGORY 0.00		**ROLLERS, VIBRATORY, SELF-PROPELLED, SINGLE DRUM**									
			COMPACTION AMERICA									
	R50BO005	BW124D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 2.9 TON, 47.2″ WIDE, 3 × 2, SOIL COMPACTOR	38 HP D-off		$44,139	12.22	2.63	3.94	0.66	1.67	57
	R50BO010	BW124PD	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 2.9 TON, 47.2″ WIDE, 3 × 2, SOIL COMPACTOR	38 HP D-off		$48,867	13.17	3.00	4.54	0.73	1.67	58
	R50BO006	BW142D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 5.5 TON, 56.1″ WIDE, 3 × 2, SOIL COMPACTOR	54 HP D-off		$74,372	19.80	4.58	6.93	1.11	2.37	106
	R50BO011	BW142PD-2	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 5.8 TON, 56.1″ WIDE, 3 × 2, SOIL COMPACTOR	54 HP D-off		$79,870	21.05	4.93	7.45	1.20	2.37	72

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R50		***COMPACTION AMERICA (continued)***											
	R50BO007	BW177D-3	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 7.9 TON, 66.4″ WIDE, 3 × 2, SOIL COMPACTOR	77 HP	D-off		$106,648	28.40	6.55	9.89	1.60	3.38	139
	R50BO012	BW177PDJ-3	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 8.3 TON, 66.4″ WIDE, 3 × 2, SOIL COMPACTOR	77 HP	D-off		$120,601	31.53	7.41	11.20	1.81	3.38	146
	R50BO008	BW213D-3	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 11.5 TON, 83.9″ WIDE, 3 × 2, SOIL COMPACTOR	185 HP	D-off		$137,041	41.45	8.38	12.65	2.05	8.12	260
	R50BO013	BW213PDH-3	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 14.1 TON, 83.9″ WIDE, 3 × 2, SOIL COMPACTOR	185 HP	D-off		$150,928	44.56	9.24	13.95	2.26	8.12	275
	R50BO009	BW219DH-3	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 20.6 TON, 83.9″ WIDE, 3 × 2, SOIL COMPACTOR	181 HP	D-off		$205,633	56.62	12.62	19.08	3.08	7.94	407
		CATERPILLAR INC. (MACHINE DIVISION)											
	R50CA001	CS-323C	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 4.6 TON, 50″ WIDE, 3 × 2, SOIL COMPACTOR	70 HP	D-off		$73,968	20.65	4.54	6.86	1.11	3.07	97
	R50CA003	CS-431C	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 6.9 TON, 66″ WIDE, 3 × 2, SOIL COMPACTOR	105 HP	D-off		$90,447	26.38	5.53	8.36	1.35	4.61	138
	R50CA005	CS-433C	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 7.1 TON, 66″ WIDE, 3 × 2, SOIL COMPACTOR	105 HP	D-off		$104,727	29.59	6.42	9.70	1.57	4.61	141
	R50CA009	CS-563D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 12.2 TON, 84″ WIDE, 3 × 2, SOIL COMPACTOR	153 HP	D-off		$134,017	39.02	8.15	12.27	2.01	6.72	246

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R50	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	R50CA011	CS-583C	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 16.5 TON, 84″ WIDE, 3 × 2, SOIL COMPACTOR	145 HP D-off		$167,760	46.13	10.23	15.44	2.51	6.36	246
	R50CA002	CP-323C (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 4.6 TON, 50″ WIDE, 3 × 2, SOIL COMPACTOR	70 HP D-off		$85,254	23.18	5.24	7.92	1.28	3.07	104
	R50CA004	CP-433C (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 7.1 TON, 66″ WIDE, 3 × 2, SOIL COMPACTOR	105 HP D-off		$115,774	32.06	7.10	10.73	1.73	4.61	146
	R50CA012	CP-563D (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, PAD FOOT, 12.5 TON, 84″ WIDE, 3 × 2, SOIL COMPACTOR	153 HP D-off		$157,857	44.37	9.62	14.51	2.36	6.72	269
	INGERSOLL RAND CO.											
	R50IP001	SD-40D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 4.9 TON, 54″ WIDE, SOIL COMPACTOR	76 HP D-off		$78,555	22.05	4.82	7.28	1.18	3.34	91
	SAKAI AMERICA, INC.											
	R50SI024	TW350 Combo	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 1.5 TON, 39.5″ WIDE, 2 × 1, ASPHALT COMPACTOR	28 HP D-off		$32,475	8.95	1.98	2.97	0.49	1.23	25
	R50SI025	TW500 Combo	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 3.9 TON, 51″ WIDE, 2 × 1, ASPHALT COMPACTOR	30 HP D-off		$61,947	15.67	3.80	5.73	0.93	1.32	36
	R50SI006	SV200D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 4.6 TON, 49″ WIDE, 3 × 2, SOIL COMPACTOR	61 HP D-off		$69,186	19.12	4.22	6.35	1.04	2.68	41

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R50		***SAKAI AMERICA, INC. (continued)***										
	R50SI007	SV200T (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 4.8 TON, 49″ WIDE, 3 × 2, SOIL COMPACTOR	57 HP D-off		$75,585	20.32	4.61	6.95	1.13	2.50	43
	R50SI022	SV400D	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 7.7 TON, 67″ WIDE, 3 × 2, SOIL COMPACTOR	138 HP D-off		$95,521	29.40	5.85	8.84	1.43	6.06	156
	R50SI026	TW750 Combo	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 8.7 TON, 66″ WIDE, 2 × 1, ASPHALT COMPACTOR	104 HP D-off		$122,873	33.55	7.56	11.44	1.84	4.56	100
	R50SI023	SV400TB (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 9.6 TON, 67″ WIDE, 3 × 2, SOIL COMPACTOR	82 HP D-off		$107,849	28.97	6.61	10.00	1.61	3.60	72
	R50SI027	TW100 Combo	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 11.4 TON, 85″ WIDE, 2 × 1, ASPHALT COMPACTOR	86 HP D-off		$181,436	45.68	11.19	16.93	2.72	3.77	221
	R50SI013	SV510D-1E	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 11.5 TON, 84″ WIDE, 3 × 2, SOIL COMPACTOR	138 HP D-off		$111,522	33.04	6.80	10.25	1.67	6.06	507
	R50SI016	SV510T (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 11.9 TON, 60″ WIDE, 3 × 2, SOIL COMPACTOR	118 HP D-off		$120,451	33.91	7.35	11.09	1.80	5.18	110
	R50SI017	SV510TF (PADS)	ROLLER, VIBRATORY, SELF-PROPELLED, SINGLE DRUM, SMOOTH, 14.3 TON, 85″ WIDE, 3 × 2, SOIL COMPACTOR	118 HP D-off		$137,629	37.76	8.41	12.70	2.06	5.18	131

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
R55	**ROOFING EQUIPMENT**												
	SUBCATEGORY 0.00		**ROOFING EQUIPMENT**										
		AEROIL PRODUCTS COMPANY, INC.											
	R55AE001	EZ LOAD 270	ROOFING EQUIPMENT, KETTLE, 270 GAL, W/PUMP, TRAILER MTD	8 HP	G		$6,583	6.04	0.55	0.90	0.10	0.74	20
	R55AE002	EZ LOAD 410	ROOFING EQUIPMENT, KETTLE, 410 GAL, W/PUMP, TRAILER MTD	8 HP	G		$7,998	8.13	0.67	1.10	0.12	0.74	25
	R55AE003	EZ LOAD 680	ROOFING EQUIPMENT, KETTLE, 680 GAL, W/PUMP, TRAILER MTD	8 HP	G		$10,759	10.48	0.89	1.45	0.16	0.74	39
	R55AE004	EZ LOAD 1000	ROOFING EQUIPMENT, KETTLE, 1000 GAL, W/PUMP, TRAILER MTD	8 HP	G		$14,223	11.83	1.14	1.86	0.21	0.74	54
	R55AE008	RHINO S PEELER	ROOFING EQUIPMENT, ROOF PEELER, 16″ WIDE WALK BEHIND, POWERED WHEEL 2 × 2	8 HP	G		$4,785	2.26	0.39	0.64	0.07	0.74	6
	R55AE009	MKI9	ROOFING EQUIPMENT, 1-BLADE CUTTER, 3.75″ DEEP WALK BEHIND (ADD BLADE COST)	9 HP	G		$1,737	1.51	0.16	0.25	0.03	0.83	2
	R55AE010	MK216R	ROOFING EQUIPMENT, 2-BLADE CUTTER, 3.75″ DEEP WALK BEHIND (ADD BLADE COST)	16 HP	G		$3,194	2.70	0.28	0.45	0.05	1.48	3
	R55AE011	BUFFALO 800	ROOFING EQUIPMENT, MATERIAL BUGGY, WALK BEHIND GRAVEL SPREADER, HOPPER 800 LBS, 8CF, 4 × 2	5 HP	G		$3,263	1.48	0.25	0.39	0.05	0.46	4
		GARLOCK EQUIPMENT CO.											
	R55GL017		ROOFING EQUIPMENT, SUPER MINI SAW	5 HP	G		$1,868	1.08	0.16	0.26	0.03	0.46	2

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
R55		***GARLOCK EQUIPMENT CO. (continued)***											
	R55GL016		ROOFING EQUIPMENT, DUST MASTER	9 HP	G		$5,521	2.55	0.47	0.78	0.08	0.83	3
	R55GL011		ROOFING EQUIPMENT, DUAL BLADE CUTTER, 30″ WIDTH, SELF PROPELLED (ADD BLADE COST)	16 HP	G		$6,271	3.55	0.54	0.89	0.09	1.48	4
	R55GL018	NO. 12	ROOFING EQUIPMENT, SCRATCHER	5 HP	G		$1,945	1.11	0.17	0.28	0.03	0.46	1
	R55GL019	NO. 30	ROOFING EQUIPMENT, SCRATCHER	8 HP	G		$3,502	1.89	0.30	0.50	0.05	0.74	3
	R55GL009		ROOFING EQUIPMENT, ROTARY PLANER, 12″ WIDE PATH	11 HP	G		$2,296	1.83	0.20	0.33	0.03	0.97	2
	R55GL008	MODEL 86	ROOFING EQUIPMENT, POWER SWEEPER, 42″ WIDTH	5 HP	G		$2,754	1.34	0.23	0.37	0.04	0.46	2
	R55GL015	MODEL 1000	ROOFING EQUIPMENT, HYDRAULIC HOIST, W/175′ CABLE	9 HP	G		$8,686	3.44	0.75	1.23	0.13	0.83	8
	R55GL007	MODEL 1400	ROOFING EQUIPMENT, HYDRAULIC SWING HOIST, W/275′ CABLE	18 HP	G		$12,667	5.55	1.09	1.79	0.19	1.66	10
	R55GL013	MODEL 30	ROOFING EQUIPMENT, KETTLE, 30 GAL				$1,273	0.59	0.10	0.15	0.02	0.00	3
	R55GL014	MODEL 85	ROOFING EQUIPMENT, KETTLE, 85 GAL, SKID				$2,893	1.15	0.25	0.41	0.04	0.00	7
	R55GL001	MODEL 115	ROOFING EQUIPMENT, KETTLE, 115 GAL				$3,189	1.38	0.27	0.43	0.05	0.00	8
	R55GL002	MODEL 175	ROOFING EQUIPMENT, KETTLE, 175 GAL, W/PUMP	5 HP	G		$9,159	3.59	0.76	1.26	0.13	0.46	17
	R55GL012	MODEL 300	ROOFING EQUIPMENT, KETTLE, 300 GAL, W/PUMP	9 HP	G		$12,425	5.22	1.05	1.73	0.18	0.83	23
	R55GL003	MODEL 412	ROOFING EQUIPMENT, KETTLE, 412 GAL, W/PUMP	9 HP	G		$12,678	5.28	1.06	1.73	0.19	0.83	30
	R55GL004	MODEL 612	ROOFING EQUIPMENT, KETTLE, 612 GAL, W/PUMP	9 HP	G		$14,790	6.13	1.25	2.05	0.22	0.83	40

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
S10	**SCRAPERS, ELEVATING**												
	SUBCATEGORY 0.01		**0 THRU 200 HP**										
		CATERPILLAR INC. (MACHINE DIVISION)											
	S10CA001	613-C SERIES II	SCRAPER, ELEVATING LOADING, 11 CY, 13 TON, 4 × 2 - SINGLE POWERED	175 HP	D-off		$246,360	57.54	13.03	19.06	3.50	7.68	335
		DEERE & COMPANY											
	S10JD001	762B	SCRAPER, ELEVATING LOADING, 11 CY, 13.8 TON, 4 × 2 - SINGLE POWERED	180 HP	D-off		$244, 613	57.15	12.96	18.97	3.47	7.90	370
	SUBCATEGORY 0.02		**OVER 200 HP**										
		CATERPILLAR INC. (MACHINE DIVISION)											
	S10CA002	615-C SERIES II	SCRAPER, ELEVATING LOADING, 17 CY, 19 TON, 4 × 2 - SINGLE POWERED	265 HP	D-off		$384,633	76.75	16.14	21.24	5.52	11.63	526
	S10CA003	623-F	SCRAPER, ELEVATING LOADING, 23 CY, 25 TON, 4 × 2 - SINGLE POWERED	365 HP	D-off		$552,139	106.89	23.30	30.76	7.92	16.02	695
		DEERE & COMPANY											
	S10JD002	862B	SCRAPER, ELEVATING LOADING, 18 CY, 20.4 TON, 4 × 2 - SINGLE POWERED	268 HP	D-off		$374,959	72.99	15.87	20.98	5.38	11.76	482

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
REGION 6												
S15 SCRAPERS, CONVENTIONAL												
	SUBCATEGORY 0.00		**SCRAPERS, CONVENTIONAL**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	S15CA001	621-F	SCRAPER, CONVENTIONAL, STANDARD LOADING, 21 CY, 24 TON, 4 × 2 - SINGLE POWERED	365 HP D-off		$482,435	86.08	18.98	24.71	6.62	15.05	680
	S15CA002	631-E SERIES II	SCRAPER, CONVENTIONAL, STANDARD LOADING, 31 CY, 37.5 TON, 4 × 2 - SINGLE POWERED	450 HP D-off		$734,558	123.99	28.96	37.75	10.08	18.55	959
	S15CA003	651-E	SCRAPER, CONVENTIONAL, STANDARD LOADING, 44 CY, 52 TON, 4 × 2 - SINGLE POWERED	594 HP D-off		$948,096	159.36	37.45	48.86	13.02	24.49	1,325
S20 SCRAPERS, TANDEM POWERED												
	SUBCATEGORY 0.00		**SCRAPERS, TANDEM POWERED**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	S20CA001	627-F	SCRAPER, TANDEM POWERED, STANDARD LOADING, 21 CY, 24 TON, 4 × 4, D-9 ASSISTED LOADING	330 HP D-off	225 HP D-off	$554,770	110.01	21.90	28.56	7.62	23.62	791
	S20CA002	627-F PP	SCRAPER, TANDEM POWERED, STANDARD LOADING, 20 CY, 24 TON, 4 × 4, PUSH-PULL	330 HP D-off	225 HP D-off	$564,234	111.14	22.29	29.07	7.75	23.62	824

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
S20	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***												
	S20CA003	637-E SERIES II	SCRAPER, TANDEM POWERED, STANDARD LOADING, 31 CY, 37.5 TON, 4 × 4, D-10 ASSISTED LOADING	450 HP	D-off	250 HP D-off	$927,341	167.67	36.75	48.03	12.73	29.79	1,084
	S20CA004	637-E SERIES II PP	SCRAPER, TANDEM POWERED, STANDARD LOADING, 31 CY, 37.5 TON, 4 × 4, PUSH-PULL	450 HP	D-off	250 HP D-off	$966,359	172.32	38.33	50.12	13.27	29.79	1,117
	S20CA005	657-E	SCRAPER, TANDEM POWERED, STANDARD LOADING, 44 CY, 52 TON, 4 × 4, D-11 ASSISTED LOADING	550 HP	D-off	400 HP D-off	$1,144,119	204.90	45.57	59.72	15.71	40.43	1,519
	S20CA006	657-E PP	SCRAPER, TANDEM POWERED, STANDARD LOADING, 44 CY, 52 TON, 4 × 4, PUSH-PULL	550 HP	D-off	400 HP D-off	$1,212,488	218.81	48.13	62.96	16.65	40.43	1,594
S25	**SCRAPERS, TRACTOR DRAWN**												
	SUBCATEGORY 0.00		**SCRAPERS, TRACTOR DRAWN**										
	DEERE & COMPANY												
	S25JD001	1510C	SCRAPER, TOWED, STANDARD LOADING, 11 CY, 17 TON, 2 × 0 (ADD 225 HP TRACTOR)				$38,972	7.81	1.69	2.29	0.54	0.00	164
	S25JD002	1814C	SCRAPER, TOWED, STANDARD LOADING, 14 CY, 23 TON, 2 × 0 (ADD 360HP TRACTOR)				$49,540	9.77	2.11	2.84	0.69	0.00	193
	REYNOLDS INTERNATIONAL, L.P.												
	S25RI001	14C	SCRAPER, TOWED, 10.7–14 CY, 15 TON, 10′ CUT WIDTH (ADD 250–300 HP TRACTOR)				$36,922	7.07	1.67	2.29	0.52	0.00	136

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S25			***REYNOLDS INTERNATIONAL, L.P. (continued)***									
	S25RI002	17C	SCRAPER, TOWED, 13–17 CY, 17 TON, 12′ CUT WIDTH (ADD 350–400 HP TRACTOR)			$41,761	7.71	1.89	2.61	0.58	0.00	170
			ROME PLOW CO.									
	S25RM003	R56H	SCRAPER, TOWED, 9–12 CY, 12.5 TON (ADD 150 HP TOWING UNIT)			$95,697	18.15	4.11	5.54	1.34	0.00	203
	S25RM001	R67H	SCRAPER, TOWED, 12–17 CY, 17 TON (ADD 150 HP TOWING UNIT)			$119,768	20.78	5.31	7.28	1.67	0.00	238
	S25RM002	R89H	SCRAPER, TOWED, 18–26 CY, 25 TON (ADD 300 HP TOWING UNIT)			$135,307	23.70	5.95	8.12	1.89	0.00	382
S30	**SCREENING & CRUSHING PLANTS**											
	SUBCATEGORY 0.10		**CONVEYORS**									
			KOLBERG-PIONEER, INC									
	S30KB034	12–3050	SCREENING & CRUSHING PLANTS, FEEDER CONVEYOR, 30″ × 50′, 10 CY HOPPER & 8′ FEED, 1,500 TPH	15 HP E		$44,825	8.57	2.54	3.88	0.60	0.62	15
	S30KB035	12–3070	SCREENING & CRUSHING PLANTS, FEEDER CONVEYOR, 30″ × 70′, 10 CY HOPPER & 8′ FEED, 1,500 TPH	20 HP E		$49,875	9.82	2.77	4.22	0.66	0.83	18
	S30KB036	12–3650	SCREENING & CRUSHING PLANTS, FEEDER CONVEYOR, 36″ × 50′, 10 CY HOPPER & 8′ FEED, 2,000 TPH	20 HP E		$48,160	9.45	2.72	4.16	0.64	0.83	16

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		*KOLBERG-PIONEER, INC (continued)*										
	S30KB041	12–3670	SCREENING & CRUSHING PLANTS, FEEDER CONVEYOR, 36″ × 70′, 10 CY HOPPER & 8′ FEED, 2,000 TPH	25 HP E		$54,143	10.87	3.01	4.58	0.72	1.04	19
	S30KB001	13–2480	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 24″ WIDE × 80′ LONG, WHEEL MTD, 750 TPH	15 HP E		$28,766	5.82	1.62	2.48	0.38	0.62	14
	S30KB002	13–24100	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 24″ WIDE × 100′ LONG, WHEEL MTD, 750 TPH	15 HP E		$31,566	6.34	1.77	2.70	0.42	0.62	18
	S30KB003	13–3080	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 30″ WIDE × 80′ LONG, WHEEL MTD, 1500 TPH	25 HP E		$30,564	6.73	1.73	2.63	0.41	1.04	20
	S30KB004	13–30100	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 30″ WIDE × 100′ LONG, WHEEL MTD, 1500 TPH	25 HP E		$35,104	7.54	1.97	3.00	0.47	1.04	25
	S30KB005	13–3680	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 36″ WIDE × 80′ LONG, WHEEL MTD, 2000 TPH	30 HP E		$36,416	8.06	2.04	3.11	0.48	1.25	30
	S30KB006	13–36100	SCREENING & CRUSHING PLANTS, CONVEYOR, STACKING, 36″ WIDE × 100′ LONG, WHEEL MTD, 2000 TPH	40 HP E		$42,426	9.66	2.38	3.64	0.56	1.66	38
	S30KB007	31–2480	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 24″ WIDE × 80′ LONG, WHEEL MTD, 750 TPH	15 HP E		$31,819	6.49	1.67	2.50	0.42	0.62	22
	S30KB008	31–24100	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 24″ WIDE × 100′ LONG, WHEEL MTD, 750 TPH	15 HP E		$37,632	7.48	2.01	3.01	0.50	0.62	27

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		***KOLBERG-PIONEER, INC (continued)***										
	S30KB009	31–24125	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 24″ WIDE × 125′ LONG, WHEEL MTD, 750 TPH	20 HP E		$40,122	8.26	2.13	3.20	0.53	0.83	33
	S30KB010	31–3080	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 30″ WIDE × 80′ LONG, WHEEL MTD, 1500 TPH	25 HP E		$33,639	7.46	1.76	2.62	0.45	1.04	32
	S30KB011	31–30100	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 30″ WIDE × 100′ LONG, WHEEL MTD, 1500 TPH	25 HP E		$41,199	8.75	2.20	3.29	0.55	1.04	39
	S30KB012	31–30125	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 30″ WIDE × 125′ LONG, WHEEL MTD, 1500 TPH	30 HP E		$48,162	10.23	2.59	3.90	0.64	1.25	47
	S30KB013	31–3680	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 36″ WIDE × 80′ LONG, WHEEL MTD, 2000 TPH	30 HP E		$39,491	8.76	2.10	3.14	0.53	1.25	42
	S30KB014	31–36100	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 36″ WIDE × 100′ LONG, WHEEL MTD, 2000 TPH	40 HP E		$48,560	10.90	2.62	3.94	0.65	1.66	59
	S30KB015	31–36125	SCREENING & CRUSHING PLANTS, CONVEYOR, SIDE FOLDING STACKER, 36″ WIDE × 125′ LONG, WHEEL MTD, 2000 TPH	50 HP E		$58,478	13.17	3.19	4.81	0.78	2.08	70
	S30KB018	35–24150	SCREENING & CRUSHING PLANTS, CONVEYOR, FIXED HEIGHT STACKER, 24″W × 150′ L, WHEEL MTD, 750 TPH	25 HP E		$85,158	15.96	4.85	7.44	1.13	1.04	39

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		***KOLBERG-PIONEER, INC (continued)***										
	S30KB021	35–30150	SCREENING & CRUSHING PLANTS, CONVEYOR, FIXED HEIGHT STACKER, 30″W × 150′ LONG, WHEEL MTD, 1500 TPH	40 HP E		$100,064	19.38	5.71	8.76	1.33	1.66	56
	S30KB024	35–36150	SCREENING & CRUSHING PLANTS, CONVEYOR, FIXED HEIGHT STACKER, 36″ WIDE × 150′ LONG, WHEEL MTD, 2000 TPH	60 HP E		$117,301	23.49	6.71	10.29	1.56	2.50	84
	S30KB025	36–24100	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 24″ WIDE × 100′ LONG, WHEEL MTD, 750 TPH	20 HP E		$60,358	11.50	3.40	5.19	0.80	0.83	52
	S30KB026	36–24120	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 24″ WIDE × 120′ LONG, WHEEL MTD, 750 TPH	20 HP E		$71,842	13.45	4.07	6.21	0.96	0.83	57
	S30KB027	36–24150	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 24″ WIDE × 150′ LONG, WHEEL MTD, 750 TPH	25 HP E		$90,889	16.93	5.19	7.96	1.21	1.04	65
	S30KB028	36–30100	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 30″ WIDE × 100′ LONG, WHEEL MTD, 1500 TPH	30 HP E		$62,661	12.50	3.52	5.38	0.83	1.25	64
	S30KB029	36–30120	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 30″ WIDE × 120′ LONG, WHEEL MTD, 1500 TPH	30 HP E		$84,490	16.17	4.79	7.33	1.12	1.25	71
	S30KB030	36–30150	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 30″ WIDE × 150′ LONG, WHEEL MTD, 1500 TPH	40 HP E		$107,097	20.55	6.12	9.39	1.42	1.66	82

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		***KOLBERG-PIONEER, INC (continued)***											
	S30KB031	36–36100	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 36″ WIDE × 100′ LONG, WHEEL MTD, 2000 TPH	50 HP	E		$89,259	18.15	5.07	7.76	1.19	2.08	82
	S30KB032	36–36120	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 36″ WIDE × 120′ LONG, WHEEL MTD,2,000 TPH	50 HP	E		$107,510	21.24	6.13	9.39	1.43	2.08	93
	S30KB033	36–36150	SCREENING & CRUSHING PLANTS, CONVEYOR, ADJUSTABLE HEIGHT RADIAL STACKER, 36″ WIDE × 150′ LONG, WHEEL MTD,2,000 TPH	60 HP	E		$125,584	24.88	7.19	11.04	1.67	2.50	110
	S30KB042	1430–15	SCREENING & CRUSHING PLANTS, SURGE BIN, 25CY, BELT FEEDER, & 30″ WIDE × 40′ LONG CONVEYOR, 1500 TPH	25 HP	E		$61,166	11.88	3.49	5.36	0.81	1.04	18
	S30KB054	1936–2	SCREENING & CRUSHING PLANTS, SURGE BIN, 25CY, BELT FEEDER, & 30″ WIDE × 40′ LONG CONVEYOR, 1500 TPH	25 HP	E		$61,166	11.93	3.45	5.28	0.81	1.04	18
	S30KB053	1436–25	SCREENING & CRUSHING PLANTS, SURGE BIN, 25CY, BELT FEEDER, & 36″ WIDE × 40′ LONG CONVEYOR, 2000 TPH	35 HP	E		$67,244	13.50	3.84	5.90	0.89	1.46	20
	S30KB043	1936–3	SCREENING & CRUSHING PLANTS, SURGE BIN, 25CY, BELT FEEDER, & 36″ WIDE × 40′ LONG CONVEYOR, 2000 TPH	35 HP	E		$67,244	13.54	3.80	5.81	0.89	1.46	20
	S30KB044	1936–4	SCREENING & CRUSHING PLANTS, SURGE BIN, 25CY, BELT FEEDER, & 36″ WIDE × 40′ LONG CONVEYOR, 2000 TPH	35 HP	E		$67,244	13.54	3.80	5.81	0.89	1.46	20

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
			PUTZMEISTER INC.									
	S30PU001	TELEBELT TB 50	SCREENING & CRUSHING PLANTS, CONVEYOR, 16″ WIDE × 50′ LONG, 80 CY/HR, 1 CY HOPPER & TREMIE, 2 × 4, TRUCK MTD	215 HP D-off		$213,984	48.21	12.31	18.91	2.85	9.44	201
	S30PU002	TELEBELT TB 80	SCREENING & CRUSHING PLANTS, CONVEYOR, 18″ WIDE × 80′ LONG, 360 CY/HR, 3 CY HOPPER & TREMIE, 4 × 6, TRUCK MTD	350 HP D-off		$315,744	73.04	18.13	27.85	4.20	15.36	332
	S30PU003	TELEBELT TB 105	SCREENING & CRUSHING PLANTS, CONVEYOR, 18″ WIDE × 105′ LONG, 360 CY/HR, 3 CY HOPPER & TREMIE, 4 × 8, TRUCK MTD	350 HP D-off		$479,022	100.47	27.58	42.42	6.37	15.36	592
			TELSMITH INC.									
	S30TS001	PTC 24IN × 50FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 24″ WIDE × 50′ LONG, WHEEL MTD, 750 TPH	10 HP E		$37,414	7.01	2.12	3.24	0.50	0.42	10
	S30TS002	PTC 24IN × 70FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 24″ WIDE × 70′ LONG, WHEEL MTD, 750 TPH	15 HP E		$41,678	8.04	2.35	3.60	0.55	0.62	13
	S30TS003	PTC 30IN × 50FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 30″ WIDE × 50′ LONG, WHEEL MTD, 1500 TPH	10 HP E		$39,353	7.35	2.22	3.40	0.52	0.42	12
	S30TS004	PTC 30IN × 70FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 30″ WIDE × 70′ LONG, WHEEL MTD, 1500 TPH	20 HP E		$44,332	8.82	2.50	3.82	0.59	0.83	17
	S30TS005	PTC 36IN × 50FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 36″ WIDE × 50′ LONG, WHEEL MTD, 2000 TPH	20 HP E		$41,722	8.35	2.35	3.60	0.55	0.83	19

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
S30		***TELSMITH INC. (continued)***										
	S30TS006	PTC 36IN × 70FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 36″ WIDE × 70′ LONG, WHEEL MTD, 2000 TPH	20 HP E		$47,582	9.40	2.68	4.09	0.63	0.83	26
	S30TS007	PTC 42IN × 50FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 42″ WIDE × 50′ LONG, WHEEL MTD, 3000 TPH	20 HP E		$42,270	8.47	2.38	3.63	0.56	0.83	25
	S30TS008	PTC 42IN × 70FT	SCREENING & CRUSHING PLANTS, CONVEYOR, TRUSS FRAME, 42″ WIDE × 70′ LONG, WHEEL MTD, 3000 TPH	25 HP E		$49,144	9.99	2.76	4.21	0.65	1.04	25
	SUBCATEGORY 0.20		**CRUSHERS - VERTICAL & HORIZONTAL SHAFT IMPACTOR**									
		HEWITT-ROBINS										
	S30HW001	MODEL 13654V	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 36″ × 54″, SINGLE ROTOR, 250 TPH, W/3′ × 16′ FEEDER/4′ GRIZZLY/24″ × 8′ REJECTION CONVEYOR/& 36″ × 37′ DISCHARGE END DELIVERY CONVEYOR, TRAILER MTD (ADD 250 KW GENERATOR)	250 HP E		$282,717	39.79	8.47	9.94	3.50	10.40	804
	S30HW002	MODEL 14866V	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 48″ × 66″, SINGLE ROTOR, 350 TPH, W/4′ × 16′ FEEDER/6′ GRIZZLY/30″ × 9.5′ REJECTION CONVEYOR/& 48″ × 43′ DISCHARGE END DELIVERY CONVEYOR, TRAILER MTD (ADD 350 KW GENERATOR)	350 HP E		$380,885	54.40	11.43	13.42	4.72	14.56	1,280

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
S30		***HEWITT-ROBINS (continued)***											
	S30HW013	MODEL H4832S	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, SECONDARY, 48″ × 32″, HAMMERMILL, 500 TPH, W/3′ × 37′ FEED CONVEYOR/5′ × 16′ VIBRATORY HORIZONTAL TRIPLE DECK SCREEN/36″ × 30′ RETURN CONVEYOR/& ROTOR LIFT, TRAILER MTD (ADD 450 KW GENERATOR)	450 HP	E		$341,677	56.59	10.27	12.07	4.23	18.72	600
		KOLBERG - PIONEER, INC											
	S30KB045	CS-4250	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 42″ × 52″, 500 TPH, W/18′ × 42″ VIBRATORY FEEDER/ADJUSTABLE GRIZZLY/& BYPASS FEED, TRAILER MTD	360 HP	D-off		$414,046	55.90	12.48	14.70	5.13	15.80	548
		TELSMITH INC.											
	S30TS009	4246	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 600 TPH	300 HP	E		$251,314	42.06	7.64	9.05	3.11	12.48	595
	S30TS010	4856	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 1100 TPH	400 HP	E		$372,909	59.28	11.33	13.42	4.62	16.64	942
	S30TS011	6071	SCREENING & CRUSHING PLANTS, CRUSHERSHAFT IMPACTOR, 2100 TPH	800 HP	E		$623,518	108.19	18.95	22.45	7.72	33.28	1,950

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	
	SUBCATEGORY 0.21		**CRUSHERS - CONE**									
			KOLBERG - PIONEER, INC									
	S30KB046	1200 LS	SCREENING & CRUSHING PLANTS, CRUSHERSCONE, SECONDARY, 120 TPH @ 3/8″ -> 250 TPH @ 1″, 42″ × 50″ IMPACT CRUSHER, W/HOPPER/& 36″ × 32′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 210KW GENERATOR)	210 HP E		$412,910	51.13	12.47	14.71	5.11	8.74	550
	S30KB047	1400 LS	SCREENING & CRUSHING PLANTS, CRUSHERSCONE, SECONDARY PLANT, 42″ × 50″ IMPACT CRUSHER, 630 TPH @ 1″ -> 1050 TPH @ 2.5″, W/ HOPPER/& 42″ × 32′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 315KW GENERATOR)	315 HP E		$350,948	51.64	10.59	12.47	4.35	13.10	950
	SUBCATEGORY 0.22		**CRUSHERS - JAW**									
			HEWITT-ROBINS									
	S30HW005	MODEL J1524PF	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 15″ × 24″, 21 TPH @ 1″ -> 54 TPH @ 3″, W/2.5′ × 8′ FEEDER/2′ GRIZZLY/& 24″ × 20′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	40 HP E		$153,269	14.07	4.59	5.37	1.90	1.66	86

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
S30		*HEWITT-ROBINS (continued)*											
	S30HW006	MODEL J1536V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 15″ × 36″, 45 TPH @ 1.5″ -> 150 TPH @ 6″, W/3′ × 14′ FEEDER/4′ GRIZZLY/& 30″ × 31′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	100 HP	E		$255,250	25.02	7.68	9.04	3.16	4.16	128
	S30HW007	MODEL J2036V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 20″ × 36″, 65 TPH @ 2″ -> 223 TPH @ 7″, W/3′ × 14′ FEEDER/4′ GRIZZLY/& 30″ × 31′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	125 HP	E		$277,465	28.10	8.36	9.84	3.44	5.20	128
	S30HW009	MODEL J2142V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 21″ × 42″, 183 TPH @ 4″ -> 345 TPH @ 8″, W/3.5′ × 16′ FEEDER/ 4′ GRIZZLY/& 36″ × 34′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	150 HP	E		$300,548	31.60	9.02	10.59	3.72	6.24	152
	S30HW011	MODEL J2248V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 22″ × 48″, 115 TPH @ 2.5″ -> 240 TPH @ 6″, W/4′ × 16′ FEEDER/4′ GRIZZLY/& 48″ × 37′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	200 HP	E		$359,177	39.03	10.78	12.66	4.45	8.32	168
	S30HW008	MODEL J2436V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 24″ × 36″, 95 TPH @ 2.5″ -> 230 TPH @ 6″, W/3′ × 14′ FEEDER/4′ GRIZZLY/& 30″ × 31′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	125 HP	E		$289,933	29.00	8.74	10.29	3.59	5.20	128

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
REGION 6												
S30			***HEWITT-ROBINS (continued)***									
	S30HW010	MODEL J3042V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 30″ × 42″, 200 TPH @ 4″ -> 390 TPH @ 8″, W/3.5′ × 16′ FEEDER/ 6′ GRIZZLY/& 36″ × 55′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	200 HP E		$366,452	39.39	11.02	12.95	4.54	8.32	156
	S30HW012	MODEL J3048V	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 30″ × 48″, 340 TPH @ 5″ -> 615 TPH @ 10″, W/4′ × 16′ FEEDER/4′ GRIZZLY/& 48″ × 37′ END DELIVERY CONVEYOR, TRAILER MTD (ADD 40 KW GENERATOR)	200 HP E		$424,740	43.93	12.76	15.00	5.26	8.32	168
			KOLBERG-PIONEER, INC									
	S30KB055	CS-1536	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 15″ × 36″, 45 TPH @ 1.5″ -> 150 TPH @ 6″, W/36″ × 14′ VIBRATING FEEDER/ADJUSTABLE GRIZZLY & BYPASS/HOPPER/& 36″ × 22′ END DELIVERY CONVEYOR, TRAILER MTD, INCLUDES GENERATOR	180 HP D-off		$290,549	31.62	8.76	10.31	3.60	7.90	548
	S30KB058	1524–2416 DUPLEX PL	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 15″ × 36″, 200 TPH @ 1/4″ -> 250 TPH @ 6″, W/36″ × 14′ VIBRATING FEEDER/ ADJUSTABLE GRIZZLY & BYPASS/HOPPER/SCREEN CONVEYOR/& TRIPLE VIBRATORY SCREENS, TRAILER MTD (ADD 250KW GENERATOR & WATER TANK)	250 HP E		$294,531	36.63	8.90	10.49	3.65	10.40	391

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		***KOLBERG-PIONEER, INC (continued)***										
	S30KB056	CS-2036	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 20″ × 36″, 65 TPH @ 2″ -> 223 TPH @ 7″, W/36″ × 14′ VIBRATING FEEDER/ADJUSTABLE GRIZZLY & BYPASS/HOPPER/& 36″ × 22′ END DELIVERY CONVEYOR, TRAILER MTD, INCLUDES GENERATOR	180 HP D-off		$299,100	32.24	9.01	10.62	3.70	7.90	590
	S30KB059	2036–3024 DUPLEX PL	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 20″ × 36″, 270 TPH @ 1/4″ -> 320 TPH @ 7″, W/36″ × 14′ RECIPROCATING PLATE FEEDER/12′ LONG ADJUSTABLE GRIZZLY & BYPASS/HOPPER/& 18″ × 15′ SCREEN CONVEYOR, TRAILER MTD (ADD 300KW GENERATOR)	300 HP E		$464,128	52.11	14.02	16.53	5.75	12.48	415
	S30KB057	CS-2436	SCREENING & CRUSHING PLANTS, JAW CRUSHER, 24″ × 36″, 95 TPH @ 2.5″ -> 230 TPH @ 6″, W/36″ × 16′ VIBRATING FEEDER/ADJUSTABLE GRIZZLY & BYPASS/HOPPER/& 36″ × 22′ END DELIVERY CONVEYOR, TRAILER MTD, INCLUDES GENERATOR	223 HP D-off		$338,483	37.46	10.21	12.03	4.19	9.79	701
	SUBCATEGORY 0.30		**SCREENING PLANT**									
		HEWITT-ROBINS										
	S30HW014	V-11 6 × 16FT,DD	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 16′ VIBRATORY SLOPE DOUBLE DECK SCREENS, W/ 36″ × 16.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER, TRAILER MTD	15 HP E		$111,026	20.64	6.37	9.78	1.48	0.62	101

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

REGION 6				ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30		***HEWITT-ROBINS (continued)***											
	S30HW016	V-11 6 × 20FT, DD	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 20′ VIBRATORY SLOPE DOUBLE DECK SCREENS, W/ 36″ × 16.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER, TRAILER MTD	20 HP	E		$115,387	21.70	6.62	10.17	1.53	0.83	115
	S30HW015	V-11 6 × 16FT, TD	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 16′ VIBRATORY SLOPE TRIPLE DECK SCREENS W/ 36″ × 16.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER, TRAILER MTD	25 HP	E		$121,755	23.13	7.00	10.75	1.62	1.04	138
	S30HW017	V-11 6 × 20FT, TD	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 20′ VIBRATORY SLOPE TRIPLE DECK SCREENS W/ 36″ × 16.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER, TRAILER MTD,	25 HP	E		$123,684	23.48	7.11	10.92	1.65	1.04	167
	S30HW018	V-11 8 × 20FT, TD	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 8′ × 20′ VIBRATORY SLOPE TRIPLE DECK SCREENS, W/ 48″ × 15.5′ UNDER SCREEN CONVEYOR/7 CY HOPPER/& FEEDER, TRAILER MTD	40 HP	E		$147,087	28.68	8.36	12.80	1.96	1.66	243
		KOLBERG - PIONEER, INC											
	S30KB048	616 E-3	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 16′, VIBRATORY SLOPE TRIPLE DECK SCREENS, W/ HOPPER/36″ × 28.5′ FEEDER CONVEYOR/36″ × 18′ UNDER SCREEN CONVEYOR/& 24″ × 20′ SIDE DELIVERY CONVEYOR, TRAILER MTD	80 HP	E		$136,614	29.08	7.83	12.02	1.82	3.33	280

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S30			***KOLBERG - PIONEER, INC (continued)***									
	S30KB049	620 E-3	SCREENING & CRUSHING PLANTS, SCREENING PLANT, 6′ × 20′ VIBRATORY SLOPE TRIPLE DECK SCREENS, W/ HOPPER/42″ × 34′ FEEDER CONVEYOR/60″ × 25′ UNDER SCREEN CONVEYOR/& 30″ × 15′ SIDE DELIVERY CONVEYOR, TRAILER MTD	90 HP E		$139,698	31.58	7.59	11.46	1.86	3.74	355
	S30KB050	1822	SCREENING & CRUSHING PLANTS, WASHING/SCREENING PLANT, 6′ × 16′ VIBRATORY SLOPE TRIPLE DECK SCREENS, W/HOPPER/3 PRODUCT CHUTES/ONE FINES CHUTE TO 8′ × 32′ CLASSIFYING TANK/36″ DIA × 32′ SLOPED SCREW & CHUTE, TRAILER MTD (ADD WATER & FEEDER)	250 HP E		$187,383	47.98	10.80	16.61	2.49	10.40	416
	S30KB051	1830	SCREENING & CRUSHING PLANTS, WASHING/SCREENING PLANT, 6′ × 20′ VIBRATORY SLOPED TRIPLE DECK SCREENS, W/HOPPER/3 PRODUCT CHUTES/ONE FINES CHUTE/8′ × 32′ CLASSIFYING TANK/& 44″ DIA × 32′ SLOPED SCREW & CHUTE, TRAILER MTD (ADD WATER & FEEDER)	250 HP E		$239,366	57.15	13.83	21.29	3.18	10.40	420
	S30KB052	7208–32 S/P	SCREENING & CRUSHING PLANTS, CLASSIFYING PLANT (SAND SORT) 8′W × 32′L TANK & 44″ DIA SCREW, ADD	250 HP E		$239,182	57.07	13.86	21.36	3.18	10.40	450
			METSO MINERALS									
	S30RA002	CV 50D	SCREENING & CRUSHING PLANTS, GRIZZLY-SINGLE SCREEN, 120 CY/HR, TRAILER MTD	25 HP D-off		$52,834	10.77	3.03	4.66	0.70	1.10	130

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
S30		***METSO MINERALS (continued)***											
	S30RA003	CV 90D	SCREENING & CRUSHING PLANTS, GRIZZLY-SINGLE SCREEN, 200 CY/HR, TRAILER MTD	49 HP	D-off		$98,784	20.25	5.67	8.71	1.31	2.15	195
S35	**SNOW REMOVAL EQUIPMENT**												
	SUBCATEGORY 0.00		**SNOW REMOVAL EQUIPMENT**										
		AMERICAN ROAD MACHINERY, INC.											
	S35AR001	112	SNOW REMOVAL EQUIPMENT, SNOW PLOW, REVERSIBLE (ADD DUMP TRUCK)				$2,762	0.57	0.18	0.28	0.04	0.00	15
	S35AR002	713	SNOW REMOVAL EQUIPMENT, SNOW PLOW, 1-WAY TRIP (ADD DUMP TRUCK)				$4,201	0.86	0.27	0.42	0.06	0.00	20
S40	**SOIL & ROAD STABILIZERS**												
	SUBCATEGORY 0.00		**SOIL & ROAD STABILIZERS**										
		COMPACTION AMERICA											
	S40BO002	MPH-100 RECYCLER	SOIL & ROAD STABILIZER, 12″ DEEP × 79″ WIDE, HYDROSTATIC RECLAIMER/ SOIL STABILIZER, 4 × 2	360 HP	D-off		$303,444	74.20	16.40	24.17	4.31	17.24	339
	S40BO003	MPH-100 STABILIZER	SOIL & ROAD STABILIZER, 14″ DEEP × 79″ WIDE, HYDROSTATIC RECLAIMER/ SOIL STABILIZER, 4 × 2	360 HP	D-off		$308,975	75.15	16.70	24.61	4.39	17.24	339

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
S40			***COMPACTION AMERICA (continued)***									
	S40BO004	MPH-100 S-DM	SOIL & ROAD STABILIZER, 21″ DEEP × 79″ WIDE, HYDROSTATIC RECLAIMER/ SOIL STABILIZER, 4 × 2	360 HP D-off		$293,913	72.56	15.88	23.41	4.17	17.24	339
			CATERPILLAR INC. (MACHINE DIVISION)									
	S40CA001	RR-250	SOIL & ROAD STABILIZER, 12″ DEEP × 96″ WIDE, HYDROSTATIC RECLAIMER/ SOIL STABILIZER, 4 × 2	335 HP D-off		$312,512	74.25	16.89	24.90	4.44	16.04	357
	S40CA002	SS-250	SOIL & ROAD STABILIZER, 18″ DEEP × 96″ WIDE, HYDROSTATIC RECLAIMER/ SOIL STABILIZER, 4 × 2	335 HP D-off		$284,830	69.98	15.24	22.39	4.04	16.04	331
S45	**SPLITTERS, ROCK & CONCRETE**											
	SUBCATEGORY 0.00		**SPLITTERS, ROCK & CONCRETE**									
			ELCO INTERNATIONAL INC.									
	S45DA004	02-2	SPLITTER, ROCK & CONCRETE, 220 TON SFORCE, 1–3/4″ DIA, SIZE 2,5 GAL, 12″ DEEP HOLE REQ'D (ADD 80CFM COMPRESSOR)	80 CFM A		$11,870	3.82	0.97	1.58	0.18	0.00	1
	S45DA005	02–9	SPLITTER, ROCK & CONCRETE, 220 TON SFORCE, 1–3/4″ DIA, SIZE 9, 5 GAL, 18″ DEEP HOLE REQ'D (ADD 80CFM COMPRESSOR)	80 CFM A		$15,174	4.81	1.24	2.02	0.23	0.00	1
	S45DA007	02–12	SPLITTER, ROCK & CONCRETE, 385 TON SFORCE, 1–3/4″ DIA, SIZE 12, 5 GAL, 26″ DEEP HOLE REQ'D (ADD 80CFM COMPRESSOR)	80 CFM A		$15,810	5.01	1.30	2.11	0.24	0.00	1

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T10	**TRACTOR BLADES & ATTACHMENTS**											
	SUBCATEGORY 0.00		**TRACTOR BLADES & ATTACHMENTS**									
		CATERPILLAR INC. (MACHINE DIVISION)										
	T10CA001	D3–61–9722	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D3, 1.65 CY (ADD D3 TRACTOR)			$11,836	2.06	0.65	0.95	0.17	0.00	22
	T10CA002	D3-PA 30B	TRACTOR ATTACHMENTS, POWER WINCH, W/250′ CABLE, FOR D3 (ADD D3 TRACTOR)			$17,863	3.06	0.97	1.43	0.25	0.00	21
	T10CA004	D4–104–5683	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D4, 2.17 CY (ADD D4 TRACTOR)			$13,104	2.27	0.72	1.05	0.19	0.00	24
	T10CA005	D4-PA 30B	TRACTOR ATTACHMENTS, POWER WINCH, W/250′ CABLE, FOR D4 (ADD D4 TRACTOR)			$17,863	3.06	0.97	1.43	0.25	0.00	21
	T10CA007	D5-A C	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D5, 2.53 CY (ADD D5 TRACTOR)			$15,247	2.63	0.83	1.22	0.22	0.00	26
	T10CA008	D5-PA 30B	TRACTOR ATTACHMENTS, POWER WINCH, W/CABLE, FOR D5 (ADD D5 TRACTOR)			$17,863	3.06	0.97	1.43	0.25	0.00	21
	T10CA009	D6–108–3970	TRACTOR ATTACHMENTS, BLADE, STRAIGHT, HYDRAULIC, FOR D6, 5.09 CY (ADD D6 TRACTOR)			$24,012	4.08	1.30	1.92	0.34	0.00	58
	T10CA010	D6–108–3982	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D6, 4.16 CY (ADD D6 TRACTOR)			$22,415	3.82	1.22	1.79	0.32	0.00	60
	T10CA011	D6-PA56 WENCH	TRACTOR ATTACHMENTS, POWER WINCH, W/CABLE, FOR D6 (ADD D6 TRACTOR)			$28,150	4.77	1.53	2.25	0.40	0.00	4

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T10	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	T10CA012	D7-S	TRACTOR ATTACHMENTS, BLADE, STRAIGHT, HYDRAULIC, FOR D7, 6.75 CY (ADD D7 TRACTOR)			$36,898	6.23	2.00	2.95	0.52	0.00	77
	T10CA013	D7-U	TRACTOR ATTACHMENTS, BLADE, UNIVERSAL, HYDRAULIC, FOR D7, 10.09 CY (ADD D7 TRACTOR)			$40,497	6.84	2.20	3.24	0.58	0.00	86
	T10CA014	D7-A	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D7, 5.08 CY (ADD D7 TRACTOR)			$33,636	5.69	1.83	2.69	0.48	0.00	78
	T10CA015	D7-PA57 WINCH	TRACTOR ATTACHMENTS, POWER WINCH, W/CABLE, FOR D7 (ADD D7 TRACTOR)			$36,070	6.12	1.96	2.89	0.51	0.00	8
	T10CA016	D8-SU	TRACTOR ATTACHMENTS, BLADE, STRAIGHT, HYDRAULIC, FOR D8, 6.09 CY (ADD D8 TRACTOR)			$44,354	7.52	2.41	3.55	0.63	0.00	96
	T10CA017	D8-U	TRACTOR ATTACHMENTS, BLADE, UNIVERSAL, HYDRAULIC, FOR D8, 15.30 CY (ADD D8 TRACTOR)			$48,039	8.14	2.60	3.84	0.68	0.00	106
	T10CA018	D8-A	TRACTOR ATTACHMENTS, BLADE, POWER ANGLE, HYDRAULIC, FOR D8, 6.09 CY (ADD D8 TRACTOR)			$42,390	7.20	2.30	3.39	0.60	0.00	108
	T10CA019		TRACTOR ATTACHMENTS, BLADE, PUSH PLATE, FOR D8, (ADD D8 TRACTOR)			$1,184	0.25	0.07	0.09	0.02	0.00	5
	T10CA020	D8, PA58VS WINCH	TRACTOR ATTACHMENTS, POWER WINCH, W/CABLE, FOR D8 (ADD D8 TRACTOR)			$36,391	6.22	1.98	2.91	0.52	0.00	33
	T10CA021	D9-SU	TRACTOR ATTACHMENTS, BLADE, SEMI-U, HYDRAULIC, FOR D9, 17.70 CY (ADD D9 TRACTOR)			$65,189	11.07	3.54	5.22	0.93	0.00	145

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T10	*CATERPILLAR INC. (MACHINE DIVISION) (continued)*											
	T10CA022	D9-U	TRACTOR ATTACHMENTS, BLADE, UNIVERSAL, HYDRAULIC, FOR D9, 21.40 CY (ADD D9 TRACTOR)			$70,762	11.99	3.83	5.66	1.00	0.00	158
	T10CA023	D9, PA59 WINCH	TRACTOR ATTACHMENTS, POWER WINCH, W/CABLE, FOR D9 (ADD D9 TRACTOR)			$46,048	7.87	2.49	3.68	0.65	0.00	5
	T10CA024	D10-SU	TRACTOR ATTACHMENTS, BLADE, SEMI-U, HYDRAULIC, FOR D10, 24.20 CY (ADD D10 TRACTOR)			$90,304	15.34	4.89	7.22	1.28	0.00	244
	T10CA025	D10-U	TRACTOR ATTACHMENTS, BLADE, UNIVERSAL, HYDRAULIC, FOR D10, 28.70 CY (ADD D10 TRACTOR)			$97,534	16.55	5.28	7.80	1.38	0.00	270
	T10CA026	D11-SU	TRACTOR ATTACHMENTS, BLADE, STRAIGHT, HYDRAULIC, FOR D11, 35.50 CY (ADD D11 TRACTOR)			$139,230	23.63	7.55	11.14	1.98	0.00	367
	T10CA027	D11-U	TRACTOR ATTACHMENTS, BLADE, UNIVERSAL, HYDRAULIC, FOR D11, 45.00 CY (ADD D11 TRACTOR)			$150,421	25.51	8.16	12.03	2.14	0.00	423
	DEERE & COMPANY											
	T10JD001	915 V-RIPPER	TRACTOR ATTACHMENTS, DEEP TILLER, 5 × 7 V SHAPED, 175″ WIDE, 7 SHANKS (ADD 200HP TRACTOR W/PTO)			$10,395	2.00	0.55	0.80	0.15	0.00	17
	LELY PACIFIC, INC.											
	T10LE001	200-15	TRACTOR ATTACHMENTS, POWER HARROW, 80″ WIDE ROTERRA ROTARY HOE (ADD 40 HP TRACTOR W/PTO)			$6,990	1.42	0.38	0.56	0.10	0.00	13

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T10		*LELY PACIFIC, INC. (continued)*										
	T10LE002	250-15	TRACTOR ATTACHMENTS, POWER HARROW, 100″ WIDE ROTERRA ROTARY HOE (ADD 45 HP TRACTOR W/PTO)			$7,897	1.56	0.43	0.63	0.11	0.00	15
	T10LE003	300-20	TRACTOR ATTACHMENTS, POWER HARROW, 120″ WIDE ROTERRA ROTARY HOE (ADD 50 HP TRACTOR W/PTO)			$8,547	1.67	0.46	0.68	0.12	0.00	17
	T10LE004	350-35	TRACTOR ATTACHMENTS, POWER HARROW, 140″ WIDE ROTERRA ROTARY HOE (ADD 60 HP TRACTOR W/PTO)			$14,583	2.69	0.80	1.17	0.21	0.00	27
	T10LE005	400-35	TRACTOR ATTACHMENTS, POWER HARROW, 160″ WIDE ROTERRA ROTARY HOE (ADD 75 HP TRACTOR W/PTO)			$16,273	2.96	0.88	1.30	0.23	0.00	29
T15	**TRACTORS, CRAWLER (DOZER) (includes blade)**											
	SUBCATEGORY 0.01		**0 THRU 225 HP**									
	CATERPILLAR INC. (MACHINE DIVISION)											
	T15CA002	D-3C SERIES III LGP	TRACTOR, CRAWLER (DOZER), 70 HP, LOW GROUND PRESSURE, W/1.64 CY SEMI-U BLADE (ADD ATTACHMENTS)	70 HP D-off		$87,830	20.73	4.41	6.15	1.33	3.35	170
	T15CA020	D-4C SERIES III	TRACTOR, CRAWLER (DOZER), 80 HP, POWERSHIFT, W/2.18 CY SEMI-U BLADE (ADD ATTACHMENTS)	80 HP D-off		$91,146	21.98	4.57	6.38	1.38	3.83	161
	T15CA005	D-4C SERIES III LGP	TRACTOR, CRAWLER (DOZER), 80 HP, LOW GROUND PRESSURE, W/2.18 CY SEMI-U BLADE (ADD ATTACHMENTS)	80 HP D-off		$103,207	24.20	5.17	7.22	1.56	3.83	171

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T15	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***												
	T15CA021	D-5C SERIES III	TRACTOR, CRAWLER (DOZER), 90 HP, POWERSHIFT, W/2.50 CY POWER ANGLE BLADE (ADD ATTACHMENTS)	90 HP	D-off		$104,651	25.11	5.25	7.33	1.58	4.31	187
	T15CA022	D-5C SERIES III LGP	TRACTOR, CRAWLER (DOZER), 90 HP, LOW GROUND PRESSURE, W/2.50 CY POWER ANGLE BLADE (ADD ATTACHMENTS)	90 HP	D-off		$114,032	26.84	5.71	7.98	1.72	4.31	196
	T15CA024	D-5M XL	TRACTOR, CRAWLER (DOZER), 100 HP, POWERSHIFT, W/3.37 CY SEMI-U BLADE (ADD ATTACHMENTS)	100 HP	D-off		$144,651	33.15	7.25	10.13	2.18	4.79	270
	T15CA008	D-6M XL	TRACTOR, CRAWLER (DOZER), 140 HP, POWERSHIFT, W/ 5.60 CY SEMI-U BLADE (ADD ATTACHMENTS)	140 HP	D-off		$186,509	43.44	9.35	13.06	2.82	6.70	321
	T15CA023	D-6R	TRACTOR, CRAWLER (DOZER), 165 HP, LOW GROUND PRESSURE, POWERSHIFT, W/5.09 CY SEMI-U BLADE (ADD ATTACHMENTS)	165 HP	D-off		$208,269	49.06	10.43	14.58	3.14	7.90	409
	T15CA009	D-6R WHA	TRACTOR, CRAWLER (DOZER), 165 HP, W/14.3 CY BLADE, TRASH/WASTE HANDLING ARRANGEMENT	165 HP	D-off		$280,494	62.40	14.05	19.63	4.23	7.90	434
	T15CA011	D-6R LGP	TRACTOR, CRAWLER (DOZER), 165 HP, LOW GROUND PRESSURE, W/5.09 CY SEMI-U BLADE (ADD ATTACHMENTS)	185 HP	D-off		$247,456	57.60	12.40	17.32	3.74	8.86	364
	CASE CORPORATION												
	T15CS004	550H WT	TRACTOR, CRAWLER (DOZER), 67 HP, POWERSHIFT, W/1.90 CY UNIVERSAL BLADE (ADD ATTACHMENTS)	67 HP	D-off		$94,455	21.76	4.74	6.61	1.43	3.21	146

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T15		*CASE CORPORATION (continued)*											
	T15CS005	650H WT	TRACTOR, CRAWLER (DOZER), 80 HP, POWERSHIFT, W/2.50 CY UNIVERSAL BLADE (ADD ATTACHMENTS)	75 HP	D-off		$96,775	22.69	4.85	6.77	1.46	3.59	168
	T15CS006	850H WT	TRACTOR, CRAWLER (DOZER), 89 HP, POWERSHIFT, W/2.60 CY UNIVERSAL BLADE (ADD ATTACHMENTS)	91 HP	D-off		$119,896	27.99	6.01	8.39	1.81	4.36	187
	T15CS007	1150H WT	TRACTOR, CRAWLER (DOZER), 118 HP, POWERSHIFT, W/ 3.90 CY UNIVERSAL BLADE (ADD ATTACHMENTS)	119 HP	D-off		$164,375	38.00	8.24	11.51	2.48	5.70	264
		DEERE & COMPANY											
	T15JD005	450H LT	TRACTOR, CRAWLER (DOZER), 70 HP, POWERSHIFT, W/2.00 CY ANGLE BLADE (ADD ATTACHMENTS)	70 HP	D-off		$74,599	18.27	3.74	5.22	1.13	3.35	155
	T15JD006	450H LGP	TRACTOR, CRAWLER (DOZER), 74 HP, LOW GROUND PRESSURE, W/2.15 CY ANGLE BLADE (ADD ATTACHMENTS)	74 HP	D-off		$90,222	21.41	4.52	6.32	1.36	3.54	165
	T15JD007	650H	TRACTOR, CRAWLER (DOZER), 90 HP, POWERSHIFT, W/2.60 CY ANGLE BLADE (ADD ATTACHMENTS)	90 HP	D-off		$100,816	24.40	5.05	7.06	1.52	4.31	185
	T15JD008	750C-II LT	TRACTOR, CRAWLER (DOZER), 140 HP, POWERSHIFT, W/ 5.60 CY ANGLE BLADE (ADD ATTACHMENTS)	140 HP	D-off		$178,813	42.02	8.96	12.52	2.70	6.70	317
	T15JD009	750C-II LGP	TRACTOR, CRAWLER (DOZER), 140 HP, LOW GROUND PRESSURE, W/4.84 CY ANGLE BLADE (ADD ATTACHMENTS)	140 HP	D-off		$191,091	44.28	9.57	13.38	2.88	6.70	365
	T15JD010	850C	TRACTOR, CRAWLER (DOZER), 185 HP, POWERSHIFT, W/ 7.44 CY SEMI-U BLADE (ADD ATTACHMENTS)	185 HP	D-off		$215,708	51.73	10.81	15.10	3.26	8.86	404

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T15		***DEERE & COMPANY (continued)***											
	T15JD011	850C LGP	TRACTOR, CRAWLER (DOZER), 185 HP, LOW GROUND PRESSURE, W/7.14 CY SEMI-U BLADE (ADD ATTACHMENTS)	185 HP	D-off		$265,166	60.86	13.28	18.56	4.00	8.86	420
		KOMATSU AMERICA INTERNATIONAL COMPANY											
	T15KM001	D31E-20	TRACTOR, CRAWLER (DOZER), 70 HP, HYDROSHIFT, W/1.65 CY POWER ANGLE BLADE	70 HP	D-off		$91,495	21.39	4.58	6.40	1.38	3.35	123
	T15KM002	D37E-5	TRACTOR, CRAWLER (DOZER), 75 HP, HYDROSHIFT, W/1.95 CY POWER ANGLE BLADE	75 HP	D-off		$100,355	23.36	5.03	7.02	1.52	3.59	149
	T15KM003	D58E-1B	TRACTOR, CRAWLER (DOZER), 130 HP, HYDROSHIFT, W/3.70 CY POWER ANGLE BLADE	130 HP	D-off		$180,380	41.66	9.04	12.63	2.72	6.22	328
	T15KM013	D65EX-12	TRACTOR, CRAWLER (DOZER), 190 HP, POWERSHIFT, W/ 5.09 CY STRAIGHT TILL BLADE	190 HP	D-off		$261,161	60.44	13.08	18.28	3.94	9.10	410
	T15KM007	D85E-21	TRACTOR, CRAWLER (DOZER), 225 HP, POWERSHIFT, W/6.80 CY STRAIGHT TILL BLADE	225 HP	D-off		$341,987	77.62	17.13	23.94	5.16	10.77	624
	SUBCATEGORY 0.02		**226 HP THRU 425 HP**										
		CATERPILLAR INC. (MACHINE DIVISION)											
	T15CA012	D-7R	TRACTOR, CRAWLER (DOZER), 230 HP, POWERSHIFT, W/ 6.75 CY SEMI-U BLADE (ADD ATTACHMENTS)	230 HP	D-off		$341,200	69.00	15.15	20.47	4.91	11.01	552
	T15CA014	D-7R LGP	TRACTOR, CRAWLER (DOZER), 240 HP, LOW GROUND PRESSURE, W/6.75 CY STRAIGHT BLADE (ADD ATTACHMENTS)	240 HP	D-off		$402,948	79.57	17.89	24.18	5.80	11.49	598

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T15	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***												
	T15CA016	D-8R	TRACTOR, CRAWLER (DOZER), 305 HP, POWERSHIFT, W/ 15.3 CY SEMI-U BLADE (ADD ATTACHMENTS)	305 HP	D-off		$409,349	84.52	18.17	24.56	5.89	14.60	755
	T15CA017	D-9R	TRACTOR, CRAWLER (DOZER), 405 HP, POWERSHIFT, W/ 17.7 CY SEMI-U BLADE (ADD ATTACHMENTS)	405 HP	D-off		$564,628	115.65	25.07	33.88	8.13	19.39	1,033
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	T15KM008	D155AX-5	TRACTOR, CRAWLER (DOZER), 310 HP, POWERSHIFT, W/ 11.5 CY SEMI-U BLADE	310 HP	D-off		$421,480	86.80	18.72	25.29	6.07	14.84	864
	T15KM012	D275A-2	TRACTOR, CRAWLER (DOZER), 405 HP, POWERSHIFT, W/16.7 CY SEMI-U BLADE	405 HP	D-off		$628,603	125.98	27.91	37.72	9.05	19.39	1,118
	SUBCATEGORY 0.03		**OVER 425 HP**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T15CA018	D-10R	TRACTOR, CRAWLER (DOZER), 570 HP, POWERSHIFT, W/ 28.7 CY SEMI-U BLADE (ADD ATTACHMENTS)	570 HP	D-off		$724,612	129.97	29.28	38.65	9.95	23.50	1,442
	T15CA019	D-11R	TRACTOR, CRAWLER (DOZER), 850 HP, POWERSHIFT, W/ 44.0 CY SEMI-U BLADE (ADD ATTACHMENTS)	850 HP	D-off		$1,304,078	225.03	52.68	69.55	17.90	35.05	2,255
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	T15KM014	D375A-2	TRACTOR, CRAWLER (DOZER), 525 HP, POWERSHIFT, W/ 24.2 CY SEMI-U BLADE	525 HP	D-off		$883,179	149.84	35.67	47.10	12.12	21.65	1,472

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T15	***KOMATSU AMERICA INTERNATIONAL COMPANY (continued)***												
	T15KM011	D475A-2	TRACTOR, CRAWLER (DOZER), 860 HP, POWERSHIFT, W/33.5 CY SEMI-U BLADE	860 HP	D-off		$1,467,286	248.32	59.27	78.26	20.14	35.46	2,285
T20	**TRACTORS, WHEEL TYPE (DOZER)**												
	SUBCATEGORY 0.00		**TRACTORS, WHEEL TYPE (DOZER)**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T20CA001	814-B F	TRACTOR, WHEEL (DOZER), 220 HP, ARTICULATING, 4 × 4, W/ 3.77 CY STRAIGHT BLADE	220 HP	D-off		$287,988	47.99	12.36	17.03	3.84	9.07	365
	T20CA002	824-G	TRACTOR, WHEEL (DOZER), 315 HP, ARTICULATING, 4 × 4, W/ 6.70 CY STRAIGHT BLADE	315 HP	D-off		$425,270	71.90	18.15	24.96	5.67	12.99	690
	T20CA003	834-B	TRACTOR, WHEEL (DOZER), 450 HP, ARTICULATING, 4 × 4, W/ 13.70 CY STRAIGHT BLADE	450 HP	D-off		$633,961	102.67	26.95	36.99	8.45	18.55	902
T25	**TRACTORS, AGRICULTURAL**												
	SUBCATEGORY 0.10		**CRAWLER**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T25CA006	CH 65E	TRACTOR, AGRICULTURAL, CRAWLER-RUBBER TRACK, 267 HP, 3 POINT HITCH	267 HP	D-off		$170,798	45.09	9.61	14.52	2.35	11.72	331
	T25CA007	CH 75E	TRACTOR, AGRICULTURAL, CRAWLER-RUBBER TRACK, 292 HP, 3 POINT HITCH	292 HP	D-off		$187,567	49.45	10.55	15.94	2.58	12.82	341

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T25	***CATERPILLAR INC. (MACHINE DIVISION) (continued)***											
	T25CA008	CH 85E	TRACTOR, AGRICULTURAL, CRAWLER-RUBBER TRACK, 353 HP, 3 POINT HITCH	353 HP D-off		$203,326	55.62	11.44	17.28	2.80	15.49	350
	SUBCATEGORY 0.20		**WHEEL**									
	DEERE & COMPANY											
	T25JD008	7410	TRACTOR, AGRICULTURAL, WHEEL, 105 HP, 4 × 4, PTO, 3 POINT HITCH	105 HP D-off		$57,028	17.59	3.74	5.88	0.80	4.61	74
	T25JD009	7710	TRACTOR, AGRICULTURAL, WHEEL, 135 HP, 4 × 4, PTO, 3 POINT HITCH	135 HP D-off		$57,112	19.27	3.75	5.89	0.80	5.93	89
	T25JD010	8100	TRACTOR, AGRICULTURAL, WHEEL, 165 HP, 4 × 4, PTO, 3 POINT HITCH	165 HP D-off		$90,786	28.03	5.91	9.25	1.28	7.24	179
	T25JD014	8310	TRACTOR, AGRICULTURAL, WHEEL, 205 HP, PTO, 3 POINT HITCH	205 HP D-off		$124,800	37.09	8.19	12.86	1.76	9.00	170
	T25JD012	9200	TRACTOR, AGRICULTURAL, WHEEL, 310 HP, 4 × 4, PTO, 3 POINT HITCH	310 HP D-off		$132,507	46.15	8.00	12.25	1.87	13.61	310
	T25JD013	9400	TRACTOR, AGRICULTURAL, WHEEL, 425 HP, 4 × 4, PTO, 3 POINT HITCH	425 HP D-off		$171,229	60.31	10.60	16.37	2.41	18.65	338
T30	**TRENCHERS, CHAIN TYPE CUTTER**											
	SUBCATEGORY 0.00		**TRENCHERS, CHAIN TYPE CUTTER**									
	CASE CORPORATION											
	T30CS003	MAXI SNEAKER C	TRENCHER, CHAIN TYPE CUTTER, 36″ DEEP, 6″ WIDE, 4 × 4	37 HP D-off		$26,101	7.76	1.67	2.57	0.38	1.62	25

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T30		*CASE CORPORATION (continued)*											
	T30CS004	360	TRENCHER, CHAIN TYPE CUTTER, 60″ DEEP, 14″ WIDE, 4 × 4, W/BACKHOE & BLADE	30 HP	D-off		$28,136	7.89	1.74	2.66	0.41	1.32	42
	T30CS005	460	TRENCHER, CHAIN TYPE CUTTER, 60″ DEEP, 16″ WIDE, 4 × 4 × 4, W/BACKHOE & BLADE	33 HP	D-off		$34,074	9.36	2.13	3.25	0.50	1.45	65
	T30CS006	560	TRENCHER, CHAIN TYPE CUTTER, 72″ DEEP, 16″ WIDE, 4 × 4 × 4, W/BACKHOE & BLADE	46 HP	D-off		$47,918	13.11	3.02	4.64	0.70	2.02	82
	T30CS007	660	TRENCHER, CHAIN TYPE CUTTER, 72″ DEEP, 16″ WIDE, 4 × 4 × 4, W/BACKHOE & BLADE	56 HP	D-off		$58,474	15.96	3.70	5.69	0.85	2.46	91
	T30CS008	860	TRENCHER, CHAIN TYPE CUTTER, 84″ DEEP, 18″ WIDE, 4 × 4 × 4, W/BACKHOE & BLADE	79 HP	D-off		$76,000	21.12	4.79	7.36	1.11	3.47	119
	DITCH WITCH (The Charles Machine Works) I												
	T30DW012	1220	TRENCHER, CHAIN TYPE CUTTER, 36″ DEEP × 6″ WIDE, WALK BEHIND	13 HP	G		$8,679	3.54	0.56	0.85	0.13	1.30	8
	T30DW013	1820	TRENCHER, CHAIN TYPE CUTTER, 48″ DEEP × 16″ WIDE, WALK BEHIND	18 HP	G		$12,969	5.14	0.82	1.26	0.19	1.80	13
	T30DW014	3610	TRENCHER, CHAIN TYPE CUTTER, 60″ DEEP × 16″ WIDE, 4 × 4 (W/BLADE)	35 HP	D-off		$30,712	8.73	1.91	2.91	0.45	1.54	39
	T30DW005	3500	TRENCHER, CHAIN TYPE CUTTER, 63″ DEEP × 12″ WIDE, 4 × 4 (W/DBL PIVOT)	44 HP	D-off		$33,024	9.73	2.06	3.15	0.48	1.93	42
	T30DW015	4500	TRENCHER, CHAIN TYPE CUTTER, 52″ DEEP × 12″ WIDE, 4 × 4 (W/BLADE)	52 HP	D-off		$44,648	12.72	2.81	4.31	0.65	2.28	45
	T30DW016	5110	TRENCHER, CHAIN TYPE CUTTER, 80″ DEEP × 24″ WIDE, 4 × 4 (W/BLADE)	53 HP	D-off		$49,403	13.80	3.13	4.82	0.72	2.33	49
	T30DW017	7610	TRENCHER, CHAIN TYPE CUTTER, 90″ DEEP × 24″ WIDE, 4 × 4 (W/BLADE)	74 HP	D-off		$56,803	16.59	3.59	5.52	0.83	3.25	58

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T30	***DITCH WITCH (The Charles Machine Works) I (continued)***												
	T30DW018	8020	TRENCHER, CHAIN TYPE CUTTER, 90″ DEEP × 30″ WIDE, 4 × 4 (W/BLADE)	78 HP	D-off		$71,412	20.00	4.53	6.98	1.04	3.42	66
	T30DW011	HT100	TRENCHER, CHAIN TYPE CUTTER, 69″ DEEP × 8″ WIDE, 4 × 4 (W/BLADE, CWLR)	106 HP	D-off		$148,435	38.32	9.58	14.84	2.16	4.65	158
	T30DW010	R100	TRENCHER, CHAIN TYPE CUTTER, 96″ DEEP × 24″ WIDE, 4 × 4 (W/BLADE)	106 HP	D-off		$126,223	34.41	7.90	12.11	1.84	4.65	95
	TESMEC USA, INC.												
	T30TM001	TRS 900-A	TRENCHER, CHAIN TYPE CUTTER, 3′ DEEP × 4″-8″ WIDE, CRAWLER (W/CRUMBSHOE)	185 HP	D-off		$260,136	67.12	16.79	26.01	3.78	8.12	375
	T30TM004	TRS 900-A-SL	TRENCHER, CHAIN TYPE CUTTER, 3′ DEEP × 4″-8″ WIDE, CRAWLER (W/CRUMBSHOE) SELF LEVEL	185 HP	D-off		$280,945	71.67	18.14	28.09	4.09	8.12	400
	T30TM009	TRS 1000-A	TRENCHER, CHAIN TYPE CUTTER, 4′ DEEP × 5″-12″ WIDE, CRAWLER (W/CRUMBSHOE)	270 HP	D-off		$368,027	95.42	23.75	36.80	5.35	11.85	550
	T30TM002	TRS 900-B	TRENCHER, CHAIN TYPE CUTTER, 4′ DEEP × 12″ WIDE, CRAWLER (W/CRUMBSHOE)	185 HP	D-off		$264,635	68.11	17.08	26.46	3.85	8.12	405
	T30TM005	TRS 900-B-SL	TRENCHER, CHAIN TYPE CUTTER, 4′ DEEP × 12″ WIDE, CRAWLER (W/CRUMBSHOE) SELF LEVEL	185 HP	D-off		$295,499	74.86	19.08	29.55	4.30	8.12	430
	T30TM007	TRS 900-SLO	TRENCHER, CHAIN TYPE CUTTER, 4′ DEEP × 12″ WIDE, CRAWLER (W/CRUMBSHOE) SELF LEVEL, OFFSET	240 HP	D-off		$355,360	90.99	22.94	35.54	5.17	10.53	450
	T30TM008	TRS 900-SLO	TRENCHER, CHAIN TYPE CUTTER, 6′ DEEP × 18″ WIDE, CRAWLER (W/CRUMBSHOE) SELF LEVEL, OFFSET	240 HP	D-off		$369,099	93.99	23.83	36.91	5.37	10.53	470

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T30		*TESMEC USA, INC. (continued)*										
	T30TM003	TRS 900-B	TRENCHER, CHAIN TYPE CUTTER, 8′ DEEP × 24″ WIDE, CRAWLER (W/CRUMBSHOE)	185 HP D-off		$283,418	72.21	18.29	28.34	4.12	8.12	425
	T30TM006	TRS 900-B-SL	TRENCHER, CHAIN TYPE CUTTER, 8′ DEEP × 24″ WIDE, CRAWLER (W/CRUMBSHOE) SELF LEVEL	185 HP D-off		$317,433	79.65	20.49	31.74	4.62	8.12	450
	T30TM012	TRS 1100	TRENCHER, CHAIN TYPE CUTTER, 8′ DEEP × 26″ WIDE, CRAWLER (W/CRUMBSHOE)	350 HP D-off		$484,845	125.38	31.29	48.48	7.05	15.36	850
	T30TM014	TRS 1300	TRENCHER, CHAIN TYPE CUTTER, 10′ DEEP × 26″ WIDE, CRAWLER (W/CRUMBSHOE)	503 HP D-off		$740,197	189.70	47.77	74.02	10.76	22.08	1,550
	T30TM010	TRS 1000-B	TRENCHER, CHAIN TYPE CUTTER, 10′ DEEP × 30″ WIDE, CRAWLER (W/CRUMBSHOE)	270 HP D-off		$410,834	104.78	26.51	41.08	5.97	11.85	650
	T30TM013	TRS 1300	TRENCHER, CHAIN TYPE CUTTER, 14′ DEEP × 42″ WIDE, CRAWLER (W/CRUMBSHOE)	402 HP D-off		$755,956	187.55	48.79	75.60	10.99	17.64	1,550
	T30TM015	TRS 1300	TRENCHER, CHAIN TYPE CUTTER, 16′ DEEP × 42″ WIDE, CRAWLER (W/CRUMBSHOE)	503 HP D-off		$783,272	199.13	50.56	78.33	11.39	22.08	1,550
		VERMEER MANUFACTURING CO.										
	T30VE007	T-455	TRENCHER, CHAIN TYPE CUTTER, 6′ DEEP × 7.5″-24″ WIDE, CRAWLER, HYDROSTATIC	85 HP D-off		$127,362	32.55	8.22	12.74	1.85	3.73	195
	T30VE008	T-555	TRENCHER, CHAIN TYPE CUTTER, 8′ DEEP × 8″-24″ WIDE, CRAWLER, HYDROSTATIC	140 HP D-off		$216,334	55.05	13.97	21.63	3.15	6.14	225
	T30VE009	T-655	TRENCHER, CHAIN TYPE CUTTER, 8′ DEEP × 10″-24″ WIDE, CRAWLER, HYDROSTATIC	180 HP D-off		$318,473	79.60	20.56	31.85	4.63	7.90	425

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T30	*VERMEER MANUFACTURING CO. (continued)*												
	T30VE010	T-755	TRENCHER, CHAIN TYPE CUTTER, 10′ DEEP × 14″-36″ WIDE, CRAWLER, HYDROSTATIC	250 HP	D-off		$409,842	103.45	26.45	40.98	5.96	10.97	660
T35	**TRENCHERS, WHEEL TYPE CUTTER**												
	SUBCATEGORY 0.00		**TRENCHERS, WHEEL TYPE CUTTER**										
			CLEVELAND TRENCHER										
	T35CT001	9624	TRENCHER, WHEEL TYPE CUTTER, 72″ DEEP, 21.5″ WIDE, ROUND BUCKET, CRAWLER	140 HP	D-off		$183,324	47.83	11.84	18.33	2.67	6.14	230
	T35CT002	9600-S	TRENCHER, WHEEL TYPE CUTTER, 72″ DEEP, 24″ WIDE, ROUND BUCKET, CRAWLER	140 HP	D-off		$225,234	56.99	14.54	22.52	3.28	6.14	229
	T35CT003	246-FD	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 24″ WIDE, ROUND BUCKET, CRAWLER	185 HP	D-off		$253,026	65.57	16.33	25.30	3.68	8.12	320
	T35CT005	7036-HD-2	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 27.5″ WIDE, ROUND BUCKET, CRAWLER	102 HP	D-off		$236,667	57.40	15.28	23.67	3.44	4.48	282
	T35CT006	7036-3	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 33.5″ WIDE, ROUND BUCKET, CRAWLER	102 HP	D-off		$225,290	54.92	14.55	22.53	3.28	4.48	263
	T35CT004	7036-HD	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 36″ WIDE, ROUND BUCKET, CRAWLER	102 HP	D-off		$238,119	57.71	15.37	23.81	3.46	4.48	286
	T35CT007	7036-SD	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 36″ WIDE, ROUND BUCKET, CRAWLER	102 HP	D-off		$249,320	60.17	16.10	24.93	3.63	4.48	340
	T35CT008	8700-2	TRENCHER, WHEEL TYPE CUTTER, 84″ DEEP, 36″ WIDE, ROUND BUCKET, CRAWLER	150 HP	D-off		$317,624	77.75	20.50	31.76	4.62	6.58	425

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T35		***CLEVELAND TRENCHER (continued)***										
	T35CT009	7648-SD	TRENCHER, WHEEL TYPE CUTTER, 90″ DEEP, 48″ WIDE, ROUND BUCKET, CRAWLER	150 HP D-off		$372,619	89.78	24.05	37.26	5.42	6.58	455
	T35CT010	7648-SD-4	TRENCHER, WHEEL TYPE CUTTER, 90″ DEEP, 42″ WIDE, ROUND BUCKET, CRAWLER	150 HP D-off		$370,642	89.34	23.92	37.06	5.39	6.58	497
	T35CT011	400W-HD	TRENCHER, WHEEL TYPE CUTTER, 108″ DEEP, 72″ WIDE, ROUND BUCKET, CRAWLER	175 HP D-off		$439,821	105.87	28.39	43.98	6.40	7.68	672
T40	**TRUCK OPTIONS**											
	SUBCATEGORY 0.10		**CRANES/HOISTS, PERSONNEL & MATERIAL HANDLING**									
		AUTO CRANE CO.										
	T40AH001	A50A	TRUCK OPTIONS, CRANE, HYDRAULIC, 3.5 TON, 32′ BOOM (ADD 21,000 GVW TRUCK & FLATBED)			$19,285	4.22	1.25	1.93	0.28	0.00	34
	T40AH002	A72A	TRUCK OPTIONS, CRANE, HYDRAULIC, 5.0 TON, 32′ BOOM (ADD 26,000 GVW TRUCK & FLATBED)			$23,062	5.01	1.50	2.31	0.34	0.00	44
	T40AH003	A95	TRUCK OPTIONS, CRANE, HYDRAULIC, 6.6 TON, 36′ BOOM (ADD 32,500 GVW TRUCK & FLATBED)			$32,904	7.03	2.13	3.29	0.48	0.00	63
	T40AH004	A125	TRUCK OPTIONS, CRANE, HYDRAULIC, 8.6 TON, 41′ BOOM (ADD 46,000 GVW TRUCK & FLATBED)			$36,737	7.81	2.37	3.67	0.53	0.00	71

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
			PALFINGER INC.									
	T40PA001	PC 2300	TRUCK OPTIONS, CRANE, HYDRAULIC, 2-ARM ARTICULATING, 2.4 TON, 21′ BOOM (ADD 25,000 GVW TRUCK & FLATBED)			$8,278	1.95	0.54	0.83	0.12	0.00	9
	T40PA002	PK 13000	TRUCK OPTIONS, CRANE, HYDRAULIC, 3-ARM ARTICULATING, 5.3 TON, 61′ BOOM (ADD 28,000 GVW TRUCK & FLATBED)			$25,297	5.45	1.64	2.53	0.37	0.00	35
	T40PA003	PK 19000	TRUCK OPTIONS, CRANE, HYDRAULIC, 3-ARM ARTICULATING, 8.3 TON, 70′ BOOM (ADD 30,000 GVW TRUCK & FLATBED)			$35,930	7.65	2.32	3.59	0.52	0.00	51
	T40PA004	PK 27000	TRUCK OPTIONS, CRANE, HYDRAULIC, 3-ARM ARTICULATING, 9.0 TON, 69′ BOOM (ADD 52,000 GVW TRUCK & FLATBED)			$54,561	11.50	3.52	5.46	0.79	0.00	61
	T40PA005	PK 48000	TRUCK OPTIONS, CRANE, HYDRAULIC, 2-ARM ARTICULATING, 12.5 TON, 82′ BOOM (ADD 60,000 GVW TRUCK & FLATBED)			$76,601	16.04	4.94	7.66	1.11	0.00	1,072
	T40PA006	PK 60000	TRUCK OPTIONS, CRANE, HYDRAULIC, 2-ARM ARTICULATING, 14.9 TON, 82′ BOOM (ADD 62,000 GVW TRUCK & FLATBED)			$79,349	16.60	5.12	7.93	1.15	0.00	126
	SUBCATEGORY 0.20		**DUMP BODY, REAR**									
			GALION DUMP BODIES, INC.									
	T40GN001	PACKAGE 89-F	TRUCK OPTIONS, DUMP BODY, REAR, 16–23.5 CY DUMP BODY (W/HOIST) (ADD 36,000 GVW TRUCK)			$9,920	2.05	0.70	1.12	0.14	0.00	42

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
			MIDLAND MANUFACTURING INC.									
	T40MY002	KLEENSIDE	TRUCK OPTIONS, DUMP BODY, REAR, 7.5 CY, AIR GATE (W/ HOIST) (ADD 30,000 GVW TRUCK)			$4,269	0.88	0.30	0.48	0.06	0.00	21
	T40MY004	KLEENSIDE	TRUCK OPTIONS, DUMP BODY, REAR, 10.0 CY, AIR GATE (W/ HOIST) (ADD 35,000 GVW TRUCK)			$6,133	1.26	0.43	0.69	0.08	0.00	31
	T40MY005	KLEENSIDE	TRUCK OPTIONS, DUMP BODY, REAR, 13.6 CY, AIR GATE (W/ HOIST) (ADD 35,000 GVW TRUCK)			$8,729	1.80	0.61	0.98	0.12	0.00	33
	T40MY006	KLEENSIDE	TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/ HOIST) (ADD 50,000 GVW TRUCK)			$9,925	2.05	0.70	1.12	0.14	0.00	40
	SUBCATEGORY 0.30		**FLATBEDS, WITH SIDES**									
			KNAPHEIDE MANUFACTURING CO.									
	T40KF011		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 8′			$3,146	0.58	0.21	0.31	0.05	0.00	11
	T40KF013		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 10′			$3,337	0.61	0.22	0.33	0.05	0.00	14
	T40KF014		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 12′			$3,581	0.66	0.23	0.36	0.05	0.00	16
	T40KF016		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 16′			$4,303	0.78	0.28	0.43	0.06	0.00	16
	T40KF018		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 20′			$5,193	0.96	0.34	0.52	0.08	0.00	18
	T40KF020		TRUCK OPTIONS, FLATBED, W/SIDE RACKS, 8′ × 24′			$6,043	1.10	0.39	0.60	0.09	0.00	20

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.41		**HOIST, ELECTRIC DRIVE**									
		KNAPHEIDE MANUFACTURING CO.										
	T40KF021		TRUCK OPTIONS, HOIST, ELECTRIC DRIVE, PTO, 8′ TO 14′, 7 TON,			$2,541	0.59	0.17	0.25	0.04	0.00	15
	T40KF023		TRUCK OPTIONS, HOIST, ELECTRIC DRIVE, 16′ TO 24′, 7 TON			$3,347	0.70	0.22	0.33	0.05	0.00	4
	T40KF024		TRUCK OPTIONS, HOIST, ELECTRIC DRIVE, 16′ TO 24′, 14 TON,			$3,904	0.81	0.26	0.39	0.06	0.00	6
	T40KF022		TRUCK OPTIONS, HOIST, ELECTRIC DRIVE, PTO, 16′ TO 24′, 20 TON,			$4,935	1.05	0.32	0.49	0.07	0.00	18
	SUBCATEGORY 0.50		**TRANSIT MIXERS**									
		NO SPECIFIC MANUFACTURER										
	T40XX034	RDTM-8	TRUCK OPTIONS, TRANSIT MIXER, 8.0 CY, HYDROSTATIC, 100 GAL, (ADD 60,000 GVW TRUCK)	235 HP D-on		$149,097	45.67	10.02	15.84	2.10	12.18	266
	T40XX035	RDTM-9	TRUCK OPTIONS, TRANSIT MIXER, 9.0 CY, HYDROSTATIC, 100 GAL (ADD 66,000 GVW TRUCK)	250 HP D-on		$149,235	46.70	10.03	15.86	2.10	12.95	270
	T40XX036	RDTM-10	TRUCK OPTIONS, TRANSIT MIXER, 10.0 CY, HYDROSTATIC, 100 GAL, (ADD 66,000 GVW TRUCK)	285 HP D-on		$149,342	49.08	10.04	15.87	2.10	14.77	274
	T40XX037	RDTM-11	TRUCK OPTIONS, TRANSIT MIXER, 11.0 CY, HYDROSTATIC, 100 GAL, (ADD 70,000 GVW TRUCK)	285 HP D-on		$149,535	49.12	10.06	15.89	2.11	14.77	285

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T40			***NO SPECIFIC MANUFACTURER (continued)***									
	T40XX038	RDTM-12	TRUCK OPTIONS, TRANSIT MIXER, 12.0 CY, HYDROSTATIC, 100 GAL, (ADD 75,000 GVW TRUCK)	285 HP D-on		$149,734	49.16	10.07	15.91	2.11	14.77	295
	SUBCATEGORY 0.60		**WATER TANKS**									
			ROSCO MANUFACTURING CO.									
	T40RS001		TRUCK OPTIONS, WATER TANK, 2,000 GAL (ADD 28,000 GVW TRUCK)			$18,026	3.19	1.12	1.69	0.27	0.00	38
	T40RS002		TRUCK OPTIONS, WATER TANK, 3,000 GAL (ADD 40,000 GVW TRUCK)			$20,946	3.70	1.29	1.96	0.31	0.00	45
	T40RS003		TRUCK OPTIONS, WATER TANK, 4,000 GAL (ADD 50,000 GVW TRUCK)			$23,098	4.10	1.44	2.17	0.35	0.00	55
	SUBCATEGORY 0.70		**ALL OTHER OPTIONS**									
			BRODERSON MANUFACTURING CORPORATION									
	T40BD001	MN-42-F	TRUCK OPTIONS, GUILLOTINE CONCRETE BREAKER, DEMOLITION 4′ DIA PUNCH, FROST CHISEL, 14″ LONG DEMOLITION BLADE OR 12″ × 7″ ASPHALT BLADE, 4 × 2	112 HP D-off		$91,746	24.32	5.89	9.12	1.33	4.92	105

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T45	**TRUCK TRAILERS**											
	SUBCATEGORY 0.10		**BOTTOM DUMP**									
		MIDLAND MANUFACTURING INC.										
	T45MY004	40′ MC 2000	TRUCK TRAILER, BOTTOM DUMP, 21.0 CY, 28 TON, 40′ TANDEM, 2 AXLE, CLAMSHELL (ADD TOWING TRUCK)			$25,476	5.09	1.31	1.93	0.34	0.00	152
	T45MY005	40′ TC 3000	TRUCK TRAILER, BOTTOM DUMP, 21.0 CY, 30 TON, 40′ TRIAXLE, CLAMSHELL (ADD TOWING TRUCK)			$34,975	6.94	1.77	2.60	0.47	0.00	138
	T45MY006	38′ MC 3000	TRUCK TRAILER, BOTTOM DUMP, 23.0 CY, 30 TON, 38′ TRIAXLE, CLAMSHELL (ADD TOWING TRUCK)			$35,890	7.10	1.83	2.69	0.48	0.00	145
	T45MY007	40′ MC 3000	TRUCK TRAILER, BOTTOM DUMP, 23.0 CY, 30 TON, 40′ TRIAXLE, CLAMSHELL (ADD TOWING TRUCK)			$34,702	6.89	1.75	2.58	0.46	0.00	152
		NO SPECIFIC MANUFACTURER										
	T45XX001		TRUCK TRAILER, BOTTOM DUMP, 27 TON (ADD TOWING TRUCK)			$32,649	6.24	1.77	2.67	0.43	0.00	122
	T45XX003		TRUCK TRAILER, BOTTOM DUMP, 30 TON (ADD TOWING TRUCK)			$37,495	7.06	2.06	3.11	0.50	0.00	160
	SUBCATEGORY 0.20		**END DUMP**									
		MIDLAND MANUFACTURING INC.										
	T45MY015	28′ SK2000	TRUCK TRAILER, END DUMP, 28 CY, 36 TON, 2 AXLE (W/HOIST) (ADD TOWING TRUCK)			$27,649	5.45	1.44	2.13	0.37	0.00	115

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T45	***MIDLAND MANUFACTURING INC. (continued)***											
	T45MY016	32′ ST 2400	TRUCK TRAILER, END DUMP, 28 CY, 36 TON, 2 AXLE (W/HOIST) (ADD TOWING TRUCK)			$28,069	5.50	1.45	2.16	0.37	0.00	130
	T45MY017	39′ SK 2300	TRUCK TRAILER, END DUMP, 39 CY, 50 TON, 3 AXLE (W/HOIST) (ADD TOWING TRUCK)			$30,907	6.24	1.53	2.24	0.41	0.00	170
	NO SPECIFIC MANUFACTURER											
	T45XX008		TRUCK TRAILER, END DUMP, 20 CY, 24 TON (ADD TOWING TRUCK)			$26,018	5.04	1.39	2.08	0.35	0.00	110
	SUBCATEGORY 0.30		**PUP TRAILER**									
	MIDLAND MANUFACTURING INC.											
	T45MY018	14′ SK 2100	TRUCK TRAILER, PUP TRAILER, 10 CY, 13 TON, 2 AXLE (W/ HOIST) (ADD TOWING TRUCK)			$18,580	4.43	1.07	1.64	0.25	0.00	80
	T45MY019	14′ SL 2100	TRUCK TRAILER, PUP TRAILER, 12 CY, 15 TON, 2 AXLE (W/ HOIST) (ADD TOWING TRUCK)			$18,425	4.40	1.06	1.62	0.25	0.00	80
	NO SPECIFIC MANUFACTURER											
	T45XX009		TRUCK TRAILER, PUP TRAILER, 8 CY, LONG TONGUE (ADD TOWING TRUCK)			$27,537	6.08	1.77	2.77	0.38	0.00	86
	T45XX010		TRUCK TRAILER, PUP TRAILER, 10 CY, LONG TONGUE (ADD TOWING TRUCK)			$28,139	6.19	1.80	2.84	0.38	0.00	86
	T45XX032		TRUCK TRAILER, PUP TRAILER, 13 CY, 14.5 T, 3 AXLE (ADD TOWING TRUCK)			$35,387	7.38	2.47	3.98	0.48	0.00	92
	T45XX033		TRUCK TRAILER, PUP TRAILER, 16 CY, 18.0 T, 4 AXLE (ADD TOWING TRUCK)			$41,771	8.73	2.92	4.70	0.57	0.00	100

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.41		**LOWBOY, RIGID NECK, DROP DECK**									
			EAGER BEAVER									
	T45EA006	GSL	TRUCK TRAILER, LOWBOY, 35 TON, DETATCHABLE GOOSENECK, 2 AXLE, 8′6″W × 22′ L (ADD TOWING TRUCK)			$28,771	5.65	1.41	2.06	0.38	0.00	150
	T45EA007	50GSL/3	TRUCK TRAILER, LOWBOY, 50 TON, DETATCHABLE GOOSENECK, 3 AXLE, 8′6″W × 24′ L (ADD TOWING TRUCK)			$45,998	8.66	2.28	3.34	0.61	0.00	205
			NO SPECIFIC MANUFACTURER									
	T45XX011		TRUCK TRAILER, LOWBOY, 25 TON, 2 AXLE (ADD TOWING TRUCK)			$27,577	4.88	1.50	2.25	0.37	0.00	95
	T45XX012		TRUCK TRAILER, LOWBOY, 30 TON, 2 AXLE (ADD TOWING TRUCK)			$29,197	5.12	1.59	2.39	0.39	0.00	115
	T45XX013		TRUCK TRAILER, LOWBOY, 35 TON, 2 AXLE (ADD TOWING TRUCK)			$30,678	5.41	1.66	2.50	0.41	0.00	110
	T45XX014		TRUCK TRAILER, LOWBOY, 35 TON, 3 AXLE (ADD TOWING TRUCK)			$37,512	6.66	2.02	3.03	0.50	0.00	127
	T45XX015		TRUCK TRAILER, LOWBOY, 40 TON, 3 AXLE (ADD TOWING TRUCK)			$38,364	6.78	2.06	3.10	0.51	0.00	136
	T45XX016		TRUCK TRAILER, LOWBOY, 50 TON, 3 AXLE (ADD TOWING TRUCK)			$42,924	7.54	2.31	3.47	0.57	0.00	145
	T45XX017		TRUCK TRAILER, LOWBOY, 60 TON, 3 AXLE (ADD TOWING TRUCK)			$45,571	8.06	2.42	3.62	0.61	0.00	175
	T45XX018		TRUCK TRAILER, LOWBOY, 70 TON, 3 AXLE (ADD TOWING TRUCK)			$47,788	8.40	2.55	3.82	0.64	0.00	213

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			CWT
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T45	***NO SPECIFIC MANUFACTURER (continued)***											
	T45XX019		TRUCK TRAILER, LOWBOY, 75 TON, 3 AXLE (ADD TOWING TRUCK)			$52,336	9.07	2.82	4.23	0.70	0.00	220
	T45XX020		TRUCK TRAILER, LOWBOY, 80 TON, 4 AXLE (ADD TOWING TRUCK)			$52,460	9.28	2.80	4.19	0.70	0.00	268
	T45XX021		TRUCK TRAILER, LOWBOY, 90 TON, 4 AXLE (ADD TOWING TRUCK)			$55,041	9.66	2.95	4.43	0.73	0.00	293
	T45XX022		TRUCK TRAILER, LOWBOY, 100 TON, 4 AXLE (ADD TOWING TRUCK)			$62,534	10.95	3.33	4.99	0.83	0.00	312
	T45XX023		TRUCK TRAILER, LOWBOY, 120 TON, 4 AXLE (ADD TOWING TRUCK)			$74,961	13.05	3.98	5.96	1.00	0.00	350
	SUBCATEGORY 0.50		**FLATBED TRAILER**									
	NO SPECIFIC MANUFACTURER											
	T45XX025		TRUCK TRAILER, FLATBED, 25 TON, 2 AXLE (ADD TOWING TRUCK)			$25,617	4.35	1.36	2.04	0.34	0.00	110
	T45XX034	32	TRUCK TRAILER, FLATBED, 40 TON, 32.0 ft, 2 AXLE (ADD TOWING TRUCK)			$25,578	4.21	1.49	2.30	0.34	0.00	103
	T45XX035	40	TRUCK TRAILER, FLATBED, 40 TON, 40.0 ft, 2 AXLE (ADD TOWING TRUCK)			$27,170	4.45	1.59	2.45	0.36	0.00	110
	SUBCATEGORY 0.60		**MISCELLANEOUS/UTILITY**									
	NO SPECIFIC MANUFACTURER											
	T45XX026		TRUCK TRAILER, MISCELLANEOUS/UTILITY, TILT BED, 12 TON, 2 AXLE (ADD TOWING TRUCK)			$14,701	2.81	0.80	1.19	0.20	0.00	62

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T45	***NO SPECIFIC MANUFACTURER (continued)***											
	T45XX027		TRUCK TRAILER, MISCELLANEOUS/UTILITY, TILT BED, 16 TON, 2 AXLE (ADD TOWING TRUCK)			$16,667	3.19	0.88	1.31	0.22	0.00	65
	T45XX028		TRUCK TRAILER, MISCELLANEOUS/UTILITY, TILT BED, 20 TON, 2 AXLE (ADD TOWING TRUCK)			$19,264	3.67	1.01	1.49	0.26	0.00	67
	T45XX024		TRUCK TRAILER, MISCELLANEOUS/UTILITY, ATTACHMENT, HELPER DOLLY, 60 TON TRAILER MAX (ADD TOWING TRUCK)			$23,996	4.11	1.27	1.90	0.32	0.00	62
	SUBCATEGORY 0.70		**WATER TANKER TRAILER**									
	NO SPECIFIC MANUFACTURER											
	T45XX029		TRUCK TRAILER, WATER TANKER, 4000 GAL, W/PUMP (ADD TOWING TRUCK)	63 HP D-off		$67,621	13.36	3.46	4.94	0.99	2.77	170
	T45XX030		TRUCK TRAILER, WATER TANKER, 5000GAL, W/PUMP (ADD TOWING TRUCK)	63 HP D-off		$69,119	13.78	3.47	4.92	1.01	2.77	240
	T45XX031		TRUCK TRAILER, WATER TANKER, 6000 GAL, W/PUMP (ADD TOWING TRUCK)	63 HP D-off		$83,235	15.83	4.21	5.98	1.22	2.77	250
T50	**TRUCKS, HIGHWAY (Add attachments as required)**											
	SUBCATEGORY 0.01		**0 THRU 10,000 GVW**									
	GMC AND CHEVROLET											
	T50GM001	S10	TRUCK, HIGHWAY, 3,500 GVW, 4 × 2, COMPACT	120 HP G		$13,723	6.32	0.86	1.32	0.20	2.77	26

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T50		*GMC AND CHEVROLET (continued)*											
	T50GM004	R26	TRUCK, HIGHWAY, 8,600 GVW, 4 × 2, (SUBURBAN)	285 HP	G		$34,095	15.11	2.18	3.36	0.50	6.58	50
	T50GM005	V26	TRUCK, HIGHWAY, 8,600 GVW, 4 × 4, (SUBURBAN)	285 HP	G		$36,659	15.65	2.34	3.62	0.53	6.58	52
		NO SPECIFIC MANUFACTURER											
	T50XX001	4 × 2 1/2 130 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 1/2 TON PICKUP, 4 × 2	130 HP	G		$13,667	6.69	0.84	1.28	0.20	3.00	43
	T50XX002	4 × 2 3/4 130 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4 × 2	130 HP	G		$16,514	7.30	1.02	1.56	0.24	3.00	40
	T50XX003	4 × 2 1 180 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4 × 2	180 HP	G		$18,812	9.21	1.17	1.79	0.27	4.16	41
	T50XX004	4 × 4 1/2 130 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 1/2 TON PICKUP, 4 × 4	130 HP	G		$16,574	7.32	1.03	1.57	0.24	3.00	43
	T50XX005	4 × 4 3/4 130 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4 × 4	130 HP	G		$19,492	7.95	1.21	1.85	0.28	3.00	45
	T50XX006	4 × 4 1 180 CONV GAS	TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4 × 4	180 HP	G		$20,203	9.55	1.26	1.93	0.29	4.16	45
	T50XX007	4 × 2 1/2 130 CREW GAS	TRUCK, HIGHWAY, CREW, 1/2 TON PICKUP, 4 × 2	130 HP	G		$14,513	6.86	0.90	1.37	0.21	3.00	45
	T50XX008	4 × 2 3/4 130 CREW GAS	TRUCK, HIGHWAY, CREW, 3/4 TON PICKUP, 4 × 2	130 HP	G		$17,502	7.48	1.08	1.65	0.25	3.00	47
	T50XX009	4 × 2 1 180 CREW GAS	TRUCK, HIGHWAY, CREW, 1 TON PICKUP, 4 × 2	180 HP	G		$21,559	9.74	1.34	2.06	0.31	4.16	45
	T50XX010	4 × 4 1/2 130 CREW GAS	TRUCK, HIGHWAY, CREW, 1/2 TON PICKUP, 4 × 4	130 HP	G		$19,699	7.95	1.24	1.89	0.29	3.00	48
	T50XX011	4 × 4 3/4 180 CREW GAS	TRUCK, HIGHWAY, CREW, 3/4 TON PICKUP, 4 × 4	180 HP	G		$21,137	9.75	1.32	2.02	0.31	4.16	55
	T50XX012	4 × 4 1 180 CREW GAS	TRUCK, HIGHWAY, CREW, 1 TON PICKUP, 4 × 4	180 HP	G		$22,194	9.94	1.39	2.13	0.32	4.16	45
	T50XX013	4 × 2 1/2 75 CONV DSL	TRUCK, HIGHWAY, CONVENTIONAL, 1/2 TON PICKUP, 4 × 2	75 HP	D-on		$17,903	4.89	1.12	1.71	0.26	0.94	39

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T50		***NO SPECIFIC MANUFACTURER (continued)***										
	T50XX014	4 × 2 3/4 75 CONV DSL	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4 × 2	75 HP D-on		$19,864	5.32	1.24	1.89	0.29	0.94	40
	T50XX015	4 × 2 1 130 CONV DSL	TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4 × 2	130 HP D-on		$22,911	6.75	1.43	2.20	0.33	1.63	43
	T50XX016	4 × 4 1/2 130 CONV DSL	TRUCK, HIGHWAY, CONVENTIONAL, 1/2 TON PICKUP, 4 × 4	130 HP D-on		$21,343	6.47	1.34	2.05	0.31	1.63	43
	T50XX017	4 × 4 3/4 130 CONV DSL	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4 × 4	130 HP D-on		$21,539	6.57	1.34	2.06	0.31	1.63	45
	T50XX018	CONV DSL 4 × 4 1 130	TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4 × 4	130 HP D-on		$25,789	7.38	1.62	2.49	0.37	1.63	49
	T50XX019	4 × 2 3/4 130 CREW DSL	TRUCK, HIGHWAY, CREW, 3/4 TON PICKUP, 4 × 2	130 HP D-on		$20,575	6.30	1.28	1.96	0.30	1.63	47
	T50XX020	4 × 4 3/4 130 CREW DSL	TRUCK, HIGHWAY, CREW, 3/4 TON PICKUP, 4 × 4	130 HP D-on		$24,888	7.22	1.56	2.39	0.36	1.63	55
	T50XX021	4 × 2 1 130 CREW DSL	TRUCK, HIGHWAY, CREW, 1 TON PICKUP, 4 × 2	130 HP D-on		$22,604	6.70	1.42	2.17	0.33	1.63	48
	SUBCATEGORY 0.02		**OVER 10,000 THRU 30,000 GVW (Chassis only-Add options)**									
		NO SPECIFIC MANUFACTURER										
	T50XX023	4 × 2 20KGVW GAS	TRUCK, HIGHWAY, 20,000 LBS GVW, 2 AXLE, 4 × 2 (CHASSIS ONLY-ADD OPTIONS)	210 HP G		$35,425	20.30	1.86	2.72	0.50	11.32	70
	T50XX024	4 × 2 25KGVW GAS	TRUCK, HIGHWAY, 25,000 LBS GVW, 2 AXLE, 4 × 2 (CHASSIS ONLY-ADD OPTIONS)	210 HP G		$30,755	19.58	1.61	2.34	0.44	11.32	72
	T50XX022	4 × 2 25KGVW DSL	TRUCK, HIGHWAY, 25,000 LBS GVW, 2 AXLE, 4 × 2 (CHASSIS ONLY-ADD OPTIONS)	180 HP D-on		$44,966	13.60	2.38	3.48	0.64	5.09	88

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T50	***NO SPECIFIC MANUFACTURER (continued)***												
	T50XX026	4 × 2 30KGVW DSL	TRUCK, HIGHWAY, 30,000 LBS GVW, 2 AXLE, 4 × 2 (CHASSIS ONLY-ADD OPTIONS)	210 HP	D-on		$60,297	17.25	3.18	4.63	0.86	5.93	105
	T50XX025	4 × 4 30KGVW DSL	TRUCK, HIGHWAY, 30,000 LBS GVW, 2 AXLE, 4 × 4 (CHASSIS ONLY-ADD OPTIONS)	170 HP	D-on		$59,352	15.79	3.12	4.56	0.84	4.80	97
	SUBCATEGORY 0.03		**OVER 30,000 GVW (Chassis only - Add options)**										
	NO SPECIFIC MANUFACTURER												
	T50XX027	4 × 2 35KGVW DSL	TRUCK, HIGHWAY, 35,000 LBS GVW, 2 AXLE, 4 × 2 (CHASSIS ONLY-ADD OPTIONS)	265 HP	D-on		$96,011	26.81	4.46	6.24	1.34	10.82	126
	T50XX028	6 × 4 45KGVW DSL	TRUCK, HIGHWAY, 45,000 LBS GVW, 2 AXLE, 6 × 4 (CHASSIS ONLY-ADD OPTIONS)	230 HP	D-on		$96,145	25.39	4.43	6.17	1.34	9.39	135
	T50XX029	6 × 4 55KGVW DSL	TRUCK, HIGHWAY, 50,000 LBS GVW, 2 AXLE, 6 × 4 (CHASSIS ONLY-ADD OPTIONS)	310 HP	D-on		$88,518	28.51	4.07	5.66	1.24	12.65	144
	T50XX030	6 × 6 70KGVW DSL	TRUCK, HIGHWAY, 70,000 LBS GVW, 2 AXLE, 6 × 6 (CHASSIS ONLY-ADD OPTIONS)	350 HP	D-on		$113,221	33.81	5.24	7.31	1.58	14.29	180
	T50XX031	6 × 4 75KGVW DSL	TRUCK, HIGHWAY, 75,000 LBS GVW, 2 AXLE, 6 × 4 (CHASSIS ONLY-ADD OPTIONS)	400 HP	D-on		$103,625	35.08	4.79	6.68	1.45	16.33	197
T55	**TRUCKS, OFF-HIGHWAY**												
	SUBCATEGORY 0.10		**RIGID FRAME**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T55CA007	769D	TRUCK, OFF-HIGHWAY, RIGID FRAME, 31.7 CY, 41.6 TON, 4 × 4, REAR DUMP	450 HP	D-off		$554,001	81.14	18.56	22.70	7.21	10.77	740

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T55	*CATERPILLAR INC. (MACHINE DIVISION) (continued)*												
	T55CA002	773D	TRUCK, OFF-HIGHWAY, RIGID FRAME, 46.9 CY, 57.7 TON, 4 × 4, REAR DUMP	650 HP	D-off		$753,857	104.61	25.15	30.66	9.82	15.56	955
	T55CA003	777D	TRUCK, OFF-HIGHWAY, RIGID FRAME, 78.6 CY, 100 TON, 4 × 4, REAR DUMP	870 HP	D-off		$1,135,129	153.53	37.90	46.23	14.78	20.83	1,542
	KOMATSU AMERICA INTERNATIONAL COMPANY												
	T55KM009	HD325-6	TRUCK, OFF-HIGHWAY, RIGID FRAME, 31.4 CY, 44 TON, 4 × 4, REAR DUMP	488 HP	D-off		$517,020	78.74	17.29	21.12	6.73	11.68	1,590
	T55KM010	HD465–5	TRUCK, OFF-HIGHWAY, RIGID FRAME, 44.7 CY, 61 TON, 4 × 4, REAR DUMP	715 HP	D-off		$758,146	117.23	25.30	30.86	9.87	17.12	2,119
	T55KM011	HD605–5	TRUCK, OFF-HIGHWAY, RIGID FRAME, 52.3 CY, 67 TON, 4 × 4, REAR DUMP	715 HP	D-off		$817,937	123.04	27.35	33.40	10.65	17.12	2,352
	T55KM012	HD785–5	TRUCK, OFF-HIGHWAY, RIGID FRAME, 78.7 CY, 100 TON, 4 × 4, REAR DUMP	1,082 HP	D-off		$1,080,106	154.86	36.02	43.89	14.07	25.90	3,670
	T55KM013	HD1500–5	TRUCK, OFF-HIGHWAY, RIGID FRAME, 102 CY, 165 TON, 4 × 4, REAR DUMP	1,486 HP	D-off		$1,795,192	250.90	59.64	72.52	23.38	35.57	5,500
	T55KM014	730E	TRUCK, OFF-HIGHWAY, RIGID FRAME, 145 CY, 205 TON, 4 × 4, REAR DUMP	2,000 HP	D-off		$2,118,851	313.23	69.80	84.41	27.59	47.88	7,150
	SUBCATEGORY 0.20		**ARTICULATED FRAME**										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T55CA008	D25D	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 18 CY, 25 TON, 4 × 4, REAR DUMP	260 HP	D-off		$327,682	61.29	14.74	20.70	4.39	8.99	471
	T55CA009	D30D	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 22 CY, 30 TON, 4 × 4, REAR DUMP	285 HP	D-off		$385,104	71.76	17.30	24.27	5.16	9.86	519

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
T55			***CATERPILLAR INC. (MACHINE DIVISION) (continued)***										
	T55CA010	D250D SERIES II	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 18 CY, 25 TON, 6 × 6, REAR DUMP	214 HP	D-off		$332,726	61.26	14.95	20.98	4.46	7.40	424
	T55CA011	D300E SERIES II	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 22 CY, 30 TON, 6 × 6, REAR DUMP	260 HP	D-off		$393,388	73.39	17.64	24.73	5.27	8.99	488
	T55CA012	D350E SERIES II	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 25 CY, 35 TON, 6 × 6, REAR DUMP	285 HP	D-off		$462,795	83.77	20.84	29.28	6.20	9.86	599
	T55CA013	D400E SERIES II	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 28 CY, 40 TON, 6 × 6, REAR DUMP	385 HP	D-off		$470,749	92.39	21.05	29.47	6.31	13.31	653
			DEERE & COMPANY										
	T55JD001	250C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 18 CY, 25 TON, 6 × 6, REAR DUMP	237 HP	D-off		$255,934	53.79	11.30	15.74	3.43	8.20	355
	T55JD002	300C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 22 CY, 29 TON, 6 × 6, REAR DUMP	251 HP	D-off		$295,331	59.72	13.12	18.32	3.96	8.68	401
	T55JD003	350C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 25 CY, 35 TON, 6 × 6, REAR DUMP	335 HP	D-off		$391,148	79.78	17.34	24.20	5.24	11.58	571
	T55JD004	400C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 29 CY, 40 TON, 6 × 6, REAR DUMP	410 HP	D-off		$439,018	92.66	19.38	26.98	5.89	14.18	635
			KOMATSU AMERICA INTERNATIONAL COMPANY										
	T55KM015	HM350-1	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 35.7 TON, 19.1–25.9 CY, 6 × 6 × 2, REAR DUMP	389 HP	D-off		$471,693	92.92	21.05	29.46	6.32	13.45	630
	T55KM016	HM400–1	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 40.3 TON, 21.6–29.2 CY, 6 × 6 × 2, REAR DUMP	430 HP	D-off		$541,821	107.41	24.11	33.70	7.26	14.87	668

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	VOLVO CONSTRUCTION EQUIPMENT GROUP												
	T55VO002	A-25C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 14–18 CY, 25 TON, REAR DUMP, 4 × 4	251 HP	D-off		$263,076	53.41	11.72	16.37	3.53	8.68	348
	T55VO003	A-25C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 14–18 CY, 25 TON, REAR DUMP, 6 × 6	251 HP	D-off		$291,767	59.90	12.92	18.01	3.91	8.68	392
	T55VO005	A-30C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 17–22 CY, 30 TON, REAR DUMP, 6 × 6	296 HP	D-off		$338,486	63.57	15.26	21.44	4.54	10.24	461
	T55VO004	A-35C	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 19–25 CY, 35 TON, REAR DUMP, 6 × 6	322 HP	D-off		$438,530	82.89	19.68	27.59	5.88	11.13	567
	T55VO006	A-40	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 21–29 CY, 40 TON, REAR DUMP, 6 × 6	395 HP	D-off		$483,796	95.29	21.60	30.21	6.49	13.66	660
T56	**TRUCKS, OFF-HIGHWAY/PRIME MOVER TRACTORS & WAGONS**												
	SUBCATEGORY 0.10		PRIME MOVER TRACTORS										
	CATERPILLAR INC. (MACHINE DIVISION)												
	T56CA006	776D	TRUCK, OFF-HIGHWAY, PRIME MOVER TRACTOR, 4 × 4, RIGID FRAME	938 HP	D-off		$1,061,206	153.43	35.37	43.09	13.82	26.20	1,164
T57	**TRUCKS, VACUUM**												
	SUBCATEGORY 0.00		TRUCKS, VACUUM										
	CUSCO INDUSTRIES												
	T57CU001	INDUSTRIAL VAC 130	VACUUM, 5500 GAL, 750 CFM, TRAILER MTD, REAR DOOR & HYDRAULIC DUMP SYSTEM (ADD TOWING TRUCK)	76 HP	D-off		$82,630	18.04	4.45	6.56	1.17	3.34	76

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
T57		*CUSCO INDUSTRIES (continued)*										
	T57CU002	SS INDUST. VAC 130	VACUUM, 5500 GAL, 750 CFM, STAINLESS STEEL, TRAILER MTD, REAR DOOR & HYDRAULIC DUMP SYSTEM (ADD TOWING TRUCK)	76 HP D-off		$101,126	21.15	5.46	8.04	1.44	3.34	76
	T57CU003	2527	VACUUM, 5500 GAL, 2,100 CFM, TRAILER MTD, REAR DOOR & HYDRAULIC DUMP SYSTEM (ADD TOWING TRUCK)	115 HP D-off		$149,640	31.41	8.08	11.92	2.12	5.05	115
	T57CU004	3827	VACUUM, 5500 GAL, 3,170 CFM, TRAILER MTD, REAR DOOR & HYDRAULIC DUMP SYSTEM (ADD TOWING TRUCK)	177 HP D-off		$170,537	38.34	9.22	13.59	2.42	7.77	177
	T57CU005	5327	VACUUM, 5500 GAL, 4,550 CFM, TRAILER MTD, REAR DOOR & HYDRAULIC DUMP SYSTEM (ADD TOWING TRUCK)	335 HP D-off		$184,416	49.41	9.97	14.70	2.62	14.70	335
T60	**TRUCKS, WATER, OFF-HIGHWAY**											
	SUBCATEGORY 0.00		**TRUCKS, WATER, OFF-HIGHWAY**									
		KLEIN PRODUCTS, INC.										
	T60KI001	KT-50	TRUCK, WATER, OFF-HIGHWAY, 5000 GAL, W/CAT 613C TRACTOR	175 HP D-off		$215,511	41.59	9.89	13.76	3.01	7.68	320
	T60KI002	KT-60	TRUCK, WATER, OFF-HIGHWAY, 6000 GAL, W/CAT 621E TRACTOR	330 HP D-off		$336,600	69.53	15.37	21.34	4.70	14.48	580
	T60KI003	KT-80	TRUCK, WATER, OFF-HIGHWAY, 8000 GAL, W/CAT 631E TRACTOR	450 HP D-off		$543,850	106.45	24.95	34.71	7.59	19.75	751
	T60KI004	KT-100	TRUCK, WATER, OFF-HIGHWAY, 10000 GAL, W/CAT 631E TRACTOR	450 HP D-off		$114,709	48.64	4.65	6.10	1.60	19.75	811

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
M10			***KLEIN PRODUCTS, INC. (continued)***									
	T60KI006	KT-120	TRUCK, WATER, OFF-HIGHWAY, 12000 GAL, W/CAT 651E TRACTOR	550 HP D-off		$660,038	128.22	30.41	42.37	9.22	24.14	1,097
			SOUTHWEST CONSTRUCTION EQUIPMENT CO.									
	T60SO001	STT-60	TRUCK, WATER, OFF-HIGHWAY, 6000 GAL, W/CAT 621E TRACTOR	330 HP D-off		$389,911	76.70	17.89	24.89	5.44	14.48	610
	T60SO002	STT-80	TRUCK, WATER, OFF-HIGHWAY, 8000 GAL, W/CAT 631E TRACTOR	450 HP D-off		$540,466	106.58	24.74	34.37	7.55	19.75	812
	T60SO003	STT-100	TRUCK, WATER, OFF-HIGHWAY, 10000 GAL, W/CAT 631E TRACTOR	450 HP D-off		$548,595	107.67	25.12	34.91	7.66	19.75	897
	T60SO004	STT-120	TRUCK, WATER, OFF-HIGHWAY, 12000 GAL, W/CAT 651E TRACTOR	550 HP D-off		$681,748	133.61	31.18	43.32	9.52	24.14	1,149
	T60SO005	STT-140	TRUCK, WATER, OFF-HIGHWAY, 14000 GAL, W/CAT 651E TRACTOR	550 HP D-off		$693,156	135.15	31.72	44.08	9.68	24.14	1,184
W25	**WATER & CO2 BLASTERS**											
	SUBCATEGORY 0.10		**LOW PRESSURE, (< 5,000 PSI)**									
			SIOUX STEAM CLEANER CORPORATION									
	W25SD001	513-5-E	WATER BLASTER, LOW PRESSURE, COLD WATER, 1400 PSI	5 HP E		$3,568	2.08	0.42	0.71	0.06	0.30	4
	W25SD005	514-4-G	WATER BLASTER, LOW PRESSURE, COLD WATER, 2500 PSI, 4 GPM	11 HP G		$4,818	4.22	0.56	0.96	0.08	1.61	4
	W25SD003	515-5-G	WATER BLASTER, LOW PRESSURE, COLD WATER, 3000 PSI	14 HP G		$5,514	5.09	0.64	1.10	0.09	2.05	5

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE			VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN		CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
W25	***SIOUX STEAM CLEANER CORPORATION (continued)***												
	W25SD002	EN-140-H4-1800	WATER BLASTER, LOW PRESSURE, HOT WATER, 1800 PSI	3 HP	E		$8,579	4.27	1.00	1.72	0.14	0.18	5
	W25SD004	370H	WATER BLASTER, LOW PRESSURE, HOT WATER, 3000 PSI, TRAILER MTD	23 HP	G		$10,756	9.08	1.22	2.10	0.17	3.36	19
	NO SPECIFIC MANUFACTURER												
	W25XX005	COLD 3/1000G	WATER BLASTER, LOW PRESSURE, COLD WATER, 700 PSI, 3 GPM	5 HP	G		$1,644	1.66	0.20	0.33	0.03	0.73	4
	W25XX006	COLD 4/1000G	WATER BLASTER, LOW PRESSURE, COLD WATER, 1200 PSI, 3 GPM	5 HP	G		$2,313	1.97	0.27	0.46	0.04	0.73	4
	W25XX007	COLD 4/2000G	WATER BLASTER, LOW PRESSURE, COLD WATER, 2000 PSI, 4 GPM	8 HP	G		$3,127	2.90	0.37	0.63	0.05	1.17	2
	W25XX008	COLD 4/3000G	WATER BLASTER, LOW PRESSURE, COLD WATER, 3000 PSI, 4 GPM	11 HP	G		$3,222	3.47	0.37	0.64	0.05	1.61	6
	W25XX009	HOT 4/1000G	WATER BLASTER, LOW PRESSURE, HOT WATER/ STEAM, 1000 PSI, 4 GPM	8 HP	G		$6,523	4.48	0.76	1.30	0.11	1.17	6
	W25XX010	HOT 6/3000G	WATER BLASTER, LOW PRESSURE, HOT WATER/ STEAM, 3000 PSI, 6 GPM	24 HP	G		$9,985	8.97	1.16	2.00	0.16	3.51	10
	SUBCATEGORY 0.20		**HIGH PRESSURE, (> = 5,000 PSI)**										
	NLB CORPORATION												
	W25NL001	6200E	WATER BLASTER, HIGH PRESSURE, 50 GPM @ 6000 PSI	200 HP	E		$60,660	46.43	7.05	12.13	0.98	12.16	118

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
W25		***NLB CORPORATION (continued)***											
	W25NL003	201536D	WATER BLASTER, HIGH PRESSURE, 13.2 GPM @ 20000 PSI, SKID, W/50 LF HOSE & CLEANING LANCE	150 HP	D-off		$65,898	44.64	7.66	13.18	1.07	9.78	78
	W25NL002	20253D	WATER BLASTER, HIGH PRESSURE, 22 GPM @ 20000 PSI, SKID (ADD TRUCK, FLATBED TRAILER & WATER TANKER)	335 HP	D-off		$102,670	77.86	11.94	20.53	1.67	21.83	140
	W25NL005	20600D	WATER BLASTER, HIGH PRESSURE, 53 GPM @ 20000 PSI, SKID (ADD TRUCK, FLATBED TRAILER & WATER TANKER)	700 HP	D-off		$253,188	181.66	29.43	50.64	4.11	45.62	200
	W25NL004	4400	WATER BLASTER, HIGH PRESSURE, HYDRODEMOLITION UNIT CONCRETE BUSTER (ADD MODEL 20600D WATER BLASTER)	40 HP	D-off		$135,884	69.44	15.57	26.72	2.21	2.61	80
	SUBCATEGORY 0.30		**STEAM CLEANERS**										
		ALKOTA CLEANING SYSTEMS, INC.											
	W25AO001	90	WATER BLASTER, STEAM CLEANER, 90 GPH, 200 PSI	1 HP	E		$2,370	1.69	0.28	0.47	0.04	0.06	4
	W25AO002	120	WATER BLASTER, STEAM CLEANER, 130 GPH, 325 PSI	1 HP	E		$2,908	2.19	0.34	0.58	0.05	0.06	4
	W25AO003	181	WATER BLASTER, STEAM CLEANER, 180 GPH, 250 PSI	2 HP	E		$4,301	2.92	0.50	0.86	0.07	0.12	6
	W25AO004	240	WATER BLASTER, STEAM CLEANER, 240 GPH, 250 PSI	2 HP	E		$4,156	3.10	0.49	0.83	0.07	0.12	6
	W25AO005	301T	WATER BLASTER, STEAM CLEANER, 300 GPH, 100 PSI	4 HP	E		$8,860	5.97	1.03	1.77	0.14	0.24	10
	W25AO006	246	WATER BLASTER, STEAM GENERATOR, 100 PSI	1 HP	E		$5,708	3.49	0.66	1.14	0.09	0.06	7

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	REGION 6												
	SUBCATEGORY 0.40		CO2 BLASTERS										
			COLD JET										
	W25CJ001	P750B	CARBON DIOXIDE (CO2) BLASTER, 600 LBS/HR, SINGLE HOSE DELIVERY (ADD 65–100 CFM COMPRESSOR)	20 HP	E		$65,791	21.09	5.38	8.77	0.99	0.90	34
	W25CJ002	P1500B	CARBON DIOXIDE (CO2) BLASTER, 1200 LBS/HR, SINGLE HOSE DELIVERY (ADD 65–150CFM COMPRESSOR)	24 HP	E		$101,989	32.24	8.34	13.60	1.54	1.08	37
	W25CJ003	P3000B	CARBON DIOXIDE (CO2) BLASTER, 1200 LBS/HR, DUAL HOSE DELIVERY (ADD 65–200CFM COMPRESSOR)	24 HP	E		$175,615	54.37	14.36	23.42	2.65	1.08	66
	SUBCATEGORY 0.50		WET ABRASIVE BLASTING SYSTEM (TORBO)										
			KEIZER TECHNOLOGIES AMERICAS, INC										
	W25KZ001	TORBO M120	WATER BLASTER, WET ABRASIVE BLASTER, 4.2 CFT, 170 PSI, (INCLUDES HOSES & NOZZLE, ADD 350 CFM AIR COMPRESSOR)	350 CFM	A		$17,771	2.09	0.86	1.16	0.28	0.00	4
	W25KZ002	TORBO M120	WATER BLASTER, WET ABRASIVE BLASTER, 4.2 CFT, 170 PSI, W/MIX RUST INHIBITOR INJECTOR (INCLUDES HOSES & NOZZLE, ADD 350 CFM AIR COMPRESSOR)	350 CFM	A		$19,678	2.31	0.95	1.28	0.31	0.00	4
	W25KZ003	LOC RESTORATION UNIT	WATER BLASTER, WET ABRASIVE BLASTER, 4.2 CFT, 170 PSI, W/LOC RESTORATION UNIT (INCLUDES HOSES & NOZZLE, ADD 350 CFM AIR COMPRESSOR)	350 CFM	A		$20,118	2.35	0.97	1.31	0.31	0.00	4

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN		CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
W25	***KEIZER TECHNOLOGIES AMERICAS, INC (continued)***												
	W25KZ004	TORBO M320	WATER BLASTER, WET ABRASIVE BLASTER, 13.0 CFT, 170 PSI, (INCLUDES HOSES & NOZZLE, ADD 385 CFM AIR COMPRESSOR)	385 CFM	A		$28,600	3.34	1.37	1.86	0.44	0.00	8
	W25KZ005	TORBO XL320	WATER BLASTER, WET ABRASIVE BLASTER, 13.0 CFT, 170 PSI, (INCLUDES HOSES & NOZZLE, ADD 385 CFM AIR COMPRESSOR)	385 CFM	A		$33,783	3.96	1.63	2.20	0.53	0.00	8
	W25KZ006	TORBO XL320	WATER BLASTER, WET ABRASIVE BLASTER, 19.0 CFT, 170 PSI, (INCLUDES HOSES & NOZZLE, ADD 385 CFM AIR COMPRESSOR)	385 CFM	A		$34,424	4.04	1.66	2.24	0.54	0.00	9
	W25KZ007	TORBO XL320	WATER BLASTER, WET ABRASIVE BLASTER, 19.0 CFT, 170 PSI, W/MIX RUST INHIBATOR INJECTOR, (INCLUDES HOSES & NOZZLE, ADD 385 CFM AIR COMPRESSOR)	385 CFM	A		$36,722	4.30	1.77	2.39	0.57	0.00	9
W30	**WATER TANKS**												
	SUBCATEGORY 0.10		**PORTABLE WITH WHEELS**										
	SOUTHWEST CONSTRUCTION EQUIPMENT CO.												
	W30SO001	EWT-8C	WATER TANK, PORTABLE, WHEEL, 8000 GAL, 10″ PIPE	8 HP	G		$42,649	6.52	1.98	2.75	0.60	0.80	130
	W30SO002	EWT-10C	WATER TANK, PORTABLE, WHEEL, 10000 GAL, 10″ PIPE	8 HP	G		$50,773	7.55	2.36	3.29	0.71	0.80	170
	W30SO003	EWT-12C	WATER TANK, PORTABLE, WHEEL, 12000 GAL, 10″ PIPE	8 HP	G		$55,252	8.12	2.57	3.59	0.77	0.80	185

Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

CAT	REGION 6 ID.NO.	MODEL	EQUIPMENT DESCRIPTION	ENGINE HORSEPOWER FUEL TYPE MAIN	CARRIER	VALUE (TEV) 2000 ($)	TOTAL HOURLY RATES ($/HR) AVERAGE	STANDBY	ADJUSTABLE ELEMENTS DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.20		SKID MOUNTED									
	SOUTHWEST CONSTRUCTION EQUIPMENT CO.											
	W30SO004	WST-8	WATER TANK, SKID, 8000 GAL, 10″ PIPE			$27,102	3.25	1.29	1.81	0.38	0.00	107
	W30SO005	WST-10	WATER TANK, SKID, 10000 GAL, 10″ PIPE			$30,244	3.62	1.43	2.02	0.42	0.00	122
	W30SO006	WST-12	WATER TANK, SKID, 12000 GAL, 10″ PIPE			$34,879	4.18	1.66	2.33	0.49	0.00	142
W35	**WELDERS**											
	SUBCATEGORY 0.10		ENGINE DRIVEN									
	NO SPECIFIC MANUFACTURER											
	W35XX020	GAS 150 AC	WELDER, ENGINE DRIVEN, GAS, AC, 150 AMP, 4.5 KW, PORTABLE SKID	11 HP G		$2,066	2.06	0.13	0.19	0.03	1.36	2
	W35XX021	GAS 225 AC/DC-CC	WELDER, ENGINE DRIVEN, GAS, AC/DC-CC, 225 AMP, 5–8 KW, TRAILER MTD	17 HP G		$5,434	3.61	0.33	0.49	0.08	2.09	6
	W35XX022	GAS 250 AC/DC-CC/CV	WELDER, ENGINE DRIVEN, GAS, AC/DC-CC/CV, 250 AMP, 9 KW, TRAILER MTD	18 HP G		$5,487	3.79	0.33	0.50	0.08	2.22	6
	W35XX023	GAS 300 DC-CC	WELDER, ENGINE DRIVEN, GAS, DC-CC, 300 AMP, 3 KW, TRAILER MTD	45 HP G		$9,099	8.56	0.56	0.84	0.14	5.54	14
	W35XX024	DIESEL 400 DC-CC/CV	WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2–10 KW, TRAILER MTD	48 HP D-off		$14,669	6.06	0.90	1.36	0.22	2.62	21
	W35XX025	DIESEL 500 DC-CC/CV	WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 500 AMP, 4 KW, TRAILER MTD	42 HP D-off		$16,383	5.99	1.01	1.52	0.25	2.29	18

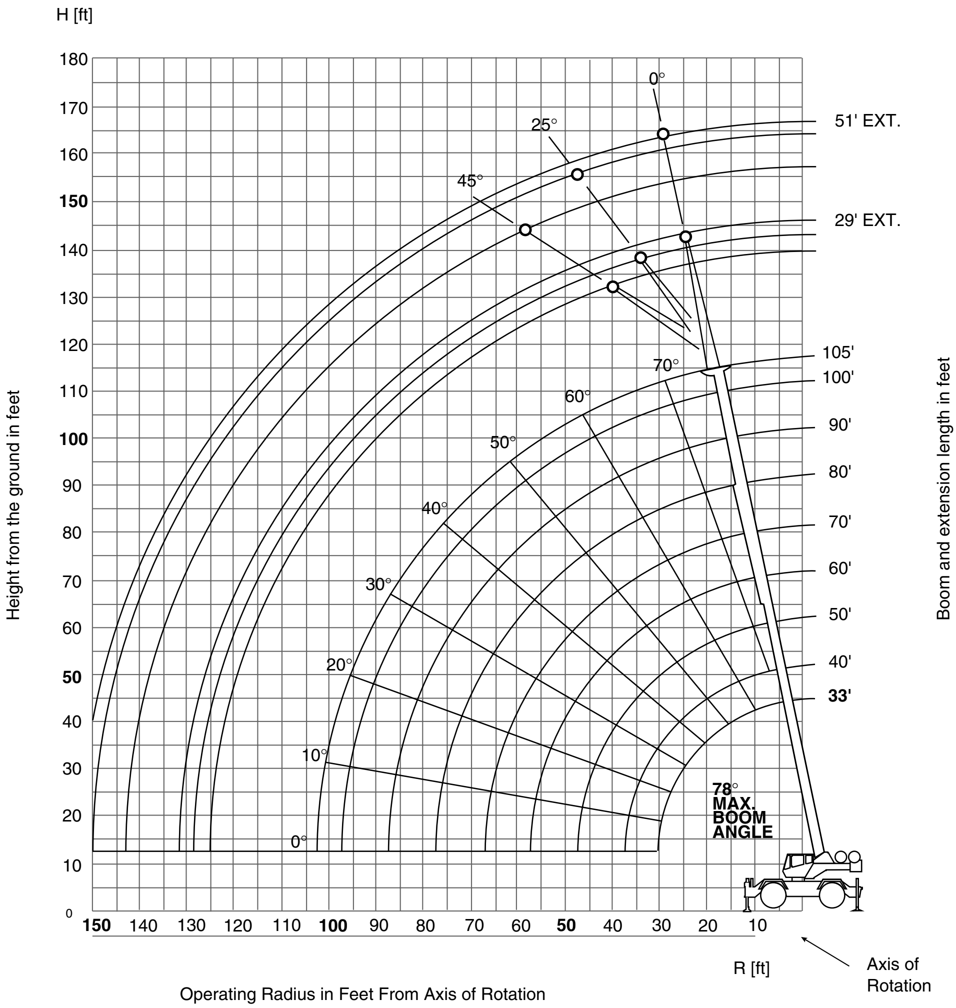
Table 2-1. HOURLY EQUIPMENT OWNERSHIP AND OPERATING EXPENSE

	REGION 6			ENGINE HORSEPOWER FUEL TYPE		VALUE (TEV)	TOTAL HOURLY RATES ($/HR)		ADJUSTABLE ELEMENTS			
CAT	ID.NO.	MODEL	EQUIPMENT DESCRIPTION	MAIN	CARRIER	2000 ($)	AVERAGE	STANDBY	DEPR	FCCM	FUEL	CWT
	SUBCATEGORY 0.20		ELECTRIC DRIVEN									
		LINCOLN ELECTRIC COMPANY										
	W35LC018	SP-170T	WELDER, ELECTRIC DRIVEN, 170 AMP, WIRE FEEDER	5 HP E		$813	0.32	0.07	0.11	0.01	0.10	1
	W35LC010	LINCWELD 225/125	WELDER, ELECTRIC DRIVEN, 225 AMP, STICK	15 HP E		$468	0.51	0.04	0.06	0.01	0.29	1
	W35LC019	IDEAL ARC SP-225	WELDER, ELECTRIC DRIVEN, 250 AMP, WIRE FEEDER	11 HP E		$2,303	0.81	0.19	0.31	0.03	0.21	3
	W35LC011	IDEAL ARC R3R-300	WELDER, ELECTRIC DRIVEN, 300 AMP, STICK	27 HP E		$2,867	1.35	0.23	0.38	0.04	0.52	4
	W35LC012	IDEAL ARC R3R-400	WELDER, ELECTRIC DRIVEN, 400 AMP, STICK	35 HP E		$2,883	1.56	0.23	0.38	0.04	0.67	5
	W35LC013	IDEAL ARC R3R-500	WELDER, ELECTRIC DRIVEN, 500 AMP, STICK	41 HP E		$2,872	1.72	0.23	0.38	0.04	0.79	5
	W35LC020	PROCUT 80	WELDER, ELECTRIC DRIVEN, CUTTING TORCH, 85 AMP, PLASMA	26 HP E		$3,543	1.48	0.29	0.47	0.05	0.50	1

Appendix B: Heavy Equipment Product Guides

This appendix contains a sample of standard equipment manufacturer's guides for use in solving the types of problems described in chapter 4.

Working range – 105 ft. Main Boom



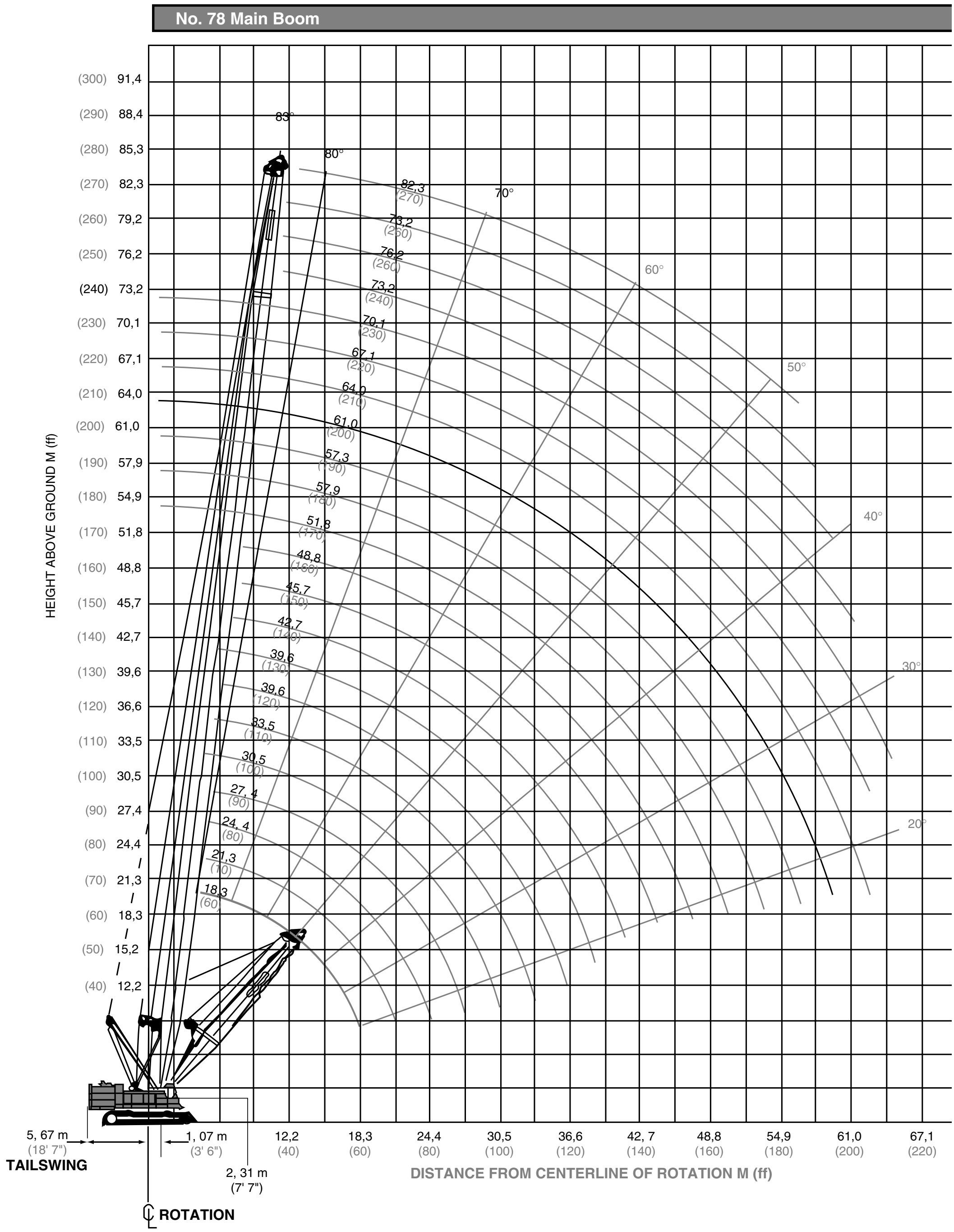
RT650E load chart

33-105 ft. | 11,250 lbs | 100% 22' 6" spread | 360

Pounds

Feet	33	40	50	60	70	80	90	100	105
10	100,000 (69.5)	80,550 (73.5)	67,250 (77)						
12	87,100 (65.5)	79,150 (70.5)	64,200 (75)	*56,100 (78)					
15	69,050 (59.5)	69,550 (65.5)	59,950 (71)	51,800 (75)	45,200 (77.5)				
20	50,500 (47.5)	50,950 (57)	51,400 (64.5)	44,500 (69.5)	38,550 (73)	34,450 (75.5)	*31,400 (78)		
25	38,300 (32)	38,850 (47)	39,350 (58)	39,650 (64.5)	37,100 (68.5)	29,850 (72)	27,250 (74.5)	21,000 (76.5)	18,350 (77.5)
30		30,700 (34.5)	31,200 (50.5)	31,500 (58.5)	31,700 (64)	26,350 (68)	24,100 (71)	21,000 (73.5)	18,350 (74.5)
35			25,450 (41.5)	25,750 (52.5)	26,000 (59)	23,650 (64)	21,500 (67.5)	19,150 (70)	18,350 (71.5)
40	See Note 16		20,850 (30.5)	21,200 (46)	21,600 (54)	21,350 (59.5)	19,400 (64)	16,650 (67)	18,300 (68.5)
45				17,100 (38)	17,350 (48.5)	17,300 (55)	17,300 (60)	14,650 (64)	15,750 (65.5)
50				13,950 (28)	14,150 (42.5)	14,200 (50.5)	14,200 (56)	13,000 (60.5)	14,300 (62.5)
55					11,700 (35)	11,750 (45.5)	11,850 (52)	11,900 (67)	12,000 (59)
60					9,730 (26)	9,870 (39.5)	9,980 (47.5)	10,100 (53.5)	10,150 (55.5)
65						8,300 (33)	8,440 (42.5)	8,600 (49.5)	8,680 (52)
70						6,960 (24.5)	7,170 (37.5)	7,340 (45.5)	7,430 (48.5)
75							6,080 (31)	6,290 (40.5)	6,390 (44.5)
80							5,130 (23)	5,380 (35.5)	5,490 (40)
85								4,580 (29.5)	4,720 (35)
90								3,880 (22)	4,020 (29)
95									3,400 (21.5)
Minimum boom angle (∞) for indicated length (no load)									0
Minimum boom angle (ft.) at 0∞ boom angle (no load)									105

NOTE: () Boom angles are in degrees.
#LMI operating code. Refer to LMI manual for operating instructions.
*This capacity is based on maximum boom angle.


No. 78 Main Boom
HEIGHT ABOVE GROUND M (ff)
(300) 91,4
(290) 88,4
(280) 85,3
(270) 82,3
(260) 79,2
(250) 76,2
(240) 73,2
(230) 70,1
(220) 67,1
(210) 64,0
(200) 61,0
(190) 57,9
(180) 54,9
(170) 51,8
(160) 48,8
(150) 45,7
(140) 42,7
(130) 39,6
(120) 36,6
(110) 33,5
(100) 30,5
(90) 27,4
(80) 24,4
(70) 21,3
(60) 18,3
(50) 15,2
(40) 12,2
83°
80°
70°
60°
50°
40°
30°
20°
5, 67 m (18' 7")
TAILSWING
1, 07 m (3' 6")
2, 31 m (7' 7")
ROTATION
12,2 (40)
18,3 (60)
24,4 (80)
30,5 (100)
36,6 (120)
42, 7 (140)
48,8 (160)
54,9 (180)
61,0 (200)
67,1 (220)
DISTANCE FROM CENTERLINE OF ROTATION M (ff)

Heavy-lift load charts

Liftcrane Boom Capacities -Series 2
Boom No.78

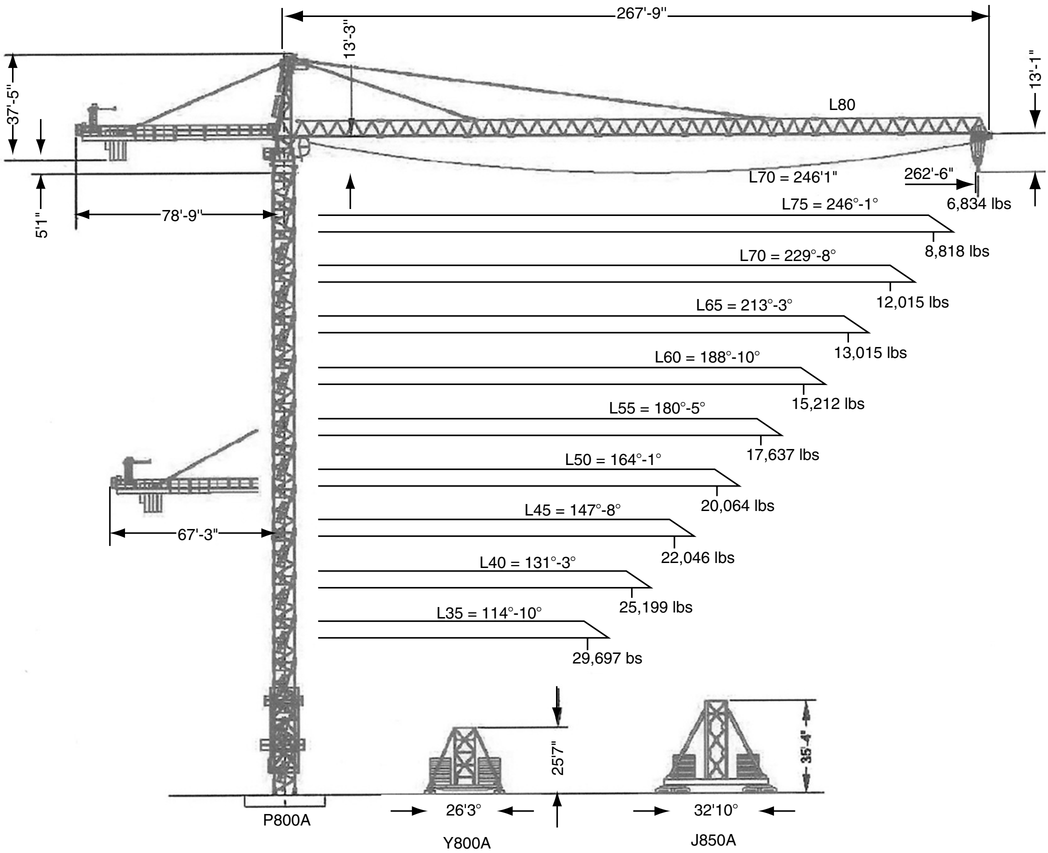
64 410 kg (142,000 lb) Counterweight 19 960 kg (44,000 lb) Crawler Framer Counterweight

360° Rating kg (lb) × 1000

Boom m (ft) / Radlus	18,3 (60)	24,4 (80)	30,5 (100)	36,6 (120)	42,7 (140)	48,8 (160)	51,8 (170)	57,9 (190)	64,0 (210)	70,1 (230)	76,2 (250)	82,3 (270)
4,0 (13)	160,0 (352.8)											
4,5 (15)	146,1 (316.7)	– (275.5)										
5,0 (17)	131,9 (281.3)	119,9 (259.9)										
6,0 (20)	110,8 (240.6)	109,6 (239.9)	96,3 (210.7)	– (192.2)								
7,0 (24)	95,2 (201.2)	95,2 (201.0)	89,0 (191.7)	81,5 (175.9)	– (157.9)							
9,0 (30)	74,1 (160.9)	74,0 (160.7)	73,9 (160.2)	70,1 (152.2)	64,3 (140.6)	58,6 (128.1)	58,3 (123.0)	– (116.6)				
10,0 (34)	64,5 (135.0)	65,0 (135.9)	65,1 (136.0)	63,2 (134.7)	60,1 (127.5)	54,9 (118.4)	52,6 (113.4)	50,7 (109.9)	47,3 (102.7)	– (97.1)		
12,0 (40)	49,6 (107.1)	49,9 (107.8)	49,9 (107.8)	50,0 (107.9)	49,8 (107.7)	47,5 (103.2)	46,2 (100.5)	44,2 (96.0)	41,3 (89.7)	39,0 (84.7)	37,1 (80.5)	
14,0 (50)	40,0 (78.4)	40,3 (79.1)	40,3 (79.1)	40,3 (79.1)	40,2 (78.8)	40,2 (78.5)	39,6 (78.3)	37,8 (78.5)	35,6 (72.5)	33,5 (68.0)	31,6 (64.0)	29,6 (59.6)
18,0 (60)	28,1 (60.6)	28,4 (61.5)	28,4 (61.5)	28,4 (61.5)	28,3 (61.1)	28,1 (60.8)	28,0 (60.6)	27,7 (59.8)	27,4 (59.3)	26,0 (56.4)	24,5 (53.3)	22,7 (49.3)
22,0 (70)		21,4 (49.5)	21,5 (49.6)	21,5 (49.6)	21,3 (49.2)	21,2 (48.9)	21,0 (48.6)	20,7 (47.8)	20,4 (47.3)	20,2 (46.7)	19,6 (44.9)	18,2 (41.8)
24,0 (80)		18,9 (40.8)	19,0 (41.0)	19,0 (41.0)	18,8 (40.6)	18,6 (40.3)	18,5 (40.0)	18,2 (39.2)	17,9 (38.7)	17,7 (38.1)	17,4 (37.4)	16,4 (35.5)
26,0 (90)			16,9 (34.5)	16,9 (34.5)	16,7 (34.1)	16,6 (33.8)	16,5 (33.5)	16,1 (32.7)	15,8 (32.2)	15,6 (31.5)	15,2 (30.9)	14,8 (30.1)
30,0 (100)			13,5 (29.2)	13,6 (29.4)	13,4 (29.0)	13,3 (28.7)	13,2 (28.4)	12,8 (27.6)	12,6 (27.1)	12,3 (26.4)	12,0 (25.8)	11,6 (25.0)
34,0 (110)				11,2 (25.3)	11,0 (25.0)	10,9 (24.6)	10,8 (24.4)	10,4 (23.5)	10,1 (23.0)	9,8 (22.3)	9,5 (21.7)	9,2 (20.9)
36,0 (120)					10,0 (21.6)	9,8 (21.2)	9,7 (21.0)	9,3 (20.1)	9,1 (19.6)	8,8 (18.9)	8,5 (18.3)	8,2 (17.5)
40,0 (130)					8,3 (18.7)	8,2 (18.4)	8,1 (18.2)	7,7 (17.3)	7,4 (16.8)	7,1 (16.1)	6,8 (15.5)	6,5 (14.7)
42,0 (140)						7,4 (16.0)	7,3 (15.8)	6,9 (14.9)	6,7 (14.4)	6,4 (13.7)	6,1 (13.1)	5,7 (12.3)
46,0 (150)						6,2 (13.9)	6,1 (13.7)	5,7 (12.8)	5,5 (12.4)	5,1 (11.6)	4,9 (11.0)	4,5 (10.2)
48,0 (160)							5,6 (11.9)	5,1 (11.0)	4,9 (11.6)	4,6 (9.9)	4,3 (9.2)	4,0 (8.4)
52,0 (170)								4,2 (9.4)	4,0 (9.0)	3,7 (8.3)	3,4 (7.6)	2,9 (6.7)
54,0 (180)								3,8 (8.0)	3,6 (7.6)	3,3 (6.9)	2,9 (6.2)	2,5 (5.2)
56,0 (185)								3,3 (7.3)	3,2 (7.0)	2,8 (6.2)	2,6 (5.6)	2,0 (4.4)

MD 485B-M20

Maximum Capacity = 44,092 lbs



Rated Load Chart

SM-DM Trolley

Capacity (lbs)

Hook Radius	Jib Length 262'-6"	246'-1"	229'-8"	213'-3"	198'-10"	180'-5"	164'-1"	147'-8"	131'-3"	114'-10"
20'-0"	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
30'-0"	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
40'-0"	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
50'-0"	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
60'-0"	42,374	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
70'-0"	35,358	39,405	44,092	44,092	44,092	44,092	44,092	44,092	44,092	44,092
80'-0"	30,159	33,405	40,112	40,230	41,687	43,369	44,092	44,092	44,092	44,092
90'-0"	26,152	29,322	35,015	35,119	36,409	37,898	38,494	38,932	39,166	39,388
100'-0"	22,970	25,936	30,966	31,059	32,217	33,553	34,088	34,481	34,691	34,889
110'-0"	20,830	23,001	27,673	27,757	28,807	30,018	30,503	30,859	31,050	31,230
114'-10"	19,746	22,046	26,293	26,374	27,378	28,537	29,001	29,342	29,524	29,697
120'-0"	18,684	21,112	24,941	25,019	25,979	27,087	27,530	27,856	28,030	
130'-0"	16,876	19,130	22,639	22.710	23,596	24,616	25,025	25,325	25,485	
131'-3"	16,672	18,907	22,380	22.451	23,327	24,338	24,742	25,040	25,189	
140'-0"	15.331	17,437	21,126	21.178	22,031	22,506	22,884	23,163		
147'-8"	14,294	16,301	19,807	19.856	20,666	21,564	21,915	22,046		
150'-0"	13,996	15,974	19,427	19.476	20,271	21,156	21,501			
160'-0"	12,831	14,697	17,945	17,990	18,735	19,563	19,886			
164'-0"	12,401	14,226	17,398	17,442	18,168	18,976	19,280			
170'-0"	11,805	13,573	16,640	16,682	17,392	18,161				
180'-0"	10,895	12,575	15,482	15,522	16,182	18,918				
180'-5"	10,897	12,533	15,433	15,473	16,132	16,865				
190'-0"	10,082	11,685	14,447	14,485	15,111					
196'-10"	9,574	11,127	13,800	13,837	14,440					
200'-0"	9,352	10,884	13,518	13,554						
210'-0"	8,692	10,161	12,678	12,713						
213'-3"	8,491	9,940	12,422	12,456						
220'-0"	8,093	9,504	11,916							
229'-8"	7,564	8,925	11,244							
230'-0"	7,546	8,906								
240'-0"	7,046	8,357								
246'-1"	6,763	8,047								
250'-0"	6,586									
260'-0"	6,162									
262'-6"	6,063									

	Max. Load Radius									
From	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"	10'-2"
To	58'-0"	63'-6"	73'-8"	73'-10"	78'-2"	78'-10"	79'-11"	80'-9"	81'-2"	81'-6"