# State and Development of Life-Cycle Cost Analysis Models in Strategic Cost Management

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## ABSTRACT

The substantial increase of indirect costs is one reason that total cost considerations have gained prominence in purchasing decisions. Developed for specific applications, models for life-cycle cost analysis differ significantly. Standardization of the models would enable them to be used more widely. A necessary prerequisite for standardization is to clarify the circumstances and purposes of using the models in practice. For gauging the degree of standardization, we need information on how the cost categories/drivers and requirements for the models vary depending on the object being examined. Moreover, several contingency factors must be considered. This research sheds light on the state and design of life-cycle cost models in practice. An empirical study in the United States and in Germany compares the prevalence and the design of models in practice with the requirements for standardization described in the literature. On the basis of the empirical results, we derive implications for the design of standardized models and for further research.

***Keywords:*** Strategic Cost Management, Purchasing, Total Cost of Ownership, Life Cycle Costing, Life Cycle Assessment, Strategic Purchasing

## INTRODUCTION

The substantial increase of indirect costs over the last decade has caused the recent prominence of total-cost considerations in purchasing decisions for capital goods. This development is supported by the availability of detailed cost information, enabled by improved performance-measurement systems and information technology. The trend toward an assessment based on total costs also has been intensified by soaring energy costs, which have forced decision makers to regard the energy efficiency of their plants, machinery, and products as a crucial factor. Many companies have begun to use life-cycle cost-analysis models as to manage costs. These models make it possible to keep a precise and comprehensive record of the costs involved in an investment and are a reliable aid in the purchasing decision.

Prevalent tools in strategic cost management are the concepts of Total Cost of Ownership (TCO) and Life Cycle Costing (LCC) (Zsidisin 2003, Ellram 1998). LCC focuses on an analysis of the costs for alternative suppliers of capital goods and is primarily being applied in the manufacturing industry, but also in construction projects and energy technology (Heilala et al. 2006). Within the framework of an LCC analysis, the initial investment and subsequent costs are examined over the entire life cycle of the capital goods (Jackson and Ostrom 1980, Heilala et al. 2006). Usually, the LCC approach pays no

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attention to the transaction costs in purchasing or other categories of transaction costs and so, even within the framework of a total cost assessment in purchasing, it is seen as just one aspect of the TCO analysis. Over and above the LCC analyses, TCO is also regarded as a tool for applying transaction-cost theory to the relationship between the purchasing department and the supplier (Ellram 1995). With regard to process optimization within the organization or along the supply chain, it can even be argued that TCO can only be allocated to strategic cost management if it is actually used at the strategic level to optimize processes (Ellram 1998, Labro 2001). Given the possibility of analyzing and optimizing transaction costs along the entire supply chain, TCO is used not just for capital goods but also for consumer goods.

Few standard models or standardized structures calculate TCO/LCC and the relevant cost categories and cost drivers (Suttell 2005, Heilala 2006 et al., Ellram 1994). Requirements from business practice regarding standard TCO/LCC models, cost categories, and cost drivers are considered in the existing literature in the form of case studies. However, only the requirements of individual industries tend to be examined; cross-industry TCO/LCC models that consider practical requirements are few. As a first step, Ferrin and Plank (2002) have classified cost categories and cost drivers into core cost categories, creating the starting point for further research examining dependencies between core cost categories and objects under consideration within TCO/LCC analysis, as well as related cost drivers.

Empirically grounded information research on the prevalence and the design of life-cycle cost models in different industries is needed. Moreover, the dependency of the models on contingency factors, such as country and sector specificities, must be examined. The aim of this study is to shed light on the state and design of life cycle cost models in practice and to investigate further details on cost categories and cost drivers based on the research of Ferrin and Plank (2002). We intend to deepen and update the results of Ferrin and Plank and to investigate whether the increasing importance of energy costs has led to more-detailed and wider TCO/LCC models.

Our analyses focus on the manufacturing industry because TCO/LCC assessments play a comparatively minor role in the service sector (Ferrin and Plank 2002). We also disregard the information technology industry because its specificities make it difficult to derive findings relevant for other industries. As an exception, we consider the established model of the Gartner Group for comparison. It was the first information technology TCO model and therefore is the most mature.

The paper is structured as follows: First, we provide an overview on extant life-cycle cost models. We examine the extent to which the models fulfill the requirements for standardization defined in literature. After a description of our research design, we present the results of an empirical study in Germany and the United States and compare the results to the requirements described in the literature. Finally, we derive managerial implications for the implementation of life-cycle cost models.

## REQUIREMENTS FOR A STANDARD MODEL

Several authors have stressed that the wider dissemination and use of TCO/LCC models depends on the possibility of standardization and user friendliness (Milligan 1999, Ragona 2002, Heilala et al. 2006). A standard model in purchasing and sales will save time and improve the calculated values within the customer-supplier relationship. In addition, the supplier will know the purchasing criteria of his customer more precisely.

With the help of case studies, Ellram (1995) indicates the cases for which standardized models would be better and the cases that would benefit from individual models. Standardized TCO models are adopted if, for example, data is exchanged with suppliers during a supplier evaluation and the models are used to assess and monitor supplier performance. If the content and format of the TCO data made available to the supplier is constantly changing, the data would be of little help to the supplier in its efforts to optimize its offering. Conversely, individual models are used during the supplier selection process for major purchases if individual cost factors or everchanging market conditions are to be considered individually when choosing a supplier. Here, a standard model would be too inflexible and not very reliable.

The need for standardization of TCO/LCC models is emphasized time and again in writings on the topic. Several general requirements for the standardization of TCO/LCC have been identified (Degraeve and Roodhooft 2000, Degraeve 2005, Ellram 1995, 1997, Heilala et al. 2006, Hurkens 2006, Labro 2001). In general, a standard model should be able to consider

- Quantitative and qualitative factors
- Entire life cycle/flexible consideration period
- System efficiency/overall equipment efficiency (OEE)
- Revenue effects on the entire value chain
- Transaction costs
- Information on accuracy and risks of estimates
- Interdependencies between variables

In Table 1, we list prevalent models and note the extent to which they fulfill the requirements for standardization described in the literature. First, we note whether models were designed for individual, capital-intensive plants and systems (A) or for repeat bulk acquisitions of low-value assets (T), and whether they relate to concrete, sophisticated models (M) or to the development

**TABLE 1:** Life-Cycle Cost Management Models

| | common | | | | | criteria | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **model** | **sector** | **model type LCC or TCO** | **guideline or model** | **type of objects considered** | **standard vs. individual** | **overall life cycle** | **system efficiency (OEE)** | **cost categories pre-defined** | **transaction costs** | **revenue effect** | **applicable in purchasing** | **applicable in R&D** | **applicable in sales** | **qualitative factors** | **ABC as basis** | **interdependency of variables** | **accuracy, risk of estimates** | **number of criteria matched** |
| SEMI E35 (2007) | semiconductor | COO | M | A | S | y | y | y | y/p | n | y | y | y | n | n | n | y | 8 |
| Hurkens, Wynstra (2006) | common | TCO | M/G | T | I | y | n | n | y/p | y | y | y | y | y | y | n | n | 8 |
| VDMA (2006) | VDMA | LCC | M | A | S | y | p | y | n | n | y | y | y | n | n | n | n | 5 |
| NAFEM (2006) | food equipment | LCC | M | A | S | y | n | y | n | n | y | y | y | n | n | n | n | 5 |
| Degreave et al. (1997-2005) | common | TCO | M | T/A | S | y | p | p | y | n | y | y | n | y | y | y | n | 7 |
| Razum (Rockwell) (2003) | e-moter/common | TCO | M | T/A | S | y | n | n | y | n | y | y | y | n | n | n | n | 5 |
| Bierma (2000) | chemical | LCC | M | A | S | y | y | y | n | n | y | y | n | y | n | n | n | 6 |
| Ellram (1993-1998) | common | TCO | M | T/A | S | y | n | y | y | n | y | y | y | y | y | n | n | 8 |
| Carr and Ittner (1992) | common | LCC | M | T | S | n | p | y | y/p | y | y | y | n | y | n | n | n | 6 |
| Monczka and Trecha (1988) | electronics | TCO | G/M | T | I | n | n | n | y/p | n | y | n | y | y | n | n | n | 4 |
| Kaufmann (1969) | food | LCC | M | A | I | y | p | y | n | n | y | y | n | y | n | n | n | 5 |
| Krokowski (1998) | common | TCO | M | T | I | y | n | n | y/p | n | y | n | n | y | n | n | n | 4 |
| Gartner Group (2003) | IT | TCO | M | A | S | y | n | y | y | y* | y | y | y | y | y | n | y | 10 |
| VDI (2005) | production capital | LCC | M | A | S | y | y | y | n | n | y | y | y | y | n | n | n | 7 |
| VDV (2003) | traffic | LCC | M | A | S | y | y | y | n | n | y | y | y | n | n | n | n | 6 |
| DIN (2005) | common | LCC | G/M | T/A | A | y | y | y | y/p | n | y | y | y | y | n | n | y | 9 |
| UNIFE (1997) | railway | LCC | M | A | S | y | y | y | n | n | y | y | y | n | n | n | y | 7 |
| | | | | | **number of models** | **15** | **6** | **12** | **10** | **3** | **17** | **15** | **12** | **11** | **4** | **1** | **4** | |

*effects regarding costs etc. are considered until end-user of a guideline for the creation of a model (G). The column "Standard vs. Individual" shows whether the model is standardized (S) or individual (I) and must be adapted to the application scenario in question on a project basis. In the "criteria" matrix, we indicate whether a model takes each criterion for standardization into consideration (y), does so in part (y/p), or fails to do so at all (n).

Some models match most of the criteria (right-hand column in Table 1), whereas others do not seem suitable for use as a standard model. The cost categories to be examined are stipulated in the majority of the models (12 out of 17). LCC models, for example, which are used to calculate the life-cycle costs of production plants and machinery, record operating costs in great detail, whereas TCO models give operating costs limited attention. Other cost categories that are handled quite differently in various TCO and LCC models are disposal costs and storage. In the chemical industry these categories are quite important, while in other industries they are less so (Bierma 2000).

As Ferrin confirms (2002), the main cost categories and drivers can be standardized in principle, but in practice the nature of the object examined, the context of the application, and the sector also need to be taken account. So while a number of TCO and LCC models meet many of the requirements for standard models, further research is needed to clarify the circumstances for and purpose of using the models in practice, with a particular focus on how cost categories and requirements for the models vary depending on the object being examined.

## RESEARCH DESIGN

The questionnaire for this study was based on the results of the literature analysis and interviews with industry experts in the United States and Germany. The use of TCO and LCC in the United States is reported earlier in the literature than is their use in Germany, a fact we felt could aid our investigation of the influence of maturing level on TCO and LCC application. Both countries have a widespread and developed manufacturing industries, which we felt could help to prevent country-based bias in our data analysis.

We targeted manufacturing companies with more than 100 employees. We used a commercial database to find company name, address, e-mail, telephone number, contact person, and position for the 5,000 records selected randomly for each country. Each company provided a contact, in its sales and/or purchasing departments, who completed an online pre-test. The contacts were then telephoned to clarify questions, wording, difficulties, and anomalies in completing the form. We also asked about the total length of time they took to complete the test, their interest in the survey, and their other observations. Changes were made to the pre-test, the questionnaires were printed, and the survey was initiated.

Letters containing a link to the online questionnaire were sent to companies in the United States (5,000) and Germany (5,000). The paper questionnaire was identical to the online questionnaire. Respondents had the option of filling out either, which made the answering as easy and efficient as possible. One week later, the survey was initiated in the form of a telephone follow up. The objective of the follow up was to check whether the right contacts had been written to for TCO and LCC within the companies. This was also necessary because in many companies the allocation of this topic within the organization has yet to be clarified, a fact that was revealed in discussions with the experts. In total, 1,500 companies in the United States and 2,088 companies in Germany were contacted by telephone after being randomly picked from the 10,000 records. The total number of companies that showed an interest in taking part in the survey was 681 (407 online and eleven by postal mail in Germany and 263 in the United States).

More than 90% of companies in Germany that did not wish to take part in the survey did not use TCO or LCC, according to the contacts reached. A similar trend among U.S. companies could be identified, although we cannot quote an exact figure because of the difficulty we had reaching contacts. After further follow up, we finally received 98 questionnaires. The response rate of approximately 14% is satisfactory when compared to similar studies and given the fact that TCO and LCC are not very widespread.

In terms of the spread of TCO and LCC, the sample generated is not normally distributed, since more than 90% of the companies contacted that did not take part in the survey did not use TCO or LCC. The sample mainly contains companies that do use the models. The basis of the sample is also reinforced by the interest of companies actively applying TCO and LCC to respond compared with other companies that do not use TCO and LCC. Quite a number of companies, that did not complete the questionnaire after originally showing a willingness, finally mentioned that they did not use TCO or LCC. For the purposes of hypothesis testing, the number of cases is only of limited to checking individual correlations. Nonetheless, the sample allows us to describe the use of life cycle cost models in the companies and to identify the relevant cost categories and cost drivers and other practical requirements.

## RESULTS

### *Composition of the Sample*

In total, 59 German companies, 30 U.S. companies, and 9 other companies took part in the survey. The significantly lower participation rate of U.S. companies may be due to a dislike of filling out questionnaires.

The breakdown of participating companies by sector allocation is presented in Table 2. One company did not answer the question about sector allocation, and there are 13 incidences of overlap, resulting in a total of 110 allocations.

The table shows the sample's broad sector coverage, which allows us to collate as many requirements as possible for a standard model from a variety of sectors. The data in the "others" category cover, among other sectors, aviation and space travel, medical technology, pharmaceuticals, and defense technology.

The companies average 9,488 employees, with averages of 8,196 employees for U.S. companies and 10,112 employees for German companies. Because it is not uncommon for one person to have several roles, particularly in small and medium-sized companies, respondents may have chosen multiple answers regarding their functions within their companies. The survey's focus on purchasing and sales is reflected in the 45 answers from purchasing managers and 25 answers from sales and marketing managers. Twenty-one purchasing managers are from the United States and 19 from Germany. Nineteen German participants and four from the United States worked in sales and marketing. Another 20 answers are from general managers responsible for purchasing and/or sales and marketing, in most of the cases. From Germany, four controllers and five manufacturing managers answered the survey. The fact that in Germany employees from the area of controlling (management accounting) participated in the study matches the assumption that the conceptual origins in controlling were advanced by German publications (Back-Hock 1988). There are comparatively few U.S. participants from outside the sales environment. We assume that sales continue to be based heavily on price in the United States (Anderson et al. 2007).

**TABLE 2:** Allocation of Cases to Industry Sector and Home Country

| **Industry Sector** | **Frequencies and Share (in%)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **n=98** | **USA** | | **Germany** | | **Other countries** | | **Total** | |
| Chemicals | 2 | 5.7% | 2 | 3.1% | 0 | 0.0% | 4 | 3.6% |
| Rubber and plastics | 2 | 5.7% | 0 | 0.0% | 0 | 0.0% | 2 | 1.8% |
| Electrical engineering | 2 | 5.7% | 8 | 12.5% | 3 | 27.3% | 13 | 11.8% |
| Machinery and can manufacturers | 1 | 2.9% | 24 | 37.5% | 1 | 9.1% | 26 | 23.6% |
| Automobile manufacturers and suppliers | 2 | 5.7% | 9 | 14.1% | 0 | 0.0% | 11 | 10.0% |
| Metal goods manufacturers | 10 | 28.6% | 6 | 9.4% | 0 | 0.0% | 16 | 14.5% |
| Others | 16 | 45.7% | 15 | 23.4% | 7 | 63.6% | 38 | 34.5% |
| Total | 35 | 100.0% | 64 | 100.0% | 11 | 100.0% | 110 | 100.0% |

### State of Implementation

The general findings on the state of the implementation of TCO/LCC models are presented in Table 3. Multiple answers were allowed, which is why three companies indicated that they were in both the planning and the introduction phases.

The results in Table 4 show that, on average, more companies are considering implementing TCO/LCC in Germany than in the United States. This finding is consistent with increased promotion of TCO/LCC by German associations. Germany's largest industrial association, the VDMA (Verband Deutscher Maschinen- und Anlagenbauer), created a lot of interest among its members when it introduced the LCC model (VDMA 2006) The percentage of companies using TCO/LCC in Germany is higher than in the United States—a surprising fact because research papers on the topic appeared in U.S. publications earlier (and have appeared more often) than in German ones.

The reasons given for not using TCO are that companies lack the resources, it is not required by customers, there are no standard models available, and it is too time-consuming. The results in Table 4 underscore the need for standard models to reduce time spent and justify the demand for standard models. Other reasons for not using TCO/LCC mentioned by U.S. companies are a lack of consensus concerning the best approach and the inability to transfer from production to other areas.

### Requirements from Business Practice for a Standard Model

The requirements for a standard model are presented in Table 5 and corroborate the findings of the literature analysis. All the requirements are considered of above-average importance (all variables measured on a Likert scale from 1=completely unimportant to 5=very important). The use of a standard TCO/LCC model for development purposes is considered the most important requirement (4.08). Not far behind are data accuracy (4.07) and use without an existing cost accounting system (4.07). The possibility of defining the period for consideration in the model individually is considered the least important (3.15). In other words, there is a need for stan-

**TABLE 3:** Status of the Introduction of TCO/LCC

| **Status of TCO/LCC** | **Frequencies** | | | |
|---|---|---|---|---|
| **n=94** | **US** | **Germany** | **Other countries** | **Total** |
| First ideas or plan to implement TCO/LCC | 7 | 19 | 2 | 28 |
| Implementation on going | 5 | 7 | 1 | 13 |
| Application/optimization/maintenance after TCO/LCC implementation | 5 | 16 | 3 | 24 |
| No implementation planned as of today | 11 | 16 | 2 | 29 |
| Total | 28 | 58 | 8 | 94 |

**TABLE 4:** Reasons for Not Introducing TCO/LCC

| **Reason for not introducing TCO/LCC** | **Frequencies (multiple responses)** | | | |
|---|---|---|---|---|
| **n=45** | **US** | **Germany** | **Other countries** | **Total** |
| Too time consuming | 9 | 7 | 1 | 17 |
| No available resources | 13 | 10 | 2 | 25 |
| No customer requirements | 6 | 12 | 1 | 19 |
| No standard model available | 7 | 9 | 1 | 17 |
| Other reasons | 5 | 5 | 1 | 11 |
| Total | 40 | 43 | 6 | 89 |

dardization and simplification in the application of TCO/LCC models.

### *Cost Categories and Cost Drivers*

In a study conducted by Ferrin and Plank (2002) among the members of the National Association of Purchasing Management (NAPM), the authors asked whether there are cost drivers that are relevant for all types of commodities. The majority of respondents said it was possible to identify a series of main cost drivers. However, the question of which cost categories the core/main cost drivers belong to was left unanswered. In Table 6, the core cost categories depending on the TCO/LCC

**TABLE 5:** Model Requirements

| | n | mean | s.d. |
|---|---|---|---|
| Applicable in R&D | 92 | 4.1 | 1.0 |
| Data accuracy considered | 92 | 4.1 | 0.9 |
| Applicable without accounting system | 92 | 4.1 | 1.1 |
| Applicable in manufacturing | 92 | 4.0 | 0.8 |
| Applicable in sales | 93 | 3.7 | 1.2 |
| Applicable in purchasing | 92 | 3.7 | 1.0 |
| Type of object considered | 91 | 3.7 | 1.2 |
| Qualitative factors | 93 | 3.6 | 1.0 |
| Data exchange (confidentiality) | 92 | 3.6 | 0.9 |
| Extendable | 90 | 3.6 | 1.1 |
| Pragmatic | 92 | 3.6 | 0.9 |
| Cost categories pre-defined | 91 | 3.5 | 1.2 |
| Individual life time considered | 93 | 3.2 | 1.2 |

**TABLE 6:** Core Cost Categories Depending on the Object of the TCO/LCC Analysis

| | TCO/LCC analysis object | | | | | | |
|---|---|---|---|---|---|---|---|
| Core cost categories | Capital goods | Raw material | Sub-assemblies | Manufactured parts | Packaging | Service | MRO |
| Operating costs | 58% | 35% | 33% | 29% | 36% | 50% | 38% |
| Quality costs | 23% | 65% | 67% | 76% | 36% | 44% | 46% |
| Logistic costs | 15% | 50% | 33% | 35% | 18% | 19% | 8% |
| Technological advantages | 38% | 15% | 33% | 29% | 0% | 6% | 8% |
| Capabilities/reliability of suppliers | 19% | 15% | 28% | 29% | 27% | 44% | 23% |
| Maintenance and repair costs | 62% | 5% | 11% | 12% | 0% | 50% | 38% |
| Inventory costs | 4% | 40% | 17% | 29% | 18% | 0% | 8% |
| Transaction costs | 0% | 10% | 17% | 18% | 9% | 13% | 23% |
| Life cycle costs | 46% | 5% | 22% | 18% | 9% | 25% | 23% |
| Initial costs (incl. price) | 81% | 55% | 72% | 65% | 64% | 38% | 54% |
| Customer related costs | 8% | 0% | 17% | 6% | 0% | 13% | 15% |
| Opportunity costs | 0% | 5% | 0% | 0% | 0% | 0% | 8% |
| Others (e.g. disposal costs) | 0% | 0% | 6% | 0% | 18% | 0% | 0% |
| Number of surveys per object category | 26% | 20% | 18% | 17% | 11% | 16% | 13% |

objects for the study at hand are shown. The percentages in the cells indicate how many companies consider each cost category/cost driver in their application of the models

Table 7 shows the relevance of individual cost categories and cost drivers grouped under five core cost categories used by Ferrin and Plank (2002). Compared to existing research, the results show in more detail the use of cost categories and cost drivers for certain TCO/LCC objects in practice. This data provides a more comprehensive understanding of the main influence factors on TCO/LCC based on empirical research and will help, in practice, to determine the relevant cost elements for TCO/LCC analysis more efficiently. For capital goods, the most relevant cost elements based on a threshold of 25% are price, reconstruction costs, labor for operations, tooling/consumables, operating supplies (e.g., energy), labor for maintenance, spare parts, service cost, and down-time costs. Those cost elements need to be analyzed to provide the data for TCO/LCC analysis of capital goods; other cost elements can be ignored initially. The user has to decide whether to eliminate or to add missing cost elements in case there is an existing deeper understanding of the object under consideration. If there is no need for user-specific changes, the results in Table 6 provide a

**TABLE 7:** Cost Categories and Cost Drivers Depending on the Object of the TCO/LCC Analysis

| | Capital goods | Raw material | Sub-assemblies | Manufactured parts | Packaging | Service | MRO |
|---|---|---|---|---|---|---|---|
| **Initial costs** | | | | | | | |
| Price (inc. spare parts & warranty) | 82% | 48% | 73% | 81% | 73% | 60% | 50% |
| Reconstruction costs | 32% | 7% | 13% | 25% | 0% | 7% | 13% |
| Setup/installation customer/supplier | 18% | 7% | 13% | 19% | 9% | 27% | 13% |
| **Operating costs** | | | | | | | |
| Labor | 46% | 19% | 33% | 44% | 45% | 47% | 38% |
| Tooling/consumables | 39% | 11% | 20% | 19% | 18% | 27% | 13% |
| Operating supplies (energy, gas, etc.) | 32% | 37% | 0% | 13% | 9% | 7% | 0% |
| Floor/space costs | 18% | 7% | 20% | 13% | 18% | 0% | 6% |
| **Quality costs** | | | | | | | |
| Failure costs | 18% | 33% | 87% | 63% | 36% | 13% | 19% |
| Inspection costs | 14% | 33% | 67% | 38% | 27% | 13% | 25% |
| **Logistic costs** | | | | | | | |
| Freight/transport costs | 18% | 56% | 87% | 50% | 64% | 7% | 25% |
| Duties and taxes | 7% | 15% | 33% | 19% | 18% | 0% | 0% |
| Packaging | 4% | 11% | 20% | 13% | 9% | 0% | 6% |
| **Maintenance costs** | | | | | | | |
| Labor | 32% | 0% | 13% | 13% | 9% | 53% | 38% |
| Spare parts | 46% | 48% | 7% | 13% | 36% | 40% | 50% |
| Special tools/measurement devices | 18% | 4% | 7% | 6% | 18% | 7% | 56% |
| Service costs | 25% | 0% | 0% | 6% | 0% | 40% | 19% |
| Downtime costs | 39% | 15% | 7% | 19% | 18% | 33% | 25% |
| n | 28 | 27 | 15 | 16 | 11 | 15 | 16 |

starting point for a focused TCO/LCC analysis with respect to the object under consideration. The selection of the relevant cost elements for the object under investigation should be made with a threshold above 25%. Doing so will reduce the number of cost elements and simplify, as well as speed up, the TCO/LCC analysis.

Table 8 provides some indication of values for core cost categories. The percentage value shows the bandwidth of the corresponding core cost categories in relation to the overall cost (100%). The numbers in brackets show the number of cases considered. The percentage values give a basic illustration of the distribution of costs over cost categories and may therefore be helpful, particularly for introducing TCO and LCC to companies.

In practice, the values in Table 8 can be used if there is no proper cost information available or if the analysis of respective cost elements would take a long time. But due to the limited number of data available from empirical research, as well as the large variance of different objects within one object category, e.g. power plants vs. fluid pumps, the accuracy of the values is quite limited. We recommended determining cost values individually using the procedure described above and the cost categories and cost drivers in Tables 5 and 6.

#### *Transaction Costs*

Research by Labro (2001) has shown that transaction costs account for less than 5% of total costs. In the present study, transaction costs were no more than 10-20% of the total costs. Table 9 displays the relevance of different transaction-cost factors. The scale ranges from 1=completely unimportant to 5=very important. Transaction costs are only considered at a third of the companies observed, and then only as TCO/LCC analysis becomes more established in the companies.

According to companies that already work with transaction costs, raw materials/commodities, subassemblies, and manufactured parts are considered the most important objects (Table 10). For the objects that are being examined, the survey has shown that supplier evaluation, supplier relationship management, supplier replacement costs, and costs for market/supplier analysis top the scale of importance for the individual transaction cost categories at companies that already take transaction costs into account.

**TABLE 8:** Value Indicators for Core Cost Categories

| | Capital goods | Raw material | Sub-assemblies | Manufactured parts | Packaging | Service | MRO |
|---|---|---|---|---|---|---|---|
| Operating costs | 10-30% (4) | 50-60% (3) | 5-20% (2) | 10% (1) | 5% (1) | 5-70% (2) | 10-15% (2) |
| Quality costs | 33% (1) | 15-30% (4) | 20-30% (2) | 30% (1) | 30% (1) | 20-33% (2) | 20-33% (2) |
| Logistic costs | 50% (1) | 10-40% (5) | 40% (1) | 20-40% (2) | n.a. | 50% (1) | 20% (1) |
| Technological advantages | 50% (1) | 20% (1) | 20-40% (2) | n.a. | n.a. | n.a. | 50% (1) |
| Capabilities/reliability of suppliers | 33% (1) | 30% (1) | 20% (1) | n.a. | n.a. | 30-40% (3) | 33% (2) |
| Maintenance and repair costs | 20-30% (2) | 15% (1) | n.a. | n.a. | n.a. | 85% (1) | 15% (1) |
| Inventory costs | n.a. | 20-25% (3) | 20% (1) | 20-25% (2) | 15% (1) | n.a. | n.a. |
| Transaction costs | n.a. | 10% (2) | n.a. | 15% (1) | 20% (1) | 20% (1) | 20% (1) |
| Life cycle costs | 10-50% (3) | 10% (1) | n.a. | n.a. | n.a. | n.a. | n.a. |
| Initial costs (incl. price) | 10-50% (4) | 40-65% (2) | 10% (1) | 40% (1) | 35% (1) | 33-70% (3) | 33-90% (3) |
| Customer related costs | 33% (1) | n.a. | 10% (1) | n.a. | n.a. | 33% (1) | 33% (1) |
| Opportunity costs | n.a. | 10% (1) | n.a. | n.a. | n.a. | n.a. | n.a. |
| Others (e.g. disposal costs) | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |

n.a.=not available
( ) number of cases

Table 10 shows that there is a difference in the perceived importance of taking transaction costs into account between companies that consider transaction costs in their TCO/LCC analysis and companies which do not. The latter group does not pay a lot of attention to transaction costs because the average value is always around 2 on a scale from 1=completely unimportant to 5=very important. The group of companies considering transaction costs is mainly looking at transaction costs for raw material, manufactured parts and subassemblies.

### *Revenue Effects*

Very little attention has been devoted to revenue effects affecting the customer or end user. In our study, only 25% of the companies surveyed took this effect into account. Where it is considered, it is mainly from the point of view of the sales department. Purchasing departments are only persuaded by corresponding references or by very high percentage revenue advantages that benefit their company (Wynstra and Hurkens 2005).

### *System Efficiency/OEE*

Participants in our survey rate the consideration of the OEE factor important, particularly for capital goods and components. For other objects of the TCO/LCC analysis, the OEE factor is seen as less important. Generally speaking, the significance of the OEE assessment increases as companies become more experienced in dealing with TCO/LCC analyses. In practice, OEE is mainly used for capital goods; manufactured parts; service; and maintenance, repair, and operating supplies (MRO).

**TABLE 9:** Relevance of Transaction Cost Factors

| n=40 | Companies taking transaction costs into account | | |
|---|---|---|---|
| **Relevance of individual transaction cost factors** | **Yes** | **No** | **All** |
| Supplier evaluation | 4.1 | 2.8 | 3.3 |
| Supplier change over costs | 3.7 | 2.8 | 3.1 |
| Market/supplier analysis | 3.5 | 2.8 | 3.0 |
| Supplier connection (data transfer) | 3.7 | 2.7 | 3.0 |
| Supplier development | 3.4 | 2.8 | 3.0 |
| Pre-negotiation | 3.0 | 2.9 | 2.9 |
| Demand analysis/-evaluation | 3.3 | 2.7 | 2.9 |
| Contract administration | 2.6 | 2.7 | 2.7 |
| Order handling/-transfer | 3.2 | 2.2 | 2.6 |
| Financial transactions | 3.3 | 2.2 | 2.6 |

**TABLE 10:** Relevance of Transaction Costs with Respect to the Object Under Consideration

| n=40 | Transaction costs considered | | |
|---|---|---|---|
| **Relevance of transaction costs** | **Yes** | **No** | **All** |
| Capital goods | 2.6 | 1.9 | 2.2 |
| Raw material | 3.2 | 1.8 | 2.3 |
| Sub-assemblies | 2.9 | 1.7 | 2.1 |
| Manufactured parts | 3.1 | 1.9 | 2.3 |
| Packaging | 2.6 | 1.6 | 1.9 |
| Service | 2.7 | 2.2 | 2.4 |
| MRO | 2.0 | 2.0 | 2.0 |

#### *Qualitative Factors*

In practice, including qualitative features enables factors that are difficult to assess in monetary terms to be integrated into the TCO/LCC analysis. In our study, 28 out of the 39 companies that answered these particular questions reported taking qualitative factors into consideration.

Most of the qualitative features investigated (on-time delivery, support by suppliers or service, market position of supplier, quality, technical support, and product development by supplier) are considered important by our respondents. The market position of the suppliers is used by 29% of companies, suggesting less importance for the consideration of this factor in TCO/LCC analysis. Technical support and product development by the supplier are considered more frequently in the United States than in Germany, perhaps because German companies are not as specialized as U.S. companies. German companies might have more technical know-how in-house and might not rely as much on suppliers' product development. The same phenomenon might explain support by supplier on services.

The functional area also influences the qualitative factors within TCO/LCC analysis. While most qualitative factors are similarly important across functional areas, on-time delivery is significantly more important for the customer's management and purchasing. In contrast, the sales force of the supplier does not pay much attention to this factor. Based on this finding, we can conclude that there are opportunities for the selling company to perform well in on-time delivery. Moreover, the sales department might get different results from TCO/LCC analysis than do their customers, which might mislead them in the sales process. Sales should take on-time delivery into account for TCO/LCC analysis as well as within the customer delivery process itself.

#### *Consideration Period*

The time period considered in TCO/LCC analysis differs from case to case. In practice the time period taken into account differs depending on the object analyzed. The results of our study show that TCO/LCC analysis looks at one to five years or more for capital goods. Packaging and raw material is analyzed within one to five years or less. All other objects are in between, i.e. in the range from less than one year up to more than five years.

The difference between capital goods and raw materials, as well as packaging, is because the latter two are consumables and the supplier and product can be changed over time. Capital goods are normally used longer in order to pay back the investment and they cannot be easily exchanged within the next shipment. Subassemblies, manufactured parts, services, and MRO are in between that timeframe. They can be easily replaced with a new product or supplier unless they are tailor-made to supply a manufactured part or subassembly.

#### *Influence of Other Context Factors*

The context factors we have discussed so far for the different TCO/LCC model elements are the type of object under consideration, function, and country. Our research also investigated sector, company size, and maturity level of the different model features. Company size had almost no influence. Influence of the sector was difficult to determine because the number of samples in some sectors was quite limited. OEE is used by almost all companies investigated within electrical engineering and is very rarely used in the chemical and the production machinery sector. This might be due to the fact that the model of the trade organization Semiconductor Equipment and Materials International, or SEMI, widely used in the electrical engineering industry, considers OEE (SEMI 1995, 2007).

Another influence of context factors was the high accuracy of TCO/LCC results required by German companies, especially from production machinery companies compared to others. This might result out of the fact that most of these companies are on the way to implementing TCO/LCC. They have not yet determined the optimal balance between accuracy and time-consumption for the analysis. Another reason might be the greater use of cost-accounting systems in German companies and the deeper involvement of suppliers and/or customers in TCO/LCC analysis. Finally, cost-accounting systems and OEE are used more frequently at companies with greater experience applying TCO/LCC. Such companies also have a slight tendency to look at transaction costs more often.

## DISCUSSION

The differences our study has unearthed between TCO/LCC models, using the contextual factors country and sector, can serve as indicators for the use and configuration of a standard model. In Germany, qualitative features and transaction costs are used more frequently and model calculations are more precise than in the United States. OEE is taken into account more often in electrical engineering than machinery and plant manufacturing, the chemical industry, and other sectors. The investigation of contextual factors related to TCO/LCC models enhances existing research from Ferrin and Plank (2002), which explores cost categories and sorts them based on a study of purchasing managers in the United States.

The consideration period chosen for a TCO/LCC analysis tends to be longer in sales than in purchasing and management. We recommend that the players involved at the customer/supplier interface agree on a common consideration period for a TCO/LCC analysis at the outset. A common model and framework for TCO/LCC analysis ensures transparent decision making within the supply chain (Ragona 2002, Heilala et al. 2006).

On-time delivery is considered very important by managers and purchasers. Sales should also put more focus on timeliness for TCO/LCC analysis as well as for delivery.

The importance of the different model requirements in practice matches the requirements identified in the literature. Also, the required elements within a standard model have been confirmed. Core cost categories, cost categories and cost drivers can be standardized based on our results. It is possible to select the most relevant cost categories and drivers before starting the TCO/LCC analysis. The selection provided in Tables 6 and 7 is the starting point for cost evaluation. At a later stage, cost elements can be optimized based on experience. If there are no data available for single core cost categories, a rough value for core cost categories in percent of TCO/LCC is provided in Table 8. This pre-selection framework for different TCO/LCC analysis objects, based on empirical results, is unique. It extends existing research from Ferrin and Plank (2002) as well as existing TCO/LCC models by not only providing all possible cost categories, but also by pre-selecting the most important cost categories depending on the type of object under consideration.

Transaction costs are considered almost exclusively by the purchasing department, a result that corresponds with existing research on transaction costs (Ellram 1993a, Ellram 1994, Ellram and Siferd 1998, Degraeve et al. 2000, Degraeve et al. 2004a, Degraeve and Roodhooft 2000). The supplier may want to optimize product costs and also to take account of the transaction costs incurred by the customer's purchasing department. Though it has been shown that transaction costs are of minor importance on the whole, in some cases they might be important.

Finally, using the phase structure, we analyzed the influence that the maturity of TCO/LCC in the company has on the elements of the model. Transaction costs, OEE, and revenue effects are used more frequently as TCO/LCC becomes more established. These elements of the TCO/LCC analysis should not be considered immediately when TCO/LCC is introduced, but instead added as the company gains experience. The same applies to the use of a cost-accounting system and the involvement of customers or suppliers in data collection. Here, too, we recommend that the TCO/LCC analysis be automated as its use in the organization becomes more and more established, not at the very outset. The influence of TCO/LCC maturity level on the use of cost accounting systems, transaction costs, revenue effects, and OEE has not been investigated in the previous research discussed above.

## CONCLUSION

This paper investigates the standardization of life-cycle cost-analysis models in strategic cost management. We have examined the requirements for a standard model, as described in the available literature, and verified them with the help of an empirical study.

The results from our research confirm the relevance to practice of model requirements identified in the literature. The standard model elements, core cost categories, qualitative factors, consideration period, OEE, revenue effects, and transaction costs have been examined. The relevance of these elements depend on context factor country, sector, company size, object type, and function has been evaluated, and the relevance of detailed features for qualitative factors, consideration period, OEE, and transaction cost has been determined.

We have evaluated the relevance of core cost categories identified by Ferrin and Plank (2002) to the object type under consideration. We also investigated some core cost categories in detail and determined underlying cost categories and cost drivers most relevant in practice. Finally, we have shown rough value indicators for core cost categories to support the application of TCO/LCC analysis when cost data for single core cost categories is missing.

Finally, our study has expanded the knowledge on the state and development of life-cycle cost-analysis models in practice. While others have assumed that the models are widely used in the manufacturing industry, we have found that TCO/LCC is still not very widespread in practice. Obviously, the increase of indirect cost and soaring energy costs in recent years have not boosted the implementation of the models in strategic cost management. Our research revealed that the main reasons companies do not use TCO/LCC are time constraints and lack of resources, know-how, customer interest, and standardized models. However, quite a number of companies have recently started TCO/LCC implementation projects. This research should help those companies implement TCO/LCC more quickly, by focusing on the main issues from the beginning.

## REFERENCES

Anderson, J. C., N. Kumar, and J. A. Narus. 2007. *Value merchants*. Boston: Harvard Business School Press.

Back-Hock, A. 1988. Lebenszyklusorientiertes Produktcontrolling. Berlin: Springer.

Bierma, T. J. 2000. Chemical management: reducing waste and cost through innovative supply strategies. New York: Wiley.

Brown, R. J. 1979. A new marketing tool: Life-cycle costing. *Industrial Marketing Management* 8: 109–113.

Carr, L. P., and C. D. Ittner. 1992. Measuring the cost of ownership. *Journal of Cost Management* 6: 42–51.

Cavinato, J. L. 1991. A total cost/value model for supply chain competitiveness. *Journal of Business Logistics* 13: 285–301.

Degraeve, Z., E. Labro, and F. Roodhooft. 2000. An evaluation of vendor selection models from a total cost of ownership perspective. *European Journal of Operational Research* 125: 34–58.

———. 2004a. Constructing a total cost of ownership supplier selection methodology based on activity based costing and mathematical programming. Vlerick Leuven Gent Working Paper Series 2004/08, Leuven.

———. 2004b. Total cost of ownership purchasing of a service: The case of airline selection at Alcatel Bell. *European Journal of Operational Research* 156: 23–40.

Degraeve, Z., and Roodhooft, F. 1999. Effectively selecting suppliers using total cost of ownership. *The Journal of Supply Chain Management* 35: 5–10.

———. 2000. A mathematical programming approach for procurement using activity based costing. *Journal of Business Finance & Accounting* 21: 69–98.

Degraeve, Z., F. Roodhooft, and B. van Doveren. 2005. The use of total cost of ownership for strategic procurement: A company-wide management information system. *Journal of the Operational Research Society* 56:51–59.

DIN. 2005. *DIN EN 60300-3-3-2004*. DIN DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE.

Ellram, L. M. 1993a. A framework for total cost of ownership. *International Journal of Logistic Management* 4: 49–60.

———. 1993b. Total cost of ownership: Elements and implementation. *International Journal of Purchasing & Materials Management* 29: 3–12.

———. 1994. A taxonomy of total cost of ownership models. *Journal of Business Logistics* 15: 171–191.

———. 1995. Total cost of ownership: An analysis approach for purchasing. *The International Journal of Physical Distribution and Logistics Management* 25: 4–20.

Ellram, L. M., and F. Feitzinger. 1997. Using total profit analysis to model supply chain decisions. *Journal of Cost Management* 11: 12–21.

Ellram, L. M., and S. P. Siferd. 1993. Purchasing: The cornerstone of the total cost of ownership concept. *Journal of Business Logistics* 14: 163–184.

———. 1998. Total cost of ownership: A key concept in strategic cost management Decisions. *Journal of Business Logistics* 19: 55–84.

Ferrin, B.G. and R.E. Plank 2002. Total cost of ownership models: An exploratory study. *Journal of Supply Chain Management* 38: 18–29.

Gartner Group. 2003. Measurement distributed computing chart of accounts. Chart of Accounts E-Rev.

Heilala, J., K. Helin and J. Montonen. 2006. Total cost of ownership analysis for modular final assembly systems. *International Journal of Production Research* 44: 3967–3988.

Hurkens, K., W. van der Valk, and F. Wynstra. 2006. Total cost of ownership in the service sector: A case study. *The Journal of Supply Chain Management*, 42: 27–37.

Jackson, D. W., and L. L. Ostrom. 1980. Life cycle costing in industrial purchasing. *Journal of Purchasing and Materials Management* 16: 8–12.

Kaplan, R. S., and R. Cooper. 1998. Cost and effect: Using integrated cost systems to drive profitability and performance. Boston: Harvard Business School Press.

Kaufman, R. J. 1969. Life cycle costing: Decision making tool for capital equipment acquisitions. *Journal of Purchasing* (August): 16–31.

Labro, E. 2001. *Total cost of ownership supplier selection based on activity based costing and mathematical programming*. Katholieke Universiteit Leuven: Faculteit der Economische en Toegepaste Economische Wetenschappen.

Milligan, B. 1999. Tracking total cost of ownership proves elusive. *Purchasing* 127: 22-23.

Monczka, R. M., and S. J. Trecha. 1988. Cost-based supplier performance evaluation. *Journal of Purchasing and Materials Management* 24: 2–7.

Monczka, R. M., R. Trent, and R. Handfield. 2002. *Purchasing and supply chain management*. Mason: South Western.

NAFEM. 2006. *LCC model NAFEM 2006 full version 1*. North American Association of Food Equipment Manufacturers, Chicago.

Ragona, S. 2002. Cost of ownership (COO) for optoelectronic manufacturing equipment. Paper presented at 2002 Microsystems Conference, Rochester, NY.

Razum, J. 2003. Envision value: Introducing industrial total cost of ownership. Greenville: Rockwell Automation.

SEMI. 1995, 2007. Guide to calculate cost of ownership (COO) metrics for semiconductor manufacturing equipment (SEMI E35-307). San Jose: Semiconductor Equipment and Materials International.

Shields, M. D. and M. S. Young. 1991. Managing product life cycle costs: An organizational model. *Journal of Cost Management for the Manufacturing Industry* 3: 39–51.

Suttell, R. 2005. Investments for life(cycle). *Buildings* 99: 68–70.

UNIFE. 1997. *Guidelines for life cycle cost*. The UNIFE LCC Group.

VDMA. 2006. Prognosemodell für die Lebenszykluskosten von Maschinen und Anlagen. Berlin: Beuth Verlag.

VDV. 2003. Verband Deutscher Verkehrsunternehmen. Ausschuss für Betriebshöfe und Werkstätten; Ausschuss für Kraftfahrwesen. Life Cycle Cost (LCC) bei Linienbussen. *VDV Mitteilungen*, No. 2315: 1-23.

VDI. 2005. *VDI-Richtlinie. VDI-Handbuch Betriebstechnik*. Verein Deutscher Ingenieure, Berlin: Beuth Verlag.

Wouters, M., J. C. Anderson, and F. Wynstra. 2005. The adoption of total cost of ownership for sourcing decisions – a structural equations analysis. *Accounting, Organizations and Society* 30: 167-191.

Wynstra, F., and K. Hurkens. 2005. Total Cost and Total Value of Ownership. Eßig, M. (ed.). *Perspektiven des Supply Management. Konzepte und Anwendungen*. Berlin: Springer, 263-482.

Zsidisin, G. A., L. M. Ellram, and J. A. Ogden. 2003. The relationship between purchasing and supply management perceived value and participation in strategic supplier cost management activities. *Journal of Business Logistics* 24: 129–155.