Construction Equipment Economics

V2

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HOW TO USE THIS BOOK.

Ideas jump around as they wish. Words must follow each other in a straight line.

Therein lies the challenge of writing a book like this.

The book is written for everyone involved in the management of heavy mobile equipment. It is meant for practicing professionals who make decisions and juggle complex problems on a day-to-day basis.

It is not a text book. It is a desk book that is full of ideas, examples and inspiration. It should be on your desk not on a forgotten book shelf. It needs to be used and must become dirty, dog eared and full of personal notes. Use it to look for methods, ideas and inspiration. Enjoy the challenge of thinking differently.

There are no simple solutions and no shortcuts to change. Use this book to understand what you do, think creatively about the future and have courage in your decisions.

Do not start at the beginning and read right through. Start with a chapter or section that looks interesting and addresses your concern. Explore from there. Browse and think; don't look for answers.

Three things will help:

1. The table of contents is very different and worth reading. There are notes about what is covered in each section and you should use these to go directly to sections that address the topics you wish to explore.
2. Many internal references have been included in the text to help find associated similar but different ideas in other parts of the book. The references are shown in red text. Use them to jump around and add depth to your reading.
3. There are many tables, charts and graphs. There are very few solid pages of text. Learning and understanding is a visual experience. The level of detail is sufficient for implementation – do not let it distract you if all you want to do is understand the basics.

Equipment management is an exceptionally broad subject. You need to know a little about organizational behavior, accounting, finance, statistics, algebra and, of course, oil and grease. Do not let the quantitative aspects, the many spreadsheets and the many graphs put you off. Yes, you do need to "do the numbers" and yes, it is necessary to develop the quantitative tools required for implementation. But it need not be complicated. A working knowledge of Excel will help and Appendix 1 and 2 will give you guidance on what to do if you do not wish to implement the more complex curve fitting and statistical procedures set out in Section 4-4 and Section 5-2.

The most important thing is for you to grasp the fundamental ideas and for you to move forward with implementation. Look carefully at Chapter 16 and know that:

Success comes not from knowledge but from the implementation of that knowledge.

and

There are no right answers, only intelligent decisions.

Table of Contents.

Part II. KNOW YOUR COSTS.

Part III. MANAGE FLEET AVERAGE AGE.

Construction Equipment Economics

A FRAMEWORK.

Construction equipment management is a complex and controversial subject that touches almost every aspect of the heavy construction business. Complexity comes from the fact that it embraces many different skills ranging from maintenance and operations to accounting, finance and information technology. Controversy comes from the fact that there are no generally accepted practices when it comes to the management of construction equipment. Everyone has their own idea as to what is important and how it should be done.

The accounting and finance profession has well established generally accepted practices that guide decisions, set standards and measure performance in a given situation. There are clear guidelines about the form and format of an income statement and balance sheet. Everybody knows the terminology, understands the structure and values the metrics. This is not the case in equipment management. Every company manages its fleet differently and there are, at this time, no generally accepted principles to guide managers in complex, far reaching and costly decisions. Differences in approach make it difficult to agree on requirements and effective solutions remain as elusive as ever.

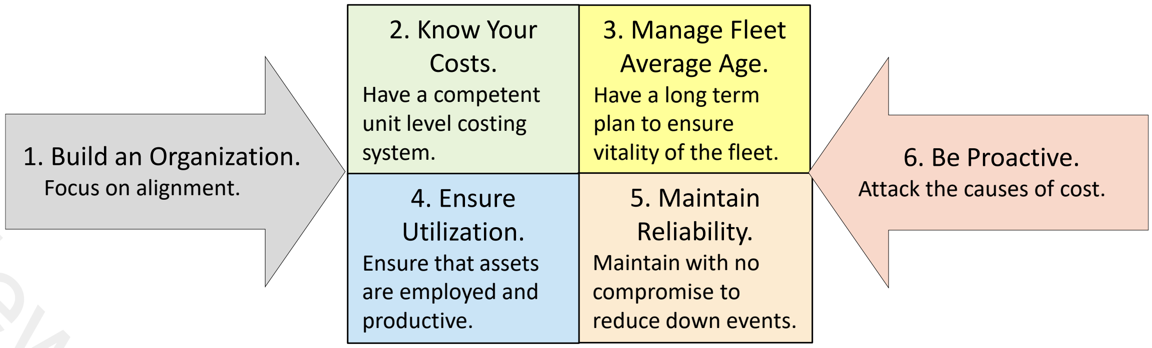
The fundamental belief in equipment as a corporate asset varies from company to company depending on history, the personalities involved and the nature of the work done. Some companies, particularly those close in history and culture to their founding fathers, see equipment as the personal private property of the proprietor. They believe that equipment is an essential asset and that pride of ownership is the key to success. Others are concerned with production above all else and see equipment as a self-destructive means to an end. They believe that equipment is used up in the production of work and that it is more important to produce work than it is to manage and conserve equipment as a significant corporate asset.

There is value to both points of view and therein lies the art of equipment management. We balance a need to build work and achieve production targets with the need to extend the life and maintain the quality of assets that are slowly but inevitably consumed in the production process.

A lifetime of experience has led me to believe that there is a framework that can be used to develop generally accepted principles in the management of construction equipment. This book does, I hope, provide a starting point.

I have had the opportunity to pursue my passion for many years and have had the privilege of working with the very best in the business. Everything has taught me that the following are critical to success in setting objectives and meeting goals:

1. Build a robust organization. This makes it possible to focus on critical functions, drive for excellence and maintain alignment between the many different well held beliefs regarding construction equipment management.
2. Know your cost. You must know what it costs to own and operate each class and category of equipment in the fleet and you must use this knowledge to estimate the cost of future work, manage current operations and take the many strategic decisions required on a day-to-day basis.
3. Manage fleet average age. The company must develop and maintain a structured long-term plan to manage the fleet replacement process and ensure that the composition of the fleet supports strategic and business development goals.



A Framework. *A lifetime of experience has taught me to believe that there is a framework that can be used as a starting point in the development of some generally accepted principles for the management of construction equipment.*

4. Ensure utilization. Equipment assets must be employed and productive. Equipment is only an asset when it is up and running and producing contributory work. When this stops the investment becomes a liability. Utilization is the key to recovering the fixed costs of ownership.
5. Maintain reliability. It is essential to establish and measure the effectiveness of a maintenance program that reduces emergency down events and unplanned downtime to the absolute minimum. The cost and impact of an emergency down event is such that there can be no compromise in implementing effective and efficient scheduled and condition-based maintenance programs.
6. Be proactive. Excessive cost is a symptom of problems in the organization. The cost itself is not the problem and little is achieved by obsessing over money that has already been spent. Be proactive in decision making. Age, utilization and reliability can and should be used as lead indicators to identify and tackle problems before they occur and reduce future expenditure.

This book is, not surprisingly, organized in terms of this framework.

Part I, Build Your Organization, comes first as little can be achieved if functions, roles, responsibility, authority and accountability are either not understood or not aligned for success.

Part II, Know Your Cost, comes next as a detailed knowledge of equipment costs and the risks involved in estimating both owning and operating costs are essential to everything that follows. The rate calculation and the complexities involved in this important estimate are, of course, discussed in detail.

Part III, Manage Fleet Average Age, follows logically after Part II and uses the fact that hourly owning cost goes down with age while hourly operating cost goes up with age to develop a clear definition of the optimum ownership period and define the tools needed to support the replacement decision.

Part IV, Ensure Utilization, moves from the emphasis on cost established in Part II to develop the operational metrics needed to gain a full understanding of Deployment, Availability and Utilization as three metrics needed to ensure that the fleet is active and that owning costs are likely to be recovered.

Part V, Maintain Reliability, focuses on the maintenance enterprise and on Availability and Reliability as two key metrics likely to provide a leading indicator of increases in operating cost.

Part VI, Be Proactive, stresses the importance of implementation. It comes last and uses a knowledge of the tools and processes available to develop lead indicators and move away from reactive cost-based decision making.

Implementation of the tools and techniques set out in the book will be a voyage of discovery. The processes required will touch on almost every aspect of the company, you will learn a lot and success will most definitely be a team sport.

You will, most likely:

- Involve the whole of the corporate leadership team in reviewing Part I and deciding exactly how best to structure the company and define responsibilities in order to manage the fleet in the interests of the company as a whole.
- Involve estimating, accounting and job costing to study Part II and decide how best to record and present the cost data needed to establish and calibrate the internal rates required for estimating and job costing as well as the budgets required in the budgeting and financial control process.
- Consult technical and financial experts to work through Part III and set up the fleet age benchmarks, capital budgets and long-term financing plans needed to ensure a rational and consistent approach to fleet replacement. They will know that replacement may be able to be delayed but, in the long run, it cannot be denied.
- Work with experts in construction operations, business development and strategic planning to understand future workloads and use the concepts in Part IV to measure utilization and ensure that the size and composition of the fleet is in line with the size and scope of available markets and business opportunities.
- Work with experts in field maintenance operations, shops and yards to go through Part V and ensure that you have a maintenance enterprise that will, without compromise, maintain the fleet, maximize its life and reduce un planned and costly down events to the absolute minimum.
- Work through Part VI to understand the difference between cause and effect and the importance of lead indicators in the proactive decision making required to lower cost.

Your voyage will teach you that everyone does it differently and that it frequently takes a lifetime, or in some cases generations, to discover that there are no right answers only intelligent solutions.

A few of the ideas you develop will work perfectly. All will give inspiration for improvement and all will point towards a better future.

It frequently takes a lifetime, or in some cases generations, to discover that there are no right answers only intelligent solutions.

LEAD INDICATORS.

Recording and measuring the frequency of near miss incidents is a well-accepted tool for identifying opportunities for improvement in safety performance. The logic is simple – a near miss is a lead indicator. It is, in reality, an accident that only just did not happen. If we can eliminate or reduce near misses we will – most certainly –reduce accidents and improve safety performance.

We can learn from this as we seek to manage the hourly cost of owning and operating construction equipment. Let's look at the three areas identified in the framework.

Age:

Construction equipment – by and large – experiences wear out failure. If this is taken to the extreme then, the cost of operating the machine will, at some point, be so high as to cause the average cost per hour, life to date to increase. This point is known as the optimum ownership period. It is logical to assume that machines operated past this point will have higher costs than similar machines operated at or around their optimum ownership period.

Therefore, if we define optimum ownership period as the minimum cost point in the life of a machine,

And, if we manage age, then we are, in fact, taking action to reduce average cost per hour, life to date.

Utilization:

We experience owning costs – by and large – on an annual or monthly basis. Simple arithmetic tells us that hourly owning cost will go down if we work more hours in a given month or year. It is pretty logical to assume that the higher the utilization, the lower the hourly owning cost.

Therefore, if we define utilization as the number of hours a machine works in a month,

And, if we manage utilization, then we are, in fact, taking action to reduce hourly owning cost.

Reliability:

We incur cost – repair parts and labor at the very least – each and every time a machine goes down. It is pretty logical to assume that a machine that breaks down frequently will have a higher operating cost than a similar machine that breaks down less frequently.

Therefore, if we define reliability as the number of times a machine goes down per 1,000 hours,

And, if we manage reliability, then we are, in fact, taking action to reduce hourly operating cost.

Part I. BUILD YOUR ORGANIZATION.
Chapter 1. Functions and Structure.

Building an effective organization is the foundation for success in construction equipment management. The process is complex due to the fact that there is frequently a wide range of competing opinions regarding the best way to manage the fleet at an operational level.

At one end of the spectrum are the expectations of individuals whose careers and passions are narrowly focused on the construction or production operations required to build the work. These "Construction" managers focus on project goals; on completing the project safely, to the required quality, on time and on budget. They believe the completion of their project is the single most important goal and see equipment as nothing but a means to that end.

At the other end of the spectrum are the expectations of the individuals whose careers and passions are focused on the maintenance and management of the equipment throughout its life cycle. These "Equipment" managers see themselves as stewards of the equipment as a long-term company asset that is deployed and respectfully used on many projects. They believe that, in most cases, it is more important to optimize the ownership period of a machine than it is to optimize the completion of a project.

These two competing points of view are good. They are part of the business and add to the vitality, challenge and fascination of the industry. They contribute to performance if kept aligned in a clear and functioning organization. They lead to extremely bad results when confusion and individual agenda grow to swamp the goals of the organization as a whole.

The vast majority of construction companies define Construction and Equipment as distinct responsibility centers within the organization to focus expertise, build leadership and measure performance within the company. Construction, or site management teams are short term teams with expertise in getting the work built. They are assembled for a very specific purpose – to complete a particular project – and they work according to short term single-use plans and budgets designed to achieve specific project goals.

Equipment, or equipment management teams are similar but different. They are long-term teams with expertise in managing equipment throughout its ownership period. They work according to standing plans, policies, procedures and budgets designed to optimize the return on an asset expected to serve the company over many years.

The difference between Construction and Equipment in terms of primary focus, time horizon and expertise is given in Figure 1.1.

The balance between Construction and Equipment as two mutually interdependent responsibility centers within the company is critical. There is no doubt that:

- the company survives, grows and flourishes through the efficiency of its construction and/or production operations.
- construction and/or production operations cannot reach required levels of performance unless they have the required equipment and that it performs to required levels of productivity and reliability.

	Construction or site management teams.	Equipment or equipment management teams.
Primary focus.	Achieve defined short term project goals.	Support construction operations. Manage the fleet for its full lifecycle.
Time horizon.	Short term teams. Single use plans, schedules and budgets.	Long term teams. Standing plans, policies, procedures and budgets.
Expertise.	Get the work built. Complete the project safely, to the required quality, on time and on budget.	Optimize the return on equipment assets expected to serve the company for many years.

Figure 1.1. *Construction and Equipment teams differ significantly when it comes to their primary focus, the time horizon of their decisions and the expertise they contribute to company operations.*

The name given the Equipment responsibility center varies from company to company depending on the scope of the activities performed. "Shops" are relatively small operations that move, repair, store and look after the fleet whereas "equipment divisions" or "equipment companies" are larger more complex operations with clearly stated functional and financial responsibilities. The job title of the person responsible for the unit also varies from shop foreman through to director or vice president of equipment operations depending on the scope of activity, responsibility, authority and accountability.

Establishing responsibility centers, defining the role they play within the company and maintaining relationships is not a simple task. This is particularly important for centers such as Construction and Equipment where decisions taken by one can have a profound impact on the other.

Construction and Equipment go hand in hand. They are mutually interdependent. They can and must work together within a competent, well defined and functioning organization.

This chapter lays the foundation and helps to answer two questions:

First. What do you expect your equipment management team to do? What functions must they perform in order to manage the fleet as a resource, as an asset, and as an essential part of the success of the organization as a whole?

Second. How do you structure your organization? How do you define the required responsibility centers, how do you use them to establish clear definitions of roles, responsibilities, authority and accountability and, above all, how do you maintain alignment between different parts of your organization?

Chapter 2 takes the discussion about organization a step further by presenting material that emphasizes the importance of alignment and the simple fact that success is, without doubt, a team sport.

The material in this chapter is presented in four sections.

Construction companies are complex organizations that must be structured for success.

SECTION 1-1.

Equipment Management Functions.

Equipment management is a complex and difficult task that affects almost every aspect of a company's operations. The skills required vary from those of the master mechanic to finance, accounting and organizational behavior. The way in which companies manage their fleet depends more on the personalities involved than careful planning and forethought. There is no "one-size-fits-all" company and there is no "one-size-fits-all," right way to manage a fleet.

There are, however, six functions that must be competently performed in order to get the job done. They are presented as segments in Figure 1.2. Let's describe the functions and use the figure to make sure that all the bases are covered and that everyone understands their responsibilities as well as the contribution they make to the business.

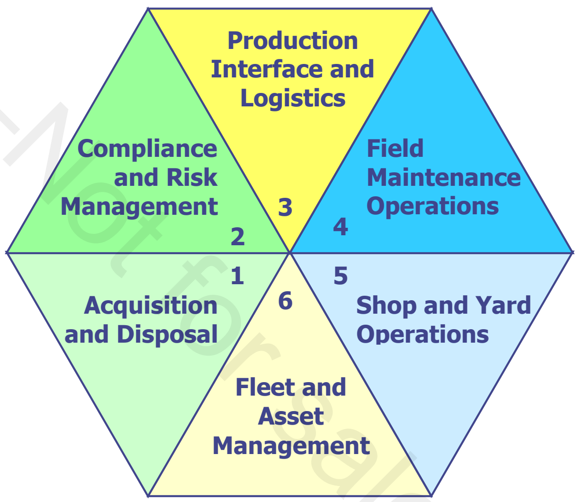


Figure 1.2. *The Six Functions of Equipment Management.*

1. **Acquisition and Disposal –** Acquisition and disposal make up the first portion of total owning cost. It is more than a question of buying low and selling high. Acquisition requires wise long-term technical and commercial decisions based on a knowledge of the market and established relationships with dealers, manufacturers and finance organizations. Companies need to develop specifications tailored to their needs, have policies on standardization and know how to structure purchase, loan, lease and rental agreements suited to their financial and tax situation.

   Disposing of equipment at the best possible price is also not a simple task. It requires an understanding of the used equipment market to explore every possible alternative and maintain effective relationships with dealers and agents.

   This is basically a procurement function. The individuals concerned must be able to negotiate the best deal possible and develop technical and commercial procurement contracts to acquire or dispose of equipment identified in the fleet age planning process. (see Section 9-1). Construction and Equipment are, or should be, equal stakeholders in the process. Construction ensures that the equipment is able to produce the required quantity and quality of work; Equipment ensures that the selected equipment can be supported in the field and is consistent with fleet standardization policies. The function is frequently seen as a corporate overhead with budgets and control mechanisms established to suit.

2. **Compliance and Risk Management –** This function makes up the second portion of total owning cost and covers the steps needed to ensure that the fleet complies with all regulations and is licensed, insured and inspected as needed. On the surface it appears to be a relatively simple routine task. It is, however, growing in cost and complexity on a daily basis as more and more emphasis is placed on complex insurance requirements, emissions standards and safety regulations. This function becomes extremely complex when operations are performed in many states or in international markets. It simply cannot be neglected.

   This is an administratively intense clerical function. The individuals concerned must be fully knowledgeable of all statutory requirements and must ensure that each machine is licensed, insured, inspected and certified as required. Their objective is to reduce exposure to risk and ensure that corporate assets can be legally operated wherever they may be. This function is also frequently funded and managed as a corporate overhead.

3. **Production Interface and Logistics –** Acquisition and disposal ensure that companies have the required equipment in their fleet; compliance and risk management ensure that it is legal. The production interface and logistics function ensures that it is in the right place at the right time.

   Effective dispatch and tracking operations are essential for fleet utilization and many companies run large transportation fleets that move equipment on a regular basis and provide information on the location and deployment of individual assets. (see Section 12-2).

   Mobilizing equipment and moving it from site to site so that it is in the right place at the right time is a responsibility that lies at the interface between Construction and Equipment. The cost of moving the equipment as well as the cost of the people who apply for permits, track the current location of equipment and manage the process is frequently a direct job cost and should not form part of the equipment owning and operating cost calculation.

4. **Field Maintenance Operations –** This function covers all the actions needed to ensure that the equipment is up and running and able to work on a daily basis. It includes fueling and daily inspections, condition-based and preventive maintenance and the replacement of wear parts. The costs involved form part of total operating cost and are frequently included in the equipment rate. Questions arise when it comes to deciding who sets field maintenance standards, who is responsible for differences between actual and budgeted costs and who is responsible for managing field maintenance tecnicians. Clearly, small projects cannot assume these responsibilities. Large projects can and frequently do.

   This is the first, and in many ways the most important, of the pure Equipment functions. Construction and Equipment are both stakeholders in the process – both want it done well and both know it is the first line of defense against unplanned failure. (see Section 14-2). Scheduling of the necessary work requires careful coordination and field tecnicians truly serve two masters.

   Large projects justify the full-time on-site presence of field tecnicians integrated into the project team and responsible for all field maintenance operations. When this happens, a project level account is established to receive the true cost of field maintenance operations. Costs are balanced against the "income" received from a component of the hourly, daily or weekly operating cost rate and the project is responsible for any over or under recoveries. This aligns responsibility and accountability but it does, of course, require a clear definition of maintenance standards and policies as well as an effective mechanism to ensure that standards are followed regardless of project cost or time pressures.

5. **Shop and Yard Operations –** Changes in machine design, shortages of field personnel and the need to work under controlled conditions means that little repair, renovation or rebuild work is done in the field. Shop and yard operations, either self-performed or outsourced, lie at the heart of a process whereby machines that have completed a field assignment, are repaired, renovated or rebuilt and made ready for their next job.

Shops and yards are easy to unbundle and are frequently managed as responsibility centers with costs allocated, managed and controlled using a standard work order process. True costs are set against individual machines and compared with an "income" received from the hourly, daily or weekly operating cost recovery rate. Competent shops are critical for the success and many companies benefit from the efficiency and specialization achieved by outsourcing all or part of this function.

Shop and yard costs make up the second component of total operating cost and their success determines the long-term capability and reliability of the equipment fleet.

6. **Fleet and Asset Management –** The fleet and asset management function is responsible for strategic decisions regarding fleet composition, fleet average age, capital expenditure, finance, tax and return on investment. It uses data developed in other functions, interfaces with the company strategic planning process and develops the rates, estimates, budgets, benchmarks and standards needed to manage the whole process.

   A focus on this function can achieve substantial benefits and successful companies excel in the analysis needed to balance the strategic technical, operational and financial aspects of managing the fleet as a major corporate asset.

   Looking at fleet and asset management as a separate specialized function gives it the stature it deserves in the organization. The equipment asset in a heavy construction company frequently accounts for more than a third of total corporate assets and the cost of owning and operating the fleet is frequently larger than any other single project.

   Fleet and asset management is a specialized function. It uses and processes data generated in other functions to do the analysis required to inform unit-level decisions about rebuilding or replacing machines, balancing fleet average age and adjusting fleet size and composition to meet changing company demands.

The six functions and their arrangement in the hexagon given in Figure 1.2 can be used to draw some general conclusions regarding the way companies are organized to manage their fleet.

First, functions 1 and 2 make up the owning costs, functions 4 and 5 make up the operating cost. Interestingly each has a long term "invest-for-the-future" component (1 and 5) and each has a monthly or hourly cost component (2 and 4). Function 3 makes sure the fleet is deployed in the right place at the right time, function 6 makes sure that the fleet age, size and composition match corporate requirements.

Second, the three functions in the top half of the hexagon – compliance and risk management, production interface and logistics and field maintenance operations deal with short-term immediate issues of primary concern to Construction teams whose success depends on having equipment that is legal, in the right place and working. The teams that manage these functions must do so within a framework of clear and strongly enforced policies.

Third, the three functions in the bottom half of the hexagon – acquisition and disposal, shop and yard operations and fleet and asset management are long-term strategic functions of primary concern to the company and its long-term future. There is no doubt that the lower three functions are the province of Equipment and that they should be managed for the long run. Competence in these functions is a corporate responsibility and a prerequisite for the success of the business as a whole.

Fourth, it should be possible to review each of the functions and asses its importance to the company. It should also be possible to identify the individuals or teams who have primary responsibility for each function and it should, above all, be possible to use the functions as the starting point for a procedures manual which ensures that all the functions are competently performed by the right people at the right time.

The six functions are often combined or "bundled" within one organization that charges a single defined and agreed hourly rate for the equipment used by projects. Under the right circumstances, this centralized approach works well. (see Section 1-2). The devil is, as ever, in the details. Cost, reliability and availability of equipment is a constant source of debate. Accountability clashes with authority and a stovepipe mentality soon develops with neither Equipment nor Construction recognizing the challenges faced and contributions made by anyone other than themselves.

Combining the functions into one organization with clear objectives and a single revenue source based on the internal rental rate is simple and straightforward. Simplicity can be a strength. But oversimplification can also be a weakness. Splitting the functions, setting objectives and establishing revenue streams for each acknowledges the complexity of fleet management and makes it possible to focus expertise on the task at hand.

Summary of Activity by Function.

1. Acquisition and Disposal.	4. Field Maintenance Operations.
• Specification and selection. • Standardization. • OEM Negotiations. • Disposal.	• Fuel. • Lubrication and oil analysis. • Condition assessment. • Preventive maintenance. • Wear parts.
2. Compliance and Risk Management.	**5. Shop and Yard Operations.**
• Licensing. • Insurance. • Inspection and authorized repair. • Emissions compliance. • Taxation and duty.	• Fabrication. • Refurbishment. • Storage and inventory control. • Repair and rebuild. • Record keeping and work orders.
3. Production Interface and Logistics.	**6. Fleet and Asset Management.**
• Project planning. • Operations analysis. • Long range fleet planning. • Fleet balancing. • Dispatch and transport.	• Data analysis. • Rate calculations. • Economic life and fleet planning. • Capital budgeting. • ROI and financial analysis.

Clear responsibilities with corresponding authority and accountability can be defined for each of the six functions.

The Pros and Cons of Centralization.

Every company sets up an internal organization structure to help manage its fleet, assign roles and responsibilities and provide a focus for the expertise needed to keep their equipment reliable, efficient and cost effective. Every company is different. Some adopt a decentralized style with all decisions regarding the selection, operation, maintenance and disposal of equipment made at the project level while others centralize decisions in a full-service organization that serves as an independent "in-house rental organization".

The fact that so many different styles exist suggests that there is no perfect "one-size-fits-all" solution. Every company is slightly different and every company has a structure that reflects its history, the nature of its business and the overall philosophy of its management. The important thing is that a well-understood organization structure is in place and that it improves business performance without adding unnecessary bureaucracy and complexity.

Let's set up an imaginary company and use it to discuss the pros and cons of a centralized full-service Equipment group and better understand the principles and implications.

The company, as shown in Figure 1.3, is relatively simple – there is an overall corporate entity, three Construction Divisions and an Equipment Division. The Construction Divisions are responsible for achieving project goals and report results at the company level. The Equipment Division is responsible for all matters relating to the management of the fleet. It serves the three Construction Divisions by supplying equipment to the projects as and when needed. Like the vice presidents of the Construction Divisions, the VP of the Equipment Division reports business results to the CEO at the company level.

The projects in the Construction Divisions (numbered 1 to 9) pay an internally generated job charge for the equipment they use and see this as a cost to be set against the income received from producing completed construction. (see Section 13-2). The Equipment Division sees the "rent" received as revenue against which they offset the actual cost of owning and operating the equipment used by the projects. It is all nice and neat; the projects in the Construction Divisions make money by producing completed construction and paying for the cost of labor, equipment and materials; the Equipment Division makes money by "renting" equipment to the projects at a pre-determined rate (see Section 2-2) and recovering the cost of depreciation, parts, labor, fuel, ground engaging tools and the like.

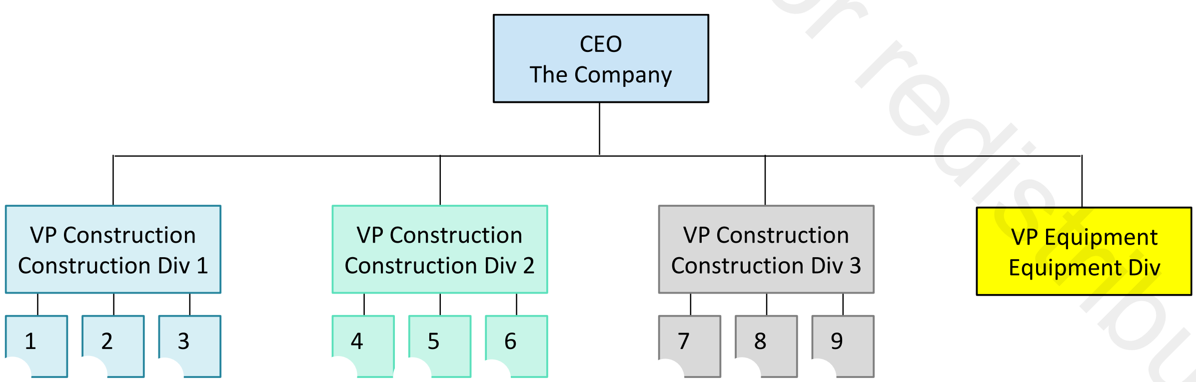


Figure 1.3. *In a centralized structure, the equipment group is seen to be a stand-alone business unit that reports at a corporate level.*

The strengths and weaknesses of this organization structure can be reviewed under three headings:

1. **Specialization vs. Stovepipe Mentality**

   Centralizing all equipment decisions into one business unit provides a focus for the expertise needed to manage the fleet. The VP of the Equipment Division has responsibility for the success of the business unit, has authority to make decisions and is accountable for the results. The unit works within the corporate structure to set criteria for selection, maintenance, repair, rebuild and replacement decisions. It agrees to the internal rental rate and commits to standards for the availability and reliability of the equipment it supplies. The projects focus entirely on putting the equipment to work and achieving maximum production. They are not burdened with any aspect of equipment management and simply call for the equipment they need, receive it, use it and return it when done.

   This very specialized approach certainly has advantages. It also, regretfully, breeds a stovepipe mentality where managers in the Construction and Equipment divisions neither understand nor have empathy for the challenges that face their counterparts. Success is defined within each division, an "us vs. them" mentality becomes the norm. Decisions are sub-optimized as each party looks to their responsibilities with little, if any, regard for the success of the organization as a whole.

2. **Improved Utilization vs. Complex Details**

   The fact that the Equipment Division serves all construction divisions and projects means that it can move equipment around to balance need and availability across the whole company. The internal rental rate and job charging system makes it simple to levy pre-determined charges regardless of whether a machine remains in one place for a couple of days or a couple of years. The pitfalls of moving machines from job to job and not having a sense of ownership on any one job is overcome by the fact that the equipment division assumes responsibility for cost and consistent decision making throughout the economic life of the machine.

   The flexibility to move machines from job to job and the internal rental rate structure requires a number of complex rules regarding minimum hours, idle time and dual rates to minimize hording and encourage jobs to make equipment available for transfer to other projects. (see Section 13-2). Complex rules for back charging to cover abuse on prior jobs often have to be implemented and it is not unusual for the system to fall victim to controversy, dispute and internal gaming.

3. **Simplified Budgeting and Costing vs. False Perception of Cost**

   A predetermined internal rental rate of $120 per hour for a motor scraper provides a good, stable and simple starting point for estimating cost per cubic yard and measuring the difference between estimated and actual costs. The only snag is that the $120 per hour is, itself, an estimate of the hourly owning and operating cost for the scraper based on a large number of assumptions including ownership period, utilization and lifetime repair costs. (see Section 6-1).

   Projects and operating business units use the internal rental rate as a proxy for the actual cost of equipment when they calculate and report their results at a corporate level. Differences between the internal rental rate and the actual cost of the equipment can have a significant impact on equipment selection, estimating, operating results and accountability. The internal rental rate system is thus often swamped by complex cost reallocation procedures designed to ensure that projects are charged as close to the actual cost for their equipment as possible. As with extra charges for idle time and back charges for abuse, reallocations of cost based on differences between rental rates and actual costs are extremely difficult, complex and fraught with danger. (see Section 7-6).

Many companies set their equipment operations up as a centralized full-service organization and use the centralized structure to good effect. Four things are important for successful implementation:

First The location and size of projects undertaken must make it possible for the company to gain the maximum benefit from the fact that moving machines from job to job is supported by a simple charge out procedure.

Second The work undertaken must not require any special or unique expertise to design, fabricate and use specialized equipment. The work must require a relatively simple standardized fleet that can be used in many applications and moved easily and efficiently.

Third Communication and understanding of shared goals and interests within the company must be such that rules for setting and applying rental rates and reallocating budget variances do not add conflict and unnecessary complexity to a relatively simple way of doing business.

Fourth A balance between the responsibility, authority and accountability of the short-term, production-focused Construction teams responsible for meeting operational requirements and the long-term, asset-management-focused Equipment teams responsible for the cost of the equipment throughout its ownership period must be constantly reviewed to ensure that the business as a whole remains the primary focus of the organization.

Advantages.	Disadvantages.
The Equipment Division assumes full responsibility for the management of the asset throughout its life.	Construction Divisions and projects see equipment as nothing more than a means to an end. They have little if any commitment to the full ownership period of the machines.
The equipment rates are pre-determined and used for estimating, cost control and management performance throughout the company.	The equipment rate grows to become accepted as a definition of equipment cost. Construction seldom, if ever, experience the true cost of owning and operating equipment and have little motivation to minimize true equipment cost.
Equipment is easily moved from project to project and fleet deployment is optimized across the company.	While deployment is optimized, complex rules are required to manage utilization once deployed to site. Construction managers are frequently shielded from the cost impacts of low utilization.
Equipment management standards and norms are set and maintained centrally for the fleet as a whole.	Project level operating requirements can override centralized maintenance, standardization and selection decisions.
Budgeting, costing and reporting are simple and based on a well understood standard rate.	Complex rules to allow or compensate for different levels of utilization, unusual wear and tear and differing site conditions add complexity while seldom improving accountability.

There are a number of advantages and disadvantages associated with a centralized equipment division.

The Case for a Regionalized Fleet.

There are several advantages to centralizing the fleet and placing all equipment assets under the direct control of a knowledgeable and experienced equipment manager who is responsible for equipment operations across the company as a whole. (see Section 1-2). The concept certainly works well and many companies have significantly improved equipment operations by creating what is essentially an in-house rental house.

Centralization works under the right conditions but it is not a one size fits all solution. There are many advantages: let's look at the three that are cited most frequently.

First, leadership in the Equipment division represents the company in all things equipment, centralizes expertise and information and establishes standards. Second, the centralized group is able to move equipment freely and quickly between jobs in order to maximize utilization by managing the fleet as a single asset. Third the centralized group sets internal rates and establishes an internal charge out mechanism to charge jobs for the equipment they use and credit the company equipment account. (see Section 13-2).

These are three significant advantages and a centralized equipment division should work well. When this is not the case the problem frequently lies in the internal rates and the internal charge out mechanism. These can never be perfect and there are invariably very different opinions when it comes to determining exactly how much to charge jobs for the equipment they use. (see Section 13-2).

Accountability is also an issue. Jobs see themselves as accountable for the internal equipment charges and frequently have little commitment to the true cost of the equipment they use. They do everything they can to reduce job charges to the lowest level possible within the scope of company policy and – sometimes – beyond. Job margins are based on internal charges which thereby become part of the mechanism used to reward and recognize successful superintendents and project managers.

A centralized structure is based on the assumption that individual project results are aggregated at a divisional or corporate level. This means that neither construction division nor regional vice presidents are accountable for true equipment cost. The final reconciliation between equipment charges and true equipment costs only happens "two levels up" at the total company level when results from Construction divisions and from the Equipment division are finally consolidated into a single company level profit and loss statement. By that time, the individual project manager, superintendent or operator who was accountable for the true cost of equipment used to build the work on an individual project, is lost in the complexity of the organization. (see Section 7-6).

Lack of accountability for true equipment cost at a job or regional level introduces some really bad behaviors. Hoarding and abuse are two that come quickly to mind. Comments like "I am not going to return this machine, I've got to pay for it any way" and "Who cares about the dent, it is their machine and all costs are in the rate any way" become commonplace.

Figure 1.4 shows an organizational structure that can be successfully used to overcome many of the negative impacts of a single centralized structure. The company is very similar to Figure 1.3 in that it has an overall corporate entity and three Construction Divisions each headed by a vice president of Construction with each running three projects. The difference is that each Construction Division (or Region) is responsible for its own regionalized equipment fleet that reports directly to and is consolidated into the results produced by each region. There is a corporate vice president of equipment who has a "dotted line" oversight responsibility for the management of the three regionalized fleets.

The corporate vice president of equipment and the group shown on the right of Figure 1.4 work to ensure that the company enjoys as many of the positive aspects of centralization as possible. They provide focused expertise in equipment management, develop uniform procurement specifications and maintenance standards that reflect best current practices and bring required standardization to the company. They develop relationships with manufacturers, financiers and dealers to consolidate the company's value as a customer for new equipment, parts

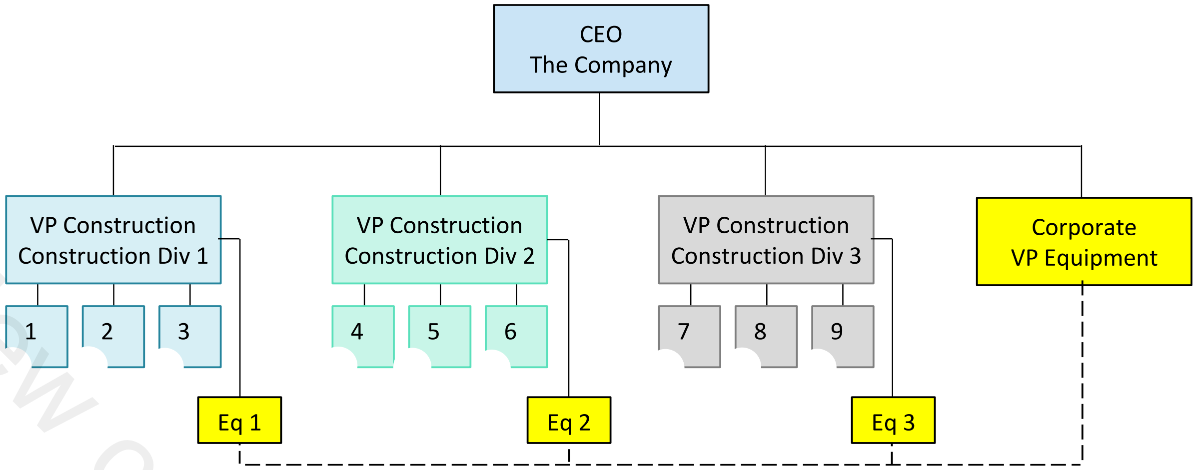


Figure 1.4. *Equipment managers in each region are responsible to the vice president of construction for the region in which the equipment is deployed. They work with support and co-ordination from a corporate vice president of equipment.*

and service. Their expertise in the structuring of loans and leases assists in developing an optimum procurement strategy and their knowledge of technology adds value by consolidating and disseminating new developments.

The corporate-level equipment group can also advise on the internal rates and the internal charge out mechanism used to charge jobs for the equipment they use. The importance of standardized rates diminishes as the company grows and jobs vary more and more in type or location. Standardized rates are probably not a good thing for a company that works in Vermont and Texas. Setting appropriate rates and establishing charge out mechanisms suited to each construction region is clearly a matter of agreement between the vice president of operations for the region and the corporate vice president of equipment.

The most significant advantage of a regionalized equipment structure comes in the area of improved accountability. If a project manager says, "I am not going to return this machine, I've got to pay for it any way" then the regional vice president of construction to whom the project manager reports will say, "It is our machine, we need the utilization to recover our fixed cost of ownership, return it to the yard so that I can sell it or redeploy it." If a project manager says, "Who cares about the dent, it is their machine and it is in the rate any way." then the regional vice president of construction will say, "It is our machine, we are responsible for the true costs. Look after our equipment."

The fact that the final reconciliation between equipment charges and true equipment costs takes place within a given construction region also renders moot many of the highly emotional discussions about the rate and the internal charge out mechanism. (see Section13-2). If project managers believe a rate is too high or if they do not like the process by which unrecovered fixed costs arising from lack of utilization are charged to their jobs then it is a matter to be solved within their operating division with the guidance and advice of the corporate vice president of equipment.

Everyone knows that the actual costs will lie where they fall and that regional performance will be measured as the difference between money earned and the true cost of earning that money. Internal charges are eliminated at a regional level. Games with utilization, rates and under reported hours stop right there.

There are, in practice, two levels of regionalization. A "hard" regionalization when the operating regions are in fact separate companies that own and operate the equipment they use. A profit or loss statement on the Equipment account is produced in the normal course of business and this is consolidated with the profit or loss statement for Construction to produce the final company profit and loss statement. Equipment transfers between companies occur very seldom and are treated as buy/sell events. A "soft" regionalization of the fleet occurs when regions are defined by geography or business line and when profit or loss statements for the equipment in a given region are produced as sub totals within the company equipment account.

These regional sub totals for the over or under recoveries relative to the standardized rates are consolidated with the gain or loss statements from Construction at a regional level to give a true profit and loss statement for the region. Equipment transfers between regions are handled by coding the unit to the appropriate region for the appropriate period.

The key point is that the final reconciliation between equipment charges and true equipment costs happens "one level up" and that the vice presidents of each construction region can take action with their direct reports to remedy the situation and improve the region's performance. We have moved from "them and us" to "you and me".

It seems trite but, it makes a lot of sense to align the organization and reporting structure used for Equipment with that used for Construction and cause the regional vice president of construction to be responsible for all operations. But, it must be done under the guidance of a vice president of corporate equipment operations who represents the company in all things equipment, centralizes expertise and information and establishes standards. If not, the company is headed for chaos and duplication.

Regionalizing the fleet and holding regional vice presidents accountable for equipment cost can and does work. It is possible to decentralize operating decisions while at the same time centralizing the standards necessary to achieve excellence across the company.

Success depends on three things:

First the wisdom and value added by the corporate level equipment group;

Second the support they earn at a corporate level, and

Third the universal acceptance of the fact that equipment is a corporate asset that demands specialized management.

Equipment assets require to be managed throughout their lifecycle. Decentralization in the extreme and a lack of attention to equipment as a corporate asset can cause the fleet to become an over-exploited wasteland in an organization focused entirely on short-term results.

SECTION 1-4.

The Case for a Capital Company.

Owning costs make up between twenty-five and thirty percent of the total cost of owning and operating a fleet. It is a big portion and, fortunately, a very manageable portion. Most of the costs are defined when you ink the deal and most of the money is spent up front when you take possession of the asset and put it to work. There are not a lot of uncertainties but there are a lot of complexities. Careful analysis can and does pay big dividends.

The specialized nature of owning costs and the fact that they demand high levels of expertise in accounting and finance cause many companies to establish two separate and distinct responsibility centers for fleet management. The first is responsible for all investment and fleet ownership decisions and costs while the second is responsible for all operating decisions and costs. The entities can be separate accounts within the overall company or, as is increasingly the case, set up as separate corporations with similar or slightly different ownership structures.

Figure 1.5 shows how it works and how costs and charges flow between the entity responsible for investment decisions and costs – labeled CapCo – and the entity responsible for the operating decisions and costs, labeled RunCo. Clearly, one CapCo can centralize all the investment and ownership decisions for several and, if necessary, very different RunCos.

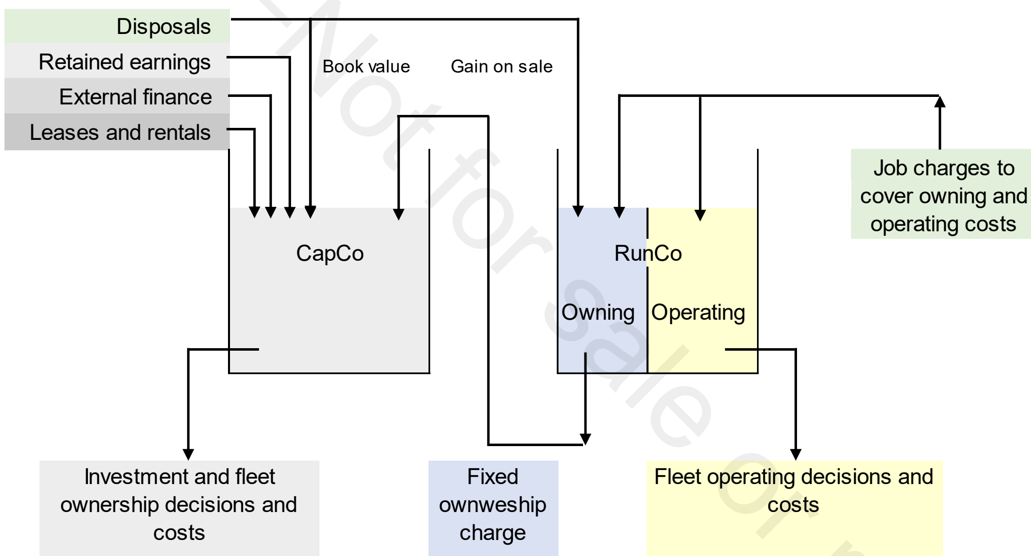


Figure 1.5. *A separate entity, CapCo, brings specialized expertise to the management of all equipment acquisition decisions and owning costs. It does, in fact, play the role of "an in-house lease house."*

CapCo starts the process off by acquiring the equipment needed to support operations and achieve the company's long-term goals. This is not a trivial exercise as capital is a scarce and expensive resource and construction is an extremely capital-intensive business. There are two basic ways in which CapCo is able to acquire equipment. First, by using retained earnings and, if necessary, external finance, to buy and take ownership of new capital investments in the fleet. Second by entering into "right to use agreements" such as leases and rentals which detail the terms and conditions under which CapCo has the right to use equipment owned by third parties.

These two fundamentally different methods of acquiring equipment impact the balance sheet differently and each has its own strengths and weaknesses. (see Section 11-5). Prudent use of available finance, managing cash and cash flow, maintaining desirable balance sheet ratios and implementing complex tax codes lie at the heart of the expertise that CapCo brings to the table. It is a specialized subject that requires a level of financial sophistication beyond the reach of many.

The equipment acquired by CapCo is made available to RunCo where it is used as required to complete construction and generate payments that flow into the job account. (see Figure 3.1). RunCo pays CapCo a fixed ownership charge for all the equipment deployed on its projects regardless of the manner in which it has been acquired. RunCo is responsible for all operating decisions and costs and balances its books by charging jobs an hourly, daily or weekly use rate for the equipment and then using this "revenue" to (i) offset the fixed ownership charges levied by CapCo and (ii) cover the actual operating costs of the equipment used to do the work.

The disposal of assets at the end of their economic life generates a flow of funds that enables CapCo to extinguish any remaining debt, write off the book value of the machine and get the asset off the asset register. If there is a gain on sale relative to book value then the gain accrues to RunCo as it was through their good efforts that the value of the machine exceeded expectation. If there is a loss on book value then, by the same token, the difference between book value and residual market value is made up by RunCo.

It all seems pretty simple. But, as with most things, the devil is in the details. Let's consider four.

First.

RunCo pays a fixed ownership charge for all machines deployed on its projects. RunCo recovers these charges by charging jobs an hourly, daily or weekly rate for the equipment they use. The risks of not recovering fixed costs therefore lies with RunCo. This is entirely appropriate as RunCo almost certainly championed the purchase decision and RunCo is, or should be, able to manage both the availability and the utilization of the asset. (see Section 13-1).

There is no reason why this charge should be uniform throughout the life of the machine. Setting it higher than average in the early years makes it possible to recover capital and reduce book value faster.

Second

The fact that RunCo benefits when the residual market value received on disposal exceeds book value gives it a stake in the long-term value of the machine and encourages it to look after the asset. This is again entirely appropriate as RunCo is responsible for all operating decisions and can, through good practices and effective training, significantly affect the market value of the equipment it uses.

Third

CapCo "owns" the equipment and is responsible for ensuring that (i) company assets retain their value and achieve their assumed ownership periods and (ii) the company honors the terms and conditions of right to use agreements. This means that CapCo must be responsible for establishing and enforcing all required preventive and condition-based maintenance procedures. (see Section 14-2). This is not negotiable and is an absolutely essential part of any process where one entity owns an asset and another maintains and operates that asset.

Fourth

Each entity focuses on what it does best. RunCo produces completed work safely, on time, on budget and to the required quality. It operates the fleet in a way that maximizes productivity, and reliability and reduces operating costs. It knows the owning cost of the equipment deployed on its projects and maximizes its position relative to CapCo by increasing utilization and focusing on the decisions needed to recover fixed ownership charges.

CapCo seeks out and inks the best deals possible and optimizes the way in which the company finds and pays for scarce capital resources. It manages a very substantial portion of the asset side of the company balance sheet and marshals the skills and resources needed to do this with unerring success.

Many smaller companies do not clearly distinguish between capital asset management (CapCo) and fleet operations management (RunCo) and the equipment manager assumes both responsibilities on a day-to-day basis. This is fine and it often works very well. The problem is that asset management decisions frequently come second relative to the day-to-day firefighting associated with running field operations and are not given the attention they deserve. (see Section 11-2).

NOTES.

Part II. KNOW YOUR COSTS.
Chapter 6. The Rate Calculation.

This chapter does have the wrong title. The use of the word "calculation" makes it sound as if it is a precise process with one correct solution. Nothing could be further from the truth. Calculating – or more correctly, estimating – a rate is fraught with uncertainty. There is too much uncertainty for there ever to be a right answer and there are thousands of ways to do the calculation.

Figure 3.1 and the material covered in Chapters 4 and 5 confirm the fact that owning and operating costs are a mixture of costs and charges some of which occur on an annual basis because you have the machine in your fleet and some of which occur on an hourly basis because you have turned the key and put it to work. The chapters also confirmed that there is substantial uncertainty associated with owning and operating costs which vary with age, application and operation throughout the ownership period of a machine.

Figure 6.1 shows how the pieces fit together and emphasizes the fact that the rate calculation:

(i) Is based on estimated owning and operating costs and,

(ii) can be nothing more than an estimate of the costs likely to be experienced throuth the ownership period of the machine.

This leads to the very important statement that:

The accuracy and quality of the rate calculation depend on the accuracy and quality of the cost estimates used not on the complexity or sophistication of the method used to perform the calculation.

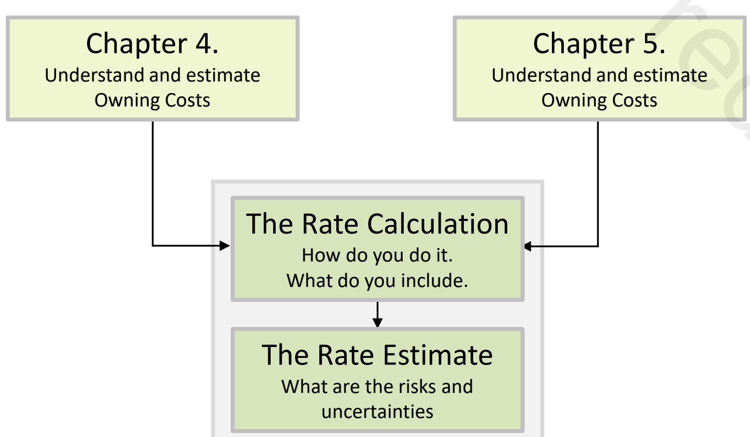


Figure 6.1. *The rate calculation is based on estimated owning and operating costs and is, in and of itself, an estimate of future costs.*

With regard to the rate calculation itself, there are two questions:

1. How do you do it and
2. What do you include.

How do you do it.

As stated above, there are many different ways to do a rate calculation. At one end of the spectrum there are complex methodologies based on the net present value of the cash flow after tax. At the other end of the spectrum are methodologies based on simply adding up the costs expected through the estimated ownership period of the machine and dividing the total by the total number of hours likely to be worked in that period.

Section 2-3 recommended using transparent, well-understood methodologies to improve communication and understanding in the rate-setting processes. Complexity in the calculation does not add to accuracy in the estimate produced and the simplest workable methodology should always be used.

What do you include.

Section 4-3 discussed whether or not there is a need to provide for a return on owners' equity in the owning cost portion of the rate calculation and suggested that it be included based on the capital-intensive nature of equipment operations, the complexity of financial management and the need for good choices between sophisticated financing, lease and rental options. This is, however, a matter of discussion and agreement within the organization as many believe that rates should focus primarily on cost recovery.

Section 4-4 focused on residual market value and argued that it should be included in the calculation because (i) zero is the worst guess you can make (ii) an assumption of zero produces rates that are, and are perceived to be, less than competitive, and (iii) little will be done to maximize the value of the machine during its ownership period and at time of sale if residual value is assumed to be zero and there is no expectation of any benefit when the machine is sold.

The material in this chapter is presented in three sections.

A Format for the Rate Calculation.

The only way to calculate the actual owning and operating cost of a machine is to wait until you have sold it, add up all the money spent and divide by the hours worked. This could be an interesting thing to do but will be of historical interest only. The secret to success and the real challenge lies in estimating future costs rather than recording what has happened.

Estimating rates using an open, transparent and well-understood methodology is one of the most important things that can be done to reduce conflict and misunderstanding between Construction and Equipment. (see Section 2-3). Much is achieved by using a standard format that is understood and accepted by all and where the various estimates that must be made are open and in the clear. Black box calculators where you "plug in the numbers" and "get the answers" help little when it comes to building trust and producing calculations that everyone sees as fair and reasonable. Spreadsheets, on the other hand, do this very well. Every number is open and visible and every number can be discussed and agreed when reviewing and communicating the results.

Good estimating requires that available data are used wisely, that realistic assumptions are made and that the uncertainties involved are well understood. If an excavator is purchased for $310,000 and the residual market value is estimated to be $70,000 after four years then it easy to calculate depreciation at $60,000 per year. The depreciation rate could be as high as $60 per hour if utilization is assumed to be 1,000 hours per year or it could be as low as $24 per hour if utilization is assumed to be 2,500 hours per year. The skill lies not in the arithmetic but in the estimates and the underlying assumptions.

A typical simple hourly rate calculation is given in Figure 6.2. It can be analyzed under six headings:

1. **The Heading Panel.**

   The heading panel is shown in rows 1 to 4.

   Column C gives routine information concerning (i) the make and model of the rate group for which the estimate is being performed and (ii) the name of the estimator who prepared the estimate and the date on which it was done.

   Column D of the heading panel is important in that it identifies the study groups that were used to calculate the residual market value and repair parts and labor curve coefficients used in the analysis. We see that the residual market value coefficients were calculated using data from study group ERMV5 – the study group identified in Figure 4.7 and used in the curve fitting process described in Section 4-4. We see that the repair parts and labor curve coefficients were calculated using data from study group RPL9 – the study group identified in Figure 5.3 and used in the curve fitting process described in Section 5-2.

   Column E identifies the four coefficients. Column F gives their values as determined in Sections 4-4 and 5-2. These are inputs to the calculation and appear in grey cells - F1, F2, F3 and F4.

2. **Estimated Ownership Period and Utilization Assumptions.**

   The assumptions made regarding the estimated ownership period and utilization appear in rows 5 to 8.

   Row 5 gives the estimated ownership period of 8 years as an input in a grey cell. Row 6 gives the assumed value for the expected utilization in the first year of ownership as an input in a grey cell. Row 7 gives an estimate of the number of hours per year that utilization is expected to decline after the first year. The value of 100 hours per year given as an input in the grey cell means that annual utilization will decline from 2,000 hours in the first year to 1,900 hours in the second year, 1,800 hours in the third year and so on as the machine ages.

   The above three assumptions are used to calculate row 8 - the estimated hours worked in the ownership period. Row 8 and the value in row 8 are shown in red to emphasize the fact that the estimated hours worked in the ownership period plays an extremely important part in the calculation. (see Section 13-1).

A	B	C	D	E	F	G
1	Make and Model	ABC	Coeficients from ERMV5	K	0.8184	see Section 4-4.
2		MSD 2		EXP	-0.506	
3	Analysis by	Pete Smith	Coefficients from RPL9	A	0.0066	see Section 5-2.
4	Date	July 2020		B	0.0073	
	Item	**Calculation**	**Value**	**Units**	**Rate: $/hr**	**Notes**
5	Estimated ownership period		8	yrs		
6	Estimated utilization, first year		2,000	hrs per yr		See Section 12-3.
7	Estimated annual decline in utilization		100	hrs per yr		
8	Estimated hourrs worked in ownership period		**13,200**	hours		
9	Purchase price		$450,000			
10	Estimated residual market value %		22%	%		see Saction 4-4.
11	Depreciation	9 - (9 x 10)	$350,191	for 8 yrs		see Section 4-2.
12	**Rate to cover depreciation**	11 ÷ **8**			$26.53	per hour
13	Annual interest rate		6%	% per year		see Section 4-3.
14	Basis for calculating annual interest	SAV	$274,904			see Section 4-3.
15	Annual cost of interest on capital	13 X 14	$16,494	per yr		
16	**Rate to cover interest on capital**	(15 x 5) ÷ **8**			$10.00	per hour
17	Annual cost of insurance, licenses etc		$12,000	per yr		
18	**Rate to cover other owning**	(17 x 5) ÷ **8**			$7.27	per hour
19	**TOTAL OWNING COST**	12 + 16 + 18			$43.80	per hour
20	Wear Parts - direct cost		$2,600	per set		see Section 5-1.
21	Factor on cost		1.2			For installation
22	Expected life		500	hours		Based on conditions
23	**Rate to cover wear parts**	21 x 22 ÷ 23			$6.24	per hour
24	Tires/Tracks - direct cost		$42,000	P&B and replace		See Section 5-1.
25	Factor on cost		1.1			For installation
26	Expected life		5000	hours		Based on conditions
27	**Rate to cover tires/tracks**	25 x 26 ÷ 27			$9.24	per hour
28	PM service - direct cost		$5,000	each cycle		see Section 5-1.
29	Factor on cost		1.3			For travel
30	PM Service interval		2000	hours		Fixed by policy
31	**Rate to cover PM**	29 x 30 ÷ 31			$3.25	per hour
32	CBM Inspection - direct cost		$1,200	each		see Section 14-2.
33	Factor on cost		1.1			For analysis
34	Inspection interval		750			Fixed by policy
35	**Rate to cover CBP program**	36 x 37 ÷ 38			$1.76	
36	**Repair parts and labor %**		136%			see Section 5-2.
37	Estimated total repair parts and labor cost when sold		$611,582	sum		see Section 5-2.
38	**Rate to cover repair parts and labor**	42 ÷ **8**			$46.33	per hour
39	**TOTAL DIRECT OPERATING COST**	23 + 27 + 31 + 35 + 38			$66.82	per hour
40	Fuel - direct cost		$2.25	per gal		see Section 5-1.
41	Fuel - dispensing cost		$0.75	per gal		
42	Fuel consumption		7	GPH		Based on records
43	**Rate to cover fuel**	(40+41) x 42			$21.00	per hour
44	Apportioned indirect cost based on revenue		$12,000	per yr		See Section 5-5.
45	**Rate to cover apportioned indirect cost**	(44 x 5) ÷ **8**			$7.27	per hour
46	**TOTAL OWNING AND OPERATING COST**	19 + 39+ 43 + 45			$138.89	per hour

Figure 6.2. *A format for the hourly rate calculation.*

3. **Owning Costs.**

The owning cost calculation is given in rows 9 to 19.

The first thing to notice is that depreciation has been kept very simple. It is defined as the difference between the purchase price and the estimated residual market value (see Section 4-2) and there is no mention of any complex or controversial depreciation policy.

The next thing to notice is that a provision has been made for the cost of interest on capital. This is based on the arguments presented in Section 4-3 and allows for the fact that both lenders and equity investors expect a return on their investment.

The purchase price for the machine under study is certainly an input to the calculation and is given in the grey cell, D9. The estimated residual marked value percentage given in D10 is based on the values for K and EXP given in F1 and F2 and calculated as described in Section 4-4. This is used to calculate the depreciation in row 11 and the rate to cover depreciation in row 12.

If the analysis described in Section 4-4 has not been done and if values for K and EXP are not available then an estimated value for the residual market value percentage will need to be entered as an input in cell D10. This can be done using the graphical technique set out in Appendix 1.

The annual interest rate used in the cost of capital calculation is an input to the calculation and is given in the grey cell, D13. The simple average value (SAV) between the purchase price and residual market value is given in D14. The annual cost of capital is given in D15 and the rate to cover the interest on capital is given in F16.

The annual cost of licenses, insurances and the like is an input to the calculation and is given in the grey cell, D17. The rate to cover this is given in F18.

Row 19 totals the three owning cost categories to give the total owning cost in cell F19.

4. **Direct Operating Costs.**

The direct operating cost calculation is given in rows 20 to 39.

The relatively constant categories (see Section 5-1) that can be estimated using a knowledge of the cost of an action and the interval between successive actions are estimated in rows 20 to 35. Each category uses the same approach; the first row gives the direct cost of the action; the second row gives a factor to allow for performing the action (traveling to site and doing the work); the third row gives the interval between successive actions and the fourth row gives the hourly rate.

The repair parts and labor calculation is given in rows 36, 37 and 38. The estimated repair parts and labor percentage given in row 36 is based on the values for A and B given in F3 and F4 and calculated as described in Section 5-2. This is used to calculate the estimated repair parts and labor cost in row 37 and the rate to cover repair parts and labor in row 38.

If the analysis described in Section 5-2 has not been done and if values for A and B are not available then the total repair parts and labor cost for the estimated hours in the ownership period will need to be estimated and entered as an input in cell D37. The graphical technique given in Appendix 2 can be used to assist in estimating a value for cell D37.

Row 39 totals the five direct operating cost categories to give the total direct operating cost per hour in cell F39.

5. **Fuel.**

The rate to cover fuel is calculated in rows 40 to 43 using the same four-row approach as that used for the relatively constant direct operating cost categories. The direct cost of fuel in row 40 is a major risk and the rate to cover fuel must be clearly and independently calculated.

6. **Indirect costs and Total Owning and Operating Costs.**

These are shown in rows 44 to 46 where the apportioned indirect costs (see Section 5-5) are added to the calculation as the input given in the grey cell, D44. The rate to cover this cost is given in cell F45.

Cell F 46 totals cells F19, F39, F43 and F45 to give the total estimated owning and operating cost per hour.

The format given in Figure 6.2 is intended to be an example and an inspiration. There is no doubt that a standard, open, transparent and well-understood methodology for doing the rate calculation improves communication and brings consistency to this important function. The routine use of a format like Figure 6.2 builds confidence in the process and makes sure that all the estimates used are clear and well understood.

Improving Estimates

The estimates used in the rate calculation determine the result.
The following steps can and will improve the estimating process:

1. Use a reasonable number of clear and well-understood cost types. For owning costs use at least three, depreciation, interest and other owning costs, such as licenses, insurance and property tax. For direct operating costs use at least four – wear parts, tires or undercarriages, maintenance and repair parts and labor. Keep the fuel calculation separate.
2. Make sure that there is a match between the cost types you use to estimate the rate and the types you use to record actual costs. If you estimate undercarriage costs separately then it is important that your accounting system records undercarriage costs under a separate code so that you can compare estimated with actual, build your database and develop the records you need.
3. Focus on what you know. You probably need to make fewer assumptions and have more data than you think. If you have been running excavators for several years then you should have a very good idea how many hours they work in a year and how old they are when you sell them. On the other hand, if you are estimating the cost for the first tree spade you have ever owned, then hours worked per year will be a real guess. There is also a lot of information available in the public domain – auction results are available and provide an excellent basis for estimating residual values.
4. Don't be overly conservative and assume the worst case. It does not take much courage to assume that the residual value is zero. It is also not very smart as zero is most certainly wrong. Being conservative is fine, it reduces the risk of painful surprises and "leaves the profits in the iron." Being overly conservative will, however, result in high estimates and uncompetitive rates. The losses will be in the bids you never won.
5. Use a standardized and well-understood format for the calculation. Standardized formats for owning and operating cost estimates are given in most manufacturers' literature. They are not perfect but are simple, easy to understand and get the job done. Develop a format of your own based on Figure 6.2, understand it, use it consistently and improve it by comparing actual values with estimated values and collecting the records you need. It is better to know and understand a simple process than to lose touch with reality by pumping numbers into a complex formula.

Sensitivity Analysis.

Sensitivity analysis is a well-known and accepted way of finding out how the result of a complex calculation is impacted by a change to any one of the many estimates needed to arrive at the final answer. If change influences the answer a lot then the calculation is said to be sensitive to that estimate; if there is little or no impact then the calculation is not sensitive to that estimate.

The rate calculation set out in Section 6-1 is a complex calculation with the final result depending on many estimates. Performing a sensitivity analysis and finding out where the critical numbers lie therefore makes a lot of sense.

The process is not complex once you have a standard spreadsheet-based format like that given in Figure 6.2. All that is necessary is to:

i. identify the estimates to be studied,
ii. vary the estimated value used in the calculation by a given percentage, (20% is typically used),
iii. redo the calculation with all other estimates left as they were in the base case and,
iv. note the impact on the final answer.

Figure 6.3 shows the necessary calculations for six of the estimates made in Section 6-1. Columns A and B match those used in Figure 6.2. Column D gives the base values used in the calculation. Columns C lowers the base value used by 20% and column E increases the base value used by 20%.

Columns F, G and H give the lower, base and higher values for the estimated owning and operating cost per hour given the identified changes made to each of the six estimates.

A	B	C	D	E		F	G	H
			Estimated value				Estimated O&O cost per hour	
Row	Estimate	Lower by 20% to	Base Value	Increase by 20% to		Lower value	Base Value	Higher value
8	Estimated hours worked	10,560	13,200	15,840		$ 150.80	$ 138.89	$ 130.80
9	Purchase price	$ 360,000	$ 450,000	$ 540,000		$ 131.59	$ 138.89	$ 146.20
10	Residual market value %	18%	22%	26%		$ 139.98	$ 138.89	$ 137.90
13	Annual interest rate	5%	6%	7%		$ 137.23	$ 138.89	$ 140.56
37	Estimated total repair parts and labor	$ 489,266	$ 611,582	$ 733,898		$ 129.63	$ 138.89	$ 148.16
40	Fuel - direct cost	$ 1.80	$ 2.25	$ 2.70		$ 135.74	$ 138.89	$ 142.04

Figure 6.3. *Sensitivity analysis performed on the basic rate calculation shows the impacts of a 20% reduction and a 20% increase in selected estimates used in the calculation given in Figure 6.2.*

The impact of change in the values for each of the six estimates analyzed is plotted in Figure 6.4. As can be seen, the impact varies tremendously.

The results are, of course, dependent on the relative costs used in the calculation and do not hold in all cases. All that can be said is that the costs used in Figure 6.2 produce a situation where:

- Utilization – defined as hours worked when sold at the end of the estimated ownership period – clearly has the largest impact on the estimated total owning and operating cost per hour. This is discussed again in Section 13-1.
- Repair parts and labor, purchase price and fuel are, in that order, the next most important estimates.
- Annual interest rate and residual market value play a surprisingly small part in the analysis.

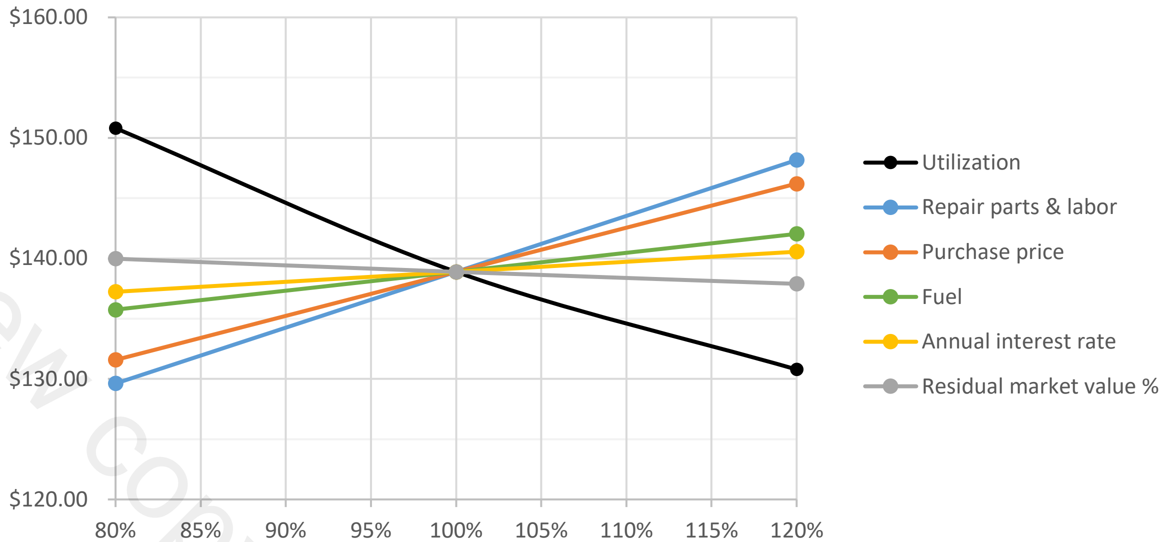


Figure 6.4. *Utilization, repair parts and labor and purchase price have the most influence on the estimated owning and operating cost rate.*

Sensitivity analysis is a powerful tool that provides important and meaningful insights into any complex calculation. Indeed, a case can be made for the fact that it is of little value to know that a machine is estimated to cost $138.89 per hour without being able to answer the questions, “On what does this depend?” and “How sensitive is the calculated rate to change in any one of the input parameters?”

The impact of utilization on the rate is discussed in detail in Section 13-1.

Equipment owning and operating costs are subject to substantial risk and uncertainty. Annual utilization and repair parts and labor play a major role.

Calibrating the Rate Calculation.

The equipment rate means many things to many people and is fraught with emotion and misunderstanding. It is used across the company to estimate costs and measure performance and people forget that it is nothing more than an interim estimate for the actual cost the company expects to experience throughout the ownership period of a particular class or category of equipment.

The need to establish an hourly, weekly or monthly rate for a machine stems from the fact that most equipment costs occur in relatively large discrete amounts spread at random times throughout the life of the machine. The rate averages out these large infrequent expenditures and spreads them evenly over the ownership period so that costs can be estimated and performance can be measured over shorter periods. The rate is, in fact, much like an insurance premium – relatively small amounts paid at regular intervals to cover the cost of the large transactions that are expected to, but hopefully will not, occur at random infrequent points in the future. As with an insurance premium, the higher and more frequent the claims, the higher the payments.

Figure 6.5 shows that equipment rates play a critical part in three important aspects of construction management.

First. It is used in estimating where it is multiplied by the estimated time needed to do the work to calculate the budgeted cost for a particular job phase code.

Second. It is used in job costing where it is multiplied by the time taken to do the work to calculate the actual cost of the phase code.

Third. It is used as a cost-recovery and budgeting mechanism within the equipment account where it is multiplied by the time a machine works or is charged to jobs to establish the budgeted cost for owning and operating the machine.

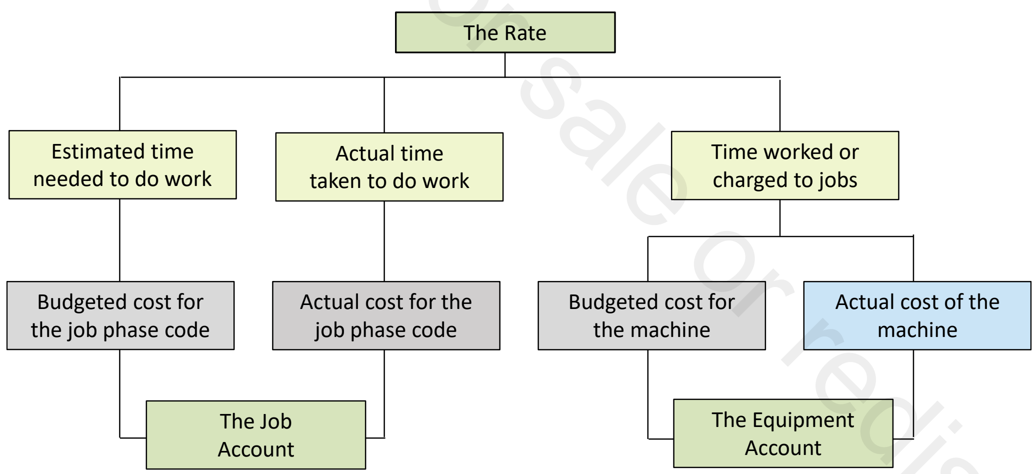


Figure 6.5. *The rate is used in estimating to determine the budgeted cost, in job costing to determine the actual cost and in equipment costing to determine the budgeted cost for each machine.*

The fact that the rate influences so many parts of the business makes it critically important to set an accurate, reasonable and defendable rate for each class or category of equipment. The task most certainly requires substantial thought, careful analysis and good judgment.

Figure 6.6 shows how many areas can be used to focus on, calculate and calibrate the rate. The process starts at the bottom left of the diagram with a good theoretical calculation using the best available estimates and a standard format such as that given in Section 6-1. The value obtained provides a theoretical baseline for owning and operating costs under the assumed conditions and helps to show how internal policies for the

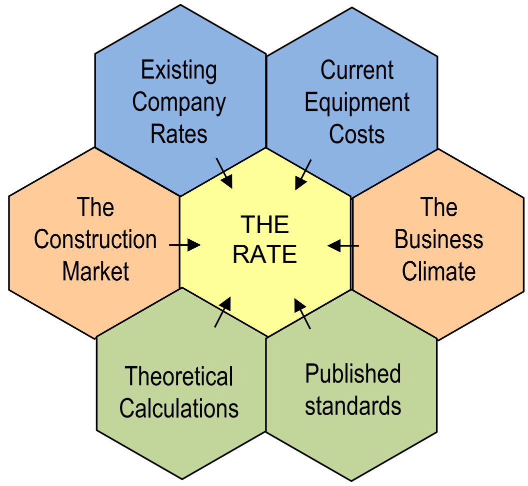


Figure 6.6. *Many areas can be used to calculate, set and calibrate the rate.*

calculation of inputs such as depreciation and the cost of capital affect the rate. The insights provided by a theoretical calculation are greatly enhanced if the calculation is repeated using a range of values for age and utilization so that both the magnitude and the timing of the optimum ownership period and optimum cost point can be determined. (see Section 8-4). This gives benchmark values for minimum cost as well as the optimum ownership period and provides the information needed to set up a structured and quantitative approach to fleet replacement planning. (see Section 9-2). Theoretical calculations are also very good when it comes to splitting the rate into its principal cost types such as owning costs, operating costs, fuel and indirects. (see Section 7-3).

It is always a good idea to test or calibrate the theoretical calculations using published standards and norms as shown in the bottom right of the diagram. Many agencies publish what they believe the rate for a given class of machines should be under the conditions they assume. Every company is different and individual experience can vary tremendously with time, location and economic factors. Great care should therefore be taken when using industry-wide published standards and they must be constantly adjusted for changes in input costs such as labor and fuel. They do, however, provide a very good starting point and managers must be in a position to explain why the calculated rate for a 4 cubic yard, 200 hp wheel loader comes to $95 per hour while the method proposed by the Corps of Engineers produces a result of $52 per hour.

The top row of the diagram shows a very different process for setting equipment rates. It relies on the fact that the company has been in business for a while, that it keeps good records and that it can use current cost information to set budgets, calibrate existing rates and ensure that rates reflect current costs as well as possible. (see Figure 7.7).

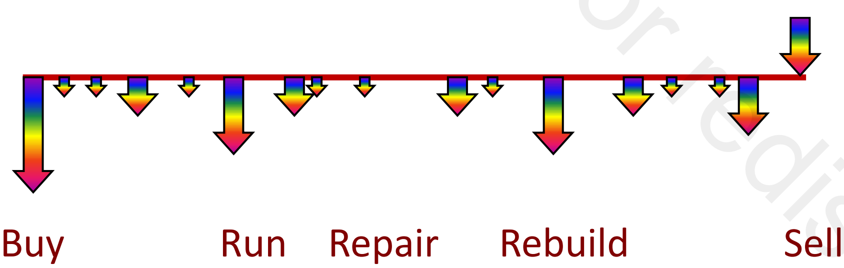
Using accurate current equipment costs to establish and calibrate rates that enable each category of equipment to recover its actual costs is the gold standard. It is not easy to do and it is not foolproof. The future does not necessarily reflect the past and historical data cannot be used without care and judgment. This is particularly true when categories are relatively small and when the age of individual units within a category is not well distributed. It also requires that cost data be collected and grouped by both cost type and equipment rate class. Collecting costs into cost-type buckets that are too coarse can easily produce meaningless results and lead to a situation where "if you have enough things then, on the average, the average will be average". As an absolute minimum, cost types should be segregated into ownership, operating, fuel and indirect costs and equipment should be defined clearly by rate class as detailed in Section 7.2.

The two cells on the side of the diagram provide what many see to be the ultimate way to calibrate either theoretical or experience based rates. "What will the market bear?" is a very real fact of life in a competitive world and all aspects of company operations must be examined if calculations and available data produce rates that differ from like-for-like comparisons in the competitive arena.

Setting, maintaining and constantly calibrating a realistic set of internal rates that represent all the transactions that are likely to occur throughout the ownership period of the various units in the fleet is an important high-risk operation. So, what can be done to improve performance? Five things.

1. Recognize and accept that the rate is an estimate. It is one number that is used on an ongoing basis in many places to represent or average out a vast array of transactions that occur at various points throughout the ownership period of a machine. Some of these transactions will be big, some will be small. Some will occur on an annual basis and some will be directly proportional to the hours worked. Representing them with one hourly, daily or monthly number is more art than science.
2. Recognize that the use of the rate in calculating job cost variances and equipment cost variances affects only intra organization measures of performance. The only critical use of the rate is in estimating where it influences the contract value of the work to be built. Recognize the risks involved, provide sufficient contingency and mark up to cover them.
3. Be reasonable and realistic when setting the two most important numbers in the rate calculation – the estimated ownership period and the estimated annual utilization. If the estimated life is too long you will lower the depreciation portion of the rate but you will most certainly increase the repair parts and labor portion of the rate. If annual utilization is unrealistically high you will lower the rate but constantly under recover the fixed cost of ownership.
4. Understand the difference between owning and operating costs and estimate an owning rate and an operating rate as two different and distinct portions of the total rate. Owning costs are largely fixed when you ink the deal and the major uncertainty lies in your estimated annual utilization. With operating costs, your major risks are application and operation. (see Section 3-2). Use your data, they reflect your conditions. Focus on the skill of the hand that turns the key and the hand that turns the wrench.
5. Know the components of the total rate and use these sub rates and your cost coding system to generate budgets, actuals and variances by principal cost type such as depreciation, repair parts and labor, wear parts and fuel. Review, calibrate and adjust your rates regularly using your knowledge of which principal cost type is gaining or losing. Do not let gains in one cost type subsidize losses in another. Know where the gains and losses lie, take action. (see Section 7-4).

The rate is not just a simple number. It is the cornerstone of estimating, job costing and equipment cost management. Get it wrong and you introduce uncertainty and inaccuracy that impact many parts of the organization.



A machine generates over 2,000 cost events during its ownership period. Some will be big; some will be small. The rate adds and averages the all the cost events to give a value that can be used to estimate the cost of a given "slice of life" on a given project.

Many Names for the Same Thing. If a machine has a rate of $65 per hour and if it is charged to operations for 100 hours, then the $6,500 charge can be described in many ways.
1. Equipment cost – Estimators and construction managers see $65 as a real value for the "equipment cost." They use it in estimating and job costing and seldom make adjustments to reflect reality. This neglects the fact that the $65 per hour is in itself an estimate with substantial variability and supports the notion that the equipment actually costs $65 per hour. As with all estimates, the actual cost may, or may not, be $65 depending on many factors.
2. Equipment revenue – The equipment account sees the $6,500 as a revenue or a credit to the equipment account. This "revenue" is set against the actual cost to calculate a profit or a loss in the equipment account. This neglects the fact that the $65 per hour is in fact an internal charge and supports the notion that the equipment account actually "makes" or "loses" money.
3. Earned budget – The concept here is that the $65 per hour is a budget rate that is multiplied by the hours worked as a way to generate or "earn" a variable budgeted amount used in the classical "budget, actual, variance" analysis of an equipment account. This supports the notion that equipment earns a budget by working and that the $65 per hour "rate" is the standard cost benchmark used in the budgeting process.
4. Cost recovery – The concept here is that the $65 per hour is a routine systematic hourly charge needed to compensate for or recover the actual costs expected to be experienced over a given period – normally the ownership period of the machine. This supports the notion that "the rate" is, in the final analysis, nothing more than the average of the costs experienced and that everyone in the company can contribute to a lower "rate" by making decisions that reduce actual equipment costs to a minimum.

Many people look at "THE RATE" from many different points of view.

Part III. MANAGE FLEET AVERAGE AGE.

Chapter 9. Fleet Age Management.

Few things are more important than managing the average age of a fleet. The number of scrapers or rock drills that a company owns makes it possible to get the job done today. The average age of the fleet and the amount invested in fleet replacement enables the company to be competitive in the future. Fleet cost and fleet age are two very different measures. One looks to the present and the other looks to the future. Both are important and both deserve careful attention.

When a company buys an excavator, it adds a finite and relatively well-known number of “excavator hours” that can be used to produce work in the future. It is like putting gas in a car – a fixed quantity is purchased now and used to travel in the future. Everyone knows that you must “buy what you burn” or else the car will end up running on empty. The same is true for the fleet. Equipment must be replaced as it is used or else the company will end up with a dilapidated, over-age fleet that can journey no further.

The buy-what-you burn concept is not complicated - if the company runs six excavators an average of 1,500 hours per year and if it believes that the optimum ownership period for an excavator is 9,000 hours then it must, in the long run, buy one excavator per year to replace the 9,000 excavator hours “burned up” during the year.

Age management and a stable disciplined approach to the ongoing investments required to maintain the capability of the fleet are essential for the long-term success of the company. A downturn in the market, overly competitive pricing and a reluctance to reinvest in the fleet very quickly lead to a downward spiral where:

- uptime and reliability are no longer sufficient to complete work on time and on budget. Jobs run late, margins evaporate and cash flow becomes a very serious problem,
- downtime and repeated failures demand inordinate amounts of repair parts and labor. Operating cost budgets are exceeded and everyone fights fires,
- low or negative margins make it difficult to finance capital investments in new equipment. Everyone blames the other. Maintenance spending and capital investment are cut in a knee-jerk reaction to what is seen as a short-term problem,
- the problem continues, the situation gets worse and the spiral continues downward.

Breaking the spiral is extremely difficult. It is best to avoid it by measuring and maintaining the average age of the fleet and by realizing that a continuously productive fleet requires a continuous level of capital investment. Companies cannot expect to continue and succeed if they do not “buy what they burn”. Purchasing, financing or leasing a machine cannot – or should not - be an impulse decision. Ownership periods are relatively long and the number of “excavator hours” brought into stock when the company buys an excavator are slowly but undeniably used up in the production of work. It is absolutely true that:

You may be able to defer replacement but you cannot, in the long run, deny replacement.

The vast majority of fleet "age" management decisions are based on two assumptions:

1. "Age" is defined in terms of hours worked or miles traveled.
2. The only possible action is to get rid of the old machine and replace it with a new and similar unit.

Both these assumptions are simplifications. The optimum ownership period and the machine age zones described in Chapter 8 are based on hours worked but hours worked is most definitely not, and should not be, the only criterion used to define "age". Cost, reliability and utilization are certainly factors in the definition of an optimum ownership period. They do, however, correlate closely with age in hours worked or miles traveled and so little is lost by simplifying things and focusing only on age in hours or miles.

The assumption that the only possible action is to replace a machine with a similar unit is, however, more serious. Construction is a constantly changing world and every replacement decision is an opportunity to resize or reconfigure the fleet by moving an old unit out and acquiring a new similar or very different unit. Every replacement decision is also an opportunity to consider the wisdom of rebuilding an existing unit and adding capacity by extending the optimum ownership period of an existing machine. (see Chapter 10).

Regardless of the simplifications made, two things are important:

First. There must be a routine and disciplined process to identify machines that are beyond their prime. This reduces the danger of throwing good money after bad and ensures that the sum of owning and operating costs is kept at or close to the minimum.

Second. The process must make it possible to take a long-term view of the capital requirements associated with fleet replacement. This provides structure and predictability to the capital budgeting process (see Chapter 11) and significantly improves all owning cost decisions.

The material in this chapter builds on Chapter 8 to discuss practical issues and develop practical tools and techniques. Two selected case studies are used to show how the fleet age management process works in practice.

Fleet Age Balance.

"How long do I keep it?" is a question that equipment managers ask every day. They know that replacing machines at a relatively young age reduces repair costs, shop labor and downtime but increases the amount of capital invested in the fleet. They also know that if they increase fleet age then capital expenditure comes down, repair parts and labor go up and efficient repair facilities become critical for success. Striking a balance between a capital-intensive young fleet and a repair-intensive old fleet is more art than science. Section 9-2 presents a high-impact analytical tool to help the fleet age planning process but success comes from knowing the implications of fleet average age and finding a balance that suits the company and the nature of its various operations.

Calculating the optimum ownership period or sweet spot for a certain class of equipment is not very difficult using the methodologies and the age zone concept set out in Section 8-3. These give a good starting point but do not take into account the many intangible factors that invariably cause practice to deviate from theory.

The first factor is, of course, the reality of the industry. Careful analysis may show that it is time to replace two of the four twin-engine scrapers in the fleet but no scraper work may be on the horizon after the current six-month project is complete. So, it is wiser to hang on to the two old machines for another thousand hours or so and wait until there is more confidence about future work. The second, equally important factor is capital availability. There may be ample work on the horizon but financial constraints and prudent decisions regarding the structure of the balance sheet may be such that you cannot invest in new scrapers for a year or two. So, the decision is to give the old machines a thorough overhaul, replace a few key components and keep them in your fleet for the next while.

The third factor relates to an executive style, feeling and philosophy as to how old the fleet should be. Some managers believe that the fleet should be "young and good" as this is an important part of the image they wish to project and an essential ingredient for success on the high-tempo, high-production jobs the company undertakes. Other managers believe that machines are built to last and that they can run forever if they are looked after and maintained with care and affection. They believe that appearance is not a factor and that availability and downtime are not important especially if an extra machine or two is available on standby.

These two styles have clear pros and cons and it is important to understand what happens if the fleet – or certain parts of the fleet – are kept younger or older than the ever-elusive optimum point. Figure 9.1 lists the advantages and disadvantages. Each will be reviewed in turn.

Keeping the fleet average age young.

The principal advantage is that the company has good equipment ready to work long hours on high-tempo jobs without delays and disruptions due to equipment failure. Reliability and uptime are good, frequent replacements make it possible to keep pace with the latest advances in technology and every machine is a billboard for the company's high standards. Large and complex repair facilities will not be needed and the infrastructure required to maintain the fleet will be small, simple and manageable – the company will not get involved with expensive, complex and risky rebuilds.

It sounds too good to be true but there are disadvantages. First of all, the amount of capital tied up in the fleet is high and achieving a satisfactory return on investment or return on owners' equity is difficult. High levels of capital expenditure together with the loans and leases needed to leverage equity means that annual financial costs are high. To cover financial costs and get the most out of the company's substantial capital investment, equipment must work many hours. This heightens the risk involved in bid volumes, weather and other factors that so often affect a construction company's actual work volume.

	If the fleet average age is younger than normal.	If the fleet average age is older than normal.
Advantages.	Able to work long hours on high-tempo jobs without delays and disruptions. Reliability and uptime are good. The focus is on preventive and condition based maintenance. No need for expensive, and risky rebuilds. There is no need to establish large and complex repair facilities. Every machine is a billboard for the company.	Capital invested in the fleet is lower. The annual cost of finance does not drive the organization. Not critical to work long hours and undertake high tempo jobs to recover high capital and fixed costs. The company is not severely affected by periods of low utilization.
Disadvantages.	The amount of capital tied up in the fleet is unusually high. Financial metrics such as return on investment are difficult to achieve. Annual financial costs are high. High utilization is essential to cover annual financial costs.	Lack of reliability and low availability can adversely impact operations. Substantial repair facilities are required. Fixed costs associated with repair facilities, labor and overhead must be managed. Could fall behind the technology curve.

Figure 9.1. *Maintaining fleet average age is more art than science. There are advantages and disadvantages associated with working on either side of the norm.*

Three things are necessary if the company is to succeed and maintain a low fleet average age.

First. Managers must understand equipment finance and the company must have a sound financing strategy. (see Chapter 11).

Second. The company must have the infrastructure needed to obtain and perform work at a high tempo. The investment in the fleet must be well utilized and the company will not be profitable if it does not use its strong young fleet to the fullest extent possible.

Third. The company must have excellent dealer relationships and effective warranty administration. It will be spending a lot on new equipment and dealers must stand by and provide the support required, promised and paid for in the purchase agreement.

Letting the fleet average age increase.

The advantages are almost exactly the opposite to those of a young fleet. Less capital will be invested, the annual cost of finance will not drive the organization and it will not be critical to work long hours and undertake high-tempo jobs. Some of the fleet will be “paid for” and the company will not be as severely affected by periods of low utilization due to bid volumes, weather or workload fluctuations.

There certainly are disadvantages associated with an old fleet. Availability and reliability (see Section 15-1) can easily reach a stage where they impact operations and the company will need to have expertise in owning and operating substantial repair facilities. Shop facilities and other infrastructure require investment and, while many of the costs such as parts and direct labor are variable, attention will have to be paid to the fixed costs associated with repair facilities, labor and overhead. Long machine lives may also cause the company to fall behind the technology curve and become exposed to the risk of parts availability and cost.

What is needed to be successful under these conditions?

First. Running effective and efficient shops must be a core competency. This is much more easily said than done. The facilities themselves need to be first-class, technician training needs to keep pace with changes in technology and shop capacity must be sufficient to support demand.

Second. Equipment will be bought for the long term and selection is therefore critical. Parts and rebuilt component availability are key decision factors and total lifecycle cost is more important than purchase price.

Third. Operational planning will have to be flexible enough to accommodate the reality of downtime. Field crews will need to understand that the luxury of lower fixed owning cost does not come without a price and that availability will be less than perfect.

Two things are critical:

First - Know what you are doing. It is impossible to get the average fleet age exactly right. Know and develop a policy or style that suits the company as well as each class of machines in the fleet. It would seem appropriate for key production machines to be kept young and reliable. It would also seem appropriate for highly stressed self-destructive vibrating equipment to be replaced on the early side of the norm. Stable, simple and inherently reliable machines can be kept for longer.

Second – Stick to a style. Changing company policy or style can be difficult, time-consuming and expensive. A change from a capital-intensive young fleet to a repair-intensive older fleet carries with it a decision to develop the core competencies needed to own and operate effective and efficient repair shops. This is not easy, it requires a significant investment in money, time and talent. Changing from a repair-intensive older fleet to a newer less repair-intensive fleet is impossible without access to substantial amounts of long-term stable capital and without the constant high volumes needed to support significant capital investment in a fleet.

Changing from a repair-intensive older fleet to a newer less-repair-intensive fleet requires substantial amounts of stable long-term capital.

SECTION 9-2.

Age Based Replacement Planning.

Fleet replacement planning is an extremely important part of equipment management. It:

- lowers cost by ensuring that as many machines as possible are at or near their minimum cost.
- reduces waste by identifying machines that are becoming increasingly more expensive.
- forms the basis for fleet replacement, financial planning and capital budgeting decisions.

Figure 9.2 uses the optimum ownership period concepts discussed in Section 8-1 and the machine age zone concepts discussed in Section 8-3 to develop a simple high impact graphical tool for use in the fleet age planning process. It starts with the current age of a given group of machines and uses a reasonable number of estimates to show how the group is likely to age in the future. The use of the tool in practice has given rise to it being widely known as "The Churn Chart".

	A	B	C	D	E	F	G	H	I	J	K
1				Optimum life-cycle period.							
2		90%		↓	110%		120%		130%		
3											
4											
5				Optimum ownership period	Annual usage	Hours now	Expected future age in the given number of years ahead				
6							1	2	3	4	5
7	Unit #	Make	Model	Hrs	Hrs/yr	Data					
8	LRT 12-1	Wests	2	9,000	1,200	12,750	13,950	15,150	16,350	17,550	18,750
9	LRT 12-2	Wests	2	9,000	1,200	11,290	12,490	13,690	14,890	16,090	17,290
10	LRT 12-3	Wests	2	9,000	1,200	11,100	12,300	13,500	14,700	15,900	17,100
11	LRT 15-1	North	C3	14,000	1,500	15,879	17,379	18,879	20,379	21,879	23,379
12	LRT 14-4	North	C3	10,000	1,500	10,090	11,590	13,090	14,590	16,090	17,590
13	LRT 14-5	North	C3	10,000	1,500	9,800	11,300	12,800	14,300	15,800	17,300
14	LRT 15-2	Wests	2A	9,000	1,200	8,400	9,600	10,800	12,000	13,200	14,400
15	LRT 17-2	Wests	2A	9,000	1,200	8,220	9,420	10,620	11,820	13,020	14,220
16	LRT 14-1	Wests	2A	12,000	1,200	11,100	12,300	13,500	14,700	15,900	17,100
17	LRT 17-3	Wests	2A	12,000	1,200	10,900	12,100	13,300	14,500	15,700	16,900
18	LRT 14-3	Wests	2A	12,000	1,200	10,600	11,800	13,000	14,200	15,400	16,600
19	LRT 18-1	North	C3	10,000	1,500	6,689	8,189	9,689	11,189	12,689	14,189
20	LRT 18-2	North	C3	10,000	1,500	5,432	6,932	8,432	9,932	11,432	12,932
21	LRT 18-3	North	C3	10,000	1,500	5,400	6,900	8,400	9,900	11,400	12,900
22	LRT 19-1	North	C3	10,000	1,500	3,678	5,178	6,678	8,178	9,678	11,178
23	LRT 19-2	North	C3	10,000	1,500	2,100	3,600	5,100	6,600	8,100	9,600
24	LRT 20-1	Wests	2C	9,000	1,200	1,111	2,311	3,511	4,711	5,911	7,111
25	LRT 20-2	Wests	2C	9,000	1,200	989	2,189	3,389	4,589	5,789	6,989

Figure 9.2. *"The Churn Chart" – a high-impact graphical tool for use in fleet age planning.*

Implementation is simple and straightforward. No exotic or unusual data is required and the output is easy to understand and use. The following six steps produce the required results.

First:

Identify and describe the units under study. This is usually a given rate class or easily identified group of machines for which a replacement strategy is required. Columns A, B and C, rows 8 to 25 show that the chart has been prepared for a group of 18 large rubber-tired loaders with some variety in their date of purchase, make and model.

Second:

Define an optimum ownership period for each machine in the group. This can be done using analytical techniques similar to those described in Section 8-1 or, if necessary, by using experience gained when operating similar machines under similar conditions. Optimum ownership periods can be the same for the group as a whole or they can be adjusted on a unit by unit basis to handle special cases when machines are rebuilt and the optimum ownership period is extended. Column D, rows 8 to 25 gives the estimated optimum ownership period for each unit in the group. They vary slightly by make and model and it can be seen that LRT 15-1 (row 11) has been rebuilt to give it a 14,000 hour life as opposed to the 10,000 hour optimum ownership period for the other North model C3 loaders.

Third:

Decide on the positioning and length of the machine age zones. Section 8-3 defined two methods – the first based on the magnitude of the minimum cost and the second based on the optimum ownership period. Row 3 shows that the zones have been defined relative to the optimum ownership period. The green zone lies between 90% and 110%, the yellow zone between 110% and 120%, the orange zone between 120% and 130% and the red zone beyond 130%. Machines in the yellow, orange and red zones will thus most likely have marginal costs per hour that exceed their average life-to-date cost per hour and are candidates for replacement. Red and orange zone machines are clearly the most urgent.

Fourth:

Estimate the expected annual usage in hours per year for each machine in the group. These can be based on available data or on the utilization expected in the years ahead. Usage hours can be set on a unit-by-unit basis as shown in column E. It can be seen that all units are expected to work 1,200 hours per year except for the North model C3 loaders which are expected to work 1,500 hours per year.

Fifth:

The age of each unit in hours worked forms the starting point for the analysis. Known values are entered into Column F, rows 8 to 25 and the cells are colored according to the age zone in which a particular unit falls. It can be seen that LRT 12-1 is over the threshold for the red zone and should be replaced as soon as possible. LRT 12-2 and 12-3 are over the threshold for the orange zone and are also urgent candidates for replacement. The same can be said for LRT 15-1 which, despite the fact that it has been rebuilt, is yellow or more than 10% over its estimated optimum ownership period. The other units in the group are in either the green or the blue zone and there is no need to consider them as candidates for replacement at this time.

Sixth:

The value of the Churn Chart comes in columns G to K where the current age (Column F) is advanced by the expected annual usage (Column E) to determine and expected future age and age zone for each unit in each of the next five years. Looking horizontally along a given row shows how one machine moves through the age zones. Looking vertically up a given column shows the age zones in which the units are likely to fall in a particular year. The fact that the group becomes predominantly "red" if nothing is done to replace candidate units and maintain the fleet average age is abundantly clear.

The Churn Chart is a high impact graphical tool that looks into the short to medium term future to show what will happen to the age balance for a particular group of machines if nothing is done to replace hours burned up in the production of work.

Every hour worked causes a machine to move ever closer to the red zone – the time when the cost of each additional hour worked is greater than the average cost of all hours worked life to date. The process happens day by day and it should not come as a surprise when a machine that is currently in the yellow zone reaches the orange and/or red zone in the next year or so. The churn chart provides the visual impact – the facts speak for themselves.

The full optimum ownership period calculation set out in Section 8-1 is seldom worth it if the analysis is only used to determine the hourly rate. The value of the optimum ownership period calculation becomes very apparent when it is used to understand how hourly costs increase with age and if this is used to establish a rational and consistent replacement policy that keeps the average fleet age well balanced and as close to the minimum cost point as possible.

SECTION 9-3.

Other Factors in Replacement Planning.

Age, measured in hours worked or miles traveled is widely used in the replacement planning process because:

1. It is easy to measure.
2. It is relatively easy to forecast for the short to medium-term future.
3. The concept of an optimum ownership period based on age in hours worked or miles traveled is well understood and accepted. (see Section 8-1).
4. Many of the other factors that would cause a machine to be a candidate for replacement are believed to correlate closely with age in hours or miles.

It certainly is true that if you manage age, you will probably manage cost, reliability, utilization, obsolescence and the host of other factors that define the point at which a machine is "beyond its prime". Intuition, experience and prejudice – in other words "I think so" - also correlate closely with age and the vast majority of fleet age management tools are based on age and age alone.

Data processing and rule-based decision making have progressed to the stage where it is both feasible and practical to develop a ranking tool that considers more than age in the replacement decision and that gives guidance on the best course of action. Implementation is hindered more by an inability to define what is meant by "beyond its prime" than by the complexities of data collection and processing. It is extraordinarily difficult to capture and precisely define "I think so" when it comes to the replacement decision.

Figures 9.3 and 9.4 give an example of what can be done and show both the challenges and the potential. Implementation requires three distinct steps.

First:

Define the metrics and required values that will be used to rank units for review.

As noted above, age, measured in hours worked or miles traveled is most likely to be among the metrics. So are cost, reliability and utilization as there is no doubt that these three factors play a significant role in identifying machines that are candidates for replacement.

Required values are subjective but the process is facilitated by the fact that two values are required – one that is considered to be "good" and representative of a machine that is "in its prime" and another that is considered to be "bad" or representative of a machine that is "past its prime" and should be seen as a candidate for replacement. (see Chapter 10).

Defining "good" and "bad" values is a very contentious process. It seems to be relatively easy to define a metric but much more difficult to set and commit to the threshold values needed to take action. There is little discussion that hours worked in the last 12 months is a good metric for utilization – but is 2,000 hours a good value or should it perhaps be 1,800?

Figure 9.3 gives an example.

Row 1 Identifies the class of units under study.

Rows 2 and 3 describe the age, cost, reliability and utilization metrics used where:

- Age is measured as hours worked, LTD.
- Cost is measured as a percentage of the current cumulative repair parts and labor cost divided by the budgeted value obtained from a standard RPL cost curve. (see Section 5-2).
- Reliability is measured as the number of reported emergency down events (RED events) per 1,000 hours worked life to date. (see Section 15-1).
- Utilization is measured as the number of hours worked in the last 12 months. (see Section 13-1).

Rows 4 and 5 give the required values that define "good" and "bad" values for each metric. These will be used to define a scoring system able to standardize and combine actual values for each metric.

	A	B	C	D	E
1	Metrics and required values for			**Class B Loaders**	
2		Age	Cost	Reliability	Utilization
3		Hours Worked LTD	% RPL curve value	RED events per 1,000 LTD	Hours worked last 12 mo
4	Good, 10 points	5,000	80%	5	2,000
5	Bad, 0 points	10,000	140%	15	1,000
6	Weight	25%	25%	35%	15%

Figure 9.3. *Metrics and required values.*

Second:

Set up the scoring system able to standardize and combine the actual values for each metric. This requires a little mathematics but is quite straightforward. The good value for each metric and all values better than the good value are assigned 10 points. The bad value for each metric and all values worse than the bad value are assigned zero points. Values between good and bad values are allocated points between 10 and zero on a linear scale. Certainly, something other than a linear scale can be used but the complexity this adds is hard to justify.

The values for each metric are combined into a single weighted score using the weighting factors given in row 6 of Figure 9.3. The loaders under review determine the productivity of their associated haul units and thus reliability is weighted higher than any other metric. (cell D6).

Third:

Collect the data for each unit under study and use the scoring system to calculate a score for each metric as well as a weighted average score.

The results are given in Figure 9.4.

	A	B	C	D	E	G	H	I	J	F
1		Age	Cost	Reliability	Utilization	Scores				
2	Unit Number	Hours Worked LTD	% RPL curve value	RED events per 1,000 LTD	Hours worked last 12 mo	Age	Cost	Reliability	Utilization	Weighted average score
3	BA 46	11,500	140%	12.00	900	0.00	0.00	3.00	0.00	0.5
4	BC 15	9,500	130%	8.00	1,200	1.00	1.67	7.00	2.00	2.4
5	BC 19	9,234	110%	16.00	1,350	1.53	5.00	0.00	3.50	2.9
6	BB 19	8,200	120%	7.00	1,567	3.60	3.33	8.00	5.67	4.9
7	BB 22	7,500	110%	6.00	1,500	5.00	5.00	9.00	5.00	5.6
8	BC 27	6,789	90%	10.00	1,545	6.42	8.33	5.00	5.45	6.3
9	BA 28	6,235	123%	7.00	2,200	7.53	2.83	8.00	10.00	7.3
10	BA 54	3,500	98%	12.00	2,100	10.00	7.00	3.00	10.00	8.2
11	BB 35	2,978	115%	7.00	1,900	10.00	4.17	8.00	9.00	7.9
12	BA 62	2,500	92%	3.60	1,800	10.00	8.00	10.00	8.00	8.8

Figure 9.4. *A multi-variate ranking tool that calculates a weighted average score based on metrics for age, cost, reliability and utilization.*

Fourth:

Review the results. Figure 9.4 contains a lot of information. BA 46 “strikes out” in almost every metric and is clearly a candidate for replacement. The same is true for BC 15 and BC 19. The units in rows 10, 11 and 12 are doing well and there is no reason to consider them as candidates for replacement. BA 54 should, however, be looked at from a reliability point of view and BB 35 should be looked at from a cost point of view. Units in rows 6 to 9 are typical of units in the middle period of their lives – they have good points and bad points but are probably not candidates for replacement.

Everyone has their opinion. Figure 9.4 seeks to add some defendable order to the process.

SECTION 9-4.

Case Study # 9.1 Developing a Replacement Plan.

This case study details a situation where optimum ownership period and fleet age planning concepts were used to establish age zones and set up a fleet age management process for a relatively small group of mid-size haul trucks. All the analysis is based on actual data that has been factored as needed to protect privacy. The calculated values are therefore not representative of what can be expected. The nature of the data and the curves produced are, however, true to the actual situation.

Setting.

The company-owned and operated a group of seven mid-sized haul trucks and was concerned about the fact that they may be keeping some of the units in their fleet "far too long." They wished to check this concern and establish a more rational and "defendable" fleet replacement strategy based on a fleet replacement planning "churn chart" similar to the one described in Section 9-2.

Data.

Good data was available for the purchase price, hours worked LTD and the cumulative cost of repair parts and labor LTD for the seven units currently in the fleet and for four units that had recently been sold because "we were pretty convinced that they were tired and no longer worth keeping." Residual value data was also available for the four recently sold units.

Columns A to D of Figure 9.5 give the data for two of the four units that had been recently sold.

	A	B	C	D	E	F	G	H
1	Unit	Purchase price	Hours worked LTD	Repair Cost LTD	Total cost LTD	Total cost ÷ Pp	ERMV%	Total cost ÷ Pp - ERMV%
2	MHT 10-1	$ 160,022	5,151	$ 8,822	$ 168,843	106%	35%	70%
3			6,907	$ 27,321	$ 187,343	117%	30%	87%
4			9,940	$ 51,553	$ 211,575	132%	25%	107%
5			14,388	$ 77,915	$ 237,936	149%	21%	128%
6			14,545	$ 111,343	$ 271,365	170%	21%	149%
7			15,469	$ 116,521	$ 276,543	173%	20%	152%
8			15,567	$ 117,063	$ 277,085	173%	20%	153%
9			15,736	$ 124,898	$ 284,920	178%	20%	158%
10	MHT 10-2	$ 164,419	10,107	$ 70,083	$ 234,502	143%	25%	117%
11			11,491	$ 74,268	$ 238,687	145%	24%	122%
12			12,947	$ 88,505	$ 252,924	154%	22%	132%
13			15,175	$ 124,897	$ 289,316	176%	21%	155%
14			15,400	$ 127,746	$ 292,165	178%	20%	157%
15			17,329	$ 136,389	$ 300,809	183%	19%	164%

Figure 9.5. *Data used in the analysis of the recently sold units.*

Analysis of recently sold units to establish age zones.

The total cost model as detailed in Section 8-2 was used to analyze the four recently sold units and establish age zones that could be used as the basis for a rational and "defendable" fleet replacement strategy. The 7 steps in the process were:

1. Determine the total cost to "buy and operate" each of the four units by adding the purchase price and total repair cost LTD. The results are shown in Column E.
2. Allow for the fact that there was a substantial variation in the purchase date and purchase price of the four units in the study by dividing the total cost in Column E by the purchase price given in column B and thereby expressing all costs as a percentage of purchase price. The results are shown in Column F.

3. Estimate the residual market value percentage for each of the units using known values obtained and the curve fitting techniques described in Section 4-4. The results are shown in Column G.
4. Determine the total cost to "buy, operate and sell" each of the four units by deducting Column G from Column F. The results are shown in Column H.
5. Plot columns F and H against hours worked and add the best fit trend lined to produce Figure 9.6. The black data points are a plot of Column F, they show how the total cost to "buy and operate" the units grew as hours worked increased up to, and in some cases beyond, 18,000 hours. The red data points are the plot of Column H. They lie below their corresponding black data point by an amount equal to the estimated residual market value at that time (Column G) The trend lines through the data points show the upward sloping nature of each data set.
6. Insert the green average cost per hour LTD line drawn from the origin with a slope that just touches (forms a tangent with) the red "buy, operate, sell" line. The tangent point defines the optimum ownership period and forms the center of the green zone.
7. Add the age zones relative to the optimum ownership period and complete Figure 9.6 as shown.

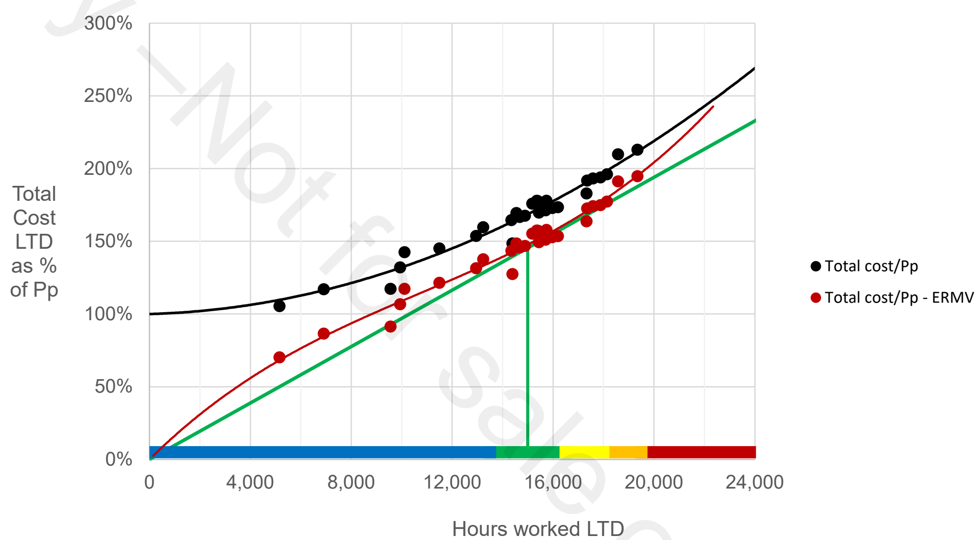


Figure 9.6. *The total cost model used to determine the optimum ownership period using data from four recently sold units.*

Figure 9.6 shows that the optimum ownership period for mid-sized haul trucks working in the company's various applications is at or close to 15,500 hours. It shows that the company did keep the four units "far too long." And that they probably were "tired and no longer worth keeping."

The fact that there was data available beyond the optimum ownership period means that it was not necessary to extrapolate beyond the range of the data and adds confidence to the analysis.

Development of a fleet replacement planning "churn chart" for units currently in the fleet.

A fleet replacement planning "churn chart" was developed for the seven current units in the fleet using the methodology described in Section 9-2.

This required the following 7 steps:

1. List the seven units as shown in Columns A, B and C, Rows 8 to 14.
2. Establish the expected life for the units using the analysis of the previously sold units. This is given in Column D, Rows 8 to 14.
3. Establish the boundaries for the age zones as shown in Row 3.
4. Estimate the likely annual usage for the units in the fleet and enter the values in Column E, Rows 8 to 14.
5. Record the age on each unit and enter the values in Column F, Rows 8 to 14.
6. Perform the calculations needed to produce Columns G to K, Rows 8 to 14.
7. Color code the values in the cells as per the established age zones.

The company went beyond the methodology set out in Section 9-2. By adding Rows 26 to 28.

Row 26 is the total of Rows 8 to 14. It shows that:

- If all units were new, they would have 108,500 hours in "stock"
- The expected annual usage, or "burn rate" for all units totals 12,800 hours per year.
- The total of all the hours on the units is 93,275 at this time with this number growing by 12,800 hours per year.

Row 27 is the "hours in stock" expressed in hours calculated as the 108,500 in D26 minus the hours "burned up" as totaled in Row 26, Columns F to K.

Row 28 is Row 27 divided by the annual "burn rate" to give the hours in stock expressed in years. The current "stock" is very nearly exhausted within a year so the situation is urgent.

The results are shown in Figure 9.7. The fleet appears well balanced but there is no room for complacency.

- MHT 14-1 and 14-2 are clearly candidates for replacement.
- The "burn rate" for the group is nearly the expected life of a single unit and so the replacement plan should allow for about one truck per year.
- Stock in hours or years becomes very small within a year and so replacement decisions cannot be delayed.

	A	B	C	D	E	F	G	H	I	J	K
1				Expected life							
2			90%	↓		110%		120%		130%	
3											
4											
5				Expected life	Annual usage	Hours now	Expected future age in the given number of years ahead				
6							1	2	3	4	5
7	Unit #	Make	Model	Hrs	Hrs/yr	Data					
8	MHT 14-1	Souths	455	15,500	1,700	20,543	22,243	23,943	25,643	27,343	29,043
9	MHT 14-2	Souths	455	15,500	1,700	18,764	20,464	22,164	23,864	25,564	27,264
10	MHT 14-3	Souths	455	15,500	1,700	14,890	16,590	18,290	19,990	21,690	23,390
11	MHT 17-1	Souths	455	15,500	1,700	13,278	14,978	16,678	18,378	20,078	21,778
12	MHT 18-1	Easts	921	15,500	2,000	10,200	12,200	14,200	16,200	18,200	20,200
13	MHT 18-2	Easts	921	15,500	2,000	9,800	11,800	13,800	15,800	17,800	19,800
14	MHT 19-1	Easts	921	15,500	2,000	5,800	7,800	9,800	11,800	13,800	15,800
26			Totals	108,500	12,800	93,275	106,075	118,875	131,675	144,475	157,275
27			Stock Hrs			15,225	2,425	-10,375	-23,175	-35,975	-48,775
28			Stock Yrs			1.19	0.03	-0.10	-0.19	-0.27	-0.34

Figure 9.7. *Fleet replacement planning "churn chart" produced for seven mid-sized haul trucks currently in the fleet.*

Case Study # 9.2 Managing the Optimum Ownership Period.

This case study details a situation where optimum ownership period and fleet age planning concepts were used to establish a proactive fleet age management process for a relatively small group of rubber-tired loaders. All the analysis is based on actual data that has been factored as needed to protect privacy. The calculated values are therefore not representative of what can be expected. The nature of the data and the curves produced are, however, true to the actual situation.

Setting.

The company has recently purchased a group of six loaders all of which, at the time of the study, had worked for less than 5,100 hours. They wish to:

1. Estimate and keep track of what is likely to be the optimum ownership period for units similar to the loaders they have purchased.
2. Set up a process to ensure that they do not" throw good money after bad" by keeping the machines beyond their optimum ownership period.

The company knows that the current age on the machines is very much less than the optimum ownership period and that currently available data will have to be extrapolated into the future to produce the required results.

Data.

Good data is available for the purchase price, hours worked LTD and the cumulative cost of repair parts and labor LTD for the five units in the group. Columns A to D of Figure 9.8 give the data for two of the five units to show what is available.

Analysis of similar units sold on auction in the recent past leads the company to believe that residual market values for loaders of this type can be estimated using the techniques described in Section 4-4 with a value of K = 0.8 and EXP = 0.6.

	A	B	C	D	E
	Data				
1	Unit	Purchase price	Hours worked LTD	Repair Cost LTD	Repair cost per hour
2	MSL 6	$ 334,874	2401	$ 25,415	$ 10.58
3	MSL 6		3009	$ 26,318	$ 8.75
4	MSL 6		3356	$ 28,487	$ 8.49
5	MSL 6		3479	$ 29,209	$ 8.40
6	MSL 6		4154	$ 35,313	$ 8.50
7	MSL 6		4280	$ 38,984	$ 9.11
8	MSL 6		4482	$ 39,917	$ 8.91
9	MSL 6		4869	$ 60,116	$ 12.35
10	MSL 7	$ 340,340	489	$ 1,532	$ 3.13
11	MSL 7		888	$ 2,938	$ 3.31
12	MSL 7		1130	$ 4,355	$ 3.85
13	MSL 7		2021	$ 12,173	$ 6.02
14	MSL 7		3251	$ 18,823	$ 5.79
15	MSL 7		3704	$ 22,468	$ 6.07
16	MSL 7		4573	$ 51,072	$ 11.17
17	MSL 7		5051	$ 75,506	$ 14.95

Figure 9.8. *Data available for two of the five units in the group are given in Columns A to D. Data for the other three units is in the same format.*

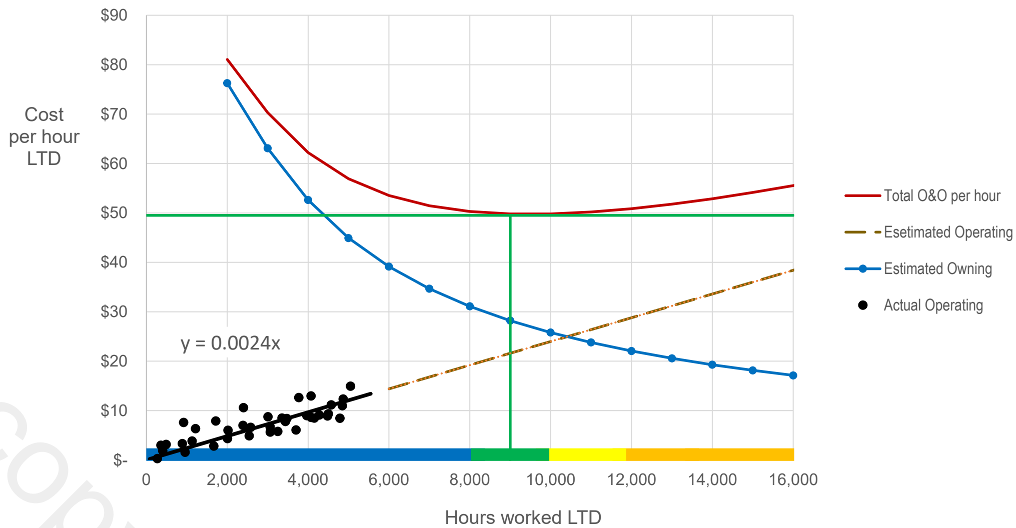


Figure 9.9. *Graph produced after completing the seven steps required to estimate the optimum ownership period for the loaders and track progress towards that point.*

Analysis.

Six steps were needed to complete the analysis and build the graph shown in Figure 9.9. Each will be described in turn.

Step 1.

Use the data to calculate the repair cost per hour LTD for all six loaders, plot the results on the graph and insert a trend line to obtain a good understanding of how repair cost per hour is likely to increase as the units accumulate ever more hours worked LTD. (see Section 5-2).

The calculation is done in Column E of Figure 9.8 and is simply Column D divided by Column C. The results are plotted as the black data points in Figure 9.9. The trend line through the data points is shown as the upward sloping black line in Figure 9.9. The equation of this line (y = 0.0024x) shows that operating costs life to date for the existing machines grew at a rate of $2.40 per hour for every 1,000 hours worked.

Step 2.

Create a "theoretical machine" that exhibits the same cost characteristics as the existing loaders and that can be used to estimate the owning and operating cost per hour for a machine which has:

- The same purchase price as the actual machines.
- The same residual market value characteristics as the actual machines.
- The same growth in repair parts and labor costs as the actual machines.

This is shown in Figure 9.10 which gives

- The assumed hours worked by the theoretical machine in Column A.
- The estimated residual market value % (ERMV%) for the "twin" in Column B calculated using the techniques described in Section 4-4 with K = 0.8 and EXP = 0.6.
- The estimated residual market value for the "twin" in Column C based on the values in column B and an average purchase price of $323,000 as was the case for the five actual machines.
- The estimated owning cost for the "twin" calculated as the purchase price minus the estimated residual value is in Column D and the owning cost per hour is in Column E.

	A	B	C	D	E	F	G
1	Calculated values						
	Assumed hours	ERMV%	RMV	Pp - RMV	Own per hour	Opp per hour	O&O per hour
2	1000	80%	$ 258,400	$ 64,600			
3	2000	53%	$ 170,480	$ 152,520	$ 76.26	$ 4.80	$ 81.06
4	3000	41%	$ 133,666	$ 189,334	$ 63.11	$ 7.20	$ 70.31
5	4000	35%	$ 112,475	$ 210,525	$ 52.63	$ 9.60	$ 62.23
6	5000	30%	$ 98,381	$ 224,619	$ 44.92	$ 12.00	$ 56.92
7	6000	27%	$ 88,186	$ 234,814	$ 39.14	$ 14.40	$ 53.54
8	7000	25%	$ 80,396	$ 242,604	$ 34.66	$ 16.80	$ 51.46
9	8000	23%	$ 74,206	$ 248,794	$ 31.10	$ 19.20	$ 50.30
10	9000	21%	$ 69,143	$ 253,857	$ 28.21	$ 21.60	$ 49.81
11	10000	20%	$ 64,907	$ 258,093	$ 25.81	$ 24.00	$ 49.81
12	11000	19%	$ 61,299	$ 261,701	$ 23.79	$ 26.40	$ 50.19
13	12000	18%	$ 58,181	$ 264,819	$ 22.07	$ 28.80	$ 50.87
14	13000	17%	$ 55,453	$ 267,547	$ 20.58	$ 31.20	$ 51.78
15	14000	16%	$ 53,041	$ 269,959	$ 19.28	$ 33.60	$ 52.88
16	15000	16%	$ 50,891	$ 272,109	$ 18.14	$ 36.00	$ 54.14
17	16000	15%	$ 48,958	$ 274,042	$ 17.13	$ 38.40	$ 55.53
18	17000	15%	$ 47,209	$ 275,791	$ 16.22	$ 40.80	$ 57.02
19	18000	14%	$ 45,617	$ 277,383	$ 15.41	$ 43.20	$ 58.61
20	19000	14%	$ 44,161	$ 278,839	$ 14.68	$ 45.60	$ 60.28
21	20000	13%	$ 42,823	$ 280,177	$ 14.01	$ 48.00	$ 62.01

Figure 9.10. The "theoretical machine" used to estimate the owning and operating cost per hour for a wheel loader with characteristics similar to the actual machines.

Step 3.

Plot the owning cost per hour for the theoretical machine given in Column E as the blue line in Figure 9.9. The line slopes downwards as expected and as described in Chapter 3.

Step 4.

Estimate the operating cost per hour for the theoretical machine by making a reasonable extrapolation of the knowledge gained in Step 1. This is done by adjusting the values in Column F of Figure 9.10 knowing that (i) the values will grow as a straight line and (ii) the values are likely to increase by $2.40 per hour for every 1,000 hours worked (as they have in the past for the existing machines). Record the estimated values as Column F of Figure 9.10. Plot Column F as the brown line in Figure 9.9. The line slopes upwards as a reasonable extrapolation of the data in hand for the five existing machines.

Step 5.

Add Columns E and F to produce Column G – the estimated owning and operating costs for the theoretical machine. Plot the results as the red line in Figure 9.9.

Step 6.

Add the green lines to identify the optimum ownership period and the minimum cost for the theoretical machine.

The optimum cost of $49.81 per hour and the optimum ownership period of 9,000 produced in the six-step process described above can be used as a reasonable estimate for the six loaders currently owned and operated by the company. The current age is well below the optimum ownership period and the company has clearly not reached the point where it is "throwing good money after bad" by keeping the machines too long.

Repeating the process on an annual basis will give better insights into the growth in repair parts and labor costs, refine the estimated optimum ownership period and provide a good early indicator of when units enter the green or yellow zones and become candidates for replacement.

Buy What Burn.

It is not complicated.

When you buy a machine with an estimated ownership period of 15,000 hours, what are you buying.

1. One machine.
2. 15,000 hours of productive capacity.

As you use machines, you are "burning up" that productive capacity.

Your fleet is older to-night than it was this morning.

So, you have to buy what you burn. If you do not, you are living off your seed corn and your fleet is losing its ability to produce work into the future.

If you are running 36 trucks and, if a truck lasts 36 months, then you are "burning up" one truck per month and you had better "buy" one truck per month.

Construction Equipment Economics

Part VI. BE PROACTIVE.

Chapter 16. Implementation.

Early explorers entering the interior of darkest Africa frequently came from the east coast and traveled up the Zambezi River. They could go about 500 miles by canoe until they got to some rapids and could go no further. The Tonga tribesmen who rowed the canoes called these rapids “Kebrabassa”.

The word means “The job is finished”.

Well, that is where we are. We have done the heavy lifting.

- Part I discussed organization structure and the fact that equipment management is a team sport.
- Part II was about knowing your costs and about the importance of a competent equipment costing system.
- Part III discussed fleet average age and the tools needed to maintain a balanced fleet.
- Part IV defined utilization and its impact on fixed cost recovery.
- Part V focused on reliability and the balance between age, cost and reliability.

We can now discuss implementation.

This is where the rubber meets the road and where knowledge brings value.

Success comes not from knowledge but from the implementation of that knowledge.

The three sections of this chapter provide some background and then outline two very different approaches:

SECTION 16-1.

Financial and Operational Metrics.

Companies are very good at collecting data when the transaction in question involves money. Every transaction on a credit card is recorded in detail and processed almost instantaneously because it is a commercial transaction. Transactions that do not have dollar signs attached to them are different. Operational metrics that measure performance are nice to have but, unlike financial metrics, are not required to ensure that transactions proceed as they should and that the books of account are kept "straight". We know to the penny how much was spent to buy the parts required for the repair but we seldom measure how long the machine was down while it was being repaired.

The fact that commercial transactions are recorded in the normal course of business means that accurate and timely cost data is frequently available. This can cause managers to place too much emphasis on cost in reporting and decision making. Yes, cost is critically important and there is no doubt that knowing and managing cost is the price of admission to the construction industry. It must, however, be understood that cost is the end result of the decision-making process and not the cause of the many events that have led to the current situation.

The only way you resolve a cost overrun is to find out why and fix the problem. You cannot reduce repair costs by putting away your check book and not spending on repair parts and labor. You solve the problem by asking the why questions needed to identify the root cause of the spending and improve reliability and availability.

Figure 16.1 shows how the system works. The key financial metric, cost per hour (see Chapter 7) is used to ask the first question, is there a problem with owning cost (see Chapter 4) or is there a problem with operating cost. (see Chapter 5). These metrics measure the end result of everything that has gone before. They are often in place and are calculated on a routine basis by coding invoices, work orders and time cards.

Accounting standards and established business processes cause costs to be processed with the discipline needed to flourish in the commercial world. They measure the end result and act as a fire alarm when things go wrong. They record the situation as it was in the recent past and seldom provide information needed to solve problems and improve performance. (see Section 16-2).

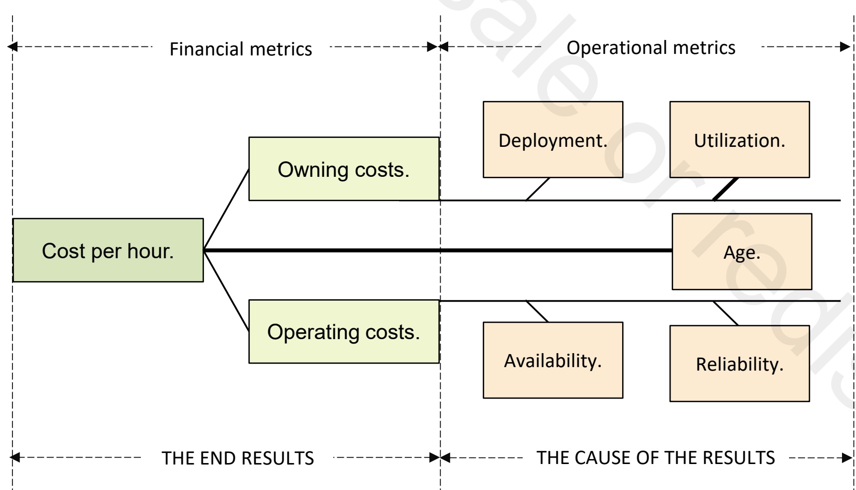


Figure 16.1. Financial and operational metrics. *Financial metrics measure the end result. Operational metrics measure what is happening in the field on a day-to-day basis.*

The operational metrics given on the right-hand side of Figure 16.1 provide deeper insights. They measure how the fleet is performing and are essential for the root cause analysis needed to ask tough questions, solve day to day problems and lower cost.

Operational metrics do not enjoy the level of standardization and acceptance that the accounting profession has brought to financial metrics and, above all, the required data is seldom part of a commercial transaction. The time a technician works on a machine is recorded with precision because it is required for payroll; the time the machine is down or awaiting repair is seldom recorded despite the fact that availability is a critically important operational metric.

Figure 16.1 shows five important operational metrics that can be used to measure machine performance. Two, deployment and utilization, affect owning costs and two, reliability and availability affect operating cost. The fifth, age, is the key determinant of the optimum ownership period and summarizes the whole situation.

All the operational metrics have been discussed in detail in Chapters 8, 12 and 15. Suffice to say here that:

Deployment. Deployment prompts questions relating to the size and composition of the fleet, the wisdom of the original acquisition decision and the wisdom of disposing of the machine sooner rather than later. It is impossible to recover the owning cost on an un-deployed unit and deployment is thus an excellent lead indicator of owning cost recovery. You absolutely do not want your money invested in the bank of un-deployed equipment. (see Section 12-2).

Utilization. Utilization is, in the vast majority of cases, a function of job site management. It should prompt questions relating to job planning as well as the means, methods, sequence and flow of operations. Utilization is also a lead indicator of owning cost recovery and is a critical factor in the owning cost per hour calculation. (see Section 13-1).

Reliability. Section 15-1 argued that reliability measured the effectiveness of the maintenance enterprise in preventing unplanned delays or disruptions to production. Every down event is a cost event and reliability is an excellent lead indicator of repair parts and labor cost per hour. It is simple common sense; reliable machines are cheaper to run than machines that break down frequently.

Availability. Availability differs from reliability in that it measures the duration of down time as opposed to the frequency of down events. Like reliability, it is a key driver and lead indicator of operating cost – the longer the machine is down, the more likely you will spend on repair parts and labor and the fewer working hours you have to recover the costs. (see Section 12-2).

Age. Section 8-1-detailed the methodology used to estimate the optimum ownership period or "sweet spot" where the sum of hourly owning and hourly operating costs reach a minimum because the machine has worked long enough to reduce owning costs but not long enough to experience unnecessarily high operating costs. Age is thus a clear lead indicator of total cost per hour and plays a dominant role in the repair rebuild replace decision.

The clear distinction between financial metrics (the end results) and operational metrics (the cause of the results) set out in Figure 16.1 makes it possible to define the following two very important differences in style regarding the analysis and management of equipment costs:

I. Reactive cost analysis.

   The reactive approach uses financial (cost) metrics as a "fire alarm" to signal the need for corrective action and give some guidance as to the forensic analysis that must be performed to find the root cause of the problem and take the action needed to improve performance. An example of how this is done and a structured process for arriving at a possible course of action is given in Section 16-2.

II. Proactive cost analysis.

   The proactive approach is based on the premise that cost is defined by performance and that selected operational metrics can be used as lead indicators to attack the causes of cost and reduce waste to a minimum. Section 16-3 describes how utilization, reliability and age can be used to get ahead of the game and manage rather than respond to adverse trends in performance.

The financial metrics – owning cost and operating cost per hour do little more than trigger required action. Operational metrics, deployment, utilization, reliability, availability and age help tell you why and direct your action to the right place. Success is less about knowing your cost than it is about having the operational metrics needed to be proactive, ask the right questions, find root causes and improve performance.

SECTION 16-2.

Reactive Cost Analysis.

Reactive cost analysis is triggered by the fact that present costs are, for some reason or another, higher than budgeted and that something needs to be done to:

First: discover why.

Second, do something about it.

Reactive cost analysis is a backward-looking process. Information used to initiate action is based on past results and the assumption is that the future will look a lot like the past. This is very risky when it comes to equipment. The fact that a machine ran cheaply last year does not mean that it will run cheaply next year. Perhaps it will be exactly the opposite.

You do not improve cost by agonizing over the past. You improve cost by getting to the root cause of the problem and by taking action. You must look to the future. It is no good crying over spilled milk. Find out where and why the milk was spilled and do what is required to stop it from happening again.

Budgets and cost reports help to set rates and balance the equipment account. (see Chapter 7). They also identify areas that require attention and should provide the information required to take action based on fact rather than intuition. Deciding what to do is, in most cases, more art than science. There is frequently no “right answer” but there certainly are some principles involved.

Figure 16.2 sets out a logical approach and shows how a knowledge of cost can be combined with other information to arrive at a number of possible action steps. Let’s go through Figure 16.2 from top to bottom and from left to right.

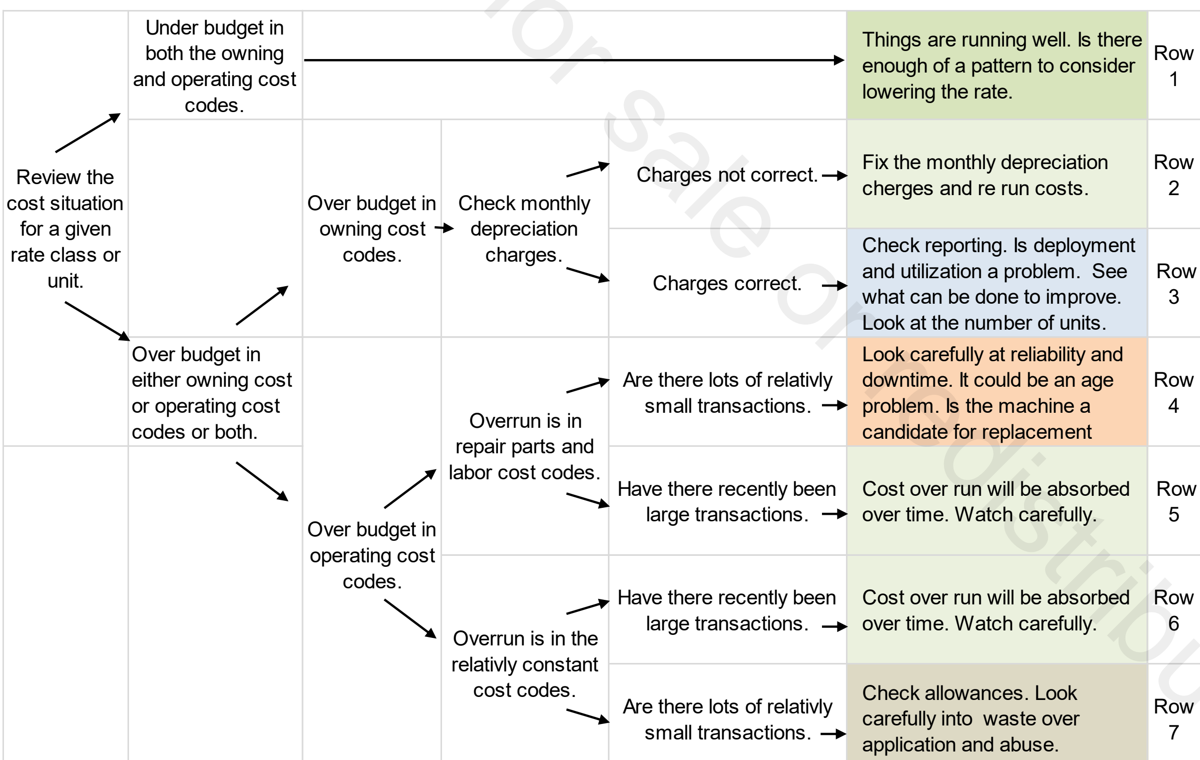


Figure 16.2. *A logical process to perform reactive cost analysis and use a knowledge of cost to define a number of possible action steps.*

The first thing to do is to use the process set out in Section 7-4 to review the cost situation for a given rate class (machines that are essentially the same and that share the same internal charge out rate) or unit. If the rate class or units in the class are under budget with regard to both the owning cost and the operating cost codes then the top line takes you to Row 1. Things are running well. A trend or pattern is sufficient reason to consider lowering the rate and setting new cost targets for the rate class.

If the class or units in the class are over budget then the first thing to do is to find out if the overrun is in the owning cost codes, (Chapter 4) or the operating cost codes (Chapter 5) or both. This is a critical first step as the action required to rectify the situation is entirely dependent on whether the root cause lies in the owning cost codes or the operating cost codes.

If the class or a unit in the class is over budget in the owning cost codes then action must be focused on fixed cost recovery. The first thing to do is to check if the monthly depreciation charges have been correctly calculated in accordance with company policy and correctly charged to the unit or group. If not, then the incorrect charges need to be fixed and the costs re-run (Row 2). If the charges are correct then the overrun in the budget can only be due to the fact that utilization is low (Chapter 13) and the machine(s) have not worked or have not been reported as working for the anticipated number of hours, days or weeks. This ends at Row 3 with three possible steps, (1) check whether the utilization reporting is correct, (2) see what can be done to improve deployment and utilization, (3) look at the possibility of reducing the number of units in the rate class to better fit current workloads. In every case, deployment and utilization as defined in Chapter 12 are the key metrics.

If the problem lies in the operating cost codes (Chapter 5) it means that the class or units in the class are over budget when it comes to recovering the variable costs associated with cost codes like wear parts, tires/tracks, preventive and condition-based maintenance and repair parts and labor. There are two possibilities. First, the overrun is in the repair parts and labor codes (Section 5-2) which increase with the age or, second, the overrun is in the relatively constant codes (Section 5-1).

If the problem lies in the repair parts and labor codes then, again, there are two possible reasons. Either the machine is experiencing a lot of relatively small transactions with costs occurring frequently. The number of work orders and the number of RED events per 1,000 are high. This ends at Row 4 and a need to look seriously at reliability (Chapter 15). Check if the repair work is done properly or if there is a lot of repair rework on the same machine and the same component. Is the machine a candidate for replacement? (Chapter 9).

Budget overrun situations can and do occur in the repair parts and labor codes when the machine has recently undergone a major repair and has not as yet accumulated the hours needed to bring hourly costs back into line. If this is the case, then the diagram ends in Row 5. The machine needs to be watched carefully.

If the problem lies in the relatively constant categories and codes then there are again two possibilities. First, there have recently been large transactions due to the fact that the undercarriage or tires have been replaced. This flows to Row 6 and the need to wait to accumulate the hours required to bring costs into line. Second, there are all kinds of small expensive transactions in the constant codes. This ends in Row 7. This is not a good situation and requires a careful review of waste, over application and abuse.

Figure 16.2 shows how a knowledge of equipment costs can be used to identify seven endpoints that detail what can be done to improve performance. Row 1 enables this knowledge to be used to lower rates and be more competitive. Row 2 is a simple administrative check so it should not be a problem. Rows 5 and 6 require patience – it is necessary to wait it out and absorb the impacts of large infrequent expenditures. Hopefully, the decisions to do the work were good and that costs will, with time, return to normal.

Rows 3, 4 and 7 are the tricky ones. Row 7 requires a detailed disciplined approach to day-to-day cost management. Watch for over-application and eliminate waste.

Rows 3 and 4 are where the problems lie and where most of the money is spent. There is no short cut and success depends on three things. First, a detailed knowledge of cost to analyze the situation and get to the root cause. Second, a knowledge of deployment and utilization to take action and fix the problems in row 3. Third, a knowledge of reliability and downtime to analyze problems, take action and fix problems in row 4.

Reactive cost analysis can and does work but remember that cost is a symptom. You fix problems and improve performance by determining the root cause and taking action.

SECTION 16-3.

Be Proactive – Attack the Causes of Cost.

The basic premise is that

Cost is defined by performance and can be reduced by identifying and managing a relatively small number of lead indicators.

The various sections in the book have identified and detailed three lead indicators of equipment cost. Experience and success in the industry have led to the firm belief that a laser focus on these three causes of equipment costs will improve performance and give the confidence required to know that costs – whatever they may be – are as competitive as possible.

AGE.

Chapter 8 identified age as a lead indicator of owning and operating cost per hour. Figure 16.3 repeats Figure 8.8 to show how the life to date cost per hour increases with age and confirms that the marginal cost of every hour a machine spends in the yellow, orange or red zones (age zones beyond the optimum ownership period) is more expensive than the average cost per hour of all previous hours worked, LTD.

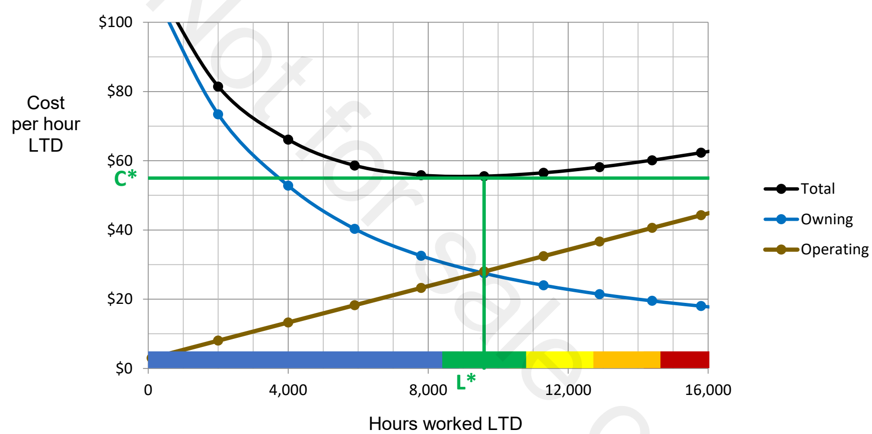


Figure 16.3. *Every hour a machine spends in the yellow, orange or red zones is more expensive than the average cost of all previous hours. Age is a lead indicator of cost per hour.*

Machines do not last forever and you absolutely have to keep the average age of your fleet round the sweet spot where the sum of owning and operating cost reaches a minimum. We all know that machines that are beyond their optimum ownership period are likely to have high costs and that next year will be more expensive than the average of all prior years. You also do not want the average age of your fleet to be too young as this will cause you to experience high depreciation and finance costs and will create a false sense of security in your operating cost budget. It is a delicate balance that requires constant vigilance.

Again, four things to do. (1) Establish reasonable expectations for the optimum ownership period and know where each machine in your fleet is relative to the target lives you have established. (2) Plan ahead. If your benchmark life is 13,000 hours then it should not come as a big surprise when a 10,000-hour machine becomes a candidate for replacement in two years' time. (3) Use a well-planned age management and fleet replacement process as a way to constantly resize and reconfigure your fleet. Every replacement is an opportunity to do something new and different. (4) Know that it is possible, and in some cases very necessary, to delay replacement but you cannot, in the long run, deny replacement. It is hard work and very expensive to wind back the clock on an old fleet.

UTILIZATION.

Chapter 13 identified utilization as a lead indicator of owning cost per hour. Figure 16.4 repeats Figure 13.5 to show the way owning cost per hour varies with utilization.

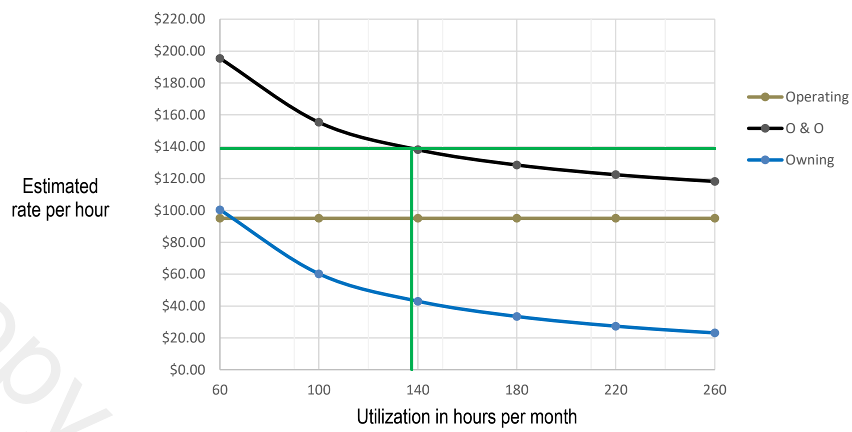


Figure 16.4. *Owning cost per hour decreases with increasing utilization. Utilization is a lead indicator of owning cost per hour.*

Successful implementation requires a laser focus on utilization. Low utilization is a root cause and early warning sign of overruns in hourly owning costs. If the fixed costs of ownership come to $6,000 per month and you have set an owning cost budget of $40 per hour based on 150 hours of utilization per month then it should not come as a big surprise that you will be over budget by $20 per hour if the machine only works 100 hours.

So, what do you need to do? Be on top of at least the following four things: (1) Know and understand the two components of utilization: deployment – the number of weeks a machine spends on site - and field utilization – the time the machine works when it is on site. (2) Set good benchmarks for both deployment and field utilization. Is it reasonable to expect that the machine will be on site for 40 weeks in the year, is it reasonable to expect that the machine will work 35 hours per week when it is on site? (3) Use these benchmarks in your owning cost rate calculation and know that you will not achieve this rate if you do not achieve your utilization benchmarks. (4) Measure and manage both deployment and utilization. Be ruthless when it comes to under deployed machines. There is no reason to provide a home in your fleet for "in case we need them" machines: size your fleet for the average of times not the best of times - there is always the possibility of renting.

RELIABILITY.

Chapter 15 identified reliability as a lead indicator of operating cost per hour. Figure 16.5 repeats Figure 15.9 to show the balance between age, cost and reliability and confirm that managing reliability – the frequency of RED events per 1,000 hours - is critical to managing repair parts and labor cost per hour.

Successful implementation requires that reliability is measured and managed. Increasing frequency of down events is a root cause and early warning sign of increases in repair parts and labor cost. Know how often a machine experiences a reported emergency down event (RED event) and disrupts production due to mechanical failure. Each RED event has two impacts. The planning and productivity on the job are impacted and, spending on repair parts and labor increases due to another upward spurt.

So, what do you need to do to attack the causes of increasing repair parts and labor cost? Again, four things. (1) Train, motivate and lead your operators. Make sure that they are the best in the business. Operators are your first line of defense against RED events. (2) Make sure that your field technicians are knowledgeable and

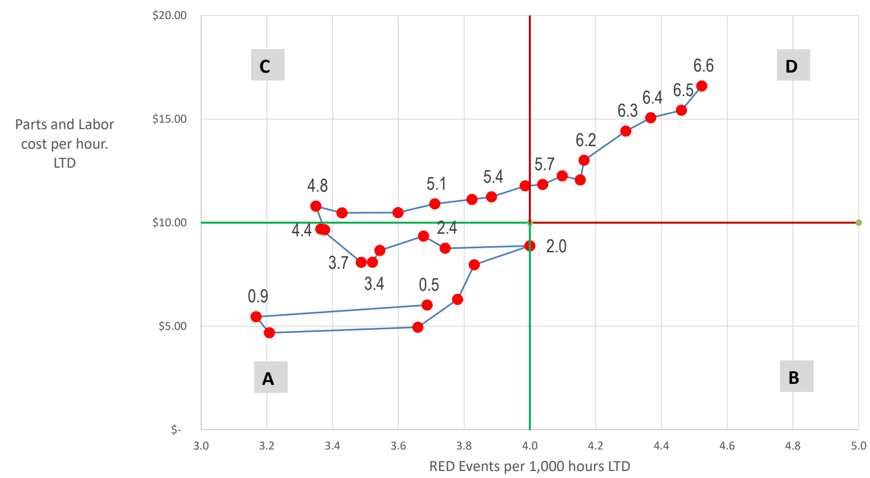


Figure 16.5. *Repair parts and labor per hour increases as reliability decreases. Reliability is a lead indicator of operating cost per hour.*

trained on the latest equipment. Make sure that they have the time and resources needed to not only repair the machine but also to eliminate the cause of the original breakdown. You cannot afford to let Red events repeat. (3) Maintain without compromise. Have a good system to observe, measure and report on the condition of your machines. A worn hose or a cut tire are a warning sign of a pending RED event. Backlog reported problems and get the required work done before the machine fails and costs go through the roof. (4) Record and report RED events. Measure your ability to be proactive and prevent failures. Know that a dollar spent on prevention is worth many more dollars spent on repair. Believe that it is possible to dramatically reduce the frequency of RED events.

AGE, UTILIZATION and RELIABILITY are causes of cost.

Proactive management in these areas can prevent problems and minimize the forensic analysis needed to uncover adverse cost trends and attempt to resolve problems of the past. We know that bad utilization causes owning cost per hour to exceed budget; that bad reliability causes repair parts and labor costs to increase and that old machines have owning and operating costs above the minimum.

Use this knowledge, be proactive rather than reactive and avoid rather than solve problems.

Yes, cost reports are important and, yes, they guide our decisions in complex difficult to see situations. But let's get utilization, reliability and age right, manage them with skill, care and attention on a daily basis and then worry about cost.

Cost.

Part II KNOW YOUR COST.

Chapters 3 to 7.

Reactive cost analysis.

A cost reports act as a "fire alarm" to signal the need for corrective action and give some guidance on to required action.

Effective action will look into:

1. Utilization.
2. Reliability.
3. Fleet average age.

Proactive cost analysis.

Cost is defined by performance. Selected lead indicators are used to attack the causes of cost and reduce cost to a minimum.

Lead indicators are used to manage adverse trends.

1. Utilization points to owning cost.
2. Reliability points to operating cost.
3. Age points to possible deterioration in both.

Age.

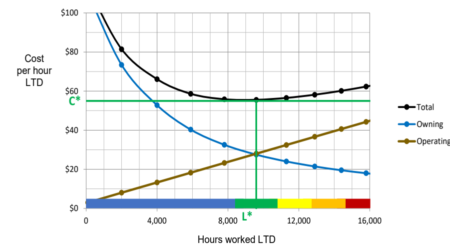
PART III MANAGE FLEET AVERAGE AGE.

Chapters 8 to 11.

The optimum ownership period or "sweet spot" occurs when the sum of hourly owning and hourly operating costs reach a minimum

Age is a lead indicator of total cost per hour

Every hour that a machine spends in the yellow, orange or red age zones is more expensive than all the average cost of all the hours worked life to date.



Utilization.

PART IV ENSURE UTILIZATION.

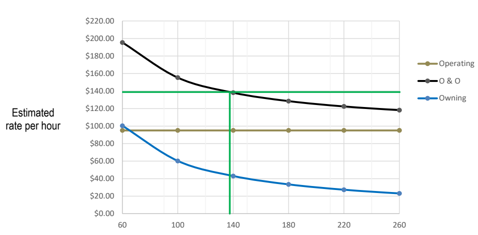
Chapters 12 and 13.

The fixed costs of ownership are recovered by putting the asset to work and producing completed construction.

Utilization is a key determinant of owning cost per hour.

Utilization is a lead indicator of owning cost recovery and owning cost per hour.

Low utilization will cause owning costs to be under recovered.



Reliability

PART V MAINTAIN RELIABILITY.

Chapters 14 and 15.

Every down event is a cost event. Repair parts and labor cost per hour increase exponentially as the machine ages because both the frequency and the magnitude of "spurts" in repair expenditure increase.

Reliability is a lead indicator of operating cost per hour.

Deteriorating reliability will cause operating costs to increase.