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Approach for successful LCC Data collection and analysis

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ABSTRACT

Companies continuously have to make important decisions about future investment projects and options. Especially, in the manufacturing and plant engineering industry a major part of the total costs is caused by investment costs. In many cases more than 50% of the total costs are not regarded due to the fact, that only purchasing costs are considered (Asiedu & Gu 1998, p. 890; Geißdörfer 2008, p. 1-3). In order to avoid this deficiency, Life Cycle Costing is a highly auspicious option. Well-structured Life Cycle Costing analysis provides a complete overview about the total cost structure of a product in each phase of its individual lifetime. Thus, the initial investment decision will be optimized due to the fact that all follow-up costs are considered. In a long term perspective the holistic investment proposal is more sustainable and eventually also more favorable than an initial investment decision, mainly based on purchasing costs (Barringer 2003, p. 2, Zimmermann 2005, p. 2).

Although decision makers are aware of the importance and need of Life Cycle Costing during investment decisions, there is still a lack of Life Cycle Costing appliance in practice. The latter often results from a huge complexity of Life Cycle Costing models and none validated appliance to a special case. Also, the question how to collect data effective is often not solved.

Among this background this paper provides a general overview of different Life Cycle Costing approaches. Following this overview a description is given how an accredited Life Cycle Costing model can be applied to a practical case - using DIN EN 60300-3-3 as an example. Moreover, it is demonstrated which dimensions and parameters have to be considered for a Life Cycle Costing analysis. Subsequently, there will be an overview about key factors that are mandatory for a successful data collection. Finally, lessons learned based on the experiences within a European research project are presented.

Keywords: Life Cycle Costing, Data Collection, Data Analysis

1. INTRODUCTION

In order to remain competitive in the rising pressure and uncertainty of today's market economy, substantiated investment decisions are of significant importance (Schweiger, 2009). Many investment decisions are however still based on traditional cost-benefit analyses, which often solely consider the initial purchasing costs of an investment (Boussabaine, Kirkham & Richard, 2004). This is often inappropriate and short-sighted since in various industry sectors, e.g. the engineering and manufacturing sector, a major part of the total investment costs is caused by the follow-up costs of the initial acquisition e.g. through maintenance, reparations or disposals (Geißdörfer, 2009). In order to adequately choose among investment options it is crucial to use a holistic costing perspective that considers the entirety of the arising costs.

One widely acknowledged holistic costing approach is the Life-cycle costing concept (LCC), which was originally designed for procurement purposes in the US Department of Defence but has since been transferred to various industry sectors (Korpi & Ala-Risku, 2008). The essence of the technique is to segregate investment into separate phases over their life-cycle and to identify cost drivers of each phase (Kreuz, 2005).

Despite of the widely acknowledged significance of the LCC approach, there is still a lack of LCC usage due to implementation complexity in industry environments. The complexity is centred around the identification and calculation of potential cost drivers. In particular the multiple sources (organizations) which are involved in the data collection process; the data from the vendor's product have to be matched with the internal, often sensitive, data of the user. Data within the user's organization is often spread among various functional departments which then have to be identified and gathered together adding to the complexity of the process of cost driver identification. Another challenging aspect of the LCC approach is the complex calculation of costs and time ratios related to the different types of item that follow the successful data collection (Perera, Morton & Perfrement, 2009), e.g. material durability, maintenance costs or the frequency of repairs.

Numerous tools have been developed in order to facilitate the LCC approach. These tools however vary significantly according to their applied perspectives, the degree of standardization and the ease of use. Choosing the appropriate LCC approach out of the variety of developed tools remains a challenging task.

In order to reduce the variety of LCC models to a manageable number, the next section of this paper will provide a structured overview of the most important LCC approaches. In essence, it will compare the different LCC approaches according to their applicability in different industry sectors, their ease of use, their different life cycle phases as well as their core disadvantages and advantages. The overview will provide potential users with a reduced number of relevant tools that would support their decision for an appropriate LCC approach.

2. MODELS OF LIFE-CYCLE COSTING

There are a tremendous amount of LCC tools that have been published in recent years (Bünting, 2009). The proposed models however can vary according to their perspective. LCC models can be developed from the user's or the supplier's perspective. The majority of models however have concentrated on the user's perspective in which life cycle calculations facilitate the choice between different investment options (Korpi & Ala-Risku, 2008). From the supplier's perspective, LCC models can however also be of added value e.g. as a foundation of their negotiations in which the detailed demonstration of the occurring costs serves as a strategic marketing instrument (Geißdörfer, 2009).

In addition to the various perspectives, the LCC models further differ according to their division and labelling of the particular life cycle phases (Lorenzer et al. 2009). The specification of the amount and the duration of the different phases generally depend on the nature of the asset under investigation (Christensen et al., 2005). Despite the dependence on the asset for the exact determination of the LCC phases, certain consensus dominates on the division of the three core phases of the traditional life cycle analysis see figure 1 (Bockskopf in Schweiger 2009).

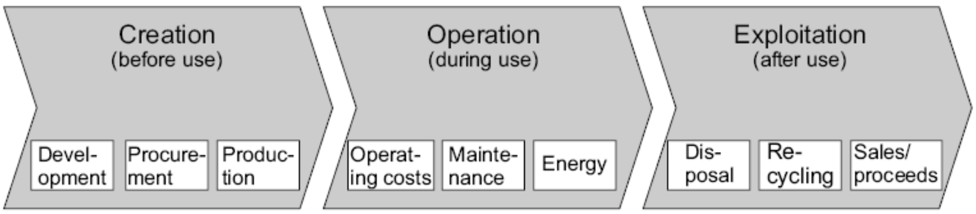

FIGURE 1: Three core LCC phases, (Bockskopf in Kiel, 2007)

These phases include the creation, operation and exploitation of the chosen asset and subsequently determine cost drivers before, during and after the implementation of the asset.

Yet another feature that distinguishes the different LCC approaches is their level of individualization. While some companies, especially members of the automobile sector have designed their individual LCC models (e.g. the MTCO-approach of Daimler, (Büning in Schweiger, 2009)) which fit their particular corporate and industry context, other LCC models intend to be standardized and subsequently applicable to a wide range of sectors and products. In the field of standardized life-cycle costing approaches there are several norms which co-exist in the market (Christensen, 2005). These norms, developed by industry and federal associations, offer detailed guidelines for the consideration of the right costing elements during the analysis of total life cycle costs and on adequate methods for the identification and the calculation of these elements (Bockskopf in Kiel, 2007). They include benchmark values and are thus able to reduce the complexity of cost driver calculations and data collection approximations as they offer the user a reliable point of reference (Henn, 2009).

As these norms are not tied to particular assets, they can be applied to different projects and investments types (Kreuz, 2005), which can become especially valuable for organizations operating in various industry sectors or in different sections of the value chain. Applying a standard, consequently allows these organizations to employ the same LCC approach over a range of investments. By applying the same LCC approach to several investments, the organization may, in addition, increase its LCC expertise and may become able to transfer this knowledge to even other parts of the organization (Geißdörfer, 2009).

Realizing the relevance of these LCC norms, the following section will present a detailed description of a selection of the most relevant concurrent LCC norms.

3. IDENTIFICATION OF SELECTED LCC NORMS

This section will elaborate on each of these standardized LCC models in detail and will illustrate these models, reduce the previously mentioned complexity as well as reveal/mention/show their main (dis-) advantages. Most of the LCC norms consider the three previously mentioned life cycle phases, however most models concentrate on a detailed description of the operation phase (Abele in Schweiger, 2009). The cost driver evaluation can be accomplished based on qualitative and/or quantitative data. The models further differ according to their applied context and their evaluation perspective. A detailed description of the models follows:

TABLE 1: Overview of life cycle cost standardized models

LCC Norm	Context	Perspective	Phases	Data-Evaluation	Pro +	Contra -
VDMA 34160	Engineering Industry	User	1. Creation & Acquisition 2. Operation 3. Exploitation	Quantitative	+ consideration of sales revenue	- no consideration of indirect costs
DIN EN 60300-3-3	No specified context, general applicability.	User & Vendor	1. Creation & Acquisition 2. Operation 3. Exploitation	Qualitative & Quantitative	+ comprehensive analysis including sensitivity forecasts	- challenging application for user
VDI 2884	Manufacturing Industry	User & Vendor	1. Creation & Acquisition	Quantitative	+ detailed perspective of user and vendor	- no illustration of specific examples
UNIFE LCC	Railway Industry	User	1. Operation	Quantitative	+ LCC philosophy to railway industry	- ignores disposal costs

VDMA 34160

The LCC model 34160 was developed by the VDMA (short for: Verband Deutscher Maschinen- und Anlagenbau) which is a German Engineering Federation that represents a network of approx. 3,000 engineering companies in Europe. Among others, the association irregularly publishes guidelines and calculation models for good conduct in the economy. The core motivation of VDMA 34160 was to introduce an engineering-specific standard for the calculation of life cycle costs, which can be applied throughout the entire industry (Schweiger, 2009). In essence, VDMA 34160 provides guidance for the identification of costing elements and the definition of formulas for their calculations during the life cycle phases of plant and machinery (VDMA, 2010).

The calculation model differentiates costing elements between the three phases before, during and after the life-time of the particular plant or machinery, see figure 2. The total life cycle costs are represented by the sum of all expenditures which are necessary for the utilization of the machine from its acquisition to its disposal (Bockskopf in Kiel, 2007).

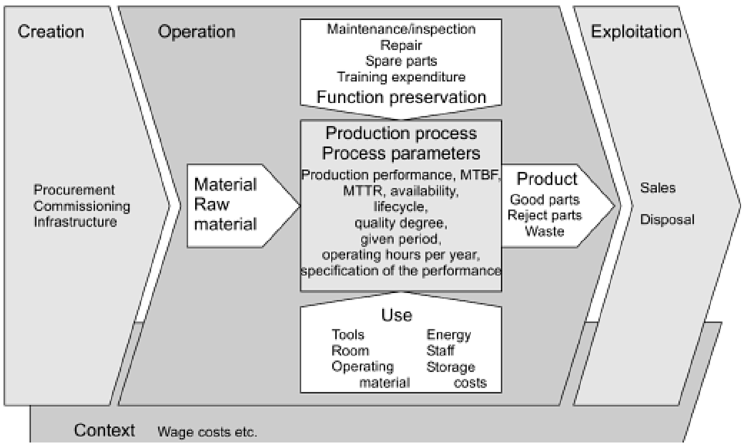

FIGURE 2: Phases and Elements of VDMA 34160

The model defines costing blocks for each phase and corresponding instructions for their calculation. In the *creation* phase, the relevant costs are focused on the acquisition, the implementation and the allocation of the necessary infrastructure. During the *operation* phase, the model differentiates the four costing aspects 'material', 'product', 'use' and 'function preservation'. The underlying data needed for these calculations is defined by customer-specific conditions and is specified by the seller, including e.g. average value and amount of mid-term reparations, availability and time frame of examination. During the *exploitation* phase the VDMA model considers costs, incurred by the potential disposal of the machine such as recycling, destruction or scrapping as well as potential revenues from the sale of the used asset, represented by its residual value. In this context, the VDMA 34160 is the first life cycle costing model that considers the potentially resulting revenues of the asset's sale in the end of the exploitation phase (Bockskopf in Kiel, 2007). Next to the costs occurring during the particular phases, VDMA 34160 includes 'contextual costs' which occur over the entire life time of the asset under investigation. These costs may include indirect cost items of e.g. labour and energy.

Concerning the calculation of total life cycle costs, the VDMA 34160 is structured in a way that the costing elements of each phase are systematically subdivided into their constituent parts, see figure 3.

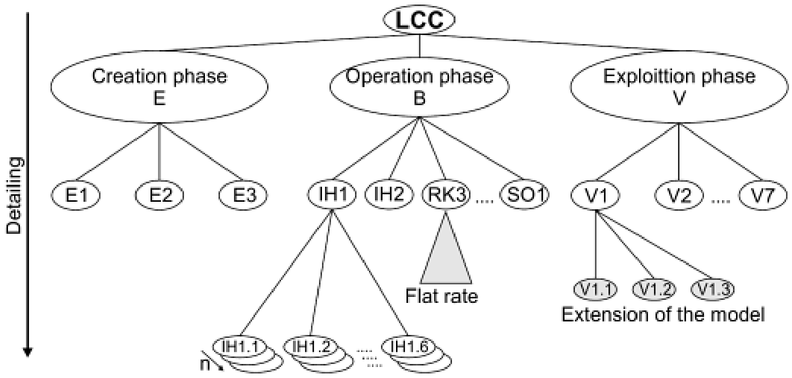

FIGURE 3: Costing elements VDMA 34160

For every relevant costing category, the VDMA 34160 provides detailed calculation methods and benchmark values. The corresponding categories are gradually added until the final summation of total life cycle costs. The VDMA approach considers all relevant costs but is based on quantitative data. Indirect costs of e.g. the integration of the asset into current production structures or the necessary training of the labour force are not taken into account (Kreuz, 2005). In addition, the model assumes the adaptability of the costing approach to different contexts and specific implementation conditions. In this context, it is based on the assumption of comparable outputs of different assets. However, if quality of output and degree of performance are not comparable, the results of the model would not be of any added value.

Even though the results of the forecasted costs of the asset serve the seller and the user of the asset equally, the consideration of costing elements concentrates on the user's perspective. A holistic costing approach including both parties would for example include development and construction costs, which are however neglected by the VDMA 34160. The period under consideration is explicitly defined as the section of the machine's life that begins with its procurement and ends after its service life. In this context, the model represents a particular ambiguity, since costs before and after the period under consideration are only to be included if they 'have a cost influence on the service life'. However, no details are given concerning the identification and assessment of this influence (Bockskopf in Kiel, 2007).

DIN EN 60300-3-3

DIN, the German Institute for Standardization is a registered non-profit association, which is based in Berlin since 1917. Its primary task is to work closely with its stakeholders in order to develop consensus-based standards that adequately meet market requirements (Geißdörfer, 2009).

The introduced standard DIN EN 60300-3-3 (2005) that considers the forecasting of life cycle costs, is concentrated on reliability management. In this way, the DIN standard identifies costs which are directly and indirectly associated with the reliability of an asset. In essence, the goal of the DIN life cycle cost guideline is to provide data on which to base the investment decision for a given asset (Bockskopf in Kiel, 2007). As opposed to the previously described VDMA standard, the DIN model divides the life of an asset into the following six phases.

1. Concept & Definition
2. Outline & Development
3. Assembly
4. Installation
5. Operation & Maintenance
6. Disposal

FIGURE 4: DIN six phases of LCC

These six phases offer a detailed description of costing elements during the life of a given asset, which can however be accumulated into three core costing areas that are then used for the calculation of total life cycle costs, see figure 4.

$$\text{LCC}_{\textit{Total}} = \text{Costs}_{\textit{Aquisition}} + \text{Costs}_{\textit{Ownership}} + \text{Costs}_{\textit{Disposal}}$$

FIGURE 5: Total life cycle costs DIN

The DIN guideline further describes methods for cost breakdown structures, which should be applied in order to detect the relevant cost elements. The illustration of various costing methods provides the user with an adequate overview of the relevant methods which can then be tailored to the individual needs of the user organization (Bockskopf in Kiel, 2007). The document further delivers detailed example calculations which ease the application of the model to the user (Abele in Schweiger, 2009), appendices provide samples of individual topics such as 'typical cost generating activities' or 'parameterized calculations of costs' (DIN 60300-3-3, 2005). In addition, the influences of data integrity on statements regarding availability, optimism and pessimism forecasts as well as sensitivity ratios for risk estimations are included (DIN 60300-3-3, 2005).

Even though, the DIN standard enhances cost calculations of the creation phase of the asset (Abele in Schweiger, 2009), the guideline provides the most comprehensive description of the elements involved in life cycle costing (Geißdörfer, 2009). The perspective of the user is stressed by the DIN 60300-3-3 but the results of the calculations could be of added value for the vendor as well, since the transparent cost structures of his asset represent a foundation for potential cost-related optimizations (Kreuz, 2005).

In summary, the detailed explanations of the costing blocks and the illustrative examples of the appendices will enable the user to define both the subject of life cycle costing and to understand the goals, phases and related aspects of conceptual design and modelling of the tool in great detail (Bockskopf in Kiel, 2007). Furthermore, the user is able to set up and evaluate various costing models and structures in order to select the one appropriate for his context.

VDI 2884

VDI (German: Verein Deutscher Ingenieure), the association of German Engineers has issued the life cycle costing model VDI 2884 in 2005 with the title 'Purchase, operation and maintenance of production equipment, using Life Cycle Costing' (VDI 2884, 2005). The core motivation of this forecasting model is to two-folded. On the one hand, it intends to support the user by the selection of different production equipment options and to deliver an evaluation framework for innovative configurations to the vendor (Abele in Schweiger, 2009). On the other hand, VDI 2884 proposes a detailed calculation methodology for the concrete estimation of life cycle costs of a chosen asset (VDI 2884, 2005).

Even though, the VDI approach specifically considers both perspectives of the user and the vendor, it is primarily formulated from the view of the user. From the user's perspective, the standard applies to the procurement of alternatively offered investments with reference to the entire life cycle. From the vendor's perspective VDI 2884 can be used to support economically feasible and customer-oriented planning and development. The model is based on the calculated life cycle costs, decisions made in the development phase, which are mainly concentrated on the initial reduction of costs. These are set against the resulting follow-up costs of later phases in the life cycle (VDI 2884, 2005). Figure 5 graphically illustrates the different perspectives and corresponding life cycle phases under investigation.

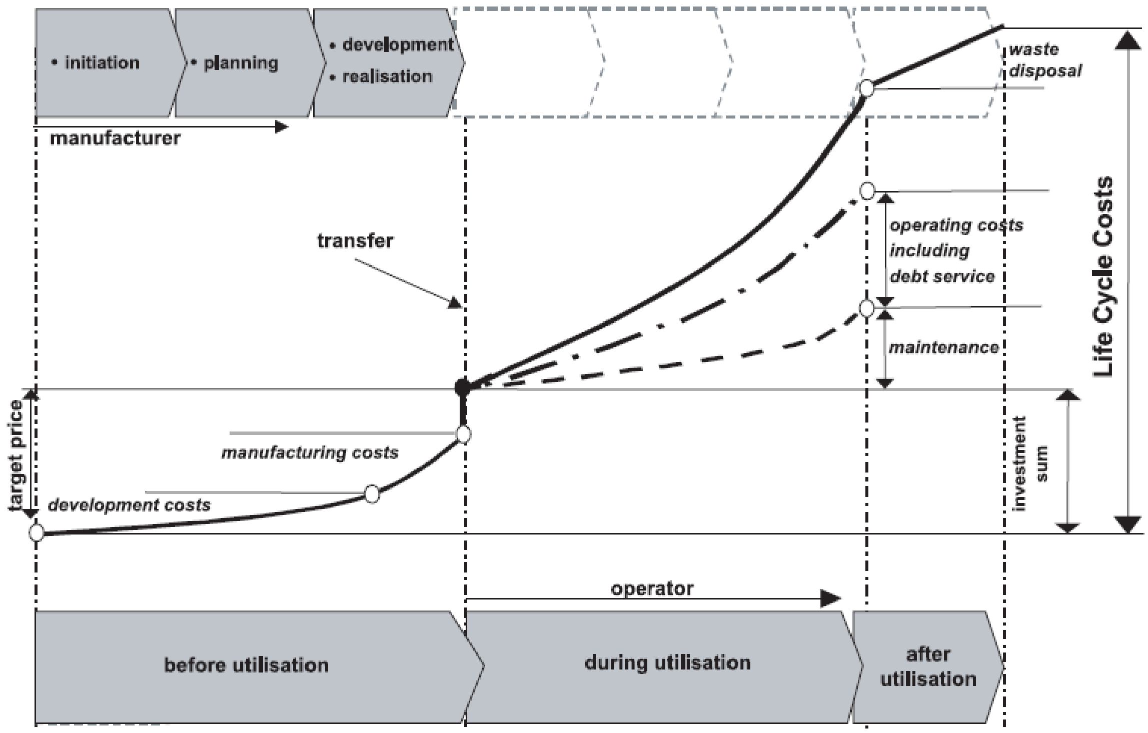

FIGURE 6: Graphic presentation of Life Cycle Costs

Life cycle costs are defined as the total costs and revenues that a system generates throughout its service life from the perspective of the machine operator (Bockskopf in Kiel, 2007). The VDI approach identifies four areas of importance that need to be considered during the process of life cycle cost calculations (VDI 2884, 2005).

1. Prognosis
2. Representation
3. Explanation
4. Design

FIGURE 7: Areas of importance, VDI

In the prognosis area, life cycle costs, consisting of revenues and follow-up effects of investment options, which cannot be quantified monetarily, must be estimated. These predicted estimations then constitute the foundation for the comparative assessment of alternatives. The identified costing factors must in turn be representative in order to provide support for the decision-making process. This is regarded in the second area of importance. The third area raises awareness of the fact that costing elements should not only be identified but also explained in detail. This is necessary in order to actively influence the particular costing block and the connected issues of time and quality. Finally, in the design area, the various options for the optimization design, in addition to the identified costs, must be recognized and potential methods for cost reductions should be identified.

Three tables of the VDI 2884 document, corresponding to the three typical life cycle phases, list the usual costing elements to account for in the phases before, during and after the utilization of the asset. Gathering the necessary information to forecast incurred costs and gained revenues during the life cycle is regarded as the most complex stage. The three tables offer a pragmatic approach to facilitate this stage and consequently to reduce the associated complexity. Further, the VDI 2884 supports the decision-making process by evaluating risks such as unreliable data sets (Bockskopf in Kiel, 2007). The prognostic nature of the LCC approach can consequently be substantially reduced with the use of this standard. The

VDI 2884 finally recommends the implementation of sensitivity analyses, which has also been incorporated by the previously described DIN model.

However, a weakness of the VDI model is that it fails to provide a specific forecasting model example, which would be useful as orientation for the user of the model. Instead it offers various suggestions to support the user and the vendor without specific guidance on how to proceed in detail.

UNIFE LCC

UNIFE, the union of the European railway industries, was associated in 1991 based on the request for the urgent need to merge the European railway markets into a one single market (UNIFE, 2010). Currently, UNIFE is composed of 16 national organizations, as associated members representing another 900 railway supply companies (UNIFE, 2010). UNIFE's role is to represent its members' interests at the level of both European and international institutions and the mission of the association is to pro-actively develop an environment in which UNIFE members can provide competitive railway systems for increased rail traffic. So far UNIFE has delivered railway interoperability and standardization for improved life cycle cost as well as standards for reliability, availability, maintainability and safety.

Life cycle costing in the railway industry has mainly focused on the prediction of investments on railway vehicles (Daneka & Richtara, 1999). Today's mass transit market, however, has rapidly been changed to a turnkey system, where the supplier is forced to treat life cycle costing methods not only for vehicles but for the entire railway system (Schweiger, 2009). The UNIFE LCC model divides total life cycle costs into investment, operation and life support costs throughout the life stage of a system. The concerned phases are defined as:

1. Concept & Definition
2. Design & Development
3. Manufacturing
4. Installation (including on-site testing and commissioning)
5. Operation & Maintenance

$$LCC = C_{investment} + C_{operation} + C_{life\ support\ cost}$$

FIGURE 8: Phases and Total LCC costs, UNIFE

Since the UNIFE LCC model is a customer-oriented LCC model, it emphasizes the investment, operation and life support costs. Disposals costs are however, neglected in the UNIFE LCC model.

The UNIFE LCC model is mainly focused on the operation and maintenance of railway vehicles. It focuses on the financial aspects, depreciation, income, expenditure costs over the life of a system are however not included (Jun & Kim, 2007). It is a rather technical LCC calculation, but the cost calculations fail to take any logistical or administrative delays into account. Further, the model ignores part of the infrastructure related expenses (Daneka & Richtara, 1999). Despite of these shortcomings, UNIFE LCC contributed significantly towards the practical usage of the LCC philosophy in the railway vehicles manufacturers and user sphere.

4. PRACTICAL CASE APPLICATION

The railway industries throughout Europe are exposed to an increasing competitive pressure caused by various less costly transportation and logistics modes. Industrial competitors from Russia and Asia push with lower-cost offerings into the European market and challenge the established railway industries. The European Commission initiated the project called "Integrated European Signalling System" (INESS) to revitalize the European rail transport. The program aims to reduce the overall life cycle costs of railway signalling systems in order to help the competitiveness of the European railway industry and also to provide suppliers to a healthy market to make sales.

To achieve the goal of reduced total life cycle costs an interdisciplinary consortium was founded, consisting of six railway partners, six industry partners, two research partners and the International Union of Railways. All phases of the life cycle of a railway signalling system were to be taken into consideration as part of the project.

The consortium concentrated on the question of the LCC in detail and recognized that a formal model was needed. Members of the project decided to apply DIN EN 60300-3-3 since this approach stood out with its generic stance and its good transferability to the railway industry.

To conduct a valid analysis of LCC and to get substantive results at the end, reference data was collected from all the all railway- and industry-partners. DIN EN 60300-3-3 provides a generic framework for this task based on a cube-shaped model. It assigns each cost element to one of the three dimensions of cost category, product /work breakdown structure and life cycle phase. It provides a mechanism through which all the important LCC aspects can be examined in detail. Furthermore this configuration provides the capability to investigate individual dimensions to different depths of detail.

Before a data collection could be undertaken all three dimensions of the cost elements were defined by the consortium in detail.

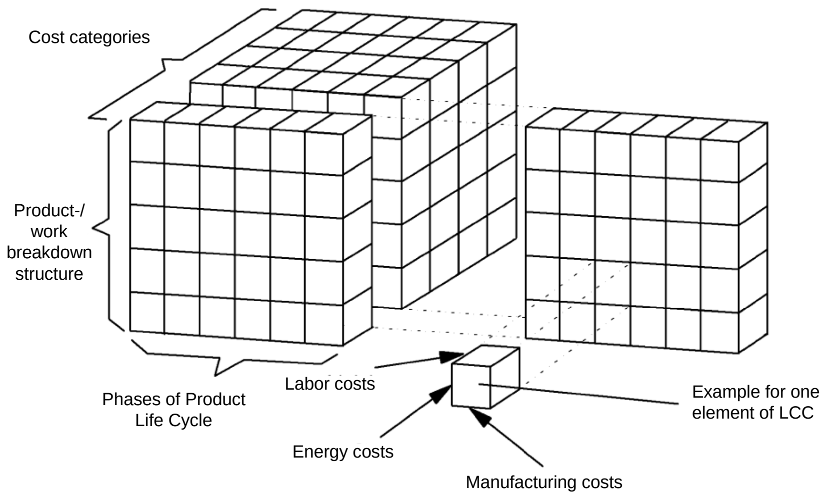

FIGURE 9: Concepts of cost elements

Members of the consortium were split up into three workgroups, and all partners were provided with a clear understanding of the underlying DIN model. Each group focused on one dimension and was asked to develop the relevant aspects and particular objects for analysis. After each workgroup had defined their objects of analysis all workgroup-results were gathered and the entire consortium developed a template that to be used for the following data collection.

The actual data collection had previously been structured and planned by the consortium. The plan divided the data collection-process into three different steps, first the data conditioning and preparation by the railway- and industry-partners, second the actual data collection by the collection teams and third the data evaluation and analysis by the FIR. Furthermore the consortium asked each railway and industry-partner to install in-house expert teams, to prepare and condition the relevant data ahead of the actual data collection. This resulted in an initial exercise by the in-house teams to collect and condition the data followed by the completion of a data collection template. After the templates were completed they were sent to the collection team one week in advance to the actual data collection.

The second step was the actual onsite data collection which was planned to last for two days and was conducted by the partner's expert team and a specially assigned collection team consisting of members from the FIR and the DB Netz AG, supported by members of the DLR. This phase of the data collection started with an introduction of the collection team, the INESS project and the purpose of the whole data collection, in order to ensure everybody had a common basic level of information since in practice not every member of the in-house teams was familiar with the INESS-project. Afterwards, industry and railway partners respectively presented the results of their data-conditioning-effort. Within this presentation the following topics were to be addressed to ensure an in-depth understanding of the information by the collection team regarding railway- and industry-project specifications:

1. Detailed project description
2. Explanation of the data source
3. Report of general effort
4. Assessment of data quality
5. Filled-out Excel-template

After the onsite-visit by the collection team, the railway and industry partners carried out a final check of the data, before the third and final process step, the data evaluation and analysis, could be undertaken. The evaluation and analysis was carried out in different work streams of the INESS project. After all collected data had been compared and evaluated; the total life cycle costs for different types of interlocking systems could be estimated and stated.

However the scheduled data collection could not be carried out as planned. After the first onsite-visits by the different collection teams were completed it became apparent that neither the railway nor the industry partners were capable of providing the data needed to fill out the template. There were several reasons for this unexpected trend. First, to many railway and industry partners the mutually developed template seemed to be too complex for the task of the data collection. Second, some partners had a lack of resources needed to conduct the required data preparation, collection and conditioning processes. As the result none of the partners was able to deliver fully completed templates leading to the problem that a detailed data-analysis was simply not realizable. It also turned out that industry-partners in particular had different expectations concerning the data-template. In their opinion the life cycle phases needed to be addressed differently.

At this point it was decided to discontinue the initial scheme for data collection and replace it with an alternate process. It was agreed by the consortium to develop two different, much less complex templates, one for the railway partners, and one for the industry partners to obtain comparable sets of data. The data needed for the new template was then extracted from the data collected for the previous scheme. The following two figures represent the redesigned, adjusted templates:

	Company - Project	xxx				
	Phase	System Implementation		Operations	Maintanance	Other
	Cost Category	Hardware	Labour	Labour	Labour	All
Traffic Control System						
Core System						
Field Elements						
Connection to FE						
RBC						
	∑	**0**	**0**	**0**	**0**	**0**
	Total Project Costs	**0**				

FIGURE 10: Final data collection template for railway partners

		Material	Labour	Sub Total	Capital	Total
	Company					
	Project					
	Cost Categories	Material	Labour	Sub Total	Capital	Total
Design	Indirect	0,0%	0,0%	**0,0%**	0,0%	**0,0%**
	CTC	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Core IXL	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Field	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
		0,0%	**0,0%**	**0,0%**	**0,0%**	**0,0%**
		Material	Labour	Sub Total	Capital	Total
Installation	Indirect	0,0%	0,0%	**0,0%**	0,0%	**0,0%**
	CTC	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Core IXL	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Field	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Civils & Cabling	0,0%	0,0%	**0,0%**	0,0%	**0,0%**
		0,0%	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Indirect	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Direct	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**
	Total	**0,0%**	**0,0%**	**0,0%**	**0,0%**	**0,0%**

FIGURE 11: Final data collection template for industry partners

These two templates were the basis for the data-collection and ultimately the following data-analysis. For the railway partners, basically three lifecycle phases were considered for the analysis - System Implementation, Operations and Maintenance. Other costs which could not be allocated to one of these categories were summarized within “Other”. The life cycle phases of the industry partners were Design and Installation.

In total, eleven railway partner and ten industry partner projects were analysed at this stage of the INESS-project. All railway partner contributed data for two projects, except one partner who could only provide data of one project. Apart from one, each industry-partner contributed data of two projects.

After this modified data-collection-process was finished all collected data was analysed and categorized into different types of interlocking systems and diverse types of projects. As a result a detailed list of identified cost drivers was established.

In retrospect it can be said that DIN EN 60030-3-3 is very well suited for the life cycle cost analysis of the European railway industry, since it delivers a generic approach but still incorporates rigorous scientific techniques. Consequently it was possible to confidently apply the basic model to the railway industry specifications and be able to conduct a thorough data analysis. However it has to be stated that a detailed understanding of the industry is still necessary in order to avoid problems similar to those that occurred during the initial data-collection-process within INESS-project. An initial approach which required too complex analysis required far more resources from the partners than was available leading to a noticeable delay the whole project.

REFERENCES

Aldinger, A.L., (2009). *Methode zur strategischen Leistungsplanung in wandlungsfähigen Produktionsstrukturen des Mittelstandes***.** Institut für Industrielle Fertigung und Fabrikbetrieb der Universität Stuttgart**,** 2009.

Abele, E. Dervisopoulus, M., Kuhrke, B. (2009) *Bedeutung und Anwendung von Lebenzyklusanalysen bei Werkzeugmaschinen* in Schweiger, S. (2009) Lebenszykluskosten optimieren. Paradigmenwechsel für Anbieter und Nutzer von Investitionsgütern. GWV Verlage, Wiesbaden, 2009.

Barringer, H.P. A life cycle cost summary. International Conference of Maintenance Societies (ICOMS-2003).

Bockskopf, V. in Kiel, E. (2007) Antriebslösungen. Mechtronik für Produktion und Logistik. Springer-Verlag, Berlin Heidelberg, 2007.

Chen, G., Adrian, D., Williams, D.P., (2007) Life cycle costing. Encyclopedia of Public Administration and Public Policy, Pages 1164–1167. Second Edition, CRC Press, 2007.

Christensen, P.N., Sparks, G.A., Kostuk, K.J. (2005) A method-based survey of life cycle costing literature pertinent to infrastructure design and renewal. Canadian Journal of Civil Engineering, Vol. 32, p. 250-259, 2005.

Daneka, A., Richtara, M. (1999) New Approaches to the Life Cycle Costs Philosophy of the Railway Vehicles. Institute of Transport, VSB – Technical University of Ostrava, Czech Republic.

DIN EN 60300:2005-03, Zuverlässigkeitsmanagement-Teil 3-3: Anwendungsleitfaden_Lebenszykluskosten (IEC 60300-3-3:2004), Beuth Verlag, Berlin 2005.

Enparantza1 R., Revilla1 O., Azkarate A., Zendoia, J. (2006). A Life Cycle Cost Calculation and Management System for Machine Tools. 13th CIRP International conference on life cycle engineering, 2006.

Geißdörfer, K. (2009) Total cost ownership and Life cycle costing. LIT Verlag, Münster, 2009.

Hastak, M. Mirmian, A. Richard, D.(2003) A Framework for Life-cycle Cost Assessment of Composites in Construction. Journal of Reinforced plastics and composites, Vol. 22, No. 15/2003.

Jun, H.K., Kim,J.H., (2007) Life Cycle Cost Modeling for Railway Vehicle. International Conference on Electrical Machines and Systems 2007, Oct. 8-11, Seoul, Korea.

Korpi, Ala-Risku (2008). Life cycle costing: a review of published case studies Managerial Auditing Journal, Vol. 23 No. 3, 2008, pp. 240-261.

Kreuz, C. (2005) Kundenorientierte Unternehmensrechnung. Dissertation Universität Düsseldorf. Deutscher Universitätsverlag /GWV Fachverlage GmbH, Wiesbaden, 2005.

Schweiger, S. (2009) Lebenszykluskosten optimieren. Paradigmenwechsel für Anbieter und Nutzer von Investitionsgütern. GWV Verlage, Wiesbaden, 2009.

VDI 2884: 2005-12, Beschaffung, Betrieb und Instandhaltung von Produktionsmitteln unter Anwendung von LCC Life Cycle Costing. Beuth Verlag, Berlin 2005.

VDMA-Einheitsblatt 34160: 2006-06, Prognosemodell für die Lebenszykluskosten von Maschinen und Anlagen, Beuth Verlag, Berlin, 2006.