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## Life Cycle Engineering and Management – Fostering the Management-orientation of Life Cycle Engineering Activities

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### Abstract

Life Cycle Engineering (LCE) is a promising approach for directing engineering activities towards sustainability. Although LCE includes not only technical and ecological but also economic target figures, management-orientation is rather limited and issues affecting the success of innovation processes are neglected. This is shown based on a literature review. For contributing towards closing this gap, this paper presents suggestions to foster the market-, customer-, and supply chain-orientation of LCE: its extension by business modeling and integration with Target Costing. Elements of these approaches are illustrated by the research activities of the Cluster of Excellence MERGE.

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### 1. Introduction

Striving for sustainability becomes more and more an imperative for all institutions and individuals in economy as well as society. Sustainable acting implies focusing a long-term perspective. Hence, the engineering of systems should be directed towards the entire life cycle in order to improve their sustainability. This is the dogma of Life Cycle Engineering (LCE) – a concept which is defined as “engineering activities which include: the application of technological and scientific principles to the design and manufacture of products, with the goal of protecting the environment and conserving resources, while encouraging economic progress, keeping in mind the need for sustainability, and at the same time optimizing the product life cycle and minimizing pollution and waste” [1].

Regardless of technological progress, innovative systems (resulting from LCE) will only be successful in terms of being implemented in companies or established at markets if they are economically advantageous from the point of view of the involved institutions and decision-makers. An economic perspective has always been considered by LCE literature: the

inclusion of economic targets is one of its characteristics [2]. However, LCE was originated by engineering scientists and the engineering perspective is dominating. A review of LCE literature shows that the economically-oriented considerations are mostly limited to including single economic targets in LCE activities [2]. This goes along with the wide negligence of other issues influencing the success of innovation processes [3]: market-, customer-, and supply chain-orientation in terms of assuring user benefit and economic profitability of the system to be engineered for all relevant stakeholders, the application of – market-oriented and other – concepts and methods prominent in management sector (e.g., Target Costing (TC), Knowledge Management) and issues of leadership, culture, organization, and human resources. Only very few publications address management topics as well: Umeda et al. include management-related influencing factors, options, tasks (such as coherence management, business modeling), and methods in their framework of life cycle development and concept of life cycle planning [4]. Not explicitly focusing on LCE, Meier et al. discuss different business models for industrial product-service systems [5].

However, the first approach is not deeply elaborated in terms of management, the second one focused on a specific type of object. So, a negligence of management topics in LCE still has to be stated.

This is not surprising due to the engineering focus of the approach. However, to include these issues in LCE or to integrate them with LCE promises a higher probability of successful innovations generated. Hence, here it is intended to foster the management-orientation of LCE by showing ways for its extension by or integration with management-relevant issues – towards a Life Cycle Engineering and Management. Therefore, the market-, customer-, and supply chain-orientation as important facets of management are focused.

## 2. LCE and its management-orientation

The following short analysis of the management-orientation of LCE is based on a literature review conducted by Peças et al. [2]. Firstly, they suggest a taxonomy of LCE consisting of four levels referring to the intended type of contribution, the theoretical foundation, the LCE activities, and the reference objects of LCE. The activity level is additionally divided into the dimensions decision perspective, target perspective, tasks, methods, and information and knowledge. Then, the taxonomy is used to give a survey on the state-of-the-art of LCE. The results of this survey [2] shall now be discussed from a management perspective starting with the *contribution*. It was found that empirical studies are not present in the publications analyzed. This lack of empirical studies implies a lack of knowledge about how LCE is performed in company practice, factors affecting its successful operations, and existing barriers. This hinders the design, implementation, and organization (or: management) of LCE in companies and calls for further research activities.

The analysis of the *theoretical foundation* shows that only seven publications consider management theories. This clearly reveals that LCE concepts and methods are only weakly substantiated by insights from the management research area. This can be explained by the origin of the concept; it might reflect the opinion that such insights are not highly valuable for LCE activities. However, amongst others findings from strategic management theory (e.g., about success factors at the market or resource level), innovation theory (about the design of innovation processes, barriers for innovation success, etc.), planning and control theory (e.g., about the design of planning and control cycles and activities), as well as organizational and human resource management theory (about leadership, culture, incentive systems, etc.) seem to be helpful for conducting LCE activities as well as designing and organizing them. Here, some of these findings are addressed in the context of market-, customer-, and supply chain-orientation.

Concerning the *decision perspective*, most of the publications argue from a company perspective. A supply chain-related view is only present in two papers. This disregards the strong influence of the supply chain characteristics on the life cycle performance from the company perspective as well as the fact that success of an entire supply chain is even a prerequisite for the success of a

single company participating in that chain. This calls for a stronger consideration of supply chains in LCE. Furthermore, in LCE theory, the customers' view is almost neglected. It is primarily addressed by striving for product's reliability and serviceability design and modeling, without considering user benefit and economic profitability of the products and processes. Finally, market considerations and the concept of Business Modeling (BM) are neglected as well. Summarizing, from a management point of view LCE should be extended or complemented by a stronger focus on markets, customers, and supply chains.

Referring to the four *tasks* of LCE included in the taxonomy, the results show a non-uniform picture with a certain dominance of analysis/forecasting tasks. From a management point of view, this is a hint for the necessity of a further discussion of the tasks and the corresponding scope of LCE. For systematic decision-making, the accomplishment of all analyzed tasks (description and recording, analysis and forecasting, evaluation, design, and engineering) seems to be mandatory. This argues for conceptualizing LCE as an integrated approach covering all these tasks (or as a well-defined element of such an approach). Therefore, insights from planning and control theory about the design of feed forward and feedback cycles and available methods may be useful. Going beyond the taxonomy, the scope of analyzed potential tasks has been extended to leadership, organization, coordination and control. The analysis shows that none of these management tasks is present in LCE literature. However, this field cannot be addressed here.

Concerning the *methods*, the analysis shows that there is a considerable variety of suggested or applied methods with Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) as the most frequently mentioned ones. Besides LCC and LCA, methods are used or suggested in a disparate way – a mature and integrated methodology of LCE being widely accepted among researchers does not exist. Besides LCC, only the related concept of life cycle value, traditional as well as flow cost accounting approaches [6,7], methods of multi-criteria decision making, and Quality Function Deployment (in only one publication) have been suggested in LCE literature. This implies the quite surprising negligence of the well-known and established customer-oriented engineering and management method of TC. BM as well as other multifaceted instruments of management such as market research, coordination approaches, incentive schemes, etc. are also neglected. Closely coupled with the application of methods is the issue of information and knowledge. Undoubtedly, significant information and knowledge are indispensable prerequisites for successful LCE and making them available is a major challenge: they refer to the entire life cycle and LCE acts in the early life cycle phases where typically data availability is low and uncertainty is high. Nevertheless, knowledge management concepts such as suggested in management literature [8] have not been established in LCE literature so far. A corresponding extension might be based on considerations concerning life cycle-related (cost) management and cost knowledge management in engineering [9,10].

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