Life Cycle Cost Model for Estimating and Forecasting Future Budget Needs for Machinery

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Abstract

This paper explores the application of LCC (Life Cycle Costing) concept for asset management. The proposed LCC model provides a structure breakdown of cost (SBC) of machinery such as initial cost, operating cost, energy cost, maintenance cost, opportunity cost and disposal cost that can be applied to asset. The machinery in plant is used a case study in the model. The reliability and availability theories are applied in the model for calculating. Consequently, the proposed model provides a tool for estimating and forecasting future budget needs for machinery and making decision for business plan.

Keywords: Life cycle cost, Reliability, Cost Estimate

1. Background/ Objectives and Goals

Plant users and operators have long recognized that the capital costs of purchase and installation are not the only cost which affect a plant's economic viability, and that in choosing between competing tenders an assessment must also be made of likely operating and maintenance costs. However, at the time when tenders are submitted, while capital costs may be fix, operating and maintenance costs are based on predictions of likely plant availability and behaviors are shown in fig. 1 and fig. 2.

Until now, there are few case studies published with examples of Life cycle cost (LCC) use in plant and how to get required data or the Structure Breakdown of Cost (SBC) into the models. (Marcus, B., Martin K, 2016). It was found that the applications and theoretical LCC-models are investigated, 2/3ds of publications originated from construction, only 6 of 55 cases are from manufacturing, 5 of these used deterministic cost data and did not take stochastics into account. Only one was on machining equipment. A search was made in Scopus on "Lifecycle cost" OR "Total cost of ownership" AND "case" gave4713 hits, of which the majority were published after 2001 is shown in fig.3. Most of these regarded power and energy industry and/or construction industry, in line with Korpi, E, and Ala-Risku T.(2008).

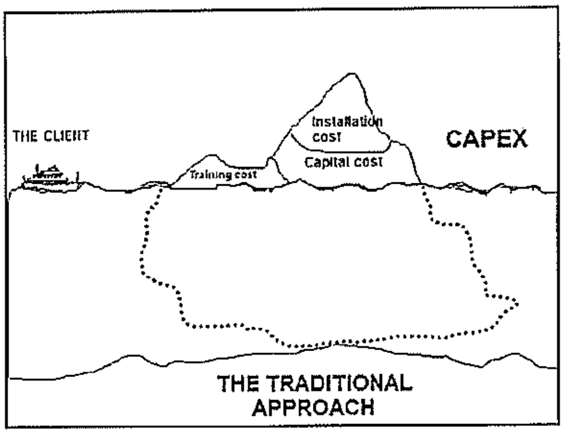

Fig.1: The Traditional Approach

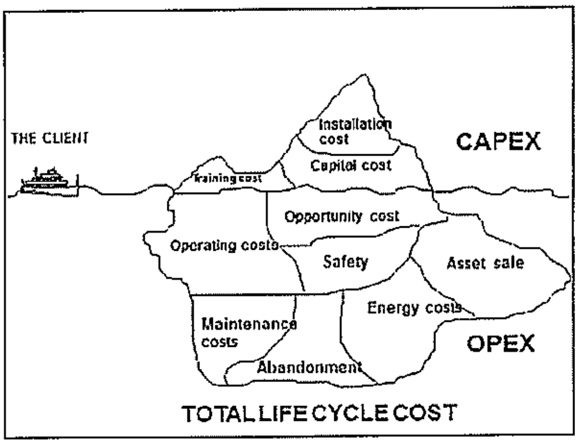

Fig.2: Total Life Cycle Cost

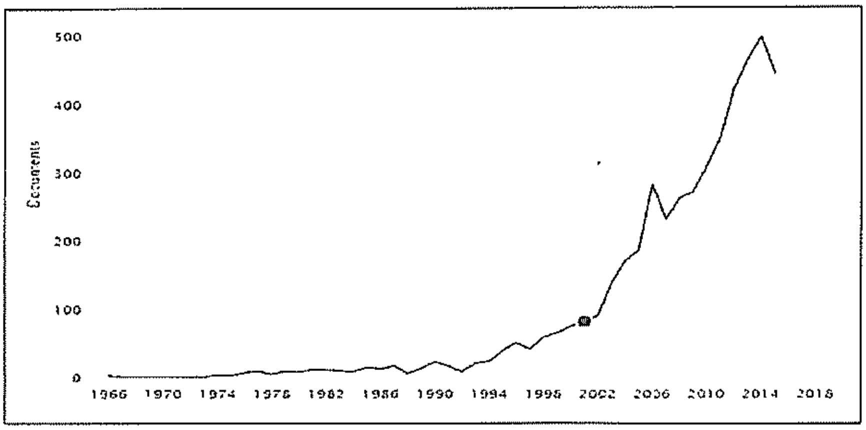

Fig3. The number of LCC case studies published in Scopus (Marcus, B., Martin K, 2016)

2. Methods

This paper presents how to use a LCC model for estimating and forecasting future budget needs for machinery analysis has been performed on plant equipment. The proposed LCC model provides a structure breakdown of cost (SBC) of machinery such as initial cost, operating cost, energy cost, maintenance cost, opportunity cost and disposal cost that can be applied to the asset is shown in fig. 4.

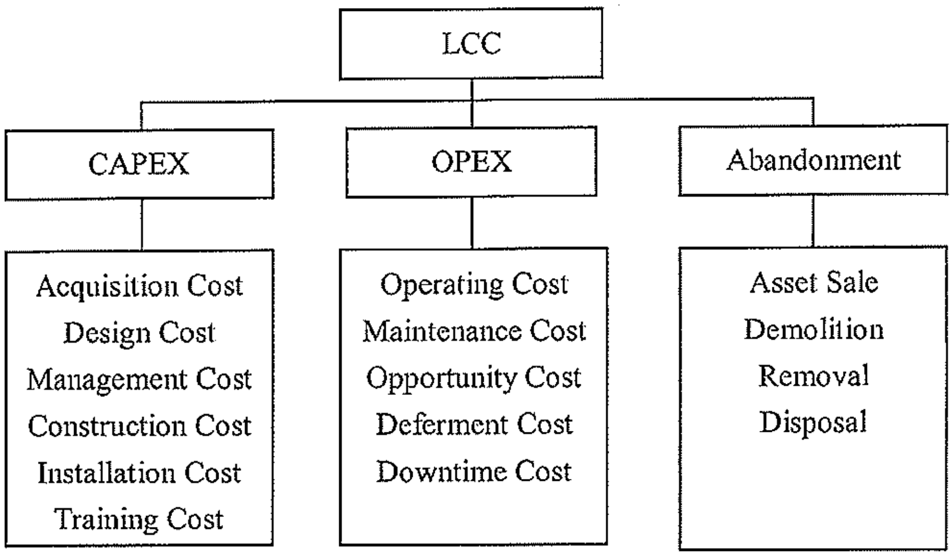

Fig. 4: Life cycle cost components

Life Cycle Cost (LCC) was defined by the British Standard Glossary of Maintenance Management Terms in Terotechnology (BS3811, 1993)
".. the technique of considering the total cost of ownership of an item of material, taking into account all the costs of acquisition, personnel training, operation, maintenance, modification and disposal, for the purpose of making decisions on new or changed requirements and as a control mechanism in service, for existing and future items."

Capital Expenditure (CAPEX)
The initial capital costs can be divided into sub categories of costs:
• Purchase cost
• Acquisition/finance costs;
• Installation/commissioning/training costs.

Operating Expenditure (OPEX)
This category includes the cost of operating and maintaining the system throughout its programmed life cycle. The operating costs of an asset would include direct labor, direct expenses, indirect labor, indirect materials, fuel power and establishment costs. The estimation of these costs is based on both predicted and actual experience of the performance of similar assets. In most organizations, cost estimates regarding assets are prepared by Engineering Departments. Maintenance costs include direct labor, spare part of routine and non-routine maintenance, equipment and purchased services. Maintenance costs can normally be broken down into smaller classification such as:
• Regular planned maintenance;
• Unplanned maintenance (responding to faults)

Deferment Cost or Opportunity Cost

Deferment Costs are lost revenue that result from planned and unplanned shutdowns

In this case the total life cycle cost of machine has three major components that are shown in Fig.4. The total life cycle cost is given by

$$LCC_{mc} = CAPEX + \sum_{i=1}^{NL}\left[\frac{\left[\left(OC_{mc,i} + MC_{mc,i}\right) + OPC_{mc,i}\right]}{(1+r)^{i}}\right] - \frac{AS}{(1+r)^{NL}} \qquad (1)$$

The definitions of symbols used in above equations are given below:

LCC_{mc} is Life cycle cost of machine

CAPEX is Capital expenditure

OC_{mc} is Operation cost of machine

MC_{mc} is Maintenance cost of machine

r is Discount rate

NL is Lifetime of machine in years

OPC_{mc} is Opportunity cost of product loss

AS is Asset sale

Maintenance cost model is

$$MC = RTMC + NRTMC \qquad (2)$$

where

$RTMC$ is Routine maintenance cost

$NRTMC$ is Non-routine maintenance cost

Routine Maintenance Costs model is

$$RTMC = (RMT \times RMLC) + SPC_{RT} \qquad (3)$$

where

$RTMC$ is Routine maintenance cost

RMT is Routine maintenance time

$RMLC$ is Routine maintenance labor cost per hour

SPC_{RT} is Spare parts costs of routine maintenance

Non Routine Maintenance Costs

This section presents three general formulas to determine an item's reliability, mean time to failure and hazard rate for using in the model (8).

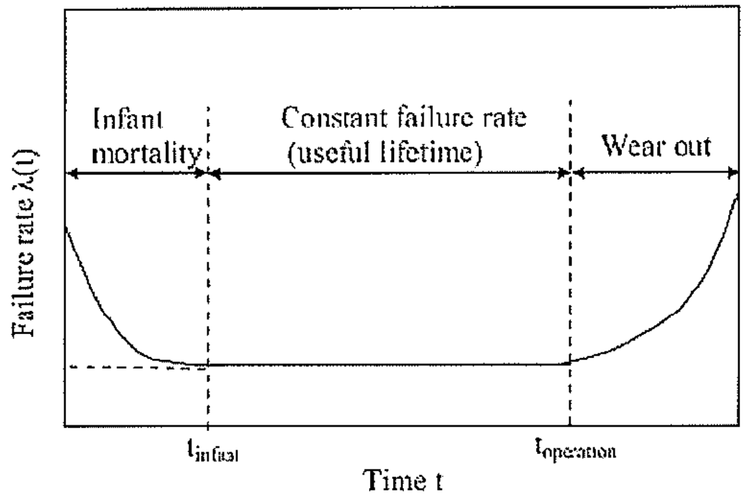

Fig.5: Bathtub hazard rate curve

This is a curve used to represent the failure behavior of many engineering items such as machine, pump. The curve can be divided into three parts: infant mortality period (decreasing hazard rate region), useful lifetime period (constant hazard) and wear out period (increasing hazard rate region).The useful lifetime failures are random failures because they occur unpredictable.

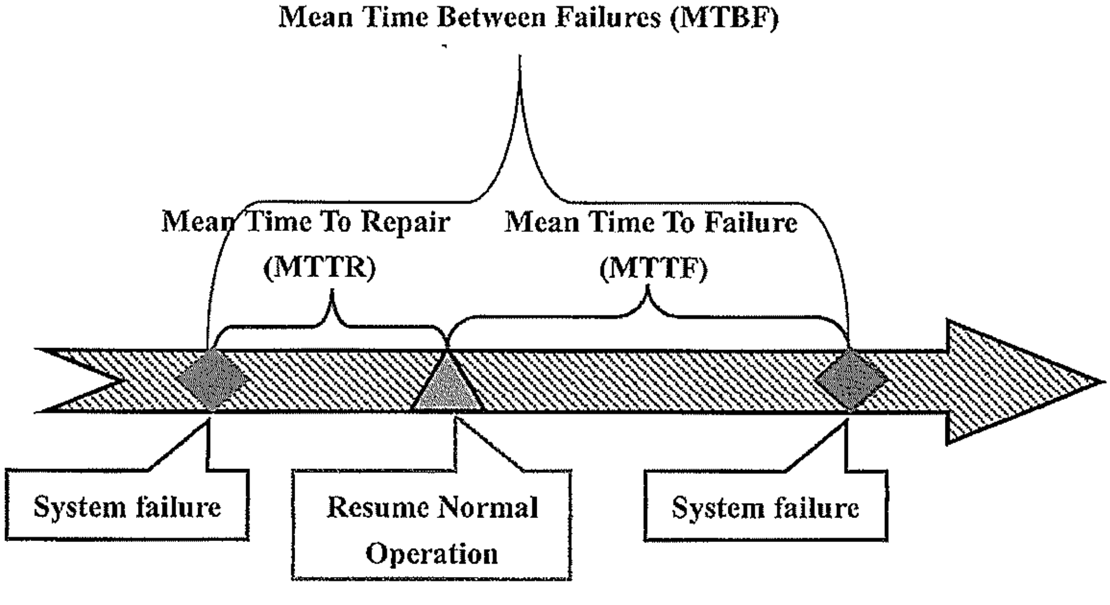

Fig.6: Relation of MTBF, MTTR and MTTF

Mean time between failures (MTBF) is the mean (average) time between failures of a system, and is often attributed to the useful life of the device i.e. not including infant mortality or end of life if the device is not repairable. Mean time to Repair (MTTR) is the mean time of downtime caused by system failures/number of failures. Mean time to failure is the mean time fail of a system again after it was repair expected to last in operatiòn is shown in fig.5and fig.6.

The Reliability is the probability that an item will carry out its mission satisfactorily for the desired period when used according to specified condition (Dhillon, B.S.,1989). The formula to determine an item's reliability is

$$R(t)=e^{-\int_0^t \lambda(x)dx} \quad (4)$$

where

t is time

$\lambda(x)$ is the item's hazard rate or the time dependent failure rate

$R(t)$ is the item 's reliability

An item's reliability is expressed by

$$R(t)=e^{-\lambda t} \quad (5)$$

λ is the item's constant failure rate

The mean time to failure (MTTF) of an item is given by

$$MTTF=\int_0^\infty R(t)dt \quad (6)$$

Substitution of equation (5) into equation (6) yields

$$MTTF=\int_0^\infty e^{-\lambda t}dt=\frac{1}{\lambda} \quad (7)$$

$$NRTMC=LT_{so}\times NRMLC\times\left[\frac{MTTR_{mc}}{MTBF_{mc}}\right]+SPC_{NRT} \quad (8)$$

where

LT_{so} is Lifetime of the scheduled operating hour

$NRMLC$ is Non-routine maintenance labor cost per hour

$MTTR_{mc}$ is Mean time to repair of machine

$MTBF_{mc}$ is Mean time between failures of machine

SPC_{NRT} is Spare parts cost of non-routine maintenance

Opportunity Cost of Product Loss

$$OPC = OCRM + OCNRM \tag{9}$$

Given

$OCRM$ is Opportunity cost on routine maintenance

$OCNRM$ is Opportunity cost on non-routine maintenance

Opportunity Cost on Routine Maintenance

$$OCRM = RMT \times CAP_{Rate} \times P_{price} \tag{10}$$

where

RMT is Routine maintenance time

CAP_{Rate} is Capacity of machine units per hour

P_{price} is Product Price per unit

Opportunity Cost on Non-Routine Maintenance by

$$OCNRM = \left(LT_{so} \times \left[\frac{MTTR_{mc}}{MTBF_{mc}} \right] \times CAP_{Rate} \times P_{price} \right) + \left(SDT \times CAP_{Rate} \times P_{price} \right) \tag{11}$$

Where, SDT is Supply Delay Time

Then, Maintenance Cost of Machine by

$$MC_{mc} = \left(RMT \times RMLC \right) + SPC_{RT} + \left(LT_{so} \times NRMLC \times \left[\frac{MTTR_{mc}}{MTBF_{mc}} \right] + SPC_{NRT} \right) \tag{12}$$

And Opportunity cost of product loss by

$$OPC_{mc} = \left(RMT \times CAP_{Rate} \times P_{price} \right) + \left(\left(LT_{so} \times \left[\frac{MTTR_{mc}}{MTBF_{mc}} \right] \times CAP_{Rate} \times P_{price} \right) + \left(SDT \times CAP_{Rate} \times P_{price} \right) \right) \tag{13}$$

Then,

Substituting Equation (12) and (13) into Equation (1)

$$LCC_{mc} = CAPEX + \sum_{i=1}^{NL} \left[\frac{\left[\left(OC_{mc,i} + MC_{mc,i} \right) + OPC_{mc,i} \right]}{(1+r)^{i}} \right] - \frac{AS}{(1+r)^{NL}} \tag{1}$$

3. Results

The proposed LCC model of the machine can be used to give guidelines on what components to consider when purchasing new machining equipment. This model can be used for estimating and forecasting future budget needs for machinery from the first year until the end of life of machine or the asset. The difficultly of this model is the data is availability or not, such as the failure rate of the machine, MTTR, MTBF. In general the routine maintenance can predict from manual of the machine or using TPM (Total Productive Maintenance) activity. The MTTR and MTBF are collected by operator for calculating failure rate. In oil and gas industry, the offshore and onshore reliability data (OREDA) book contain data from a wide range of component and system used in offshore and onshore installation and subsequently update by the consortium of : BP Petroleum, Total, Statoil, Shell, Angie, ENI, Gassco and Petrobras .The reliability data are classified under the following main heading machinery equipment such as pump, gas turbine, electric equipment such as electric generator and motor, control and safety equipment such as fire and gas detector and sub- sea equipment such as control system and flowline.

4. References

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