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PURDUE

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**PROFITABILITY VERSUS CONSTRUCTION
EQUIPMENT MAINTENANCE**

An Independent Research Study

Submitted to the Faculty

of

Purdue University

by

Craig A. Clutts

In Partial Fulfillment of the

Requirements for the Degree

of

Masters of Science in Engineering

May 2010



Purdue University
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Engineering and Management
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West Lafayette, Indiana 47907-2051

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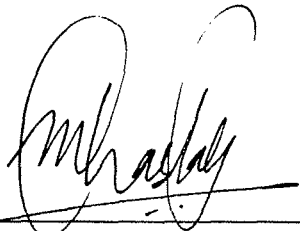
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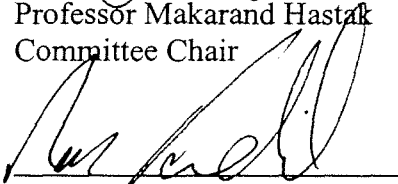
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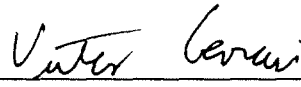
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DEDICATION

To God, family, country. Accomplished by God's blessings and for His glory. Supported by family: David and Donna Clutts (parents), Alicia Clutts (wife), C.T. and Bella (children) and many others. Sent by the United States Naval Civil Engineer Corps.

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ABSTRACT

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Construction equipment is a high cost of capital investment necessary for the successful existence of a private construction company and essential to the mission success of the Naval Construction Force (NCF). The highest impact cost factor other than the initial purchase investment is the expenses related to maintenance and repair. As the equipment ages, the ownership costs decrease and the operating expenses increase as the maintenance and repairs requirements grow. Both private and public entities desire to manage this high dollar investment for optimization of a perceived profit.

This project recommends a decision support model that can be used by private and public entities alike to determine the best fit acquisition method between rent-lease-buy and guidance for profitability optimization. Methods of life cycle cost estimating and decision methods were researched and compared. Data was acquired from equipment rental companies, private construction companies and the NCF. This data was analyzed to select the appropriate decision factors and develop the Construction Equipment Profitability Optimization Model (CEPOM). This model can be implemented by small private construction companies with minimal overhead and a small charging base, and a public entity such as the NCF.

CHAPTER 1. INTRODUCTION

The construction industry is fragmented and consists of a high number of small firms scattered throughout the country with different specialties and capabilities. Many of these companies are individual or family operated corporations that have to struggle to establish a foothold and maybe for continuity of operations as well. For those companies that require construction equipment in execution, the investment tied up in long-term equipment carries a high risk that must be managed. It is this concern that will be addressed in this Independent Research Study. This research will evaluate whether a small construction company is better off financially in renting, leasing or purchasing construction equipment.

Due to the nature of the construction industry, these small companies also need a tool or set of parameters to use in budgeting equipment expenses for the year and for each job being bid. Therefore, this research will explore the best methods in estimating the maintenance costs for construction equipment, with respect to two separate categories: Preventive Maintenance and Corrective Maintenance (Repairs). This research will cover only small size private construction companies and the Naval Construction Force (NCF).

Definition of a Small Company: At this point, it is important to define a small, private construction company. This is the focus area for the study because of the significant impact of high dollar investments on smaller entities. A small company is one that has a limited base for financing heavy overhead related to a full maintenance staff or an equipment management division. A small company may range from a single, self-employed individual up to 19 personnel with a handful of operators and low annual revenues (typically less than \$1 million/year). This was developed by comparing census data, Small Business Administration (SBA) and European Commission documentation (European Commission 2005, SBA 2010, U.S. Census Bureau 2008). The following table

shows the resulted class sizes related to the category of construction and subcategory of heavy/civil engineering construction.

Table 1-1 Company Size Classification Compiled from Several Resources

COMPANY SIZE CLASSIFICATION	NUMBER OF PERSONNEL EMPLOYED
Micro	0-4
Small	5-19
Medium	20-99
Large	100 and greater

Since the author of this report is a Civil Engineer Corps Officer in the United States Navy, there is a desire and obligation to apply this research to the occupation of the naval community. To do this, it is the intention to compare the budgeting methods and equipment management principles of the private sector to the budget allocation and construction equipment aging within the Seabee world of Civil Engineer Support Equipment (CESE). The most significant difference financially is that of an assigned budget by the U.S. Navy and Congress. The expenditures remain the same and lead to an interesting link between budgeting and fleet aging. The money within the Naval Construction Forces budget for CESE that is not expended on Preventive Maintenance or Corrective Maintenance (PM/CM) is then allowed to be used for purchasing new equipment.

Previous NCF studies have revealed the average age of NCF existing CESE to be around 20 years old which is much higher than the 9 years old average within the private sector. This higher average age results in a higher cost of maintenance. Therefore, the NCF is striving to reduce the average age to a better fit. The age is not expected to be the same as the private sector because of the CESE life cycle including storage time. For a private sector company, it is desired that assets not be idle but continuously paying for themselves and making additional value. Within the Navy, equipment is rotated from use, to storage, to use in order to ensure a proper amount of operational readiness is maintained. This will affect the evaluation by not allowing a direct correlation of

equipment life cycles, possibly requiring a different measure of use hours or life in years than conventional for the private sector.

1.1. Objectives

There are two sets of objectives for this research. The first set of objectives deal with construction equipment management for a small construction company in the private sector. The second set of objectives concern the efficient management of the Navy budget regarding maintenance and acquisition of CESE.

1.1.1. Small, Private Construction Company

- Determine the best evaluation method for a small construction company to use in deciding whether to rent, lease or purchase construction equipment. Does this change with the size of the company?
- Determine the best method to use in estimating Preventive Maintenance and Corrective Maintenance costs. Should it be measured by % of purchase price, depreciation, expected life, warranty period or operating hours?
- Determine the best method to use in deciding whether to replace a piece of construction equipment. Should it be measured by % of purchase price, depreciation, expected life, warranty period or operating hours?
- Determine the best method to use in estimating construction equipment cost for a bid.
- Determine whether the stated life expectancy by the equipment manufacturer is true for operational use, warranty purposes, or supplier job security.

1.1.2. Naval Construction Force

- Determine how best to correlate construction equipment usage and expense data from private sector to the Navy CESE life cycle and budget.

- Determine the best method in estimating a reasonable annual maintenance expense for CESE.
- Determine the best average age goal for CESE to allow reliability while maintaining appropriate proportion of maintenance and new acquisition mixture within budget.
- Determine what affect long-term storage has on the financial decisions to be made.

1.2. Scope

The focus of this research was narrowed to the two largest construction equipment decisions faced by both the private and public sectors. The first decision is identifying the best acquisition method for obtaining the needed assets. The second decision is how to optimize the return or execution of that equipment throughout its life. These two areas outline the scope of this research as follows:

- Recommend or develop the best process to select a construction equipment acquisition method.
- Recommend how to optimize on profitability related to the acquired equipment.
- Ensure the recommendations can be applied to both private and public entities.

1.3. Profitability Defined

1.3.1. Private

Common within the private sector is the essential livelihood of the company by profit making. If the company cannot recover its costs and create value, the entity will close due to either no or negative rate of return. Profitability in a capitalist economy is not as simple as raising the charged rate to receive more revenues because of the existing and inherent desire of competition. It is the goal of this study to recommend measures related to construction equipment acquisition and maintenance for optimization of profit.

1.3.2. Public (Government)

Profitability for a public entity is much different. Profitability is recognized as the optimization of the given budget to fulfill all mission funding requirements. The different pools of money and their restrictions are not part of this study. So, in general, it will be assumed that a budget exists for funding the costs related to maintaining and acquiring the equipment. Within this given budget, the older the equipment, the higher the percentage of funding is spent on maintenance and less on new acquisitions. This creates a cycle of diminished returns. There is likely a fluctuating breaking point that optimizes this cycle within a given budget, but it is the goal of this study to recommend an estimated period. Simplified, profitability for the NCF is realized when less of the budget is spent on maintenance and more funding is available to renew the fleet providing higher probability of mission success through optimized equipment readiness.

1.4. Report Format

This report is comprised of four chapters. Chapter 1 has outlined the need for this research, the objectives and the scope. Chapter 2 consists of the background information compiled mostly from literature review on the given topic. Chapter 3 describes the methodology used to develop the recommended decision support tool. It includes the factors of focus related to the construction equipment life cycle, the data acquired and its analysis. Finally, chapter 4 presents the developed model, describes its applicable use and discusses an example for both the private and public sector.

CHAPTER 2. LITERATURE REVIEW

Many publications have been written on the subject of construction equipment management. Most of these references cover areas of productivity, equipment selection, equipment use, and estimating costs. Within the areas significant to this study, the common topics are that of quantitative costs and qualitative considerations for decision making.

2.1. Life Cycle Costs

Construction equipment costs are typically established through hourly rate calculations. This hourly rate coupled with a productivity estimate provides planners and estimators with enough information to develop a unit cost for bidding. In determining the hourly rates, a periodic cost is divided by the periodic use in hours. The accuracy of the rate depends on the period considered and the data used. Another way of looking at these quantities is that of life cycle costs (LCC).

2.1.1. Importance

Life cycle costing has been a common perception for facility maintenance, and is beginning to be seen in many more recent journal articles related to construction equipment (Bennett 2008, Staff 2009, Louisiana Machinery 2010). However, most textbooks tend to the hourly and unit cost calculations. The importance of a total LCC is the normalizing of all related expenses for a more precise comparison of alternatives. It involves identifying and quantifying all costs related to the entire life of a piece of equipment instead of a specified shorter period such as monthly rentals suggest. LCC is also helpful in recognizing the inherent difference related between the private sector and

NCF CESE and in projecting a third economic life often ignored and explained in a later section.

2.1.2. Developing Rates

The hourly and unit cost rates are calculated based on a summation of four areas of costs: Ownership, Operating, Overhead and Profit. In this study, Ownership and Operating costs are the focus as overhead and profit costs are unique to the entity and will be common between the different acquisition methods.

The costs of ownership exist when equipment is purchased and accrues whether the equipment is operated or not. This cost builds up when a piece of equipment sits idle. The operating costs only accrue when the piece is used. Each of these has several common factors for calculating and is explained further below.

The hourly rate is figured by dividing the summation of annualized costs by the hours of operation throughout that year. Most references use an average total annual hours of use. This study will apply annual use from collection of data from both the private industry and that of the NCF.

2.1.3. Ownership Costs

Ownership costs are all expenses related to the specific equipment whether it is being operated or sitting idle. These include costs related to the purchase, the insuring, the licensure, applicable taxes, storage and security. Purchasing costs are captured through depreciation and interest or investment impacts. Ownership costs are typically figured into an hourly rate that will be passed on to project or overhead accounts.

2.1.3.1. Depreciation

The largest portion of purchase costs are accounted for through depreciation. Depreciating is the accountant's measure of reduced value of the used asset (Ross et al. 2008). It establishes the estimated book value of the equipment, decreasing over time and

requiring payback by revenues created through the equipment's employment. Caterpillar (2010) labels depreciation as the "recovery value". It is an accounting method which tracks the current worth of the equipment and also to recover the purchase cost from the internally/externally charged rate.

2.1.3.1.1. Cost Establishing A Rate

There are five main methods of determining depreciation: Straight-Line, Sum-of-Years or Sum-of-Digits, Declining Balance which could have a multiple factor, Average Annual Investment and the Internal Revenue Service (IRS) Modified Accelerated Cost Recovery System (MACRS). The first three are standard and computations remain similar.

The Average Annual Investment is calculated differently throughout the industry. Schaufelberger (1999) follows suit with the finance and accounting sector calculating the annual cost based on the original purchase and install price annualized by the time value of money (TVM) (Ross, et al. 2008). Day and Benjamin (1973) calculate this value using the useful life in years as seen in the following formula, where u is useful life in years and c is initial cost:

$$AvgAnInvest = \frac{1}{2} \left(\frac{u+1}{u} \right) c \quad \text{Eq. 2-1}$$

Peurifoy and Schexnayder's (2002) computation adds the factor of a salvage value (S) as shown, using P as the initial price, and n as the useful life in years:

$$AvgAnInvest = \frac{P(n+1) + S(n-1)}{2n} \quad \text{Eq. 2-2}$$

If the salvage value is set to zero, these two calculations are equivalent.

Common practice throughout the industry and reported by Caterpillar (2010) and Government Fleet (2009) is to use the straight-line method for calculating rates based on the purchase price reduced by the cost of tires (to be included in operating costs) and the projected salvage value.

2.1.3.1.2. Salvage Value

Determining a salvage value for a piece of equipment tends to vary more than the depreciation techniques used. Peurifoy and Schexnayder (2002) refer to four different charts used to calculate salvage value as a percentage of the initial purchase price dependent upon the age of the equipment. Each of the four charts represents a different

life cycle classification. The first chart applies to machines that wear out from use and unlikely have secondary uses. The second chart relates to special purpose equipment that retains their value well if properly maintained. The third chart depicts a situation where new product prices escalate and the equipment value may increase before declining. The fourth chart may be used for estimating the value of equipment that has more than one useful life. These charts are located in Appendix Figure A-1.

In a recent thesis, a detailed study of agricultural and forestry equipment values was conducted through analysis of recorded auction prices and manufacturer publications. Lucko and Vorster (2003) then formulated a multi-linear regression to estimate the salvage value based on factors related to the region or location, the manufacturer and the condition rating. U.S. Army Corps of Engineers (USACE) refers to the use of the Green Guide last published by Penton Media, Inc. This book is a compilation of most heavy equipment auction results in North America throughout the year. Interestingly, the Caterpillar affiliated Louisiana Machinery offers customers a contracted, therefore guaranteed, salvage value at the time of purchase.

No common salvage determination method was found; however, the USACE (2007) technical publication is often referenced. This leads to an expectation that those with access to the Green Guide Auction Report would feel most comfortable with its referenced data. This makes sense as it directly reports what the current market values are from actual sales. The recommended value for salvage is to use zero unless making an early decision to replace the equipment before the end of its useful life. This allows the recovery of all capital spent on the initial purchase and considers the future salvage value as negligible.

2.1.3.1.3. Tax Benefit (MACRS)

Most companies run two separate depreciation accounts on the same piece of equipment: one method for taxes purposes, and the second for accounting and charging rates to activities. The benefit of the MACRS introduced by the Tax Reform Act of 1986 (TRA-86) is the forward loaded tax benefit. In the year of purchasing equipment, it is not realized as 100% expense reducing the tax basis for the year. The value is transferred from a cash or liability to a long-term asset. MACRS allows the realized expense to be

accelerated from a typical straight-line or other method. Its design is to allow the book value to reflect the expected market value based on a property class applying percentages each year to a life expectancy for the class. Construction assets are considered property class 15.00 with a life expectancy of 5 years under the General Depreciation System (GDS). MACRS recognizes that not all purchases will happen on the first day of the year and accounts for this by applying only a half year to the first and last year of depreciation, resulting in a 6-year depreciation cycle for construction assets (Rosenhagen 2010).

This tax benefit is calculated by applying the company's tax rate to the depreciation amount for that year. This number is recognized as a factor of consideration for the rent-lease-buy decision but not included in life cycle costing for rate calculations. In considering profitability, it is best for the company to use the required MACRS applied to the purchase price reduced by the tires cost and ignoring any expected salvage value. This maximizes the first year expenses and tax benefit by including tire purchase. It also maximizes net present value (NPV) of the life cycle costs due to the TVM effects.

2.1.3.1.4. Overhaul

One of the major maintenance costs for a piece of equipment is any overhauls conducted. This cost may be categorized differently from separate companies. Day and Benjamin (1973) consider this as an ownership cost due to the large capital investment which may be applied to raise the book value of the equipment and result in further depreciation. Stewart (2006), Nunnally (2007), and Government Fleet (2009) do not distinguish overhauls separately from the maintenance piece of operating costs. All three do relate overhaul costs as to the replacement decision discussed later.

Equipment Watch (2010) further explains that companies often include overhaul contingencies in the charged rate up front enabling the build-up of funds for overhaul costs such as replacements of engines, transmissions, pumps, or undercarriages. A complete overhaul would instead be applied as described by Day and Benjamin (1973).

The benefit of formulating rates to create an escrow for major repairs is desirable to minimize delay in conducting repairs and maximizing availability. Major overhauls allowing depreciation may also permit financing alternatives releasing the use of

company capital. It is best to account for expected major repairs and leave overhaul calculations to those related to Replacement decisions.

2.1.3.2. Interest

Interest cost to the ownership of a piece of equipment is also referred to as the investment cost. Though Day and Benjamin (1973) stated that, whether internal funding or external finance funding is used, the cost of interest should be accounted for in rates calculations, Peurifoy and Schexnayder (2002) did not address the matter. In every case of inclusion, the factor is calculated by a percentage applied to the average value of the equipment (for year or life).

Nunnally (2007) introduced the application of the bank rate if used or the company's desired rate of return if internally funded. Day and Benjamin (1973) gave a range of 5-15%. Schaufelberger (1999) merely added the percentage to the minimum acceptable rate of return (MARR) for all non-depreciation ownership costs. This is similar to USACE (2007) application of the facility capital cost of money (FCCM) and depreciation for their costs. Karzon (1994) selected a unique route of applying the Presidential Budget rate or cost of capital (COC) of Treasury Securities @ 10yr maturity equal to 6.9% at the time. Due to the reduced time within the analysis, Karzon (1994) adjusted the 6.9% and used 6%.

In the author's experience from government contracting, 10% profit was found to be common. The use of the profit margin as a correlating company rate of return is valid. Applying the bank charged interest rate is appropriate if externally financed. To maximize profitability and balance risk of rate levels if internally financed, it is best to apply the closest related government security as Karzon (1994) identified. If the 10-yr maturity Treasury Security is 6.9%, this is the most confident cost of capital investment due to the guaranteed return expected from government backed investments.

2.1.3.3. Insurance

Throughout the industry, it is common to apply the insurance rate directly to the average annual investment for calculating hourly rates. Very little discussion is made on the subject of insurance as each company will be charged a specific rate due to the perceived risk by the surety. Day and Benjamin (1973) and Peurifoy and Schexnayder (2002) both estimated the rate at a range of 1-3%. Therefore, within this study, the average rate of 2% will be used. Each company should analyze this cost by the rate assigned from the partnered surety.

2.1.3.4. Taxes and Licenses

Similar to the standard of applying the insurance costs for rate development, the industry applies a percentage to the average annual investment. Day and Benjamin (1973) estimated this cost at a rate of 1-5%. This rate accounts for all license and property tax requirements from federal, state and local regulations. Within this study, the average value of 3% will be used as the cost factor. Each company should be able to better estimate these costs specific to their locale from research or historical reference.

2.1.3.5. Storage

Ownership costs related specifically to the equipment may go beyond those of purchasing and applicable fees discussed. Depending upon the size of the fleet and company policy, costs related to storage may be incurred. These can include rental expenses for storage lots, storage facilities, excess land purchased for lay down, wages for guards or handlers, cost of security equipment or other direct overhead costs (Nunnally 2007). Day and Benjamin (1973) estimated this cost to be less than 1% applied to the average annual investment. Peurifoy and Schexnayder (2002) gave a range of 0-5%.

In his thesis related to the Pre-positioned War Reserve Material System (PWMRS), Cyr (2002) discussed the storage costs related to climate-controlled warehouses. Though these government facilities physically exist, the climate control is a misnomer, and related only to a building envelope shielding the equipment from the

falling elements, not temperature or humidity. If this was applicable, the depreciation of the facility and annual expenses would be considered as other direct overhead.

Due to concerns of profitability, most of these circumstances for costs are not applicable to small, private construction companies or the government. Therefore, it is recommended that these costs be ignored in most circumstances and within this study.

2.1.3.6. Availability / Readiness

Availability will be discussed as one of the qualitative factors to the rent-lease-buy decision later. Fuerst et al. (1992) identified the importance of availability and included the determination in the following equation:

$$Availability = \frac{hrsused}{hrsused + hrsunusable} \quad \text{Eq. 2-3}$$

In developing the specifications for a Fleet Management System, Fuerst et al. (1992) identified this calculation as a factor to be considered in determining the size of the fleet. The relation to hourly rates was the fact that within a fleet, specific equipment was more desirable or obtained higher use and thus skewed the average annual investment cost over different hours for each piece. This resulted in uneven ownership hourly costs.

This calculation is misleading as it does not consider the hours at which the machine was available but unused. No other reference identified availability as a quantitative factor. This topic is further addressed as a qualitative factor in decision making.

2.1.3.7. Other

Nunnally (2007) identified a special circumstance that may require consideration when applicable. This is the offer of IRS breaks to promote credit. IRS announcements in the past have included depreciation bonuses and investment credits which permitted certain companies to claim additional tax benefits from the purchase of long-term assets. As this is not a common circumstance, it will not be considered for this study.

2.1.4. Operating Costs

Methods for estimating operating costs are quite standard in classifying the input factors. The differences lie in the estimating process. Typically, two processes are found: those related to calculating individual factor costs, those considering an overall operating cost factor. Operating cost factors such as fuel consumption, fuel / oil / grease, and tires are commonly addressed. Special items that may be high wear and require periodic replacement such as teeth are often lumped into another factor. Finally, those costs related to maintenance and operator involvement tend to vary more.

2.1.4.1. Fuel

The first factor of operating costs listed in a rate calculation is typically the fuel consumption. Manufacturers often supply a basis of calculation similar to Caterpillar (2010) which includes several pages of fuel factor tables for specific equipment as a function of the equipment's specific use and operating condition. Schaufelberger (1999) simplifies the factors as a function of the fuel required (gas or diesel) and the operating condition. Most commonly found is a formula or factor related to the horsepower of the equipment. Day and Benjamin (1973) included a load factor within the calculation. Peurifoy and Schexnayder (2002) simplified the formula for standard conditions as follows:

$$GasEngineConsumption = \frac{.06 gal}{fwhp - hr} \quad Eq. 2-4$$

$$DieselEngineConsumption = \frac{.04 gal}{fwhp - hr} \quad Eq. 2-5$$

These methods are all simple to use and decent estimations. The best method for any long-term equipment employer is to maintain records and apply historical trends to future estimations. If these are lacking, the manufacturer's reference is the best starting point. In this situation, the USACE fuel factor will be used.

2.1.4.2. FOG

The costs related to filters, oils, and greases is typically calculated as a percentage of the hourly fuel costs by applying a developed factor related to operating conditions. The most direct method was explained by Day and Benjamin (1973) in developing the lubricating oil costs as a function of the crankcase capacity and number of hours between changes. The U.S. Army Corps of Engineers modifies the common hourly fuel use adjusted by a factor by applying a labor adjustment factor (LAF) as a function of locality. Peurifoy and Schexnayder (2002) simply stipulate to reference the manufacturer's recommendation and make any adjustments to the circumstances of the environment as necessary (i.e. operating conditions, use).

As with the fuel consumption factor and the method discussed by Day and Benjamin (1973), the best estimate will be created from the historical records of the specific entity. When first starting out, it is recommended to use either the manufacturer's recommendation or the USACE (2007) calculation and factors. Both of these are developed from field data and highly regarded throughout the industry. Appendix Figure A-2 gives an example manufacturer's spreadsheet for calculating FOG and maintenance developed by Caterpillar and found at Louisiana Machinery (2009).

2.1.4.3. Maintenance

Maintenance costs are commonly considered the highest percentage of cost related to operating a piece of equipment. It is also referred to by Peurifoy and Schexnayder (2002) as the highest percentage of cost related to the equipment's entire life cycle. The breakdown given was 37% of LCC is related to maintenance and repair, 25% to depreciation, 23% to operating costs and 15% to overhead. This high percentage of cost due to maintenance is precisely the reason of the research title. As other factors will exist whether the piece is rented, leased or bought, the maintenance costs can shift hands in the process. The secondary impact condition is the level of service to the equipment directly impacts its life and therefore the hourly rate or cost calculations.

Just as the depreciation was based on the purchase price minus tires, so the maintenance is also related. The tire costs for purchase and repair is calculated separately.

Most methods of developing an estimated cost of repair relate a repair factor to the hourly depreciation rate or the purchase price less tires for a total LCC. Nunnally (2007) introduces a year digit factor similar to the of sum-of-year depreciation to calculate the annual repair costs from total repair and the hours used. USACE (2007) only modifies the repair factor to depreciation rate by applying an economic adjustment factor and the labor adjustment factor (LAF) for localities. Others refer back to the manufacturer, the dealer, or the Caterpillar spreadsheet. Just as USACE applied the LAF, Cyr (2002) used \$61/hr and Stewart (2006) used a burden rate of \$70/hr.

These methods are varied and produce different results. None of these can compare to historical data from the individual entity. A few decisions drastically affect the estimating process. First of all, there is a level of maintenance expected of the operator. Then, within the individual entity, there is another level of maintenance capability dependent on labor skills, time availability and space to work. Any major overhauls or contracted maintenance will be executed by licensed personnel able to provide warranty and trained in the specifics. These are referred to as organic, intermediate and depot level maintenance (Arratia 2003).

Day and Benjamin (1973) defines minor maintenance as any activity that can be conducted in the field in less than 15 minutes. This work would include typical daily inspections, greasing, replacement of belts, and other small work to hydraulics or attachment swaps. Arratia (2003) actually compares the capability of manufacturer/dealer partnerships such as that of Caterpillar to the capabilities built in to the military structure of the U.S. Marine Corps Engineers. Arratia correctly explains the similar execution of field repairs by CAT and the USMC Engineers, but skews the statement of capability referring that CAT is much more prepared. The statement referred to the lack of field repair capability because of being limited to HMMWV (High Mobility Multi-Wheeled Vehicle) space. As depicted by Figure 2 below, the maintenance trailer is outfitted to conduct the same maintenance actions for which a typical CAT service truck would be prepared.

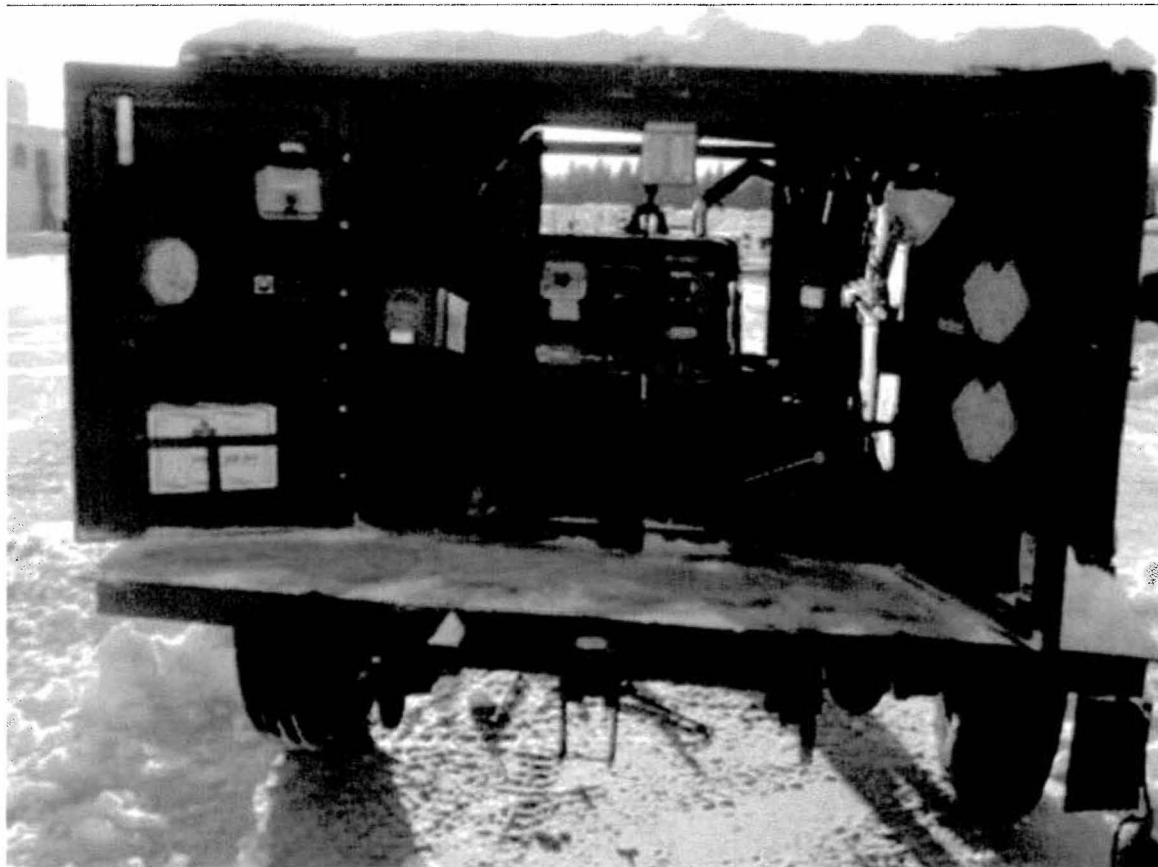


Figure 2-1 M103-A3 Trailer Mounted Portable Welding Shop

The Naval Construction Force includes within its table of allowance (TOA) a maintenance truck that hauls fuels, oils, greases, welders, tools, and spare parts required to conduct field repairs. All three parties do establish depot level maintenance spaces for the longer major repairs. The benefit of a CAT contract for this maintenance is the on-shelf stock of parts inventory not typically held by the military due to the shift to “just-in-time” supply functions.

These factors and the maintenance execution decision by a small, private construction company are essential to the cost calculations and the ultimate decision of equipment acquisition method.

2.1.4.3.1. Preventive

It is important to notice the many references to the importance and benefit of preventive maintenance (Day and Benjamin 1973, Mitchell 1998, Schaufelberger 1999, Peurifoy and

Schexnayder 2002, Panagiotidou and Tagaras 2006, Stewart 2006, Nunnally 2007). Caterpillar (2010) estimates major repair costs to triple if the problem is not resolved before failure. Others estimate an 80% savings.

2.1.4.3.2. Corrective

Blaxton et al. (2003) developed the following calculation for unscheduled repair costs:

$$URC = \frac{T_{so} * MLC * MTTR}{MTTF} \quad \text{Eq. 2-6}$$

Where T_{so} is the scheduled operating hours, MLC is the maintenance labor costs, MTTR is the Mean Time To Repair and MTTF is the Mean Time To Failure. This method is helpful for those with data, but in the beginning it is recommended to use the USACE (2007) method.

2.1.4.4. Tires

Tire costs are typically discussed in two parts: purchase price, repair costs. When calculated, the repair costs are applied as a factor of the purchase cost. Commonly, the total tire cost is 15% higher than the purchase cost to account for the repairs in between purchases and then divided by the tire life in hours.

USACE (2007) goes further to apply a wear factor to the maximum life and locality adjustment factors. Day and Benjamin (1973) also reduced the life by factors that were related to the tire inflation, speed of operation, surface used on, and a load factor. Peurifoy and Schexnayder (2002) and USACE were the only references differing from the 15%. Peurifoy and Schexnayder (2002) only extended the costs to 16% higher than purchase. USACE introduced a tire recap scenario which was estimated at 50% of the initial purchase cost and would last 80% of the original life. This would be a significant savings or profit benefit to a construction contractor.

2.1.4.5. Special Items

Special items are also referred to as high-wear items such as cutting edges, ripper bits, shanks, teeth, etc. These equipment pieces are typically disposable or expendable and

designed to be replaced as needed. It is hard to estimate a replacement time frame and the costs are typically not large causing many references to ignore this cost factor. When established, the common practice is to simply divide the initial cost by the estimated life in hours and include in the hourly operating costs. For this study, the special items will be ignored as most long-term rental/lease agreements include this as a charge to the user if broken and typical replacements costs are not significant.

2.1.4.6. Operator

Operator costs vary as much as the maintenance costs, but may remain level within a local area. It is important to explain the costs that affect operations and profit regarding operator wages, but will not be included in this study as typically ignored within industry for calculating equipment costs.

Costs regarding operators are not only those related to hourly wages. It must also reflect the fringe benefits and taxes for the operator. These two costs together are often referred to as the burden rate. It may be estimated as 10-30% higher than regular hourly wages, but should be addressed much more carefully.

A small, private construction company should calculate all of the costs for the operator and add these together. It should include the wages, insurance, taxes, vacation time, workers compensation and any other direct cost from the employment of that individual. After these costs are summed, the division by total hours expected to work will develop the hourly cost of the operator.

It is important to consider the specific piece of equipment and the company policy regarding its operation. For example, a crane will require more than one individual for its operation. There might be two riggers and a guide in addition to the operator. If the piece of equipment is a dump truck and company policy requires a backing guide due to the area of operation of a flagman, then this should also be accounted.

Most methods found did not include operator wages due to the fluctuation within different areas and the requirement is common across the acquisition methods. In comparisons, a textbook typically includes the same operator costs across the different methods. It is paramount for the owner to include operator costs when calculating rates

for estimating and bidding as this will directly impact costs, overhead base and the overall profit.

For this study, the operator wages will be ignored for two reasons. First, it is common for the equipment no matter whether the equipment is rented, leased or purchased. It may be possible in rental agreements to also negotiate an operator's rate. This is common for crane rentals and other special equipment. If a negotiated rate is available, it is recommended to use the most cost efficient source of labor, internal or external. USACE (2007) provides adjustment factors for labor rates and the regional economic rate.

The second reason for exclusion in this study is the common practice for labor to be accounted in a different pool of funds from that of equipment. This provides a more standardized method of handling human resource (HR) policies, needs and costs.

2.1.4.6.1. Wages and Fringe Benefits

When including labor cost for equipment calculations, it is important to include any fringe benefits in this factor. These benefits include overtime, vacation time, health insurance, worker's compensation, related taxes for unemployment or social security and any other fringes provided for by the company. It was estimated by Day and Benjamin (1973) to typically add 10-20% to the hourly wage. Schaufelberger (1999) estimated it higher around 20-30%. From industry experience, the common number seen is near 35%.

Within this study, the fringe benefits for the labor will not be considered. As with the operator's wages, this number is important for overall accounting, estimating and bidding. Profitability will be maximized by minimized labor costs whether organic or outsourced. The balance requirement for the owner is to ensure reduced labor costs are not impacting the attraction, retainage or productivity of the labor force.

2.1.4.6.2. Additional Costs to Military

When applying labor costs through activity-based costing (ABC) for military operations, there are several added complications which often result in preferred outsourcing for cost cutting. There are additional fringe benefits to the service members implemented due to the higher risk job. This may include family separation allowances, additional medical

and dental benefits to the member and family, or pay/tax benefits related to hazardous duty.

The larger complication is that of a supporting network. A military unit is not created by only direct workers, but also includes support personnel. This increases the indirect or “overhead” costs related to each individual operator. The cost of administrative personnel, corpsmen, communication specialists, and other supply personnel would have to be prorated to an hourly wage rate charged. Related to construction equipment itself is also the organic maintenance group as described in the framework of decision making recommended in the results of this study.

2.1.4.7. Transportation

It is important to note what is not included in the calculations. Each reference explains the items not included. For the most part, these factors or costs are discussed elsewhere. The significant factor to introduce now due to the relationship with operating costs is the mobilization and demobilization. When renting for a short time, the rental company will transport at a cost passed to the customer. This is sometimes a flat rate within a certain distance, a base rate plus mileage or an hourly rate. If the equipment is leased or purchased, the transportation is now the responsibility of the individual entity and must be executed by organic means or contracted. These costs are rarely discussed and will be ignored as a quantitative analysis. It will be mentioned again as a qualitative factor for decision making. Gransberg et al. (2006) estimated that transportation costs of equipment mobilization and demobilization could be \$100-\$150k for a \$3 million project. This equates to a range of 3.3% to 5% of the overall project costs.

2.1.4.8. Other

Caterpillar (2010) introduces a cost not often seen, the undercarriage cost. This cost is typically accounted for in the maintenance/repairs. However, if a person wants to see the estimated cost related to undercarriage damage, CAT has established a set of factors in table format that can be applied to formulate. The table includes a base cost, a factor for

the impact conditions, the abrasiveness of the surfaces and a “z” factor depending upon the equipment. This study will continue with the process of the undercarriage damages being included in the repair/maintenance costs of the equipment.

The USACE (2007) also permits the charging of “standby” equipment in certain circumstances. For this situation, a calculation has been determined to be half the depreciation rate plus the FCCM/hr. This basically shares half of the ownership cost between the contractor and the USACE. This practice is not pertinent to this study but an interesting consideration within government contracting.

2.1.5. Overhead

Overhead rates are very distinct for each entity, typically applied to the overall project and therefore rarely addressed. With respect to overhead costs related to construction equipment, these factors are addressed as ownership costs related to storage, security and other direct costs. Occasionally, equipment overhead is used as the terminology for a percentage rate reflecting the cost of ownership to the hourly depreciation rate and including the costs for taxes, license, insurance, etc.

This cost is mentioned due to the relationship of profitability. Any additional costs incurred by the company are passed to the customer through the contract price. As this is most often not related directly to a piece of equipment, it will be ignored for this study.

2.1.6. Profit

Profit for a private company is the additional revenues gained above any costs incurred. It is defined a bit differently by Panagiotidou and Tagaras (2006) as the following formula:

$$Profit = RevInControl - RevOutControl - RepairCosts - PreventiveMaint \quad Eq. 2-7$$

Where there are revenues produced by the equipment at different operating capabilities, either “in control” or “out of control” signifying the reduced productivity or revenue when in need of maintenance.

The authors saw a strong relationship between profit and maintenance costs. Through applying collected data to this formula, a justification was made to the importance of preventive maintenance in reducing LCC by preventing more expensive failure repairs and extending the useful life of the equipment.

As the different methods of acquisition are introduced and considered, the largest distinguishing factor other than usage is the responsibility of maintenance costs. Profits will be maximized if the equipment is in proper operating order enabling highest availability hours, productivity and lowest failure and accident rates.

Basis of profit for the Naval Construction Force is not much different. There is not an exchange of money in the sense of profit to the leadership, but there is a gain of financial flexibility that benefits the operators, leadership and customers – the taxpayers. Within a given budget, if less money is spent on repairing equipment, then more money is available to overhaul other pieces or purchase new equipment. If more new equipment is purchased, then the expected repair costs would decrease allowing purchase of more new equipment. This is reflected in the sum-of-year (ascending repair costs vice descending depreciation) repair costs method introduced earlier by Nunnally (2007).

If productivity was a grade factor for profit, there exists an inherent difference between the two considered benefactors of this study. For the private sector, an 80% productivity factor or operating 50min out of every hour is looked upon as good and the goal for all. In the government sector, specifically military, the productivity is expected to be closer to 67% because of the inherent differences caused by the “friction-of-war”, the operational tempo of the unit, the high administrative requirement and the intertwined military duties that must be balanced (Blaxton et al. 2003).

2.2. Acquisition Methods

Construction equipment can be procured for use by three major methods: rent, lease or buy. These methods are explained and discussed below.

2.2.1. Rental

Construction equipment of all sizes is available from rental companies. Many companies grew on the use of individuals with the knowledge and capability of executing the work themselves, but without the need and financial ability to purchase. If one wanted to add an in-ground pool in their backyard, a rented backhoe for self-operating was much cheaper than hiring a contractor to complete. Today, many construction companies rent the equipment needed for execution of their daily business due to the benefits of outsourcing and shifting responsibilities to another entity.

Common rental equipment is available in all types and sizes from small generators and pumps to large loaders and tower cranes. The equipment discussed within this study can be rented at time increments of daily, weekly, and monthly. As the time increment grows smaller, the hourly rate is increased. Day and Benjamin (1973) found that a typical weekly rent charge was between 25% and 40% of the monthly rate. The daily rate was typically about 33% of the weekly rate. Interestingly, for those deciding to work more than one shift, the additional rate is often half rate of the first shift for each additional shift. This fact of 3 shifts costing about the same as two days may be beneficial for the military to consider because mission requirements often dictate around the clock operations and this would reduce a comparable hourly cost rate.

It is important to understand what is commonly included within the rental charge and what additional charges may apply to the customer. Some terminology seen within the industry is the comparison of “hot” and “cold” rates. This refers to the inclusion or exclusion of an allowance for operating expenses such as fuel and labor. Typically, the rental rates are “cold” unless otherwise negotiated (Day and Benjamin 1973). With today’s bidding environment and access to computers, it is most common to see each line item explicitly identified in the rental charge breakdown.

The rental rate commonly includes maintenance not related directly to a renter’s negligence or high-wear items. The ability to call the rental company upon breakdown and transfer the responsibility is perceived as an important benefit. The rate does not include insurance which may or may not be available from the rental company or the

transportation costs for delivery and pickup. All of these factors need to be considered in the analysis of the rental costs.

Besides the actual cost factor, other pros and cons are quickly identified with the option of renting. The benefits range from those related to time, capital investment and other intangibles. There is an inherent flexibility with renting that allows short-term contracts and clears the worksite and the charges built-up from any idle equipment while allowing the selection of the best fit equipment for the job and trial use before purchasing. The ability of acquiring high-dollar and necessary equipment for success relieves the upfront requirement of capital investment or long-term financing. The fixed costs of the rental equipment also make it easier for entities to estimate the overall cost of the operation with less likely fluctuations (Fuerst et al. 1992).

Cons to the rental option are typically related to the cost and availability. The costs can run anywhere from 10-60% higher than cost to own when comparing hourly rates (Day and Benjamin 1973). It is recognized by all as the highest cost compared to leasing and purchasing. When a construction company requires a specific piece of equipment and they own it, the decision is simple. When the construction company rents the equipment and a piece is quickly needed, the rental company may or may not have the inventory available to support the requirement (Peurifoy and Schexnayder 2002). This is often minimized by partnerships built between the rental company and the contractor; however, it applies more risk to the completion of the project. When renting is applied to a government entity scenario, the issues of being self-insured and possible sabotage must also be weighed (Blaxton et al. 2003).

2.2.2. Lease

A lease can be structured differently from company to company. It is best generalized as a long-term rental contract with the option to purchase or return to the rental company at the end of the agreed time. A lease agreement often includes the preventive maintenance and some form of breakdown response coverage. For this study, a lease will be considered to include those services expected from a rental agreement with exclusion of insurance, high-wear items, transportation and negligence by the lessee.

A lease is often used for long-term required special equipment such as a tower crane (Schaufelberger 1999). It is a short-term compared to a purchase, but long-term compared to rentals. Nunnally (2007) explains the flexibility of long-term use without a down payment or capital investment which is countered by Peurifoy and Schexnayder's (2002) identification of the security deposit often required upfront similar to residential rentals. The benefits of a lease are reduced cost of renting with secured availability, no required separate financing and lack of requirement for an in-house mechanic (Day 1973, Peurifoy and Schexnayder 2002, and Nunnally 2007). The negative considerations are still higher costs than ownership, with a long-term commitment and loss of benefit of the salvage value return at the end of use (Peurifoy and Schexnayder 2002).

Blaxton et al. (2003) explains the concern of government leasing in regards to the Federal Acquisition Regulations (FAR) slanted to a preference of purchase and requiring lease-to-own option if leasing is considered. For this study, a lease will be considered as a 5 year contract at the given rate with the purchase at a reduced amount at the conclusion of the term.

2.2.3. Own

Ownership is the upfront purchase of a piece of equipment whether by cash or financing. The complete responsibility of all maintenance, transportation and condition of the equipment is held by the sole ownership entity. It permits the control of availability and mechanical condition of the equipment (Peurifoy and Schexnayder 2002). It allows a company to standardize its fleet for efficiency in training, operating, and maintaining (Schaufelberger 1999). It is economically preferred over renting and leasing with expectations that the entity will own only the equipment best suited for its tasks and enough to maintain competitiveness (Day and Benjamin 1973). The unique and largest financial benefit identified by Nunnally (2007) is the tax incentive related to ownership.

Cons associated with ownership include fluctuating demand, rapid changing technology, building costs while idle and the tied up working capital (Day and Benjamin 1973, and Nunnally 2007). Schaufelberger (1999) recognizes the typical 20-40% rate of

return on working capital for the construction industry and 10-12% cost of financing; therefore, recommending outside financing as the best method of purchasing equipment.

2.2.4. Comparison and Risks

Throughout the industry there are several common points listed when comparing the pros and cons of the rent-lease-buy decision alternatives. The following table is a summary list of the most common points. The last section referring to specialized customer of the government was compiled from significant issues identified by Karzon (1994) and Arratia (2003).

Table 2-1 Acquisition Method Comparison Chart

AREA	RENT		LEASE		BUY	
	PROS	CONS	PROS	CONS	PROS	CONS
Financial	No Down Payment	Highest Cost	Low Security Deposit	Higher Cost than Buy	Lowest Cost	Costs Accrue at Idle
	Additional Shifts Reduced		No Disposal Cost	Loss of Salvage Value	Salvage Value	Disposal Cost
	Fully Deductible		Fully Deductible		MACRS Tax Benefit	Fund Right Jobs to Employ
	Working Capital Free		Working Capital Free			Working Capital Investments
	Fixed Cost		Fixed Cost			
	Short-Term		Long-Term			
	Increase Borrower Capacity		Off-Balance Sheet Finance			
	Reduced Inventory		Hedge Against Inflation			
		Full Finance (Ship/Install)				
Availability		Possible Delay (week notice)	Controlled Resource		Controlled Resource	
Responsibility	Includes Maintenance, Downtime	High-wear items, Insurance	Negotiate Maintenance		Pride of Ownership (care & maint.)	
Flexibility	Updated Technology		Purchase Option		Schedule	Obsolescence
	Test Before Purchase				Standardize	
Government		FAR preference to Buy	Lease-Purchase Option			
		Government Liability				
		Security				

The choice of renting is most common for short-term or specific project needs. Because of this option's high cost, it is important for the contractor to acquire the minimum amount of equipment required for successful completion. This reduced inventory avoids the extra costs associated with warehousing, security and other direct overhead requirements for maintenance and management. When Naval Facilities Engineering Command (NAVFAC) implemented internal rental rates for customer requirements by direction from the Chief of Naval Operations (CNO), it was quickly apparent that the realized total costs at the customer level created an immediate reduction in needs. This explicit cost for tracking is beneficial for estimating and bidding. However,

in regards to profitability, this option is only recommended for short-term projects or spikes in the fleet requirement.

Leasing is common for long-term required special equipment such as a tower crane or tunneling equipment. This option reduces cost from the rental option and provides the benefit of less concern to equipment management regarding disposal, maintenance (as negotiated), tracking, and shares the responsibility between the lessor and lessee. Many large contractors use this option primarily as an outsourcing method. It is also common for contractors working out-of-state or in a location away from the main headquarters and existing fleet.

Purchasing the equipment consolidates the benefits and responsibilities on a sole party enabling pride of ownership in care and maintenance while reaping the lower cost and additional tax benefits. The purpose of this study is to determine if this option is best for small, private construction companies whom do not require a large fleet and lack overhead structure or financing base.

2.3. Rent-Lease-Buy Decision

The rent-lease-buy decision is complicated and requires sound evaluation of many factors. Some of these factors have been previously discussed and are categorized into two classifications below: quantitative and qualitative. These classes identify whether the factor is tangible and holds impact upon the financial benefit-cost analysis.

2.3.1. Factors to Consider

2.3.1.1. Quantitative

Financial impacting factors are summarized in a complete life cycle cost analysis typically calculated into an hourly rate as previously explained. Within the LCC, several decision factors exist that should be evaluated related to financing a purchase. The decision of whether to purchase with cash, often referred to as working capital (WC), or

external financing through the dealer or a bank. This decision dictates what rate-of-return should be used for time value of money calculations. If the equipment is purchased, the tax benefit related to depreciation and external financing also is considered.

Defining the life expectancy is crucial to determining the hourly rate. This number is typically based upon the manufacturers estimated hours. A difference of user employment percentages annually may also dictate a review of annual costs or reduced annual hour figure for more realistic calculations. The maintenance method must also be determined. In the situation of a large construction company with well-structured overhead and a large financing basis, an in-house maintenance staff and facility are likely. For a small construction company, simple maintenance is typically expected to be completed by the operator or another individual as a collateral duty and applied to minimum overhead base or even causing reduction of the overall profit.

A small portion of the industry also includes a calculation of downtime for owners. Day and Benjamin (1973) estimated that downtime would increase 10% each year for a piece of equipment. As this cost is typically a consideration of availability or with the maintenance and repair costs, it will be ignored for this study. It is recommended that downtime root causes be identified for appropriate management measures as this could symbolize poor maintenance, incorrect operation or other negative processes within the equipment management system.

2.3.1.2. Qualitative

It is essential to recognize that there are factors not related directly to cost that can impact the financial recommendation and also establish intangible constraints. The most notable is the concern of availability and benefit of resource control by ownership. It is always reassuring and a comfortable thought to know that you can control the availability and schedule of required resources. If it is decided that ownership is the right answer for a fleet, there is still an option for rental use at spikes in time of requirements which may be delayed by availability factors at the equipment rental company.

The second most common factor is truly mixed with quantitative and qualitative properties. This is the consideration of use and demand. The number of hours used affects

the operating cost accrual and the base for ownership cost rating. Often, the amount of use expected or the demand is the recommended deciding factor for choosing between rental and a long-term option. This demand is also an effect on the opposite end where a purchase will dictate the type of projects needed for useful employment and sound rate of return on that piece of equipment. The Texas Department of Transportation has developed a software system for managing replacement prioritization, TERM. It is based on three factors with age and use being two of those.

Obsolescence and improved productivity of newer models is also a consideration. This tends to be less a concern for the more common pieces of construction equipment as they have maintained a steady level in the near past. If more efficient engines or new regulations for air pollution are developed, this may become a more wide spread concern. Typically, this is more related to specialized equipment which is more often rented or leased because of the specialization and technology impacts.

Both Karzon (1994) and TXDOT's (2003) TERM program include the involvement of field interviews. Just because the financial calculations or theoretical productivity processes recommend a specific piece of equipment does not mean it is the best. This is a bigger concern for selecting a specific piece of equipment which has not been addressed within this study. It could also relate to an individual piece from a fleet of 4 or 5 of the same equipment type which continues to have higher rated downtimes, more difficulty in operation or other unique problems best remedied by disposal. These interviews could be with the operator, the maintenance person or any other person with direct involvement (i.e. foreman, superintendent, etc.).

Within the private sector, a unique concern is competitiveness. This was referred to above relating to the rental option for spike requirements. The two factors providing the most competitive position is purchasing the minimum number of required pieces of equipment and outsourcing spikes to avoid unnecessary ownership costs of idle equipment (Arratia 2003, Blaxton 2003).

A concern shared between the private and public sector, but extended further for the public entity is that of security. If construction equipment is acquired through a short-term rental agreement, then there exists a greater risk of sabotage when the equipment is

under control of the provider. This is unnecessary risk in the vital execution of the Naval Construction Force mission. If the equipment in a contingency area such as the Middle East was rented, a high probability exists that improvised explosive devices (IED's) would have been planted for injury, debilitating and deterrence. If construction equipment was rented for disaster response missions such as Haiti, there would have been a large delay awaiting the local dealers to recover or collection of equipment (locating, acquiring, preparing, transporting) from out of the country.

A measurement factor common to private and public entities is the creation through policy of an annual hour or mileage goal (Karzon 1994). If the equipment does not meet the expected goal, then a stronger evaluation of the need should be conducted. This auditing method is another process for maintaining a competitive position, reducing costs and maximizing on profitability.

2.3.2. Economic Life

Peurifoy and Schexnayder (2002) state that equipment has 2 lives: physical & economic. The industry also recognizes two separate economic lives: minimized costs and maximized return (Gransberg et al. 2006). These two economic lives are explained below. This study recognizes the physical life as an opportunity for a third type of economic life as referred to by the NCF as the service life extension program (SLEP). This system is a program which conducts inspections and overhauls as necessary to further the life of the equipment. This is the same concept as an individual retaining an automobile for many years and miles past the life expectancy because it is already "paid for". If the ownership costs are minimized after the removal of depreciation and the operating costs are a constant, then the prudent choice is to continue operating the same piece of equipment. The caveat to this life extension concept is the estimation and management of maintenance and repairs. The chart in Figure 2-2 estimates maintenance and repair costs of older equipment to significantly decrease the probability of profit which is not always the case and a generalized representation (Gransberg et al. 2006). This is further explained in the replacement decision section.

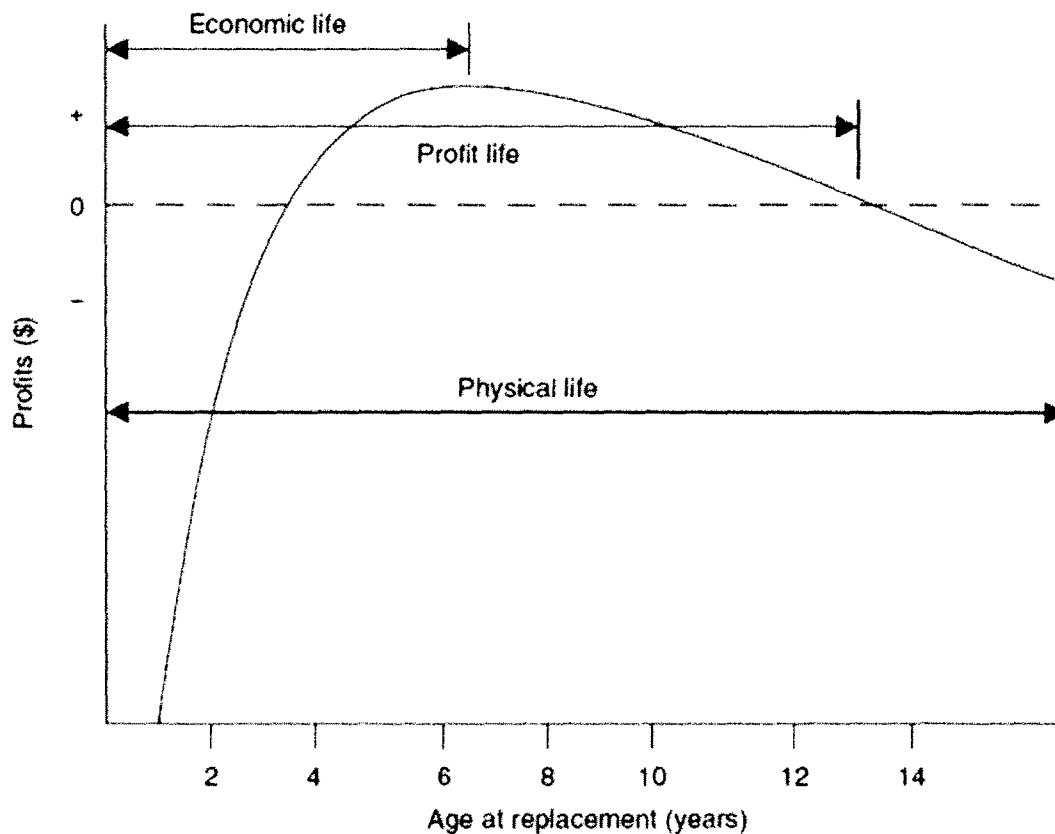


Figure 2-2 Construction Equipment Economic Chart (Gransberg et al. 2006)

2.3.2.1. Minimizing Cost

Minimizing the cost of the equipment is not synonymous with profitability. This is a process to identify when the downward curve of the ownership costs and the upward curve of the operating costs resulting in the lowest point on a summed curve as shown in Appendix Figure A-3. This can also be shown in a table format containing columns of Ownership Cost, Operating Costs and Cumulative Costs. The point at which these costs are lowest reveals the optimum replacement period for minimizing the cost. This is recommended as a sound method for the public entities desiring to optimize the taxpayers' dollars rate of return. This is all annual cost calculations not considering the hourly figured rate.

2.3.2.2. Maximizing Return

Maximizing the return is the recommended method of replacement period identification for optimizing profits for private companies. This method begins with the same as described for minimizing cost and adds the consideration of revenues generated. Annual revenues are expected to decrease each year of age due to downtime and loss of productivity by wear and tear of the equipment. The net result of annual revenue and costs predicts the annual gross profits. A cumulative average of annual profits is then calculated in the final column. The point at which the average annual profit is highest is the optimal time of replacement. This method assumes a maximum use of annual hours. It does not consider the benefit of “paid for” equipment with operating capability lasting beyond the higher ownership cost rating.

2.3.2.3. Third Economic Life

The author suggests that there is a third economic life not represented in the Gransberg et al. (2006) chart in Figure 2-2. This is the economic life of “paid for” equipment, where the operational life is extended into a negligible ownership cost life and the maintenance and operating cost has not grown significantly. This is depicted by the added green line in Figure 2-3 which widens at the far right to symbolize the expected variation of different equipment having dissimilar growths in maintenance and other operating costs. It is significant to realize this third economic life as many automobile owners and small companies use this to their advantage in executing work with lower cost equipment.

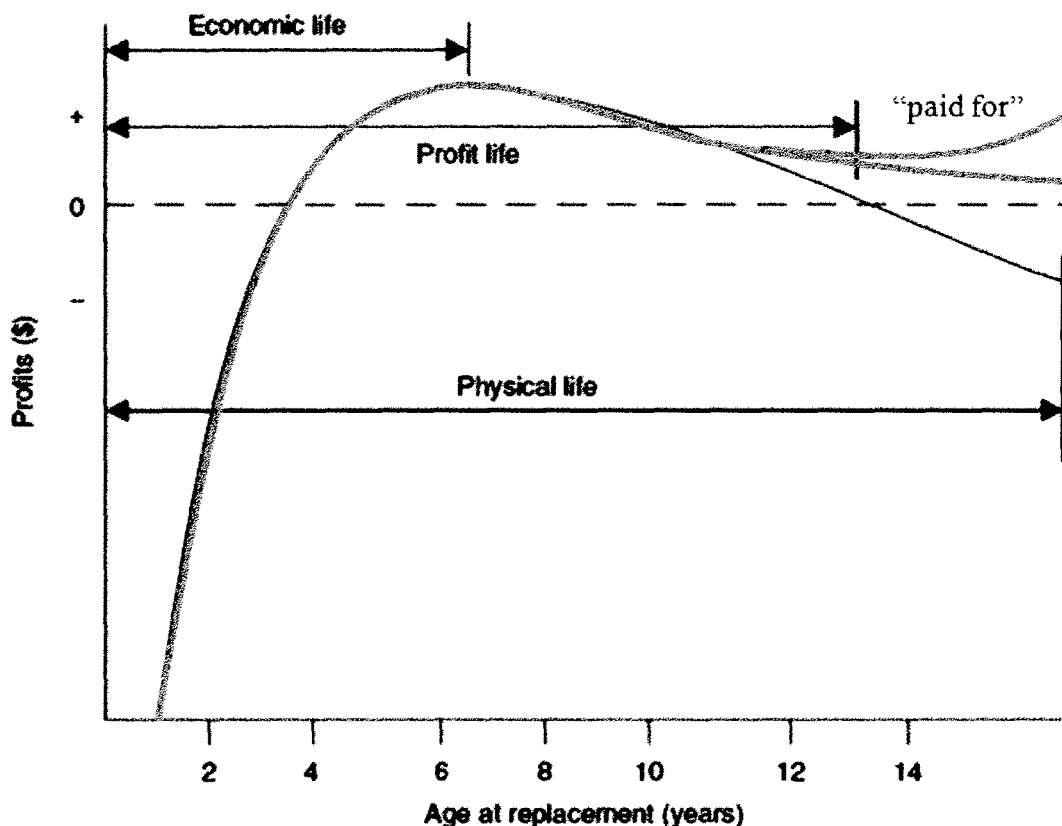


Figure 2-3 Construction Equipment Economic Chart Depicting Third Economic Life

2.3.3. Methods to Decide

The most common method of deciding whether to rent-buy-lease is by comparison of the calculated hourly costs of the different methods for the same piece of equipment. Though not considered within this study, the same cost comparison could be applied to selecting the highest benefit-cost ratio equipment for acquisition. This method provides an evaluation tool for cost efficiency and profit maximization while also weighing the financial risks of the acquisition decision alternatives as described by Gransberg et al. (2006).

The break-even point is a method that takes the hourly rate comparison one step further to show what usage is required to recognize the benefit of the longer-term rent, lease or purchase (Schaufelberger 1999). Because the average hourly rate is not constant between daily, weekly, monthly rentals and with the lease and ownership options, the

break-even method can be used to also decide the optimum rental period for the given projected use required. This method can be further enhanced by applying Karzon's (1994) recommended annual hour or mileage goals.

The more common method of the rent-lease-purchase decision is that of a qualitative analysis. There are often organizational policies that set the parameters or boundaries of processes to assist in guiding the entity towards its vision. Within a private company, policy statements regarding equipment acquisition could include the preference to own for control of scheduling, availability, and mechanical condition through pride of ownership. The policy could also state preference of acquisition method based on maintenance standards or the placement of responsibility and risk. These policies could result in a requirement to purchase, lease-to-own, rent, or even to subcontract equipment intensive activities. Gransberg et al. (2006) established a table presented below that reveals the preferred acquisition method by selecting those qualitative characteristics that are desirable to the end-user.

TABLE 9.4
Customer Criteria for Equipment Acquisition

Customer Criteria	Cash Purchase	Finance Purchase	Lease	Rent
Wants ownership	x	x		
Optional ownership			x	
Use and return only				x
Off-balance sheet accounting			x	x
100% Financing		x	x	
Trade-in value	x	x		
Expense 100% of payments			x	x
Need tax write-off	x	x		
Lowest total cost (ownership)	x			
Lowest monthly payment (use)			x	
Uncertain future work			x	x
Avoid debt			x	x
Try out equipment			x	x
Improve cash flow			x	
Plan equipment replacement		x	x	x
Minimize equipment disposal concerns			x	x

Figure 2-4 Customer Criteria for Equipment Acquisition (Gransberg et al. 2006)

Government entities are likely to have policies in place to assist in this decision, but are also required to follow the Federal Acquisition Regulations (FAR) mandated by government to protect the taxpayers' investment and promote best capital competitive processes. Karzon (1994) interpreted the FAR to prefer outright purchasing in construction equipment acquisition. When discussing the option of leasing, Karzon (1994) explained that it may be permitted but likely would require a lease-to-purchase option to maintain government sovereignty in the ownership decision. Arratia (2003) extended Karzon's (1994) study of military equipment acquisition by studying the possibility of private finance initiative (PFI) as a British developed form of public-private partnership (PPP) as an acquisition method. PPP's have been implemented widely throughout the U.S. for utilities and housing. The British experience with PFI for equipment seemed to be positive but still has a lot of negative connotation to overcome with the U.S. due to mission requirements and control preferences.

2.4. Important Consideration for Owners

For those entities that purchase equipment, there are several items that should be considered in order to maximize on your profitability. The following categories of cost control and the replacement decision assist in this endeavor.

2.4.1. Cost Control

Minimizing expenses is a major factor for protecting the estimated project costs and projected profit. This cost control can be implemented through many different factors identified and explained below.

2.4.1.1. Standardization

If an entity requires more than one piece of equipment, then standardization will provide efficiencies in processes and costs. By purchasing equipment in the same manufacturer family, costs may be reduced by negotiated purchase cost reduction as a return customer,

loyalty. Costs are also minimized by permitting a decreased quantity of spare parts to be on hand as many should be interchangeable. Training of operators and maintenance personnel as well as the operating should be more efficient by similar methods in the design and controls. Fortunately, the larger manufacturers produce a varied fleet of products that are typically comparable to the other competitors. This will benefit the entity by providing additional methods of savings to maximize on profits (Schaufelberger 1999).

2.4.1.2. Preventive Maintenance

In Panagiotidou and Tagaras's (2006) study of preventive maintenance (PM) affects on equipment life cycle costs, it was proven that preventive maintenance improves reliability and reduces total maintenance costs as the name projects. The resulting method of establishing proper PM is related to observed quality of operations. As the quality of operations decreases before required PM, then the time should be adjusted sooner. If the loss of significant quality is not of a concern and only cost avoidance, then the maximization of expected profit would be to operate to completion with hopes of no failure.

Preventive maintenance is recognized as a cost control factor often poorly implemented. PM is essential to minimizing repair costs and avoiding failures. Day and Benjamin (1973) explain that the burdensome paperwork related to PM scheduling, tracking and completion coupled with the lack of immediate seen benefit are the largest causes of PM system failure. Day and Benjamin (1973) continue to report that properly maintained equipment provides the benefit of higher availability at over 90% for newer equipment and greater than 80% for older equipment. This availability then directly impacts the higher productivity and higher profit. The recommendation is made if greater than 80% availability cannot be achieved then the equipment should be replaced. It is estimated that properly followed PM can avoid 80% of failures and reduce the repair costs by 50% (Caterpillar 2000).

2.4.1.3. Policies

Companies often incorporate for the tax benefit and the organizational structure of authority and responsibility. This incorporation often requires many policy statements to be created. It is recommended the same be done for equipment processes. As a company invests in construction equipment, the assets must be watched and controlled for the best of the company. These policies could be related to preventive maintenance as discussed above, or even the use authorization. Karzon (1994) suggested that a goal annual hour or mileage usage was an effective way to measure whether a piece should be retained or let go. If the equipment did not get the goal usage, then the annual ownership costs was spread over less hours or mileage causing the hourly or per mile cost to be higher than desired or competitive with other acquisition methods. This was found to be a particular problem as certain equipment was requested due to favoritism causing a wide range of averaged costs. A policy drafted and implemented could prevent this favoritism or provide methods approved for making equipment management decisions and maximizing on profits

2.4.1.4. Training

Training can be a benefit for all companies, not just those with a standardized fleet. Proper training improves efficiency by ensuring operators know the importance of different factors on their productivity. An example if the setup of operating patterns. The more efficient the operation results in higher profits from increased productivity and less wasted effort.

Operator training can also include minor maintenance and proper inspection techniques. This can minimize maintenance man requirements, instill ownership and accountability by the operator and assist the operator in sensing when something is not right with the equipment. All of these can result in lower costs and higher profits.

Another more intangible benefit can be improved morale from cross-training. As an operator gets proficient at one piece, the productivity may plateau or even degrade due to boredom, redundancy and complacency. By cross-training on different equipment and

changing the operation and focus of the operator, short-term decreased productivity of the new operator typically improves quickly and increases morale and safety.

The most important training is that regarding safety. Safety directly impacts productivity and profits. Safety minimizes incidents and maintains a level of order throughout the site with awareness of others. Less accidents reduces costs of injury and corrective maintenance as well as establishing better historical records which reduces insurance premiums. Safety is paramount for that of protecting lives, but also increases profitability of the same company.

2.4.1.5. Supervision

Similar to that of implementing policies, supervision improves efficiency by enforcing lessons learned, policies and best found techniques. Supervision enables the execution of “inspect what you expect”. Everything a company designs to minimize costs or maximize profits must be managed and overseen. Just as with the preventive maintenance systems failing due to individuals not seeing the immediate benefit, other factors may also be ignored.

2.4.1.6. Equipment Records

Equipment records are typically one of the first policies implemented by a company in order to track the costs of each asset and apply historical costs to future estimating. The records should track usage, task, operating conditions, daily inspection findings, fuel consumption, maintenance actions, and any other significant factor related to that single piece. These records enable the best preventive maintenance system to be implemented, and data collection for equipment management decisions.

Once these records are maintained for a significant period of time, the entity can now begin using actual costs to estimate hourly rates and make better comparisons regarding rent-lease-buy, replacement, growth or reduction of the fleet decisions.

2.4.2. Replacement Decision

Equipment physical failure is not the only time for replacement as indicated by Peurifoy and Schexnayder's (2002) citation of two different lives: physical and economic. The replacement decision is based off the deciding point of when a piece of equipment should be disposed of, overhauled or replaced. Bennett (2008) found that life cycle costs for equipment could be defined differently by separate individuals; therefore, Bennett said a number of personnel should be brought together to ensure overall understanding of the LCC and comparing models. This study intends on identifying the most common models of decision support system tools regarding the replacement decision and identifying the best suited for a small, private construction company and the Naval Construction Force.

2.4.2.1. Methods to Decide

Most common method of replacement decision support system tools is the chart and the table. Before computers were so common and accessible, the manufacturer and other partnerships such as the American Equipment Distributors would collect and compile data in order to develop charts that could be mass produced for decision guidance. Now that the personal computer is common, the formation of comparison tables seems to be the most common.

Day and Benjamin (1973) simplified the table method in the following calculation to determine when best to replace the existing equipment, where R is revenue, C is cost, x is existing equipment, r is replacement equipment and j is varied between 1 to 15 to find optimization of profit:

$$\sum_1^{15} Profit = \sum_1^j Rx - \sum_1^j Cx + \sum_j^{15} Rr - \sum_j^{15} Cr \quad \text{Eq. 2-8}$$

The comparisons seen through several examples suggest that this formula should be modified to likely have 2 replacements within a 15 year period (Peurifoy and Schexnayder 2002, Gransberg et al. 2006).

Everyone expects the ownership costs to decrease and the operating cost to increase as the equipment ages. Nunnally (2000) estimates productivity of newer models will improve 5% each year which in turn results in an obsolescence of 5% each year. Day

and Benjamin (1973) estimated downtime to increase 10% each year. Stewart (2006) recognizes that preventive maintenance is an important factor not significant in the cost but by extending the useful life and availability of the equipment decreasing the hourly cost. Blaxton et al. (2003) found a similar result from studying the military's service life extension program (SLEP). This is very similar to an overhaul which is costly but offsets by the benefit of extending the useful life and therefore reducing the hourly cost.

Day and Benjamin (1973) also introduced a "suitability" factor. This is a calculation based on a common operating cost and differing ownership cost and productivity.

$$\frac{eo + kv}{qa_1} < \frac{er + kv}{qa_2} \quad \text{Eq. 2-9}$$

Where eo is cost of ownership, er is cost of rent, kv is the operating cost and qa is the productivity for each scenario.

The mathematical modeling process is described by Douglas (1975) and referenced throughout most of the literature reviewed. The methods of minimum cost and maximized return discussed early are recommended by Gransberg et al. (2006) for public and private entities, respectively. Gransberg et al. (2006) further identify two less often described methods: intuitive and payback period. The intuitive method is common throughout the industry as a time-saving factor. It is the reliance upon "professional judgment" of the equipment manager. It consists mostly of the manager's experience and financial goals of the entity, typically being considered upon identification of overhaul need or significant productivity decrease.

The payback period concept is often used in conjunction with other methods during times of market uncertainty, fluctuating demand and volatile technology. The estimated revenues and costs are compared each year until a break-even point is identified. This predicts the point at which the equipment begins to produce revenues that extend beyond that of the capital investment required for ownership (Gransberg et al. 2006).

Another related factor is the realization of excess equipment with a fleet during overall evaluation. If the equipment is truly excess, then it is accruing additional costs

that must be spread over the charged rates of other equipment as an overhead. The quick disposal of this excess equipment will optimize on profitability by minimizing unnecessary costs (Karzon 1994).

The USACE (2007) provides a calculation of adjusted ownership rates for used equipment purchases. This is unique and important as the depreciation resets to a new clock period and different established purchase value (USACE 2007, Ross 2008).

2.4.2.2. Example

For a simple scenario, consider a personally owned truck that was purchased new for \$12,000 in 1996 and paid off in 1998. Over the life, only \$3500-\$4000 has been spent on corrective repairs. It is now 2009 and repairs are required estimating \$2500. The given vehicle is used primarily for transportation to and from work. The replacement decision is whether to conduct the repairs and retain the truck or replace it with another automobile.

The cheapest alternative transportation considering reliability and access would cost about \$10,000 at a monthly payment of about \$200 if financed at five years and a common interest rate. This alternate would be a four door car with higher gas mileage but without capability of hauling larger materials if required so these considerations will be ignored.

Excluding operating costs, the repairs would be equivalent to just over 12 months of the alternative. If the deciding factor is future costs per month and the repairs would leave the truck in an operating condition expected to last longer than 12 months, then it has outlived the breaking point. If the overall life of the truck is compared to a monthly cost, then summation of initial price and repairs is $\$12,000 + \$4000 + \$2500 = \$18,500$ over 15 years resulting less than \$103 per month.

This example was simplified to show how two perspectives on a single deciding factor can be skewed if not looking at the entire life cycle costs. When applying the replacement decision to more expensive construction equipment it gets much more complicated by adding in other ownership costs, much higher maintenance and repair costs, operating costs, the projected demand, usage, age and many other factors as discussed.

CHAPTER 3. METHODOLOGY

The research began with literature review of background material summarized in the previous chapter. This background established industry norms and identified differences and uniqueness among references.

Upon completion of the literature review and a summary of findings, the focus of this study was clarified and limitations established. Next was a comparison of methods for weighing the focus factors and identification of desired data. The data was used to compare methods and evaluate decision factors.

Final, a preferred method was developed from segments of other methods and modifications to the desired result. Finally, a case study was applied to provide an example of the new framework for decision-making assistance.

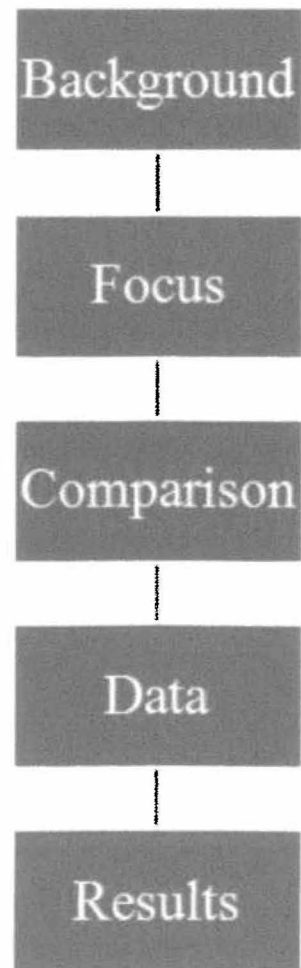


Figure 3-1 Methodology Flowchart

3.1. Focus Factors

The focus of this study began by establishing the objectives of assisting small, private construction companies and the Naval Construction Force in the acquisition method decision of rent-lease-buy for construction equipment. The second desired benefit is that of optimizing financial profitability for the private company and optimizing the replacement determination for the NCF. In order to relate these two and establish boundaries, five types of equipment were identified as common, essential pieces: backhoe, excavator, loader, skid steer and forklift. The summarized literature review also lead to the reduction of focus factors as displayed in the table below.

Table 3-1 Cost Factors for Construction Equipment

OWNERSHIP	RENT	LEASE	OWN	COMPARISON REQUIRED
Depreciation			X	YES
Salvage Value			X	YES
Tax Benefit			X	YES
Interest			X	YES
Insurance	N/I	N/I	X	NO
Tax/License			X	YES
Storage	N/I	N/I	X	NO
OPERATING				
Fuel	X	X	X	NO
FOG	INC	INC	X	YES
Maintenance/Repair	INC	N/I	X	YES
Tires	X	X	X	NO
Special Items	X	X	X	NO
Operator	X	X	X	NO
Transportation	X	X	X	NO
OTHER				
Overhead	X	X	X	NO
Profit	X	X	X	NO

NOTE: N/I is not included, INC is included.

Within the LCC of equipment are four main areas of ownership, operating, overhead and profit. As shown in the table, there are common requirements across all three acquisition methods. These costs that are accrued in all three situations are ignored. This is typically not the case, but seems to be more productive and time efficient. The main ownership cost factors that are common include both insurance costs and the storage requirement. For a larger company that is deciding between purchasing an entire fleet and outsourcing, the storage costs become a more significant factor, not the case for this study.

Regarding the operating costs, the majority of these factors are paid for by the end-user in all three circumstances. The changing costs lie in the area of maintenance including regular filter/oil/grease service as well as maintenance and repair. These maintenance groups could also be labeled as scheduled and unscheduled maintenance or within the NCF preventive and corrective maintenance.

The last two areas of overhead and profit are also constant across the board. For the private company, the equipment costs add to the overhead base and the mark-up base for profits. For the public entity such as the NCF, the overhead is a much more complicated subject funded by other pools of money. This was further explained in the operating costs wage section of this report.

3.1.1. Demand

The first focus factor within this study is demand. This is a higher level overview than the often related estimated hour calculation for a project. The demand consideration for this factor is a combination of two questions and answers. The first question is related to longevity of the need. It requires the determination of whether the equipment is needed on a short-term, long-term or uncertain period of time. The second question is that of commitment to future work. If it is determined to proceed with a long-term acquisition method, it establishes a commitment to soliciting the obligatory work required for employment of the equipment and avoidance of idle accrual of unnecessary costs.

3.1.2. Maintenance Costs

The operating factor with most impact on the costs of the equipment differing in the comparison of acquisition methods is that of maintenance and repairs. It is usually the largest cost related to operating as well. As previously stated, minimization of maintenance and repair costs is realized by implementing and following a strong preventive maintenance program (scheduled maintenance) which will assist in avoiding/predicting failure and reducing corrective maintenance (repair) costs.

This focus factor must be evaluated in two steps. The first step is a policy decision of the method for maintenance. The method could be as simple as identifying the operator or another employ as a collateral maintenance man. This may minimize the indirect costs related to maintenance. If the private company grows to the need of a larger fleet, a maintenance staff may be developed or a larger equipment management division. The larger company has a greater overhead base for applying these indirect costs enabling better competition with outsourced maintenance and one of the reasons for focusing on the smaller, private companies. The maintenance may also be negotiated within the rental or lease rates or outsourced completely for all equipment. It is recommended by this study that a small, private construction company consider training the operator or another employ to conduct minor repairs and outsource the major repairs in order to minimize on costs and optimize the profitability.

The second step to analyzing the maintenance cost factor is a comparison of the estimating methods, comparing these with collected data and recommending the best procedure for projecting costs. This operating costs factor has the most varied group of calculation methods. Therefore, the data received is essential to selecting the closest comparison. The limitation to this study is the low number of data points received from private construction companies due to the sensitivity of the proprietary information vital to competitiveness and livelihood.

3.1.3. Equipment Age

The factor of equipment age is considered as a dependency factor to the maintenance costs. As the equipment ages, the ownership costs decrease. Simultaneously, the

operating costs increase due mostly to the additional costs related to maintenance and repairs with a smaller cause by reduced productivity to wear and tear. The equipment age is also a decision factor in relating the company's policy statements regarding the 3 economic lives of equipment discussed in an earlier section.

3.1.4. Workforce

The workforce factor is also directly related to the maintenance method. If overtime is required of a collateral duty maintenance man, this adds cost to the equipment LCC at a minimum level. The hiring of a maintenance staff or creation of an equipment management division drastically increases workforce costs. The second most cost effective workforce selection is in general the method of outsourcing.

3.2. Unaddressed Factors

Due to the time limitation of this research, several factors were assumed as a given or ignored in order to develop a recommended framework for deciding the acquisition method, replacement and optimizing the profitability. These factors are the equipment selection (given), productivity concerns, and equipment attachments.

3.2.1. Equipment Selection

Throughout this study, five pieces of construction equipment were addressed due to the commonality between the private sector and the Naval Construction Force. Therefore, the selection was given. If the equipment has not already been selected, it is recommended to begin by shopping different manufacturer websites to familiarize with what products are available. Cost effectiveness and versatility are two important factors. Many methods throughout this study will assist in comparing the hourly rates for two different pieces. The versatility may be simply selecting a tractor (dozer) that can be used in clearing and grubbing, excavating, leveling and backfilling all on the same project (Schaufelberger 1999).

3.2.2. Productivity

After identifying pieces to compare, the productivity can be calculated as found in Schaufelberger (1999). The hourly rate calculated above can then be adjusted by the productivity to determine a unit cost for comparison. This comparison will require estimations of the operating conditions, soil characteristics and operator's efficiency.

3.2.3. Attachments

Attachments are relevant to the cost and the versatility of the equipment. Throughout this study, no discussion or application of attachment costs were included. These can get costly as is the case for a skid steer where over 50 different attachments are available. A common example for a skid steer besides a loader bucket would include a set of forks, an auger, a hydraulic hammer and a grapple. These attachments will increase the usage due to the varied tools available and possibly increase productivity if not spending too much time interchanging attachments.

3.3. Data

Government Fleet (2009) explained the difficulty of equipment management without data. One public office had lost all of their newly established data collection system due to flood damage to both electronic and hard copies. The article identified the problem of collecting data points for a starting point. Many different methods have been described within this literature review, but this public entity was able to recreate their management system through shared data from other peer entities. It is important to note that these were public entities. Private entities often refrain from sharing this proprietary information that is vital to the profitability of the company and its existence.

It is desired to receive data from four different source types for analysis. The first is small, private construction companies that employ the use of construction equipment. The second and third desired sources are construction equipment rental companies and equipment manufacturers. Finally, data will be required from the NCF in order to apply

the evaluation methods to seek ways of improving CESE budget administration and life cycle management.

In order to facilitate the link between private sector construction equipment and NCF CESE, a short list of commonly used commercial equipment that requires only minor changes such as paint color for NCF use was selected for this study.

1. CAT 420D Backhoe / Loader
2. John Deere 200 LC Tracked Excavator
3. CAT 924 Wheeled Front-end Loader
4. Bobcat / Skid Steer, Tracked
5. SKYTRAC Telescopic Forklift

It is desired to find data on these specific makes and models; however, it is more important to find data on the type of equipment and its operational capability.

The following financial data is required in order to conduct the analysis (summarized with sources in Appendix Table A-1):

- Purchase price
- Maintenance costs (preferably distinguished as Preventive and Corrective)
- Life expectancy
- Operational use records
- Desired, time in operation life maintenance costs are incurred
- Environment of employment (climate, experience of operator, etc.)
- Desired, annual budget versus actual spent
- Company financial statements (summary of equipment expenses)

The data collected will then be analyzed in using several methods. Those methods found through literature review will be put to the test for comparison. Additional measures will be applied using ratios and analysis from CE 521 Construction Business

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1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

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14. ABSTRACT. A brief (approximately 200 words) factual summary of the most significant information.

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Management as well as MGMT 600 and MGMT 610 Financial Accounting and Financial Management, respectively.

3.3.1. Rental Companies

In analyzing the rent-lease-buy decision, data related to the rental rates and inclusions were essential. Ideally, receiving data on the usage and maintenance costs would have lead to an even closer analysis and value of the rental or lease option. Due to the nature of sensitive data for competitiveness throughout the industry, data collection was simplified to the advertised rates before negotiations and what inclusions or exclusions existed. As it was found most rental equipment is less than 4-5 years old, the expected maintenance costs would be minimized.

Upon collection of data from four rental companies, it was found that rental agreements typically include maintenance and repair costs coverage. It does not include the transportation costs for pick-up and delivery, or the insurance. In the given lease agreement rates, the scheduled maintenance is covered but unscheduled repairs are not. This would likely be negotiated for inclusion but this data was not given. Lease agreements have the same exclusions as rental for transportation and insurance. Therefore, this study will ignore the cost of insurance and hauling because it would be the customer's responsibility whether rented, leased or owned.

The following table represents the average rates obtained through data collection from construction equipment rental companies. The average rental rate is also shown as a converted hourly rate for comparison. Note that 160 hours was used for conversion of the monthly rate. This is the conservative approach used by most rental companies though some references recommend a 176-hour month.

Table 3-2 Analyzed Data from Rental Companies

Model	RENT (AVERAGE)					
	DAY	DAY HRLY	WEEK	WK HRLY	MONTH	MN HRLY
	(8HRS)		(40HRS)		(160HRS)	
BACKHOE	\$ 246.67	\$ 30.83	\$ 770.00	\$ 19.25	\$ 2,133.33	\$ 13.33
EXCAVATOR	\$ 660.00	\$ 82.50	\$ 2,116.67	\$ 52.92	\$ 5,833.33	\$ 36.46
WHEELED LOADER	\$ 484.33	\$ 60.54	\$ 1,502.67	\$ 37.57	\$ 4,308.33	\$ 26.93
SKID STEER	\$ 195.00	\$ 24.38	\$ 633.75	\$ 15.84	\$ 1,826.25	\$ 11.41
TELEHANDLER	\$ 255.00	\$ 31.88	\$ 748.33	\$ 18.71	\$ 2,128.33	\$ 13.30

The unnegotiated lease rates provided were the same as the monthly rental rate. It is important to understand that the lease rate equal to the monthly rental rate is not covering the same inclusions and value. As stated above, the lease maintenance coverage was only for the scheduled preventive maintenance. Each rental company contacted also operated as a dealership. The purchase price quoted for pieces of equipment equivalent to those in the Naval Construction Force TOA is in the following table.

Table 3-3 Purchase Price from Caterpillar Dealer

Model	Year	Purchase Price
BACKHOE	2008	\$ 60,000.00
EXCAVATOR	2008	\$ 110,000.00
WHEELED LOADER	2008	\$ 90,000.00
SKID STEER	2008	\$ 18,000.00
TELEHANDLER	2008	\$ 40,000.00

3.3.2. Private Construction Companies

The following table reflects the average use and average hourly maintenance costs as a summary of all retrieved data from private construction companies.

Table 3-4 Analyzed Data from Private Construction Companies

Model	Qty	Annual Use (Hrs)	Annual Maint Cost	Maint \$/hr
BACKHOE	1	846.0	\$4,686.99	\$5.54
EXCAVATOR	3	1162.5	\$31,807.57	\$27.36
WHEELED LOADER	2	1531.7	\$9,169.89	\$5.99
SKID STEER	1	521.0	\$2,785.30	\$5.35
TELEHANDLER	24	1051.5	\$4,163.01	\$3.96

3.3.3. Naval Construction Force

The NCF provided data covered a 6 month period of the selection equipment classes and was retrieved from two different sources. It is important to annotate two characteristics of this data. First, the data received was compiled only of equipment assigned to deployed units and not those in ready reserve storage. The equipment placed into inactive equipment maintenance (IEM) was ignored as this is identified excess equipment and unused. Therefore, the calculated use is a fairly realistic calculation of actively employed fleets. The second characteristic is that of the time period. Though the use data and maintenance costs data originated from different sources, the same 6 month calendar period is represented as actual recorded.

Table 3-5 Analyzed Equipment Usage from Naval Construction Force

Model	Qty	IEM	6MONTH USE (HRS)	AVG ANNUAL USE (HRS)	IEM ADJUSTED ANNUAL USE	ANNUAL % USE (1920 HRS)
BACKHOE	13	1	5669.4	872	945	49.2
EXCAVATOR	11	0	3765	685	685	35.7
WHEELED LOADER	21	4	6213	592	731	38.1
SKID STEER	2	0	334	334	334	17.4
TELEHANDLER	23	9	4504	392	643	33.5

Table 3-6 Analyzed Equipment Maintenance Costs from Naval Construction Force

Model	Qty	6MONTH MAINT.	AVG ANNUAL MAINT.	AVG ANNUAL USE (HRS)	MAINT. \$/HR
BACKHOE	11	\$1,041.50	\$2,083.00	945	\$2.20
EXCAVATOR	6	\$465.90	\$931.80	685	\$1.36
WHEELED LOADER	17	\$656.10	\$1,312.10	731	\$1.79
SKID STEER	1	\$230.00	\$460.00	334	\$1.38
TELEHANDLER	12	\$832.00	\$1,664.00	643	\$2.59

This data resulted in annual average use, percentage employment and maintenance cost rates for comparison with private company data.

3.3.4. Data Analysis

The data analysis included determining an equivalent time to purchase based on average rental rates, comparing average equipment use between small, private construction companies and the NCF, comparing the average maintenance cost between the small, private construction company and the NCF, and calculation the percentage of an NCF man year used in the average operation of the equipment.

Table 3-7 shows that for most equipment, less than 2 years of monthly rentals would have purchased the same piece. This analysis suggests that over an expected life of a piece of equipment, if the demand is equal to or greater than the equivalent time to purchase, then it is better to purchase. Similarly, a short-term classification should be less than 1.5 years over a given equipment life.

Table 3-7 Equivalent Time to Purchase Based on Average Rental Rates

Model	RENT (AVERAGE)		PURCHASE (1)	EQUIV	
	MONTH (160HRS)	MN HRLY		MONTHS	YRS
BACKHOE	\$ 2,133.33	\$ 13.33	\$ 60,000.00	28	2.34
EXCAVATOR	\$ 5,833.33	\$ 36.46	\$ 110,000.00	19	1.57
WHEELED LOADER	\$ 4,308.33	\$ 26.93	\$ 90,000.00	21	1.74
SKID STEER	\$ 1,826.25	\$ 11.41	\$ 18,000.00	10	0.82
TELEHANDLER (3)	\$ 2,128.33	\$ 13.30	\$ 40,000.00	19	1.57

Next, a comparison of the average annual use of construction equipment within small, private construction companies and the NCF is displayed in Table 3-8.

Table 3-8 Comparison of Average Annual Use (Hrs)

Model	Annual Use (Hrs)	
	Private	NCF
BACKHOE	846.0	945
EXCAVATOR	1162.5	685
WHEELED LOADER	1531.7	731
SKID STEER	521.0	334
TELEHANDLER	1051.5	643

As expected, the use by the NCF is typically lower; however, the use for the backhoe is very similar. This is likely due to the backhoe being a very versatile piece of equipment that can be fitted with many attachments, fits in most workspaces and is often easier to learn to operate. This is the reason a backhoe has been selected for use in the example presented in Chapter 4.

A comparison of average maintenance costs is shown in Table 3-9. The rates calculated for the private entities and the NCF as drastically different. As stated by Arratia (2003) and Blaxton et al. (2003), government equipment records are not often seen as accurate. This is caused by the many different pools of money within the

budgeting system. The software system used to collect this data for the NCF includes labor hours, parts cost and other parameters like delay time for part delivery. This system does not include any liquids, transportation requirements, or other personnel related costs such as operator performed maintenance.

Table 3-9 Comparison of Average Maintenance Cost per Hour

Model	Maintenance Cost (\$/hr)	
	Private	NCF
BACKHOE	\$5.54	\$2.20
EXCAVATOR	\$27.36	\$1.36
WHEELED LOADER	\$5.99	\$1.79
SKID STEER	\$5.35	\$1.38
TELEHANDLER	\$3.96	\$2.59

The numbers produced from the private entities supports an average expected maintenance cost equal to 100% of the purchase cost over the life of the equipment as suggested by USACE (2007) and Caterpillar (2010).

A fourth analysis was executed for the NCF alone. This was the comparison of annual percent use of the equipment compared to the average expected direct labor hours produced by a military person. This is simply a ratio of average use as a percentage of hours divided by the estimated 67% of a year that military personnel do direct labor because of the high administrative requirements and other military duties imposed on the individual. This is displayed in Table 3-10.

Table 3-10. Percentage of NCF Man-Year Used in Average Operation of the Equipment

Model	AVERAGE ANNUAL USE	ANNUAL % USE (1920 HRS)	PER PERSON
BACKHOE	945	49.2	73.4%
EXCAVATOR	685	35.7	53.3%
WHEELED LOADER	731	38.1	56.9%
SKID STEER	334	17.4	26.0%
TELEHANDLER	643	33.5	50.0%

CHAPTER 4. RESULTS AND DISCUSSION

The result of this study was the development of a decision tool, Construction Equipment Profitability Optimization Model (CEPOM). This tool can be applied to both private and public entities. A description of this model and results of applying this model to the small, private construction company and the NCF is found below.

4.1. Recommended Method for Decision

The figure to the right displays the recommended decision support framework for acquisition selection and profitability optimization. The implementation of this framework guide for the small, private construction company and the public entity of the Naval Construction Force differs but the conceptual process still holds true. This study assumes the equipment need and selection has been satisfactorily completed. The process is broken into two separate segments related to the main objectives of this study: Acquisition Decision and Profitability Optimization. Each method has an in-depth explanation below.

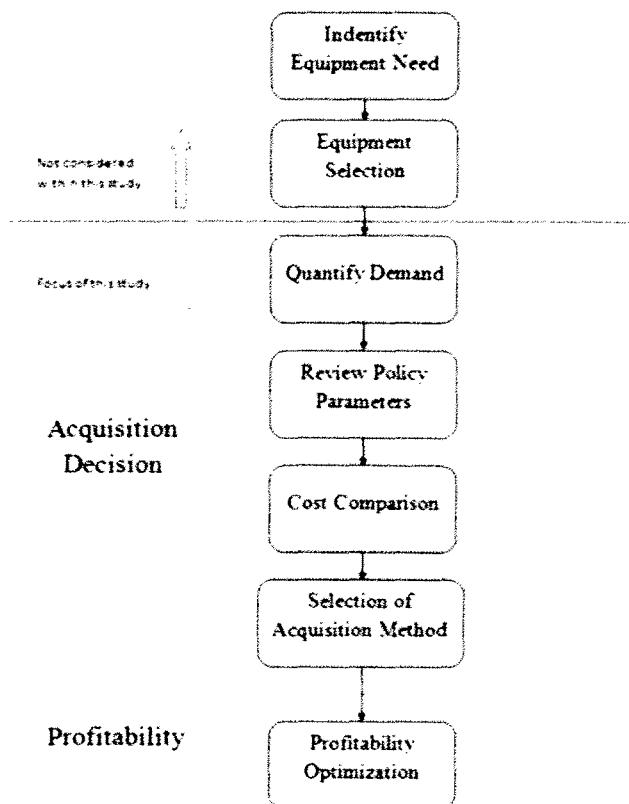


Figure 4-1 Framework for Decision Tool

The entity will first identify the requirement and the equipment desired for fulfillment. The first step related to this study is that of quantifying the demand. As stated before, this is a high level decision of short-term/testing, long-term or uncertain. If the equipment need is only for a short period project, to use for a trial period while deciding what equipment to purchase, or to fill a short period spike requirement, then the demand would be classified as short-term/testing. If the equipment requirement is known to be a perpetuity, fulfill a several year project need, or expected to be necessary for the continued success of the entity, the demand would be classified as long-term. If the equipment need does not fit either of these two descriptions, then the demand would be classified as uncertain. This correlates to the first line of Part A within the CEPOM, "Quantify Demand".

The next step is to identify the policies set in place or parameters identified by the decision-maker related to qualitative and financial preferences. It is recommended that four areas be ranked. The first is the capability of financing. This can cover both the risk of financing the entity as perceived by the financing institution and the desirable management of working capital. Secondly, the desired type of asset management. This relates to the preference of minimizing owned assets, wanting the option to purchase or desiring full control of availability and condition (pride of ownership). Thirdly, the desired confidence in estimating charged rates. This refers to the comfort of fixed costs through rental agreements, semi-fixed costs through lease agreements until negotiated to contract or the variable costs related to estimating and realty differences in ownership. Finally, the placement of maintenance responsibility related to the equipment. Whether it is preferred that the risk and responsibility of equipment maintenance and repair be retained by a dealer through a rental, held at the entity with a requirement as establishment of pride in ownership and control of mechanical condition or determined through negotiations of a lease agreement. It is recommended that all four of these areas within policy parameters be ranked across the row by filling in a 0, 1, or 2 independently. The sum of these ranking columns will represent a preference ranking of acquisition method by the policies or qualitative factors of the entity. This second step correlates to the "Review Policy Parameters" section of Part A of the CEPOM.

Next is a cost comparison. This may not be seen as necessary because of the expected higher cost of renting, decreased cost of a lease and lowest cost of ownership revealed through most evaluation methods. It is recommended that a cost comparison still be made for two reasons. First, to ensure the proper factors are being compared. Most hourly rate comparisons use the Ownership & Operating (O&O) hourly rate to compare with the rental cost over available hours. As represented previously, not all O&O is included in a rental agreement therefore skewing this comparison. The second reason is that of an assumed use of available hours. It is proven in the data analysis that the number of available use hours for owned equipment is highly unlikely. The highest annual use percentage was that of the backhoe, likely due to its versatility, at just under 50%. If a piece is rented for 1 week and used at the nominal efficiency of 80% or 50 minutes per hour, this results in a much different rate than a cost over the 100% available use. This realistic estimation of use hours is paramount to ensure a true comparison of the costs, just as important as identifying the common factors.

This step of "Cost Comparison" within Part A requires the calculations guided in Part B. The CEPOM then normalizes the cost across the row of three alternatives. Notice, it is the users prerogative of which rental rate to use for comparison; however, it is expected that the monthly rate calculation be used as it is more attractive. This establishes a weighted value which is then used as the denominator in a benefit-cost ratio. The higher benefit-cost ratio is the recommended construction equipment acquisition method.

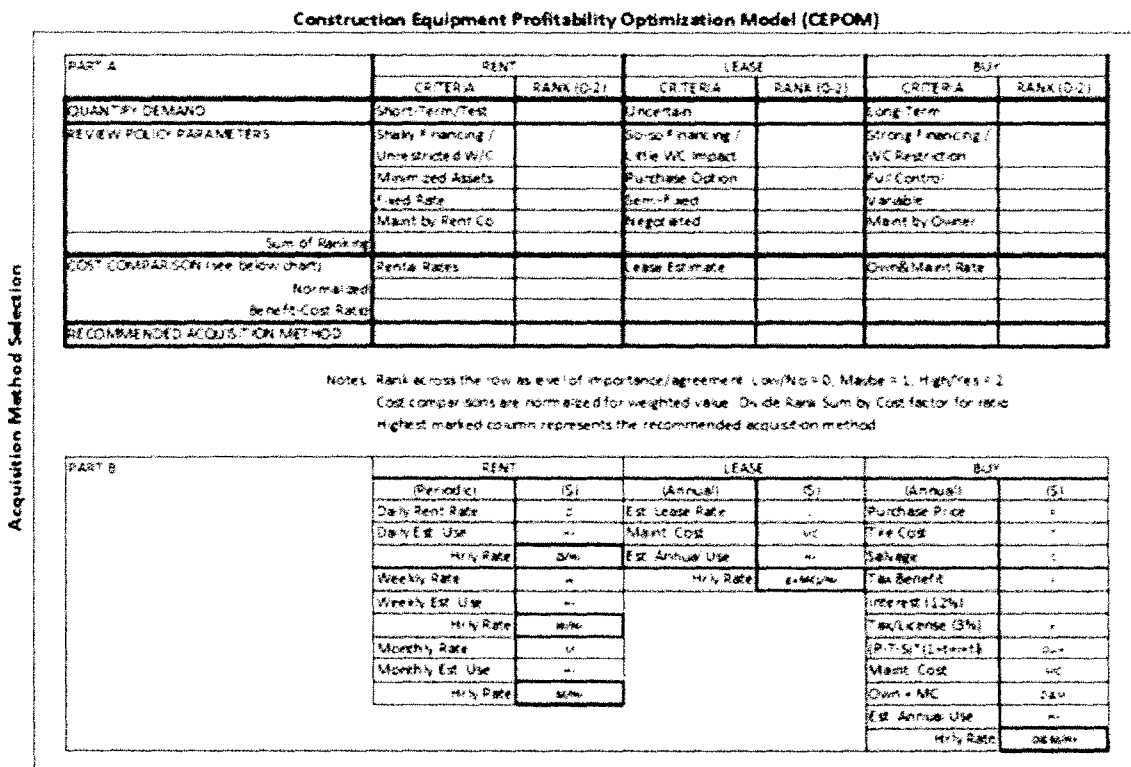


Figure 4-2 CEPOM Acquisition Selection Method

The second portion of the Construction Equipment Profitability Optimization Model (CEPOM) is that of profitability optimization. The model establishes two distinct methods for the separate private and public entities. Each of these separate methods is explored in detail in the follow subsections.

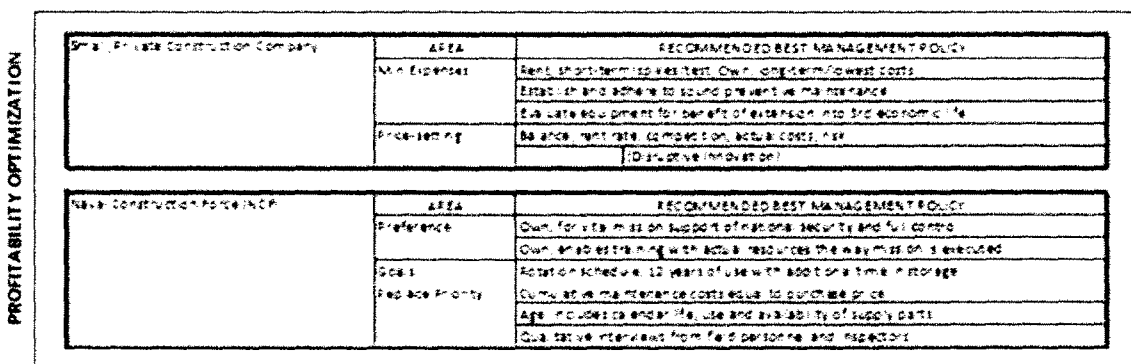


Figure 4-3 CEPOM Profitability Optimization

4.1.1. Small, Private Construction Company

It is expected that typically a small, private construction company will select renting as the method for short-term or trial period equipment needs and ownership for all others because of the financial benefit. This permits the isolation of high rental rates to only impact a short period and not accrue ownership charges of excess equipment. If the company is unsure of the demand, then the selection of leasing or evaluating break-even points is recommended. After selection of the acquisition method, there are two areas of important factors to optimize on the private company's profit. These are the areas of minimizing costs and "price-setting" or developing bid charge rates.

To minimize long-term expenses, the private company chooses ownership. Optimization of profit includes minimizing the maintenance/repair costs through implementation of a sound preventive maintenance plan as previously discussed (Caterpillar 2000, and Panagiotidou and Tagaras 2006). The second possible minimized cost is a life extension into the third economic life presented allowing equipment that has negligible ownership costs to continue providing revenue.

The second area of "price-setting" is rarely seen in construction equipment management literature and left to the business focused literature. Though many references exist for guidance in this area, it is recommended that Anthony et al. (2008) disruptive innovation technique be used. This process of price-setting requires additional research outside of this study to develop the actual rate. The process is simple. First, identifying what the target market is willing to pay, researching comparable prices in the industry, and establishing the estimated bottom-up expenses. After these three numbers are found, a comparison can be charted to see what gap lies between that of the "willingness-to-pay" rate and the expected expenses. This gap reveals a possible profit margin. This is then balanced with competitor prices and the risk comfort of the company in bidding.

This research recommends that optimization of profitability will be realized when the expenses are minimized and the charged rate for bidding is that of the higher hourly rate of renting or RSM means averaged price for the local economy. This comfortably puts

the owner in a position of reaping the benefits of purchasing equipment while having the option to rent in a required circumstance.

4.1.2. Naval Construction Force

Profitability for a public entity is much different. As defined in the introduction, profitability is recognized as the optimization of the given budget to fulfill all mission funding requirements. The different pools of money and their restrictions are not part of this study. So, in general, it will be assumed that a budget exists for funding the costs related to maintaining and acquiring the equipment. Within this given budget, the older the equipment, the higher the percentage of funding is spent on maintenance and less on new acquisitions. This creates a cycle of diminished returns. There is likely a fluctuating breaking point that optimizes this cycle within a given budget.

It is recommended that three areas of management policies are used to optimize the public budget cycle. The first area is recognizing the preferences of ownership. This fulfills the mission requirements and optimizes on the training capacities. It is also the lowest annual cost, optimizing the budget program over several years. The second area of goals is a recommended life cycle for placement. For the NCF, this must include the time in warehouse storage (PWRMS) or at sea (PMF). This research recommends, based on the highest percentage of annual use and manufacturer's life expectancy, that this time period should be 12 years plus the time spent in storage (assuming storage is out of the environment, but not climate controlled).

The third area of factors is the replacement prioritization. It was found to be similarly structured over the three Departments of Transportation discussed. Within this, three policies are recommended. The prioritization of replacement should include those pieces of equipment that have had cumulative maintenance/repair costs equal to that of the purchase price (not including the preservation and de-preservation significant to the warehousing cycle). This is based on the two methods of LCC calculations, Caterpillar and USACE, estimating that over a full life 100% of the purchase price less tires would be spent on maintenance. Two other primary methods were thrown out due to the skewed numbers related to data collected. These were the Association of General Contractor's

(AGC) method of applying 250% of the depreciation value as the estimated costs of maintenance/repair excluding FOG and the Peurifoy method estimating lifetime maintenance/repair costs at 60% of the purchase value. Age should also be considered by not just manufacturer date but also use life in hours or miles and the availability of repair parts which has been found to be an issue late in the life of NCF CESE. Finally, a qualitative analysis involving interviews from field personnel and inspectors (preservation process) should be considered for the specific pieces.

These management policies will minimize cost and maximize equipment condition for mission success. Depending on the best fit cycle for the operational tempo of units, the recommended replacement age of equipment will fluctuate. Limited data availability affected the proof of this recommendation.

4.1.2.1. Inherent Differences

NCF equipment requirements and use are inherently different from that of a private company. Equipment average annual use is much less due to the ready reserve requirement for national security. The operation of equipment is significantly different by environments, adaptations and operators. The environment for equipment use is dependent upon the locale of the mission. It could be mountainous terrain of Pakistan after an earthquake, the jungles of Southeast Asia after a typhoon, the deserts of the Middle East or the snowy environment of Afghanistan. The combat environment has also established a requirement for adapting the equipment for armor which affects productivity through demand of power to air conditioning units and power decrease for the extra weight not included in the design.

The operator is a subject of its own. Typically, within a small, private construction company there are only a few operators, maybe even one, that will employ that piece of equipment. This rests the responsibility and pride of ownership on a small number more easily supervised. Within the NCF, this piece may be operated by 12 different service members in one unit across three units in a year and maintained by just as many different individuals. This is the reason for ownership being important for training capacity. The further magnification of this impact on equipment life is a greater

number of new operators. In a small, private company, a new operator may only be seen every few years. Within the NCF, the majority of operators have had less time on that piece of equipment than a private operator will accumulate in a year. All of these inherent differences affect the equipment life.

The equipment specifications are very similar to commercial needs with few changes. Until 2006, the NCF would purchase products from manufacturers such as Caterpillar and John Deere with only one change – the paint color. The equipment would be painted by the manufacturer before delivery to the U.S. Navy. The common color was “Seabee green” until the conflict in Iraq changed some color needs to “desert tan.” Since 2006, the requirement or specification of armor has also been established. Typically, the armor is merely an addition to the commercial equipment which results in reduced productivity and possibly increased maintenance requirements due to the heavier weight not considered within the design phase (as seen in the life cycle of high-mobility multi-wheeled vehicles or HMMWV’s). The use of commercial products with minor changes is the preferred method of acquisition for reducing cost and benefiting from a wider target market of the supplier.

4.1.2.2. Current Plan

With the requirement of a ready reserve fleet, it was determined by the NCF that a cycle of rotating equipment from use to the warehouse would be better than leaving equipment in either state for its life. As with any mechanical system, construction equipment is designed for use so a storage period will create maintenance requirements due to lack of lubrication through operation.

In the past, it was figured that a rotation of warehousing the new equipment for a period of 4-5 years, then rotate to use for 4-5 years and when repeated gave a sound 20 year life and balanced use. In 2006, the NCF estimated that a private company would typically replace at 9 years and found a best fit goal for the NCF at 12 years.

4.1.2.3. Changes by Contingencies

Through operational requirements in the Middle East, many older pieces of equipment had to be replaced and a new requirement of armor was identified. Some of the armor was developed in the field for adaptation and others were purchased with an assembled design. All of the requirements and cost of war (COW) budget supplements stopped the cycle reduction towards the goal of 12 year average life equipment and in some cases completely reset an entire fleet, referred to as a table of allowance (TOA) as specified by policy for a given unit.

4.1.2.4. Recommended Adaption

As previously stated, it is the recommendation of this study to have a goal cycle equal to 12 years of use plus the time in ready reserve. Likely a period in the range of 16 to 20 years depending on the costs of fleet rotation, preservation and de-preservation which is out of the scope of this project. This 12 years is based on the data received from the NCF for CAT 420D Backhoe average annual use and the life expectancy by Caterpillar. As the backhoe was found to have the highest use, it was determined to be the deciding equipment factor.

4.2. Example

In order to better show how to implement the CEPOM, two examples have been included in this report: one example for a small, private construction company, and one example for the NCF. Summaries of the results are included in the following subsections. The completed CEPOM forms for each example are located in the Appendix, Figures A-6 and A-7.

4.2.1. Small, Private Construction Company

As an example for a small, private construction company, the author used the CEPOM to consider the acquisition of a backhoe for use as a perpetual asset as the single piece of

construction equipment in a newly found company. The rankings of 0, 1, or 2 may change from person to person and even more likely between different companies. The end result is expected to be the same due to the number of rows being ranked and the conclusion of the benefit-cost ratio.

The summed rankings for the three alternatives were 3, 5 and 9 for rent, lease and buy, respectively. Part B calculations were calculated on the data acquired and averaged in Chapter 3. The maintenance costs are calculated as 100% of the purchase price over the life of the equipment as suggested by USACE (2007) and CAT (2010). The percentages used in the buy column are averages from background information found in Chapter 2. The resulting prices were \$13.33, \$15.94 and \$12.33 per hour for rent, lease and buy, respectively.

The normalized weights were not drastically different only ranging from 30% to 38%. The final benefit-cost ratios were found to be 9, 13, and 30 for rent, lease and buy, respectively. The result was a preference of purchase with lease as a second and rent as the least preferred or beneficial option.

The profitability optimization portion of the CEPOM is not discussed as it is recommended all of these guidelines be implemented and followed for minimizing cost and maximizing revenues. The end result is an optimal rate of return from equipment use and ultimately the best profit margin possible.

4.2.2. Naval Construction Force

As an example for the NCF and for comparison with the previous example, the author used the CEPOM to consider the acquisition of a backhoe for long-term use as a highly versatile piece of equipment essential to high-mobility units. The rankings of 0, 1, or 2 are more likely to change between different contracting offices as the interpretation of the FAR may be enforced differently. The end result is still expected to be the same.

The summed rankings for the three alternatives were 3, 2 and 9 for rent, lease and buy, respectively, displaying less interest in the lease option than the private example. Part B calculations were the same as the private example except for the buy column. Many of the percentages used in the buy column for the private entity are not applicable

to the public entity. There is no interest charged or taxes and licenses fees, and no recognition of tax benefits for owning. This results in a different hourly rate for NCF purchase at \$11.70 per hour.

The normalized weights were not much more drastic, ranging from 29% to 39%. The final benefit-cost ratios were found to be 9, 5, and 32 for rent, lease and buy, respectively. The result was a preference of purchase with rent as a second and lease as the least preferred or beneficial option. This does not consider the interpretation of the FAR limiting acquisition to purchase or lease with option as described by Karzon (1994).

4.3. Significance of the CEPOM

The CEPOM is unique in being the first model found to include many different aspects of construction equipment management into a concise and simple decision tool. The most significant value added to the industry by the CEPOM is the identification of the different cost factors common and uncommon between the acquisition alternatives, resulting in a more accurate comparison of overall costs.

The CEPOM also focuses on the inclusion of several factors typically left separated. First, it includes quantitative and qualitative factors within a single decision analysis. Secondly, it compares the entire LCC of purchasing to the rent and lease alternatives to provide a comparison not focused on short-term ownership with high recovery value costs (depreciation) skewing the compared rates. Thirdly, the model allows the user to calculate rates based on realistic hours of use instead of a textbook or manufactured estimation of available hours. This is vital as only the using entity knows how many hours of use that equipment will actually see in the given maximum number of available hours. Fourthly, the model covers optimization of the equipment use and not only the best method of acquisition. Because of these combined factors, CEPOM can be implemented by beginners for equipment management and referred to by experienced managers in evaluating the existing processes.

Finally, CEPOM was developed for use by both private and public entities. The background literature reviewed for this research was segregated and addressed only one sector at a time. This model is applicable to both.

4.4. Expanded Benefits

While performing this research, a few select pieces of construction equipment were analyzed due to time allotted. The future extension of this research would be to continue developing more refined evaluation methods for construction specialties and sizes of private companies. This would consist of analyzing a greater variety of pieces of construction equipment enabling segregation of specialty fields and allowing fleet management evaluation to be built for the larger companies.

A larger company would have an easier time applying a small overhead to large projects or many small projects to support an in-house maintenance workforce. This provides more oversight and ownership to equipment operation and profitability. If a larger company can charge a fraction of a percent higher on their bids to support this auxiliary support arm, they are likely to extend the life expectancy of the equipment permitting more profitability from a piece of equipment that has already paid for itself several times and costs a small percentage to maintain compared to the company that must charge for a long-term lease with maintenance included or short-term rentals and insurance expenses.

For the NCF, further analysis could involve a completely new route of comparing host nation rental agreements and local sub-contracts versus organic operation. This study would have to specify the environmental concerns of working in contingency areas and focus on long-term reconstruction decision-making such as continuing in Iraq or other humanitarian missions such as in Africa, South America and other parts of the world. The additional risks of the circumstance would likely be the deciding factor, but the financial evaluation methods could be easily applied for supporting information.

The life cycle of NCF CESE is unique and establishes an interesting further desire to explore what are alternative methods of meeting mission requirements and minimizing cost or loss of life expectancy of the equipment. It is proposed that instead of looking into

a deeper research on this topic in a traditional sense, it would be best for a committee or panel of personnel from the NCF, private construction companies, equipment manufacturers and academia along with assistance from a disruptive innovation consultant to brainstorm and find alternatives that could be analyzed. It is suspected that several of these alternatives would cause a paradigm shift in the planning process of the government and give challenge to determining which ones would have to be stricken due to regulations.

4.5. Limitations

This independent research is limited to only a few pieces of construction equipment due to the nature of differences in the private sector equipment and CESE Fleet as well as time allotted. It is also limited to the data available for analysis. Further benefits would be realized with integration of analysis methods from the experts in the field of mathematics, statistics, and equipment owner/operators.

Some private companies may not benefit from the research due to those pieces of construction equipment selected. For example, a steel erection company may need other information to analyze the decision whether to purchase their own crane. A crane is a very important piece of construction equipment or NCF CESE, but does not often get used within the NCF and therefore was left out of the research to focus on the primary pieces employed and higher density.

Due to the fragmented nature of the construction industry and the inherent differences of every construction project, no one method will suit every purpose. The results of this research will provide a detailed rule of thumb method for decision-making use by a small construction company in the private sector and the larger public agency with a large fleet, such as the NCF.

4.6. Future Extensions

Due to the time limitation of this study, there are several future extensions possible for both the small, private construction company and NCF (public) entities. For the private

entity, the comparison of different maintenance execution methods and data analysis would provide additional support for the developed method, refine it or prove another method for considering this factor of organic (in-house) maintenance, outsourcing or inclusion in rental rates. This significantly impacts the direct costs, the overhead costs and the organizational structure of the company, all impacting profitability.

For the public entity, a comparison of those units with ready reserve storage requirements and those without would further refine or support the above recommendations related to optimal cycle periods. Further analysis of the cycle transfer costs for preservation, de-preservation, transportation and related indirect overhead will enable a better comparison of cycle period benefits for optimization of equipment life and the budget program. In the case of the NCF, more exploration of budget funding and related concerns would also improve the results.

A deeper study into the affect of unique equipment specifications by the NCF compared to the private sector would be another possible extension. If the only change remained the paint color, the existing comparisons would stand with the recognized limitations. With a unique requirement for armor within the military use, a comparison of the productivity impacts and cost impacts of NCF equipment versus the private sector would likely reflect changes in the LCC analysis conducted in this research.

For both the private and public entity, three future extensions are recommended. First, it is recognized that evaluating the comparison of outsourcing the equipment activities through subcontracting was not considered. This is not an available alternative for all military requirements, but it is for those within peace environments. Secondly, a study of the separated maintenance costs between PM and CM or scheduled and unscheduled maintenance would enhance the analysis of costs and profitability. Finally, implementing the developed method and retrieving data as well as feedback would further support or refine the CEPOM.

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APPENDIX

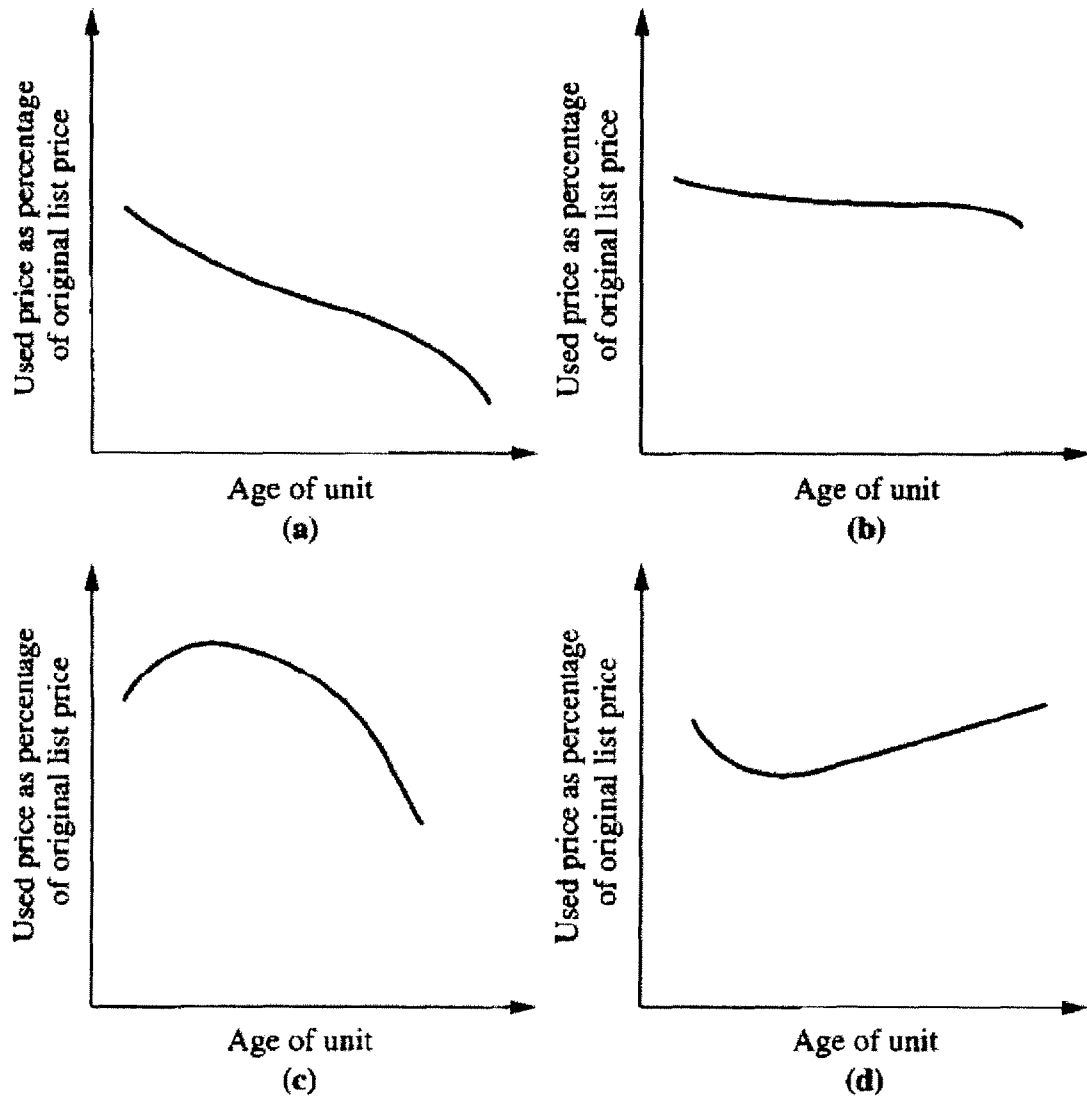


Figure A-1 Used Equipment Price as a Percentage of Original List Price (Peurifoy and Schexnayder 2002)

***Note:** All responding vendors should adjust the values in Blue to reflect actual costs relative to region and or territory. The spreadsheet will then calculate the total cost for each maintenance item relative to the expected period of ownership. The items listed should directly reflect those procedures outlined in the manufacturers Owning and Operating Manual for the machine that has been specified.

Backhoe Loader Life Cycle Cost Bid Form:

Yr/Make/Model _____

Item

No.

	Backhoe Loader	
1	Purchase Price	0
2	Trade In Price / Offer	0
3	Total Maintenance Costs (From Scheduled Maintenance Calculation Form Attached)	\$0.00
4	Maximum Repair Costs (Extended Warranty)	0
5	Residual / Salvage Value	0
	Total Bid Price (1 - 2 + 3 + 4 - 5)	\$0.00

Backhoe Loader Scheduled Maintenance Calculation Form:

Instructions: The intent of this form is to determine the total scheduled maintenance costs that can be expected during the established period of ownership. Service intervals, number of grease fittings, and capacities should be taken directly from the manufacturer's lubrication and maintenance manual. Unit costs given are equal for all vendors. Although there may be a slight variance due to refill capacities, these total costs are made up of labor, overhead, lost production, gaskets, lubricants, filters, and supervisory time. The comparison examines the service intervals for the various units bid and assumes that the manufacturer's recommendations, if followed exactly, will allow the costs that are to be incurred on each unit, to be calculated with reasonable accuracy.

<u>Period of Ownership</u>	<u>Avg Hrs / Year</u>	<u>Number of Years</u>	<u>Total Hours</u>
	0	0	0

A. Grease Fittings: (Per one (1) unit)

Determine the number of fittings at each interval. Insert each number as indicated (if none, write none). Perform calculations and total in the last column.

<u>Total Hrs. Operation</u>	<u>Service Interval</u>	<u>No. of Fittings</u>	<u>Cost Per Fitting</u>	<u>Total</u>
0	10	0	\$0.25	\$0.00
0	50	0	\$0.25	\$0.00
0	100	0	\$0.25	\$0.00
0	250	0	\$0.25	\$0.00
0	500	0	\$0.25	\$0.00
0	1000	0	\$0.25	\$0.00
0	2000	0	\$0.25	\$0.00
Total Cost (A)				\$0.00

B. Engine Oil & Filter: From manufacturer's maintenance manual determine crankcase drain and refill interval. Insert this hourly number and perform the calculation to arrive at the total cost for an engine oil change.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Cost of Filters	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00
<u>Total Hrs. Operation</u>	<u>Service Interval</u>		
0	0	Total Cost (B)	\$0.00

C. Transmission Oil: From manufacturer's maintenance manual determine transmission drain and refill interval. Insert this hourly number and perform the calculation to arrive at the total cost for a transmission oil change.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Cost of Filters	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00

<u>Total Hrs. Operation</u>		<u>Service Interval</u>		
	0	0	Total Cost (C)	\$0.00

D. Hydraulic System: From the manufacturer's maintenance manual determine the hydraulic system's drain and refill interval. Insert this hourly number, insert the total capacity (in gallons) and perform the calculation to arrive at the total cost for a hydraulic system service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Cost of Filters	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00

<u>Total Hrs. Operation</u>		<u>Service Interval</u>		
	0	0	Total Cost (D)	\$0.00

E. Front & Rear Axle Oil: From the manufacturer's maintenance manual determine the Axle's drain and refill interval. Insert this hourly number, insert the total capacity (in gallons) and perform the calculation to arrive at the total cost for an Axle service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Cost of Filters	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00

<u>Total Hrs. Operation</u>		<u>Service Interval</u>		
	0	0	Total Cost (E)	\$0.00

F. Front & Rear Final Drive (Planetary): From the manufacturer's maintenance manual determine the Front & Rear Final Drive drain and refill interval. Insert this hourly number, insert the total capacity (in gallons) and perform the calculation to arrive at the total cost for a Front and Rear Final Drive service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Cost of Filters	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00

<u>Total Hrs. Operation</u>		<u>Service Interval</u>		
	0	0	Total Cost (F)	\$0.00

G. Cooling System: From the manufacturer's maintenance manual determine the cooling system's drain and refill interval. Insert this hourly number, insert the total capacity (in gallons) and perform the calculation to arrive at the total cost for a cooling system service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Number of Gallons	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00
<u>Total Hrs. Operation</u>		<u>Service Interval</u>	
	0	0	Total Cost (G) \$0.00

H. Engine Vibration Damper: From the manufacturer's maintenance manual determine the Engine Vibration Damper replacement interval (If Required). Insert this hourly number, insert the labor cost and perform the calculation to arrive at the total cost for an engine vibration damper service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Parts	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00
<u>Total Hrs. Operation</u>		<u>Service Interval</u>	
	0	0	Total Cost (H) \$0.00

I. Hydraulic Hoses: From the manufacturer's maintenance manual determine the Hydraulic Hose replacement interval (If Not Required write None). Insert this hourly number, insert the labor cost and perform the calculation to arrive at the total cost for an engine vibration damper service.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Parts	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00
Cost per Change			\$0.00
<u>Total Hrs. Operation</u>		<u>Service Interval</u>	
	0	0	Total Cost (I) \$0.00

J. Other: From the manufacturer's maintenance manual include the cost of any other items that have a recommended service interval that falls within life of the contract.

	<u>Units</u>	<u>Cost Per Unit</u>	<u>Total</u>
Parts	0.0	\$0.00	\$0.00
Labor	0.0	\$0.00	\$0.00

Cost per Change				\$0.00
<u>Total Hrs. Operation</u>		<u>Service Interval</u>		
	0	0	Total Cost (J)	\$0.00

TOTALS: (Per one (1) unit) Listed below are each of the categories just calculated. Insert the total number of each category in the space provided and add the column.

A. Grease Fittings	\$0.00
B. Engine Oil and Filters	\$0.00
C. Transmission Oil	\$0.00
D. Hydraulic System Changes	\$0.00
E. F&R Axle Oil Changes	\$0.00
F. F&R Final Drive Changes	\$0.00
G. Cooling System Changes	\$0.00
H. Engine Vibration Damper	\$0.00
I. Hydraulic Hose Replacement	\$0.00
J. Other	<u>\$0.00</u>
TOTAL SCHEDULED MAINTENANCE COSTS:	\$0.00

Figure A-2 Backhoe Loader Maintenance Specifications Spreadsheet (CAT 2009)

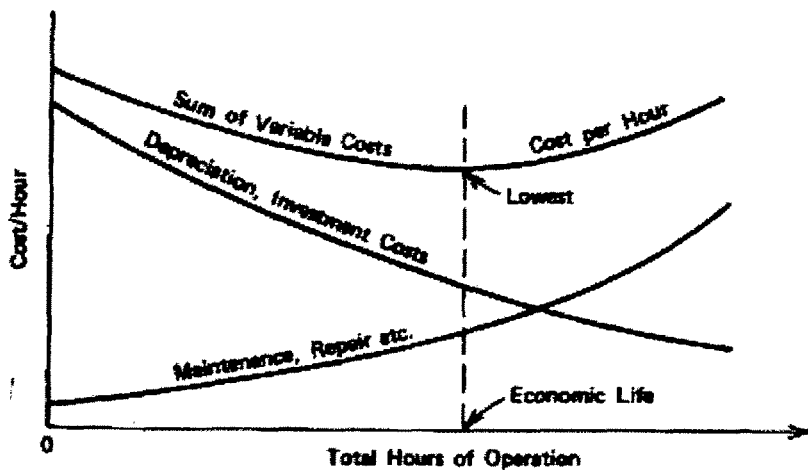


Figure A-3 Chart of Equipment Variable Costs (Day and Benjamin 1973)

	PRIVATE CONSTRUCTION COMPANY	EQUIPMENT RENTAL	EQUIPMENT MANUFACTURER	NAVAL CONSTRUCTION FORCE
Purchase Price	X	X	X	X
Maintenance Costs (PM / CM)	X	X		X
Life Expectancy	X	X	X	X
Operational Use Records	X	X		X
<i>Desired</i> , time in operation costs incurred	X	X		X
Environment of employment (climate, operator experience, etc.)	X	X		X
<i>Desired</i> , annual budget versus actual expended (maintenance, rental, lease, purchase)	X	X		X
Company financial statements (summary of equipment expenses)	X	X		

Table A-1 Required Data from Each Source Identified

	ZONE A Moderate	ZONE B Average	ZONE C Severe
FELLER BUNCHERS	Continuous felling and stacking in good underfoot conditions. Flat ground uniform trees below 305 mm (12 inches). 18,000 Hr	Continuous cycling in good under- foot conditions. Rolling terrain, some trees up to 508 mm (20 inches) or some hardwoods. 15,000 Hr	Continuous cycling in steep terrain over stumps and fallen trees. Most trees 508 mm (20 inches) or larger hardwoods. 10,000 Hr
BACKHOE LOADERS	Light duty utility applications in light to medium soil. Trenching depths less 1.83 m (6 ft.) 12,000 Hr	Utility applications in medium to heavy soil. Occasional use of con- stant flow implements. Dig depths to 3.05 m (10 ft.) 10,000 Hr	Production applications or digging in rock. Regular use of constant flow implements. Dig depths over 3.05 m (10 ft.) 5,000 Hr

Figure A-4 Estimated Equipment Life in Hours (CAT 2000)

Backhoe Loader/Landscape Loaders

John Deere	Case	Caterpillar	EarthForce	Fermec	Fox	Hydremat	JCB	Komatsu	New Holland	Terex
210LE	570 L XT 2 570 L XT 2 Turbo	—	—	650B	410-4	—	212SU	—	545D LV60 LV60T	
310G	580 M 580 M Turbo	416D	EF6 EF6E	750B		—	212S 214-e	—	LB75.B	
310SG 315SG	580 Super M	420D 420D IT	—	760B		—	214 214e-4 214-e Turbo	WB140-2 WB140PS-2	LB110 LB115.B LB90	SMB2041
410G	590 Super M	430D 430D IT	—	960B 960SB		—	214S 215S 217 217S	WB150AWS-2 WB150-2 WB150PS-2	—	
710G	—	446B	—	960SB		908B	—	—	—	

Figure A-5 Competitive Equipment Cross-Reference (John Deere 2003)

Construction Equipment Profitability Optimization Model (CEPOM)

PART A	RENT		LEASE		BUY	
	CRITERIA	RANK (0-2)	CRITERIA	RANK (0-2)	CRITERIA	RANK (0-2)
QUANTIFY DEMAND	Short-Term/Test	0	Uncertain	1	Long-Term	2
REVIEW POLICY PARAMETERS	Shaky Financing / Unrestricted W/C	0	So-so Financing / Little WC Impact	1	Strong Financing / WC Restriction	2
	Minimized Assets	1	Purchase Option	1	Full Control	2
	Fixed Rate	1	Semi-Fixed	1	Variable	1
	Maint by Rent Co.	1	Negotiated	1	Maint by Owner	2
Sum of Ranking		3		5		9
COST COMPARISON (see below chart)	Rental Rates	13.33	Lease Estimate	15.94	Own&Maint Rate	12.33
	Normalized	0.32		0.38		0.30
	Benefit-Cost Ratio	9.36		13.05		30.37
RECOMMENDED ACQUISITION METHOD						

Notes: Rank across the row as level of importance/agreement. Low/No = 0, Maybe = 1, High/Yes = 2.
 Cost comparisons are normalized for weighted value. Divide Rank Sum by Cost factor for ratio.
 Highest marked column represents the recommended acquisition method.

PART B	RENT		LEASE		BUY	
	(Periodic)	(\$)	(Annual)	(\$)	(Life)	(\$)
	Daily Rent Rate	247	Est. Lease Rate	25596	Purchase Price	60000
	Daily Est. Use	8	Maint. Cost	5000	Tire Cost	3000
	Hrly Rate	30.875	Est. Annual Use	1920	Salvage	0
	Weekly Rate	770	Hrly Rate	15.9354167	Tax Benefit	-4%
	Weekly Est. Use	40			Interest (12%)	12%
	Hrly Rate	19.25			Tax/License (3%)	3%
25596	Monthly Rate	2133			(P-T-S)*(1+i+it)	63270
5000	Monthly Est. Use	160			Maint. Cost	60000
	Hrly Rate	13.33125			Own + MC	123270
					Est. Life Use	10000
					Hrly Rate	12.327

Small, Private Construction Company	AREA	RECOMMENDED BEST MANAGEMENT POLICY
	Min Expenses	
		Establish and adhere to sound preventive maintenance
Price-setting		Evaluate equipment for benefit of extension into 3rd economic life
		Balance; rent rate, competition, actual costs, risk (Disruptive Innovation)

Naval Construction Force (NCF)	AREA	RECOMMENDED BEST MANAGEMENT POLICY
	Preference	
		Own, enables training with actual resources the way mission is executed
Goals		Rotation schedule, 12 years of use with additional time in storage
Replace Priority		Cumulative maintenance costs equal to purchase price
		Age; includes calendar life, use and availability of supply parts
		Qualitative interviews from field personnel and inspectors

Figure A-6 CEPOM Example for a Small, Private Construction Company

Construction Equipment Profitability Optimization Model (CEPOM)

PART A	RENT		LEASE		BUY	
	CRITERIA	RANK (0-2)	CRITERIA	RANK (0-2)	CRITERIA	RANK (0-2)
QUANTIFY DEMAND	Short-Term/Test	0	Uncertain	0	Long-Term	2
REVIEW POLICY PARAMETERS	Shaky Financing / Unrestricted W/C	0	So-so Financing / Little WC Impact	0	Strong Financing / WC Restriction	2
	Minimized Assets	2	Purchase Option	1	Full Control	2
	Fixed Rate	1	Semi-Fixed	1	Variable	1
	Maint by Rent Co.	0	Negotiated	0	Maint by Owner	2
Sum of Ranking		3		2		9
COST COMPARISON (see below chart)	Rental Rates	13.33	Lease Estimate	15.94	Own&Maint Rate	11.70
	Normalized	0.33		0.39		0.29
	Benefit-Cost Ratio	9.22		5.14		31.51
RECOMMENDED ACQUISITION METHOD						

Notes: Rank across the row as level of importance/agreement. Low/No = 0, Maybe = 1, High/Yes = 2.
 Cost comparisons are normalized for weighted value. Divide Rank Sum by Cost factor for ratio.
 Highest marked column represents the recommended acquisition method.

PART B	RENT		LEASE		BUY	
	(Periodic)	(\$)	(Annual)	(\$)	(Life)	(\$)
	Daily Rent Rate	247	Est. Lease Rate	25596	Purchase Price	60000
	Daily Est. Use	8	Maint. Cost	5000	Tire Cost	3000
	Hrly Rate	30.875	Est. Annual Use	1920	Salvage	0
	Weekly Rate	770	Hrly Rate	15.9354167	Tax Benefit	0%
	Weekly Est. Use	40			Interest (12%)	0%
	Hrly Rate	19.25			Tax/License (3%)	0%
25596	Monthly Rate	2133			(P-T-S)*(1+i+i+t)	57000
5000	Monthly Est. Use	160			Maint. Cost	60000
	Hrly Rate	13.33125			Own + MC	117000
					Est. Life Use	10000
					Hrly Rate	11.7

Acquisition Method Selection

Profitability Optimization

Small, Private Construction Company	AREA	RECOMMENDED BEST MANAGEMENT POLICY
Min Expenses		Rent, short-term/spikes/test; Own, long-term/lowest costs
		Establish and adhere to sound preventive maintenance
Price-setting		Evaluate equipment for benefit of extension into 3rd economic life
		Balance; rent rate, competition, actual costs, risk (Disruptive Innovation)

Naval Construction Force (NCF)	AREA	RECOMMENDED BEST MANAGEMENT POLICY
Preference		Own, for vital mission support of national security and full control
		Own, enables training with actual resources the way mission is executed
Goals		Rotation schedule, 12 years of use with additional time in storage
Replace Priority		Cumulative maintenance costs equal to purchase price
		Age; includes calendar life, use and availability of supply parts
		Qualitative interviews from field personnel and inspectors

Figure A-7 CEPOM Example for the Naval Construction Force

