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Machining Equipment Life Cycle Costing Model with Dynamic Maintenance Cost

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Abstract

This paper presents how a Life cycle cost or Total cost of ownership analysis has been performed on machining equipment in a Swedish company. Life cycle cost models used in case studies are compared to an empirical model, used at the company, where dynamic energy, fluid, and maintenance cost are included. Linear and variable factors in the models are analyzed and discussed regarding data availability and estimation, especially with emphasis on maintenance. The life cycle cost aspect of the equipment give guidelines to consider operation, maintenance, tools, energy, and fluid cost in addition to acquisition cost, when designing/specifying the equipment.

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Keywords: Life Cycle Costing; Total cost of ownership; sustainable manufacturing; Maintenance management; equipment design

1. Introduction

1.1. Background

Researchers suggest use of Life cycle costing (LCC) as a preferred option when making investments, and there are several models and processes described of how to do so. However, in metal working industry when buying machine tools or similar equipment the uses of these models are rare. A survey in UK showed that 78% of industrial respondents rarely use LCC [1]. The academic models given may be too complex and LCC-tools for practical use may miss crucial aspects with regards to machine tools.

There are few case studies published with examples of LCC use in manufacturing and how to get the required data into the models. This paper presents how a Life cycle cost or Total cost of ownership (TCO) analysis has been performed on manufacturing equipment in a Swedish company. In this paper a customer perspective on the LCC is taken (i.e. a TCO) where although the life of equipment can be said to comprise of initiation, pre-study, project, realization, closing on commission, and disposal phase [2], all supplier development costs (R&D, initiation, pre-study, and projecting) are included in the price or acquisition cost.

1.2. Aim and research questions

This paper elaborates on theory and difficulties in practical use of LCC for machine tools. It is a case study of descriptive and empirical character and aims to show how LCC, or TCO, if you will, has been used in practice from the user company perspective, and discuss collection and application of data. The paper presents some theory regarding LCC as well as Life cycle profit (LCP); and suggestions on how to use LCC for machine tools. In the case, LCC is utilized in order to make a decision on whether to acquire a new machine, recondition existing machines, or run the existing machines with an increased cost and risk. Depending on in which phase

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the LCC is made there might be need to use different types of scenarios, i.e. predictive (in acquisition phase) explorative (early design phase) and normative (pre-acquisition) [3]. This case is mainly predictive.

The research questions for the paper are:

- How can LCC (or TCO) and LCP be used in assessing a new acquisition compared to reconditioning/renovation?
- What are the crucial parameters to include?
- How is stochastic and dynamic maintenance accounted for?

2. Research Methodology (materials and methods)

The researchers have used a combination of literature analysis and action research to facilitate analysis of the findings from a case study research [4].

The case study context is a large automotive driveline systems manufacturing site. The site fabricates, assembles, and paints components. Roughly 700 employees tend roughly 300 manufacturing machines, various assembly equipment, test benches, a hardening shop, and a paint shop. Historical cost outcome of machining equipment were used as input in modeling the future LCC of reconditioning or investing in new equipment.

A review of related research within the area of manufacturing equipment design with aid of LCC, LCP, and TCO is a base for the paper. The major part of the literature analysis was performed in Scopus and Google Scholar to find cited models and to search for case studies involving metalworking equipment.

The researchers have been working in the company's Maintenance engineering department and Production development engineering department respectively. The empirical models have been used in these roles and thus the empirical research mainly points out gaps and possibilities in using these models. Action research is useful to achieve thorough understanding and to get access to data in order to e.g. formulate hypotheses [5], although less useful for proving general theories.

3. Frame of reference/Literature analysis/Background

3.1. Life cycle cost

The term Life Cycle Cost (LCC) applied on manufacturing equipment can be used in different settings and thus have different definitions. First it can be used from the viewpoint of equipment users as in the case studied, or the supplier, (or even the society). With a user's viewpoint LCC and TCO have often been defined in similar ways and both may include not only cost aspects but also LCP, performance and profit aspects [6, 7, 8, 9, 10]. Wååk [11] further separates LCC by two different applications, and Hermann et al. [8] and Thiede et al. [9] give a similar definition of TCO:

- LCC is a measure of a system's or equipment's collected economic consequences during its entire life length [11].
- LCC is a comparative figure for a system's or equipment's collected economic consequences during its entire life length where some simplifications and exclusions have been performed in order to facilitate the utilization of the comparative figure [11].
- TCO subsumes all costs that occur for the operator of a machine [8, 9].

As much as 66% of production equipment's future life cycle cost is tied in the production planning and concept design phase and up to 85% of the total LCC is tied in the system design phase [12, 13], see Fig. 1. However, the cost outcome is more or less reversed as the major costs occur in the use phase of the production equipment. Therefore, having a LCC approach early in the equipment management process is valuable for decision-making.

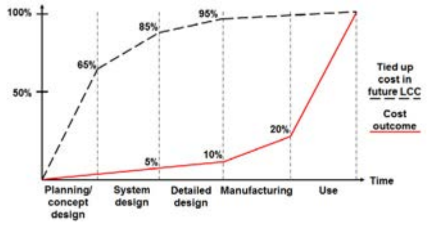

Fig. 1.Cost structures in life cycle costing [13].

In LCC-analysis it is common to separate the analysis in different machine life stages [14]. Only considering acquisition cost can lead to severely higher costs in the operational phase where costs are to a high degree dynamic [8, 9]. The stochastic and variable natures of maintenance cost are mentioned in 3.3. Fig. 2 shows how different costs occur at different life cycle stages and that they vary over time. The dynamics of increasing corrective maintenance in later lifetime is shown. The difference in costs due to market fluctuation is not shown in fig 2, but is important for the difference between historical cost outcome and future LCC.

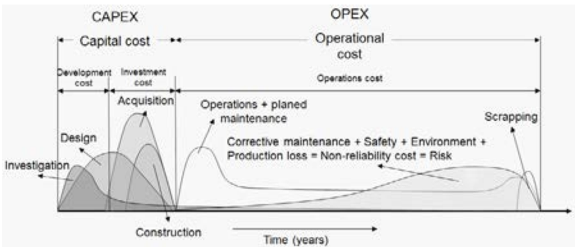

Fig. 2. Life cycle cost analysis [15].

It can be wise to visualize the costs in a Pareto analysis or similar such as a pie chart in order to visualize that the project and acquisition costs are often much smaller than the life support and operations costs. It is quite common to include all supplier costs, research, development design project and equipment production costs into the acquisition cost and to disregard disposal costs [10].

3.2. Life cycle profit

Having a low LCC does not necessarily mean having a high Life Cycle Profit (LCP). There are a number of different