Design Model for the Sustainability Management of Manufacturing Companies

Felix Sohnius(✉), Martin Iglauer, and Robert H. Schmitt

Laboratory for Machine Tools and Production Engineering WZL of RWTH, Aachen University, Campus-Boulevard 30, 52074 Aachen, Germany
f.sohnius@wzl-mq.rwth-aachen.de

Abstract. This paper presents a design model that supports the systematic steering and operationalization of sustainability in manufacturing industry at all corporate levels. Studies show (e.g. Ramboll Group, Smurfit Kappa) that companies are aware of both the need for and the opportunities of corporate sustainability. Corporate sustainability means improving environmental and social effects as well as conditions, while operating profitably in the long term. However, companies face the challenge of resolving the complexity of corporate sustainability. Due to this challenge, the sustainability management model presented in this paper provides a holistic framework that addresses the relevant elements, fields of action and interrelationships of sustainability management in manufacturing companies. A top-down approach enables the management of sustainability at several corporate levels. In addition, various design elements enable the integration of submodels through which a further concretization and operationalization of corporate sustainability can be realized.

Keywords: Sustainability Management · Sustainable Production

1 Introduction

Responsible and far-sighted behavior is more important than ever for the continuation of a livable world and a healthy society considering today's global developments and the effects of human actions (e.g. climate change, pandemics, resource scarcity and inequality). In this respect, sustainability provides the guiding principle for a conscious and life-saving use of ecological, social, and economic resources [1]. The strategic direction and operational actions of a manufacturing company determine whether it makes a positive or negative contribution to sustainable development [2].

In this context companies are faced with the challenge of resolving the complexity of corporate sustainability through systematic steering as part of sustainability management. The complexity is particularly formed by the interwoven relationships of sustainability over the entire product life cycle, the requirements of all stakeholders and the uncertainty of the effects of sustainability-driven decisions. To address this complexity, a systematic business orientation and an effective operationalization is crucial. A company's resources, goals and opportunities must be brought together across divisions

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at the normative, strategic, and operational level. For sustainability management, it is important not to create isolated solutions, but to establish an overall corporate solution. In this respect, a holistic sustainability management model is required that supports the management of sustainability at all corporate levels [3, 4].

Based on the previously described challenges, the following research question is derived: "Can the complexity of corporate sustainability be addressed and solved by a holistic management model?" In this paper, such a sustainability management model is introduced. Section 2 initially presents the key requirements for sustainability management in manufacturing companies as well as existing approaches that have been evaluated based on these requirements. Section 3 covers the principles and methods used to develop the model, while Sect. 4 introduces the design model. Section 5 discusses the evaluation of the model before concluding the paper with a summary and outlook in Sect. 6.

2 State of the Art

This chapter focuses on the review of existing frameworks in sustainability management. In view of the challenges and problems described at the beginning of this article, four scientific publications will first be presented and evaluated.

Busch et al. – Framework for Shaping Sustainability in Manufacturing Companies: The framework establishes a connection between sustainability aspects and the product life cycle via nine fields of action. In addition, three overarching sustainability goals are defined for the phases of the product life cycle. With a requirement-specific character, fields of action are described predominantly at the strategic level, which can lead to an increase in corporate sustainability. These also include the perspective on the use and management of data. However, essential aspects of sustainability management such as the corporate mission statement, circular economy, stakeholders, operationalization of sustainability or internal and external communication remain unaddressed [5].

Briele et al. – Internet of Sustainability (IoS): The Internet of Sustainability (IoS) model is an extension of the existing data-driven framework Internet of Production (IoP) [6]. The model consists of three data layers (Raw Data Layer, Smart Data Layer and Smart Expert Layer) that enable data aggregation from raw data to information mining in the economic, environmental, and social sustainability dimensions. In addition, the model connects the data layers across the entire product lifecycle in terms of the circular economy. The IoS model represents a promising approach to data management in sustainability management and structuring along the circular economy, but it only refers to data aspects. With a view to a holistic management model, this aspect must be brought into line with other aspects of sustainability management [7] .

Panagiotakopolous et al. – Viable System Model in Sustainability Management: The research links corporate sustainability to the Viable System Model (VSM). Specifically, a model is proposed that enables the stepwise integration of sustainability aspects via the basic structure of the VSM. The VSM describes the interrelationships of the three main elements management, operations, and environment. This basic structure enables

the integration of sustainability aspects in an organization via three analysis steps respectively three different layers (Business Management Layer, Sustainability Management Layer and Sustainability Issue Layer). This approach helps to break down superordinate tasks at the normative and strategic level into specific subtasks at the operational level. However, due to an increasing number of models at the issue level, there is a risk of increasing complexity. Furthermore, some required and already mentioned aspects (in section Busch et al.) are not considered [8].

Lozano – Framework of Organizational Sustainability: The input-output model relates elements of corporate sustainability to one another. The model can be described in terms of five categories: inputs (e.g., material, human resources), system elements (e.g., management, organizational systems, governance), internal and external stakeholders, outputs (e.g., products and services), and resource efficiency & effectiveness. The model represents an organizational framework that enables a holistic view of companies to locate fields of action of corporate sustainability on the normative and strategic management level. However, the entire level of operational management is not mapped, nor is the principle of circular economy [9].

This brief overview shows that none of the approaches offers a detailed product lifecycle-oriented sustainability management model that identifies the most important corporate components as well as their fields of action, synergies, and conflicting goals. Furthermore, there is a deficit in the transfer of normative and strategic into operational aspects and thus in the operationalization of sustainability through quantitative and qualitative methods, instruments, and key figures. To satisfy this need for research, the model development not only relies on the positive aspects of the scientific publications, but also on the contents of existing and established approaches. These include ISO standards (e.g. ISO 14001, 26000, etc.), management models (e.g. St. Gallen Management Model, Aachen Quality Management Model, etc.) and reporting standards (e.g. Global Reporting Initiative, etc.).

3 Methodology for the Creation of the Design Model

In this paper, the approach according to Böhm Et Al. is used for model building. This process consists of two successive abstraction stages. In the first abstraction step, a thought model of the real system is created and sketched. In a further abstraction step, this thought model is represented in a more detailed and tangible form with the help of language, figures, pictures, graphics, numbers, etc. [10] In addition, the concept Architecture of Integrated Information Systems (ARIS) according to Scheer and the interpretation in the context of engineering modeling according to De Lange is used. With the help of the model theory and the five views of ARIS, the scientifically based structuring of the design model and the holistic derivation of individual design elements is ensured. The concept provides a simple and at the same time holistic structuring via the following five different views: [11, 12].

- **Organizational view**: Mapping of the organizational structure and units involved.

- **Functional view**: Operations or activities that transform inputs into outputs. Since certain goals are pursued via functions, they are also part of the function view.
- **Performance view**: Input and output performances processed in the function view. They are the yardstick for the fulfillment of the functions.
- **Data view**: Mapping of all relevant data such as environment data, input and output information, and their interrelationships.
- **Steering view**: Defining relations between all views and enabling a holistic context

The ARIS concept is moreover utilized in the following chapter to present individual design elements of the model in a structured manner.

4 Design Model for the Sustainability Management of Manufacturing Companies

At the beginning of this chapter, the overall design model is introduced in Fig. 1. It presents the relevant elements, fields of action and interrelationships of sustainability management in manufacturing companies in a holistic manner. Subsequently, the individual design elements of the model are presented following the ARIS logic.

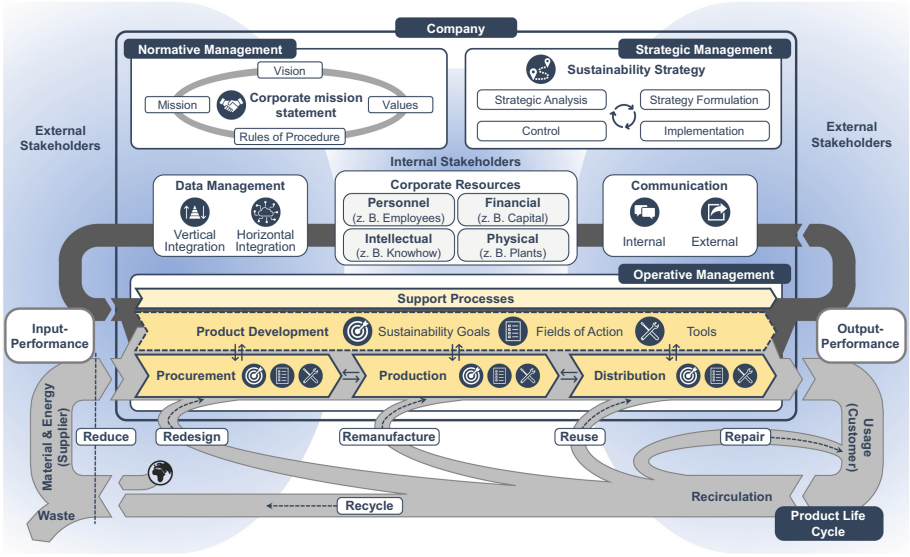

Fig. 1. Corporate sustainability management model

Design Elements of the Organizational View. The design elements of the organizational view represent the basis and thus the regulatory framework of the design model. In this context, the steering of a company is basically to be carried out via the design elements *normative*, *strategic,* and *operative management*. In operative management,

the core processes – *product development, procurement, production,* and *distribution,* as well as *support processes* – are primarily addressed. These processes are not only decisive for the value creation of a company, but also have significant influence on corporate sustainability. *Product development*, often classified as a support process in the literature, is however mapped as a core process in the sustainability management model, as it has a significant influence on many sustainability aspects of a product and many dependencies on the aforementioned processes. Besides the company's internal design elements, the entire product life cycle must be considered in the sense of the circular economy. To this end, the design elements of *material & energy*, *usage* and *recirculation* are integrated into the design model. As a further design element of the organizational view, both *internal stakeholders* and *external stakeholders* who place requirements on the company are integrated. These are to be seen as the central element against which corporate sustainability is aligned and sustainability performance is measured.

Design Elements of the Functional View. The requirements of the stakeholders are processed in normative and strategic management via their design elements of the functional view. In normative management the *corporate mission statement* must be established. Building on this, the *sustainability strategy* is to be developed in strategic management. These two design elements set the guard rails for operational management. The operative management serves to operationalize sustainability. For this purpose, three design elements are deduced from the functional perspective. *Operational sustainability goals* are to be derived from the strategic goals. In this context, key figures must be developed. The purpose of key figures in general is to create transparency, but above all, to make decisions more objective by presenting complex issues in a way that is easy to understand, enabling the formulation of goals and strategies, and facilitating goal-oriented corporate management. This applies not only to general corporate issues, but also to the complex topic of sustainability. The goals must be addressed in operational management to managers and experts in the respective organizational areas and must be compared with existing goals to identify conflicts or synergies. *Fields of action* are to be identified to pursue the defined sustainability goals. The fields of action are to be integrated into existing operational processes or extend them. Similar to the sustainability goals, conflicts with existing fields of action must be avoided and synergies created. *Tools*, as the third design element in operative management, serve to further operationalize sustainability, i.e., to concretize, measure and practically implement the corporate mission statement and the sustainability strategy. The operationalization is to be managed by quantitative and qualitative methods as well as key figures.

Design Elements of the Performance View. Sustainability performance is to be understood as both the input and output performance of a company. Input and output variables, as well as transformation processes, are to be planned and evaluated according to economic, ecological, and social aspects. The sustainability performance relates to the *company resources* (e.g. human, financial, intellectual and physical), to the upstream product life cycle phase *material & energy* as well as to the products and services provided on the market in the *usage* phase. The design elements of the functional view define target values for the strived sustainability performance as well as procedures and tools for achieving these.

Design Elements of the Data View. Data management as a design element of the data view serves to provide data to optimally support the processes of sustainability management. The approach of BRIELE ET AL. addresses the use and integration of sustainability data to incorporate them into decision-making processes. In the design model, a distinction is made between *vertical data integration* (including data collection, availability, storage, and provision) and *horizontal data integration* (data networking within and outside the company). Against this background and the topic of data analytics, SCHMITT ET AL. understand sustainability analytics as a key element for achieving the goal of vertical and horizontal data integration. This includes data-driven methods and tools that transform raw data into information and knowledge on sustainability topics [13].

Design Elements of the Steering View. The design elements of the steering view address the linking of the individual organizational areas of a company. *Interface management* is viewed on the one hand between normative, strategic, and operational management. On the other hand, interface functions describe tasks and challenges that are to be solved through interaction between individual internal and external organizational areas as well as stakeholders. In this context, interfaces are to be understood as organizational points at which information, goods or financial resources are exchanged. The main challenges are the identification and optimization of interface functions as well as the systematic coordination of the cooperation between the business units. *Communication* is another design element of the steering view. Internal communication, especially to raise awareness of vulnerability within the company, as well as external communication to create transparency, credibility and a good reputation must be addressed. Furthermore, *recirculations in the product life cycle* are to be considered as design elements of steering view. These are aligned with the 6R's of sustainability methodology. Each organizational area is supposed to reflect the 6R's in the design of its goals and tasks, and thus develop solutions for sustaining the circular economy. The element *Repair* serves to maintain a product in its usage phase and extend this via service, maintenance, and repair concepts. *Reuse* involves returning used functional products back to the market through a company's distribution channels. *Remanufacturing* involves refurbishing used defective products or components into as-new form and returning them to the market directly or as part of new products. *Redesign* is particularly aimed at sustainable product design for future product generations. However, redesign also concerns the sustainable redesign of processes, resource use and partnerships. *Recycling* enables the conversion of materials assigned to waste into new raw materials. *Reduce* aims at trimming down material and energy consumption to decrease the amount of natural and harmful resources as well as waste in the circular economy [14].

5 Evaluation

In evaluating the design model, the expert interview method was used. Three experts – a managing director operations, a quality manager, and a production manager – from a globally operating and producing company group in the mechanical and plant engineering sector were selected to evaluate the model.

The first evaluation section assessed the relevance of corporate sustainability and the understanding of its complexity. To sum up, they confirm the challenges that were already made clear in the introduction. In detail, the experts see the challenge in the sustainable transformation of the corporate structures via existing processes and structures, the management of sustainability via suitable processes, the definition and use of sustainability indicators, the inclusion of the entire value chain and product life cycle and the raising of awareness in the global workforce.

In a second evaluation section, the model was assessed quantitatively and qualitatively regarding solving these challenges. The quantitative evaluation is carried out using a ten-point scale for the five factors *understandability*, *accuracy*, *completeness*, *applicability,* and *usefulness*. The rating is mostly between 8 and 9, in rare cases 10 or 7. The qualitative evaluation of the factors also shows a good rating. In short, the experts assess the design model as a holistic management model that maps the relevant elements and interrelationships, enables the step-by-step and area-by-area integration of sustainability aspects, and can be harmonized with existing structures. As optimization possibilities, the concretization of sub-models and the elaboration of a procedure for transferring the abstract model into concrete processes are mentioned.

6 Conclusion and Outlook

This paper presents a design model for managing the sustainability of manufacturing companies. A literature review identifies the key requirements for the sustainability management and confirms the need for a management model to address and resolve the complexity of corporate sustainability. A two-step process of model building was applied, which additionally considers the concept of Architecture of Integrated Information Systems (ARIS). Design elements of the organizational, functional, performance, data, and steering view are developed as well as summarized and structured in a design model. This model holistically maps the relevant elements, fields of action and interrelationships of sustainability management in manufacturing companies. Moreover, it enables the integration of sub-models for further concretizing or operationalizing corporate sustainability. An initial practical and application-oriented model evaluation by experts from a globally operating and manufacturing company provides indications that the model is well suited for the integration of sustainability aspects and the establishment of a sustainability management system. In summary, the design model thus contributes to answering the research question by enabling the management of corporate sustainability via a top-down approach.

However, in future research, the model must be further developed. The design elements such as product development or production must be concretized by sub-models, which in turn can be integrated into the design model. In this context, practice-oriented solutions are to be elaborated that flesh out selected design elements in detail. In this way, the design model could be completed step by step. For the application of the model in practice, a procedure or a guideline must be developed. There is a further need for research in the validation of the design model. For this purpose, the application of the model through case studies in manufacturing companies is suitable. In these case studies, the design model could be applied as an aid for a gap analysis for the topic of corporate sustainability.

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