Development Methodology for Sustainable Solutions

Christian Grefrath, Dirk Wagner, Marco Macchi, Maria Holgado Granados and Sebastian Stermann

1 Introduction

This chapter aims to develop a framework which enables companies to analyse and optimise their processes in order to increase their sustainability. Based on the methodological and scientific gaps that were identified in Sect. 2 in Chap. "State of the Art Regarding Existing Approaches", the authors offer a holistic concept by combining and integrating various management and operational methods and supportive tools.

The intended improvements cover all three dimensions of sustainability: on the one hand, improvements of processes might increase a company's productivity and efficiency and, thus, lead to economic sustainability. On the other hand, also social

C. Grefrath (✉)
Global Product Line Management, Pumps & Rotary Drilling Equipment, MHWirth GmbH, Kölner Str. 71-73, 41812 Erkelenz, Germany
e-mail: christian.grefrath@mhwirth.com

D. Wagner
Product Management Service TLS, TRUMPF Laser GmbH, Aichhalder Str. 39, 78713 Schramberg, Germany
e-mail: Dirk.Wagner@de.TRUMPF.com

M. Macchi
Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milano, Italy

M.H. Granados
EPSRC Centre for Industrial Sustainability, University of Cambridge, Cambridge, United Kingdom

S. Stermann
Front-Office System Planning, Transmission System Operation Brauweiler, Amprion GmbH, Von-Werth-Str. 274, D-50259 Pulheim, Germany
e-mail: sebastian.stermann@amprion.net

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and environmental aspects of sustainability can be captured. Well-organised processes and conflict-free communication between divisions have the potential to tremendously improve employees' contentedness.

2 Conceptualisation of a Development Methodology for Sustainable Solutions

According to the gap analysis presented in Sect. 2 in Chap. "State of the Art Regarding Existing Approaches", system boundaries must be broadened from an individual company to a value network level, which covers the whole life cycle. The new methods should support actors defining what sustainability means to their solutions within their industry and to business (models) of all involved actors—and break those targets down to activities of each stakeholder that take place. To realise the development on a network level an interdisciplinary approach with interaction of all involved stakeholders during the development process has to be realised.

According to these conclusions, the development methodology for sustainable solutions should cover several phases of life cycle and the activities of the relevant stakeholders, here called dimensions. This approach is shown in Fig. 1.

The present methodologies support sustainable development at operational level, but the descriptions on how to set strategic objectives are partly missing. In other words, baseline for sustainable development should be strategic activities that integrate the central idea of sustainability—here called *central initiation*. Besides these strategic activities, procedures have to be defined to conceptualise sustainable solutions in terms of products, services or product-services systems—here called *conceptual dimensions*. To cover also activities of stakeholders, that act during the life cycle more operationally, and allow also sustainable innovation and development from their perspective, all planning activities have to be regarded in the Development Methodology for Sustainable Solutions—here called *operational dimensions*. These activities require a multilevel approach to sustainability, in order to understand the self-interests of involved actors and ensure their commitment.

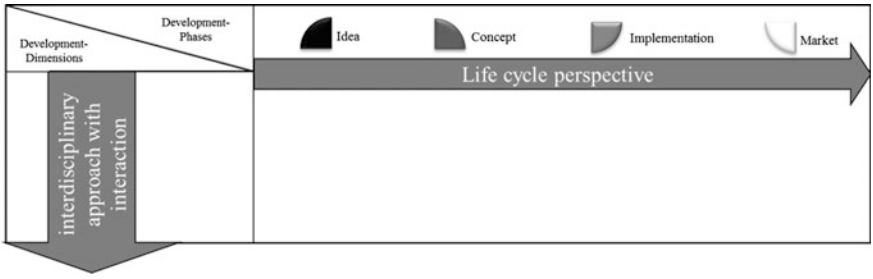

Fig. 1 Interdisciplinary approach over the whole life cycle

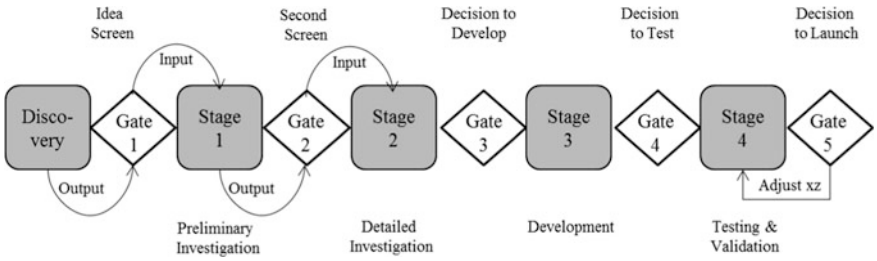

Fig. 2 Example state gate model for all development dimensions (adapted from Cooper 2000)

Each of those activities in the named dimensions will be described with stages and gates, according to the stage–gate model (Cooper 2000). The stages resemble the different "proof of design activities" which have to be executed in the whole development process. To guarantee the quality of the results of the development, methodology gates serve as check points within the process. Besides, these gates foster the integration and the interaction of all stakeholders, as they provide the operator of the methodology with guidance/checklists whether all important aspects to develop a sustainable solution and the perspective of all stakeholders have been considered. In the following, the important activities and tools for the development methodology are mentioned. Furthermore, responsibilities and interfaces to other stages and gates are highlighted. Consequently, the Development Methodology for Sustainable Solutions covers stages and gates for every development dimension (see as an example in Fig. 2).

The dimensions of the framework are listed below.

- Strategy development,
- Business model development,
- Technology development,
- Product-service system development,
- Product development,
- Service development,
- Sourcing planning,
- Manufacturing planning,
- Distribution and logistical planning,
- Service and spare parts operational planning,
- End-of-life and recycling planning.

For each dimension, well-established approaches have been identified and partly adjusted (see Sect. 1 in Chap. "State of the Art Regarding Existing Approaches"). The adjustment of each method has been quite different. Each method has been subdivided into single steps, each ending with a clear gate to check the result of the previous stage. Further, the methods have been improved towards their integration of the three aspects of sustainability. In several cases, sustainability is only partially or not at all integrated into the method. In this case, it has to be completed within this methodology for sustainable solutions.

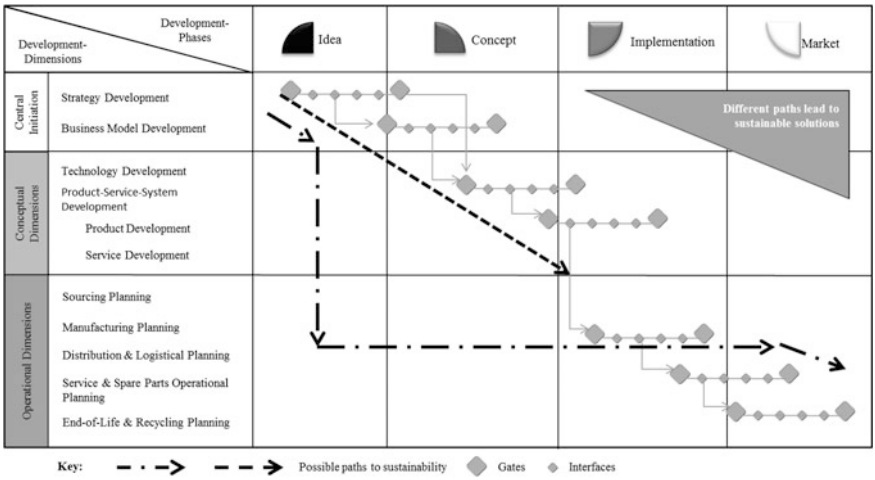

Fig. 3 Development framework for sustainable solutions

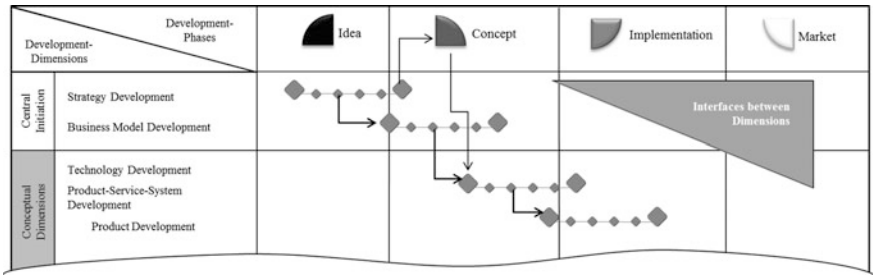

Fig. 4 Interfaces and gates between dimensions

3 General Development Framework

A sustainable solution may be a product, a service, a new operating practice, a new business model or a combination of any or all of these. So the assumption is that sustainability can be realised through changes in any business activities. The suggested Development Methodology for Sustainable Solutions tries to give a framework for different paths to sustainability, without having a strict step by step approach that has to be executed by the company or the value network (see Fig. 3). The main innovation of this all-embracing methodology is to emphasise all important connections and interfaces between the different methods. By subdividing each method into specific stages and gates, it is possible to find existing interfaces or to define new necessary interfaces for an improved cooperation and thereby reaching a higher degree of sustainability.

An interdisciplinary approach of a solution development process is able to reach a new level of sustainability by a clear, open, well-organised and well-described cooperation of all participating stakeholders, acting in different dimensions.

In the next section, the conceptualised dimensions of the framework will be described in detail, showing the interfaces between all the methods to be able to develop sustainable solutions (Fig. 4).

4 Development Methodology for Sustainable Solutions

The following section enhances the framework which is introduced in Sect. 2 with detailed content regarding different methodologies, tools and interfaces of the different dimensions. The sections are structured in the same way as the dimensions of the framework. The content of every stage/gate is presented and adequate tools are introduced. Furthermore references to responsibilities and interfaces are given. Figure 4 shows different interfaces (small buttons) and gates (big buttons) within the framework. The tools which are mentioned are going to be described in detail in the upcoming sections.

4.1 Methods—Central Initiation

Strategy Development

Strategies exist at several levels in any organisation—ranging from the overall business (or group of businesses) through different operations and organisation levels to individuals working in it. Corporate strategy is concerned with the overall purpose and scope of the business to meet stakeholder expectations. Strategic analysis, strategy development (choices) and strategy implementation are the key elements of a strategic management process. In an academic discussion, at least four views of strategy development processes can be distinguished. They are rational planning, planning as a guided learning process, planning on the basis of logical incrementalism and emergent strategy formation (Idenburg 1993). Strategic analysis is about analysing the strength of businesses' position and understanding the important external and internal factors that may influence that position. Strategy development involves understanding the nature of stakeholder expectations (the "ground rules"), identifying strategic options, and then evaluating and selecting strategic options. Strategy implementation typically is the hardest part. Implementing a strategy may require organisational, operational or business model changes such as creating new units, merging existing ones, new operations or division of work or even changing offerings, developing new products or services and modifying the earning logic. Therefore, it is important that many internal communication channels exist between different divisions within a company.

The next section goes through the three stages of general strategy process: (1) strategic analyses, (2) strategy development and (3) strategy implementation, the appropriate tools for each stage, and the gates in which the results of the stage in question are analysed.

Stage 1: Strategic Analysis

The strategic analysis stage targets to identify through structured analysis both the external and internal drivers. It provides important input, and it is strongly linked to the first stage of business modelling process. The tools appropriate for this stage should support participants in defining the business purpose, industry-related requirements, norms and opportunities including the firm position to sustainability (current and future) and its drivers. *Corporate Sustainability Continuum, System SWOT and PESTLE and STEEPLED* were identified as tools supporting first stage of business modelling process.

Gate 1

To pass through the gate 1, it has to be decided whether the strategy group has enough knowledge to bring out the vision and can go further to strategy development.

Stage 2: Strategy Development

The second stage, strategy development, is guided by the vision and defines the strategic choices. Also within this stage, the link to business modelling process is strong, e.g. *sustainable business model archetypes and scenario analyses* can be utilised to illustrate different options regarding sustainability. Furthermore, business model concretises these strategic choices by defining customers, offering, key resources, value network and earning logic.

Gate 2

Within this gate, the participants of strategy development stage should be able to illustrate the strategic choices to the whole organisation. The gate can be passed when it is defined where and how the organisation will compete and cooperate.

Stage 3: Strategy Implementation

Strategy implementation stage is the translation of chosen strategy into organisational actions so as to achieve strategic goals and objectives. Many methods and approaches related to this organising stage are originally change management tools and thereby vision, mission and values of the organisation are brought to guide the strategy implementation. In this stage, tools *such as strategic portfolio management, balanced scorecard and KPIs* can be used.

Gate 3

Strategy implementation should be a two-way process where it is possible to change the strategy also through a bottom-up approach. The gate can be passed when

interfaces and communication channels within the company and with external stakeholders are defined.

Business Model Development

This section will elaborate on the process and a portfolio of tools and methods that assist in the design of sustainable business model/s. The process and toolset will support and be part of the idea and conception phases of the development framework for sustainable solutions, while being aligned with strategy development. Sustainable business modelling consists of five steps and each step is accompanied by a selection of tools that will assist firms in understanding and delivering sustainability. The objective is to assist companies in developing future-oriented and novel forms of business that will deliver sustainability through a clearly defined sustainable business modelling process whilst adapting to the requirements for sustainability. The tools have been identified or specifically designed to focus on generating business model innovation for sustainability from a system perspective. The toolset includes tools and methods that assist in developing and transforming the new sustainable value proposition.

Stage 1: Purpose of the Business

This stage is about 'setting the scene'. It involves developing an understanding of the rationale of the business along with its values and sustainability, whilst identifying the company's position and drivers for engaging in sustainability along with anticipated threats and opportunities for environmental and social sustainability. The tools that assist in this stage are *System SWOT analysis*, *PESTLE/STEEPLED* and *sustainability continuum* including an introductory presentation on the process and where necessary, a brief overview of sustainability.

Gate 1

To pass through this gate, the identification of the company's business purpose, drivers and its progress/path towards sustainability has to be determined.

Stage 2: Identify Potential Stakeholders and Select Sustainability Factors/ Priorities

This stage is about identifying the stakeholders in the industrial network and sustainability priorities that will assist in exploring the new sustainable value proposition. The purpose of the organisation and understanding of sustainability and target position for the future from the previous stage helps towards determining sustainability priorities. The tools that will assist in this stage are the *value mapping tool, scenario management tool, Global Reporting Initiative Guidelines* (GRI guidelines) and *industry specific Sustainability Accounting Standards Board* (SASB).

Gate 2

This gate can be passed when a set of stakeholders and sustainability priorities are selected for the next stage.

Stage 3: Explore and Develop new Opportunities for Sustainable Value Proposition

This stage is about generating a new sustainable value proposition/s towards designing a sustainable business model with a focus on the industrial network. It is concerned with understanding and analysing various forms of value across the network to develop the new sustainable value proposition. Useful tools are the *scenario management* and *value mapping tool*.

Gate 3

To pass through this gate, a presentation of new sustainable value proposition or a selection of propositions has to be considered.

Stage 4: Concept Generation and Selection

This stage involves the selection of one or a combination of feasible business models, concepts or solutions for the transformation of the new sustainable value proposition or propositions (stage 3) so as to seek ways/paths to capture opportunities for value creation, whilst minimising negative value and maximising positive value in the network. The tools that will assist at this stage are the *sustainable business model element archetypes typology* and *sustainability impact calculation tool*.

Gate 4

To pass this gate, a decision on an archetype/solution or a combination of archetypes has to be opted.

Stage 5: Define and Develop the Value Creation and Delivery System, and the Value Capture Mechanism

Stage 5 includes the identification and potential development of the value delivery and capture system (key activities, channels, resources) whilst analysing the cost incurred through the life cycle to assist in evaluating the options. This stage builds on steps 2 and 3 on the understanding of stakeholder value and value exchanges in the network. The tools that will assist this stage are Osterwalder and Pigneur (Osterwalder and Pigneur 2010) *business model canvas* and *the life cycle cost (LCC) estimation tool* (developed in WP3 by ELCON and VTT). The business model canvas supports in the coordination and configuration of the key activities, resources, partners and channels and the value exchanges and value capture between stakeholders in the network.

Gate 5

To pass through this gate, the mechanism for the value creation, delivery system and value capture has to be determined.

4.2 Methods—Conceptual Dimensions

Technology Development

Technology management includes several managerial disciplines that enable organisations to manage their technological knowledge in the creation of competitive advantage. There are several methods used in technology management such as technology strategy development (role of technology in organisation), technology forecasting (identification of possible relevant technologies), technology road mapping (mapping technologies against business and market needs), technology project portfolio (what projects are under development) and technology portfolio (what technologies are in use).

Sahlman (Sahlman 2010), for instance, is suggesting that enterprises should consider defining and developing the necessary structures and objectives for strategic technology management to proactively manage impacts of technology for competitiveness of the enterprise and for sustainable development of its socioeconomic environment. There are multiple theoretical as well as practical frameworks for defining elements of technology management (for summary, see, e.g. (Sahlman and Haapsalo 2011).

Stage 1: Define the Requirements for New Technology

In this stage, the corporate management group defines needs and requirements of the new technology based on the strategic work. The tools appropriate for this stage should support participants in defining the business purpose, industry-related requirements, norms and opportunities including the firm position to sustainability (current and future) and its drivers. Therefore, *Porter´s five forces* analysis and *road mapping* are useful tools.

Gate 1

As an output of the first stage of technology development process, a specification of new required technology should be available. The strategic alignment of this specification has to be evaluated before the decision of moving towards the second stage can be taken.

Stage 2: Evaluate Your Own Technology Portfolio and Your Own Capabilities to Develop the Required Technology

At this stage, managers of different technology disciplines (e.g. mechanical, automation, hydraulics and electricity) should cooperate in order to increase cross-functional knowledge in an organisation in the early phase of the development activities. If suitable technology could be identified during the portfolio evaluation managers of an organisation are already capable to judge the readiness to move on to other processes (PSS, service or product development processes). If suitable technologies are not available in the organisation, the capabilities of

organisation should be evaluated and issues such as whether they are competitive enough to conduct the activities related to new technology development should be taken up.

Gate 2

To pass through this gate, a decision needs to be taken on whether it is possible to use current technology in new application and move on to other development processes.

Stage 3: Search Suitable Technologies from Outside

Search new technologies from outside. Technology searching activities could be conducted simultaneously with the portfolio evaluation. The methods related to searching of new technology could include, e.g. *competitor and network analysis*, *patent database studies* and other business intelligence activities.

Gate 3

The technology search should produce further information to decision-making on what is the most feasible way to develop the required technology.

Product-Service System Development

The effect of standardised development methods is useful to reduce development costs, development time and improve the quality of produced goods or services (Bullinger and Scheer 2006). Therefore, it is important to create clearly defined standards to develop an even more complex product-service system. For the development of product-service systems, various approaches already exist. Nonetheless, most of them do not focus on sustainability with its three different perspectives: economic, social and environmental sustainability. Although most of these approaches integrate them slightly, they do not sufficiently concentrate on sustainability.

Stages and Gates

Tukker and Tischner (2006) discovered that the main process of PSS development can be roughly subdivided into three main steps, considering the analysed PSS development approaches. The identified steps are the analysis-phase, the creation-phase and, thirdly, the implementation and realisation-phase.

Stage 1: Preparation and Introduction

In the stage of Preparation and Introduction, a general plan of the development project and an appropriate project team is to be set up. After forming the project team consisting of various experts, the team members need to be familiarised with the idea of a product-service system concept. For a further stakeholder analysis, the stakeholder value mapping tool can be used. Here, every value can be illustrated for every stakeholder to get an easy overview of changes for each stakeholder.

Gate 1

In gate 1, it has to be checked whether the team really consists of all necessary experts concerning the planned PSS.

Stage 2: Analysis on PSS Opportunities

The first step in stage 2 is to select areas with priority needs. Therefore, the project team has to investigate which need areas or markets in general come into question. Afterwards, they have to prioritise these markets to detect the most interesting ones, where they might carry out the PSS project (e.g. by priority setting matrix). Furthermore, the own existing PSS of the company is to analyse regarding possible opportunities towards a new PSS for the company. Here, the Strategy and Business Model Development has to be included to guarantee that the PSS fits into the general business model of the company. Regarding possible opportunities, threads, etc., of a PSS, the project team is to use a *SWOT analysis*. Another important tool is the *scenario analysis*. As a next step, the project team has to analyse the needs of their possible clients. For this purpose, it defines relevant market segments and underlying client needs for the selected areas. This may be done by simple but *persistent questioning approaches*. The next substep is to draft a system map of the current system that is to be improved or changed by the new PSS.

Gate 2

The project team has to decide, based on what they investigated and found out before, whether the PSS is actually interesting for the company and sufficiently sustainable in all three aforementioned aspects of sustainability.

Stage 3: PSS Idea Generation

The project team's next task is to generate ideas for the possible new PSS. Using the information of the previous stage, i.e. client needs and the results of the SWOT analysis, the idea generation could start e.g. by different creativity tools. These might be, for instance, *brainstorming, brainwriting*, etc., whilst creating possible ideas, sustainability guidelines (SustainValue 2012) should be used permanently. The complete set of new ideas is now to be described systematically within an idea description sheet and checked against sustainability requirements for sustainable solutions.

Gate 3

Firstly, in gate 3, it is important that the project manager controls the completeness check conducted in stage 3. Additionally, the project manager has to check whether and to what extend the aspect of sustainability is included within the new idea.

Stage 4: PSS Concept and Design

In stage 4, the project team works on the PSS design and structure. An essential aspect of the PSS structure is the examination of interactions and interdependences of all concerned actors. In addition, an evaluation of different system components and whether they match is a main aim. Tools as *service blueprint or FMEA* could be used to support the PSS development. As a next step, a make-or-buy decision has to be made. It is important to include surrogates of the dimensions of Sourcing

Planning and Manufacturing Planning to include their valuable expertise in the field of sourcing and production

Gate 4

The project team has to decide whether to implement the system, to go back to the idea of the beginning of the design stage or to cancel this idea at all.

Stage 5: PSS Implementation Plan

In the final stage of the PSS development, the PSS implementation plan is to be defined. Therefore, the project team defines a list of implementation issues, e.g., within a workshop. Implementation issues might closely correlate with the results of the SWOT analysis in stage 3, the stage of idea generation. Once these issues are defined and completed, the project manager has to produce a management report to introduce the PSS and its possible implementation. In order to support the implementation plan, *the Sustainable Impact Calculation Tool* is recommended to use.

Gate 5

At gate 5, the project manager has to make sure that the implementation plan is complete, consistent and accomplishable.

Product Development

Considering the different product development approaches, it gets clear that most of the existing ones do not fulfil the requirement of clear development steps including specific control gates. In addition, most approaches have no real focus on sustainability during the whole development process. Both the clear structure and the established position in industry of the product development model of Pahl and Beitz (2006) recommend the usage of their model in this development methodology. Important aspects considering sustainability within the development process have to be added. Pahl and Beitz created an overall product development process which can be used intersectorally due to its generality. They describe the two main parts of a product development process as the analysis and later on the synthesis phase. Their development approach is subdivided into the four main steps of the development and engineering process. These steps are "planning and clarification of task", "conceptual design", "development" and "elaboration of product documentation". Further, the section "Implementation and market launch" will be added.

Stage 1: Planning and Clarification of Task

At the beginning of a product development process, the general tasks have to be clarified by a product development team for the specific development process. The clarification of the tasks to be performed by the product serves a gathering of all information towards the detailed requirements of the product, their conditions and modalities as well as their specific meaning. The result of this clarification process should be a product specific requirement list. Furthermore, *scenario analysis* should be conducted.

Gate 1

The requirement list developed in stage 1 has to be checked towards completeness before the development process goes on to the concept stage.

Stage 2: Conceptual Design

Within the conceptual stage, the stage of planning and clarification of the task will be abstracted to its basic challenges and problems. Before starting the conceptual design, the project team has to clarify if a step by step approach really is necessary for this specific development project. Therefore, it is recommended to check if already known solutions may be a foundation for further concept and elaboration steps or if the whole concept phase might be unnecessary by these existing solutions.

Gate 2

To pass through this gate, the developed concept has to be checked due to its crucial importance for the whole development process. This can be done by screening all possible conceptual solutions and the evaluation process towards the determined concept.

Stage 3: Embodiment Design

Within the stage of embodiment design, the design of the previously generated concept is developed. The design will be developed in accordance to technical, economical and sustainability criteria. Therefore, it is important to include specific data considering the life cycle behaviour of previous and similar products. Here, the knowledge and experience of the service planning dimension must be included into the development process. During the stage of embodiment design, the product designers have to determine an overall layout design, a preliminary design of the form and the production process. In addition, they have to provide solutions for all auxiliary functions. The development takes place by using scale drawings, critically reviews as well as technical and economic evaluation.

Gate 3

To pass through this gate, the definitive layout has to be controlled by the project manager. It has to be checked against all embodiment-determining requirements (for main and auxiliary functions).

Stage 4: Detail Design and Elaboration of Product Documentation

The detail design stage contains the process to complete the embodiment of technical products. Therefore, final instructions considering shapes, forms, dimensions and properties of the surface will be implemented towards all single product components. Furthermore, the selection of materials is to be defined as well as the final scrutiny of underlying production methods, procedures and costs. Here, the dimensions of Sourcing Planning and Manufacturing Planning should be involved into the development activities. Another task of this stage is to elaborate the

production documents including drawings of components and assemblies and related lists of all parts.

Gate 4

In gate 4, it is to control if all final instructions are fully implemented. Furthermore, the selection of the specific product materials as well as the production methods is to be checked considering all three aspects of sustainability (economic, social and environmental). Finally, all documents have to be checked for completeness and consistency.

Stage 5: Implementation and Market Launch

Although Pahl and Beitz (2006) do not include the step of product implementation and market launch it can be integrated into a full product development process. Due to the fact that this step already is described in detail within the section of product service system development a short reference to Sect. 4.2, stage 5 is sufficient.

Gate 5

The contents of stage 5 have to be checked by the project manager at first. He has to make sure that the implementation plan is complete, consistent and accomplishable. If it is not, he has to take care that appropriate improvements will be done.

Service Development

Towards the dimension of service development, different useful methods and approaches can be found. Both structure and extent of these development approaches vary enormously. Whereas some of them stop after the definition of the service idea (Sontow 2000), others include all phases up to the implementation of the new service and the following market phase. One of these methods is the FIR service engineering approach (DIN 2008, 1082:2008–05). Although all approaches do not have their focus on sustainability, or consider it at all, the FIR service engineering approach can be used for this development concept for sustainable solutions. Nonetheless, considering the topic of sustainability important aspects has to be included in this approach.

Stage 1: Activation and Definition

At the beginning of stage 1, the whole development process gets activated. It starts with the generation of possible ideas. The first idea generation can be supported by simple creativity tools as *brainstorming and brainwriting*. After generating ideas, possible customers have to be identified. Here as well, a market research could support the customer identification. In addition, the stakeholder value mapping tool (UC, cf. PSS development) can be integrated in this process. At the end of stage 1, appropriate objectives for each specific service development process have to be formulated. Thereby, it is important to integrate sustainability factors, e.g., by using sustainability guidelines.

Gate 1

The service management has to control if the new service idea fits into the existing portfolio of PSS, products and services. In addition, it is to check whether the new service idea is in accordance with the company strategy and its general business model.

Stage 2: Planning

At the beginning of this stage, a team of service experts has to do a detailed market research for the service idea found in stage 1 and create a provisional plan for the market launch at the end of the development process. Beside conventional market research tools, the stakeholder value mapping tool can as well be of interest to include all possible stakeholders affected by the new service idea. Furthermore, the responsible service experts have to do a detailed technical evaluation. Here, it is important to corporate closely with the department of Technology Development to check the technical sense and feasibility of the service. Using the tool of service blueprinting might be of help to get an overview of the needed infrastructure for the service introduction. Another tool that can be used for decision-making is systems dynamics: this would also be useful in order to plan and prepare the infrastructure. The next step in this stage is to create a sustainable business model around the new service concept. Therefore, the information towards the architecture, technical aspects and needed infrastructure of the service has to be used. In this context, the service experts have to create a requirements specification sheet. At the end of stage 2, a detailed development plan with a clear performance and requirements specification sheet as well as a business model for the new service have to be generated.

Gate 2

To pass through gate 2, different aspects regarding the plan of the new service idea have to be checked by the management of the service department. Beginning with the evaluation of the of the service idea based on the internal and external feedback, a clear decision has to be made if the service idea will reach the stage of concept and infrastructure development.

Stage 3: Development of Concept and Infrastructure

The first step in this stage is the development the service prototype and its technical introduction in first test runs. After this is done, the detailed resource planning can start. Now the rough and conceptual planning of stage 2 has to be concretised. Therefore, a close cooperation between the dimensions of service development, sourcing planning and as well the dimension of end-of-life and recycling planning has to be given. In addition, a detailed programme considering the market launch has to be developed. Therefore, different concepts need to be generated. These concepts are the sales, the marketing and the communications concept.

Gate 3

After the development and usage of the first service prototypes, a first practical economic efficiency analysis has to be conducted. Furthermore, the service management has to test the consistency of the service concept, infrastructure, sourcing, end-of-life, training programme, sustainability, etc.

Stage 4: Implementation

In stage 4, the new service will be converted to the pilot stadium. In this further testing phase, last gaps and weaknesses can be eliminated. After this is done the *service blueprint* can be finalised. Now it is possible to structure the new service in different modules as a basis for specific adaption towards customers' wishes.

Gate 4

To pass through gate 4, it has to be controlled if the new service is still cost effective or if previous changes altered things in that extend that sufficient cost-effectiveness is not given anymore.

Stage 5: Market Phase

At the beginning of the market phase, the service has to be further adapted to the customers wishes and requirements. Here, the cooperation between service technician and service experts has to be close to optimising the service in case of need.

Gate 5

In gate 5, there has to be a general control by the service management considering the service performance in the field.

4.3 Methods—Operational Dimensions

Sourcing Planning

The concept of strategic sourcing emphasises the link between strategic objectives and sourcing operations of a company—sourcing planning considers strategic sourcing decisions before the actual purchasing processes and supply chain management. Since materials, components and services purchased represent significant part of companies' sales in the present networked economy are ethical sourcing as well as green supply chain management principals utilised in many Western companies. In this section, sourcing planning has been divided into two main tasks. First at the strategic level, the main task is to set the targets to sourcing. Then at the operative level, the task is to search and evaluate possible suppliers. The first task considers the opportunities, objectives, and pay-offs between the choices related to

sustainability within sourcing. Thereby, in accordance with strategy development, it aims to find answers to the "Why?" question. The second task is related to the operative "What?", e.g. the supplier searching and evaluation oriented activities of sourcing planning. Within this section, these two tasks are considered as two main stages of sourcing planning for sustainability.

Stage 1: Set the Strategic Targets to Sourcing

At the strategic level, the main stage of sourcing planning is to set the targets for sourcing. This stage considers the opportunities, objectives, and pay-offs between the options related to sustainability within sourcing. Different *portfolio analyses* have been typical tools of strategic sourcing and purchasing, since Kraljic (1983) presented his well-known purchasing portfolio. Based on this approach, Pagell et al. (2010) have presented the sustainable purchasing portfolio model. Furthermore, *portfolio management approach* presented in strategy development section can be utilised also within the strategic sourcing planning. The sustainability matrix could be utilised to evaluate the interests of various stakeholders and thus align the interests of all involved actors.

Gate 1

At the first gate, the managers of the company—both corporate and sourcing managers—have to define sustainability guidelines for sourcing. This means defining the importance of sustainability in sourcing decisions.

Stage 2: Search for and Evaluation of Possible Suppliers

At the operative level the main stage of sourcing planning is the search for and evaluation of possible suppliers (contract partners). Similarly to the first stage several different methods and tools can be utilised for this work. The two stages are also closely linked together, so strategic considerations related to sustainability principles of sourcing should guide the supplier search and evaluation process. The comparison between possible suppliers and supplier classifications are typically done based on different purchasing portfolio criteria. Two tools, which support especially supplier selection, are of great importance. Those are the *maturity model* and *the supplier evaluation matrix*.

Gate 2: Selection of Suppliers (contract partners)

To pass through this gate, the sourcing managers and purchasers have to select the contract partners from the possible suppliers based on the analyses and comparisons made at search and evaluation stage.

Manufacturing Planning

Manufacturing planning considers the long-term decisions with regard to the manufacturing system (re)configuration, and subsequent (re)organisation of resources. This is also variably referred to by means of other terms such as manufacturing system design, facilities planning, factory planning. On the whole, this process deals with all the decisions related to the long-term planning of an industrial

plant where manufacturing operations are executed—both in the case a new plant is built from green field, and when the plant already exists and replanning is required for performance improvement. Further on, the manufacturing planning process typically covers many issues such as process technology and equipment selection, capacity planning and work load balancing, facility layout and material handling system design, etc. Indeed, many of these issues also matter to the manufacturing strategy (Hayes and Wheelwright 1984; Fine and Hax 1985; Leong et al. 1990; Miltenburg 2005), regarding a long-term perspective of operations in manufacturing facilities; amongst them, both process technology and production facilities, but also human resources as well as organisation structure and control, are under concern in manufacturing planning, which in turn affect the capability of the manufacturing system to compete on basic performances such as cost, quality, delivery reliability and speed, flexibility and innovation (Safizadeh et al. 2000).

Stages and Gates

The method herein proposed consists of the typical phases of systems engineering. Hence, stages (and related gates) are organised through an analysis-phase, a design-phase and an implementation and realisation-phase. The analysis-phase concerns the study of the operational performances of different system design alternatives. The analysis-phase is needed for providing inputs to the subsequent design-phase, when the planning decisions are finalised by means of selection of the best manufacturing system (re)configuration and subsequent (re)organisation of its resources. The implementation and realisation-phase is intended in the broadest sense, since it covers the activities to be managed for (re)configuring/(re)building hardware structures, and service, manufacturing and control software, as well as for hiring and training personnel, and developing or changing the human organisation and control of the manufacturing facility.

Stage 1: Preparation and Introduction

In the stage 1 of Preparation and Introduction, a general plan of the development project and an appropriate project team is to be set up. After forming up the project team, the team members initially need to be familiarised with the idea of the PSS design, having a specific concern on the relevant implications for the operations of the manufacturing plant. Possible tools in order to scheme out the sustainability requirements may be taken from competence areas which are close or within the industrial engineering area. TQM (Total Quality Management) is a typical area where tools can be found, for example the *Quality Function Deployment* (QFD)—to relate stakeholder requirements to the requirements for the manufacturing system design. Another tool—originally proposed for strategic/management decisions, soon applied in many other contexts, also industrial engineering area—is the *Analytic Hierarchy Process* (AHP).

Gate 1: Preparation and Introduction

In gate 1, it has to be checked whether the project team really consists of all necessary experts needed in order to develop manufacturing planning solutions compliant to the stakeholders' requirements of the PSS under development.

Stage 2: Analysis of System Design Alternatives (economic and technical requirements)

Stages 2 and 3 are needed in order to analyse different system design alternatives, with the purpose to provide an assessment under the three known sustainability pillars. This stage 2 specifically focuses on the economic and technical requirements, taking into account the economic and technical factors related to the key operational requirements of the manufacturing system established at stage 1. Each system design alternative is then assessed after considering such requirements. On the whole, this analysis stage is carried on following a "traditional" manufacturing system design approach, with the purpose to support economic sustainability, and to compete on basic performances such as manufacturing cost, product quality, delivery reliability and speed.

Gate 2: Analysis of System Design Alternatives (economic and technical requirements)

To pass through this gate, the project manager has to decide in close cooperation with the project team whether the possible development project should be undertaken or not. For this reason, they have to decide, based on what they investigated and found out, whether there are enough alternatives to be further evaluated under other factors comprised in the environmental and social pillars, of interest for the stakeholders.

Stage 3: Analysis of System Design Alternatives (environmental and social requirements)

This stage 3 focuses on the environmental and/or social requirements, considering environmental and/or social factors related to the key operational requirements of the manufacturing system established at stage 1. Each system design alternative is then assessed after considering such requirements. At this stage 3, the environmental impact of different layout alternatives should be assessed. On the whole, a sustainable facility layout must be design and managed in order to optimise the energy flows of a plant and minimising wastefulness and inefficiency, for example by reusing the emission as an input for the system itself. More in details, an evaluation can be implemented only when the data about the consumption behaviour of each individual equipment included in the system is available. So, the first matter of concern of this approach should be to create a reliable database for the evaluation of energy consumption of each system and sub-system that compose the whole system: the database must contain the energy consumption of each component of the productive system, in order to be aware of energy consumption and losses regarding manufacturing, assembly and transportation. Last but not least, this

stage 3 should also consider the work design and task analysis in order to understand how to match the demands of the system or process to human capabilities.

Gate 3: Analysis of System Design Alternatives (environmental and social requirements)

The project manager has to decide in close cooperation with the project team whether the possible development project should be undertaken or not. For this reason, they have to decide, based on what they investigated and found, whether there are enough alternatives from which the best manufacturing configuration may be selected for implementation (at next stage 4).

Stage 4: Selection of System Design Alternative

This stage 4 collects the assessment of all the system design alternatives that has passed the "go-decision" at previous stages 2 and 3. Moreover, it uses the key operational requirements established at stage 1 as control criteria to select the best manufacturing (re)configuration and (re)organisation of resources. In particular, at this stage 4 the main objective is to create a ranking of system design alternatives, as well as to present eventual sensitivity analysis on relevant factors, whenever this is the case in order to discuss on the robustness of manufacturing planning solutions under concern. For the ranking purpose, tools to enable the evaluation of the quality of manufacturing planning solutions should be used, considering also that multi-criteria decision-making (MCDM) is essentially required for properly weighting the priority of different sustainability factors: for example, *QFD* and *AHP* can be used in line with what is being used at stage 1. Other tools should be used for effective reporting and communication towards relevant project stakeholders.

Gate 4: Selection of System Design Alternative

The whole project team has to decide on the best system design alternative to be implemented.

Stage 5: System Design Implementation Plan

Stage 5, the implementation plan of the system design alternative chosen at stage 4 has to be set up, executed and controlled. At this implementation stage 5, it is relevant to focus on the so-called group development, as a follow-up of the result of work design and task analysis—already done at previous stage 3 to assign groups/individuals to operational activities/duties, as well as to analyse the human interaction with the technical system/s.

Gate 5

The project manager has to make sure that the implementation plan is complete, consistent and accomplishable. If it is not, he has to take care that appropriate improvements will be done.

Distribution and Logistical Planning

Distribution and logistical planning refers to the management of the flow of resources between the point of origin and the point of destination. The resources managed in logistics can include physical items, such as food, materials, equipment, liquids and staff, as well as abstract items, such as time, information, particles and energy. The logistics of physical items usually involves the integration of information flow, material handling, production, packaging, inventory, transportation, warehousing and often security.

Two main objectives in logistical strategy can be identified: firstly, companies strive to reduce cost, for instance fuel, taxes, salaries, etc. Secondly, not only variable costs, but also capital is to be reduced in order to ensure a stable market position. This capital may be reduced by diminishing investments and fixed costs. Finally, the improvement of the service quality is an important motive behind logistical planning.

Stages and Gates

In order to get a systematic understanding of the challenges, it is sensible to divide distribution and logistical planning into four thematic fields. First of all, each company is embedded in a legal system. Secondly, the economic and organisational framework of the company has to be considered. As a third issue, the production related conditions have to be considered. Finally, not only the company itself and the environment in which it acts have an influence on distributional questions. In the following, 4 stages and consecutive gates are suggested. Within each stage, the four aforementioned issues are kept in mind and explicitly addressed if necessary.

Stage 1: Production—When and Where?

As a first step, the aspect of *when* to produce a certain good is important. Dependent on the product's characteristics such as perishability, value, size, degree of immateriality (especially for service systems), or customer behaviour, for instance frequency of orders, it might make sense to produce a certain amount in advance to avoid supply shortfalls. In particular, companies with more than one factory have to consider *where* goods should be produced in order to minimise transport costs to the customer.

Gate 1

To pass this gate, it has to be checked whether the chosen production and delivery system is the most efficient one or not.

Stage 2: Potential Analysis/Audit

At stage 2 a potential analysis has to be done in order to compare the customer´s expectations to the company´s potentials. A potential analysis consists of five distinct analyses which capture, taken together, all relevant influential factors: requirement analysis, performance analysis, process analysis, structure analysis as well as *benchmarking*. The result of this analysis is a detailed idea of what the

company has to provide in order to offer sustainable solutions and thus maintain long-term customer relationships. Beside economical sustainability, customer satisfaction has a high impact on social sustainability.

Gate 2

At the end of stage 2, several loops back to other division are advisable. The results of the requirement analysis can serve the planning of a single set of orders. Alternatively, they can be used to make predictions about customer behaviour as a whole.

Stage 3: Delivery Trajectory

Logistical planning tackles not only the question of how to deliver a product to its final destination; it also has to account for a combination of several orders. Thus, in order to increase sustainability, the most efficient solution regarding vehicle, optimal utilisation of capacities, fuel, but also time has to be chosen. Three different kinds of heuristic approaches can be used to guess systematic trajectories that might be preferred over bare arbitrary ones. Those are *heuristic approaches* (i.e. nearest neighbour), *the milk run method* and *the cross-docking method*.

Gate 3

The methods described should lead to an optimised delivery trajectory, taking several logistical options into account.

Step 4: Optimise Customer Satisfaction via Efficient Consumer Response (ECR) in Logistical Planning

In this step, the focus is changed towards customer satisfaction and, thus, a social and economic sustainability. The aim is to enable a company to react on consumers' demands as soon as possible by establishing long-term relationships and tool-based interactions between producer, wholesale trade, retail trade and consumer. ECR is a joint trade and industry body to make the market more responsive to consumer demand and promote the removal of unnecessary costs from the supply chain. One of those tools is *Quick Response* (QR) that tries to unify load units and informational systems of producer, wholesale trade and retail trade, especially designed for the grocery and fabric sector, QR-enabled companies to reduce their delivery times, an increase on deliveries on time, less waste and a reduction of costs.

Service and Spare Parts Operational Planning—Maintenance

Nearly every organisation today is looking for some ways to improve maintenance. Proper maintenance does not only help to keep the life cycle cost down; it also contributes positively to the overall performance of the company. However, maintenance also contributes significantly to the total cost, and this often forms the basis of performance improvement demands to the maintenance department (Waeyenbergh and Pintelon 2002). The search for maintenance improvements is

focused on finding a programme, approach or methodology that will improve the productivity of maintenance labour whilst at the same time improving production equipment reliability, availability, and productivity (Kister and Hawkins 2006).

Stage 1: Assessment of the Current Situation; Definition of the Maintenance Policy, Strategy, Objectives and KPIs

At the beginning of stage 1, the whole maintenance planning process gets started. An assessment of the current situation has to be done. It must consider all aspects related to the maintenance of equipment where information is available. After this is done, the production or authorisation of the overall maintenance policy by the organisations´ top management has to be realised. The maintenance policy provides the framework around which the maintenance strategy, objectives and plans are developed and implemented. The result will be the development of the draft maintenance policy. After this done, the organisation will establish or review a long-term maintenance strategy. The maintenance strategy has to demonstrate how the maintenance policy is to be implemented and how it will support the organisational strategic plan. After this done, the organisation will establish or review a long-term maintenance strategy. The maintenance strategy has to demonstrate how the maintenance policy is to be implemented and how it will support the organisational strategic plan. If the objectives and strategy as well as the performance measures are inconsistent with the declared overall business strategy, the *balanced scorecard* (BSC) has to be introduced (Kaplan and Norton 1992).

Gate 1

After stage 1 is done, it has to be checked whether the assessment of the current situation in the maintenance management of the organisation considers all aspects related to the maintenance. After this done, it has to be checked whether maintenance policy, strategy, objectives and KPIs are clearly defined. Furthermore, it should be checked whether the maintenance policy is consistent with the organisational strategic plan.

Stage 2: Assets Priority Considering the Sustainability Factors

Once the objectives have been defined and a maintenance strategy has been designed, it is of vital importance for the management of the maintenance department to establish the ranking of the physical assets of the organisation based on their criticality, e.g. greater or lesser impact in the global production system and/or safety of the system (business objectives). There are many qualitative and quantitative techniques that offer a systematic basis for classifying an asset as critical (C), semi-critical (SC), and non-critical (NC) based on probabilistic risk assessment and obtaining the "probability risk number" (PRN) (Moubray 1997).

Gate 2

To pass this gate, the management of the maintenance department has to control if every asset could be classified in a critical (C), semi-critical (SC) and non-critical (NC) class to get a clear overview about it.

Stage 3: Design of Maintenance Plans and Resource Allocation

At the beginning of stage 3, data from computers have to be analysed. Thereby, the different functions of equipment have to be identified. Next, failure modes have to be identified. It presents the base for the decision. Finally, the root cause of failures has to be analysed if required. With all these data, it assesses the consequences of each failure in each of the areas (operational, safety, environment and cost). After this done based on the collected information, a decision has to be taken. The decision has to set out prevention duties (technically feasible and economically profitable) for the consequences of failure modes. One of the methods used in the industry for designing strategies and maintenance plans is referred to as RCM (reliability-centred maintenance). The *RCM methodology* proposes the identification of failure modes that precede potential failures of equipment, and the execution of a systematic and uniform process.

Gate 3

Firstly, it is to check whether the maintenance plans consider all needed resources and required inventory which could be done without including the upper maintenance management. Furthermore, the middle management has to check whether all the mentioned restrictions are considered and met in the work of stage 3.

Stage 4: Implementation, Execution and Control

At the beginning of the stage 4, the design of the information system has to be checked if it is oriented to collect and to process exact information. After this done, the tasks and the persons in charge have to be subdivided in accordance to the maintenance plans. The execution of maintenance activities (once designed, planned and scheduled as described in previous sections) has to be monitored and evaluated to pursue the business objectives (business model development; strategy development) and business values of the selected maintenance KPIs. This survey and evaluation have to be done by a structured control report.

Gate 4

Firstly, it has to be checked if the information system was created and implemented in the right way in order to store and handle the historical data. The next aspect to control is the structure and the content of the report for the maintenance execution.

Stage 5: Life Cycle Analysis and Replacement Optimisation

Therefore, in the stage 5 have to be performed the evaluation and analysis of the life cycle costs of the maintenance assets. The realisation is a responsibility of the middle management of the maintenance department.

Gate 5

At the beginning of this stage, the applicable maintenance functions in each of its phases (design, manufacturing and production, etc.) have to be identified. After this done, the cost of these functions has to be calculated, applying the appropriate cost

for the duration of the life cycle. Finally, the total life cycle costs have to be analysed. Through an analysis of the life cycle cost, it is possible to determine the cost of an asset over its useful life. *The life cycle cost analysis* (LCCA) or the sustainability *impact calculation tool* (SIC) has to be used. Further on, other tools for asset life cycle simulation may be adopted, having the capabilities to represent stochastic behaviour in time.

End-of-Life and Recycling Planning

The end of a product's life cycle causes various difficulties concerning its disposal. These difficulties mainly affect environmental issues, but may also have impacts on the company's profitability or society. In order to attain an increasingly sustainable positioning of the company, it is necessary to ensure that a gross of the materials is reusable or can be environmentally friendly disposed.

The concept of recycling is used ambiguously and refers either to all kinds of waste disposal reusing components or the whole material of the product, or merely to a disposal which ensures a consistent quality of the reclaimed raw material.

Stage 1: Building a Prototype

At the beginning of each consideration about a product's end of life, a prototype is necessary. This prototype, either already physically available or a mere drawing, should be designed on the company's former experiences. It builds the basis for the following attempts to design a product that can easily and environmentally friendly be recycled.

Gate 1

To pass through this gate, specialists for end-of-life cycle planning have to talk to specialists from other divisions and check whether the prototype is realisable.

Stage 2: Reduction

Tear down is a procedure to improve existing physical goods in order to increase their sustainability. The aim is to find potentials for leaner designs which lead to cost reductions and an increased recyclability.

Gate 2

At the end of the second stage, each component must have been considered in various arrangements, using different materials, shapes or spatial order. McDonough and Braungart defined five criteria which support the reflection process (McDonough and Braungart 2002).

Step 3: Reuse

The persons responsible for the planning phase need to find alternative ways of use for the raw materials at the end of the product's life cycle. The most evolved approach to intelligent or sustainable product design is the cradle-to-cradle (c2c) conception. Its leading idea is the vision of a world without waste. The *c2c approach* was developed in 2002 by Braungart and McDonough (McDonough and

Braungart 2002). After the theoretical considerations concerning the new product's recycling, the real process of recycling has to be conceptualised.

Gate 3

The ratio of per se environmental friendly materials and the waste they bring about during their manufacturing has to be considered and be rechecked after step 3.

5 Case Study CLAAS Selbstfahrende Erntemaschinen GmbH

CLAAS Selbstfahrende Erntemaschinen GmbH is part of CLAAS KGaA mbH, an international operating manufacturer of agricultural machinery. The company employs over 9,000 people and has yearly revenue of 3.4 billion Euros (in 2012). CLAAS is facing the challenge to change their classical business model from a product selling company to one that is selling sustainable solutions for their customers. The introduced development framework should serve as a guideline to optimise the way of developing sustainable solutions and illustrate weaknesses in the present one.

Procedure

In a first step, employees of different divisions of CLAAS were introduced to the development framework and familiarised with the suggested dimensions. The different dimensions, activities, gates, responsibilities and interfaces were explained. The next step was a discussion about the dimensions and the four suggested development phases.

After the structure of the framework had been accepted and considered as complete, the next task was to classify the different roles of the participants into the given dimensions. Afterwards, the participants were asked to draw down their actual procedure for sustainable solution development into the development framework. After identifying many possible starting points for new solutions, the process for collection, assessment, prioritisation up to the decision and realisation was signed into the framework. During this procedure, many weaknesses of the actual processes were shown. For example, not explicitly defined, but necessary interfaces were identified. After drawing the actual development process and identifying weaknesses whilst doing so, a last step should be the design of target processes. Therefore, the introduced scientific development framework gives useful incentives, tools, ideas and recommended interfaces and gates to define the target processes. The consideration of different sustainability goals must also be considered whilst creating the new target process. Tools to measure and monitor sustainability goals should be integrated.

Lessons Learned

The following eight examples give a first impression of what can be analysed using the framework. They cover a broad range from issues that address interfaces between divisions as well as organisational and communicational weaknesses. The challenges CLAAS has to respond to should be seen in the context of the change from a physical product to product-service systems; a change whose necessity is confirmed by international scientific authorities.

- Communication channels between existing strategies and different divisions need to be improved in order to reach more target-orientated ideas.
- Consolidation of multidimensional idea sources should be structured in a suitable one-pager.
- One-pager, as a first outline of the idea, should also show the sustainability impacts (economical, environmental, social).
- Arrangements of higher capacities for a structured idea description and idea preparation.
- The process of idea generation is mostly based on machinery improvements. A more integrated view is missing.
- Arrange more flexible capacities to guarantee a successful realisation of projects within a project organisation.
- Missing interfaces within the organisation for the realisation of new innovative solutions.
- Mostly the innovation is machinery based. So interfaces to the central initiation are important. Loops between the PSS development and the strategy, respectively, the business development is most important.
- For the development of sustainable solutions, new issues, e.g., data privacy, ecological impacts and measurements must be considered. Therefore, interfaces from technical development to other divisions of central initiation are necessary. Due to the occurrence of new issues during the development process new responsibilities occur, too. These responsibilities are often not defined.
- Identified or existing interfaces between different divisions are sometimes using different IT standards. These circumstances lead to mistakes and hinder an efficient sustainable solution development.

6 Conclusions

The scientific achievement of the previous chapters is a framework that is supposed to be a tool and a guideline for companies or value networks to evaluate and optimise their current business processes. In this framework, which serves as a rough generalisation over prototypic companies, 3 groups—central initiation, conceptual dimension and operational dimension—consisting of eleven dimensions has been defined. The processes are divided into four chronological steps according

to the life cycle approach of the methodology: idea, conceptualisation, implementation and market. For each unit, several steps and gates are defined which contain a manifold of tools and methods in order to realise sustainable solutions and to optimise business processes. Whilst the steps provide a suggestion for a possible procedure, the gates serve as moments of reflecting and checking whether the aims of a step have been fulfilled and the processes are as sustainable as possible. The result is thus a framework that covers all business activities and explicitly suggests a detailed procedure for each division for each step in the development of sustainable solutions based on scientific approaches from considerable authorities in their field and confirmed by real companies via workshops. The aim is to enable companies to optimise their business processes towards sustainability, starting at any point in their process chain.

For an international operating company with a complex structure of functionalities and divisions, the development framework seems to be a meaningful and helpful method for realising sustainable solutions. When it comes to interfaces, the most eminent challenge is an improvement of communication processes. If companies or value groups are able to make improvements here by involving all relevant actors in the decision-making process, various immense problems, delays and complaints might be avoided.

Summarising we can conclude that the development framework is on the one hand a useful and helpful guideline to get an overview of topics to be dealt with when developing sustainable solutions. On the other hand, the framework can be used as a tool for companies to define their development processes.

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