

LCC methodology application for equipment replacement strategy definition

<http://dx.doi.org/10.1590/0370-44672018720141>

Eduardo Cruvinel Kayashima^{1,2}

<https://orcid.org/0000-0002-6377-5079>

Ubirajara Marques Junior^{1,3}

<https://orcid.org/0000-0002-5302-9451>

¹CSN Mineração - Maintenance Engineering,
Congonhas - Minas Gerais - Brasil

E-mails: ²ekayashima@hotmail.com,
eduardo.kayashima@csn.com.br,

³biramjunior@yahoo.com.br,
ubirajara.junior@csn.com.br

Abstract

Presented herein are the economic viability results when applying the analysis techniques for investments to replace mobile equipment. Due to the high cost involved in these exchanges, an economic model was designed based on Life Cycle Cost analysis and through the Equivalent Annual Uniform Cost method, evaluating and comparing the best option: to maintain or replace the equipment, and to define when is the best time for this replacement. This methodology, besides defining the best moment of replacement, is also applicable for defining the moment of the equipment purchases because this methodology allows cost annualization and consequently, it is possible to compare equipment with different life times. This means, they allow the choice of the best financial option for the company.

keywords: cost; economic feasibility; replacement.

1. Introduction

Replacing an asset is a common practice in business, and is a strategic decision of the organization that takes into account the optimization of operating costs, maintenance and better operational efficiency. With the equipment life progress, they can present excessive operational and maintenance costs, in addition to the new technological alternatives that make the fleet obsolete. In this way, the main difficulty in replacing assets is the definition of the optimal moment of substitution within their economic life. In this study, the equipment Life Cycle Cost analysis technique was used through the Equivalent Uniform Annual Cost (EUAC) methodology to verify the financial return of the asset replacement.

This method uses universally ac-

cepted accounting procedures to determine the total costs of the project or the acquisition of property. It provides all required information that is necessary, not only the capital cost, but also the future operating costs, abandonment costs and even revenue losses due to delayed or compromised production because of equipment failures. The equipment life cycle includes all steps related to the supply and use of an asset; in other words, specification, design, manufacturing, operation and maintenance, until replacement or final disposal. Life cycle cost is the sum of all the costs mentioned above.

Although the life cycle cost approach can be employed at any stage of a project life cycle, the best results are usually

achieved in the early stages, because it is at the development and design stage that future costs are determined. This project started with the methodology application in the replacement phase (end of life), and later was applied in the initial stage, during the definition of the best fleet to achieve lower production costs.

The trigger for this study's development was the intention to provide alternatives to increase competitiveness, reducing cost per worked hours, after an equipment parameter evaluation, which included: available hours, hourly productivity and component changes. The component life information was defined by the reliability curve of each component; historical and benchmark parameters were used.

2. Material and method

Life Cycle Cost in decision making

The life cycle cost is information that supports company leaders to define investment strategies in an increasingly competitive market scenario. By using universally accepted accounting procedures to determine the total cost of the project or ownership cost, it is possible to visualize possible horizons in the short or long term, defining the best alternative to be followed within a

series of conditions.

Considering all stages of an equipment life cycle, the important stages are the acquisition / replacement phases because without the correct analyses, they can include some collateral effects, that are:

- Equipment acquisition without supplier analysis, availability of spare parts and technical assistance. This

can bring some problems of reliability during the operation time, thereby compromising the company's results;

- Operation and maintenance are the highest equipment costs, and many times during the acquisition time, the only analysis that is made is the lowest purchase price. So, costs can be much higher than expected, in the future, without the asset life cycle cost analysis.

Life cycle cost objectives analysis

- Evaluation and selection of equipment and spare parts;
- Evaluation and qualification of suppliers;
- Resources optimization;
- Provide information to decide between equipment upgrade or replacement;
- Design optimization to obtain the

lowest life cycle cost;

- Integration between economic analysis and daily technical decisions.

With the present approach, it is expected to obtain the best result from the view point of cost and fleet operation, since the method was used in the two crucial moments: end of life and acquisi-

tion. In other words, the end of life was defined for the operational fleets, and the equipment that is being acquired for replacement are undergoing the same analysis. So parameters for future costs and performance are already defined and these definitions are ensured in contract, according to CSN Mineração interests.

Equivalent Uniform Annual Cost (EUAC)

The Equivalent Uniform Annual Cost (EUAC) is an indicator that allows to compare projects in different horizons of time, using all costs involved; in this case it represents all cash expenditures due to owning and operating an asset.

The EUAC is a widely used method

for fleet replacement studies, where it is difficult to represent the financial return on the asset. As a result, the EUAC will represent the cost curve year by year, and the lowest value will indicate the optimum moment to replace the equipment. Because of a situation where only

information related to equipment costs was available, the EUAC method was chosen for this study. To complement the method, an analysis was made for the operational parameters of the equipment, such as productivity and physical availability (Cruz *et al*; 2015).

$$\text{Depreciation} = \frac{\text{Present depreciation value}}{\text{Depreciation period in hours}}$$

$$\text{Present depreciation value} = \text{Acquisition price-resale price}$$

$$\text{EUAC} = \frac{\text{Accumulated net present value}}{\text{Uniform series present value factor}}$$

$$\text{Uniform series present value factor} = \frac{(1 + \text{WAAC})^n - 1}{(1 + \text{WAAC})^n \times \text{WACC}}$$

According to Cruz *et al.* (2015), the following concepts were used as a basis for the EUAC calculation:

Saved Value: represents the acquisition cost of the asset in year "0" and its estimated value for sale, year by year, considering a rate of value loss per equipment type.

Asset value loss: represents the asset value loss from one year to the other according to the value loss rate established for the equipment.

Depreciation: it is the asset cost or expense by obsolescence, which over time loses its value; that is, appropriated by the accounting area until it is reduced to zero.

The depreciation term and rate applied depends on the type of equipment.

Capital Cost: was calculated considering the sum of the saved value costs, asset value cost, and reduction of the tax benefit value.

Net Present Value: This method consists of bringing, or discounting to the earliest date of the Cash Flow, also called date zero, all the values, income and expenses of cash contained in the cash flow. The date zero was chosen arbitrarily. This method discounts cash flow at a specified rate, which is the minimum attractiveness rate.

Present Value Factor: consists of a

geometric progression simplification factor used to bring values of future periods to present values and obtain the net present value of a uniform series.

Maintenance Cost: considered preventive maintenance (performed at regular intervals, recommended by manufacturers, and in the life expectancy of components based on reliability curve), corrective maintenance and labor to perform maintenance according to our database.

Cost of Operation: consists of the sum of the costs of fuel consumption, tires, ground engaging tools and undercarriage trackpads, depending on equipment type.

Data compilation

Using software for cost management, SAP, it was possible to carry out a survey of costs, component life, labor, operational and other costs that were necessary at some point in the analysis.

After that, a careful costs analysis was carried out, as the expenses forecast with expected component changes, based on reliability curves and also benchmark information. With this, it was possible

to analyze and draw up the fleet replacement curve, based on the EUAC method. As expected, the theoretical model approached the real, with historical and reliability information.

3. Results

Components reliability

The reliability of an item corresponds to the probability of performing adequately for its specified purpose during

a certain period of time, and under predetermined conditions (CARTER, 1986).

Using this concept, truck and ma-

chine failure events were analyzed in order to determine how reliable the components are, and to verify if the lifetime suggested

by the manufacturer is correct. To explain this model, in the graphics below we showed a part of the components that were analyzed – only the expensive ones

R (t) = Reliability at any t time,
e = base of the neperian logarithms (e = 2.718), λ = failure rate, t = operation

Results Analysis: From the point of view of the reliability, the results shown in the graph below show that a part of the presented components have a stable and high reliability even

were used as an example.

Method used:

The term R (t) known as survival function, is used as a measure of per-

$$R(t)=e^{-\lambda t}$$

expected time.

Failure Rate: The failure rate is defined as the number of failures

$$\lambda = \frac{\text{failure numbers}}{\text{operation hours number}}$$

at the supposed end of life. With this result, we can infer that there is a manufacturer's calculation error as to the useful life of the component, which in this case, life could be ex-

formance. In this way, the equipment or product reliability can be expressed by the following formula, according to the exponential distribution.

per unit time. It is usually expressed in failure units per million hours. Equation:

tended. This has already been done, and the programmed exchanges are postponed in order to avoid an unnecessary exchange, reducing the maintenance costs.

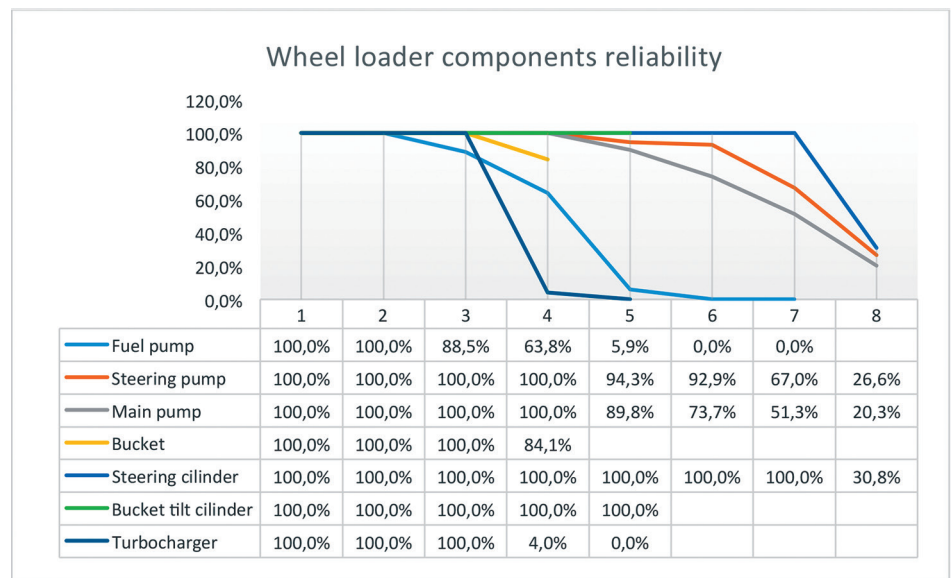


Figure 1
Wheel loader component reliability results.

COMPONENT	Manufacturer recommended component life (hours)	Component life after reliability analysis and historical data (hours)
Fuel pump	12000	12000
Steering pump	12000	16000
Main pump	12000	16000
Bucket	6000	6000
Steering cilinder	12000	14000
Bucket tilt cilinder	12000	14000
Turbocharger	12000	12000
Torque converter	12000	24000
Front axle	12000	24000
Rear axle	12000	24000
Complete diesel engine	12000	24000
Transmission	12000	24000

Table 1
Used components life for EUAC calculation.

Table 1 shows that the manufacturer's recommended life for its components are

very conservative and does not represent the component real life. This shows that

is possible to reduce maintenance costs by using reliability analysis and historical data.

EUAC applications and results

The results obtained with the equipment EUAC simulation use as premise:

- Equipment value estimated according to market price;
- Equipment sale in operational conditions;
- Component replacement within the new planned life;
- Preventive and corrective values according to SAP records;
- Life determination does not consider premature failure of components;

• Equipment replacement should occur before catastrophic component breakdown;

- Component reform values vary depending on component and equipment;
- Using numbers in a real base (without inflation);
- Minimum attractiveness according to the CSN Mineração assumption;
- Fx rate: R\$/USD 3.40;
- Preventive, corrective and component maintenance values according to the current contract costs;

• Value loss and depreciation rates vary depending on the equipment.

For the EUAC calculation, the expenses and equipment residual values were used, with a discount rate application, that allows to annualize the cash flow to provide information for decision making. The minimum EUAC is the point that determines equipment replacement (optimum replacement age).

For a better economic feasibility analysis for fleet replacement and identification of relevant information, a cost tree was used as shown below (figure 2).

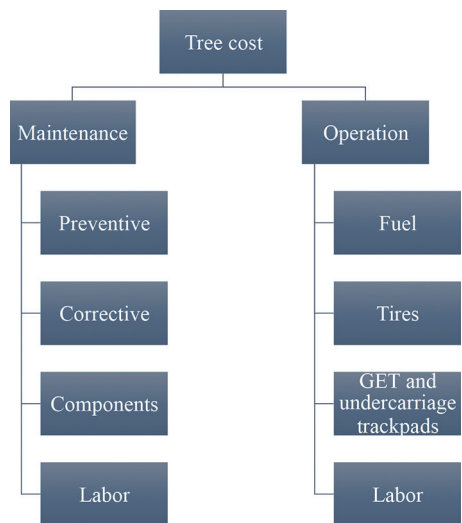


Figure 2
Tree cost.

Although tire, ground engaging tool and undercarriage trackpad costs are debited at the maintenance cost center at CSN Mineração, in this

study, they were considered in the operation account.

After selecting and processing data according to the tree cost, it was

possible to construct the tables, which represents the small fleet's annual costs, which will be shown in the analysis of fleet equipment.

Table 2
Capital cost calculation example

YEAR	SAVED VALUE	ASSET VALUE LOSS	DEPRECIATION	TAX BENEFITS	CAPITAL COST	CAPITAL COST NPV	ACCUMULATED CAPITAL COST NPV
0	R\$ 1.540.000,00				R\$ 1.540.000,00		
1	R\$ 308.000,00	R\$ 1.232.000,00	R\$ 385.000,00	R\$ 130.900,00	R\$ 2.641.100,00	R\$ 2.358.967,49	R\$ 2.358.967,49
2	R\$ 231.000,00	R\$ 77.000,00	R\$ 385.000,00	R\$ 130.900,00	-R\$ 53.900,00	-R\$ 42.999,46	R\$ 2.315.968,03
3	R\$ 173.250,00	R\$ 57.750,00	R\$ 385.000,00	R\$ 130.900,00	-R\$ 73.150,00	-R\$ 52.122,55	R\$ 2.263.845,48
4	R\$ 129.937,50	R\$ 43.312,50	R\$ 385.000,00	R\$ 130.900,00	-R\$ 87.587,50	-R\$ 55.743,03	R\$ 2.208.102,45
5	R\$ 97.453,13	R\$ 32.484,38	R\$ 0,00	R\$ 0,00	R\$ 32.484,38	R\$ 18.465,46	R\$ 2.226.567,91
6	R\$ 73.089,84	R\$ 24.363,28	R\$ 0,00	R\$ 0,00	R\$ 24.363,28	R\$ 12.369,68	R\$ 2.238.937,59
7	R\$ 54.817,38	R\$ 18.272,46	R\$ 0,00	R\$ 0,00	R\$ 18.272,46	R\$ 8.286,23	R\$ 2.247.223,81
8	R\$ 41.113,04	R\$ 13.704,35	R\$ 0,00	R\$ 0,00	R\$ 13.704,35	R\$ 5.550,79	R\$ 2.252.774,61
9	R\$ 30.834,78	R\$ 10.278,26	R\$ 0,00	R\$ 0,00	R\$ 10.278,26	R\$ 3.718,38	R\$ 2.256.492,99
10	R\$ 23.126,08	R\$ 7.708,69	R\$ 0,00	R\$ 0,00	R\$ 7.708,69	R\$ 2.490,88	R\$ 2.258.983,86

Table 3
EUAC calculation example

PRESENT VALUE FACTOR	CAPITAL COST EUAC	TOTAL OPERATIONAL COST	OPERATIONAL COST NPV	ACCUMULATED OPERATIONAL COST NPV	OPERATIONAL COST EUAC	EQUIPMENT TOTAL EUAC
1.12	Accumulated capital cost * year 1 present value factor	Year 1 maintenance + operation costs	Year 1 operational cost NPV	1 accumulated NPV	Accumulated operational cost NPV * year 1 present value factor	Year 1 - Capital cost EUAC + Operational cost EUAC
0.59	Accumulated capital cost * year 2 present value factor	Year 2 maintenance + operation costs	Year 2 operational cost NPV	1+2 accumulated NPV	Accumulated operational cost NPV * year 2 present value factor	Year 2 - Capital cost EUAC + Operational cost EUAC
0.42	Accumulated capital cost * year 3 present value factor	Year 3 maintenance + operation costs	Year 3 operational cost NPV	1+2+3 accumulated NPV	Accumulated operational cost NPV * year 3 present value factor	Year 3 - Capital cost EUAC + Operational cost EUAC
0.33	Accumulated capital cost * year 4 present value factor	Year 4 maintenance + operation costs	Year 4 operational cost NPV	1+2+3+4 accumulated NPV	Accumulated operational cost NPV * year 4 present value factor	Year 4 - Capital cost EUAC + Operational cost EUAC
0.28	Accumulated capital cost * year 5 present value factor	Year 5 maintenance + operation costs	Year 5 operational cost NPV	1+2+3+4+5 accumulated NPV	Accumulated operational cost NPV * year 5 present value factor	Year 5 - Capital cost EUAC + Operational cost EUAC

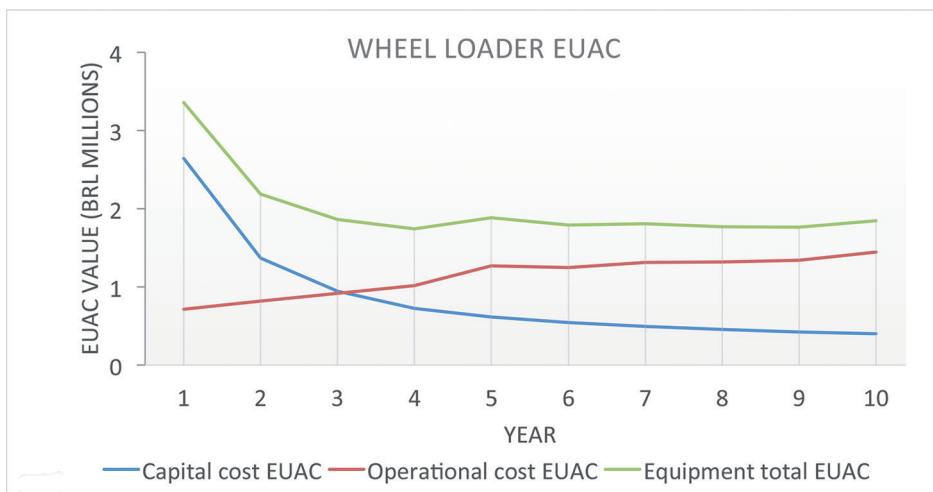


Figure 3
Wheel loader EUAC results.

Limitations

It is important to mention that this study has limitations, be they due to the factors of uncertainty or data variability.

The results are more reliable when the monitoring is done in an individualized way, equipment by equipment. Individual-

ized control gives a better safety margin for decision making, but for this, it is necessary to control the total cost per equipment.

Project risk analysis

Based on the LCC concluded studies, a Monte Carlo simulation was applied in order to consider the various possible scenarios and the probability of occurrence of these results. In a simplified way, the Monte Carlo simulation performs risk analysis based on possible results by replacing the uncertainty factors by ranges of values represented by probability functions. The results are repeated in a series of iterations, generating an output distribution that takes into account the different inputs and their respective statistical distributions.

the input variables are: Maintenance Costs, Operational Costs, Value Loss Rate and Equipment Value.

For the maintenance and operational costs, a normal distribution was used, with the expected value (calculated previously) as input and a 5% standard deviation. The normal distribution was applied because it represents the cost's possible variation, since there will be more occurrences close to the base value and, as we move away from the average value, we have a lower incidence of results.

a triangular distribution considering the most probable value equal to the maximum value was used. The maximum value was considered to be the most probable because the equipment value considered does not take into account the possible negotiations that can be carried out to improve the acquisition price and the financial conditions.

For the equipment value loss rate, the PERT distribution was used, and the inputs were the minimum, maximum and most probable values. The PERT distribution was used because, unlike the triangular

In the specific case of the LCC study,

For the equipment value simulation,

distribution, it concentrates the samples in the region around the most probable value.

All statistical variations previously

performed were used as inputs to simulate the lowest equipment EUAC value and ideal time for replacement. With the

performed simulations, it was possible to confirm the equipment's best replacement time statistically.

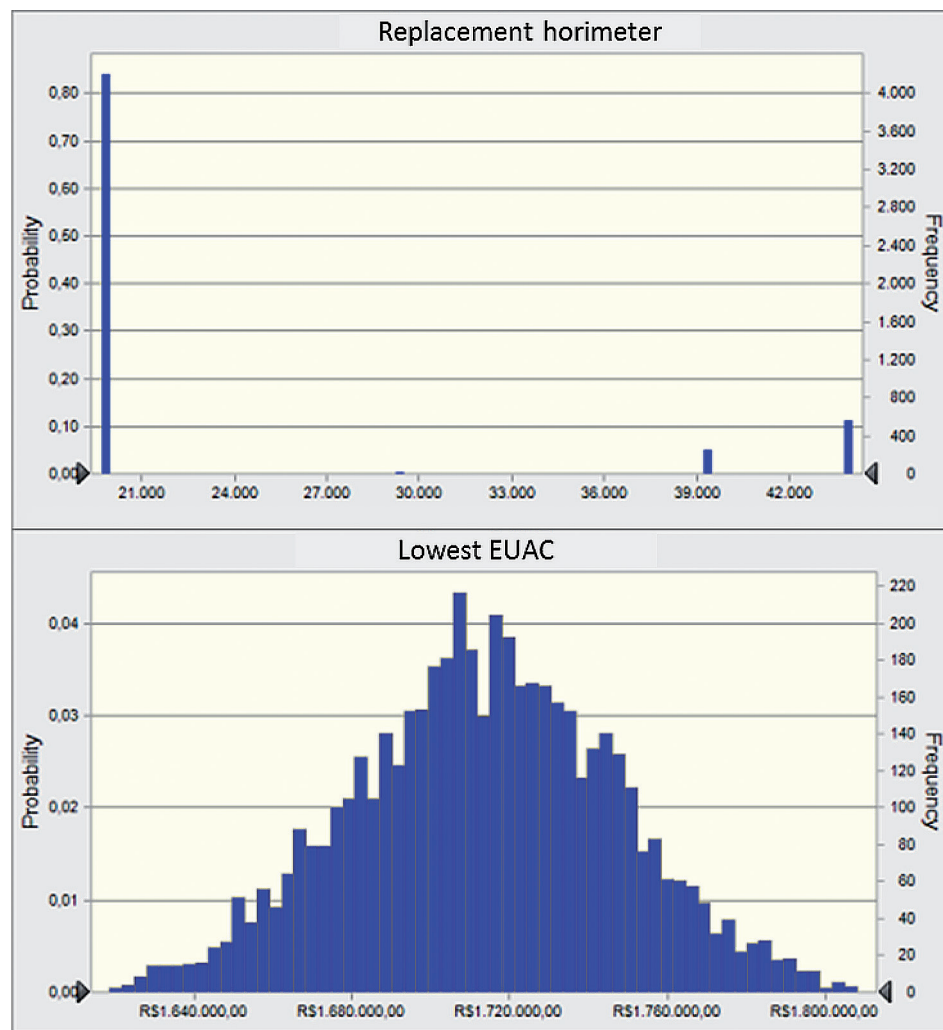


Figure 4
Monte Carlo simulation results.

4. Conclusions

Considering the maintenance and operational costs presented in this study, it was possible to determine what amount will be spent in the next 4 years in the following scenarios:

- Costs with equipment replacement;
- Costs without equipment replacement.

For this calculation, we projected the working hours for each equipment,

in the next years.

For a long term, this study will be used as an economic basis for future replacements, with all capital expenditure in Capex or Opex.

Non-replacement of this equipment is the higher cost alternative. Keeping this equipment in the next 4 years, the capital expenditures in Capex and Opex together,

could be 25% higher than the replacement option, if we keep the same conditions for operation and maintenance.

Based on the analyses of the Life Cycle Cost and Equivalent Uniform Annual Cost (EUAC), they show that it is possible to save money using this methodology to choose the best equipment supplier and the best time to replace it.

References

CARTER, A. D. S. *Mechanical reliability*. (2. ed.). London: Editora MacMilan, , 1986.492p.

CRUZ, V. N., FERNANDES, J. M., REIS, L. P. Análise do processo de substituição de equipamentos. In: ENCONTRO NACIONAL DE ENGENHARIA DE PRODUCAO, 2015, 35. Fortaleza, CE, Brasil. Análise do processo de substituição de equipamentos por meio do método caue em uma mineradora de grande porte... [S/l]: 2015. p. 1-18.

Received: 10 September 2018 - Accepted: 19 December 2018.