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Total Life Cycle Management – An Integrated Approach Towards Sustainability

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ABSTRACT

New environmental product requirements and extended product responsibility as well as the pressure to offer new better value and more innovative products are severe outside influences on companies. As a result internal and external complexity of companies increases. The paper presents the Braunschweig Framework of Total Life Cycle Management as a framework for total life cycle management differentiating structures, disciplines, and behavior on different management levels and in all life cycle phases. Life cycle phase specific disciplines as well as supporting life cycle spanning disciplines are classified according to the framework. The demand for a total life cycle management perspective is demonstrated based on an example of intersecting life cycle phases.

1 Challenges for Companies

Companies find themselves confronted with increasing internal and external complexity. Rapid changes in markets, legislation, technologies, and customer demands have a particular strong influence on the complexity of their surrounding environment. In many industries, such as the electrical- and electronics industry, but also in many supplier industries, more and more actors, products (product variants), product-accompanying services, and legislative regulations emerge within the globalized market. At the same time social and legal requirements regarding a change toward sustainable development force industries to increase effectiveness, reduce emissions, avoid hazardous substances and to decouple the economic growth and the primary resource consumption on the long-term view. As an example, some countries strive to increase national resource productivity, which includes optimizing the use of primary resources and promoting the use of secondary raw materials by promoting a recycling-society. The transformations into legal frameworks are for example the directives of the European Union considering the waste disposal of old electrical appliances (WEEE) [1] and the ban on using certain harmful substances in products (RoHS) [2]. Directives like the WEEE allocate the responsibility for product recycling to the manufacturer. The extension of the product responsibility obliges companies to comply with technical and ecological requirements, as for example recycling rate targets. Companies react to the increasing market, legal, and social pressure and accountability by offering more innovative products, customizing their products, and implementing new product and production technologies in order to gain and prevail competitive advantages. Another approach for differentiation lies in the development and supply of product-accompanying service models. Services, as for example functional sales, lead to the consequence that manufacturers carry responsibility for their products to a greater extent, although the products are already with the customer. On the whole, dynamic changes and requirements are more and more interconnected and interdependent while the product responsibility is continuously extended. The resulting complexity means a strong pressure regarding the adaptation of companies, not only as a single organization but as a part of a supply chain network. Thus, the adaptation of companies in terms of changes in structures, activities, and behavior is a challenge for management.

2 Models, Frameworks, Disciplines, and Methods in Management

The outlined challenges and trends make clear that the companies face highly complex situation to an increasing degree. Management reacts to the external surroundings with the development of the inner structures with the aim to cope with the external complexity. A growing inner complexity derives from the inter-individual

performance of tasks based on the division of labor and from the necessity to integrate and co-ordinate this performance. “Developing, designing and operating companies with regard to institutional and functional aspects as well as human resources, the management makes a fundamental contribution to coping with complexity in systems” [3]. To cope with future challenges with respect to an sustainable development, an integrated view of different sustainability-related and life cycle-related research disciplines (engineering, industrial management, social science, chemistry, etc.) is necessary. Pre-conditions for coming to terms with the increased complexity and the emerging research approaches are on the one hand a frame of reference which enables orientation, and on the other hand transparency for the integration of differentiated approaches. Company models and management frameworks should help to link different disciplines, to uncover interdependencies, and to promote the integration of disciplines and methods.

2.1 Life Cycle Management Approaches

To depict the different life cycle phases of products and to classify corresponding life cycle objectives and activities, life cycle management approaches have been developed by several researchers. At present, life cycle management [4, 5, 6, 7], closed-loop supply chain management [8, 9, 10], and life cycle planning [11, 12, 13] are more and more topics of research. Considering the product life cycle phases, the approaches start with life cycle design and engineering [14, 15, 16] and end up to product life cycle management and end-of-life management [11] with an information-oriented view on the product life cycle. While some researchers focus on the life cycle of primary goods (e.g. washing machines, cars, etc.) and address environmental issues like design for environment (DFE) or life cycle assessment (LCA), other researchers focus on the life cycle of production equipment (e.g. machine tools, robots, etc.) and address topics like life cycle maintenance or spare part management in order to maximize resource productivity. As these rather different life cycle approaches have to be synergistically incorporated by companies within their operations, these approaches in terms of frameworks, disciplines, and methods have to be contemplated considering to the mode of operations of companies.

2.2 The Viable System Model

One of the most approved model for the representation and analysis of companies and their complexity-related questions [17] is the Viable System Model (VSM) of Stafford Beer [18, 19]. The VSM helps to represent the mode of operation of a company. With this, the structured comprehension of important life cycle management issues should be made possible and connections should be pointed out. The viable system consists of five interacting subsystems which represent the invariant structure of a viable system, such as a company or an autonomous working team [see Figure 1]. The Systems 1 in a viable system contain several primary activities and thus stand for what is primarily done in the company (e.g. product development, production, sales, services, etc.). System 2 stands for how the Systems 1 are coordinated and thus represents the information channels and bodies that allow the primary activities in System 1 to communicate between each other and which allow System 3 to monitor, audit, and co-ordinate the activities within System 1. System 3 represents the operational management in terms of structures and controls that are put into place to establish the rules, resources, rights and responsibilities of System 1 and to provide an interface with the Systems 4/5. System 4 stands for the strategic management of the company. The bodies that make up System 4 are responsible for looking outwards to the environment to monitor how the company needs to adapted to remain viable. System 5 depicts the normative management that is responsible for policy decisions within the company as a whole to balance demands from different parts of the company and steer the company as a whole. In addition to the subsystems that make up the first level of recursion, the environment is represented in the model. The presence of the environment in the model is necessary as the domain of action of the system. To contextualize the internal interactions of the company, the subsystems are associated with their surrounding environment.

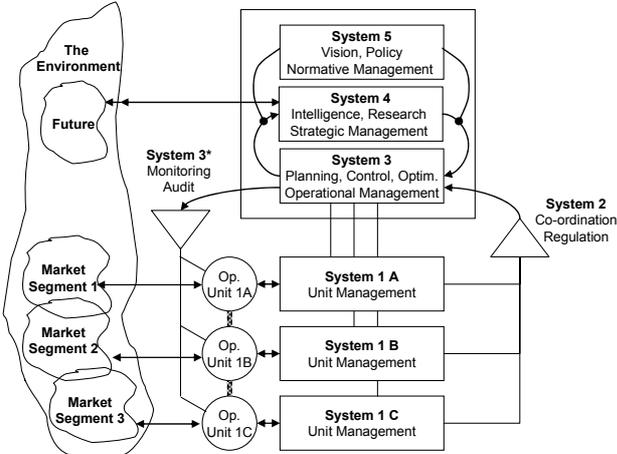


Figure 1: Simplified Viable System Model [18, 19]

From a product life cycle perspective it can be pointed out, that every life cycle phase affects different subsystems and thus different interaction mechanisms within a company. The company internal goal conflicts between different systems along the product life cycle phases can be made transparent using the VSM. With an increase in external and internal complexity in the context of an extended product life cycle perspective, objectives of different life cycle phase related systems have to be harmonized by a life cycle oriented management to achieve global optima. Furthermore, management disciplines and methods that are necessary to cope with the complexity of the product life cycle can be worked out with the help of the VSM.

2.3 The St. Gallen Management Framework

Based on the findings of the VSM, the St. Gallen Management Framework was developed by Ulrich and Krieg [20]. This management framework includes a structure for the company, for chairmanship and for organization, and thus serves as a framework which fosters the classification of disciplines and methods. Offering that structure, the framework helps to comprehend the mechanisms of a company's subsystems (Systems 1-5 of the VSM) and the embedding in its complex surroundings. The framework transfers the findings of the VSM and classifies the manifold challenges to successful and responsible management in an appropriately complex and yet integrated manner. With the development of the framework Ulrich pursues three basic matters: the meaning of integrated thinking and action when dealing with the challenge of "complexity", the meaning of a user-oriented management theory, as well as the integrative development of the normative, strategic, and operational management level within the context of a comprehensive general concept. In the following years, the St. Gallen Management Framework was extended to a "concept of integrated management" [21]. The concept divides into a normative, strategic and operational management on the one hand and into structures, activities and behavior on the other hand as management fields. For reasons of its neutral form of representation, different concepts and management systems can be added to the created frame of reference in an universal manner. Thus, it's structure can be used as a starting point for the representation of a life cycle oriented management framework.

2.4 The Braunschweig Framework of Total Life Cycle Management

The economic as well as ecological challenges require a changed frame of reference for management. The individual stages of the product life cycle must be made more consistent with each other, constant process- and information flow must be arranged, and the life cycle must be specifically managed. The Braunschweig Framework of Life Cycle Management is based on the ideas of the Viable System Model and the 'concept of integrated management' and puts up a systemic and life-cycle oriented framework for a life cycle phase comprehensive point of view on products and the corresponding processes [22, 23]. The starting-point for entrepreneurial acting is the statement of a sustainable development in the meaning of a super ordinate management philosophy [see Figure 2]. It includes the attitudes and convictions of values which influence the thinking and acting of the company's management. The centric rings in Figure 4 represent the normative, strategic and operational management. The normative and strategic management are the basis for situational events of the operational management. Besides a sectorial division into the product life cycle phases, the management levels can also be differentiated axial according to the "concept of integrated management".

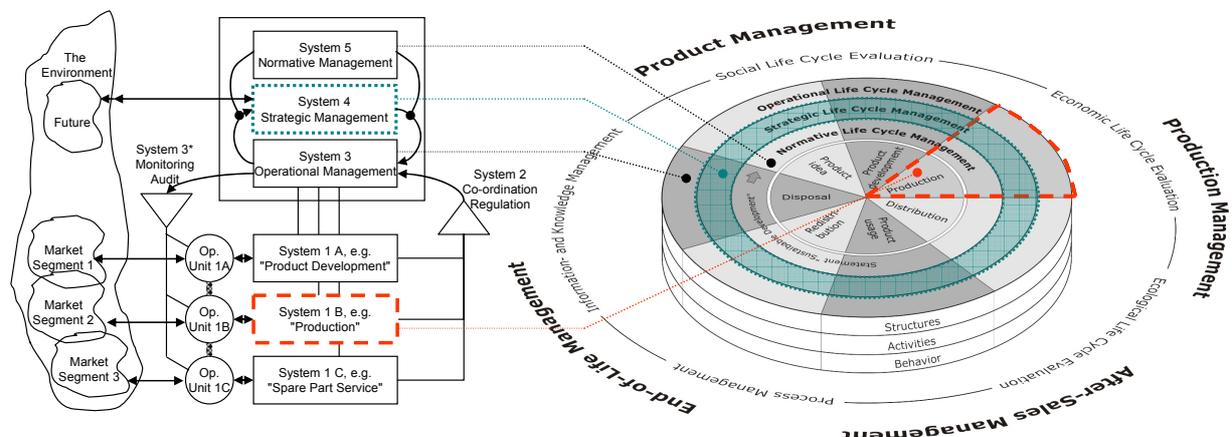


Figure 2: The Viable System Model related to the Braunschweig Framework of Total Life Cycle Management

Structures, behavior and activities are the three elements which run along all life cycle phases and through the rings of the normative, strategic and operational management. Activities in the individual product life cycles phases lead to the market service of the company and are supported by the structures and shaped by the behavior of management and employees. The number and diversity of interactions between normative, strategic, and operational management as well as the product life cycle phases explain the necessity for interlinked thinking and acting. In all sectors of the management rings life cycle management elements (structures, activities, and behavior) take place. Within the framework the normative and strategic management also have a rather forming function with regard to the development of the company. As with the Viable System Model, it is necessary, when differentiating between normative, strategic and operational tasks, to realize that this framework does not represent an institutional separation or a hierarchical allocation. “A manager can institutionally fulfill normative and strategic functions in the organization and at the same time be endeavored to obtain operative accomplishments” [21]. Applying the thoughts of Total Life Cycle Management involves challenges like goals conflicts, high complexity as well as uncertainty which have to be solved with adequate disciplines.

3 Disciplines of the Total Life Cycle Management

Particular significance is given to the disciplines of the strategic and operational management. The spatial, organizational, and temporal separation of the people involved in the product development, usage, and disposal is a particular challenge. Problems which have to be solved within the bounds of Total Life Cycle Management mostly show the following properties: a) cause and occurrence of the problem have their basis in different product life cycle phases, b) the background is often constituted by a conflict in targets between the short-term goals of the people involved in the individual life cycles phases, c) a complex situation for decision exists because economic, technical and ecological aspects must be taken into consideration at corresponding uncertainties for long periods. For reasons of those properties, the aims of a Total Life Cycle Management are to integrate all relevant disciplines with both economical and ecological target criteria. Striving towards sustainability from a normative to an operational level is a key goal of the approach since it fosters decoupling economical development from harmful environmental effects. Important disciplines are classified in Table 2.

Table 2: Life Cycle Phase-related and Life Cycle spanning Management Disciplines

	Management Disciplines	Exemplarily Activity	References
Life Cycle Phase related disciplines	• Product Management	Life Cycle Design, DfX	[14, 15, 16]
	• Production Management	Energy Eff. / Lean Product.	[3, 24]
	• After Sales Management	Spare Part Services	[8, 25]
	• End-of-Life Management	Recycling, Remanufact.	[11, 12]
Life Cycle spanning disciplines	• Economic Life Cycle Evaluation	Life Cycle Costing	[13, 26]
	• Ecological Life Cycle Evaluation	Life Cycle Assessment	[27, 28, 29, 30]
	• Social Life Cycle Evaluation	Corporate Social Responsib.	[31, 32]
	• Information- and Knowledge Mgmt.	IT-System standardization	[33, 34, 35]
	• Process Management	Business Process Engin.	[8, 35, 36]

4 Integration of different Life Cycle Perspectives

The proposed Total Life Cycle Management Framework supports to understand life cycle related complexity and to develop management measures to cope with that complexity. As an example for life cycle complexity, intersecting life cycle phases between different actors' products are considered. In this example, the primary product (e.g. a car) is produced by a manufacturer within its production life cycle phase on the one hand. The manufacturer uses a secondary product (e.g. a grinding machine) for the production of the car, that is itself located within its product usage life cycle phase on the other hand. As a consequence, two life cycle phases (production life cycle phase of the car and product usage of the grinding machine) are intersecting themselves. The complexity results by the intersection the close functional and organizational interdependencies of the intersecting life cycle phases. If the car manufacturer decides to change the design of the car within its product development phase, these changes have to be realized within the production life cycle phase of the car. For that, it is necessary to adapt the grinding machine in its own life cycle phases product development and production, so that it fulfills the requirements in its usage phase (the production phase of the car). Moreover, the machine manufacturer has to consider whether the car manufacturer employees more and more less educated workers

(different worker behavior) for the development of the machine (activity) or providing new services. Thus, the manufacturer of the grinding machine needs information on the new functional requirements of the product development phase of the car manufacturer for its own product development phase. Figure 3 depicts the intersecting life cycle phases based on the presented Framework. Considering not just one primary and one secondary product but a rapid increasing number of actors and products within supply chain and manufacturing processes, it becomes clear that the proliferating number of intersecting life cycle phases and their manifold interdependencies force complexity. Against this background, the Braunschweig Total Life Cycle Management Framework allows to understand the upcoming complexity behind that situation and to develop appropriate solutions by the integration of life cycle related as well as life cycle spanning management disciplines.

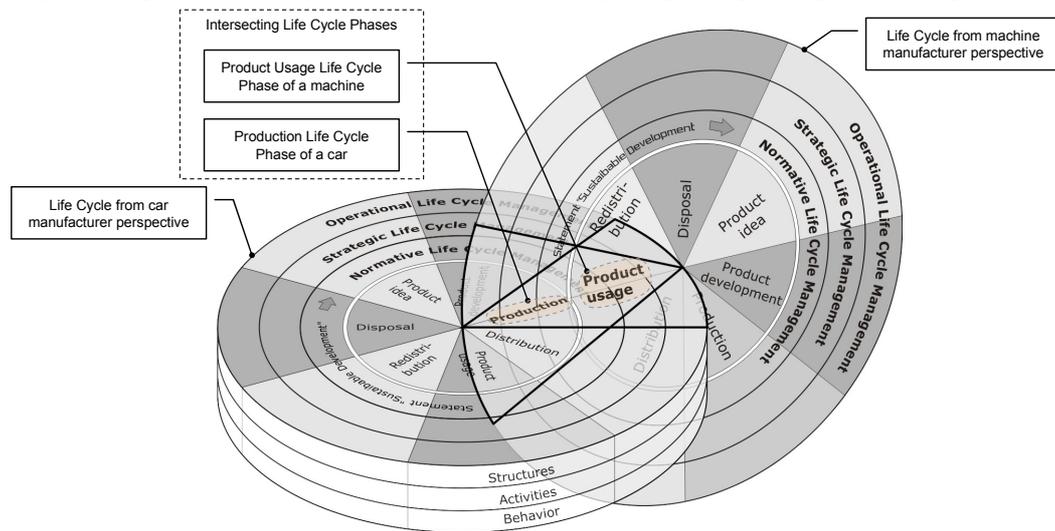


Figure 3: Example for Intersecting Life Cycle Phases within the Total Life Cycle Management Framework

5 Conclusions

Companies are confronted with rapid change in terms of extended product responsibility, new environmental product requirements as well as in offering added values, shorter innovation cycles and pressure from competition. These changes increase the external complexity companies have to cope with and cause a corresponding increase of internal complexity. The presented Braunschweig Framework of Total Life Cycle Management serves as frame for life cycle related and life cycle spanning disciplines on a normative, operational, and strategic management level. The framework shows the need for a coordination of disciplines from a management and a life cycle perspective. Thus, the framework reflects characteristic elements of life cycle challenges such as problem shifts between life cycle stages, goal conflicts and complex decision situations. The support of production management in the context of intersecting life cycle phases is presented as an example.

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