



# OPTIMUM EQUIPMENT MANAGEMENT THROUGH LIFE CYCLE COSTING

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## Abstract

Large mining operations need equipment that consistently performs as expected. The most effective way of ensuring this is to have a defined life cycle with an optimized maintenance strategy. The determination of this life cycle is an economic decision, influenced by the construction and utilization of the equipment. An effective Life Cycle Cost (LCC) tool must be able to process the many variable factors involved.

Many factors influence the costs that are associated with a machine over its life. The most variable of these are the costs of maintaining the equipment. Maintenance costs are dependent not only on the utilization of the machine, but also on the strategy that has been developed to support the machine through its life. A combination of supplier support, component changes, regular servicing and unscheduled maintenance needs to be modelled, based on a variety of drivers.

Traditionally spreadsheets have been used to model these factors, but the increasing complexity of the situation can make spreadsheets unwieldy and difficult to manage. A database solution that breaks each activity into its constituent components, links them to an associated mine plan driver and

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then aggregates the result is the ideal tool to provide a time based cost profile. RPM's XERAS financial modelling software enables such models to be built. The evaluation of a number of scenarios, representing different maintenance strategies/life cycles can be rapidly undertaken. Auditability through inbuilt tools is required to provide easy tracing of data. Use of the host company's account structure allows for reporting against the standard chart of accounts.

## Introduction

Mining operations consistently need equipment that is available, and able to perform to its maximum potential. In hard times the need for efficiency drives downtime and costs to a minimum. In boom times, the need for productivity drives availability and utilization to a maximum. The Maintenance Manager is always under pressure to make the equipment perform. The most difficult part of his job is often a lack of knowledge on how long the equipment has to last. The short term view can lead to interim fixes that accumulate into larger problems. It is always difficult to justify major overhauls and upgrades when the pressure to produce more from the mine is ever present.

Ideally each piece of equipment should be operated for a defined life. The maintenance of that equipment can then be optimized to deliver this life. Where fleets of similar equipment are in use, variations in equipment performance can be accommodated by variations in the replacement order. This is an ideal situation, but how can the Maintenance Manager convince both the Production and Finance Managers to replace the equipment at a specified life? The answer is to undertake a LCC analysis in advance of the equipment replacement decision.

Life Cycle Costing is an analysis process that identifies the costs associated with all stages of the equipment's life. Further it identifies the key drivers of these costs and how they vary with time. The sum of all of these costs represents the total outlay required to own the equipment. This cost can be expressed as an absolute, or as a rate that varies with time. When this rate is at a minimum, then the life of the equipment is at its optimum.

When some of these drivers are themselves functions of production parameters that vary with time, the analysis can become quite complex. Traditionally spreadsheets have been used to undertake this analysis. While highly flexible, spreadsheets can be difficult to interpret, depending on the logic used to create them. Modern spreadsheet products have extremely advanced analysis functions that can be used to assist in the evaluation, however their complexity makes the auditing of the process even more difficult.

An ideal solution is to use a database, with the analysis steps broken down into simple stages. A database tool that allows for standard formatting removes the errors associated with copying large areas of formulas and formats. A database tool also allows for the inclusion of auditing tools that trace data from its original entry point to its calculated outcome.

## Methodology

The costs associated with owning equipment can be grouped in the following categories:

Initial purchase, construction and commissioning costs;

- Financing costs;
- Direct operating costs;
- Maintenance costs (including overhauls);
- Downtime costs;
- Decommissioning costs; and
- Cost recovery on disposal

Depending on the business model in use for the organization, it may be relevant to consider the income generated by the equipment. When the asset is a part of an integrated mining cycle (such as a haul truck) then it is often difficult to assign a value to this production on an individual unit basis. For the purposes of clarity this paper ignores the income stream and considers only the cost stream.

### Initial Purchase, Construction and Commissioning Costs

At the start of the equipment's life, there will be considerable expenditure involved with getting the equipment into the production cycle. This is likely to involve the purchase of the equipment, its construction, and all associated tasks involved with its commissioning. While the timeframe involved in this expenditure is usually short (a matter of months) for mobile equipment, it can extend over many years for complex mineral processing plant.

At this stage, the equipment is yet to add value. In most organisations the value of these costs will be capitalized onto the balance sheet. As a result, these costs are generally tightly controlled. Justification of these costs can be a long and arduous process, so there is a tendency to drive these costs to a minimum. For the purposes of this paper we will assume an initial cost of \$3,000,000 spread over the first three periods of the equipment's life.

### Financing Costs

The cost of finance can vary greatly between organisations and with time. Even more importantly, the inclusion of financing costs against a piece of equipment is often a case of company policy. For the purposes of this paper, we will assume that the total initial cost will be financed at an interest rate of 7%.

It should be noted that across the life of the machine, the total financing cost is more than the initial cost of the machine! Beware of the sensitivity to changes in interest rates.

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## Direct Operating Costs

The operating cost of the machine is directly linked to the amount of time it is in use, and inefficiencies that accumulate through the machine's life. As the machine ages, it is expected that the overall utilisation of the machine will degrade. This has the effect of dampening the increase in costs over time. The effect is not total, and a typical curve for the cumulative operating costs.

Once again, note that over the life of the machine, the operating costs approach the same amount as the initial capital cost.

## Maintenance Costs

The maintenance costs of the machine will vary greatly with time. The hourly maintenance cost will increase as the machine ages. This is offset by the lower utilization caused by the greater maintenance needs. However, the cost of repairs will increase with time as more components require replacement. Similarly, regular overhauls will result in significant jumps in cost, but provide a higher level of availability immediately after the overhaul. The end result of this is a jagged, increasing pattern of costs accumulating across the equipment's life.

The prediction of these costs is a complex process that varies with time, equipment utilization and maintenance strategy. An integrated database tool is required to accurately model and predict this curve. The total costs are likely to be of the same order, or exceed the initial purchase price.

## Downtime Costs

Downtime costs need to be carefully modelled to ensure that the real costs of machine unavailability are captured without doubling up on the maintenance costs already identified. The downtime costs should only be those real costs that can be attributed to the lack of having the machine. A true downtime cost would be the cost of hiring a replacement machine. A backup machine provided by the equipment supplier is an example of this. The cost of such a machine is likely to be always greater than the cost of the operator's own machine. This higher rate reflects the need to have a machine available for hire, and the hirer's need to sustain a profitable business. The demand for the substitute machine will vary with availability of the operator's machine and thus shown variance with time. If we assume that there is a need for a constant level of machine operation, and that this is covered by sourcing a replacement machine, then the cost profile of this downtime can be represented by a roughly linear curve with periodic peaks due to major maintenance outages.

## Decommissioning Cost

Inevitably, there is a cost associated with the removal of a piece of equipment from use. This can vary greatly with the type of equipment under consideration, but is unlikely to vary greatly with time. An estimate of this cost is hard to make, but can

usually be associated with the initial cost of the machine. We shall assume in this case that the cost of disposal is 5% of the initial cost.

## Cost Recovery on Disposal

The value of equipment at the time of disposal is subject to the vagaries of the market at the time. I have known of operations that did not bother to scrap machines as the cost of removing the scrap from site was greater than its value at the time. In general though, a piece of equipment is inherently worth less than its initial cost from the start of its life.

The value of the machine then decays further as its life progresses. Overhauls can add value back in to the machine, but this will never restore its full value. In modelling this cost it is important to model a true estimate of what a third party would pay for the equipment and not the financial values that are carried on the Asset Register.

Note that this is a negative cost, to reflect that it is income rather than expenditure. It is a factor that needs to be carefully considered, as individual factors can make the machine worth a significant amount at certain points in time. Currently the shortage of large earthmover tyres has raised values for old machinery to extraordinary levels if they have good tyres fitted. Similarly, the tax laws in Australia at one stage made it possible to sell a one year old light vehicle for more than its purchase price if you had the right type of operation!

## Life Cycle Cost

The sum of all of these costs represents the net expenditure on the equipment over its life.

Note that the total expenditure across 60 periods is now more than three times the initial cost of the machine. This highlights that the initial cost does not represent the majority of the cost. What is more important to the analysis is that the curve increases with time. If we look at the costs on the basis of a rate rather than a total, we see how the unit costs for the machine vary with time. In particular, we note that the curve reaches a defined minimum. That is, a point in the equipment's life, the cost per period of owning the machine is at a minimum. Therefore, the cost of owning this type of machine will be minimised if it is replaced at this point in time. We have identified the life to which the machine will be managed.

## Results and Discussion

### Minimising Costs

For our example machine, we identified that there was an optimum point when the machine should be replaced to minimize costs. An indication of the scale of costs to be saved by undertaking this approach can be seen in the following table. Changing the machine out after five years with a similar machine will result in a saving of  $(\$106,385.92 - \$81,652.54) \times 120 = \$2,968,005.94$  over 60 periods. This is almost equal to the initial cost of the equipment.

Initial Machine Cost	\$3,000,000
Finance Rate	7%
Operating Cost	\$150/hr increasing over time
Maintenance Cost	\$150/hr increasing over time
Availability	95% decreasing over time
Utilisation of Available Time	95% constant
Supplementary Machine Hire	\$330/hr constant
Decommissioning Cost	\$150,000 fixed (5% of initial cost)
Cost Recovery on Disposal	80% decreasing to 2% over time
Initially Specified Life	120 Periods (10 years) @ \$81,652.54/period
Optimum Life	60 periods (5 years) @ \$106,385.92/period

### Tax, Interest, Inflation and Other Effects

The effects of taxation, depreciation, varying inflation and interest rates all have an effect on this analysis. It is important to capture these effects as they apply to the local legislation and company policy. In general, these effects tend to move the minimum point in time and value. They do not tend to change the shape of the curve significantly. Thus they will change when you need to replace the machine but not the fact that there is a clear economic argument to replace it.

### Variability

As can be seen from the discussion above, the costs associated with the machine are complex and variable. The analysis described is a simple one to show the principle. This analysis should ideally be done in advance of the purchasing decision. This will allow for the maintenance and operating practices to be tailored for the optimum life that has been identified. However, these actions then change the assumptions on which the analysis has been made.

To avoid gross generalizations, a database tool that can model a number of scenarios is best for the analysis. Correct development of such a tool will allow for consistency in analysis with variation in assumptions and data. As the analysis involves a number of operational areas of the organization, such a tool needs to be constructed so that each functional area is responsible for a defined part of the process. The ability to trace data through the model is a key requirement to ensure consistency of evaluation and improve confidence in the result.

### Conclusion

The use of a Life Cycle Costing approach to equipment replacement is common in industries such as power generation and airline transport. In these cases, the nature of the equipment and their regulation reduces the variability in costs so that the analysis is simpler. To date its use in the mining area has been limited by the highly variable nature of the costs involved and the factors that drive these costs.

Integrated database tools, such as XERAS now can allow for the development of time based models that can analyze a number of scenarios and produce reliable results. This allows the Mine Maintenance Manager the opportunity to specify equipment lives at the time of purchase and tailor the maintenance strategy to this life.