Development methodology for sustainable solutions

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SustainValue

Sustainable value creation in manufacturing networks

D3.3 DEVELOPMENT METHODOLOGY FOR SUSTAINABLE SOLUTIONS

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1 Executive summary

Deliverable 3.3 (D3.3) is part of work package 3 of the EU-funded SustainValue project. Work package 3 (WP3), which comprises of five tasks, deals with life-cycle-based products and service development. Focus of WP3 is to develop a methodology which enables companies to design and develop sustainable solutions. The first tasks of WP3 viz. T3.1, T3.2 and T3.3 were already accomplished and two deliverables (D3.1 and D3.2) which analyse requirements and gaps for development methodologies for sustainable solutions were submitted. This deliverable D3.3 considers task description T3.4: “In order to complete the development methodology the next task is to combine the identified steps and phases to a complete development methodology. This methodology allows a step by step development. It assures a structured and systematic approach by giving tasks needed to be done for a complete and successful result”.

The work carried out has involved the consortium partners including most of industrial partners to validate the results. Main result is a development framework which was developed and validated within the consortium and additional external actors. During the early phase of research when approaches for service or product development were identified and during the early interviews with the industrial partners, a first finding was that the development of sustainable solutions is not a task for single persons or a single division in a company. To develop and implement a sustainable solution several areas within and beyond the company boundaries must be considered. On different levels e.g. on network level with partners, strategic issues from top management, business model decisions, conceptual division like product engineers, operative division for logistics etc. must be involved to provide a (more) sustainable solution as a result. Hence there are several sustainability potentials on different levels which are later concretized with the help of so called dimensions. Hence the expression “development methodology” was changed to “development framework” to show and express the complex interdependencies between the different actors. Within this framework, which is a matrix combining a lifecycle perspective and an overview of different functional dimensions, different methodologies approaches are integrated and interconnected.

Thereby the interfaces can be illustrated and described and different approaches can be integrated to avoid conflicts during development and to support the essential communication between the different dimensions (respectively actors/divisions in companies).

The framework supports companies in their sustainable development process and creates transparency of the different tasks. Beside it gives several hints for useful approaches and tools. Further the framework can be used in companies as a tool itself to illustrate their own processes, interfaces, gates and communication channels. At the same time weaknesses and inefficiencies in their processes are revealed.

The framework has been validated within a big company with over 9000 employees where different division represent the dimensions as well as a small start-up company where the different dimensions are represented by only few persons. The framework introduced in this deliverable is the basis for the tools enhancing the several approaches. The tools will be described in detail in the following deliverable D3.4.
2 Terminology

Methods: Methods are systematic and elected procedures to reach previously defined targets. (cf. Gill, 2004, p. 28; Fähnrich et al., 1999, p. 53; Feldhusen, 1989, p. 27)

Methodology: Framework clustering, evaluating, and employing methods and tools

PSS: A product service system can be defined as the result of innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands. (adapted from Manzini & Vezzoli, 2002)

Process: A process is an approach in order to achieve a managerial objective through the transformation of input into outputs while processes utilize resources. (adapted from Shebabuddeen N., Probert D., Phaal R., & Platts K., 1999; Burr, 2002, p. 62).

Procedure: a specified way to carry out an activity or a process with a defined beginning and end point. (cf. ISO 9001)

Resources: the different factors needed to realize a solution. A structuring thereof, for example, is the system of Kern (cf. Kern, 1980). In addition, Gutenberg (cf. Gutenberg, 1983) structures these factors beginning with the definition of elemental factors (working hours, materials etc.) and those for planning purposes (company management). For the service engineering process, these factors can additionally be differentiated into internal and external factors (cf. Bullinger & Scheer, 2006a, p. 204)

Requirement: A requirement is a notation about the characteristics or the output of a PSS or a solution, a process, or the resources which are used in the processes (adapted from van Husen, 2007, p. 32).

Service engineering: The systematic development and design of services employing interdisciplinary models, methods and tools (cf. Bullinger & Schreiner, 2002).

Sustainable solution: A sustainable solutions is defined as combination of tangible products and intangible services to fulfil stakeholder/s need/s that deliver sustainable value (environmental, social and economic objectives).

Stakeholder: Stakeholder is an individual, group, or abstract unit that has an interest in any decision or activity of an organization (ISO 26000:2010; D1.3) The key stakeholders discussed in relation to sustainability primarily include workforce, environment, suppliers, community (consumers, citizens), governments, international organisations, non-government organisations (international and local), and the media.

Solution: The offering provided by a PSS in the finalized form for different stakeholders.

Sustainability: is a state that requires that humans carry out their activities in a way that protects the functions of the earth's ecosystem as a whole (ISO 15392 2008). Note: Sustainability has an economic, an environmental and a social dimension. (D1.1 p.8)

Tool: Tools are utilities supporting the execution of methods on a detailed level (Bullinger & Schreiner, 2002, pp. 72f.)
Value: The worth of all the benefits and rights for all stakeholders arising from the sustainable solution. Beside economic benefits further values in social and environmental objectives (e.g. health and recycling of waste) are elements of the generated value.
3 Introduction

The main aim of SustainValue is the development of industrial models, solutions and performance standards for new sustainable manufacturing and service networks. According to the project’s original work description, key challenges that sustainable manufacturing must meet are economic challenges, by producing effectively and efficiently and creating new services ensuring development and competitiveness through time. Moreover, environmental challenges have to be faced e.g. by promoting minimal use of natural resources (in particular non-renewable energy) and managing them in the best possible way while reducing environmental impact. Furthermore existing societal challenges have to be taken care of by promoting social development and improved quality of life through renewed quality of wealth and jobs.

3.1 Purpose of D3.3

Deliverable 3.3 aims to develop a framework which serves companies to analyse and optimize their processes in order to increase their sustainability. Based on the methodological and scientific gaps that were identified in D3.2, D3.3 offers a holistic concept by combining and integrating various management and operational methods and supportive tools. D3.3 can thus be seen as drawing the practical conclusions from D3.1 and D3.2 and turning these conclusions into a scientific conception. The methodology will be designed according to constraints given by industrial context and life cycle phases. The methodology which is developed within D3.3 is the key result of WP3 as a whole.

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 and environmental aspects of sustainability can be captured. Well organized processes and conflict-free communication between divisions have the potential to tremendously improve employees’ contentedness. Changes in the company’s business model, for instance increased striving for ecological sustainability, are also supported by the presented framework. Which aspect will be focused and which alterations will be made depends upon the company’s interests. Nevertheless, the framework is generally able to improve all three dimensions of sustainability.

The tacit assumption behind the following elaboration is that sustainability can be realised through changes in any business activities. Treading the business model of a company as the leading idea behind all activities, it is both possible to change the business model itself and thus influence all activities of the company; or the operational processes can be changed and might lead to a necessity of adapting the business model. To confirm that this assumption is both correct and accommodated, three business partners with significantly different business models were asked to test the framework.

The suggested framework is applicable to these change processes, both top-down and bottom-up. This feature enables a multitude of companies to use the framework in order to describe and afterwards optimize their processes regarding an increase of sustainability. For this reason, the framework is both precise and extensive in its suggestions, on the other hand individually adaptable.
3.2 Scientific Progress towards a Development Methodology for Sustainable Solutions

The overall beginning of WP3 has been in December 2011. WP3 started with task T3.1 to analyse requirements of sustainable solutions. The first step of T3.1 was a basic literature research to get an idea about the state of the art towards development methodologies, definitions of sustainable solutions and further approaches describing integrated products. In addition a workshop has been set up during the SustainValue project meeting in Aachen in January 2012 to get critical feedback from all partners of SustainValue. Between January and May 2012 several telephone conferences took place with Cambridge, VTT and POLIMI to discuss contents of WP3 in close relation to other working packages.

Deliverable D3.1 has been finalized in time and was uploaded to the commission in May 2012. Contributors towards D3.1 have been all members of the SustainValue consortium through workshops, telephone conferences and valuable comments during the creation process of the document. All objectives of T3.1 have been achieved without deviations.

Between February and June T3.2 and T3.3 have been accomplished. Firstly existing methodologies for innovation and solution engineering had to be analysed. Secondly a gap analysis for these existing methodologies, according to identified requirements of D3.1, has been conducted. The results of T3.2 and T3.3 have been discussed with VTT within a two day workshop in Aachen, June 2012.

The results have been transferred to D3.2. The document of D3.2 was commented by the partners of the consortium and subsequently expanded with their contributions. D3.2 has been finalized and uploaded to the commission in August 2012. The objectives of T3.2 and T3.3 have been achieved without deviations from the project work programme.

In July 2012 T3.4 started. T3.4 closely refers to the results that have been achieved and documented in D3.1 and D3.2. During telephone conferences with VTT and a workshop with Claas a first idea of D3.3 has been drafted, based upon the preceding results (see also Chapter 4 which describes the conceptual design of the development methodology). In addition several meetings with Claas took place to test current and possible future development methodologies and tools on Claas’ SustainValue industry case.

In late August 2012 a meeting between FIR and Claas took place in Gütersloh to create the first draft of the development framework. In this workshop, a draft has been developed which was subsequently extended and as far as possible rounded off for further detailed discussions. These discussions took place in workshops during the meeting with the consortium in Tampere in October 2012. By integrating all critical feedback a modified draft could be created. This modified draft was furthermore discussed with industry partners to verify its practical usability. Afterwards it was send to each partner for verification and possible further feedback. In addition some telephone conferences took place for discussing further details of D3.3. The development methodology for sustainable solutions could be finalized by valuable contributions of all partners working on D3.3 in April 2013.

The results of this deliverable will deliver furthermore important practical expertise and basic ideas towards necessary tools to finish T3.4 and T3.5 of WP3.
Besides, the application of the new development methodologies and tools will help especially Claas, ELCON, Riversimple and the other industry partners to execute their use cases.

3.3 Structure of the Document

This document contains seven main chapters. In Chapter 1, a summary of the most important aspects is given in order to give an overview that enables the reader to better follow the argumentation. Chapter 2 summarizes the basic terms used in this deliverable and provides short definitions as well as the most relevant sources. In the following Chapter 4, the framework that builds the crucial element of this deliverable is presented.

Subsequently, the development methodology for sustainable solutions is elaborated and examined in four sub-chapters. Chapter 5.1 elaborates on the process and a portfolio of tools and methods that assist in the design of sustainable business model/s. The process and toolset supports and is part of the idea and conception phases of the development framework for sustainable solutions, while being aligned with strategy development. After this central initiation, the next step is the conceptual dimension which forms the basis for the following operational dimension.

In addition to these theoretical elaborations, three case studies serve the validation of the framework from a practical point of view. The results are presented in Chapter 6 which is separated into three parts, each dealing with one of the three business partners.

Chapter 7 gives a conclusion after summarizing the main achievements of deliverable D3.3.

Chapter 8 summarizes the tools named in the whole development framework as a basis for the application by any user of methodology as well as for further description for the next deliverable D3.4.
4 Conceptualization of a Development Methodology for Sustainable Solutions

The assessment of current methodologies, that could help to develop sustainable solutions has shown, that no individual methodology and method can meet the requirements and targets of SustainValue. In the following chapter 4.1 the Development Methodology for Sustainable Solutions will be conceptualized based on the identified requirements (D3.1) and the outlined theory deficits (D3.2). The concept of this methodology will be called “Development Framework” and will be summarized in chapter 4.2. Each element of the Framework will be described in chapter 5 in detail.

4.1 Development Process as a Multi-Disciplinary Challenge

In the deliverable D3.1 definitions and characteristics of sustainable solutions could be acquired. Based upon several analyses and workshops the complexity of sustainable solutions has been described and requirements towards sustainable solutions have been systematically conducted (see Table 2 in D3.1 cf. SustainValue, 2012b). Furthermore relevant development methodologies have been analysed to characterise necessary requirements. Based upon all found requirements, further input of other work packages and an understanding of development methodologies, specific requirements for a development process for sustainable solutions have been methodically described (see Table 4 in D3.1). These requirements have been structured in “General requirements concerning the development process” and “Requirements concerning the development process in terms of a sustainable output and life cycle management” (cf. D.3.1, p. 34).

In the deliverable D3.2 (cf. SustainValue, 2012b), current methodologies of innovation (management) and solution engineering have been compared against the requirements described in D3.1. This study reveals various methodologies which could be used to support innovation and solution engineering within manufacturing industry during development activities.

Figure 1: Requirement towards sustainable solutions and gap analysis

According to the gap analysis presented in D3.2, 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 realize the development on a network level an interdisciplinary
approach with interaction of all involved stakeholders during the development process has to be realized.

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 (see also Figure 2).

![Figure 2: Concept – Interdisciplinary approach over the whole life cycle](image)

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 conceptualize sustainable solutions in terms of products, services or product-service 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 (see Figure 3).

![Figure 3: Concept – Interdisciplinary approach with different dimensions](image)
Each of those activities in the named dimensions will be described with stages and gates, according to the stage-gate-model (cf. Cooper, 2000, see also D3.2). 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. To have an overview about the important activities during the development methodology, a template for the stage-gate model has been developed. It covers the content, the functions/responsibilities/authorities, the interfaces to other stages/gates/dimensions and finally the tools that can be used during the stage or gate (see also Table 1).

Table 1: Concept of detailed description of the stage-gate model

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<td>Content</td>
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<tr>
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<td></td>
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Consequently the Development Methodology for Sustainable Solutions covers stages and gates for every development dimension (see as an example in Figure 4).

Figure 4: Concept – Example Stage-Gate-Model for all development dimensions

Based upon the research in D3.2 and the workshops that have been conducted with the SustainValue consortium, the following development dimensions have been identified as most relevant for the Development Methodology for Sustainable Solutions:

- Strategy Development
- Business Model Development
- Technology Development
- Product-Service-System Development
- Product Development
- Service Development
- Sourcing Planning
- Manufacturing Planning
- Distribution & Logistical Planning
- Service & Spare Parts Operational Planning
- End-of-Life & Recycling Planning

For each dimension well established approaches have been identified and partly adjusted (see chapter 5). 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.

The whole development process has been clearly subdivided into those eleven dimensions, each describing their specific part of the development process. Most innovative for this interdisciplinary development approach is that interfaces between all dimensions have been worked out and described. This enables the required interdisciplinary cooperation between all relevant stakeholders to develop sustainable solutions (see Figure 5).

![Figure 5: Concept – Interfaces between dimensions](image)

### 4.2 Conclusion: General Development Framework

As described in D3.2 an innovation can be a new commercialized idea which is significantly better than an earlier solution. Innovation can be related to products, services, technologies, business and organizational models, operational processes, or operational methods (see D3.2). Similarly, 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.

As mentioned before, the main innovation of this all-embracing methodology is to emphasize 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. As illustrated before, an interdisciplinary approach of a solution development process is able to reach a new level of sustainability by a clear, open, well organized and well described cooperation of all participating stakeholders, acting in different dimensions.

![Development Framework for Sustainable Solutions](image)

**Figure 6: Development Framework for Sustainable Solutions**

In the next chapter the conceptualized dimensions of the framework will be described in detail, showing the interfaces between all the methods to be able to develop sustainable solutions. To confirm that the *Development Methodology* is both correct and accommodated, it will be validated by the business partners with significantly different business models.
5 Development Methodology for Sustainable Solutions

The following chapter enhances the framework which is introduced in Chapter 4 with detailed content regarding different methodologies, tools and interfaces of the different dimensions. The chapters are structured in the same way as the dimensions of the framework. At the end of every subchapter, a table which summarise the stages and gates of dimension is given. The tools which are mentioned are going to be described in detail in the upcoming D3.4 or are described in the given references.

5.1 Methods – Central Initiation

5.1.1 Strategy Development

Strategies exist at several levels in any organization - ranging from the overall business (or group of businesses) through different operations and organization 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. However, the intention of this deliverable is not to take part in this academic discussion and thereby the practical strategy process is described on a very general level.

Strategic analysis and strategy development can be described as a question based process. First, the persons responsible should form a common understanding of where they are at the moment and why they are there. Then a shared purpose would define where they want to go and furthermore how to get there. These strategic choices are highlighted by vision and mission statements, and they can be concretized by business models. Here appears a first interface between the different dimensions of the presented development framework. Finally, implementation of strategy often requires changes in organization, its values and thinking.

In a continuously changing environment the strategy process is also turning to be continuous and a strategy needs to be used, reviewed, updated and refreshed regularly. In Figure 7 such a strategy driven approach is presented, which enables organisations to be proactive instead of reactive. First, strategic analysis is about analysing the strength of businesses’ position and understanding the important external and internal factors that may influence that position. Secondly, strategy development involves understanding the nature of stakeholder expectations (the "ground rules"), identifying strategic options, and then evaluating and selecting strategic options. By aligning planned operational improvements to strategy, organisations are able not only to manage the present successfully but also to create a favourable future. Anyhow, the third action - strategy implementation - typically is the hardest part. Implementing a strategy may require organizational, 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.
Concurrently, sustainable development must be aligned with other strategic targets of an individual company as well as with the targets of its network partners. The strategy of a sustainable enterprise has been defined as the process of aligning an enterprise with the business environment to maintain a dynamic balance between resilience and growth so as to align the creation of abundance: economically, environmentally and socially, and to conserve this value for future generations (cf. WCED (World Commission on Environment and Development), 1987)). If the customers are requiring sustainability and consider it critical, companies must respond to this requirement in order to continue to compete. Furthermore, to be on top, companies must find new ways to consider sustainability in their strategic choices. As pointed out by Robert et al. (2002) this may lead to a challenging situation, when the rapidly growing numbers of sustainability approaches and tools are applied without clear connection to strategy. Thus, there is a risk that these tools are viewed as conflicting, competing or as each other’s substitutes or alternatives.

Business modelling process described in the next Chapter 5.1.2 is overlapping with strategy development, because a business model provides a link between strategy and operations and enables exploitation of entrepreneurial opportunities (Figure 8). Furthermore, it can be stated that the business model provides a way for managers to analyse and communicate strategic choices (cf. Seppänen, 2008). Similarly, strategy development and implementation are strongly linked to conceptual and operational dimensions of the framework (see Chapters 5.2 and 5.3). In other words, the strategic choices should guide product, service as well as technology development and all operations from sourcing to end-of-life decisions.
Both strategic analyses and the first step of business modelling process target to describe the purpose of business and sustainability drivers. Many of these methods related to strategic analysis are originally methods of future studies, which have later on been adapted also to vision building and strategy work at company and industry levels. Such are for example: PESTE analysis, road-mapping, scenario building and SWOT. PESTE (that is sometimes also called PEST, PESTLE, STEP or STEEP) stands for Political, Environmental Sociocultural and Technological analysis of business environment (cf. Xu, 2005, p. 25). Corporate Sustainability Continuum as one of the existing tools related to this stage is dealt with in this section. There are several existing methods and tools of the strategy development which can be utilised also to business modelling process. These tools are covered in the business modelling chapter. On the other hand, the same tools can also be utilised within product and service development processes, for instance (Tukker & Tischner, 2006) sustainability SWOT presented in Chapter 5.2.2.

5.1.1.1 Introduction of Possible Methods and Tools

Typically companies have described their strategy process and its milestones. There are plenty of possible methods and tools, and despite sustainability is not included in many tools, it can be considered through them. The possible tools and methods are presented within the three stages of general strategy process: strategic analyses, strategy development and strategy implementation (see Table 2). In the next sub-chapters the sustainability-oriented tools (in italics in the table below) are described in more detail. There are plenty of sources where further information about the tools can be found. Furthermore, the following deliverable D3.4 concentrates on the description of these tools.

Table 2: Approaches of Strategy Development Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic analyses: PESTE; SWOT; MARKET/NETWORK ANALYSIS, Five Forces analysis, Competitor analysis, Corporate Sustainability Continuum, etc.</td>
<td>Porter, 1998; Humphrey, 2005; Andrews, 1980</td>
</tr>
<tr>
<td>Strategic development: vision, mission, values, generic strategies, marketing strategies, sustainability strategies (Hart and Milstein’s framework of sustainable value), Business model archetypes (Business modelling process, next chapter)</td>
<td>Hart &amp; Milstein, 2003; SustainValue D2.1</td>
</tr>
<tr>
<td>Strategy implementation: (vision, mission, values), strategy maps, Strategic portfolio management, balanced score card, KPI’s</td>
<td>Kaplan &amp; Norton, 1992; Kaplan &amp; Norton, 1996</td>
</tr>
</tbody>
</table>

5.1.1.2 Integration into Development Framework

As presented earlier in Figure 8, strategy development is followed by Business Model Development, and in practice these two are tightly interlinked. Thus, the strategy implementation stage is connected also to all other dimensions of the framework, while the main part of these operative dimensions are guided by different company level procedures and processes which should be defined by strategy and strategic choices.
5.1.1.3 Stages and Gates

This chapter 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, i.e. experiences that impact and modify the strategy. It provides important input and it is strongly linked to the first stage of business modelling process. The strategy group typically consists of the steering group of a company or a business unit. Also other persons may take part in the analysis, when more specialised information and knowledge are needed. Therefore a lot of communication channels and interfaces within a company and to external stakeholders are needed.

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 (see D2.4 SustainValue, 2013). The ‘Corporate Sustainability Continuum’ proposed by Willard (Willard, 2005) can support framing of present situation regarding to sustainable development and it is therefore represented also within this stage (see Figure 9).

![Figure 9: The corporate sustainability continuum, Willard (2005)](image)

The ‘Corporate Sustainability Continuum’ represents the progress of firms on the path towards sustainability and a firm can utilise it when exploring the question “where are we with respect to sustainability as strategic choice?”. Furthermore, it can also be utilised in studying future paths for sustainability and thereby it can be utilised also within stage 2, e.g. in strategy development. The maturity model configured in WP4 (cf. D4.2 SustainValue, 2013) can be utilised as a more detailed tool to 1) analyse firm’s current sustainability level, 2) set development objectives regarding sustainability and 3) manage performance of sustainability development.

Gate 1

The gate decision of stage 1 depends on whether the strategy group has enough knowledge to bring out the vision and go further to strategy development. Anyhow, in current fast changing business
landscape strategy work has to be done with scanty and disturbed knowledge. Thus, strategic analyses and strategy development often are an iterative process.

**Stage 2: Strategy development**

The second stage, strategy development, is guided by the vision and defines the strategic choices, e.g. where and how the organisation will compete and co-operate. Although, the strategy group has the main responsibility of strategy work, nowadays empowerment of employees is quite typical at least in western companies. Furthermore, many of the functions within one organisation may have their own strategy development tasks, as described for instance related to maintenance development in Chapter 5.3.4.

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. The possible tools for envisioning the strategic possibilities in this stage are business model archetypes and scenario analyses, which are described in other sections of this deliverable (business model archetypes are described in the next sub- Chapter 5.1.2 and scenario analyses are illustrated in Chapter 5.2.2).

**Gate 2**

The main task of this stage is to make the strategic choices. Thus, this is a very challenging task. Especially in the case of mature companies and industries renewal and innovation require learning, because of the path dependency and present understanding about success factors. Further, within this gate the participants of strategy development stage should be able to illustrate the strategic choices to the whole organization.

**Stage 3: Strategy implementation**

Strategy implementation stage is the translation of chosen strategy into organizational actions so as to achieve strategic goals and objectives. Many methods and approaches related to this organizing stage are originally change management tools and thereby vision, mission and values of the organisation are brought to guide the strategy implementation. Thus, also performance measurement tools, like balanced score card or KPI’s, can be utilised in order to lead the organisation towards the vision.

Strategic portfolio management is about project prioritisation and resource allocation to achieve new objectives for the company. It is a dynamic decision process where the list of active new products (offerings) and R&D projects (utilisation of capital and human resources) is constantly revised. Portfolio management asks questions like: Which new product projects, from the many opportunities the company faces, will be chosen? And which ones will receive top priority in utilising company resources in the best way to operationalize the company's strategy and gain the sustainability objectives?

Within the strategy implementation stage portfolio management is about finding and maintaining the right balance between short-term offerings and projects supporting current lines of business, and long-term offerings and projects that create new business (Figure 10). This dynamic process
supports decision making in current fast changing environment. Figure 10 illustrates the hierarchical view of management related to new product development projects and connections to strategic decision making. The target of the strategic co-ordination by portfolio management is simply: Do the right development projects!

![Figure 10: Offering, planning and portfolio management activities (adapted from Patterson, 2005)](image)

**Gate 3**

Strategy implementation is a continuous stage and it is not possible to define a precise gate task to this stage. Naturally, the strategy should be accessible, transparent and understood within the organization in order to be able to implement it. Furthermore, strategy implementation should be a two-way process where it is possible to change the strategy also through a bottom – up approach. Therefore interfaces and communication channels within the company and with external stakeholders should be clearly defined.

**Table 3: Method Overview – Strategy Development**

<table>
<thead>
<tr>
<th>Method</th>
<th>Strategy Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage/Gate</td>
<td>Content</td>
</tr>
<tr>
<td>Stage 1</td>
<td>Analysis, positioning</td>
</tr>
<tr>
<td>Gate 1</td>
<td>Enough documented knowledge of business environment available to bring out the vision?</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Vision, mission, values and implementation plan</td>
</tr>
</tbody>
</table>
5.1.2 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.

5.1.2.1 Introduction of Possible Methods

Business model innovation and redesign as observed by Chesbrough and Rosenbloom (Chesbrough & Rosenbloom R.S, 2002), Teece (Teece, 2010) and Zott and Amit (Zott & Amit, 2010) is key towards transforming businesses. More specifically, the transition towards a sustainable business model requires a significant shift in the way businesses are conceived and operated to create sustainable value (environmental, social and economic). Authors such as Tukker and Tischner (Tukker & Tischner, 2006), Baines et al. (Baines, 2007), Stubbs and Cocklin (Stubbs & Cocklin, 2008), Lüdeke-Freund (Lüdeke-Freund, 2010a), Anderson and White (Anderson & White, 2011) and Boons and Lüdeke-Freund (Boons & Lüdeke-Freund, 2012) have contributed towards the academic and industrial understanding on sustainable business models and modelling. However, there is still a lack of a clear design process for sustainable business modelling that will assist manufacturing firms in embedding and delivering sustainability in the purpose and business processes through a multi-stakeholder view. The summary of key findings from the state-of-art and state-of-practice reviews and gap analysis (conducted in WP2) on business models and sustainable business models are as follows:

- Business model innovation is generally ad-hoc, incremental and experimental and relies on visionary leadership.
- Broader stakeholder perspective specifically including environment and society is required (network-centric approach).
- There is a lack of design process and limited tools that can be used by manufacturing companies to innovate and evaluate novel business models, whilst considering various forms of value across the industrial network for a multi-stakeholder visibility.

The findings from above were considered in the development of the design process and supporting tools for sustainable business models. Table 4 further illustrates a summary of key approaches that provided substantial insight into the development. The design process for sustainable business modelling (SBM) and portfolio of the accompanying tools and methods (table below), is expected to support the analysis and design of sustainable business model/s to deliver sustainable value. Business model redesign could assist in embedding sustainability into the core purpose and processes of firms, whilst delivering sustainable value (environmental, social and economic). This
requires a comprehensive consideration of a system-wide perspective to rethink the value proposition and to create, deliver and capture sustainable value.

Table 4: Approaches of Business Model Development Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business models, business model innovation and business modelling</td>
<td>Chesbrough &amp; Rosenbloom R.S, 2002; Magretta, 2002; Richardson, 2008; Teece, 2010; Zott, Amit &amp; Massa, 2011; Chesbrough, 2010; Amit &amp; Zott, 2012</td>
</tr>
<tr>
<td>Sustainable business models and modelling, business case for sustainability</td>
<td>Stubb &amp; Cocklin, 2008; Lüdeke-Freund, 2010b; Schaltegger, Ludeke-Freund &amp; Hansen, 2012</td>
</tr>
<tr>
<td>Sustainable manufacturing, sustainable industrial system</td>
<td>Evans, Bergendahl, Gregory &amp; Ryan, 2009; Garetti &amp; Taisch, 2012</td>
</tr>
<tr>
<td>Business models and examples for sustainable business modelling (industrial symbiosis, product service systems, social business models)</td>
<td>Chertow, 2000; Tukker &amp; Tischner, 2006; Yunus, Moingeon &amp; Lehmann-Ortega, 2010; Boons &amp; Lüdeke-Freund, 2012; Grassl, 2012</td>
</tr>
<tr>
<td>Tools and methods (sustainability continuum, system SWOT analysis, business model canvas)</td>
<td>Willard, 2005; Tukker &amp; Tischner, 2006; Osterwalder &amp; Piégneur, 2010</td>
</tr>
</tbody>
</table>

The SBM process introduces the sustainability dimensions, the language around shared-value creation, and exploring the overarching sustainability objectives that the firm seeks to address. The specific difference for sustainability is that the analysis of market needs is not just narrowly focused on customers and shareholders, but equally on the needs of society and the environment. The proposed SBM process considers a wider set of stakeholders across the business network to deliver sustainable value that will assist manufacturers in the analysis and design of sustainable business models.

The process 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 while 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. Specific tools that have been developed and included in this deliverable are the value mapping tool and sustainable business model element archetypes typology developed in WP2 and the scenario management tool, sustainability impact calculation tool and life cycle cost estimation tool developed in WP3.
Table 5. First stage prototype SBM process and toolset

<table>
<thead>
<tr>
<th>Proposed Steps</th>
<th>Proposed Tools/Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 - Purpose of the business</td>
<td>▪ System SWOT analysis – SUSPRONET</td>
</tr>
<tr>
<td></td>
<td>▪ PESTLE/STEEPLED</td>
</tr>
<tr>
<td></td>
<td>▪ Sustainability continuum</td>
</tr>
<tr>
<td>Step 2 - Identify potential stakeholders and select sustainability factors</td>
<td>▪ Value mapping tool</td>
</tr>
<tr>
<td></td>
<td>▪ Scenario management tool (developed in WP3)</td>
</tr>
<tr>
<td></td>
<td>▪ GRI guidelines, SASB (industry-specific)</td>
</tr>
<tr>
<td>Step 3 - Explore and develop new opportunities for sustainable value proposition</td>
<td>▪ Value mapping tool</td>
</tr>
<tr>
<td></td>
<td>▪ Scenario management tool (developed in WP3)</td>
</tr>
<tr>
<td>Step 4 - Concept generation and selection</td>
<td>▪ Sustainable business model element archetypes typology</td>
</tr>
<tr>
<td></td>
<td>▪ Sustainability impact calculation tool (developed in WP3)</td>
</tr>
<tr>
<td>Step 5 – Define and develop the value creation and delivery system, and the value capture mechanism</td>
<td>▪ Osterwalder and Pigneur business model canvas</td>
</tr>
<tr>
<td></td>
<td>▪ Life cycle cost estimation tool (developed in WP3)</td>
</tr>
</tbody>
</table>

(see D2.4 - SustainValue, 2013)

5.1.2.2 Integration into Development Framework

The business model development primarily contributes to the idea and concept phases whilst providing input into the conceptual and operational dimensions (in particular product service systems development and sourcing, manufacturing and distribution planning). It has a strong link with strategy development given alignment in the outcome, particularly with stages 1 and 2 (strategy analysis and development), where tools such as the sustainability continuum and sustainable business model element archetypes for the sustainable business modelling process are shared with strategy development.

5.1.2.3 Stages and Gates

As the SBM process (stages) is iterative, where there will be frequent movements (backwards and forwards) and overlaps between stages, where the input of one stage may affect various stages hence requiring rethinking of the outcome. Moreover, given that the use of the SBM process and toolset in the context of the ‘development framework’ is primarily around idea and concept generation (with indirect input to conceptual and operational dimensions), the outcome of stages 1 and 2 will tend to be intangible/abstract set of ideas and concepts, whereas stages 3, 4 and 5 will potentially be more succinct. Hence, the gates in many instances may not have a fixed or precise output or signal to move ahead and will tend to be based on the judgement of the facilitator and users to move to the next stage.
The companies can select and use the tools at each stage as per the requirement of their business and its operations. Prompt questions (undergoing continuous refinement based on use) suggested were developed during deliverables 2.3 and 2.4 of WP2 on selection of tools.

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 following questions are suggested as prompts for this stage:

- What is the purpose of the business? What is the company’s offering such as products and services?
- What is the firm’s approach towards sustainability?
- What are the trends, opportunities, threats and drivers for sustainability?

The tools that will assist in this stage are System SWOT analysis – SUSPRONET (see Table 6), PESTLE/STEEPLED and sustainability continuum including an introductory presentation on the process and where necessary, a brief overview of sustainability. They are included in this step as they support in defining the business purpose, industry-related requirements, norms and opportunities including the firm position on sustainability (current and future) and its drivers.

Table 6: SWOT analysis (Tukker & Tischner, 2004)

<table>
<thead>
<tr>
<th>SWOT</th>
<th>Current Situation</th>
<th>Future Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strengths</td>
<td>Weaknesses</td>
</tr>
<tr>
<td>A. Environmental Dimension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ materials efficiency (including water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ energy efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ toxics/ environmental risks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ waste minimisation, re-use, recycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ transport and mobility efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ life cycle aspects, longevity, cyclic economy (technical/natural cycles)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ bio-compatibility, nature conservation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Socio-cultural dimension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ fulfilment of needs/ consumption patterns (high or moderate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ health and safety issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ living conditions/ quality of life</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ employment/ working condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ equity and justice/ relation to stakeholders (media, NGOs etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ respect for cultural diversity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Economic dimension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for the companies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ market position, competitiveness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ profitability, added value for companies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ long term business development, risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ partnerships/ co-operation/ chain value captured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ macro economic effect/ market influence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for the customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ profitability, affordability, added value for customers (tangible/intangible)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Technology, Feasibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Legislation, Regulation, Public Infrastructure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Gate 1

This stage will be determined by the identification of the company’s business purpose, drivers and its progress/path towards sustainability.

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 (developed in WP2 by UC), scenario management tool (developed in WP3 by FIR), GRI guidelines and SASB (industry-specific). The value mapping tool and scenario management tool are used in this stage as well as stage 3. The following questions are suggested as prompts for this stage:

- Who are the potential stakeholders? What do they value?
- What are the sustainability factors/priorities?

The value mapping tool at this stage assists in integrating the purpose (from stage 1) and identifying stakeholders in the network. The scenario management tool assists in the understanding of the current system and identifying key internal and external factors and forces influencing a company in stage 2. Given the similarities between the value mapping tool and scenario management tool, either of them can be used depending on the company’s preference. The guidelines (already available) are considered helpful in providing guidance for identifying sustainability priority areas.

Figure 11: Value mapping tool, (Short, Rana, Bocken, & Evans, 2012)
Gate 2

A set of stakeholders and sustainability priorities are selected for the next stage. It is important to identify the stakeholders to explore value forms for developing the new sustainable value proposition/s.

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. As in the previous stage either the value mapping tool or the scenario management tool can be used building on the output from stage 2. The following questions are suggested as prompts for this stage:

- What is the potential value exchange/s between stakeholders?
- What are the value opportunities in the network?
- How can positive social and environmental value be enhanced and negative value be minimized across the network? (builds into stage 4)

The value mapping tool, at this stage, supports exploring, mapping and analysing the relationships and exchanges between the stakeholders through mapping the current value, value destroyed and missed and value opportunities. This is carried out to develop opportunities for new sustainable value proposition/s from a system perspective without being firm-centric. The scenario management tool here assists in exploring the requirements for the future that will affect the development and transformation of a novel sustainable business model.

Gate 3

This stage will present a new sustainable value proposition or a selection of propositions to be considered in the design of a sustainable business model for embedding and delivering sustainability.

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, while 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 (developed in WP2 by UC) and sustainability impact calculation tool (developed in WP3 by FIR), either of which can be used according to the company preference. The following questions are suggested as prompts for this stage:

- What is the positive and negative value associated with the new offering across the network?
• How can the negative value be eliminated or mitigated and the positive value be maximized?
• Is there a business case for sustainability?

The sustainable business model element archetypes (Table 7) typology describes groupings of mechanisms and solutions that might contribute to building up a sustainable business model, while helping in delivering business model innovation for sustainability.

Table 7: Sustainable business model element archetypes (Short et al., 2012)

<table>
<thead>
<tr>
<th>SBM Element Archetype</th>
<th>Examples from Literature and Practice Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximise material and energy efficiency (Do more with less resources, generating less waste, emissions and pollution)</td>
<td>Bio-mimicry, Dematerialisation (products and packaging), Green Chemistry, Increased product functionality (to reduce number of products required), Lean Manufacturing, Low-carbon solutions, Slow Manufacturing</td>
</tr>
<tr>
<td>2. Create value from ‘waste’ (Turn waste streams, emissions, and discarded products into feed stocks for other products and processes, and make best use of under-utilised capacity)</td>
<td>Circular economy, Closed-loop production, Cradle-to-Cradle, Extended Producer Responsibility, Industrial symbiosis, Re-cycling, Re-manufacturing, Re-use, Sharing assets (Collaborative consumption), Take-back Management, Use excess capacity</td>
</tr>
<tr>
<td>3. Use renewable resources (Use of renewable materials and energy sources rather than finite non-renewable resources)</td>
<td>Renewable energy solutions, use of non-finite materials</td>
</tr>
<tr>
<td>4. Deliver functionality, rather than ownership (Provide services that satisfy users’ needs without having to own physical products)</td>
<td>Product Orientated PSS – maintenance, extended warranty, Use Orientated PSS – Rental, Lease, shared, Result-oriented PSS – Pay per use, PFI (Private Finance Initiative)/DBFO (Design, Build, Finance, Operate), CMS (Chemical Management Services)</td>
</tr>
<tr>
<td>5. Encourage sufficiency (Solutions that actively seek to reduce consumption and production)</td>
<td>Consumer/User Education (Educational models – communication and awareness), Demand Management (including Cap and Trade)</td>
</tr>
<tr>
<td>6. Adopt a stewardship role (Proactively engaging with all stakeholders to ensure their long-term health and well-being)</td>
<td>Frugal business, Premium branding (limited availability), Product Longevity, Responsible product distribution/promotion, Slow Fashion</td>
</tr>
<tr>
<td>7. Re-purpose the business for society/environment (Focusing the business on delivering social and environmental benefits, rather than economic profit maximisation)</td>
<td>Bio-diversity protection, Consumer care - promote consumer health and well-being, Choice-editing by retailers, Ethical Trade (fair trade), Radical transparency, Resource Stewardship</td>
</tr>
<tr>
<td>8. Integrate business with other stakeholders (Integrating business into local communities through inclusive collaborative approaches to business)</td>
<td>Alternative ownership structures – Collectives, Partnerships, Cooperatives, Employee ownership, Home-based working, Localisation</td>
</tr>
<tr>
<td>9. Develop scale-up solutions (Delivering sustainable solutions at a large scale to maximise benefits for society and the environment)</td>
<td>Crowd-sourcing, Collaborative approaches (sourcing, production, stakeholders), Licensing, Franchising, Open-innovation</td>
</tr>
<tr>
<td>10. Radical innovation (Introduce system change through introduction of radical new technologies to facilitate a greener economy)</td>
<td>Lobbying/ collaborating to change underlying principles of doing business, Step-change technology solutions – Including renewable energy solutions, radical changes in product functionality</td>
</tr>
</tbody>
</table>

It supports in the transformation of the new sustainable value proposition by providing the selection of groupings and mechanisms. These archetypes are generally only partial solutions for delivering a sustainable business model. While they can each be applied in isolation, in many cases several different archetypes may be combined to deliver a complete business model. The sustainability
impact calculation tool supports in evaluating the sustainability impact across the life cycle and in the selection of sustainable solutions.

Gate 4

This stage is determined by opting or making a decision on an archetype/solution or a combination of archetypes (using the practice examples)/solutions to develop a sustainable business model.

Stage 5: Define and develop the value creation and delivery system, and the value capture mechanism

This stage involves the analysis and design of the value creation and delivery system, and the value capture for the selection/s from stage 4. It 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 following questions are suggested as prompts for this stage:

- What are the activities, resources, suppliers/partners and channels?
- How is value created and delivered to the identified stakeholders (in stage 2)?
- How is economic value captured?
- How is value captured from public value (environmental and social) creation?

The tools that will assist this stage are Osterwalder and Pigneur (Osterwalder & Pigneur, 2010) business model canvas and the life cycle cost (LCC) estimation tool (developed in WP3 by ELCON and VTT). The business model canvas (Figure 12) 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.

![Figure 12: Business model canvas, (Osterwalder & Pigneur, 2010)](image)

The LCC estimation tool supports in the evaluation and selection of a cost effective and sustainable solution, while providing a summary of the cost incurred across the life cycle.
Gate 5

The mechanism for the value creation and delivery system and value capture will be determined, which will contribute towards transformation and implementation of the sustainable business model.

Table 8: Method Overview – Business Model Development

<table>
<thead>
<tr>
<th>Method</th>
<th>Business Model Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage/Gate</strong></td>
<td><strong>Content</strong></td>
</tr>
<tr>
<td><strong>Stage 1</strong></td>
<td>Purpose of the business</td>
</tr>
<tr>
<td><strong>Gate 1</strong></td>
<td>To be determined by the identification of the company’s business purpose, drivers and its progress</td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td>Stakeholders and sustainability factors</td>
</tr>
<tr>
<td><strong>Gate 2</strong></td>
<td>A set of stakeholders and sustainability priorities are selected for the next stage</td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td>New opportunities for sustainable value proposition</td>
</tr>
<tr>
<td><strong>Gate 3</strong></td>
<td>Presentation of new sustainable value proposition or a selection of propositions to be considered</td>
</tr>
<tr>
<td><strong>Stage 4</strong></td>
<td>Transformation of the new value proposition – selection and evaluation of the model</td>
</tr>
<tr>
<td><strong>Gate 4</strong></td>
<td>determined by opting or making a decision on an archetype/solution or a combination of archetypes</td>
</tr>
<tr>
<td><strong>Stage 5</strong></td>
<td>Value creation and delivery system and the value capture mechanism</td>
</tr>
<tr>
<td><strong>Gate 5</strong></td>
<td>The mechanism for the value creation and delivery system and value capture will be determined</td>
</tr>
</tbody>
</table>
5.2 Methods – Conceptual Dimensions

5.2.1 Technology Development

Technology Management includes several managerial disciplines that enable organizations 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 organization), 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 (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 & Haapsalo, 2011). The intention of this deliverable is not to take part in this academic discussion and so the practical decision making process related to technology development is described in a very general level.

Strategic aspects of technology management tasks are considered in the strategy development chapter. This part of D3.3 focuses on tactical and operational tasks of technology management and development. Therefore this chapter aims at stressing the importance of studying whether developing new technology is feasible before any actions or further steps in the development process of sustainable solutions are taken. The proposed steps of the technology development are described as rather high level decision making processes of an organisation. Moreover, this chapter does not consider any new tools or methodologies that support the technology development process but relies on methodologies and tools presented elsewhere in this deliverable.

The process of integrating technology and sustainable development has three main phases. The suggested process includes

- Definition needs and requirements for new technology
- Evaluation of own technology portfolio and your own capabilities to develop the required technology
- Search for suitable technologies from outside

At the operational level technology management should also pay attention to the co-operation between the development departments of different technologies (e.g. mechanical, automation, hydraulics, electricity, etc.) due to the following challenges identified of the new system design (source Michelle Boucher, Colin Kelly-Rand. System Design – Get it right the first time, Aberdeen Group 2011):

- Lack of cross functional knowledge
- Designs are becoming more complex and
- Early identification of system level problems
5.2.1.1 Introduction of possible methods

Most of the typical companies are covering activities related to technology management, whether these are structured or informal. In new technology development, there are plenty of possible approaches in which sustainability can be considered while new technology is to be developed, although these methods do not necessarily consider sustainability inherently. The possible tools and methods are presented within the four stages of general technology development phases: 1) define needs and requirements, 2) evaluate own portfolio and capabilities, 3) search for suitable technology, and 4) decision making.

Table 9: Approaches of Technology Development Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define needs and requirements for new technology: PESTE, SWOT, MARKET ANALYSIS, Five Forces analysis, Road mapping, etc.</td>
<td>Porter, 1998; Andrews, 1980; Humphrey, 2005</td>
</tr>
<tr>
<td>Evaluate your own technology portfolio and your own capabilities to develop the required technology: portfolio management (projects, IPR, patents and competences), strategic alignment</td>
<td>Cooper, Edgett &amp; Kleinschmidt, 1998, 1999</td>
</tr>
<tr>
<td>Search suitable technologies from outside: Competitor and network analysis, patent database studies, business intelligence activities, KPI's, strategic alignment</td>
<td>Zajac &amp; Bazerman, 1991</td>
</tr>
</tbody>
</table>

5.2.1.2 Integration into development framework

The first stage where the needs and requirements for new technology are defined has a strong interface with the strategy development. Input for new technology demand identification comes from the strategic objectives.

Also the second and third stages of the technology development process are utilizing the same methods than strategy development. Especially the portfolio management activities are important for these stages.

Based on the results of these stages of the technology development stages it is decided how to develop the required technology. The options are using existing technology in a new application, developing a new one, utilizing a network with suitable capabilities, and buying the required technology.

5.2.1.3 Stages and gates

Technology development decision making process is illustrated in Figure 13. The figure aims to describe process stages, inputs and outputs of each stage, decision makers and required resources (persons and methods) for each stage.
Stage 1: Define needs and requirements for new technology

Input for the identification of new technology demand comes from the strategic objectives. 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.

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 should be evaluated before the decision of moving towards the second stage can be taken. This output is used as an input for technology portfolio and competencies evaluation.

Stage 2: Evaluate your own technology portfolio and your own capabilities to develop the required technology

When the needs and requirements of the new technology have been defined (specification), most often companies should at first evaluate their own product, technology and development project portfolios in order to identify if the suitable technology is available there. In this task, managers of different technology disciplines (e.g. mechanical, automation, hydraulics, electricity etc.) should cooperate in order to increase cross functional knowledge in an organization in the early phase of the development activities. If suitable technology could be identified during the portfolio evaluation,
managers of an organization 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**

At the second gate of technology development process the managers of an organization should be able to make rather reliable decisions on whether it is possible to use current technology in new application and move on to other development processes. Managers may also have to make decisions on whether their capabilities are good enough for new technology development or should new technologies be searched from the outside.

**Stage 3: Search suitable technologies from outside**

The portfolio management model suggests that “technology scanning” activities are made continuously rather than based on the needs of a single development project. Therefore it could be stated that new 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. The decision options of the whole process are:

1. Use your own technology in new application (→ further process steps from PSS, Service or Product development)
2. Develop the technology on your own (→ further process steps from PSS, Service or Product development)
   - 3. Utilise a network in order to be capable to develop the technology (further process steps from sourcing planning)
   - 4. Buy the technology from the outside (further process steps from sourcing planning)

If the proposed decision making process related to the new technology development does not result in sufficient grounds for decision making between these four options, managers should strongly consider whether to terminate or at least put on hold the development project in question.
### Table 10: Method Overview – Technology Development

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td>Define needs and requirements for new technology</td>
<td>Corporate management group</td>
<td>Strategy development</td>
<td>PESTE; SWOT; MARKET ANALYSIS, Five Forces analysis, Road mapping, etc.</td>
</tr>
<tr>
<td><strong>Gate 1</strong></td>
<td>Specification of new technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td>Evaluate your own technology portfolio and your own capabilities to develop the required technology</td>
<td>Technology managers of variety of technologies</td>
<td>Strategy development, PSS development</td>
<td></td>
</tr>
<tr>
<td><strong>Gate 2</strong></td>
<td>Decision whether to use current tech., develop on own or search from the outside</td>
<td>Corporate management group</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td>Search suitable technologies from outside</td>
<td>Technology managers, Business intelligence</td>
<td>Strategy development, PSS development</td>
<td>Competitor and network analysis, patent database studies, business intelligence activities, KPI’s, strategic alignment</td>
</tr>
<tr>
<td><strong>Gate 3</strong></td>
<td>Decision on how the technology is to be developed</td>
<td>Corporate management group</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.2.2 Product-Service-System Development

5.2.2.1 Introduction of Possible Methods

The effect of standardized development methods is useful to reduce development costs, development time, and improve the quality of produced goods or services (Bullinger & Scheer, 2006b). 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.

Table 11: Approaches of Product-Service-System Development Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES Methodology: Design of Eco-efficient Services</td>
<td>Brezet, Bijma, Ehrenfeld &amp; Silvester, 2001</td>
</tr>
<tr>
<td>Product Service Co-design process</td>
<td>EU-Project 2004 (ProSecCo)</td>
</tr>
<tr>
<td>Product service system innovation workbook</td>
<td>James, Slob &amp; Nijhuis, 2001</td>
</tr>
<tr>
<td>Development approach of high investment product-service-systems</td>
<td>Aurich &amp; Clement, 2010</td>
</tr>
<tr>
<td>Methodology for product service system innovation</td>
<td>van Halen, Vezzoli, &amp; Wimmer, 2005</td>
</tr>
<tr>
<td>Product-service development to enhance competitiveness and eco-efficiency</td>
<td>Tukker &amp; Tischner, 2006</td>
</tr>
</tbody>
</table>

Tukker and Tischner (Tukker & Tischner, 2006) include and focus on all important aspects of sustainability within the development process of product-service-systems. They investigated several different approaches to product-service-systems development (PSS). Their aim was to figure out whether a combined PSS is automatically built in a more sustainable way, compared to a separated development of products respectively services. In their results, they describe PSS attributes which are related to sustainability, i.e. longer or more intense utilization by product- or use-orientated PSS (economic sustainability). Moreover, Tukker and Tischner found out that these aspects are not automatically included in a PSS. Therefore, they developed their own step by step approach to create a sustainable PSS. It does not only integrate all aspects of sustainability, but also helps to develop the requested sustainable PSS. Their model is subdivided into the following five steps:

1. Preparation and introduction,
2. Analysis on PSS opportunities,
3. PSS idea generation,
4. PSS concept and design,
5. PSS implementation plan.
5.2.2.2 Integration into Development Framework

After determining the strategy and the business model in the dimensions of Strategy Development respectively Business Model Development, the next step is to develop a product-service-system. Integrated herein is the dimension of Product Development as well as the dimension of Service Development. The PSS can be developed in interaction with the operational dimensions although the main part of these operative dimensions will take place after the PSS development is finished.

![Diagram: Integration of Product-Service-System Development into Development Framework]

5.2.2.3 Stages and Gates

As mentioned before, Tukker and Tischner (Tukker & Tischner, 2006) discovered that the main process of PSS development can be roughly subdivided into three main steps, considering the analyzed PSS development approaches. The identified steps are the Analysis-Phase, the Creation-Phase and, thirdly, the Implementation and Realization-Phase. In addition to these detected main development fields, Tukker and Tischner included two more steps into their practical guideline to PSS development. Taken together these five steps built a pragmatic stepwise PSS development approach, and, at the same time, represent the five stages for the development framework.

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. The initiator is responsible for inviting experts from relevant internal departments and, if needed, external company representatives to this project team. Internal departments could be Research and Development, Product Design, Marketing, Environment, Health and Safety (EHS), etc. After forming the project team consisting of various experts, the team members need to be familiarized with the idea of a product-service-system concept. For a further stakeholder analysis, the stakeholder value mapping tool (cf. Figure 15) can be used. Here, every value can be illustrated for every stakeholder to get an easy overview of changes for each stakeholder. This can be done within a project workshop aiming at PSS development.
Figure 15: Stakeholder Value Mapping Tool (University of Cambridge)

Gate 1

Stage 1 is very important for the development process due to setting the basics for the whole development process. In gate 1, it has to be checked whether the team really consists of all necessary experts concerning the planned PSS. Furthermore, all members must be familiar with the idea of a PSS after the project workshop considering the PSS introduction.

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 prioritize 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 analyze 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 scenario-analyses. The scenario analysis is a procedure based on the development of different theoretical scenarios. Furthermore, the scenarios will be compared and evaluated towards their results respectively consequences. Objective of the scenario analysis is to anticipate future developments of society and find and evaluate possibilities and strategies to meet these developments (cf. Figure 16).
As a next step, the project team has to analyze 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 sub-step is to draft a system map of the current system that is to be improved or changed by the new PSS. Within this map, previously detected threads and opportunities should be considered. With this information and the created map, the project team is able to decide whether the possible new PSS is really interesting for the company.

**Gate 2**

The main task of gate 2 is a “Go- or No-Go-Decision”. The project manager has to decide in close cooperation with the project team whether the possible PSS project should be undertaken or not. For this reason, they have 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. With help of the results in stage 2, they can weigh out all threads and opportunities for their company as well all weaknesses and strengths to decide about the possible PSS sector. In addition the planned PSS should be adjusted to the corporate idea of the company to make sure it fits to the overall strategy and business model. Using these results in combination with the system map of the possible PSS, the project team is able to decide whether to maintain this first approach or dismiss it, and start again from the beginning of stage 2.

**Stage 3: PSS idea generation**

After setting the basics in stage 1 and 2, the project team’s next task is to generate ideas for the possible new PSS. For this purpose, the project manager can organize a workshop in which all the
necessary steps towards the idea generation can be elaborated. 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., while creating possible ideas, sustainability guidelines (e.g. SustainValue, 2012a) should be used permanently. Afterwards, there should be a check for completeness whether all relevant ideas have been generated by the project team (e.g. PSS Innovation Matrix). 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. These ideas should be put in an order concerning their priority for the company. This could be done, for example, by portfolio diagrams. Furthermore, the project team has to define overall go- or no-go criteria towards the ideas created before. By means of these criteria, the ideas have to be evaluated until the new PSS is determined.

**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. Although the project team should keep the corporate company strategy in mind while working on their ideas, the project manager should recheck the matching of idea and company strategy. In doing so, interferences might occur with the dimension of Strategy Development and Business Model Development while checking the matching of idea and main company strategy.

**Stage 4: PSS concept and design**

In stage 4, the project team works on the PSS design and structure. Dependent on team size and constellations, either the whole team or just a small part of this team should be in charge. 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. Here, again, the sustainability guidelines and requirements play a leading role. The structure, for instance, can be created in a draft system map for the PSS. Furthermore, tools as service blueprint or FMEA could be used to support the PSS development. Whereas the service blueprint describes a service in detail to implement and maintain it more easily, the FMEA is an approach to identify possible points of failure to avoid making mistakes (design, concept) or to prevent doing them over and over again (usage).

As a next step, a make-or-buy decision has to be made. In order to make this decision as effective and efficient as possible, either the whole team or only some members can decide. In doing so, 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 for the make or buy decision. In case of a buy-decision, the team has to identify potential partners.
Gate 4

After this draft, the whole 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. A check list with predefined go- and no-go criteria in combination with sustainability guidelines and the Sustainable Impact Calculation Tool is a decision tool.

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

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. Otherwise he has to go the way back to the beginning of implementation stage to rework it totally. The project manager is in charge for presenting the results to the responsible board of the Strategy Development dimension. There, the final decision concerning the implementation of PSS is made. In case the PSS will not be implemented there can be a loop to stage 3 to find different ideas for another possible PSS.

Table 12: Method overview – Product-Service-System Development

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Preparation and Introduction</td>
<td>Initiator (Project manager), experts</td>
<td>Product Development, Service Development, PSS relevant dimensions</td>
<td>Project planning tools, workshop, etc.</td>
</tr>
<tr>
<td>Gate 1</td>
<td>Project manager</td>
<td>-</td>
<td>-</td>
<td>Discussion with experts, etc.</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Analysis on PSS opportunities</td>
<td>Project manager, project team</td>
<td>Strategy Development, Business Model Development</td>
<td>Priority setting matrix, SWOT analysis, scenario analysis, system map, etc.</td>
</tr>
<tr>
<td>Gate 2</td>
<td>Project manager (project team)</td>
<td>Strategy Development, Business Model Development</td>
<td>-</td>
<td>SWOT analysis, system map, etc.</td>
</tr>
</tbody>
</table>
### 5.2.3 Product Development

#### 5.2.3.1 Introduction of Possible methods

Considering the different product development approaches, it gets clear that most of the existing ones do not fulfill 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 as well the established position in industry of the product development model of Pahl and Beitz (Pahl/Beitz, 2006) recommend the usage of their model in this development methodology. Important aspects considering sustainability within the development process have to be added.

**Table 13: Approaches of product development methods**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic approach to the development and design of technical systems and products</td>
<td>VDI Guideline 2221</td>
</tr>
<tr>
<td>Stage-gate development process</td>
<td>Cooper, 2000</td>
</tr>
<tr>
<td>Product development process (Engineering Design)</td>
<td>Pahl/Beitz, 2006</td>
</tr>
<tr>
<td>Flexible product development</td>
<td>Smith, 2007</td>
</tr>
<tr>
<td>Design for X</td>
<td>Meerkamm, 2007</td>
</tr>
<tr>
<td>Product development and design engineering</td>
<td>Ponn &amp; Lindemann, 2008</td>
</tr>
</tbody>
</table>
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. Furthermore they structure their development process in clear and single stages of working in combination with following decision steps. This concept is similar to the stage-gate idea and therefore qualified to adjust to the idea of the development framework. All the different stages and steps are obligatory for a general problem-solving process. In contrast, considering different practical products, the stages and steps are just auxiliary means which can be done but are not obligatory. In each case the product development department has to check if it really is constructive towards the specific product. 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”. In addition the phase of “Implementation and market launch” will be added. It will closely relate to the last stage of Tukker’s and Tischner’s PSS development process (PSS implementation plan) (Tukker & Tischner, 2006) and the last stage Cooper uses in his stage-gate development process (market launch) (Cooper, 2000). Although Tukker and Tischner focus on PSS development the basic procedure of implementation is useable for a product development as well.

5.2.3.2 Integration into Development Framework

The process of product development is, as well as the PSS development, placed after the dimensions of strategy and business model development. Although Product- as well as Service Development is integrated within the PSS Development they can be worked on separately. In addition they are in no way dependent of the PSS development. Still the Product Development needs the concepts of the Strategy- and Business Modell Development to make sure it is in line with them.

![Diagram](image)

**Figure 17: Integration of Product Development into Development Framework**

5.2.3.3 Stages and Gates

As described before the development process of Pahl and Beitz is subdivided into four main parts. Due to the fact that the last stage of their development process ends with the creation of an appropriate documentation of the development process the stage of “Implementation and market launch” will be added in this chapter. As described before it is based on Tukker and Tischner (Tukker & Tischner, 2006) as well as Cooper (Cooper, 2000).
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 team should consist of experts of the technology development, product development, operations, marketing, etc. (cf. Chapter 5.2.2, stage 1). This clarification has to be done irrespective of whether the first idea proposal is created within the department of product planning or if it is a specific customer order. 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. A structured step by step approach to create a requirements list is illustrated in Figure 18.

| 1 | Definition of relevant market demands (including sustainability) |
| 2 | Definition of attractiveness demands considering market- and customer segment |
| 3 | Documentation of technical- and customer specific demands |
| 4 | Complete / expand product demands (e.g. by scenario analysis) |
| 5 | Determine demands and wishes towards product |
| 6 | Finalize requirements list |

Figure 18: Step by step approach creating a requirements list (cf. Pahl/Beitz, 2006, p. 188)

The requirement list is a document to specify a product so that the department of product development has a clear idea considering the accomplishment of the tasks through the product. Key questions to be answered in this context are:

- Which purpose has to be accomplished by the considered solution?
- Which characteristics does it have to possess?
- Which characteristics must it not have to show (e.g. considering sustainability)?

Gate 1

After stage 1 is done a product specific requirement list has been developed. This requirement list has to be checked towards completeness before the development process goes on to the concept stage. Special focus has to be set not just on market- and customer demands but on demands considering sustainability as well. This task can be done by the project manager of each development process.

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. In addition before starting the whole process of the concept stage it is to decide, depending on the product to develop, in which extent the conceptual design stage should be passed through.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abstraction of demands to recognize basic problems</td>
</tr>
<tr>
<td>2</td>
<td>Creation of function structures of overall function and sub-functions</td>
</tr>
<tr>
<td>3</td>
<td>Finding of active principle to fulfill sub-functions</td>
</tr>
<tr>
<td>4</td>
<td>Combination of different active principles</td>
</tr>
<tr>
<td>5</td>
<td>Choosing appropriate combinations</td>
</tr>
<tr>
<td>6</td>
<td>Concretize to possible solutions</td>
</tr>
<tr>
<td>7</td>
<td>Evaluate towards technical, economical and sustainability criteria</td>
</tr>
<tr>
<td>8</td>
<td>Determine solution (concept)</td>
</tr>
</tbody>
</table>

Figure 19: Step by step approach conceptual design stage (cf. Pahl/Beitz, 2006, p. 204)

**Gate 2**

In gate 2 the developed concept should 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. Furthermore the project manager has to clarify with the dimension of Technology Development if the concept for the new product is feasible towards its needed technology. Only if the project manager clearly agrees with the evaluation of possible solutions and the decision towards the concept, the development stage can start.

**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 behavior 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. In a lot of cases several designs are necessary before the desired appropriate design will emerge. The definite design layout has to be developed up to the point where function, durability, assembly, production, operation and cost can be controlled. In contrast to the stage of conceptual design the stage of embodiment design involves a high number of different corrective steps where steps of analysis and synthesis alternate permanently. A close cooperation with the dimensions of Manufacturing- as well as Sourcing Planning is recommended.
Gate 3

Before moving to the stage of “detail design and elaboration of product documentation” 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). In addition possible errors and disturbing factors have to be screened and in case of occurrence corrected. If a correction is not possible without further effort there has to be a cycle loop toward the beginning of stage 3 so that the product designer can rework the layout. Furthermore the technological feasibility has to be check in cooperation with the Technology Development.

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. Oftentimes CAD software is used as a designing tool.
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/Beitz (Pahl/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 chapter of Product Service System development a short reference to chapter 5.2.2, Stage 5 is sufficient.

Gate 5

See Chapter 5.2.2, Gate 5.

Table 14: Method overview - Product Development

<table>
<thead>
<tr>
<th>Method</th>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and clarification of task</td>
<td>Product management team</td>
<td>-</td>
<td>Approach requirements list, scenario analysis, sustainability guidelines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual design</td>
<td>Product management team</td>
<td>Technology Development, Manufacturing Planning, Technology Development, Manufacturing Planning</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product management team</td>
<td>Technology Development, Manufacturing Planning</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Chapter 5.2.2, Gate 5.
5.2.4 Service Development

5.2.4.1 Introduction of Possible Methods

Towards the dimension of service development different useful methods and approaches can be found. Both structure and extent of these development approaches differ greatly. Whereas some of them stop after the definition of the service idea (e.g. 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 PAS 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 have to be included in this approach.

Table 15: Approaches of service development methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service engineering process</td>
<td>Luczak, Kuster, Reddemann, Scherrer &amp; Sontow</td>
</tr>
<tr>
<td>Service planning</td>
<td>Sontow, 2000</td>
</tr>
<tr>
<td>Service-engineering architecture</td>
<td>Gill, 2003</td>
</tr>
<tr>
<td>Planning of industrial services</td>
<td>Steven &amp; Schade, 2004</td>
</tr>
<tr>
<td>Systematic process model for service-engineering</td>
<td>Bullinger &amp; Scheer, 2006b</td>
</tr>
<tr>
<td>Standardized process for the development of industrial services in networks</td>
<td>DIN PAS 1082:2008-05</td>
</tr>
</tbody>
</table>

The FIR service engineering process has been developed within a research project of the Institute for Industrial Management at RWTH Aachen University in close cooperation with industry representatives. Therefore important industry needs could be considered and integrated while developing this method. In addition the development process could be directly tested and adjusted with the support of the industry representatives. (DIN PAS 1082:2008-05)
The process consists of seven phases and in addition six control and decision gates in between these phases. Phase one represents the first initiation of the service development. Next the definition phase starts with an estimation of the customer value and a first description of the new service model. Within the phases of rough-planning, fine-planning and development the new service will be created step by step. In addition the phases of implementation and market launch introduce the new service to the market. In between these phases control gates help to check the result of each step. Each gate represents a basis for the decision to go on, to do go an iteration cycle to the beginning of the previous phase or to end the specific service development at all. Furthermore an overall feedback cycle from the phase of market launch to the first phase of activation is integrated (cf. Figure 22). (DIN PAS 1082:2008-05)

Figure 22: Service development in seven phases (DIN PAS 1082:2008-05)

Due to the clear and simple structure of the method and furthermore the integration of control gates, this service engineering approach is highly useful the development methodology. Aspects of sustainability will be implemented.

### 5.2.4.2 Integration into Development Framework

Similar to the integration of the PSS- and product development dimension, the dimension of service development is placed after determining the strategy and the business model. The service development is in the same way as product development hierarchically placed under the PSS-development. Nonetheless it can be conducted independently. This depends, as it is the same way in the dimension of product development, on the strategy and the business model of the company. Depending on that the creation of a complete sustainable solution might include PSS’s, products and services in all combinations. The service can be developed in interaction with the operational dimensions although the main part of these operative dimensions will take place after the service development is finished.
5.2.4.3 Stages and Gates

For the overall development methodology the service engineering approach will be adjusted from its previous seven phases to four stages. In detail that means that the phases of activation & definition as well as the phases of planning (rough and fine) & development will be combined to only two stages due to their basically similar content (cf. Figure 23) and its close fitting to the overall development phases (idea, concept, implementation, market).

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. Here a mixed team of service experts and service technicians as well as representatives of the dimensions of technology development, product development, marketing, etc. (see Chapter 5.2.2 PSS, Stage 1) should be founded. The first idea generation can be supported by simple creativity tools as brainstorming and brainwriting. On the other hand the idea generation process can be supported by market research, by usage of focus groups, etc. (cf. PSS development). 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, although their focus is primarily on PSS (e. g. Tukker & Tischner, 2006, Penin & Vezzoli, 2005 and SustainValue, 2012a). In case a PSS-or product development dimensions exists, there should of course take place a close and regular exchange of know-how and experience. In the last part of stage 1 the task is to formulate the customers’ value of the new service and to roughly describe and visualize the new service idea.

Gate 1

After this is done, 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 if the new service idea is in accordance with the company strategy and its general business model (last stage Business Model Development). Furthermore the implication of important sustainability aspects has to be verified (sustainability guidelines, Tukker & Tischner, 2006). As conclusion the service management has to
evaluate if the model of the new service idea is satisfactory or not. Depending on that, the development process can go on or has to make an iteration cycle to the beginning of stage 1.

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. In case co-operation partners for the new service are needed, they can be identified by this value mapping tool as well. After this is done, tests of the service concept are to be conducted. Here internal tests as well as external tests integrating customers might be done to evaluate the new service idea. At this point of the service development process it is important to compare the new service proposal the business model system to work in close unity with the basic business model.

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. In addition further interfaces with other departments have to be identified and properly planned with each specific department. Here the dimension of Sourcing Planning is highly relevant as well. These steps are closely correlated to the planning and preparation of the infrastructure which is needed for the service introduction and operation. Using the tool of service blueprinting might be of help to get an overview of the needed infrastructure (see Figure 24).

![Figure 24: Schematic Service Blueprint of a simple reparation process](image-url)
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 which is needed for the service introduction and operation; indeed, when combined with Monte Carlo simulation, it would enable the analysis of stochastic evolution of service planning through time, helpful for deciding issues related to the infrastructure required for service delivery. As an example, Legnani et al. (2010) use System Dynamics as a support tool for decision making in a PSS context. All these preparatory planning steps have to be combined and put in a performance specification sheet for the specific service.

The next step in this stage is to create a sustainable business model around the new service concept. Therefore the information toward 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**

In 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. Highly influencing as well are the technical feasibility and the structure of the service business model. Only if an adequate feasibility is given and the service can be launched in a sustainable business model. Finally the performance and requirements specification sheet have to be controlled, especially regarding the inclusion of the three dimensions of sustainability. Here as well clear sustainability guidelines (cf. annex) are useful. Just if all these requirements are fulfilled the service plan can reach the next stage. If the service plan shows clear gaps, the process has to restart in stage 2. Smaller differences might as well be modified simply by the service management or during the concept 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. These test runs are conducted “offline” which means internally within the company. The test runs are to be conducted several times to get a diverse and clear feedback. At this point interfaces with the dimension of service & spare parts operational planning and sourcing planning occur due to needed service personnel and material for the test runs. Afterwards service experts as well as service technicians can give feedback towards the service performance and result. The results of the test are to be analyzed. With the support of this feedback and test data the service is to be overworked and modified if necessary. After this is done the detailed resource planning can start. Now the rough and conceptual planning of stage 2 has to be concretized. 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. Here it is important to work in close cooperation to guarantee a sustainable way of resourcing for the new service activity.
In addition a detailed program 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. Therefore the conceptual elaboration considering the customers’ value of stage 1 should be used as well. In addition to these concepts a program to qualify own or customers’ technicians should be worked out.

All this elaboration of stage 3 should be conducted in close interface with stage 5 of the dimension of Business Model Development. There as well a concept as well as a whole infrastructure for the business model idea will be created. A close cooperation between these two dimensions at these stages will help to reach a higher degree of effectiveness and efficiency.

Gate 3

After the development and usage of the first service prototypes a first practical economic efficiency analysis can be conducted. Furthermore the service management has to test the consistency of the service concept, infrastructure, sourcing, end-of-life, training program, sustainability etc. before the beginning of the implementation stage. If inconsistencies occur, the service management might adjust them. If it is not possible without just small effort, there might be a cycle loop to the beginning of stage 3 to correct aspects which are not fitting so far.

Stage 4: Implementation

In stage 4 the new service will be converted to the pilot stadium. In contrast to a prototype service the pilot service will be conducted directly with a customer. Here technicians have to be added to the expert team, if not yet done. In this further testing phase last gaps and weaknesses can be eliminated. After this is done the service blueprint can be finalized. Now it is possible to structure the new service in different modules as a basis for specific adaption towards customers’ wishes. In addition an amplified service-FMEA can be done to describe and to rate possible failures and risks. Furthermore the operational and organizational structure has to be elaborated and implemented to even the following market launch. Now the previously developed training program has to be conducted to qualify service technicians for their new tasks.

As well as mentioned in stage 3 a close cooperation to the Business Model Development dimension (stage 5) will be helpful to implement the new service.

Gate 4

In gate 4 it is important to control 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. Furthermore the service management has to check if a large-scale market launch is feasible in all details (service consistency, sustainability, qualified service technicians, adequate resources, etc.).
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 optimizing the service in case of need. On the other hand the service experts have to inform the technicians regularly towards any adjustments of the new service. A good communication is important to improve the service further on.

Gate 5

In gate 5 there has to be a general control by the service management considering the service performance in the field. Furthermore they might check the communication of service technicians and –experts.

Table 16: Method overview - Service Development

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Activation &amp; definition</td>
<td>Team of service experts and technicians</td>
<td>PSS Development, Product Development</td>
<td>Creativity tools, market research tools, focus groups, Sustainability guidelines, etc.</td>
</tr>
<tr>
<td>Gate 1</td>
<td>Service management</td>
<td></td>
<td>Strategy Development, Business Model Development</td>
<td>Sustainability guidelines</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Planning</td>
<td>Team of service experts</td>
<td>Business Model Development, Technology Development, Service &amp; Spare Parts Operational Planning, Sourcing Planning</td>
<td>Stakeholder value mapping tool, market research tools, Service blueprint</td>
</tr>
<tr>
<td>Gate 2</td>
<td>Service management</td>
<td></td>
<td>Business Model Development, Technical Development</td>
<td>Sustainability guidelines, Go and no-go criteria list</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Development of concept and infrastructure</td>
<td>Team of service experts</td>
<td>Business Model Development, Sourcing Planning, Service &amp; Spare Parts Operational Planning, End-of-life and recycling planning</td>
<td>FMEA, Service blueprint</td>
</tr>
<tr>
<td>Gate 3</td>
<td>Service management</td>
<td></td>
<td>Business Model Development</td>
<td>Sustainability impact calculation tool</td>
</tr>
</tbody>
</table>
5.3 Methods - Operational Dimensions

5.3.1 Sourcing Planning

The concept of strategic sourcing emphasizes 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 a significant part of companies’ sales in the present networked economy, ethical sourcing as well as green supply chain management principals utilised in many western companies. For instance, “ethical sourcing” means ensuring that the products being sourced are created in safe facilities by workers who are treated well and paid fair wages to work legal and the Ethical Sourcing module is also a voluntary supplement for SQF 1000 or SQF 2000 Certified Suppliers.

There are several examples how global brand owners and original equipment manufacturers have supported sustainable development of their suppliers. There is an increasing focus among sourcing companies on sustainability and corporate social responsibility (CSR) issues. “Sustainable sourcing” has been defined as managing all aspects of the upstream component of the supply chain to maximize triple bottom line performance (Pagell, Wu, & Wasserman, 2010). Still, sustainability criteria are not yet broadly reflected in the literature on strategic sourcing decisions (Brown, 2008; Timlon, 2011).

Presented sourcing concepts related to sustainability are often criticised from their western-country or brand owner origins, e.g. the programs – like fair or ethical trade, ethical sourcing and consumerism - reach only limited number of producers or do not sufficiently consider long-term impacts to local environment in developing countries. Anyhow, in the sourcing planning it is important to notice that individual company has only limited possibilities to influence to sustainability development and thereby new forms of collaboration with new parties are needed in order to have greater sustainability impacts. For instance, collaboration with non-governmental organizations (NGO’s), local communities or other non-commercial stakeholders (general public and pressure groups) could provide new possibilities to companies to support sustainability.

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1 Traditionally, theoretical foundations of strategic sourcing decisions are found in a combination of transaction cost economies and the core competence concept.
Collaboration with these stakeholders could enable organisation that is planning the sourcing activities at the specific area, to improve its image among local employees, customers and regulators. This could help sourcing companies build trust with local stakeholders by neutralizing their nonlocal features. Thus, network or stakeholder analyses and other tools presented in strategy development chapter (5.1.1) could provide new insights to strategic sourcing decisions related to sustainability.

Supply chain management is a broad concept with many processes and systems, like information, quality and risk management. All these approaches are not gathered within this deliverable, since their comprehensive study is not on the focus of sourcing planning chapter. So far, Supply Chain Management (SCM) has been approached as coordinating the operations of (a) independently managed entities (b) who seek to maximize profits (only) individually (Jayal, Badurdeen, Dillon, & Jawahir, 2010). This approach leads to sub-optimisation and is a major obstacle for achieving network level sustainability objectives in supply-chains as well as in sourcing operations and more broadly in manufacturing industry. To improve network level sustainability, supply chains, sourcing and other manufacturing operations must be planned, designed and managed as an integrated system. Similarly, manufacturing planning, presented in the chapter 5.3.2., is also tightly connected to sourcing planning. Furthermore, distribution and logistics planning, which are considered separately in the chapter 5.3.3, are also closely linked to sourcing and supply chain management. On the other hand, the former dimensions of the development framework, including technology, product and service development considered in chapter 5.2.2 should follow the strategy and thereby specify the guidelines and decision criteria for sourcing planning.

In this deliverable 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 deliverable these two tasks are considered as two main stages of sourcing planning for sustainability.

5.3.1.1 Introduction of possible methods

In this deliverable sourcing planning has divided into two main stages: at the strategic level the main task is to set the targets to sourcing and at the operative level to search and evaluation of possible suppliers. There are several approaches that could be utilised within these stages and also sustainability can be considered through them although it is not included to many of the existing tools.

In networked economy, companies need new collaboration partners and therefore strategic network and stakeholder analyses are an important part of setting strategic objectives to sourcing for sustainability. Thus, within this stage sustainability matrix is highlighted as a tool to coordinate sustainability objectives over the boundaries of a company. Furthermore, aligning and unifying sustainability objectives can be done through “search and evaluation of possible suppliers”- stage. Supplier evaluation matrix presented in this deliverable, as well as maturity model configured in WP4, are examples of possible tools within this stage.
Table 17 presents some of the possible tools. The tools presented below are in italics (bold) and the references are related to these tools.

However, supplier or network development is also an important part of sustainable development within sourcing and supply operations and there are many industry-specific processes, methods and tools illustrating answers to the “How?”-question. These different approaches will not be dealt with in this deliverable, while the focus is on sourcing planning – not on its implementation. Implementation of sourcing plans are seen as a case specific process, and therefore comprehensive presentation of tools and methods that could be exploited in implementation is not possible.

Table 17: Approaches of sourcing planning methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set the strategic targets to sourcing: network and stakeholder analyses, portfolio management, sustainability matrix</td>
<td>Timlon, 2011; Carroll, 1991</td>
</tr>
<tr>
<td>Search for and evaluation of possible suppliers (contract partners), purchasing portfolios, supplier criteria and categorizations, supplier evaluation matrix, maturity model from WP4</td>
<td>tools from SustainValue project (WP3 and WP4)</td>
</tr>
</tbody>
</table>

5.3.1.2 Integration into development framework

Sourcing planning – as well as other operations of the development framework – should be guided by the strategy development (Chapter 5.1.1). The conceptual dimensions (Chapter 5.2), like technology or product development, specify guidelines and criteria for sourcing planning. Similarly, other operational dimensions, following the sourcing planning are also connected to it. Especially, manufacturing planning and distribution or logistics planning have overlapping operations with sourcing planning.

5.3.1.3 Stages and gates

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. Strategy and business model development form the baseline for setting targets and they should have been considered already at conceptual level within technology, product and service development, e.g. the conceptual dimensions of the development framework.

Different portfolio analyses have been typical tools of strategic sourcing and purchasing, since Kralic (Kraljic, 1983) presented his well-known purchasing portfolio. Based on this approach Pagell et al. (Pagell et al., 2010) have presented the sustainable purchasing portfolio model. Furthermore, portfolio management approach presented in strategy development chapter can be utilised also within the strategic sourcing planning.
In networked economy, companies need also new collaboration partners and therefore network or stakeholder analyses and other tools presented in strategy development chapter could provide new insights when sustainable strategic sourcing decisions are made. From the network management point of view, it is important to align the interests of involved actors and thereby sustainability matrix presented in Figure 25 could be utilized to evaluate the interests of various stakeholders. The matrix is modified from a corporate social responsibility (CSR) matrix. The CSR matrix is an important strategic tool as a conceptual framework to assist managerial decisions by integrating CSR components with organizational stakeholders (Carroll, 1991). Network or stakeholder analyses create input knowledge to the sustainability matrix, as the different stakeholders, contract partners and relationships between them are identified. On the other hand, strategy development should provide the guidelines to key issues, presented e.g. in the vertical dimension of the matrix.

![Sustainability matrix](image)

**Figure 25: Sustainability matrix (adapted from Timlon, 2011)**

### Gate 1: Strategic objectives

At the first gate the managers of company – both corporate and sourcing managers – should define sustainability guidelines for sourcing. This means defining the importance of sustainability in sourcing decisions, e.g. why sustainability should be considered in sourcing decisions and what are the main principles that should be followed when sustainable sourcing decisions are made?

### 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. Within this deliverable two tools, which support especially supplier selection, are presented. They are maturity model from SustainValue WP4 (see SustainValue, 2013 for details) and supplier evaluation matrix constructed in WP3 of the project.

The three process areas of network conditions from the maturity model configured in WP4 of SustainValue project illustrate several factors that should be considered within the both stages of sourcing planning. The maturity model proposes that objective alignment, capability matching and partnership health should be considered at the network level (Figure 26). Objective Alignment describes the match between an organization’s objectives and the objectives of potential network partners. Capability Matching describes the ability to deploy resources, skills, competences/abilities and experiences of organizations for collaborative purpose. Partnership Health indicates the condition or status of the mutually beneficial relationship between two or more potential partners within a network. The questions presented within these three process areas could be utilized in order to analyse the current state as well as to set targets towards sustainable development at network level (see D4.2 for details).

By networking it is possible to share and lower the risk of false development work and resource usage. On the other hand, networking increases complexity and organizations have a risk of being engulfed in the complexity of relationships, partners and development projects that need to be managed. In order to make the decision between the possible suppliers or partners it is important to compare their characteristics, like their resources, competences, and commitment related to co-operation. The different risk management and purchasing portfolio criteria can be utilised for this purpose, still it is important to notice that the criteria (e.g. attributes) are case-specific and they should be aligned with the strategic objectives of sourcing company. Table 18 shows an example of a supplier evaluation matrix.
Gate 2: Selection of suppliers (contract partners)

In this second gate the sourcing managers and purchasers should select the contract partners from the possible suppliers based on the analyses and comparisons made at search and evaluation stage.

After this gate the operative sourcing process will start. The whole sourcing process itself and co-operation with the contract partners (e.g. supply chain management activities) are important success factors also to sustainability, because the commitment of partners is required in order to reach the sustainability objectives of the whole network. Thus, the methods and tools related to sourcing process implementation are not gathered here as the focus of the deliverable is sourcing planning.

Table 19: Method overview - Sourcing Planning
### Gate 1

<table>
<thead>
<tr>
<th>Corporate management group</th>
<th>Sourcing managers</th>
</tr>
</thead>
</table>

### Stage 2

<table>
<thead>
<tr>
<th>Sourcing managers</th>
<th>Purchasers</th>
<th>Technology, product and service development</th>
<th>Supplier evaluation matrix, Maturity model from WP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for and evaluation of possible suppliers (contract partners)</td>
<td></td>
<td>Manufacturing planning, Distribution and logistics planning</td>
<td></td>
</tr>
</tbody>
</table>

### Gate 2

<table>
<thead>
<tr>
<th>Sourcing managers</th>
<th>Purchasers</th>
</tr>
</thead>
</table>

### 5.3.2 Manufacturing Planning

#### 5.3.2.1 Introduction of possible methods

Manufacturing planning considers the long term decisions with regard to the manufacturing system (re)configuration, and subsequent (re)organization of resources. This is also variably referred to by means of other terms such as manufacturing system design, facilities planning, factory planning, etc. 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 re-planning 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 (see, e.g. Hayes & Wheelwright, 1984, Fine & Hax, 1985, Leong, Snyder, & Ward, 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 organization 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, Ritzman, & Mallick, 2000).

Even if manufacturing planning is clearly a “traditional” process in a company and, moreover, it has been studied for a long time by research, a standardized development approach using sustainability as an integrated concept is still missing. This does not mean that the scientific works at the state of the art have not proposed insights on sustainability matters: surveying literature in fact shows a research that is jeopardized, essentially because methods developed until now are focused either on specific issues of the planning process, or on some factors of the three pillars of sustainability – within either the environment or social besides the economic pillar. Table 20 summarizes a number of recent approaches in order to provide some clues to the actual state of the art, concerning the integration of sustainability in the design of a manufacturing plant. It is worth underlining that literature does not offer approaches integrating the triple bottom line assessment.
Table 20: Approaches of Manufacturing Planning Methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framework for environmentally conscious product-process design, enabling to match stakeholders requirements (with their own priorities) with manufacturer’s design requirements</td>
<td>Madu et al., 2002</td>
</tr>
<tr>
<td>Process selection methodology considering economic and environmental factors (material waste, tool change/disposal, raw material consumption, by-product material reuse/contamination)</td>
<td>Jayachandran et al., 2006</td>
</tr>
<tr>
<td>Integrated approach based on process and simulation modelling to balance production efficiency and environmental constraints (energy efficiency, CO2 emissions, other environmental impacts)</td>
<td>Heilala et al., 2008</td>
</tr>
<tr>
<td>Methodology for designing a sustainable and environmental friendly manufacturing system combining Discrete Event Simulation and Life Cycle Assessment</td>
<td>Johansson et al., 2002</td>
</tr>
<tr>
<td>Modelling approach for generic material, energy and waste flow and interaction, in order to develop a methodology that enables zero carbon manufacturing facility creation</td>
<td>Ball et al., 2009</td>
</tr>
</tbody>
</table>

The development method proposed in this deliverable is rooted in known approaches – to align with the “traditional” literature on manufacturing planning – while introducing novel perspectives on sustainable manufacturing – to take different factors within the three pillars into account.

In this respect, it is worth observing that some key concepts on the background of the method herein presented are inspired from the “traditional” procedural approaches proposed in the past, incorporating both qualitative and quantitative objectives in the design process. One of the seminal work of such “traditional” approaches was authored by Richard Muther (Muther, 1973), who presented a Systematic Layout Planning method which has inspired also the implementation of known Computer Aided Facility Layout Planning tools. Based on this classical, but also some other sources (e.g. Tompkins et al., 2002, as a reference book for classical approaches to the design of industrial plants), the process has been divided into several steps. In particular, using the method proposed in this deliverable, the gates are particularly important in order to control the generation of system design alternatives of adequate quality under the three pillars: if acceptable solutions are not found for the environmental and/or social factors – besides economic ones –, re-design is required before actually finalizing planning decisions; this would help integrating different assessment views on sustainability factors, with the ultimate goal of over-performing sequential procedures pertaining to the classical manufacturing system design, and solely concentrated on factors of the economic pillar – such as, e.g., cost, productivity, delivery and quality.

5.3.2.2 Integration into development framework

Manufacturing planning solutions are developed as a further implementation of PSS development in case a “make-decision” has been taken. The sustainability requirements should play a leading role to this end, besides the PSS structure already designed. In particular, key objectives for manufacturing planning should be derived from PSS development (e.g. a goal may be to develop an eco-efficient manufacturing through energy flows, carbon footprint and/or environmental wastes): this would drive the long term planning of manufacturing operations in the industrial plant, and would enable that such a long term planning is well aligned (is fitting with) the PSS concept and design. Further on, manufacturing planning should be developed in interaction with PSS development, being a relevant operational dimension for the achievement of the PSS concept and design (as it operationalizes the
“make-decision”). The PSS implementation plan is a relevant, close interaction as well to manage the changes (i.e. to move from the AS-IS to the TO-BE situation), hence implementing the PSS design in the manufacturing plant.

![Figure 27: Integration of Manufacturing Planning into Development Framework](image)

### 5.3.2.3 Stages and gates

The method herein proposed consists of the typical phases of systems engineering. Hence stages (and related gates) are organized through an Analysis-Phase, a Design-Phase and an Implementation and Realization-Phase.

The Analysis-Phase concerns the study of the operational performances of different system design alternatives, in order to assess their impacts with respect to operational requirements in the three sustainability pillars. The Analysis-Phase is needed for providing inputs to the subsequent Design-Phase, when the planning decisions are finalized by means of selection of the best manufacturing system (re)configuration and subsequent (re)organization of its resources. The Implementation and Realization-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 organization and control of the manufacturing facility. Five stages are comprised within the Analysis-Phase (3 stages), the Design-Phase (1 stage) and the Implementation and Realization-Phase (1 stage).

#### 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. The initiator (i.e. the Project Manager) is responsible for inviting experts from relevant company’s departments to form up the project team. Departments could in fact provide different experts enrolled in the Industrial Engineering area of the company – Process Engineers, Manufacturing Engineers, Quality Engineers, etc. Other experts may be involved as well if needed, to represent the management counterpart responsible for sustainability factors of interest of PSS development – Health and Safety (HSE) management, energy management.

After forming up the project team, the team members initially need to be familiarized with the idea of the PSS design, having a specific concern on the relevant implications for the operations of the manufacturing plant. Concretely speaking, they should discuss and share the requirements sourced from PSS development, namely the sustainability requirements of different stakeholders of the PSS (already emerged, for example, through a stakeholder value mapping tool; when doing so, those requirements impacting on the product manufacturing activities carried on in the plant – matter of
(re)planning – should be taken into account. The discussion should also facilitate to draw out synthetic schema representing the relevant requirements to be used for evaluating the system design alternatives. This can be done within a project workshop.

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): this is a tool used for solving Multi Criteria Decision Making (MCDM) problems, which is also the case when matching to the requirements of many stakeholders (with their own priorities). These tools are some examples that can be applied with the purpose to operationalize the concepts coming from PSS development: indeed, using such tools (or similar ones) will enable identifying the key operational requirements of the manufacturing system, which is helpful in order to evaluate the system design alternatives proposed (in next stages) as potential planning solutions.

**Gate 1: Preparation and introduction**

Stage 1 is very important for the development process because it sets out the key operational requirements for the manufacturing system design – shared within the project team.

In particular, 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. Furthermore, all members must be made familiar with the idea of reaching key operational requirements for the manufacturing system design, considering the PSS introduction.

**Stage 2: Analysis of system design alternatives (economic and technical requirements)**

Stages 2 and 3 are needed in order to analyze different system design alternatives, with the purpose to provide an assessment under the three known sustainability pillars. Different matter of decisions in the (re)planning scope may be analyzed in such stages: depending on the study’s objective, they may range from the process technology and equipment selection, to the capacity planning and work load balancing, facility layout and material handling system design, work design considering the human factor, etc.

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. In particular, a set of “traditional” performance measures, together with additional judgment criteria, can be used to assess each system design alternative, in order to eventually verify its compliance with respect to both quantitative and qualitative objectives. For example, different layout design alternatives may be evaluated considering: (i) the total material handling costs, the total distance / average distance per carrier, the shape ratio (width / length) of a production area,
etc..., which are known “traditional” performance measures assessed to verify the compliance with quantitative objectives; (ii) other “traditional” judgment criteria such as flexibility, accessibility and maintainability of the production area, used in order to assess the planning solutions with respect to qualitative objectives. Another example can be related to the process technology selection: capable processes may be defined considering, first of all, the manufacturing costs for a product material and given production volume; amongst them, potential processes may be those ones that do meet the product quality criteria.

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, flexibility .... Existent tools – “traditionally” used for manufacturing system design – are available at hand of the analyst to enable both data collection and organization, as well as performance analysis: e.g., tools for Production Flow Analysis (PFA) such as “from to chart” – to collect data and organize production material flows according to the requirements of technological processes; Manufacturing Process Information Maps (PRIMAs) – providing detailed information on the characteristics and capabilities of technological processes and their variants; relationship charts – to evaluate the importance of adjacency between different activity locations, for other reasons than material flows (e.g. sharing a high cost fixture); Discrete Event Simulation (DES) – to analyze system bottlenecks and subsequent performances at system level (productivity, delivery speed, etc.) under dynamic and stochastic conditions; ... etc.

**Gate 2: Analysis of system design alternatives (economic and technical requirements)**

Stage 2 is important because it provides a first set of system design alternatives with their evaluation according to the key economic and technical requirements for the manufacturing system design. The result is essentially a “Go- or No-Go-Decision” according to these requirements; in other words, the “Go- or No-Go-Decision” considers the economic sustainability of the manufacturing planning solutions. 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. If more acceptable solutions are found at this stage 2, the “Go-Decision” allows continuing the analysis at the next stage 3, in order to assess the system design alternatives according to the key environmental and social requirements. In case of “No-Go-Decision”, it is activated a re-analysis of the stakeholder requirements in order to adjust their prioritization (back to stage 1 of this manufacturing planning process), or a further reformulation of the PSS development from which manufacturing planning was initiated (back to stage 4 of PSS development, namely PSS concept and design).

As interface, it is worth mentioning the Technology Development: in fact, process technology and/or equipment selection are matter of decisions in the (re)planning scope and, indeed, they can be considered a key lever to reduce manufacturing costs, and to improve product quality and flexibility; the interface to Technology Development is then essential, especially in order to integrate Advanced Manufacturing Technology (AMT) in the planning solutions.
Stage 3: Analysis of system design alternatives (environmental and social requirements)

Stage 3 completes the assessment of system design alternatives that has passed the “Go-Decision” at stage 2. An adequate set of alternatives should be available as input of this stage 3, with different levels of competitiveness both for economic/technical factors, and for other sustainability factors (environmental and social) of interest of the stakeholders. In this concern, depending on the study’s objective, the purpose of stage 3 is to integrate other assessments regarding the different matter of decisions in the (re)planning scope already studied at stage 2.

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. Similarly to stage 2, performance measures, together with additional judgment criteria, may be used to assess each system design alternative, in order to eventually verify its compliance with respect to both quantitative and qualitative objectives. The factors – and objectives under concern – may then enable to enlarge the scope of analysis to other pillars. For example, the design method at this stage 3 may force the manufacturing engineers to consider additional environmental factors in process selection such as material waste, tool change or disposal, raw material consumption, by-product material reuse and contamination, as well as additional costs such as landfill costs, waste storage and disposal costs. Subsequent performance measures/judgment criteria may be needed in order to assess each system design alternative, being concerned with the new factors.

Another example may come out from the optimization of energy flows, besides environmental wastes and/or emissions. It is in fact worth detailing the analysis of the energy aspect because of its relevance in manufacturing; moreover, in the last years energy efficiency has become a hot topic in industry due to the increasing price of energy and the rising awareness in society of environmental issues. Therefore, all approaches, and related tools, that consider the paradigm of energy efficient manufacturing should be considered at this stage 3; it is clear that making an energy efficient manufacturing design may mean advantages in the economic (i.e. energy price) and environmental pillars. In particular, it is known that in the early phase of layout planning is very important to take into account the energy consumption profile of a system to be implemented. Hence, at this stage 3, the environmental impact of different layout alternatives should be assessed. The approach should require: (i) to create a database for production and transportation facilities acting as energy input database (electricity, heat, hydraulic, pneumatics…), energy storage database (energy harvesting, storage methods, conversion efficiency…) and energy output database (heat losses, vibrations, etc.); (ii) to adopt an appropriate tool for performance analysis, for example different planned layout alternatives may be simulated using Discrete Event Simulation (DES); (iii) to assess each layout alternatives through a set of suitable indicators – for Environmental Performance Evaluation. On the whole, a sustainable facility layout must be design and managed in order to optimize the energy flows of a plant and minimizing wastefulness and inefficiency, for example by re-using the emission as an input for the system itself; this scope of analysis could regard not only a green-field situation, but also re-design and re-planning of a production system.

More in details, an evaluation can be implemented only when the data about the consumption behavior of each individual equipment included in the system is available. So, the first matter of
The 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. A widely database can be established using (i) previous knowledge, (ii) operators experience and (iii) equipment manufacturers knowledge; in this way, it is also possible to create a database that can be enriched and improved with data collected from sensor monitoring network installed in the system, which is useful (and opportune) in case of an existent plant subject to re-planning for performance improvement. What is more, the database should involve basically all relevant energy flows, but also may be enlarged to other environmental factors, in order to consider other flows connected to the equipment dynamics; see a summary in the following list of emissions and wastes, besides energy flows: (i) emissions and outputs to ecosphere, such as gaseous emissions (e.g. CO2, carbon monoxide...), liquid emissions (e.g. polluted water) solid emission (e.g. hazardous material) and losses (heat losses, vibrations...); (ii) solid outputs of the system: material waste, finished and semi-finished product; (iii) energy and material inputs to the process: raw and process material, compressed air, heat, hydraulics, pneumatics...; (iv) energy storage: energy harvesting, energy storage methods, energy conversion efficiency... Once all the needed data are collected, it is possible to simulate plant energy consumption, as well as evaluate emissions and wastes, through Discrete Event Simulation (DES): some specific tools for manufacturing system simulation, containing green and energy considerations, have already been developed (Herrmann, Kara, & Thiede, 2011). Simulation allows in fact taking into account the technical interdependencies between different machines/equipment and the consequences of technical and organizational measures. In this way it is possible to widen perspective on the whole production system, and to cope with the dynamics of the manufacturing problem, where all data is getting combined, resulting in a cumulative energy consumption patterns and in an evaluation of other, actual environmental impacts. Finally, a set of indicators is needed in order to assess each layout alternative designed so far. An internal process and management tool that can be used for the evaluation of environmental performance of an organization (therefore, also for the evaluation of environmental performance of the industrial plant subject of (re)planning) is the Environmental Performance Evaluation (EPE) standard. The main category of indicators described in this standard are the Environmental Performance Indicators (EPIs) that include information related to: the design, operation, and maintenance of the organization’s physical facilities and equipment; the materials, energy, products, services, wastes, and emissions related to the organization’s physical facilities and equipment; the supply of materials, energy and services to, and the delivery of products, services and wastes from the organization’s physical facilities and equipment. In this concern, using such a management standard also at system design stage, should enable to create common reporting procedures and formats for assessment, which, in the actuation of the method now discussed, may be the basis e.g. for the simulation reporting.

Last but not least, this stage 3 should also consider the work design – i.e. assignment of operational activities and duties to groups / individuals according to their competence / skills – and task analysis – i.e. a way of systematically describing human interaction with the system or process, in order to understand how to match the demands of the system or process to human capabilities. These are in fact “traditionally” part of design activities. In our concern, they should be considered in relation to the need to evaluate Human Factors and Ergonomics (HF&E). More precisely, there is a long list of
HF&E objectives – and correspondent tools to be used for evaluation – available from literature. The important point – in the method herein proposed – is to highlight, within the HF&E aspects, those related to Health and Safety (H&S) issues that are the most relevant and should be especially cared about: this would result from taking into account the key operational requirements, in particular the social requirements, of the manufacturing system.

On the whole, this analysis stage allows integrating the “traditional” manufacturing system design approach, with further assessment of sustainability factors, so to compete on performances related to the environmental and social requirements. Existent tools are extended, as well as new tools are being provided, so to be at hand of the analyst to enable both data collection and organization, as well as performance analysis: e.g., data collection on BAT (Best Available Technologies) and their cataloguing in manufacturing information maps – providing information on the characteristics and capabilities of technological processes with respect to their environmental burden (in this concern any data base built to this end should be adopted, considering the specific environmental factor, e.g. Energy data base); Environmental Performance Evaluation (EPE) and Indicators (EPIs) – as a specific standard of system management focused on environmental topics, to be used for reporting the assessment of the manufacturing planning solutions; Human Factors & Ergonomics (HF&E) tools – to cater with key social requirements, with special attention to Health & Safety issues; Discrete Event Simulation (DES) – extended in order to analyze energy flows, energy bottlenecks, as well as waste flows and emissions, to finally assess subsequent performances at system level (energy efficiency, CO2 equivalent emissions) under dynamic and stochastic conditions; ... etc.

Gate 3: Analysis of system design alternatives (environmental and social requirements)

Stage 3 is important because it aims at assessing system design alternatives according to the key environmental and/or social requirements for the manufacturing system design. The result is a “Go-or No-Go-Decision” according to these requirements; in other words, the “Go- or No-Go-Decision” considers the sustainability of the manufacturing planning solutions as a whole. 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). If enough acceptable solutions are found at this stage 3, the “Go-Decision” allows continuing at the next stage 4. In case of “No-Go-Decision”, it is activated a re-analysis of the stakeholder requirements in order to adjust their prioritization (back to stage 1 of this manufacturing planning process), or an analysis of additional system design alternatives that could be acceptable for the economic / technical requirements (back to stage 2 of this manufacturing planning process, with a review of economic / technical requirements at stage 1) or a further reformulation of the PSS development from which manufacturing planning was initiated (back to stage 4 of PSS development, namely PSS concept and design).

Similarly to stage 2, it is worth mentioning the Technology Development as interface: in fact, process technology and/or equipment selection, as they are matter of decisions in the (re)planning scope, can be considered a key lever to reduce environmental and social impacts / costs; the interface to Technology Development is then essential, especially to integrate AMT in the planning solutions.
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)organization 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. Once a limited number of alternatives is identified (i.e. two – three alternatives), a workshop should be organized involving the relevant project stakeholders, i.e. the management counterpart for the sustainability factors of interest. The workshop will end up with the final design choice, with finalized decision on the best manufacturing system (re)configuration and (re)organization of its resources. A short list of recommendation may be also prepared and reported as a follow up of the workshop, to be used as an input for the next stage 4 where implementation and realization of the system design will be 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. Instead, the sensitivity analysis relies on the assessments that could be done at stages 2-3, hence it should be carried on based on tools and modeling activities therein; on the other hand, at this stage 4, the results of sensitivity analysis are presented and thoroughly discussed for leading to the finalization of decision on the best manufacturing system (re)configuration, and subsequent (re)organization of its resources.

Gate 4: Selection of system design alternative

The whole project team has to decide on the best system design alternative to be implemented. Indeed, the team may decide whether to implement it, to go back in order to re-discuss the project ideas at the very beginning of the whole manufacturing planning process, or to cancel the idea at all. In order to support finalization of the decision, and further communications as a follow up of the decision, it is worth including a check list aimed at summarizing the predefined judgment criteria and performance measures used, in relationship to different sustainability factors, on the background.

Stage 5: System design implementation plan

In Stage 5, the implementation plan of the system design alternative chosen at stage 4 has to be set-up, executed and controlled. The plan is intended in the broadest sense, since it covers the activities related to different types of resources affected by the new design: i) hardware structures, ii) service, manufacturing and control software, iii) human resources. Important focus at this stage 5 should be in fact the human resources, which may affect (either positively or negatively) the transition towards the new designed system. Hence, proper human resources management and organizational theories and techniques should be applied to better manage the interface between the technical factors (due to hardware and software) and the human factors. In particular, 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 analyze the human interaction with the technical system/s. Indeed, linking now to some theoretical background for the implementation purpose, it is worth mentioning Mennecke et al. (1992) who classify three categories of group development models: i) linear models exhibiting “an increasing level of maturity and performance overtime”; ii) cyclical models implying “a recurring sequence of events”; iii) hybrid model which do not imply “a specific sequence of events; rather, the events that occur are assumed to result from contingent actors that change the focus of the group activities”. Linear models are perhaps the best known, most mentioned group development models in literature; besides, they seem promising for enabling a controlled maturity growth of a manufacturing planning solution that is being implemented. Gibbard et al. (1974) emphasized the fact that linear models are sequential in time, and encounter transitional stages, thus following a kind of definite order of progression. Smith (2001) also reflected on an example of transitional stages as flight of stairs, which the group must walk for achieving the progression, to eventually reach the top stage of optimal performance. Accordingly, in our method we can consider three transitional stages – as also discussed in literature – where the group development may be on progress during the entire implementation stage. Hence: i) firstly during the group development, effective conflict management skills may be very important, hence it should be necessary improving communication, reinforcing positive behaviors, and clarifying procedures for good conflict resolution (e.g., see Shani and Lau, 2005); on the whole, good relationship management is needed at this stage; ii) secondly, group members should be better able to resolve conflicts encountered when following the established procedures; indeed, the focus now become task-oriented (instead of relationship oriented), and the group begins to solve technical problems; proper processes should be followed (hence facilitated) to enable a task-oriented support toward problem identification and solving; iii) thirdly, the group may become an effective working unit; at this transitional stage, they emphasize attaining the group’s goals and objectives, which helps reaching the optimal level of performance; a group autonomy is now reached, which guarantees to target optimal performance; of course, there is need to develop all the organizational mechanisms that enable such effectiveness, maintaining the group at this level of development.

Parallel to the human resources, hardware and software should be (re)configured or (re)built, thus project managing issues arise, regarding also the purchasing, build and commissioning stage of such resources. This requires the involvement of the sourcing planning as relevant interface, because of the needs for equipment procurement and related services. “Traditional” project management are required in this phase.

**Gate 5: System design implementation plan**

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. Otherwise, he has to go the way back to the beginning of implementation stage to rework it. Proper project roles, such as project coordinators, leaders and facilitators, may be appointed depending on the project size, in order to form up a project team suitable to control the implementation plan advancement. It is important the role of facilitators
especially for what concern human resources management during the transitional stages (alias group development) to the new system.

**Table 21: Method overview - Manufacturing Planning**

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td>Preparation and introduction</td>
<td>Project Manager (Initiator), Industrial Engineering team, Management counterpart (e.g. HSE manager, Energy Manager)</td>
<td>PSS Development</td>
<td>Quality Function Deployment (QFD), Analytic Hierarchy Process (AHP)</td>
</tr>
<tr>
<td><strong>Gate 1</strong></td>
<td></td>
<td></td>
<td></td>
<td>Project Manager</td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td>Analysis of system design alternatives (economic – techn. req.s)</td>
<td>Industrial Engineering team, Project Manager</td>
<td>PSS Development, Technology Development</td>
<td>Production Flow Analysis (PFA), Manufacturing Process Information Maps (PRIMAs) Discrete Event Simulation (DES)</td>
</tr>
<tr>
<td><strong>Gate 2</strong></td>
<td></td>
<td></td>
<td></td>
<td>Industrial Engineering team</td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td>Analysis of system design alternatives (environment – social req.s)</td>
<td>Industrial Engineering team, Project Manager</td>
<td>PSS Development, Technology Development</td>
<td>Best Available Technologies (BAT), Energy data base, Environmental Performance Evaluation (EPE), Discrete Event Simulation (DES), Human Factors &amp; Ergonomics (HF&amp;E) tools</td>
</tr>
<tr>
<td><strong>Gate 3</strong></td>
<td></td>
<td></td>
<td></td>
<td>Industrial Engineering team</td>
</tr>
<tr>
<td><strong>Stage 4</strong></td>
<td>Selection of system design alternative</td>
<td>Project Manager, Industrial Engineering team, Management counterpart (e.g. HSE manager, Energy Manager)</td>
<td>PSS Development, Internal interfaces to stage 2 and 3 for sensitivity analysis</td>
<td>Quality Function Deployment (QFD), Analytic Hierarchy Process (AHP), Reporting and communication tools</td>
</tr>
<tr>
<td><strong>Gate 4</strong></td>
<td></td>
<td></td>
<td></td>
<td>Project Manager</td>
</tr>
<tr>
<td><strong>Stage 5</strong></td>
<td>System design implementation plan</td>
<td>Project Manager, Project team, Industrial Engineering team</td>
<td>Sourcing planning</td>
<td>Group development models, Project management tools</td>
</tr>
<tr>
<td><strong>Gate 5</strong></td>
<td></td>
<td></td>
<td></td>
<td>Project manager, project team</td>
</tr>
</tbody>
</table>
5.3.3 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.

In this chapter, distribution is of central interest, even though supply chain management covers all kinds of resource flows. Distribution logistics are concerned with the planning, management, control and execution of the flow of materials and the associated flow of information, from the completion of the production process to the handover of the requested products to the immediate purchaser. It is assumed that all other logistical issues, viz. procurement etc., are dealt with by other divisions or are not on an operational level. Figure 28 shows which part of supply chain management is described.

![Figure 28: Distribution planning as part of the supply chain](image)

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, viz. the number of vehicles, salaries. Finally, the improvement of the service quality is an important motive behind logistical planning.

The aim beyond an optimizing logistical process is obvious: minimizing the use of resources or an increase of customers’ contentedness may lead to more sustainable solutions and thus a better market position of the company. Nevertheless, a prioritisation is necessary as especially customer satisfaction might be in odds with cost reductions. Figure 29 gives an overview of the relevant interdependencies.
5.3.3.1 Introduction of Possible Methods

From an operational point of view, structural decisions have already been made and build the starting conditions for every logistical planning. Thus, in the following, only those approaches are discussed which deal with actual orders and their management.

The approaches discussed in the following do not exhaustively cover the broad range of scientific approaches. Moreover, the selection can be seen as one of many alternatives, either of them varying in their applicability for specific real-world companies.

In the following, four possible methods that might be used within the four stages are presented. The creation of the stages is aligning with a lecture given in 2012/13 at RWTH Aachen University (Stich & Schuh, 2012). The methods spread over more than one stage, and are not always completely act upon.

Table 22: Approaches of distribution and logistical planning methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heuristic and mathematical approaches</td>
<td>Gutin, Yeo &amp; Zverovich, 2002; Bang-Jensen, Gutin &amp; Yeo, 2004; Bendall &amp; Margot, 2006; Gillett &amp; Miller, 1974</td>
</tr>
<tr>
<td>Milk Run</td>
<td>Bartholdi &amp; Gue, 2000</td>
</tr>
<tr>
<td>Cross Docking</td>
<td></td>
</tr>
<tr>
<td>ECR</td>
<td>Wood, 1993</td>
</tr>
</tbody>
</table>
5.3.3.2 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 (Figure 30).

When trying to establish a distribution system, a company has to deal with a manifold of scaffolds limiting the company’s options. Those are important in order to resolve the conflict presented above. First of all, each company is embedded in a legal system. This influences for instance fuel or traffic taxes and the question of road tolls.

Secondly, the economic and organizational framework of the company has to be considered. The goals of the company as well as its politics determine which decisions might be made and which should rather be avoided. The financial situation, including both the amount of money that might be invested and the need of making profits are crucial in order to sustainably plan distributions.

As a third issue, the production related conditions have to be considered. Those questions include the number of factories, depots, seasonal influences, but also product value, technical capacities etc.

Finally, not only the company itself and the environment in which it acts have an influence on distributional questions. Also the customer and their demands are highly important. For example: a company might be willing to reduce its impact on the environment by using more environmentally friendly, but slower modes of transport. If this does not fit with customer expectation which need short delivery times, the solution might be economically unsustainable.

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 like perishability, value, size, degree of immateriality (especially for service systems), or customer behavior, for instance frequency of orders, it might make sense to produce a certain amount in advance to avoid supply shortfalls.

Especially companies with more than one factory have to consider where goods should be produced in order to minimize transport costs to the customer. Dependent on the kind of good that has to be distributed different production strategies should be considered. Here, the interface to production planning, taking into account availabilities of raw materials, staff etc., becomes obvious.

Gate 1:

At the end of step 1, the chosen production and delivery system is the most efficient one should be double-checked.

Stage 2: Potential analysis / Audit

Rising customer expectations present manufacturing companies with the challenge of injecting ever-greater speed and flexibility into the task of filling their orders on schedule. When companies lose their way, it is often because of inadequate implementation of standards, less-than-perfect production logistics concepts, poor interaction between different technologies and sub-optimal structures.

Therefore it might be sensible to analyze customer expectations, one’s own potentials and to compare them in a potential analysis. 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. In the following, the requirement analysis is highlighted.

A requirement analysis might be helpful to get a first impression of services that are needed in order to meet customer satisfaction, compared with the actual performance of the company. In the next stages, various decisions have to be made which depend upon customers’ needs. Thus, the following five steps can be seen as the preliminary work for the next stages.

1. Firstly, customer expectations have to be examined. This includes end consumers and traders as well as external stakeholders. There the value mapping tool introduced in Chapter 5.1.2 might be helpful.

2. Secondly, it has to be considered whether these expectations meet the goals of the company and are thus compatible with an adaption or re-structuring of logistic processes.

3. If this is the case, it is to be analyzed whether logistics deals with anything in addition to what customers demand, and which generates more costs than additional value. Moreover, missing products or services should be added to the company’s portfolio, if possible and wanted.
4. Fourthly, some companies might evaluate different customers as more valuable than others. These key-customers might be given priority. Is this is desired, various levels of service have to be specified, dealing with service times, costs etc.

5. Finally, the amount of additional services is crucial, especially for smaller companies with a less elaborated logistics. Therefore, a reduction/extension of the service portfolio might generate benefit for the company or the customer. These benefits should be estimated, so that it is eventually possible to price them, and evaluated on whether the required expenditures are promising.

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. Moreover, an early assessment of the five aforementioned aspects makes it possible to plan distributions with a minimum of ecological impact.

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 behavior as a whole. In this case, the reorientation of the business model and an implementation of standardized processes, software solutions etc. should be considered.

Moreover, not only the management, but also information from manufacturing is important. For instance: the question of which additional services might be possible depends on the production process and the good’s characteristics. If it is only possible to produce on demand, deliveries within two days cannot be offered.

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 utilization 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. Dependent on company size, financial situation and customer behavior, the amount of money spent on complex mathematical tools might differ. For companies with only a small number of deliveries, for instance, a costly tool might not be affordable or economic. The travelling salesman problem asks the following question: Given a list of destinations and the distances between each pair of destinations, which is the shortest possible route that visits each destination exactly once and returns to the origin (Applegate, Bixby, Chvatal, & Cook, 2006). The below presented heuristic approaches try to give an answer. Aspects that are neglected are capacities of vehicles, clients with higher priorities etc.
A more elaborated approach are mathematical tools that are able to take more variables into account, viz. differences in priority, loading capacities of the used vehicle etc.

*Milk Run* refers to a kind of direct supply that can be found both in procurement and distribution. It is characterized by transportation of goods from a manifold of suppliers to a company (procurement) or from a company to a manifold of customers without transshipment. The collection or delivery times of these supplies are fixed, the trajectory is given and returned packaging is taken back. Thus, Milk Run is based on the idea of an ecologically sustainable delivery system. This requires a precise coordination of all orders following local and logistical criteria. Usually, a Milk Run should cover two to ten destinations to ensure an optimum capacity.

Several goals can be reached by the use of Milk Run: a reduction of transport costs through a minimization of empty trips. This way, not only economic, but also ecological improvements are possible. Moreover, the service level might be increased due to a better control.

Milk Run has proven a sufficient way of distributing goods, especially in combination with *Cross-Docking*. Cross Docking is a distribution procedure of unloading materials from an incoming semi-trailer truck or railroad car and loading these materials directly into outbound trucks, trailers, or rail cars, with little or no storage in between (Bartholdi & Gue, 2000). This may be done to change type of conveyance, to sort material intended for different destinations, or to combine material from different origins into transport vehicles (or containers) with the same, or similar destination.
Cross Docking might lead to immense improvements, even though it is not applicable for every company. One the one hand, Cross Docking can help to reduce transport costs and ways and, thus, the use of fuel. Additionally, optimum capacities may be reached, inventory costs minimized and the time from receipt of order till dispatch can be reduced up to a 24-hour-service. On the other hand, companies have to invest much to realize cross-docking points and IT services in order to control the processes effectively.

**Gate 3:**

The methods described should lead to an optimized delivery trajectory, taking several logistical options into account. One crucial aspect has been neglected so far: the choice of an optimal trajectory presupposes that the vehicles are already chosen. For most companies, this is true. Nevertheless, if logistics should be ecologically sustainable, it is worth reconsidering the mode of transport and the impact of its change. Therefore, in this gate the choice of vehicle should be put into question and eventually be adapted.

**Step 4: Optimize customer satisfaction via ECR in logistical planning**

In order to create sustainable customer relationship, it is necessary to maximize their satisfaction. What a customer expects is highly influential for the way this satisfaction can be realized. On the one hand, a company might have customers who are dependent on low delivery costs, but able to wait for the product. One the other hand, some customers might have an urgent need for a product and are willing to pay additional delivery costs. All these options should have already been considered when the optimal trajectory was calculated. The result was the most economical and ecological way of delivering goods whilst taking customers’ individual needs into account.

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.

Efficient Consumer Response (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. In other words, ECR allows companies to seek a competitive advantage by demonstrating...
their superior ability in working together with trading partners to add value to the consumer. ECR is not a completely new approach, but rather a combination of several tools (Wood, 1993).

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. Nevertheless, QR is only meaningful for companies who sell their products to wholesale traders. Due to these significant improvements, QR has been further developed for other branches towards ECR.

ECR is able to reach the same results as QR, but in addition it combines logistical potentials of rationalizing processes with potentials of growth. There are four focus areas under ECR: Demand management, supply management, enablers and integrators, which are intended to be addressed as an integrated set. These form the basis of the ECR Global Scorecard.

Nevertheless, ECR has to be implemented by both operational and managerial persons responsible. On the other hand, ECR presuppose a change in customers’ requirements and expectations. This might not be the case for all companies which are able to plan their logistical processes based on a unique requirement analysis. For these companies, stage 4 can be neglected.

<table>
<thead>
<tr>
<th>Table 23: Method Overview – Distribution and Logistical Planning</th>
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<tbody>
<tr>
<td><strong>Method</strong></td>
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<tr>
<td><strong>Stage/Gate</strong></td>
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<tr>
<td><strong>Stage 1</strong></td>
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<td><strong>Gate 1</strong></td>
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<td><strong>Stage 2</strong></td>
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<td><strong>Gate 2</strong></td>
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<td><strong>Stage 3</strong></td>
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<td><strong>Gate 3</strong></td>
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<td><strong>Stage 4</strong></td>
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5.3.4 Service and Spare Parts Operational Planning – Maintenance

5.3.4.1 Introduction of possible methods

Every organization 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 (see Waeyenbergh & Pintelon, 2002, p. 299). The search for maintenance improvements is focused on finding a program, approach or methodology that will improve the productivity of maintenance labour while at the same time improving production equipment reliability, availability, and productivity (see Kister & Hawkins, 2006, p. 108).

Different proposals of maintenance management and maintenance planning approaches and models can be found in the literature. For the development and elaboration of the presented methodology, numerous useful approaches through the years have been considered (Table 24).

**Table 24: Approaches of maintenance planning methods**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Standard Reliability-Centered Maintenance (RCM)</td>
<td>Nowlan &amp; Howard, 1978; Moubray, 1997; IEC 60300-3-11; SAE JA 1011; SAE JA 1012</td>
</tr>
<tr>
<td>Total Productive Maintenance (TPM)</td>
<td>Nakajima, 1988</td>
</tr>
<tr>
<td>Business Centered Maintenance (BCM)</td>
<td>Kelly, 2006</td>
</tr>
<tr>
<td>A framework for maintenance concept development</td>
<td>Waeyenbergh &amp; Pintelon, 2002</td>
</tr>
<tr>
<td>Risk-based maintenance (RBM)</td>
<td>Khan &amp; Haddara, 2003</td>
</tr>
<tr>
<td>Condition-Based Maintenance (CBM)</td>
<td>Jardine, Lin &amp; Banjevic, 2006</td>
</tr>
<tr>
<td>Lean Maintenance Planning</td>
<td>Kister &amp; Hawkins, 2006</td>
</tr>
<tr>
<td>Value-driven maintenance planning (VDMP)</td>
<td>Rosqvist, Laakso &amp; Reunanen, 2007</td>
</tr>
<tr>
<td>Maintenance Management Framework</td>
<td>Crespo Marquez, 2007</td>
</tr>
<tr>
<td>Model for maintenance management in a continuous improvement cycle</td>
<td>Barberà, Crespo, Viveros, &amp; Stegmaier, 2012</td>
</tr>
</tbody>
</table>

The analysis of maintenance approaches shows that maintenance of a plant or facility can be performed by default or by plan (reactive and proactive maintenance). Although the reactive style of maintenance practices during the greatest part of the history of maintenance must be replaced with proactive maintenance practices, in order to achieve the levels of equipment reliability necessary to sustain the sustainable manufacturing goals and objectives (see Kister & Hawkins, 2006, p. 28). Moreover to attain some control over the level of maintenance, organizations must move away from maintenance by default to maintenance by plan, because a comprehensive planning and scheduling effort provides the basis for this control (see Brown, 2004). Without an effective planning and scheduling maintenance can be haphazard, costly and ineffective. Even proper management of the widely varying scope and diverse activities performed by the maintenance organization is impossible (see Kister & Hawkins, 2006, pp. 28,58). Companies that have moved to a more planned approach
tend to be better equipped to meet the numerous market changes encountered in recent years (see Brown, 2004).

The Maintenance Planning method presented here takes into account the existing maintenance and maintenance planning concepts described in literature and is grown from the experience that those concepts are often very time-consuming to implement or only valid for a special class of equipment or a specific industry. Moreover they are not ready for use in sustainable networks. Nonetheless considering there interesting and useful aspects, they can be used to some extent for this development concept for sustainable solutions.

The framework presents the maintenance planning as one of the fundamental activities in the maintenance process (see Figure 33) and it starts from the point that almost all maintenance should be planned (see Duffuaa, Raouf A. Dixon, & Campbell, 1999, p. 157) according to the sustainable requirements.

Crespo Marquez (2007) has proposed a maintenance management model consisting of 8 phases from definition of maintenance objectives and strategies (phase 1) to continuous improvement and new techniques utilization (phase 8) (See Figure 34). The whole framework is relevant to our method in SustainValue for, at least, two reasons: (i) the asset prioritization as a follow-up of maintenance objectives and strategies, (ii) asset life cycle analysis as a driver for reassessment and continuous improvement.
The methodology took inspiration from Söderholm 2007 and Crespo Marquez 2007 as foundations, and it has five stages in order to ensure efficiency, effectiveness, sustainability and continuous improvement of the maintenance planning:

1. Assessment of the current situation; Definition of maintenance policy, strategy, objectives and KPIs
2. Assets priority towards maintenance strategy, considering sustainability factors
3. Design of maintenance plans and resource allocation
4. Maintenance planning implementation, execution and control
5. Life cycle analysis and replacement optimization.

In between these phases control gates help to check the result of each step. Each gate represents a basis for the decision to go on, to return to the beginning of the previous phase or to end the maintenance planning at all.

5.3.4.2 Integration into development framework

The dimension of Maintenance Planning can be integrated into the field of operational dimensions. The sequence of the operational dimensions is not as set considering the dimension of maintenance planning. In the development framework, it is included in the dimension of Service & Spare Parts Operational Planning. Regarding the other operational dimensions, Maintenance Planning can as well be generated parallel to e.g. Sourcing Planning or Manufacturing Planning. Considering the phases of the development framework, it can, furthermore, be placed in the implementation- and market-phase due to the contents and activities of its stages and gates described as follows:
5.3.4.3 Stages and gates

Stage 1: Assessment of the current situation; Definition of the maintenance policy, strategy, objectives and KPIs

This stage takes place based on the specifications of PAS 55-1/2:2008 Asset Management in according to the model for the definition of the maintenance strategy of Crespo and the model developed by Lopez Campos and Crespo Marquez for maintenance management based on PAS 55 (see PAS 55-1: 2008; Crespo Marquez, 2007, López Campos & Crespo Márquez, 2011).

At the beginning of stage 1 the whole maintenance planning process gets started. In the case that the organization or plant already has a more or less defined maintenance management, especially if there were any maintenance methodology or procedures stage 1 starts with the baseline assessment in relation to maintenance management. The analysis has to be completed by a team of experts from maintenance department conducted by the maintenance planner. The assessment of the current situation must consider all aspects related to the maintenance of equipment where information is available, for example, issues such as planning, scheduling and execution of maintenance duties, failure history, mean time to failures (MTTF) indicators and mean time to repair/recover (MTTR), financial resources allocated to maintenance, economic impact, or in production (equipment failure) by unscheduled stop of the plant (system) or subsystem, among others (see Barberá et al., 2012, p. 54).

After this done, to achieve an accurate performance in the maintenance planning in an organization the production or authorization of the overall maintenance policy by the organizations´ top management have to be realized. The maintenance policy provides the framework around which the maintenance strategy, objectives and plans are developed and implemented. In order to define the maintenance policy a mixed team of maintenance experts as well as representatives of top management has to realize following steps (see PAS 55-1: 2008, pp. 4f):

- identify the requirements of the organizational strategic plan in terms of how it will be achieved through the maintenance manager and the principles that should be applied;
- identify the potentially conflicting expectations of the organization´s stakeholders;
- check if the maintenance policy align with the organization´s other policies;
- identify all legal, regulatory, statutory and other top management designated, mandatory maintenance requirements.
The result will be the development of the draft maintenance policy. After this done the draft maintenance policy has to be agreed at top management level, ensuring it is consistent with the organizational strategic plan and discussed with the organizations’ relevant managers, employees and other relevant stakeholders, achieving an appropriate level of consensus. As conclusion the maintenance policy has to be communicated to relevant managers, employees and other stakeholders by posting the document on notice boards, intranet, and internet and by face-to-face activities such as briefings, meetings, etc. If the organization has a maintenance policy, it has to be reviewed, following the significant changes to the operational context of the organization.

After this done, the organization 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 organizational strategic plan. The strategy has to be derived and consistent with the maintenance policy and the organizational strategic plan. Also the time horizon for a long-term maintenance strategy has to be aligned with that of the organizational strategic plan (see PAS 55-1: 2008, p. 6).

The development of maintenance strategy has to be done by the middle or upper management of the maintenance department and has to be authorized by top management. It has to include the following activities (see PAS 55-1: 2008, p. 7):

- definition of the desired outcomes related to the existing or new assets;
- summarize the broad plans and programs to achieve these desired outcomes with defined timescales and responsibilities;
- definition of the resources that are needed to deliver the plans and the actions required to secure them (skills, materials, testing and measuring equipment, etc.);
- definition of assumptions made and financial costing;
- definition of the targets against which the performance of the maintenance strategy can be measured;
- description of the means to effectively measure and report the performance and success of the maintenance strategy should be described.

After defining the maintenance strategy appropriate maintenance objectives and key indicators for the performance evaluation of the facilities (KPIs) have to be identified and formulated. The objectives shall to be as “SMART” as possible, i.e.: specific, measurable, achievable, realistic and time-based (see PAS 55-1: 2008, p. 9). The maintenance objectives and KPIs have to be derived from, and consistent with the maintenance strategy, the organization’s commitment to continual improvement and the business plan of the organization (see PAS 55-1: 2008, p. 8). Therefore, the maintenance and business objectives have to be strongly linked together (see Barberá et al., 2012, p. 48). Only by such an alignment and corporate cooperation an economic sustainability can be gained. Hereby is to ensure that the dimension of Product-Service-Systems uses the tool of Design for Reliability (DFR), which describes the entire set of tools which support product-, service- and process-design to guarantee reliability throughout the lifespan. This leads to an overall reduced maintenance demand. Thereby, sustainability characteristics can be integrated respectively amplified.

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 &
Norton, 1992). Each BSC has to be specifically designed for this organization. This allows the creation of KPIs for measuring maintenance management performance which is fully aligned to the organization’s strategic objectives. Unlike conventional measures which are control oriented, the BSC puts the overall strategy and vision at the centre and emphasizes on achieving performance targets. The measures have to be identified and their stretch targets established through a participative process which involves the consultation of internal and external stakeholders, senior management, key personnel in the operating units of the maintenance function, and users of the maintenance service so that an overall sustainable strategy could be generated. In this manner the performance measures for the maintenance operation are linked to the business success of the whole organization (Tsang, Jardine, A., & Kolodny, 1999). The BSC enables deployment and implementation of the maintenance strategy at all levels in the company, so that a usage of the BSC as well is useful in stage 2. This encourages the involvement of all those concerned in achieving the strategic objectives and achieving strategic alignment across the organization, from the transformation of the strategic plans to action plans mentioned before.

**Gate 1**

After stage 1 is done it should be checked whether the assessment of the current situation in the maintenance management of the organization considers all aspects related to the maintenance. After this done, it should be checked whether maintenance policy, strategy, objectives and KPIs are clearly defined. Furthermore it should be checked if the maintenance policy is consistent with the organizational strategic plan, the maintenance strategy with the organizational strategic plan, the maintenance policy and other organization’s policies and the maintenance objectives and KPI’s with the maintenance strategy. Due to the basic importance of these objectives and KPIs the upper management of the maintenance department should be responsible to control it. Objectives of maintenance might be directed towards availability of equipment, reliability, security, costs, quality, adequate and social personnel management, inventory of spare parts, environmental impact and sustainability, overall equipment effectiveness, life-cycle optimization, output quality, etc. In addition it is useful to check the KPIs the management of the maintenance department has chosen or developed. They should be checked for consistency, the integration of sustainability factors and completeness. The KPIs as well have to be cross-checked towards the corporate business strategy in cooperation with the dimension of Strategy Development. If gaps or errors are found in all these controlling processes, the feedback loop has to go back to the beginning of stage 1 to work it over again.

**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 organization 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). Thereby the risk is usually defined as the product of the frequency for the consequence of failure and frequency is the number of failures in a given time. Assets with the higher PRN have to be analysed first. In many cases there is no historical data on the basis of which to obtain these rates. In these cases have to be used more qualitative techniques in order to ensure adequate initial levels of effectiveness in maintenance operations.

At the beginning of stage 2 the weighing of various factors or criteria has to be evaluated depending on the needs of the organization that is used to quantify the consequence of failure. The important criteria depend on each organization, e.g. safety, environment, production, costs (operations and maintenance), frequency of failures, average repair time, etc. Thereby have to be considered the sustainable factors indicated in the Fig. 6-2 of the Deliverable 4.2, such as financial health, resource use, energy use and carbon emissions, labour standards etc. (for more details see D4.2 SustainValue, 2013, Figure 6-2). Once the assets are ranked based on their criticality, the Criticality Matrix has to be generated (cf. Figure 36).

To prioritize assets and to align maintenance actions to business targets at any time have to be used risk assessment techniques. The application of risk assessment techniques ensures that maintenance actions are effective. Moreover indirect maintenance costs, direct maintenance costs, those associated to safety, environmental risks and sustainability, production losses and ultimately to customer dissatisfaction are reduced.

In order to carry out an assets criticality analysis by applying risk assessment techniques followed steps have to be done:

1. define the purpose and scope of the analysis
2. establish the risk factors to take into account and their relative importance
3. decide the number of asset risk criticality levels to establish
4. establish the overall procedure for the identification and prioritization of critical assets.

Thereby the maintenance team needs to answer the sequence of the questions for each specific asset considered for the analysis indicated in the flowchart (see Figure 37). The classification of the assets occurs within one of the three groups A, B or C that are defined per each criterion question. The first aspect to be considered is the environmental impact of a certain production equipment or
asset. With respect to environment an asset falling within category “A” may cause an important and “business external” environmental impact in case its maintenance is not planned and carried out properly. By external impact e.g. the business unit may have to inform local authorities about the incident and adopt specific contingency plans. An example can be a failure in a cooling system producing a gas leak to the atmosphere with high-ammonia content. Category “B” is reserved for those assets whose failures may produce environmental problems that can be solved internally. This for instance would be the case of a failure producing the leak of a certain liquid that can be treated within the water network of the company, producing no external consequences to the community water network or further external environmental factors. Finally assets falling within category “C” are assets whose failures might create no environmental consequences at all.

Next have to be considered the safety issues (Figure 37). Category “A” assets are now assets whose failures may produce accidents causing temporal or permanent worker absence to the work place. Category “B” assets failures would cause only minor damage to people at work, producing no work absence. Again, assets falling within category “C” are assets whose failures might create no consequences related to safety. For the next topics in the flowchart has to be followed the same type of questionnaire.

An example of detailed maintenance tools for category A assets where the aim is to reach optimal reliability, maintainability and availability levels are: apply failure mode, effect, and criticality analysis (FMECA) for critical failure mode analysis; apply reliability centered maintenance (RCM) for optimal maintenance task selection; standardize maintenance tasks; analyze design weaknesses; continue review FMECA and RCM.

An instance of detailed maintenance tools for category C assets with the goal to sustain or improve current conditions are: apply root-cause failure analysis (RCFA) to avoid repetitive failures; standardize maintenance tasks.

After the classification of maintenance assets considering sustainability factors is realized, the maintenance strategy to follow with each category of assets has to be checked und if necessary
reviewed. The maintenance strategy has to be adjusted gradually and has to be consisted of a course of action to address specific issues for the emerging critical items under the new business conditions (Figure 38).

![Figure 38: Example of maintenance strategy definition for different category assets (adapted from Crespo Marquez, 2007)](image)

**Gate 2**

After stage 2 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. This can easily be done by considering all possible assets and the Criticality Matrix used before.

In addition there is to control if the previously developed maintenance strategy is reaching all asset categories which the maintenance management defined in stage 2 or if there are still gaps. If so the maintenance management has to adjust it, if it is easily possible. If the gap between the asset categories and the maintenance strategy is too wide there has to be a loop to the beginning of stage 2 to rework it in detail. The same procedure has to be follow regarding the objectives and KPIs developed in stage 1.

**Stage 3: Design of maintenance plans and resource allocation**

The task of designing maintenance plans and resources allocation has to be carried out by the middle management within the maintenance department.

At the beginning of stage 3 data from computers have to be analysed. Thereby the different functions of equipment have to be identified. Subsequently, each function has to be determined for any failures. 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 this 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. For each failure mode or root cause, the following needs have to be determined: the maintenance task to perform; the frequency with which it will be done; the responsibility of running it and the new risks resulting from application of the maintenance plan.
One of the methods used in the industry for designing strategies and maintenance plans is referred to as RCM (Reliability Centered Maintenance). This method is widely used and is convenient for determining the maintenance needs of any physical asset in its operating environment (Moubray, 1997). The RCM methodology proposes the identification of failure modes that precede potential failures of equipment, and the execution of a systematic and uniform process. This is for the selection of maintenance tasks that are considered useful and applicable (Moubray, 1997). Specifically, the RCM analysis methodology proposes a procedure (Moubray 1997; SAE JA 1011) that, through the formulation of seven questions, helps to identify the real needs of maintenance of assets in its operating context.

Table 25: RCM questions (Source: Moubray, 1997)

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What are the functions that must meet the asset and what is the expected performance in its current defined operating context?</td>
</tr>
<tr>
<td>2</td>
<td>How can the equipment completely or partially fail?</td>
</tr>
<tr>
<td>3</td>
<td>What is the root cause of functional failure?</td>
</tr>
<tr>
<td>4</td>
<td>What happens when a failure occurs?</td>
</tr>
<tr>
<td>5</td>
<td>What is the consequence of each failure?</td>
</tr>
<tr>
<td>6</td>
<td>What can be done to prevent or predict the occurrence of each functional failure?</td>
</tr>
<tr>
<td>7</td>
<td>What can be done, if possible, to prevent or predict the occurrence of functional failure?</td>
</tr>
</tbody>
</table>

The application of the RCM process is regulated through SAE-JA1011 (SAE JA 1011) and SAE-JA1012 (SAE JA 1012) norms. Once the maintenance activities that are considered more efficient for each critical piece of equipment are selected, the final recommendations of the RCM analysis will be set out and its implementation will take place.

Finally based on these achieved results the drafting of the maintenance plans for the installation maintenance has to be created by allocating the necessary resources (skills, materials, testing and measuring equipment, etc.) in cooperation with the dimension of Sourcing Planning and Manufacturing Planning. In addition, during the process of planning and scheduling maintenance needs, skills must be developed to discriminate different options (cost) of available resources (which can be assigned to perform a certain task in a specific piece of equipment (asset), the ideal implementation place for the task and the start and execution time. In the process of planning the resource allocation the total costs have to be evaluated and considered. The maintenance plans will help to anticipate failures and repair them with minimal impact on the system performance by eliminating the causes of some failures and identifying those faults that do not compromise system security (Campbell & Jardine, 2001). The actions on an operational level should ensure that maintenance plans are performed correctly by selected technicians by following the outlined procedures on a schedule time and using the correct tools.

Gate 3

Firstly is to check if the maintenance plans consider all needed resources and required inventory (technical data, regulations, special facilities required, spare parts, supplies, tools, monitoring equipment for the conditions, auxiliary (back-up) equipment, test equipment, personnel) which
could be done without including the upper maintenance management. Responsible for this controlling aspect is therefore the middle maintenance management. In addition it can be useful if a maintenance technician is included due to his knowledge in practical field operations. Furthermore the control group might imply directly a maintenance technician to check e.g. the needed equipment necessary in the field operations.

Furthermore the middle management has to check if all the mentioned restrictions are considered and met in the work of stage 3. Restrictions might be allocated budget, time contingent regarding programming, enforceable rules and regulations for accomplishment, operational environmental conditions, working modes, etc.

**Stage 4: Implementation, execution and control**

The maintenance execution has to be done by field operators (e.g. trained technicians) and maintenance experts. The control part has to be done by the middle management of the maintenance department.

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. These are necessary to satisfy the needed information which helps to achieve the basic objectives of maintenance management (increased efficiency and reduced costs). The data that will be later analyzed must be as reliable as possible, i.e. the sheet design or maintenance job order must be found simply and standard for operators and managers as this will be the only useful and reliable data available. This design problem is fundamental to the functioning of the system. The same happens with the rest of the documents that capture data which makes up the system.

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) have 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. Furthermore the maintenance execution has to be conducted in a secure and environmental friendly way. This has to be checked continuously within the report. The control of the maintenance execution leads to an optimization of the design of the maintenance plans, thereby improving maintenance effectiveness and efficiency which leads to an economic sustainability. Others sustainability aspects could also be evaluated based on the 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 (date, duration, costs, operators, equipment, spare parts, etc.). Therefore it is necessary to control these aspects in cooperation with the middle management and in case of need IT-experts. Tests can be conducted by set test procedures which are to be defined. If this system is insufficient in any way it has to be decided if it can be optimized directly or by a loop to the beginning of stage 4 and a restart of the stage considering the information system.
The next aspect to control is the structure and the content of the report for the maintenance execution. The report sheet has to be simple and clear so that field operators can fit in the necessary data easily without difficulties of understanding or problems considering the time needed to complete such a report. This should be done in cooperation of the middle maintenance management and field operators who should use them later on.

**Stage 5: Life cycle analysis and replacement optimization**

Often the total cost of the production system in particular those costs associated with the operation, maintenance, installation testing, staff training etc. is not visible (Ahmed, 1995) and the large number of variables that must be managed in estimating the real cost of an asset over its useful life creates a scenario of high uncertainty (Durairaj & Ong, 2002).

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

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 have to be calculated, applying the appropriate cost for the duration of the life cycle.

Finally the total life cycle costs have to be analyzed. Through an analysis of the life cycle cost it is possible to determine the cost of an asset over its useful life. The analysis of a typical asset has to include costs of planning, research and development, production, operation, maintenance and removal of equipment (Yang, 2007). The acquisition costs of equipment (including research, design, testing, production and construction) are usually obvious, but the analysis of the life cycle costs depends crucially on values derived from reliability, for example, the analysis of failure rate, the cost of spare parts, the repair times, the costs of components, etc. An analysis of the life cycle costs is necessary for optimal acquisition of new equipment (replacement or a new acquisition) (Campbell & Jardine, 2001), since it shows all the costs associated with an asset (beside the purchase price), and allows management to develop accurate predictions. Further on, it is worth using the Life cycle cost combined with stochastic analysis, in order to assess the economic impact of the failures, thus eventually helping a proper reliability and maintenance management (see Parra et al. 2008). In stage 5 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 behavior in time: this would be helpful for making a provisional assessment of maintenance plans (i.e. counting expected failures and preventive maintenance interventions along the asset life cycle); henceforth, different criticalities may be verified when making provisional plans, and also changes to maintenance policies may be applied and tested before their actual implementation. Monte Carlo simulation, Discrete Event Simulation and Systems Dynamics are all techniques applicable to this end.

In stage 5 the Life Cycle Cost Analysis (LCCA) or the Sustainability Impact Calculation Tool (SIC) has to be used.
## Table 26: Method overview – Maintenance Planning

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td>Assessment current situation, definition of maintenance policy, strategy, objectives and KPIs</td>
<td>Middle or upper maintenance management</td>
<td>Business Modell Development, Strategy Development, PSS</td>
<td>Balanced Score Card</td>
</tr>
<tr>
<td><strong>Gate 1</strong></td>
<td>Upper maintenance management</td>
<td>Strategy Development</td>
<td>Check list</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td>Assets priority, sustainability factors</td>
<td>Middle maintenance management</td>
<td>-</td>
<td>Criticality Matrix, Qualitative Criticality Assessment</td>
</tr>
<tr>
<td><strong>Gate 2</strong></td>
<td>Upper maintenance management</td>
<td>-</td>
<td>Check list</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td>Maintenance plans, resource allocation</td>
<td>Middle maintenance management</td>
<td>Sourcing Planning, Manufacturing Planning</td>
<td>RCM, FMEA</td>
</tr>
<tr>
<td><strong>Gate 3</strong></td>
<td></td>
<td></td>
<td>Check list</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 4</strong></td>
<td>Implementation, execution and control</td>
<td>Maintenance technician, Middle maintenance management</td>
<td>Business Model Development, Strategy Development</td>
<td>IT-Control-System</td>
</tr>
<tr>
<td><strong>Gate 4</strong></td>
<td>Maintenance technician, Middle maintenance management</td>
<td>-</td>
<td>Test Procedures</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 5</strong></td>
<td>Asset life cycle analysis, replacement optimization</td>
<td>Middle management</td>
<td>All Conceptual and Operational Dimensions</td>
<td>Life cycle cost analysis, Sustainable Impact Calculation Tool, Simulation Tool</td>
</tr>
<tr>
<td><strong>Gate 5</strong></td>
<td>Upper Management</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Gate 5**
Within gate 5 there is to control whether the life cycle analysis clearly considers the assets towards their criticality determined by the assets critically matrix developed in stage 2. One focus has to be put in addition on the asset categories developed as well in stage 2, emphasizing the aspects of
sustainability. If these assets are not considered in the right way, there has to be a loop to the beginning of stage 5 (if something is wrong with the assets in general there has to be a loop towards stage 2 as well). In addition the asset life cycle analysis has to be checked against the objectives and KPIs developed in stage 1.

Furthermore in gate 5 it has to be checked whether all necessary data to manage an asset life cycle analysis (technical data, operational status, related costs, value of asset, etc.) are available. Therefore there has to be a close cooperation with the conceptual dimensions and the operational dimensions.

### 5.3.5 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. According to this second understanding, all processes which lead to a decrease of quality are to be conceptually differentiated and are called *down-cycling*. The term downcycling was used by Reiner Pilz in an interview by Thornton Kay of Salvo in 1994 (Kay, 1994). Examples are the reuse of paper or plastic products. In many cases, downcycling could be avoided, but not under tenable financial, social or ecological conditions.

An approach to measure the sustainability of a company’s end-of-life planning must take all different kinds of disposal into account, and evaluate their impact on the environment. In this respect, especially those methods are to be preferred which have the lowest negative impact on the environment, also noticing social and financial aspects.

In this chapter, various approaches which aim a sustainable disposal of products are presented. Since none of them makes a clear conceptual distinction between different kinds of disposal, recycling is understood as any attempt to re-use products, components or process materials for further manufacturing processes.

#### 5.3.5.1 Introduction of Possible Methods

Sustainability refers to the maintenance to Natural Capital. This includes both natural resources and ecological processes which are essential to sustain life. By an efficient recycling, it is possible to protect this natural capital.

Ricoh, a Japanese multinational imaging and electronics company, developed a chart that gives an overview of different dimensions of recycling (see Figure 39: Recycling loops – see Ricoh Group, 2009). Each circle represents one of the company’s partners that can help develop a sustainable society. The new resources delivered by materials supplier (upper right) are transformed into a product. In this process, the materials follow the route from right to left along the upper route, finally reaching the users. The used products move from left to right until they reach the final disposal company.
The concept suggested by Ricoh offers a first idea of how a sustainable use and re-use of materials might be possible. Nevertheless, to be transferable to other companies, a theoretical framework has to be developed. Ricoh does a good job in recycling already existing disposal. Nevertheless, disposal is not only a crucial matter at the end of a life cycle, but should also be considered in the planning phase of the product. Therefore, in the following, four theoretical approaches are looked at.

Table 27: Approaches of end-of-life and recycling planning methods

<table>
<thead>
<tr>
<th>Approach</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cradle-to-Cradle</td>
<td>McDonough &amp; Braungart, 2002</td>
</tr>
<tr>
<td>reverse logistics</td>
<td>Hawks, 2006</td>
</tr>
<tr>
<td>from 3R’s to 6R’s</td>
<td>Jayal et al., 2010</td>
</tr>
</tbody>
</table>

5.3.5.2 Integration into Development Framework

None of the described methods to increase the recyclability of a product suffice in order to reach the highest possible sustainability. Nevertheless, they offer useful instructions for a limited problem scope and point in the right direction. As described before, various initial situations can be given. The presented attempt suggests a procedure for companies that are in the developing process for new product service system with the goal of a maximized sustainability.

5.3.5.3 Stages and Gates

Stage 1: Building a prototype

 Efficient recycling presupposes an intelligent product design. Many consumer goods are designed in a way that makes it hardly possible to decompose them into separate parts which can be devoted to recycling processes. Therefore, 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:**

In this first step, specialists for end-of-life cycle planning should talk to various other divisions: technology development and product development might give first insights whether a prototype is technically realizable.

**Stage 2: Reduction**

Tear down is a procedure to improve existing physical goods in order to increase their sustainability. For this purpose, the compound is decomposed while each component is evaluated concerning its recyclability, costs, design etc. The aim is to find potentials for leaner designs which lead to cost reductions and an increased recyclability. However, this approach does not give a concrete instruction of how to proceed.

A better job here do the 3R and 6R approach. The 3 R’s (Reduce, Reuse, Recycle) are described as starting point of sustainability implementation programs. The principles are the following: 1) Reduction; purchasing and using only what is necessary, 2) Reuse; find an alternative use extra materials and 3) Recycling; unused materials are transformed into new products. The focus of 3R’s is clearly on environmental efficiency, although implementation of main principles (3R’s) also can increase company’s profitability. Later on, the 6R’s approach was introduced in order to have a broader and innovation-based approach to product life cycle. Recover, Redesign and Remanufacture complemented the closed-loop product life cycle system. Closed-loop product life cycle system in 6R approach (source: Jayal et al., 2010)

On the basis of this prototype, the 3R method can be used to evaluate this prototype’s recyclability. The first R refers to the step of reduction. Only those material should be used and purchased that are necessary and not replaceable by more environmental friendly raw materials. Within this step, the tear down approach, developed by McKinsey, is a helpful tool in order to organize the reduction. The prototype is decomposed in its components and each of these is examined and evaluated according to its sustainability and recyclability.

**Gate 2:**

At the end of the second stage, each component should have been considered in various arrangements, using different materials, shapes, or spatial order. McDonough and Braungart defined 5 criteria which support the reflection process:

- **Material health**, which involves identifying the chemical composition of the materials that make up the product. Particularly hazardous materials (e.g. heavy metals, pigments, halogen compounds etc.) have to be reported whatever the concentration, and other materials reported where they exceed 100 ppm. For wood, the forest source is required. The risk for each material is assessed against criteria and eventually ranked on a scale with green being materials of low risk, yellow being those with moderate risk but are acceptable to continue to use, and red for materials that have high risk and need to be phased out. Grey for materials with incomplete data. The method uses the term ‘risk’ in the sense of hazard (as opposed to consequence and likelihood).

- **Material reutilization**, which is about recovery and recycling at the end of product life.
• Assessment of energy required for production, which for the highest level of certification needs to be based on at least 50% renewable energy for all parts and subassemblies.

• Water, particularly usage and discharge quality.

• Social responsibility, which assesses fair labor practices.

Additionally, the possibility of spare part replacement should be considered. A product will reach its end of life at a later point if it is possible to replace broken parts. Thus, alternative designs which make

**Step 3: Reuse**

After ensuring that all components are necessary and as leanly designed as possible, the next step of reuse can be initiated. 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. Both ways are possible: They may either find solutions of how to re-integrate the materials in their own production process or they may check whether the materials can be recycled for other branches. Here, the reverse logistics approach is capable of ensuring a maximum of sustainability.

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 & Braungart, 2002) as an alternative to the cradle-to-grave approach. It models human industry on nature’s processes viewing materials as nutrients circulating in healthy, safe metabolisms. In this sense, recycling means to avoid any kind of waste. In case this is not possible, the optimum use of waste products has to be ensured.

After the theoretical considerations concerning the new product’s recycling, the real process of recycling has to be conceptualized. Once all recyclable components are known and their destinations are determined, the ways of the materials as well as necessary steps in order to prepare them for their re-use have to be planned. In doing so, different production steps have to be considered. Here, reverse logistics offers a practicable tool.

Reverse logistics stands for all operations related to the reuse of products and materials. It is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Normally, logistics deal with events that bring the product towards the customer. In the case of reverse logistics, the resource goes at least one step back in the supply chain (cf. Hawks, 2006).

**Gate 3**

But not only should the product itself be designed in a lean way; it is also necessary to guarantee an efficient use of the raw materials within the production process. Wasting materials due to insufficient planning and utilization must be avoided. Thus, the ratio of per-se environmental friendly materials and the waste they bring about during their manufacturing should be considered and be re-checked after step 3. Also auxiliary and process materials are to be integrated.
### Table 28: Method overview – End-of-Life and Recycling Planning

<table>
<thead>
<tr>
<th>Stage/Gate</th>
<th>Content</th>
<th>Functions, Responsibilities, Authorities (FRA)</th>
<th>Interfaces</th>
<th>Tools (D3.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Prototype</td>
<td>End-Of-Life cycle manager</td>
<td>Technology Development, Product Development, Manufacturing</td>
<td>Cradle-to-Cradle, from 3R's to 6R's</td>
</tr>
<tr>
<td>Gate 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td>Reduction</td>
<td>End-Of-Life cycle manager</td>
<td>Technology Development, Product Development, Manufacturing</td>
<td>reverse logistics, from 3R's to 6R's</td>
</tr>
<tr>
<td>Gate 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 3</td>
<td>Reuse</td>
<td>End-Of-Life cycle manager</td>
<td>Technology Development, Product Development, Manufacturing</td>
<td>Cradle-to-Cradle, from 3R's to 6R's, reverse logistics</td>
</tr>
<tr>
<td>Gate 3</td>
<td></td>
<td>Guarantee of an efficient use of the raw materials within the production process</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6 Case Studies

In order to examine whether the suggested tools might be applicable for companies, three business partners were asked to participate in a case study. The business partners differ significantly in their business models.

CLAAS is an internationally acting concern, well established in the market with loyal clients for years, and employing more than 9,000 people. During the last years, it developed more and more to a service-system provider, instead of solely focusing on their former physical products (harvesters, tractors, field chopper etc.).

Riversimple is a young, modern kick-off company located in the UK. The aim of Riversimple is to produce highly efficient vehicles for personal transport. During the workshop, Riversimple employs a board of seven and a small team of staff.

Elcon is an SME company, which offers solutions that secure power feeding based on the principles of sustainable development to different customer segments.

These different structures of the companies are particularly useful in order to guarantee the applicability of the tools suggested in this deliverable. In this chapter, the results of the workshops are presented, framed by the question of whether the participants find the tool helpful to portray their own business and detect its potential or actual problems.

6.1 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 located in Harsewinkel Germany where the production is located as well. Claas was founded in 1913 by August Claas and is up to date a family-owned enterprise. In the past, Claas was a classical product developer which developed, produced and sold their products. For the last 15 years, Claas has been adding additional services to their product portfolio. Until now, 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 development of their current portfolio is illustrated in the following Figure 40.
6.1.1 Participants

Seven employees from different divisions of Claas were participating in the workshop. All participants have been dealing with the development of new sustainable solutions, even though on different levels. The participants from SustainValue consortium (FIR and Claas) invited employees from following divisions of Claas:

- Product strategy
- Product management
- Sales Management (Key Account)
- Supply Chain Management and Procurement
- Technical system development
- Cooperate R&D
- Systems and Service Development

The heterogeneous composition of the workshop participants was intentionally chosen. The idea beyond was to validate the different dimensions of the framework. It can count validated if all participants are able to classify their roles in the company into the frameworks dimensions.

6.1.2 Procedure

In a first step, the participants were introduced to the development framework and familiarized with the suggested dimensions. The different dimensions, activities, gates, responsibilities and interfaces were explained. It was mentioned that the framework represents a collection of scientific methods which are combined to holistic development framework. The explanation of the basic idea of this framework is essential for a shared understanding of the framework to avoid misunderstandings.

The next step was a discussion about the dimensions and the four suggested development phases. Nobody was missing an important dimension which is significant for the development or for the realisation of a sustainable solution.
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. Due to the fact that the different divisions of Claas act independently, the names of the dimensions some of the dimensions were consolidated. The two dimensions of the central initiation (Strategy Development and Business Model Development), for instance, were combined to one division which is existing within Claas. The division names of the present roles from the participants were associated to the different dimensions.

Afterwards, the participants were asked to draw down their actual procedure for sustainable solution development into the development framework. At this point, it is important to mention that Claas in general has a well-described product development process with detailed steps, gates, responsibilities and milestones. However, it was difficult to find a single starting point where new ideas or solutions occur. After identifying many possible starting points for new solutions, the process for collection, assessment, prioritization 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. Moreover, missing communication channels between different dimensions were revealed and inefficient process design could be detected. In addition, a first clue of how to reduce complexities in PSS could be found. Detailed findings during this procedure are described in the next chapter.

After drawing the actual development process and identifying weaknesses while 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 while creating the new target process. Tools to measure and monitor sustainability goals should be integrated.

### 6.1.3 Lessons Learned and Results

In this chapter, the most important findings were consolidated. The general findings concerning the adequacy of the development framework are:

- All participants get an easy access to the idea and the structure of the development framework.
- No important dimension was missing.
- The four phases of development were accepted as being adequate.
- Inefficient and unsustainable process design can be detected and communicated using the framework.

Regarding the applicability of the framework, it can be said that

- Missing interfaces between dimensions in the company can be easily identified.
- The scientific methods and tools of the framework support an improved development procedure within the company.
The consolidation of different perspectives is sensible and leads to interesting and helpful results for a more efficient and sustainable process. Improvements concerning efficiency and sustainability can be implemented.

From a methodological point of view, it can also be stressed that

- The heterogeneous structure of participants is important to merge different perspectives and experiences.

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 organizational 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 etc.) 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.

### 6.2 Riversimple LPP (UK)

Riversimple is a car company, based in the UK. It is a start-up aiming to produce highly efficient vehicles for personal transport. The company provides services by selling mobility as a service, not
the car itself as a product. Users pay a fixed monthly rental and per mile charge to cover all variable costs, including fuel.

6.2.1 Participants

Hugo Spowers is founder and chief engineer at Riversimple with an academic background in engineering from Oxford University. He founded and ran a business over 15 years, designing and building racing cars and restoring historic racing cars. He left motorsport due to environmental concerns and went on to obtain an MBA from Cranfield University, where he conducted a feasibility study into bringing hydrogen fuel cell cars to market. This led him to found Riversimple, bring together the consortium behind LIFECar and then pursue the local vehicle as a path to commercialisation.

The second participant, Nicolas Sergent, who is an engineer at Riversimple, holds a Master’s degree in industrial production and management from the ENSAM University (France) as well as a Master’s degree in Automotive Engineering from Cranfield University. He also gained a PhD (also at Cranfield) in Motorsport Engineering with the Formula one team WilliamsF1. He then left motorsport and joined Riversimple to focus on sustainable transport. Originally employed to work on the OpenSource platform, he is now in charge of vehicle development and also responsible for the SustainValue project within Riversimple.

6.2.2 Procedure

The procedure with Riversimple was quite different from the one with Claas and focused more on a scientific examination of the suggested framework. Mr Spowers and Dr. Sergent gained a deep insight into the framework through a lively discussion.

After the theoretic assumptions beyond the framework were accepted, the participants tried to apply the framework to their own business structure. Due to the limited size of the company, some distinct divisions were represented by one person, whilst others theoretically existed, but were not personally. Nevertheless, Riversimple confirmed the general applicability of the framework to their business.

In a next step, the process of idea generation was in focus. Due to the limited size of Riversimple, it is possible to discuss new ideas in the group. For this reason, everyone is allowed to convene an extraordinary meeting, in addition to those every other month. This process may be described with the framework. Nevertheless, Riversimple mentioned that interactions during these meetings are so vivid that it is not always possible to capture every single step. Moreover, they did not specify standard procedures.

6.2.3 Lessons Learned and Results

The workshop with Riversimple lead to two distinct results: firstly, the framework was attested to account for real companies and as being applicable to both describe and improve business activities. Secondly, Riversimple confirmed communication and an improvement of communicational processes as the key factors when it comes to interfaces between divisions.
One main interest of the workshop was to ensure that the framework meets real-world conditions. Riversimple accepted the division of the idea generation process into four consecutive steps: idea, conceptualization, implementation and market. Additionally, all four dimensions as well as their subdivisions were accepted and said to be complete. Here, Riversimple and Claas provide the same feedback.

Moreover, Riversimple can be seen as an example for optimized communication processes. Being a start-up, Riversimple is able to immediately discuss ideas, necessary changes and decisions. Their strong interests in including a broad range of perspectives of various stakeholders of the company (investors, users, staff, suppliers/Infrastructure partners, environment, neighbours) as well as frequent team meetings ensure a stable and flowing exchange of opinions and ideas. This way, all decision-makers are involved and informed. These results are in line with those from Claas: communication is a crucial factor that might influence the contentedness of employees and strengthen their ability for innovations.

Despite all these ideal processes that are possible due to the company’s size, Riversimple is aware of the challenges that might occur with the company’s intended expansion. Once spontaneous meetings of all relevant stakeholders are not possible anymore, a higher degree of standardization might become necessary.

At Riversimple decisions are made "as low down" as possible, with a very flat hierarchical structure. Decisions will be made according to principles rather than fixed/standard rules. Limiting bureaucratical inertia in decision making is seen as an important factor to keep the company as agile as possible.

6.3 Elcon Solutions Oy

Error! Reference source not found. presents Elcon’s network position. In the upstream direction there are large component and equipment suppliers, as well as network partners participating in assembly, manufacturing or R&D.

![Figure 41. Illustration of typical network position of the case company](image-url)
In downstream there are B-to-B customers and end-users from several sectors. According to the case company, its products are typically customized solutions for its B-to-B customers, who are project suppliers of larger systems and integrate the solutions delivered by the case company to their own offerings to end-users.

6.3.1 Participants

From the case company’s side the project group of the SustainValue project consisted of three persons; CEO Kari Frankenhauser, Sales Manager Jaana Frankenhauser and System Design Manager Juha Raukola. They presented the key areas regarding the work towards sustainable development at Elcon.

Several researchers participated in the project group from VTT’s side. Their competence areas were sustainability, business development, life-cycle and network management and LCC tools which are also in accordance with the SustainValue project plan and especially the objectives of Elcon case.

6.3.2 Procedure

The procedure with Elcon has both similarities and differences with the procedures of Claas and Riversimple. As an SME company Elcon did not have as much resources as Claas, so the project group was smaller. On the other hand, Elcon had a more settled business model than Riversimple and thereby also sustainability development should have a clear link to its business model and needs of its customers. As an SME company Elcon was agile in testing and implementation of new ideas and business concepts related to sustainability as competitive advantage.

The interaction between the research group and the company representatives was quite intensive and altogether 14 workshops were arranged during 2011 – April 2013. The main phases are shown in Figure 42. As the process description illustrates, the business development process was an opportunity for learning for both the company representatives and the researchers. The development objectives of the case company were related to both efficiency of value capturing within current manufacturing network and creation of new business opportunities related to sustainability-oriented added value to its B-to-B customers.

6.3.3 Lessons Learned and Results

From the SustainValue WP2 the representatives of the company learned valuable lessons concerning business models, their elements and archetypes. This structured information enabled them to analyse their prevailing business model which was the first step of Elcon’s development process. The description of the present state enables the identification of the development targets in order to create a new, more sustainable business model.

When the new business model was created and defined, Elcon was able to define a new and more sustainable value proposition. The implementation of the new business model set also new challenges to Elcon’s every-day operations. In order to respond to its value proposition, operational arrangements were made and new requirements for product development were identified. In this case operational changes were accomplished by networking with another manufacturing company. In this new setting Elcon’s responsibilities are in operations related to sales, services, product and
service design and development while their partner is responsible for the manufacturing of the products.

By completing these operational arrangements Elcon was able to report some preliminary results indicating that steps towards more sustainable business operations had been taken. For Elcon the new setting enabled higher manufacturing capacity and capabilities, lower fixed costs and smaller risks. For Elcon’s customers the new business model offered all services from one house, better product combinations and smaller installation costs. To the network these arrangements meant smaller costs of premises, more products to manufacture, better degree of utilization in production and new sales channels.

To be successful in the future, the main challenge of the Elcon’s new business model relates to the communication of the new value proposition. Because the network position of Elcon is not determinative and most probably the purchasing price of sustainable product is more expensive, the benefits of the sustainable product over its life cycle should be clearly communicated to Elcon’s customers or even to their customer’s customer. For value proposition communication there is a case study going on, which aims at improving Elcon’s capabilities in supporting their customers’ decision making while they are evaluating different investment options. At the moment (April 11th 2013) the prototype version of the Life Cycle Cost Estimation tool of Elcon’s products is being tested in real sales cases of Elcon. The usefulness of this approach in value proposition communication will be reported in later reports of SustainValue project.
7 Conclusions

The conclusion of this deliverable can be divided in two parts; the first dealing with a summary of the theoretical achievements in this deliverable, the second focussing on the validation of this framework from a practical point of view. Additionally, a short outlook will highlight the relation between D3.3 and D3.4.

7.1 Theoretical finding

The scientific achievement of this deliverable is a framework that is supposed to be a tool and a guideline for companies or value networks to evaluate and optimize their current business processes. In this framework, which serves as a rough generalization 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: idea, conceptualization, implementation and market.

For each unit, several steps and gates are defined which contain a manifold of tools and methods in order realize sustainable solutions and to optimize business processes. While 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 optimize their business processes towards sustainability, starting at any point in their process chain.

7.2 Practical Findings

From the workshops with Claas and Riversimple it was shown, that the framework should be understood as an image of a “prototypic company and its processes” and might be adjusted for every single company.

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 realizing sustainable solutions. Not only for an international operating company like Claas, but also for a small company like Riversimple, the development framework is a useful tool in order to develop more sustainable solutions.

All companies agreed upon the dimensions as sensible suggestions for a prototypic company organisation. Neither of them missed dimensions, the assignments of divisions to dimensions was confirmed and no division was found superfluous. Due to the different perspectives the business partners have for their significantly different business models, the framework with its theoretical assumptions can count as validated.

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. While this can be critical for big companies with decentralised offices and divisions, small companies might profit from no standardized processes. The assumption that interfaces might be a crucial element of multi-division-projects has thus been confirmed.

Summarizing 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. During this procedure there will be a lot of positive effects which are described in chapter 6 in detail.

7.3 Outlook

As mentioned in each chapter, the described tools and methods might be helpful in order to increase sustainability. Nevertheless, the adaption of them is still in its infancies. It is therefore the aim of deliverable 3.4 to develop a toolbox which contains all mentioned tools of the theoretical approaches discussed in D3.3 and to develop them further so that they are more easily applicable. D3.3 can thus be seen as a substantial work when it comes to developing a framework, but only as the preliminary work on the choice of tools and methods. D3.4 will build on these ideas and provide a substantial added value.
8 Tools

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. It is a tool used for solving Multi Criteria Decision Making (MCDM) problems, e.g. when matching to the requirements of many stakeholders (with their own priorities). This tool can be applied in order to operationalize the concepts from PSS development. Using this tool will enable identifying the key operational requirements of the manufacturing system which is helpful in order to evaluate the system design alternatives as potential planning solutions.

Balanced Scorecard (BSC)

Balanced Scorecard is a strategy performance management tool - a semi-standard structured report, supported by design methods and automation tools that can be used by managers to keep track of the execution of activities by the staff within their control and to monitor the consequences arising from these actions. BSC allows the creation of KPIs for measuring maintenance management performance which is fully aligned to the organization’s strategic objectives. Unlike conventional measures which are control oriented, the BSC puts the overall strategy and vision at the centre and emphasizes on achieving performance targets. The BSC enables deployment and implementation of the maintenance strategy at all levels in the company. This encourages the involvement of all those concerned in achieving the strategic objectives and achieving strategic alignment across the organization, from the transformation of the strategic plans to action plans.

Best Available Technologies (BAT)

Best Available Technologies and their cataloguing in manufacturing information maps provide information on the characteristics and capabilities of technological processes with respect to their environmental burden. In this concern any data base built to this end should be adopted, considering the specific environmental factor, e.g. energy data base.

Business Intelligence Tools

Business Intelligence Tools are a type of application software designed to retrieve, analyse and report data. The tools generally read data that have been previously stored, often, though not necessarily, in a data warehouse or data mart. Examples of business intelligence tools are: spreadsheets, data- and process mining, reporting and querying software, decision engineering, business performance management etc. These tools are generally standalone tools, components of ERP systems or components of software targeted to a specific industry.

Business Model Canvas

The Business Model Canvas developed by Osterwalder and Pigneur (2010) is a strategic management template for developing new or documenting existing business models. The Business Model Canvas supports the coordination and configuration of the key activities, resources, partners, channels, the value exchanges and value capture between stakeholders in the network.
Computer-aided design (CAD)

Computer-aided design is the use of computer systems to assist the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of the design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. In mechanical design, it is also known as computer-aided drafting (CAD) or computer-aided design and drafting (CADD), which describes the process of creating a technical drawing with the use of computer software.

Checklist

A checklist is a type of informational job aid used to reduce failure by compensating for potential limits of human memory and attention. It helps to ensure consistency and completeness in carrying out a task. An advanced checklist is a schedule, which lays out tasks to be done according to time of day or other factors.

Competitor analysis

Competitor analysis is an assessment of the strengths and weaknesses of current and potential competitors. This analysis provides both an offensive and defensive strategic context to identify opportunities and threats. Competitor analysis is an essential component of corporate strategy. It is argued that most firms do not conduct this type of analysis systematically enough. As a result, traditional environmental scanning places many firms at risk of dangerous competitive blind spots due to a lack of robust competitor analysis.

Corporate Sustainability Continuum

Corporate Sustainability Continuum, proposed by Willard 2005, is a tool supporting first stage of business modelling process. It can support framing of present situation regarding to sustainable development. The Corporate Sustainability Continuum represents the progress of companies on the path towards sustainability and a company can utilise it when exploring the question: “where are we regarding to sustainability as strategic choice?” Furthermore, it can also be utilised to study of future paths for sustainability and thereby it can be utilised also within the strategy development.

Creativity Tools

Creativity Tools are tools for creating an effective solution to a problem or situation. The creativity tools are organized into four categories: tools for defining the problem (breakdown, CATWOE, context map, storyboard, purposing, value analysis etc.), tools for creating ideas (brainstorming, brainwriting, crawford slip method, attribute listing etc.), tools for selecting ideas (concept screening, Delphi Method, the Kipling method etc.) and tools for implementing ideas (adoption checklist, ChangingMinds, force-field analysis etc.).

Criticality Matrix

A Criticality Matrix is a representation of failure modes along with their probabilities and severities. Items are placed in the criticality matrix according to the failure severity category and either the estimated failure mode probability of occurrence level or the criticality number.
Design for Reliability (DFR)
Design for Reliability is a process and describes the entire set of tools which support product-, service- and process-design to ensure reliability throughout the lifespan.

Discrete Event Simulation (DES)
Discrete Event Simulation is a tool for analyzing a system bottlenecks and subsequent performances at the system level (productivity, delivery speed, etc.) under dynamic and stochastic conditions. Although analyze energy flows, energy bottlenecks, as well as waste flows and emissions, to finally assess subsequent performances at system level (energy efficiency, CO2 equivalent emissions).

Energy Database
Energy Database is a database for production and transportation facilities acting as energy input database (electricity, heat, hydraulic, pneumatic etc.), energy storage database (energy harvesting, storage methods, conversion efficiency etc.) and energy output database (heat losses, vibrations, etc.). The database can be used to evaluate the energy consumption of each system and sub-system that compose the whole system. Thereby 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. The database should involve basically all relevant energy flows, but also may be enlarged to other environmental factors, in order to consider other flows connected to the equipment dynamics.

Environmental Performance Evaluation (EPE)
Environmental Performance Evaluation is an internal process and management tool that can be used for the evaluation of environmental performance of an organization (and thus, also for the evaluation of environmental performance of the industrial plant subject of (re)planning). Environmental Performance Evaluation and Indicators (EPIs) – as a specific standard of system management focused on environmental topics can be used for reporting the assessment of the manufacturing planning solutions. EPE can be considered also as a tool for the initial review within the EMAS Regulation.

Failure Mode and Effects Analysis (FMEA)
FMEA is a bottom-up inductive analytical method which may be performed at either the functional or piece-part level. It is a technique to identify possible points of failure to avoid making mistakes (design, concept) or to prevent doing them over and over again (usage). FMEA can be done to describe and to rate possible failures and risks.

Failure Mode, Effects and Criticality Analysis (FMECA)
FMECA extends FMEA by including a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.
Focus Group

A focus group is a form of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs, and attitudes towards a product, service, concept, advertisement, idea, or packaging. Questions are asked in an interactive group setting where participants are free to talk with other group members. Focus groups can support e.g. the idea generation process.

Global Scorecard

The Global Scorecard is a Capability Assessment Tool that has been designed to give a detailed understanding of the ECR (Efficient Consumer Response) capability and to highlight specific improvement opportunities of companies. ECR is able to reach the same results as QR, but in addition it combines logistical potentials of rationalizing processes with potentials of growth. There are four focus areas under ECR: Demand management, supply management, enablers and integrators, which are intended to be addressed as an integrated set. These form the basis of the ECR Global Scorecard. Nevertheless, ECR has to be implemented by both operational and managerial persons responsible.

Go/No-Go Criteria List

A Go/No-Go Criteria List is a tool that presents all the factors that may influence whether a task should proceed or not. Presenting a summary of these issues in this way can help facilitate the right decision.

Global Reporting Initiative Guidelines (GRI Guidelines)

The GRI Guidelines are standardized reporting guidelines concerning the environment contained within the GRI Indicator Protocol Set. They represent one of the world’s most prevalent standards for sustainability reporting — also known as ecological footprint reporting, environmental social governance (ESG) reporting, triple bottom line (TBL) reporting, and corporate social responsibility (CSR) reporting. The guidelines are considered helpful in providing guidance for identifying sustainability priority areas.

Group Development Models

Group development models assign groups or individuals to operational activities and duties, as well as analyse the human interaction with the technical systems. Mennecke et al. (1992) classify three categories of group development models: linear models exhibiting an increasing level of maturity and performance overtime; cyclical models implying a recurring sequence of events; hybrid model which do not imply a specific sequence of events; rather, the events that occur are assumed to result from contingent actors that change the focus of the group activities.

Human Factors & Ergonomics (HF&E) Tools

Human Factors and Ergonomics (HF&E) is a long list of HF&E objectives – and correspondent available tools to be used for evaluation. The important point in the method is to highlight issues that are the most relevant and should be especially cared about: this would result from taking into account the key operational requirements, in particular the social requirements, of the manufacturing system. Human Factors & Ergonomics (HF&E) tools are applied to cater with key social requirements, with special attention to Health & Safety issues.
Implementation Criteria List

Implementation Criteria List is a representation of all the criteria that may influence the realization of an application, or execution of a plan, idea, model, design, specification, standard, algorithm, or policy. Presenting a summary of the criteria in this way can help facilitate the right implementation.

IT-Control System

IT Control System is a device or set of devices to manage, command, direct or regulate the behaviour of other device(s) or system(s). Industrial control systems are used in industrial production.

Life-Cycle Cost Analysis (LCCA)

Life-cycle cost analysis is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings. The LCCA should be performed early in the design process while there is still a chance to refine the design to ensure a reduction in life-cycle costs (LCC).

Life cycle cost estimation tool (LCC estimation tool)

The LCC estimation tool supports the evaluation and selection of a cost effective and sustainable solution, while providing a summary of the cost incurred across the life cycle.

Manufacturing Process Information Maps (PRIMAs)

Manufacturing Process Information Maps is a tool providing detailed information on the characteristics and capabilities of technological processes and their variants.

Market Research Tools

Market research tools represent statistical and analytical methods and techniques for identification and analysis the market needs, market size, customer and competition. The successful application of market research tools is a key factor to get advantage over competitors.

Maturity Model

A Maturity Model represents a set of structured levels that describe how well the behaviours, practices and processes of an organization can reliably and sustainably produce required outcomes. A Maturity Model can be used as a benchmark for comparison and as an aid to understanding - for example, for comparative assessment of different organizations where there is something in common that can be used as a basis for comparison. The model involves five aspects: Maturity Levels, Key Process Areas, Goals, Common Features and Key Practices.

Monte Carlo Simulation

Monte Carlo simulation is a fictitious representation of reality, which uses repeated sampling to determine the properties of some phenomenon (or behavior).
Multi Criteria Decision Making (MCDM)

Multi Criteria Decision Making is concerned with structuring and solving decision and planning problems involving multiple criteria. The purpose is to support decision makers facing such problems. Typically, there does not exist a unique optimal solution for such problems and it is necessary to use decision maker’s preferences to differentiate between solutions. MCDM is essentially required for properly weighting the priority of different sustainability factors.

Political, Economic, Social, Technological and Environmental analysis (PESTLE)

PESTLE or PESTEL describes a framework of macro-environmental factors used in the environmental scanning component of strategic management. It is a tool supporting first stage of business modelling process. It is a part of the external analysis when conducting a strategic analysis or doing market research, and gives an overview of the different macro environmental factors that the company has to take into consideration. It is a useful strategic tool for understanding market growth or decline, business position, potential and direction for operations. The growing importance of environmental or ecological factors in the first decade of the 21st century have given rise to green business and encouraged widespread use of an updated version of the PEST framework.

Potential Analysis

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.

Priority Setting Matrix

Priority Setting Matrix is a representation for the selection of priority need areas. A project team selects which need areas/markets are most interesting to carry out the PSS project, e.g. food, office, clothing care etc.

Production Flow Analysis (PFA)

Production Flow Analysis is a technique for finding the families of components, and associated groups of machines, for Group Layout. PFA finds the natural division into groups and families, using the existing plant, tooling and processing methods. It also finds any exceptional components which do not fit the solution suitable for the majority. Production Flow Analysis is concerned solely with methods of manufacture, and does not consider the design features or shape of components at all. PFA uses a matrix of part numbers and machine numbers to group families.

Project Management Tools

Project management tools are tools and methods of planning, organizing, motivating, and controlling resources to achieve specific goals. Referring to sustainability can be used PRiSM (Projects integrating Sustainable Methods). PRiSM is a process-based, structured project management methodology that introduces areas of sustainability and integrates them into four core project phases in order to maximize opportunities to improve sustainability and the use of finite resources. The methodology encompasses the management, control and organization of a project with consideration and emphasis beyond the project life-cycle and on the five aspects of sustainability, People, Planet, Profit, Process and Product. It derives the framework from ISO: 21500 as well as ISO 14001, ISO 26000, and ISO 9001.
Project Planning Tools

Project planning tools are tools relating to the use of schedules such as Gantt charts to plan and subsequently report progress within the project environment.

PSS innovation matrix

The PSS innovation matrix is a newly developed tool, which can be used either as a kind of creativity tool to develop PSS ideas or to check the completeness of the collected PSS ideas. At least three workshops are necessary to complete the scan. Depending on the size and experience of the participating companies, the estimated time expense for a rough scan is 1.5-3 working days and for a thorough scan 3-20 working days.

Qualitative Criticality Assessment

Qualitative Criticality Assessment is a tool carry out an assets criticality analysis by applying risk assessment techniques followed steps have to be done: a) define the purpose and scope of the analysis; b) establish the risk factors to take into account and their relative importance; c) decide the number of asset risk criticality levels to establish; d) establish the overall procedure for the identification and prioritization of critical assets. Thereby the specific team needs to answer the sequence of the questions for each specific asset considered for the analysis indicated in the flowchart.

Quality Function Deployment (QFD)

QFD is a tool to relate stakeholder requirements to the requirements for the manufacturing system design. This tool can be applied with the purpose to operationalize the concepts coming from PSS development: indeed, using this tool will enable identifying the key operational requirements of the manufacturing system, which is helpful in order to evaluate the system design alternatives as potential planning solutions.

Quick Response (QR)

Quick Response (QR) 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. Nevertheless, QR is only meaningful for companies who sell their products to wholesale traders. Due to these significant improvements, QR has been further developed for other branches towards ECR.

Relationship charts

Relationship charts are used to evaluate the importance of adjacency between different activity locations, for other reasons than material flows (e.g. sharing a high cost fixture).

Reliability Centered Maintenance (RCM)

RCM is a method used in the industry for designing strategies and maintenance plans. This method is widely used and is convenient for determining the maintenance needs of any physical asset in its operating environment. The RCM methodology proposes the identification of failure modes that precede potential failures of equipment, and the execution of a systematic and uniform process. This is for the selection of maintenance tasks that are considered useful and applicable. Specifically, the
RCM analysis methodology proposes a procedure that, through the formulation of seven questions, helps to identify the real needs of maintenance of assets in its operating context.

**Reporting and communication tools**

The reporting and communication tools are software providing reporting and communication in enterprises. Reporting software (such as Eclipse BIRT Project, GNU Enterprise, ActiveReports, Oracle Reports etc.) is used to generate human-readable reports from various data sources. The communication tools are used to create usable information. Many tools have independent forums that provide varying levels of support or assistance.

**Requirements analysis**

Requirements analysis is a method encompassing those tasks that go into determining the needs or conditions to meet for a new or altered product, taking account of the possibly conflicting requirements of the various stakeholders, analysing, documenting, validating and managing software or system requirements. A requirement analysis might be helpful to get a first impression of services that are needed in order to meet customer satisfaction, compared with the actual performance of the company. 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. An early assessment of requirements makes it possible to plan distributions with a minimum of ecological impact.

**Requirements list**

The requirement list is a document to specify requirements. In a complex system such requirements lists can run to hundreds of pages long. This tool can be applied to specify a product so that the department of product development has a clear idea considering the accomplishment of the tasks through the product.

**Root Cause Failure Analysis (RCFA)**

Root Cause Failure Analysis is a method of problem solving that tries to identify the root causes of faults or problems that cause operating events. RCDA solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. RCFA recognizes that complete prevention of recurrence by one corrective action is not always possible. Root cause analysis is not a single, sharply defined methodology; there are many different tools, processes, and philosophies for performing RCFA.

**Scenario Analysis**

Scenario analysis is a main method of projections, analysing possible future events by considering alternative possible outcomes. The scenario analysis does not try to show one exact picture of the future. Instead, it presents consciously several alternative future developments. Consequently, a scope of possible future outcomes is observable. Not only are the outcomes observable, also the development paths leading to the outcomes. In contrast to prognoses, the scenario analysis is not using extrapolation of the past. It does not rely on historical data and does not expect past observations to be still valid in the future. Instead, it tries to consider possible developments and turning points, which may only be connected to the past. Thus objective of the scenario analysis is to
anticipate future developments of society and find and evaluate possibilities and strategies to meet these developments.

**Scenario Management Tool**

Scenario management tool assists in the understanding of the current system and identifying key internal and external factors and forces influencing a company. The scenario management tool assists in exploring the requirements for the future that will affect the development and transformation of a novel sustainable business model.

**Service Blueprint**

Service blueprinting is a tool for simultaneously depicting the service process, the points of customer contact and the evidence of the service from the customer’s point of view. It describes a service in enough detail to implement and maintain it carefully. Using the tool of service blueprinting might be of help to get an overview of the needed infrastructure.

**Standard Presentation**

Standard presentation is the process of presenting the content of a topic to an audience.

**STEEPLED (Political, Economic, Social, Technological, Environmental, Ethics and Demographic analysis)**

STEEPLED describes a framework of macro-environmental factors used in the environmental scanning component of strategic management. It is a tool supporting first stage of business modelling process. It is a part of the external analysis when conducting a strategic analysis or doing market research, and gives an overview of the different macro environmental factors that the company has to take into consideration. It is a useful strategic tool for understanding market growth or decline, business position, potential and direction for operations. The growing importance of environmental or ecological factors in the first decade of the 21st century have given rise to green business and encouraged widespread use of an updated version of the PEST framework.

**Strategic Portfolio Management**

Strategic portfolio management is about project prioritisation and resource allocation to achieve new objectives for the company. It is a dynamic decision process where the list of active new products (offerings) and R&D projects (utilisation of capital and human resources) is constantly revised. Strategic portfolio management is about finding and maintaining the right balance between short-term offerings and projects supporting current lines of business, and long-term offerings and projects that create new business. This dynamic process supports decision making in current fast changing environment. This tool is used also for the technology development process.

**Supplier Evaluation Matrix**

The supplier evaluation matrix is used to search for and evaluate possible suppliers (contract partners). In order to make the decision between the possible suppliers or partners it is important to compare their characteristics, like their resources, competences, and commitment related to cooperation.
The Sustainability Accounting Standards Board (SASB) is a US non-profit organization incorporated in 2011 to develop and disseminate sustainability accounting standards. The sustainability standards developed and maintained by SASB are the first industry-based sustainability standards that enable comparable disclosure of a minimum set of material issues—enabling all 35,000 publicly traded U.S. companies to accurately report, benchmark, and improve performance on the ESG issues that are relevant to their specific industry.

**Sustainability Guidelines**

Sustainability Guidelines lead from product orientation to PSS orientation and inclusion of sustainability aspects. They are used to cover the environmental, social and economic dimension to get inspiration for PSS idea development. They consist according Tukker & Tischner (2006) of environmental (system life optimization, mobility reduction, resources reduction, waste minimization/valorization, conservation/bio-compatibility), socio-cultural (possibility of customers consuming in a more socially responsible manner, health and safety, living conditions/quality of life, employment/working conditions, equity and justice/relation to stakeholders, respect cultural diversity) and economic dimension (market position and competitiveness, profitability/added value for companies, long-term business development/risk, partnership/co-operation, macro-economic effect).

**Sustainability Impact Calculation Tool (SIC)**

The Sustainability Impact Calculation tool supports in evaluating the sustainability impact across the life cycle and in the selection of sustainable solutions.

**Sustainability Matrix**

The Sustainability Matrix is as an assessment tool, which aims to assess all relevant national, provincial and local plans, policies and programmes (PPPs) implemented in terms of current legislation and/or other initiatives and whether implemented PPPs are, in some measure, contributing to achieving the sustainability objectives. Sustainability matrix can be utilized to evaluate the interests of various stakeholders (key actors – key issues).

**Sustainable Business Model Element Archetypes Typology (SBM Element Archetypes Typology)**

The Sustainable Business Model Element Archetypes Typology describes groupings of mechanisms and solutions that might contribute to building up a sustainable business model, while helping in delivering business model innovation for sustainability. It supports in the transformation of the new sustainable value proposition by providing the selection of groupings and mechanisms. These archetypes are generally only partial solutions for delivering a sustainable business model. While they can be applied in isolation, in many cases several different archetypes may be combined to deliver a complete business model.

**Systems Dynamics (SD)**

System Dynamics (SD) is a methodology and mathematical modelling technique for framing, understanding, and discussing complex issues and problems. It deals with internal feedback loops and time delays that affect the behavior of the entire system.
System Map

System Map is a tool to illustrate business ideas, developed with a focus on PSS. The system map consists of an illustration of the solution idea and a map of the general system organisation. The map of the general system organisation uses icons for actors and processes, furthermore lines to represent material, financial and information flows. Within this map, previously detected threats and opportunities should be considered. With this information and the created map, the project team is able to decide whether the possible new PSS is really interesting for the company.

Strengths, Weaknesses, Opportunities and Threats Analysis (SWOT Analysis)

SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or business venture, industry or marketing evaluation. This tool can support the first stage of business modelling process. According to this method the world is divided into external factors that a firm has to take for granted, and internal factors that a firm can influence. An external appraisal identifies in a firm's environment threats and opportunities that can be transformed into key success factors. An internal appraisal leads to an insight into strengths and weakness of the organisation. From this, a firm's distinctive competences can be identified.

Test Procedures

The Test Procedure is a strict guidance regarding testing conditions. It is designed to describe Who, What, Where, When, and Why by means of establishing corporate accountability in support of the test execution and implementation.

Total Productive Maintenance (TPM)

Total Productive Maintenance is a method for improved machine availability through better utilization of maintenance and production resources. Whereas in most production settings the operator is not viewed as a member of the maintenance team, in TPM the machine operator is trained to perform many of the day-to-day tasks of simple maintenance and fault-finding. Teams are created that include a technical expert (often an engineer or maintenance technician) as well as operators. In this setting the operators are enabled to understand the machinery and identify potential problems, righting them before they can impact production and by so doing, decrease downtime and reduce costs of production. TPM is a management process developed for improving productivity by making processes more reliable and less wasteful. To implement TPM the production unit and maintenance unit should work jointly.

Value Mapping Tool

The Value Mapping Tool supports exploring, mapping and analysing the relationships and exchanges between the stakeholders through mapping the current value, value destroyed and missed and value opportunities. This is carried out to develop opportunities for new sustainable value propositions from a system perspective without being firm-centric. Here, every value can be illustrated for every stakeholder to get an easy overview of changes for each stakeholder. In case cooperation partners for the new service are needed, they can be identified by this value mapping tool as well.
Workshop

Workshops are an educational seminar or series of meetings emphasizing interaction and exchange of information among a usually small number of participants.
9 Reference list


IEC 60300-3-11 (1999).


SAE JA 1012 (2002).


10 Appendix

PSS Sustainability guidelines (Tischner & Vezzoli)

<table>
<thead>
<tr>
<th>A) Environmental dimension</th>
<th>B) Socio-cultural dimension</th>
<th>C) Economic dimension</th>
</tr>
</thead>
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<tr>
<td>System life optimisation</td>
<td>Possibility to consume socially responsible</td>
<td>Market position and Competitiveness</td>
</tr>
<tr>
<td>Transportation/distribution reduction</td>
<td>Health and safety</td>
<td>Profitability/ Added Value for companies</td>
</tr>
<tr>
<td>Resources reduction</td>
<td>Living conditions/ quality of life</td>
<td>Added Value Customers</td>
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<tr>
<td>Waste minimisation/ valorisation</td>
<td>Employment/ working conditions</td>
<td>Long term Business Development/ Risk</td>
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<tr>
<td>Conservation/ biocompatibility</td>
<td>Equity and justice/ Relation stakeholders</td>
<td>Partnership/ Co-operation</td>
</tr>
<tr>
<td>Toxicity reduction</td>
<td>Respect cultural diversity</td>
<td>Macro-economic effect</td>
</tr>
</tbody>
</table>

A – Environmental dimension

A1. system life optimisation

<table>
<thead>
<tr>
<th>Guidelines level 1</th>
<th>priority</th>
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<tbody>
<tr>
<td>Can you offer services for shared use of products/infrastructures ?</td>
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<tr>
<td>Can you add to product/infrastructure offer, services for their maintenance, reparability, substitution ?</td>
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<tr>
<td>Can you add to product/infrastructure offer, services for their technological up-gradeability ?</td>
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<tr>
<td>Can you add to product/infrastructure offer, services for their aesthetic/cultural up-gradeability ?</td>
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<tr>
<td>Can you add to product/infrastructure offer, services for their adaptation to new contexts (sight of use) ?</td>
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A2. transportation/distribution reduction

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<tbody>
<tr>
<td>Can you use infrastructures for digital transfer/access of information ?</td>
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<tr>
<td>Can you seek for partnership enabling long distance activities ?</td>
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<tr>
<td>Can you seek for partnership for local resources use (info/data transfer) ?</td>
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<tr>
<td>Can you seek for partnership for on-site production (info/data transfer) ?</td>
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<tr>
<td>Can you add to product/infrastructure offer, services for their on-site assembly ?</td>
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<tr>
<td>Can you seek for partnership to reduce/avoid products or semi-finished products transportation and packaging ?</td>
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</table>
### A3. Resources reduction

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<tbody>
<tr>
<td>Guidelines level 1</td>
<td></td>
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</tr>
<tr>
<td>- Can you add to energy or material or semi-finished products, support services for their optimal use?</td>
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<tr>
<td>- Can you offer the access/availability to products/infrastructures through payment based on the unit of utility/satisfaction?</td>
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<tr>
<td>- Can you offer collective use of products/infrastructures?</td>
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<tr>
<td>- Can you outsource activities when higher specialisation and technological efficiency of products/infrastructures are available?</td>
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<tr>
<td>- Can you outsource activities when higher scale economies are feasible?</td>
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<tr>
<td>- Can you seek for partnerships aiming at the use/integration of existing infrastructures/products?</td>
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<tr>
<td>- Can you add to product/infrastructure offer design of their adaptation to the context of use aiming at resources optimisation?</td>
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<tr>
<td>- Can you add to product/infrastructure offer design services for their adaptation to use variations of resources requirements?</td>
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</table>

### A4. Waste minimisation/valorisation

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<tr>
<td>Guidelines level 1</td>
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<tr>
<td>- Can you add to product/infrastructure offer, take back services aimed at re-using or remanufacturing?</td>
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<tr>
<td>- Can you add to product/infrastructure offer, take back services aimed at recycling?</td>
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<tr>
<td>- Can you add to product/infrastructure offer, take back services aimed at energy recovery?</td>
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<tr>
<td>- Can you add to product take back services aiming at composting?</td>
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<tr>
<td>- Can you seek for localised alliances/partnership aiming at symbiotic/cascade approach for secondary resources' use?</td>
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</table>

### A5. Conservation/bio-compatibility

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<tbody>
<tr>
<td>Guidelines level 1</td>
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<tr>
<td>- Can you seek for partnership aiming at decentralised renewable/passive energy resources use?</td>
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<tr>
<td>- Can you within services offer introduce products/infrastructure based on non-exhausting/renewable and bio-degradable materials?</td>
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<tr>
<td>- Can you seek for partnership aiming at the use of local non-exhausting/renewable and bio-degradable materials?</td>
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### A6. A-toxicity

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<tbody>
<tr>
<td>Guidelines level 1</td>
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</tr>
<tr>
<td>- Can you seek for alliances with other producers aiming at toxic/harmful resources reuse or recycling?</td>
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<tr>
<td>- Can you add to product/infrastructure/semi-finished products- offer, services for the recovery/treatment of the toxic/harmful emissions they are responsible off?</td>
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</table>

**B – Social-cultural dimension**
## B1. Enable the customer to consume socially more responsible (sufficiency)

<table>
<thead>
<tr>
<th>Guidelines level 1</th>
<th>priority</th>
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</thead>
<tbody>
<tr>
<td>Can you increase your customer’s awareness about Sustainability by new PSS?</td>
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<tr>
<td>Can you offer more individual ways of fulfilling needs in a more socially responsible way, by new PSS?</td>
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<td>Can you enhance the transparency of your offer and how it contributes to Sustainability?</td>
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<tr>
<td>Can you avoid possible social rebound effects of your offer (socially counterproductive effects)?</td>
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<tr>
<td>Can you create enabling platforms/ increase the capacity of your customers through new PSS, e.g., let them participate in the design and production process...</td>
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<tr>
<td>Increase customer’s satisfaction, participation/ involvement, motivation and awareness.</td>
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## B2. Health and safety

(of employees, customers, stakeholders...)

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<tbody>
<tr>
<td>Can you improve health and safety conditions</td>
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<td>- in production</td>
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<tr>
<td>- in use</td>
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<tr>
<td>- in recycling</td>
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<tr>
<td>- in disposal</td>
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<tr>
<td>and generally/indirectly connected with the offer.</td>
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## B3. Living conditions/ quality of life

(customers/users perspective)

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<tr>
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<tbody>
<tr>
<td>Can you fulfill more socially acceptable needs or solve social problems by offering a new PSS?</td>
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<tr>
<td>Can you do “something good” for the individual and the society as a whole, increase welfare on an individual and society level by offering a new PSS?</td>
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<tr>
<td>Can you offer the new PSS with affordable prices for the specific target groups you are aiming at?</td>
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<tr>
<td>PSS may focus much more on the needs and values of customers' e.g., through the possibility to customise PSS offers individually.</td>
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<tr>
<td>PSS may integrate customers directly in the generation of the PSS and by that increase value of the offer and satisfaction of the customers.</td>
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## B4. Employment/ working conditions

(employee perspective)

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<tr>
<th>Guidelines level 1</th>
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<tbody>
<tr>
<td>PSS may create better, more interesting and more secure jobs in PSS delivery compared to product manufacturing.</td>
<td></td>
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<tr>
<td>Can you improve quality of jobs, and secure jobs by new PSS offer?</td>
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<tr>
<td>Will you be able to pay fair wages (regional standards) in the whole value chain of new PSS offer and offer adequate amount of working hours (regional standards)?</td>
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<tr>
<td>Can you increase employee’s satisfaction, motivation, participation through new PSS offers?</td>
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<tr>
<td>Can you offer work in line with the capacity of employees and offer training and personal development if not?</td>
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<tr>
<td>Can you influence also other companies in the value chain to care for good labour conditions, e.g., through new partnerships?</td>
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</table>
### 8.6 Equity and justice
(society/ global perspective)

<table>
<thead>
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<th>Guidelines level 1</th>
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<tbody>
<tr>
<td>Does your new PSS help to avoid negative effects like discrimination and exploitation of people, regions, countries?</td>
</tr>
<tr>
<td>Can you influence also other organisations involved to apply acceptable social standards?</td>
</tr>
<tr>
<td>Can you involve and respect minorities and target groups with special needs, like parents, elderly people, handicapped people, children, singles, illiterate...?</td>
</tr>
<tr>
<td>Do you have any opportunities to support partners in developing countries, e.g. through fair trade, partnership etc.</td>
</tr>
<tr>
<td>Can you help to support democratic structures through your new PSS, e.g. in developing countries?</td>
</tr>
<tr>
<td>Can you help to increase communication and understanding of people through new PSS offers?</td>
</tr>
<tr>
<td>Can you involve stakeholders, NGOs and others in the development of the PSS? Do you understand and listen to their needs and concerns?</td>
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</table>

### 8.6. Respect cultural diversity
(society/ local perspective)

<table>
<thead>
<tr>
<th>Guidelines level 1</th>
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<tbody>
<tr>
<td>Can you increase stakeholder participation and satisfaction through new PSS, e.g. your neighbours, NGOs, the families of your employees’ etc.</td>
</tr>
<tr>
<td>Can you offer them participation in decision making in new PSS?</td>
</tr>
<tr>
<td>Can you also increase their capacity, e.g.</td>
</tr>
<tr>
<td>Can you offer more education and information to stakeholders through new PSS? Take care for honest and adequate information of stakeholders, help to improve their education especially regarding sustainability issues</td>
</tr>
<tr>
<td>Can you use partnerships and synergies with other (stakeholder) organisations, to improve the PSS offer?</td>
</tr>
<tr>
<td>Globalisation is a challenge but nevertheless it is also important to have cultural and regional diversity. Can you support that by new PSS?</td>
</tr>
<tr>
<td>PSS can strengthen the role of local economy because services are created at the same time and often at the same place when and where they are consumed. Can you use this effect?</td>
</tr>
<tr>
<td>Can your PSS offer be adapted to the different regional cultures, does it respect and support regional identity and local structures?</td>
</tr>
<tr>
<td>Can you support cultural identity and diversity, e.g. customise your offer for different target groups?</td>
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<tr>
<td>Can you increase divers aesthetics and beauty through your PSS?</td>
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### C- Economic dimension

### C.1 Market position and Competitiveness

<table>
<thead>
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<th>Guidelines level 1</th>
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<tbody>
<tr>
<td>Can you improve/secure your market situation by a new PSS offer?</td>
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<tr>
<td>Can you develop PSS that are better than the offers of your competitors, e.g... lower prices, better quality, meet customers demands better...?</td>
</tr>
<tr>
<td>Can you fulfil demands of your customers that have not yet been fulfilled?</td>
</tr>
<tr>
<td>Can you gain new customers by offering a PSS?</td>
</tr>
<tr>
<td>If you look at the trends and how the market is developing which PSS will be needed over the long run? Can you offer them already today?</td>
</tr>
<tr>
<td>Can you profit from diversification through a new PSS offer, make business in a new field with new partners, get more flexible, (especially important in saturated markets).</td>
</tr>
<tr>
<td>Can you improve your position in the value chain through new PSS?</td>
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<tr>
<td>Can you improve your image by offering innovative PSS?</td>
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</table>
### C.2 Profitability/ Added Value (companies)

<table>
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<tbody>
<tr>
<td>- Can you make your company more profitable (decrease cost, increase turnover) through new PSS Strategies and therefore increase investor satisfaction/shareholder value etc.?</td>
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<tr>
<td>- By analysing and re-designing the production and consumption system the PSS improvement can be beneficial for all participating actors, not just for manufacturers.</td>
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<tr>
<td>- Can you optimise the value/production chain by offering a new PSS?</td>
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<tr>
<td>- Can you reduce the material elements in the system and therefore pay less for materials and products and increase the immaterial elements in the system, but with a very efficient organisation?</td>
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<tr>
<td>- Can you solve some recycling disposal problems through the new PSS and therefore reduce cost?</td>
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### C.3 Added Value (customers)

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</thead>
<tbody>
<tr>
<td>- Can you save your customer’s money because your offer is cheaper than competitor’s offer and you save also other cost of your customers, like disposal, measures to avoid risks etc. (make sure you mention these effects in advertising).</td>
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<tr>
<td>- Can you offer your customers more material benefit e.g. creating more income, debt/tax reduction, increasing funding opportunities, saving cost...</td>
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<tr>
<td>- Can you offer customers more immaterial benefit, e.g. satisfaction, take negative responsibilities out of his/her hands, offer highly customised solutions that are very valuable for the individual customer etc.</td>
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### C.4 Long term Business Development/ Risk

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<th>Guidelines level 1</th>
<th>priority</th>
<th>H</th>
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</thead>
<tbody>
<tr>
<td>- Can you increase your capabilities to be innovative and react more flexible on changing market trends by introducing new PSS offers?</td>
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<tr>
<td>- Also consider long term trends, when thinking about business development and try to understand how a new PSS offer will make you more flexible.</td>
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<tr>
<td>- Do you have (or know) methods how to measure the success of the PSS on the market?</td>
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<td>- Do you have measures how to learn from the success/problems of new PSS offers and use this knowledge for adaptation of the offer and new business development?</td>
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<tr>
<td>- PSS are often based on efficient information, knowledge and organisation management. Do you have the right skills and experts to manage that? If not where can you find alliances?</td>
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<tr>
<td>- Can you reduce your investment risk?</td>
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<tr>
<td>- Can you avoid to be hit by existing and upcoming legislation by offering new PSS, e.g. avoid product take back and recycling legislation, avoid toxicity problems etc.?</td>
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<tr>
<td>- Can you reduce the risk to damage your image by offering innovative and sustainable PSS, e.g. by...</td>
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### C.5 Partnership/ Co-operation

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</thead>
<tbody>
<tr>
<td>- Can you search for partnership with other companies, organisations and even your customers to improve the PSS offer, or to generate new PSS ideas?</td>
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<td>- Can you use simple and efficient ways to manage partnership and co-operation, e.g. ICT facilities etc.</td>
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</table>
## C.6 Macro-economic effect

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</thead>
<tbody>
<tr>
<td>Can you generate positive economic impacts on communities and regions through the new PSS?</td>
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<td>Can you avoid possible rebound effects of the PSS offer?</td>
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<td>Can you internalise external cost through the new PSS?</td>
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<td>Can you contribute to diverse market structures through new PSS, avoid monopolistic systems?</td>
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