Methods and Tools for Sustainable Development of Products and Services

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1 Introduction

This chapter aims to provide companies with tools and methods for the analysis and optimization of their processes in order to increase sustainability. Based on the development methodology for sustainable solutions presented before, which combine and integrate various management and operational methods and supportive tools, this chapter offers a useful tool and method box for the development of solutions that ensure maximum value of products, services, and processes throughout the complete life cycle. This box enriches all the phases of the methodology for a structured and efficient development process with practical tools assisting as well as implementing a structured development.

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2 Identification of Requirements for Tools and Methods Characterizing Their Applicability for Sustainable Solutions

Before developing new tools and evaluating existing approaches, it is important to identify requirements that tools for a structured and efficient development process for sustainable solutions should fulfill. The most relevant general requirements for tools and methods for a structured and efficient development process are the following:

Time required
The time needed to implement a tool is an important aspect to be considered. In fact, depending on the type of decisions and the willingness to spend time to find an output, some tools could not be a viable option in case availability of decisions makers is limited. The requirement is here that the tools can be used in workshops.

Skills and knowledge required
Some tools could require either specialized knowledge or particular skills to be applied, that is not always owned by a company. If the tool is too complex from this point of view, either external expertise is needed or the tool cannot be used. In our particular case, a tool that does not require a high level of skills and knowledge is preferable.

Data required
Any tool needs a set of input information/data to be used. It has to be noted that the easiness of gathering data could depend also on the specific company/sector where the tool has to be applied.

Availability of the tool
This criterion is meant to specify whether the tool is already available and can be used as it is ("on the shelf") or has to be developed according to the needs of the business modeling process (to be adapted).

Possible use of the tool
Scope of tools can be slightly different when applied to the engineering process. It was observed in some cases (e.g., validation of business model tools) that the tool has to be intended as a set of guidelines, a supporting checklist rather than a tool.

Configuration of the tool
In order to provide accessibility for everyone, the tool should be applicable to different branches and companies. Therefore, a universal framework should be used which simultaneously ensures a configuration possibility, depending on the need of the specific-use case (NaNuMA—"Nachhaltige Nutzungskonzepte für den Maschinen- und Anlagenbau" 2006).

Application-orientated development
In order to guarantee a wide range of practical usage of the tool, requirements from different user groups should be considered. The tool should be practice-orientated

while the advantages of the tool usage are obvious to the user. This is a significant factor for the success of the tool. The application of each step should be easy to understand plus the execution of the single steps should contain only small complexity. An applicable and efficient design of the method and its devices is necessary; this turns out to be an extra challenge as the users normally derive from different business sectors and departments and therefore look differently on products and processes (NaNuMA—"Nachhaltige Nutzungskonzepte für den Maschinen- und Anlagenbau" 2006).

Customer friendliness
The tools and methods should be easily usable for customers; hence, the workings steps are to define clearly with low or moderate complexity. The steps should be clearly arranged. Tools are often not accepted because they fail to address the commercial activities of a company, so the users' interests should be ranked first. The look of the tool also plays a decisive role; the design should be clear and appealing (NaNuMA—"Nachhaltige Nutzungskonzepte für den Maschinen- und Anlagenbau" 2006).

Value Network
Creation of a wide and transparent value network should be generated and exploited including partners from different business sections in order to provide a wide and holistic view on the problem (NaNuMA—"Nachhaltige Nutzungskonzepte für den Maschinen- und Anlagenbau" 2006)

3 Toolbox for the Development Methodology for Sustainable Solutions

The Development Methodology for Sustainable Solutions presented in Sect. 4 in Chap. "Development Methodology for Sustainable Solutions" suggests working with certain tools at different stages and gates in the development process of different dimensions. Below a general overview of the recommended tools is presented categorized by development phases and a compact presentation of the concrete tools. In the overview below, the different tools that are used in the Development Methodology for Sustainable Solutions are separated into the four dimensions—central initiation, conceptual dimensions, operational dimensions, and general use in all dimensions.

Tools for the central initiation

- Value mapping tool,
- Sustainable business model (SBM) archetypes,
- System SWOT analysis, PESTLE/STEEPLED, and Sustainability Continuum,
- Osterwalder and Pigneur Business Model Canvas,

- Global Reporting Initiative (GRI) and Sustainability Accounting Standards Board (SASB),
- Road-mapping,
- Sustainability matrix,
- Strategic portfolio management.

Tools for the conceptual dimensions

- Brainstorming,
- LCC estimation tool,
- Sustainability impact calculation tool (SIC-Tool),
- Scenario management tool,
- FMEA tool,
- Service Blueprinting.

Tools for the operational dimensions

- Balanced scorecard and
- Supplier evaluation matrix.

Tools for the general use in all dimensions

- Maturity assessment model and
- Systems dynamics.

3.1 Tools for the Central Initiation

Value Mapping Tool
This tool assists in stimulating innovation and developing new sustainable value proposition/s, while helping in the analysis and design of sustainable business models through mapping various forms of value and analyzing exchanges from a multi-stakeholder perspective across the industrial network. The value mapping tool is proposed to help companies understand and create new value propositions to support business model design for sustainability.

The objective of business model design for sustainability is to transform destroyed and missed value opportunities into positive new value creation.

The tool is envisaged to have applicability to all business modeling activities, from exploring opportunities for new start-ups, to assisting in redesigning business models for established large corporations. Use of the tool and the design of any workshops to use the tool should be adapted to the size and complexity of the business. For more complex businesses, it may be desirable to focus on specific business units or product lines to ensure the process is manageable. To maximize the potential of the tool, representatives or suitable proxies for each major stakeholder group should participate in the process to solicit broad perspectives on value.

Sustainable business model (SBM) archetypes
This tool supports in the transformation of the new sustainable value proposition by providing a selection of groupings and mechanisms that help in delivering business model innovation for sustainability.

The SBM archetypes describe groupings of mechanisms and solutions that might contribute to building up the business model for sustainability. The notes below summarize the sustainable business model element archetypes along with supporting examples of such innovations in practice. The main aims of the archetypes are to:

- Provide a means of categorizing and explaining business model innovations for sustainability through exemplars.
- Define generic mechanisms for actively assisting the innovation process for embedding sustainability in business models.

The archetypes adapted from (Short et al. 2012) are:

– Maximize material and energy efficiency (i.e., lean low carbon; increase functionality),
– Non-finite benign resources/processes (i.e., renewable energy sources, zero emissions solutions),
– Create value from waste (i.e., Cradle2Cradle; reuse; upcycling),
– Deliver operability rather than ownership (i.e., pay per use),
– Encourage sufficiency (i.e., consumer education; slow fashion),
– Adopt a stewardship role (i.e., fair trade; biodiversity protection),
– Repurpose business for society/environment (i.e., localization),
– Develop scale up solutions (i.e., licensing, franchising).

SBM archetypes supports in the transformation of the new sustainable value proposition by providing a selection of groupings and mechanisms that deliver sustainability

System SWOT analysis, PESTLE/STEEPLED, and Sustainability Continuum
These tools are already available (on the shelf) and have been used in industry. They are included 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.

The *SWOT analysis* is part of the output of SUSPRONET project (Tukker und Tischner 2006). The generic SWOT analysis tool was adapted to include sustainability dimensions and technology and legislation aspects. The objective of the tool is to assist firms in identifying the current and future **s**trengths, weaknesses, opportunities, and threats of the firm (business model) for sustainability.

PESTLE and STEEPLED constitute extensions of the PEST analysis (Political, Economic, Social, and Technological analysis). *PESTLE* includes legal and environmental factors and apart from the previous, STEEPLED adds also education and demographic factors. These are considered as macro-environmental factors that an organization has to take into consideration when studying its business environment.

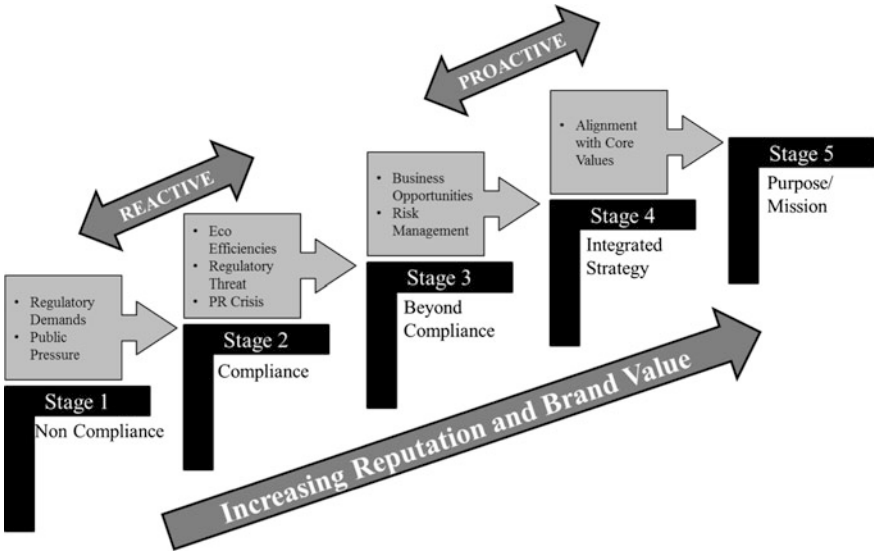

Fig. 1 The corporate sustainability continuum (adapted from Willard 2005)

It is considered as a useful strategic tool and could potentially provide additional support to the scenario management tool in understanding the current and future factors influencing the business environment.

Willard proposed the "*corporate sustainability continuum*" which represents the progress of firms on the path toward sustainability (Fig. 1) (Willard 2005). Hence, it is included in step 1 to help firms in conducting a similar study of current and future path for sustainability, which will potentially be an input to the analysis, carried out in steps 2 and 3.

Osterwalder and Pigneur Business Model Canvas

This tool supports in the coordination and configuration of the key activities, resources, partners and channels, and the value exchanges and value capture for the stakeholders across the network.

Osterwalder and Pigneur's book "Business Model Generation" offers a business model canvas and guide for working through business model conceptualization (Osterwalder und Pigneur 2010). The business model canvas seeks to develop a more generic framework with broad applicability across all industry sectors, utilizing a standardized vocabulary and semantics. Their canvas attempts to capture all the dominant components from the existing literature, and is made up of nine building blocks. Their more recent iteration of the framework renames value configuration and capabilities to give a business ontology of value proposition, customer segments, channels, customer relationships, key resources, key activities, key partnerships, cost structure, and revenue streams (Osterwalder und Pigneur 2010). The canvas places emphasis on defining concrete processes and operational

activities. Hence, it has been selected as a tool to assist in developing the value creation, delivery, and capture mechanisms.

Global Reporting Initiative (GRI) and Sustainability Accounting Standards Board (SASB)

The GRI framework was developed by the United Nations Environment Program (UNEP) along with the Coalition for Environmentally Responsible Economics (CERES) for solidarity in sustainability reporting (Labuschagne et al. 2005). The guidelines cover all three pillars of sustainability—environmental, economic, and social. It is intended to assist firms in sustainability reporting. Some examples of indicators for the three pillars of sustainability are as follows.

- Economic: wages and benefits, job creation, expenditures on outsourcing, research and development, investments in training, diversity, and other forms of human capital; traditional financial information;
- Environment: impact of activities, products, and service on air, water, land, biodiversity, and human health and welfare;
- Social: workplace health and safety, employee retention, human rights and diversity, wages, and working conditions at all company locations and outsourced operations.

The SASB approach includes "a concise and relevant sustainability accounting standards that enable companies to describe material sustainability issues affecting performance and long-term value creation" (Labuschagne et al. 2005). It provides condensed versions of sustainability indices that will potentially prove more manageable and relevant to industry and investors. The focus is on materiality—what really matters in the business. SASB have proposed sector specific sets of indices to reflect the different materiality issues of different sectors. This emphasizes on the link between business model, corporate strategy, and sustainability issues.

Road-mapping

There are several methods used in technology management, of which technology road-mapping (mapping technologies against business and market needs) is one. Road-mapping is a strategic planning tool for forecasting both the critical development needs and the steps required to reach major advances in an area studied (Glenn and Gordon 2009), and it has been defined as an approach for aligning technology and commercial perspective, balancing market pull, and technology push (Phaal et al. 2004). Through technology road-mapping companies gather information from different sources to develop near-, mid- and long-term plans for new product and process developments and R&D investments. In addition to gathering information outside the company, road-mapping tool integrates all levels and functions within a company together into a framework and a common plan. The main idea of technology road-mapping is to identify the technologies that underlie current and planned products and also to highlight the known technology developments, and the elements that will be needed to successfully develop the new product. Thus, it formulates the link between technological resources and the long-term market opportunities and integrates technology developments with

business planning, assessment of the impact of new technologies and market developments. (Shebabuddeen et al. 1999; Petrick and Echols 2004; Phaal et al. 2004). Typically technology road map is a graphical, time-based framework that presents strategic plans, critical elements and paths of the future developments on three layers, which are "technology," "products," and "markets" (Aholy et al. 2010) (Ahlqvist et al. 2010). The strength of the road-mapping approach is in the identification of obstacles, as well as solutions for dealing with these obstacles, and in the generation of shared targets and a common vision of where the company is going (McDowall and Eames 2006; Phaal et al. 2004). Therefore, in addition to integrating technology planning to business planning, technology road maps have been used in corporate strategy work and vision-building (De Laat and McKibbin, de and McKibbin 2003). The authors summarize the benefits of road-mapping into two: road-mapping enables the identification of drivers, bottlenecks and possible applications in a timeframe, and on the other hand the process can function as consensus and agenda-setting procedure.

Sustainability matrix

Sourcing planning can be divided into two main stages: strategic level in which the main task is to set targets to sourcing, and operative level in which possible suppliers are searched and evaluated. Strategic network and stakeholder analyses are an important part of setting strategic objectives for sourcing for sustainability. A sustainability matrix is a tool with which strategic targets and sustainability objectives can be set and coordinated over the boundaries of a company, and with which the diverse interests of involved actors can be evaluated and aligned (SustainValue D3.3 2012).

Sustainability matrix has been modified from corporate social responsibility (CSR) matrix that is an important strategic tool and a conceptual framework that assists managerial decisions by integrating CSR components with organizational stakeholders (Carroll 1991). CSR matrix gives an overview of the degree of importance of key CSR issue and key stakeholder and illustrates the relations between them. Therefore, the matrix includes three dimensions, key issues, key stakeholders, and the importance of each issue to each stakeholder, and thus, the matrix portrays the profile of issues for each stakeholder. With information on the importance that different issues have in regard to different stakeholders, CSR matrix helps in prioritizing CSR strategic actions and makes it possible to analyze the common and conflicting issues for stakeholders (Jansson 2008; Papaloannou and Pettersson 2012). It is a valuable tool for analyzing the strategic situation also in international stakeholder management (Jansson 2008).

In the CSR matrix, the different shading in the cells illustrates the importance of each issue for each stakeholder: the darker the shade of the cell, the more important the issue is for the stakeholder in question. Thus, CSR matrix supports companies in identifying the key issues from the view point of their key stakeholders (see Fig. 14).

Since the institutional settings differ between different situations and companies, so do the key issues and key stakeholders that are depicted in the matrix. Therefore, CSR as well as sustainability matrix needs to be formulated case-specifically.

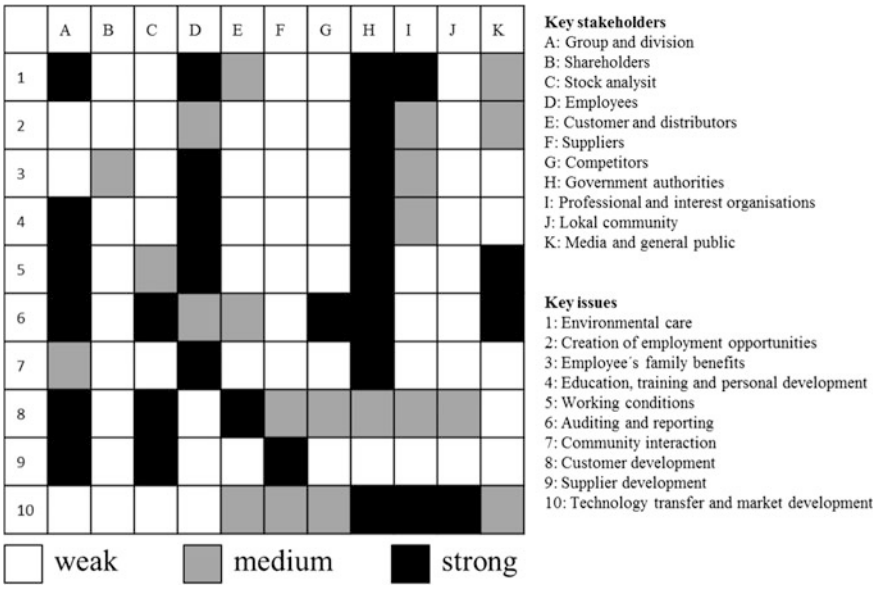

Fig. 2 An example of CSR matrix (adapted from Timlon 2011)

Strategic Portfolio Management

A company has to evaluate project opportunities and make decision how to allocate their resources appropriately to implement their business strategy. Strategic portfolio management refers to the management process that is used to control these portfolio decisions in a R&D company or network.

Cooper et al. (1999) defines portfolio management as a dynamic decision process that consists of revising company's list of current product and R&D projects. This process involves evaluating new and existing projects, selecting or killing projects and prioritizing projects in the company's project portfolio. The portfolio management process is linked to many of the company's decision-making processes. Cooper et al. (2001) define four goals for portfolio management: maximizing the value of a portfolio, seeking the right balance of projects, ensuring that the portfolio is strategically aligned, and making sure you do not have too many projects for limited resources. All in all, portfolio management is about making strategic decisions about markets, businesses, products and technologies, and about resource allocation within a company.

Strategic portfolio management can involve multiple different portfolio management techniques. These techniques can be classified in different categories, such as financial methods, optimization methods, multi-criteria methods, mapping methods, strategic approach, and behavioral approach (Cooper et al. 1999; Cantamessa 2005).

3.2 Tools for the Conceptual Dimensions

Brainstorming
Brainstorming is the best-known and significant representative method of intuitive creativity techniques, which are applied in order to support idea finding in the problem solving process in the business environment (see Eversheim 2008, 53).

Two types of brainstorming are known: traditional verbal brainstorming and electronic brainstorming (EBS) (Dennis et al. 2013, p. 139). The *classic brainstorming* process involves generating ideas by focusing on generating a large quantity of ideas while deferring evaluation until a later session. The assumption is that by generating a large quantity of ideas, there is an increased probability of producing good solutions (Paulus et al. 2013). The *electronic brainstorming* is a new computer-aided technique, which involves group members sitting at computer terminals and typing in their ideas, but also having full access to the others' ideas as they are produced (Furnham 2000, p. 27). EBS involves use of a technology such as e-mail, browser based systems, text-based chat, group support systems, and vendor-specific tools to facilitate the brainstorming process.

Furnham specifies a number of rules which have been developed to ensure that a brainstorming session is properly conducted (Furnham 2000, 22): Group size should be about five to seven people. No criticism is allowed. Freewheeling is encouraged. Quantity and variety are very important. Combinations and improvements are encouraged. Notes must be taken during the sessions. The alternatives generated during the first part of the session should later be edited for duplication and categorizations

The session should not be over-structured by following any of the preceding seven rules too rigidly.

Life Cycle Costing Estimation tool (LCC)
Life cycle costing is the process of economic analysis to assess the total cost of acquisition, ownership, and disposal of a product. The analysis offers important information for the decision making in the product design, development, use, and disposal phases. The LCC tool calculates and estimates the costs and effects of products or solutions during their life cycle. Up to five solutions can be compared simultaneously according to their annual and life time costs. The tool has three main cost categories takes into consideration in estimating the lifetime costs: acquisition costs, use costs, and disposal costs. The acquisition costs include all the costs related to acquisition and installation of the solution. The use costs are annual costs, such as maintenance costs and electricity costs. All costs that relate to recycling of components and materials as well as waste management costs are considered disposal costs.

Because the LCC tool estimates future costs the estimations include some amount of uncertainty. The LCC tool assesses this uncertainty by concluding a sensitivity analyses with Monte Carlo simulation. The simulation performs multiple calculations for situations where the future costs differ from those that were originally estimated.

Sustainability Impact Calculation Tool (SIC-Tool)
Target of the Sustainable Impact Calculation tool is to measure and assess sustainability impacts of products, services, or product service systems on society, environment, and economy. During the development process of new solutions (in form of services, products or a combination of both), a clear transparency of the long-term consequences of these solutions is needed. Even promising ideas which seems to be an improvement regarding sustainability could lead to an unexpected negative impact regarding sustainability. The Sustainability Impact Calculation tool should help to create transparency and gain an overall view of the possible sustainability impacts. Therefore, the three pillars of sustainability were assessed with the help of different KPIs. The underlying idea is that the same input data may be used to calculate impacts in different dimensions: For example, data about energy consumption are affecting costs (economy), but also resource depletion and emissions (environment).

Scenario Management tool
Scenario analysis is a procedure based on the development of different theoretical scenarios. Furthermore, the scenarios will be compared and evaluated toward 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 (D3.3 2012—FIR).

The tool was used to create more transparency of possible future developments regarding possible changes in the environment of the agricultural business. During the usage of scenario analysis tool, all three pillars of sustainability were considered. Economic interests and new market potentials were discussed as well as investigations for some possible technical developments (e.g., Internet connectivity in areas with fewer infrastructures) were organized. The identification and investigation of new environmental benefits through process optimizations were recognized as well. Even social aspects (e.g., guidance and comfort for drivers of harvesters and tractors) were addressed.

FMEA—Tool
FMEA stands for Failure Mode and Effects Analysis. The target of this tool is to improve the reliability of services, products, or processes. Based on the identification of weaknesses, the quality and the security of products, services, and processes should be assessed and improved in a second step. The tool should be used in an early stage of development to detect potential failures before they occur. So the FMEA analysis supports a preventive avoidance of failures. The advantage is that cost can be saved and security issues can be improved. Hence, the economic and social pillar of sustainability can be improved primarily. The FMEA analysis consists of five essential steps. First of all the system or the process must be identified. For the adequate description of the process, the tool Service Blueprinting could be useful. The second step is to define an adequate level of abstraction. After the identification of the main systems (parts, modules or activities), each system must be analyzed regarding weaknesses and potential failures. Each potential failure must be assessed regarding three criteria. The first criterion is the probability of

occurrence. This criterion classifies how often the failure will probably occur. To estimate the probability, a scale from 1 to 10 (improbable to high) quantifies the risk. The same scale is also used for the other criteria which are impact and likelihood of detection. After this risk assessment, the multiplication of the assessments reveals the priority number of the analysis. The last step is the definition of measures which helps to reduce the high priority number. For the three different alternatives are possible. On the one hand, measures have to decrease the probability of occurrence or the likelihood of detection. On the other hand, the impact of possible failures must be reduced with the help of the measures.

Service Blueprinting
The tool service blueprinting is basically a map or a flowchart of all service activities which are necessary to satisfy the customer needs. The tool provides some advantages. First of all, it provides a complete sketch of the service processes which leads to complete transparency of the process. This helps to communicate with other colleague's or division about the service process avoiding misunderstandings. Further, it is possible to identify relevant interfaces and necessary infrastructures. While developing the service processes with the help of the service blueprinting tool, the feasibility and the identification of potential failures occur automatically. The last mentioned advantage enhances another described method which is called FMEA (the FMEA method is also described in this document of D3.4). Different processes can be analyzed with the help of the FMEA surfaces after the first draft of the service process. The tool should be used in an early stage of development to detect potential failures before they occur and to get transparency of the process. With the help of a special structure, the processes can be drawn.

3.3 Tools for the Operational Dimensions

Balanced Scorecard
With the BSC, the management of the company can monitor and measure the activities of the company and their consistency with company's strategy. In other words, the BSC is a tool for transforming strategy into actions. The idea of the BSC is to introduce also other than financial aspects in the organization's strategy process (Kaplan und Norton 1992).

The BSC measures organizational performance from four perspectives: financial, customer, internal business process, and learning and growth. The financial perspective indicates if the strategy leads to improvement in economic success. The customer perspective defines the customer and market segments in which the business competes and the measures for the customer value propositions. The internal process perspective identifies the internal business processes that enable the organization to meet the expectations of customers and shareholders. The learning and growth perspective identifies the infrastructure necessary to achieve long-term

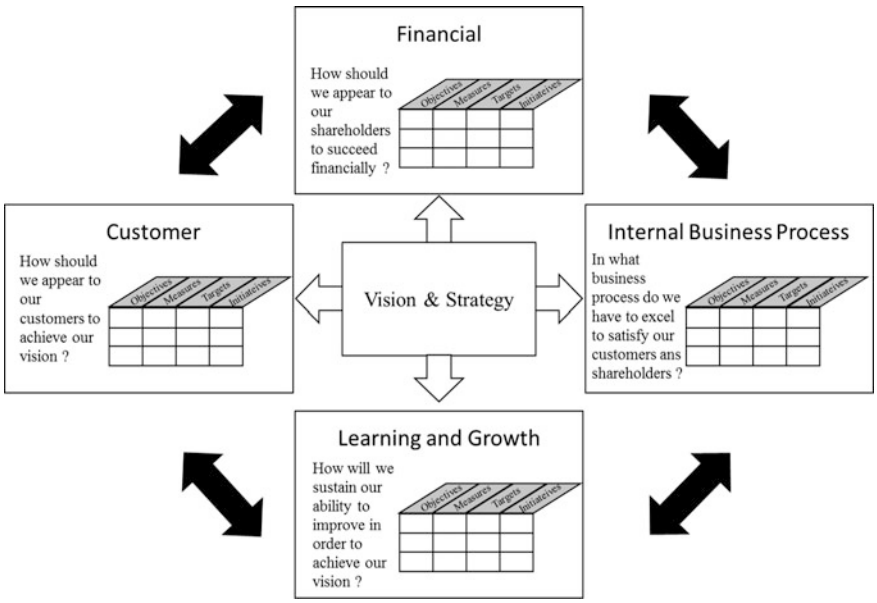

Fig. 3 Balanced Scorecard (adapted from Kaplan und Norton 1992)

growth and improvement. Each of these aspects includes strategic objectives, measures, targets, and objectives as shown in the Fig. 3 (Kaplan und Norton 1992).

The original Balanced Scorecard methodology by Kaplan and Norton has been developed further to match various needs in the modern business environment. One of the developed applications is the Sustainability Balanced Scorecard (SBSC), which adds social and environmental aspects of sustainability to the original framework. The incorporation of these aspects can be done by various different ways (Figge et al. 2002; Nikolaou and Tsalis 2013). According to Figge et al. (2002), there are three different possibilities to integrate the sustainability aspects in the BSC: integrating them in the existing standard perspectives, adding additional perspective, or formulating a special environmental and social scorecard. Nikolaou and Tsalis (2013) introduce a model where the Global Reporting Initiative's GRI guidelines are integrated with the BSC. The indicators from the GRI guidelines are used as indicators for the four BSC perspectives.

Supplier evaluation matrix

In sustainable supply chains, environmental and social criteria need to be fulfilled by members in order to remain within the chain, as it is expected that competitiveness would be maintained through meeting customer needs and economic criteria. As a response, companies have started to introduce different kinds of supplier evaluation schemes (e.g., standards, sets of criteria, supplier self-evaluation) integrating the three dimensions of sustainability criteria. With the evaluation, companies aim not only to avoid risk that can be related to the three dimensions of

sustainability, but also to ensure the product quality and the performance of the operational process (Seuring and Müller 2008). Effectual selection and evaluation of suppliers and promoting their involvement in critical supplier chain activities will result in improved firm performance via enhanced customer satisfaction (Tracey and Tan 2001). Strategic network and stakeholder analyses are an important part of setting strategic objectives to sourcing for sustainability. Supplier evaluation matrix is a tool that can be used especially when a company is defining criteria for, categorizing and finally selecting its suppliers (contract partners). In order to make the decision between the possible suppliers or partners, it is important to compare their characteristics, such as their resources, competences, and commitment related to cooperation and sustainability. The different risk management and purchasing portfolio criteria can also be utilized for this purpose. Supplier evaluation matrix gathers together various contract partner attributes which are ranked on a scale from 1 to 5 and evaluated in case of each supplier candidates.

3.4 Tools for the General Use in All Dimensions

Maturity assessment model

Maturity models normally include a sequence of levels (or stages) that form an anticipated, desired, or logical path from an initial state to maturity (Röglinger et al. 2012). One of the widely discussed maturity models is the Capability Maturity Model Integration (CMMI) which derives from the Capability Maturity Model (CMM) introduced by Paulk et al. (1993). CMM bases on the idea that improvement is done by little steps rather than by radical changes, by focusing on some process areas and by adopting some key practices therein (Macchi et al. 2011). The CMMI is a de facto standard, originally proposed for the maturity assessment in the software engineering domain, soon applied to many other application domains in business development (project management, supply chain management, etc.). Maturity assessment for network conditions and structural elements is a maturity model developed in the Work Package 4 of SustainValue project. The model is a part of the Integrated Assessment Platform for Sustainability Performance in Value Networks framework. The maturity assessment framework is developed on the basis of the CMMI methodology and is used together with the Triple Bottom Line (TBL) assessment to improve sustainability performance in value networks. The maturity assessment model defines process areas (PAs) for the assessment of the intangible elements of network conditions (three PAs) and structural components (five PAs). Each process area includes various attributes and maturity levels for scoring each attribute under evaluation. The structural elements that should be considered in the maturity assessment are strategy and business model, governance, organizational culture, product and service development, and performance management system. These process areas focus on company level and assess the sustainability performance of the core company within a network. The maturity levels for each attribute within the process areas are defined with a

questionnaire developed for the assessment (see SustainValue 2013). The questionnaire includes closed questions for each attributes of the process areas. The answer alternatives consist of practices that determine the maturity score and level of the attribute in question. Each attribute consists of maturity levels from 1 to 5, where maturity level 1 indicates low maturity level and the worst practice and maturity level 5 indicates high maturity level and the best practice. The maturity scores of individual attributes within PAs can be summarized to form an integrated score for each PA. These maturity scores for each PA form the maturity profile of the network conditions and structural elements.

Systems dynamics

System dynamics is a well-known modeling methodology and technique that can be used to support policy analysis and design of complex systems. It applies to a wide variety of processes/systems in the context of different types of environment, dealing with complex social, managerial, economic, or ecological problems. System dynamics might be adopted as a "tool" for different tasks at a planning stage of service development, also having proven capabilities for asset life cycle simulation. Moreover, thanks to its modeling flexibility, it would be used with the purpose to analyze various types of relationships in socio-technical problems (see, e.g., the case proposed by Caulfield and Maj (2002) testing Brooks' Law through system dynamics) encountered with new service ideas under development; this would eventually help providing a quantitative assessment to support tasks at the service planning stage and could be carried on at least by using the best guesses of experts, at most basing onsets of data adequate to support accurate quantitative verifications of future service plans. For what concern system dynamics methodology steps, its analysis normally consists of 5 essential steps. First of all, the system or the process under study must be structured, identifying problems of concern, selecting analysis boundaries, and collecting preliminary information and data. Step 2 of the methodology includes the identification of all the variables of the problem and the development of the influence diagrams, which is composed by casual loops between the variables. At this level, the system description is translated into rate equations of a system dynamics model: Creating the simulation model requires that the tasks of step 1 are completed; if in step 2 some gaps and inconsistencies are revealed, those must be remedied stepping back at the prior phase. This feedback scheme occurs at every step, and it follows the casual loop approach of the system dynamics methodology.

In step 3, often named dynamic modeling, a high-level map or systems diagram, showing the main sectors of a potential simulation model, is developed and all the variables are defined as so-called stock or flow (slang in the system dynamics terminology). Step 4 is then used to test various policies and strategies, for example, changing one or more internal variable, in order to identify key drivers of change, eliminate some uncertainties, and simulate different scenarios. Last, step 5 is for evaluation and implementation of changes tested through simulation; in fact, the model will show how the system is causing the troubles that are being encountered and some possible solutions may be presented and applied.

4 Conceptualization of a Possible Path to Sustainable Solutions

Goal of this section is to enable developers to develop sustainable solutions with applicable tools and methods in a value network. As there hundreds of possible tools, also for sustainability engineering (Forbes et al. 2008), it is not expedient to describe all possible tools that would be applicable. According to the gap analysis, performed in Sect. 2 in Chap. "Development Methodology for Sustainable Solutions", the approach of Tukker and Tischner (2004) was one of the most promising procedures to develop sustainable solutions, with an emphasis on sustainable product service systems. In their approach, they describe one "possible path" to sustainability based on 5 steps (Fig. 4). Each of these steps represents main tasks and tools which help to develop sustainable product service systems.

This approach is used as a basis to show a possible development path in the development framework (see Fig. 5 and Sect. 4 in Chap. "Development Methodology for Sustainable Solutions" for details of the development framework).

The work done in the previous sections and the description of useful tools for development of sustainable solutions will be used to provide a guideline for companies and value networks to develop sustainable solutions.

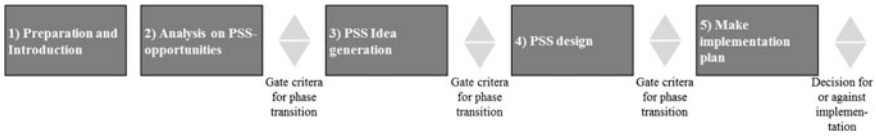

Fig. 4 Five steps of PSS development processes (adapted from Tukker and Tischner 2004)

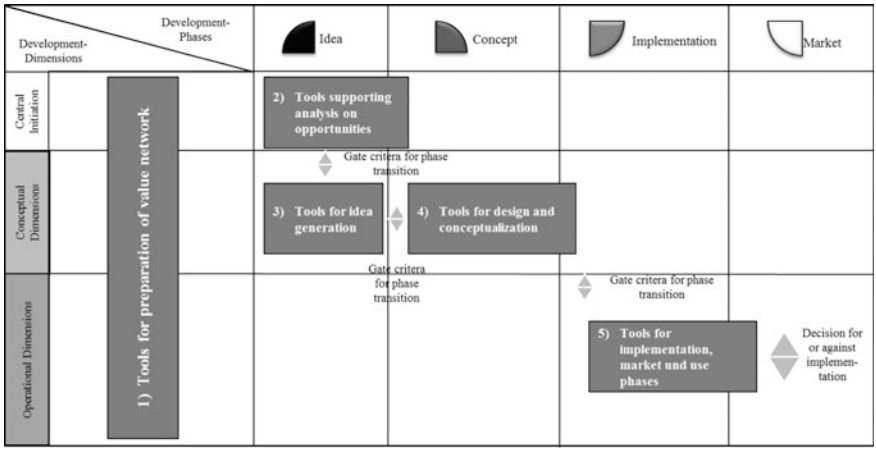

Fig. 5 Steps and tools enhancing the development framework for sustainable solutions

5 Guideline of a Possible Application of Tools

This guideline shall help a developer in a company or value network to develop sustainable solutions based on a possible path and application of relevant tools. Together with the methodologies described in the development framework it allows a holistic development of sustainable solutions. According to Fig. 5, following steps for the guideline are presented:

- Tools for preparation of value network,
- Tools supporting analysis on opportunities,
- Tools for idea generation,
- Tools for design and conceptualization,
- Tools for implementation, market, and use phases.

5.1 Tools for Preparation of Value Network

In the first step, a project plan and a team of the value network should be set up. In particular, it is important at this step, that the relevant stakeholders of the value network and possible users of the sustainable solution are considered during the team setup. The preparation can be initiated from any participants in the value network. Most suitable for an initiator would be a company that will have most stakes in the project. The initiator would invite experts and stakeholders (internally and externally) to discuss the goals and project circumstances. In this step, project planning tools that allow collaborative work shall be used.

Besides this step, the team members should familiarize with the SustainValue project outputs to fully understand the potentials, pitfalls, and possible methodologies leading to sustainability.

5.2 Tools Supporting Analysis on Opportunities

As a first step, priorities have to be made to decide which areas and markets will be most interesting and promising to develop a sustainable solution in. This step often goes along with the step to analyze the current value network and the clients need to identify possible opportunities to be more sustainable. Here, a strategic thinking with holistic tools is necessary to support a sufficient perspective on sustainability that covers all life cycles and stakeholders. In the SustainValue project, many tools have been developed, used, and tested supporting these two first steps.

5.3 Tools for Idea Generation

Finding promising ideas is the next step toward creating new sustainable solutions. Based on the approaches described in Sect. 3, the team of stakeholders should work out ideas. The goal is to find as many ideas for sustainable solutions as possible without rejecting any ideas. The evaluation and elimination would take place in a defined procedure later on.

Different tools can be used to generate ideas:

- Tools from the SustainValue project

– Value mapping tool to recognize sustainable opportunities.
– System SWOT analysis, PESTLE/STEEPLED, and Sustainability Continuum.
– Brainstorming supports the generation of new and independent ideas.
– Scenario management tool helps analyzing the different ideas and scenarios found in the brainstorming process,
– Sustainability Impact Calculation Tool (SIC-Tool),
– Maturity assessment model may help to assess ideas for their industrial and sustainable applicability.

- Additional tools (Tukker und Tischner 2004).

– Creativity tools such as Brainstorming, Brainwriting, Roadmapping for finding ideas.
– Sustainability guidelines for supporting the creativity tools.
– An Innovation Matrix for evaluating the most relevant ideas.
– Archetypical models for new value creation.

Describing the ideas is the next important sub step. The name, a short list of key product and service elements, and a design plan sketch of the system should be documented in a simple form. Beside the descriptive information, it is important to create a sustainability rating for every idea to make a comparison possible. The rating should be divided in the three dimensions of sustainability. Answering the questions by rating the product (1 = better, 0 = equal or −1 = worse) helps creating a unique score for each idea (Tukker und Tischner 2004).

Economic/profit aspects

- How profitable/valuable is the solution for the providers (can be a consortium of companies), including cost of product ion, cost of capital and market value of the solution for the provider(s)? Is it cheaper to produce than the competing product?
- How profitable/valuable is the solution for customers/consumers? Are there any concrete, tangible savings in time, material use, etc. for the customer? Does it provide priceless, intangible added value like esteem, experiences for which the customer is willing to pay highly? (both in comparison to a traditional product system).

- How difficult to implement and risky is the solution for the providers? Can a promised result be measured and delivered with a high probability, or has the client a high and uncontrollable influence on the costs? When is the return on investment expected?
- How much does the solution contribute to the ability to sustain value creation in the future? Does it give the consortium that puts the PSS on the market now and in the future a crucial and dominant position in the value chain?

Environmental/planet aspects

- How good is the solution in terms of material efficiency (including inputs and outputs/waste)?
- How good is the solution in terms of energy efficiency (energy input and recovery of energy without transportation)?
- How good is the solution in terms of toxicity (including input/output of hazardous substances and emissions without transport)?
- How good is the solution in terms of transport efficiency (transportation of goods and people including transport distances, transportation means, volume, and packaging?

Social/people aspects

- Does the PSS contribute to quality of work in the production chain (environment, health, safety; enriching the life of workers by giving learning opportunities, etc.)?
- Does the PSS contribute to the "enrichment" of life of users (by giving learning opportunities, enabling, and promoting action rather than passiveness, etc.)?
- Does the PSS contribute to intra- and inter-generation justice (equal wealth and power distribution between societal groups, North–South, not postponing problems to the next generation, etc.)?
- How much does the solution contribute to respect of cultural values add cultural diversity, e.g., customized solutions, contributing to the social wellbeing of communities, and regions (cultural values)?

5.4 Tools for Design and Conceptualization

After generating and evaluating the ideas, the design and conceptualization phase begins. The aim is to develop the idea further from a simple sketch to a detailed description of the product. The first substep is to design the new system structure and to work out the detailed design of the system, how actors interact and how elements in the system fit together. Therefore, the team can utilize following tools (Tukker und Tischner 2004).

- LCC Estimation tool for giving a feel of the life time costs of the solution.
- Sustainability Impact Calculation Tool (SIC-Tool) helps rating the solution regarding its sustainability.
- FMEA—tool helps avoiding failure in the design process.
- Service Blueprinting enables developers to visualize their ideas.
- Supplier evaluation matrix supports the process of finding reliable and sustainable business partners.
- Sustainability guidelines for supporting the design process.
- Draft system map for new system.

– Map activities and material flows.
– Map information flows.
– Map financial flows.

- Interaction story board for visualizing the points of interaction between the actors.
- Stakeholder motivation matrix compares the advantages of different stakeholders working together.

5.5 *Tools for Implementation, Market, and Use Phases*

After specifying the design and concept of the sustainable solution, the stakeholders have to work out an implementation plan. Therefore, they can make use of a list containing implementation issues related to the go/no-go criteria from the previous phase. If a feasible solution strategy for every implementation issue mentioned is found, the project can move to the next sub step. Before decision making for or against the project, the team should prepare a management presentation that includes every issue regarding the project and summarizes a business plan. Important contents of the presentation are (Tukker und Tischner 2004):

- A striking name (see description of sustainable solution idea documentation).
- Simple visualization that shows the advantages of the project in one image.
- Brief description (see description of idea documentation).

– Description of the context of the strategy (including the following points to consider).
– What is the purpose?
– Which customer segment?
– Why the change? What will it yield? Why is it recommendable?
– Why does it fit in with the company, what policy does it fit in with? Marketing Mix.

- Marketing Mix

– Product service description: Brief description of the solution.
– Price: What pricing strategy will you adopt to reach the customer segment?
– Promotion: How are you going to let customers know what you are supplying?
– Place (sales channels): How are you going to sell the sustainable solution (via Internet, directly to the customer, call centers).

- Expected result regarding financial, customer and brand issues

– What do you expect from this strategy in terms of: turnover, profit, market share, value creation, return on investment, customer loyalty, brand awareness, promotion, positioning, etc. (as far as possible give specific and concrete results).

- Advantages and Risks of the solution

– Primary target group: Briefly describe the primary target group in the customer segment.
– Positioning: What Unique Selling Points does the solution add?
– Creative Approach: In what creative way will you target the market (what is the key to success?)
– Drivers and obstacles: Which drivers promote the new solution, which risks and difficulties do you have to overcome? What does the success of the strategy depend on? What are the bottlenecks and uncertainties?

- The Investment needed

– What is needed to implement the strategy and to neutralize uncertainties and bottlenecks in terms of money, people, resources, time, R&D, strategic alliances, etc. Demonstrate what the new strategy will mean for the company.

- Next steps toward implementation including timing, needed actors.

At the end, the management should have enough information to be able to make a decision for or against the sustainable project.

6 Conclusions

The review of literature as well as the engineering practice to date reveals a lot of methods and tools that assist organizations to develop and optimize their business processes. Nevertheless, due to actual economic, environmental, and societal challenges, economic agents are confronted with the necessity to increase the sustainability of their products and processes. 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. Thereby, a useful tool and method box, which allow the development of sustainable solutions and processes, are lacking.

Hence, the main achievement of this chapter is a detailed toolbox, which companies can use by implementing the development methodology for sustainable solutions developed in this project, respectively, by analyzing and optimizing their processes in order to increase the sustainability. The identified tools corresponding to the requirements from the project context were categorized according to the structure of the methodology: central initiation, conceptual dimension, and operational dimension. A separate category of tools includes tools and techniques for the application in all dimensions.

Additionally, this chapter shows a possible development path and the suitable tools for application, which can be used as a guideline for companies and value networks to evaluate and optimize their current business processes. Together with the methodologies described in the deliverable Sect. 4 in Chap. "Development Methodology for Sustainable Solutions" the presented toolbox helps "a developer" in a company or value network to develop sustainable solutions.

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