Implementation of a Program for the Analysis of the Costs of Equipment's Maintenance until the End of their Useful Life

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Abstract **- Companies face nowadays a very competitive environment and they have to be well managed to remain sustainable. For being sustainable the company needs either to increase its prices over time or has to reduce the amount of expenses. Reducing costs may be the best option once the global market is very competitive. This work results from the intention of a company (ME-Construction Company) to get a tool to support the decisions related to the equipment management. The aim is to create a model for the analysis of the costs resulting from using ME-Construction Company's equipments. The studied case is real. This model is the Life Cycle Cost complemented by the Net Present Value and Equivalent Annual Cost. It is worked on a representative sample of the equipment of the company. The application of this model allows the manager to have the estimating tools which may support and justify his decisions in the company. During the equipment's lifetime, he may have the right perception of the evolution of the expenses and income. The company should develop an equipment costing methodology as much effective as possible in order to consider the expenses that are not included in the equipment value and to consider the equipments which release less greenhouse gases contributing to reduce the global greenhouse effect.**

Keywords— Life Cycle Cost, Adjusted Cost, Net Present Value, Equivalent Annual Cost.

1. Introduction

Life Cycle Cost (LCC) is a technique of analysis which has been used widely as an engineering tool (for example for supporting a project or an acquisition). It begins to be used now as a management tool (for example for costs analysis). It is mainly a tool that helps engineers thinking as MBA - Master of Business Administration professionals, acting as engineers by connecting engineering decisions to management. LCC helps engineers to have an overview of all expenses associated to productive assets, and to apply their experience about the general performance and about expenses to conjecture about the future, and thus they have access to useful information in order to support their decisions (see Assis and Julião, 2009).

LCC of an asset is the sum of all the expenditures in capital used to support this asset since its conception and manufacture including the operation, until the end of its useful life (White and Ostwld, 1976).

In order to respond to the needs of the companies which have to deal with huge maintenance costs, a model that allows the manager and the engineer to determine the best time to replace the equipment becomes necessary. This model, LCC, will be preferably applied to the equipment of higher initial investment, so that it minimizes the overall cost.

Thus this tool gets particular relevance once it permits to better understand that the important thing is not to know the price of nothing but to know the value of everything (Assis and Julião, 2009).

After a short presentation about costing methodologies for equipments, a model is formulated and validated. The study ends with the presentation of the results and some conclusions and recommendations.

2. Purpose

This study focuses on the implementation of a program for the analysis of the maintenance costs of the equipments until the end of their useful life. The study is developed by constructing a model which permits to increase the visibility of the total of costs that enhances the choice of the best solution for a particular equipment at the time manager has to decide about purchasing or renting or either repair or replace it.

In the specific case of ME – construction company the current problem in the responsible Department for the equipments is the decision of when to replace the equipment. This is, what is the best choice between the replacement options based on all expenses and income. In order to get answers, the equipment manager, usually makes an assessment case by case.

This problem may be overcome by implementing this model for costs and can be simply calculated for equipment that was assessed.

This model considers the end of the equipment lifetime and, through an analysis of the obtained values, permits to answer to some questions of the equipment manager, regardless the equipment is in

the acquisition, the exploration, or deactivation phases.

In this study the important to be considered is the feasibility of the model implementation considering that all data presented in the study are "distorted", despite being sustained on real information.

3. Methodology

In order to develop this work, the method of analysis of LCC is used. This model is complemented by the analysis of expenses considering other tools which support the equipment manager, such as the method of Net Present Value (NPV) for the evaluation of projects with the same life span, and the Equivalent Annual Cost (EAC), which permits to compare projects with different life spans.

A problem associated to LCC expenses is related to the uncertainty of the project's future expenditures. To deal with uncertainty, different methodologies will be used, according to the phases of the project. These methodologies are:

- estimation by analogy,
- parametric estimation methods, and
- methods of estimation by engineering procedures.

LCC of an asset may be significantly higher than the initial investment (Woodward, 1997), and in many cases it is set at the first design stage (Fig. 1). However, investment expenses are used by many companies as the main selection criterion for the purchase, or even as the sole criterion (Lindholm e Suomala, 2004). This is due largely to the ignorance of LCC technique, to the lack of a standard or guidelines that support the implementation of this technique, and especially to the lack of data about the past of the assets (Ardit and Messiha, 1999).

When LCC is used as a tool for comparison between different alternatives, its process of calculation indicates, impartially, the solution which has a lower overall expense, based on available information (Freire, 2006). According Hanafizadeh and Latif (2011), one of the most important and frequent decisions that manager face is the selection of new industrial projects. For the analysis of projects, NPV is used for the ones with the same lifetime and EAC is used for different periods. According to Sinclair (2010), EAC can be used as an analysis tool in investment decision, when comparing the annual costs of equipment with different lives spans service and operating expenses.

4. Data Processing

The identification of all involved parcels is presented as a key step in this methodology. The types of costs usually considered in this kind of analysis are:

- investment in acquisition /leasing,
- distribution expenses,
- maintenance expenses,
- operating expenses,
- financial expenses,
- training expenses,
- inventory expenses,
- stop spending;
- expenses of decommissioning, and
- environmental spending.

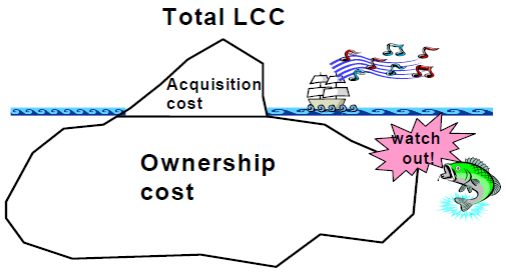

Figure 1 - LCC consists in investment in acquisition and property expenses (Dangel, 1969).

Data collection is a very important step, because all the work is supported on the collected data. If the data do not represent the true values, the results will be different from reality. In this study, the collected data represent equipments that belong to the shipyard Porto Alto of ME – Construction Company, particularly, income, assets acquisition, involved costs and actuarial rate.

5. Results and Discussion

Based on the needs of the company, a model was built to help the equipment manager to answer many questions about the three phases of the machine status in the company. The model allows the equipment manager to be able to easily determine the best option when he buys, to know the costs of the equipment during the exploration phase and deactivation phase, knowing at any time if the best option is to rebuild, sell or replace the equipment.

5.1 Acquisition Support

In the model, the option to support the acquisition of equipment permits to compare different brands that have similar characteristics, so that the equipment manager realizes the best brand to choose in a future purchase. Instead of using only historical data so far, the equipment manager may use estimated costs and revenues based on the prediction model, to be able to view the best option to buy, with the values defined by the end of equipment lifetime.

In this evaluation, about the acquisition, LCC was relevant and was complemented by EAC (the 3 equipment have different useful lives). To illustrate,

the calculations were then made for the following three equipments:

- Caterpillar 323 DL cm - 20/106;
- NLC Volvo EC 240 B - 20/501, and
- Komatsu PC 240-6 - 20/857.

In this case, Caterpillar is rented equipment with purchasing option, having been hired in 2006. ME-Construction Company has purchased the other two units in 2004.

The results of LCC for the three equipments are presented in Table 1.

Table 1 - Results to support the acquisition.

	CATERPILLAR 323 D L cm - 20/106	VOLVO EC 240 B NLC - 20/501	KOMATSU PC 240-6 - 20/857
LCC =	**244.218 €**	**223.367 €**	**271.394 €**
NPV =	**-76.183 €**	**-28.996 €**	**-36.019 €**
EAC =	**-19.282 €**	**-5.646 €**	**-7.013 €**

Based on LCC of the three analyzed equipments for the period of their lives, it is possible to conclude that the option to purchase the Volvo EC 240 B NLC is the most profitable option in terms of cost at this time. If the EAC analysis is considered it is possible to conclude that the same option would be the best option, and as the periods of lifetime are not the same, than it is necessary to use the contribution of EAC as a tool to support the decision.

After knowing which of the three assessments of existing equipments has a lower LCC at the time of the evaluation, the evolution of spending over the years may be also compared, as can be seen in the figure 2.

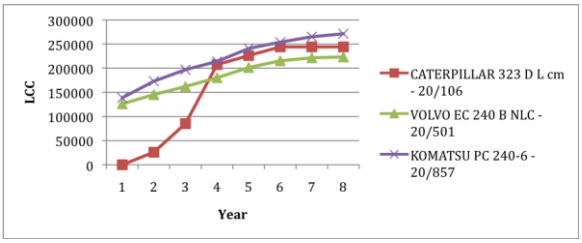

Figure 2 - LCC evolution in the acquisition evaluation.

Considering the LCC analysis over the years, presented in Figure 2, it can be concluded that, given a small project, it is more profitable to rent Caterpillar equipment until the point in which LCC of Caterpillar intercepts LCC of Volvo, which from the third year becomes more profitable until the end of the period (the end of the seven years that were analyzed).

Another evaluation which takes into account the total costs on maintenance is made. It permits to assist the equipment manager in the purchasing decision by looking at the past expenses and the forecasts of the costs for the coming years as shown in the graph in figure 3.

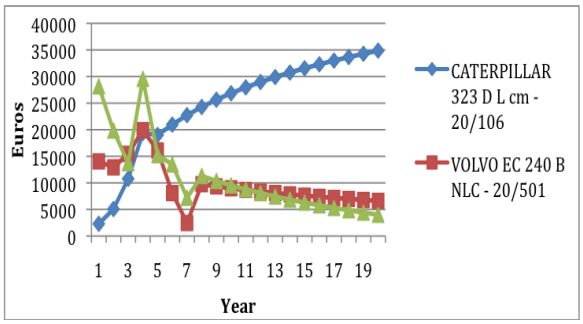

Figure 3 – Adjusted total cost on maintenance of the three equipments.

After analyzing the graphic, and comparing it with data from LCC analysis, it can be noted that the option to acquire Komatsu includes more expenses in the initial phase of its lifetime, and at the end of its life it is expected to have lower total maintenance costs (but as already mentioned, some data are not real). With the data that we have chosen to make the calculations Caterpillar would not be a good option once it may be anticipated that the total adjusted costs for maintenance have a big increase.

The adjusted costs, in this case, were calculated on the basis of the costs of the early years and as it was a rental contract with a maintenance contract included, the initial costs are higher and may deviate from the forecast of future for high values of costs.

5.2 To Rent vs to Buy

To understand what is the best option in case of doubt in the acquisition phase (option to rent or option to purchase), taking into account the existing equipments in the company, the data must be collected by brand. For this option see table 2.

Table 2 – To Buy or to Rent the Assessment (option to buy *vs* rental option).

	Option to buy	Option to rent
Brand/model	**CATERPILLAR/14 M**	**CATERPILLAR/14 M**
Year of manufacture	2010	2010
Acquisitions cost (years)	290 000,00 €	
Rental income (annual)		33 333,00 €
Year rental		20
Life (Years)	20	20
Life (hours)	26 923	26 923
Accounting life (years)	16	16
Investment value	290 000,00 €	
Monthly value of mobilization)	1 982,15 €	1 982,15 €
Normal hourly	14,14 €	14,14 €
Residual value	75 000,00 €	
Income (occupancy 70%) (annual)	**35 684,62 €**	**35 684,62 €**
Depreciation (annual)	18 125 €	
LCC	322 747 €	441 872 €
NPV	-8 670 €	21 697 €
EAC	-909 €	2 276 €

Renting is the best option because NPV is positive

Also data relating to the rental option is shown with simulated data given by the head of ME-Construction Company and Caterpillar dealer. The prediction model used in this rental or purchasing evaluation is only illustrative of the importance of the

model because the first seven years are simulated in order to obtain a forecast for the next thirteen years. In this case the simulation was done for 20 years. As can be seen in the output of the model in Table 2, it automatically gives information about which choice is more profitable, being the rental option slightly more profitable since the NPV is positive.

In Figure 3 it can be seen on the graphic the logarithm of expenses that will allow to calculate the projected expenditures for future years, based on historical data represented in cash flows, permitting to calculate the results in Table 2.

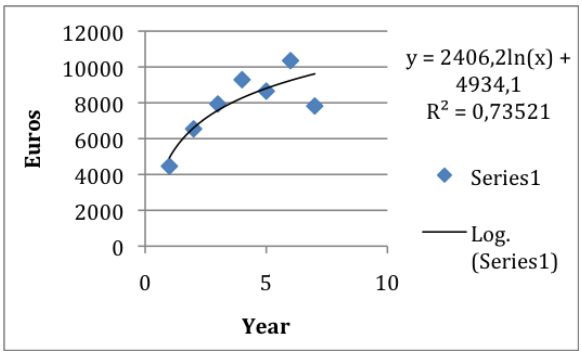

Figure 4 – Historical evolution of the total adjusted annual expenditures of the Caterpillar 14/M acquisition.

With this simulation, the equipment manager can determine easily the best option through the NPV if both have the same lifetime. If the options have different periods of life, what is quite common in this kind of evaluations, EAC is used, indicating what will be the best investment. The one that has a higher EAC is the best option and may complement this information with the results of the LCC, and then the one which gets the lower value will be the better one.

5.3 Exploration Phase

In order to understand how to draw conclusions from the model, the modeling of another equipment, the 120/340 - Drilling Soilmec R725 CFA, is made. Subsequent to the completion of costs table, it is possible to get the results to be analyzed through the graph in figure 5 and table 3. The graph in Figure 5 permits to analyze the overall maintenance costs, as well as the accounting value and LCC, during the period under review.

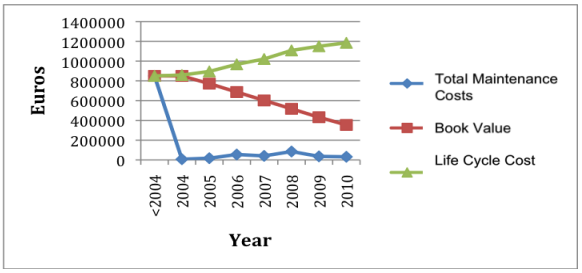

Figure 5 – Results for Drilling 120/340.

As can be seen, there is, over the years, a not very high, but increasing, value for the total maintenance costs, between 2004 and 2008, showing a slight decline in 2009. Since the total annual maintenance costs are identical, the LCC curve is linearly increasing, reflecting essentially in this case, the depreciation of equipment, what means that there are no significant reductions or increases in costs over the years.

Table 3 - Results for Drilling 120/340.

CCV =	1.184.822
VAL =	-306.160
CAE =	-41.472

With the analysis of Table 3 and as NPV is negative it is clear that the investment has not been profitable, since the updated income has not been able to cover the updated costs, to date, at current prices. However, as this analysis was only made for 12 years it is expected that, if the number of years increase, the NPV will be positive, because this type of equipment has a longer useful life.

It was found, when the collection of information from the ME-constructions was made, that not all the costs are being allocated to the equipments but just the maintenance, operation and depreciation ones. So, a simulation was done (case 2) incorporating other costs such as transportation to and from the yard, training, staging of equipment, stock, environmental and deactivation. The equipment that was used as an example was the 120 / 340 - R725 Soilmec Drilling CFA, and given the same number of years, 12 years, values for those costs were allocated to this equipment . The effect of this change is reflected in Table 4, and, as it is expected, a significant decrease in value of NPV and an increase in LCC is reported.

Table 4 - Results for Drilling 120/340.

	Case 1	Case 2
CCV =	1.184.822	1.409.102
VAL =	-306.160	-372.398
CAE =	-41.472	-50.444

It is of great importance that ME-Construction Company takes all these costs into account in a near future because they are high costs that are not being taken into account as equipment costs.

5.4 Deactivation Phase

In the last phase of maturation of the equipment after the equipment manager checks if there is any equipment that has completed its life time or is obsolete in the list view, there is a need to replace the equipment or to rebuild it. Managers have to be supported when taking their decisions. For that a model was created for the option "Repair or Replace" that allows three options. One is the reconstruction of existing equipment and the other two may be to choose between the purchase of two new models, equivalent to the old one. The tool mentioned above can also be used if the equipment suffers a serious accident and there is a need to see which option will

be more profitable for the company, to repair or deactivate and get a new one.

Table 5 - Rating Rebuild or Replace

	Option to reconstruct	Option to replace	
Brand/model	**CATERPILLAR/ 14 H CCR**	**CATERPILLAR/ 14 M**	**KOMATSU**
Year of manufacture	1997	2010	2010
Acquisitions cost	200 000€	290 000€	250 000€
Life (Years)	13	13	13
Accounting life (year)	13	13	13
Life (hours)	17 500	17 500	17 500
Investment value	145 463,00 €	290 000,00 €	250 000,00 €
Monthly value of mobilization)	1 982,15 €	1 982,15 €	1 982,15 €
Normal hourly	14,14 €	14,14 €	14,14 €
Residual value	50 000,00 €	75 000,00 €	55 000,00 €
Income (occupancy 70%) (annual)	35 684,68 €	35 684,68 €	35 684,68 €
Depreciation (annual)	11 189 €	22 308 €	19 231 €
LCC	363 009 €	468 262 €	302 505 €
NPV	-19 721 €	-89 487 €	-52 668 €
EAC	-2 550 €	-11 572 €	-6 811 €

NPV is negative in all options but the most advantageous is to reconstruct CATERPILLAR/14HCCR

In Table 5, once again, it is just needed to fill the first nine lines, and it is possible to compare which is the best option: to replace or to rebuild the equipment. The results that can be extracted from the output of the model are the LCC of the equipment, the annual depreciation and the NPV complemented by CAE to evaluate projects with different life spans.

Given the NPV analysis, we find in this simulation, that the most profitable option is to rebuild the existing equipment. The model automatically gives information about what is the best option based on data that was inserted into the table, and which is the most profitable when compared to its nearest rival. If the manager chooses not to select this option, he can analyze which of the two acquisition options has a higher positive NPV or less negative, because this is the best option to purchase. In this case it is possible to compare the projects through NPV because all of them have an expected life span of thirteen years that is equal to the accounting lifetime.

6. Conclusions and Recommendations

In conclusion, the application of this model allows the manager to have tools that will help him to calculate and justify his decisions, and it is desirable that he can have, over the lifetime of the equipment, the full perception of the expenses and income.

This model was therefore developed with the aim of functioning as a decision support tool in the company. In this sense, and into the future, the company should develop a more sophisticated equipment expenses study of its equipments since there are expenses that are not being addressed.

Given the simplicity of this model it can be implemented with the systems already used in the company, which in this particular case is SAP, so, every year, automatically, costs and revenues are updated and allow projections of future costs based on past data, credible and real.

In a future development ME-Construction Company might aim not only to select their equipment at the lowest LCC and higher NPV / EAC, but also choose to release less greenhouse equipment in order to reduce the greenhouse effect, since this factor is not being contemplated, in order to have a brighter future for everyone.

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