Framework for Sustainable Value Creation in Manufacturing Network —

Struktur für eine nachhaltige Wertschöpfung in der Fertigung

Cadre pour la création de valeur durable dans la fabrication

ICS:

Descriptors:
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Foreword

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties on 2013-12-10, the constitution of which was supported by CEN following the public call for participation made on 2013-05-13.

A list of the individuals and organisations which supported the technical consensus represented by the CEN Workshop Agreement is available to purchasers from the CEN-CENELEC Management Centre. The following organisations officially took part to the development of this CWA:

- Center for Industrial asset management, University of Stavanger
- CLAAS
- Elcon Solutions Oy
- FIDIA S.p.A.
- Institute for Industrial Management at RWTH Aachen University (FIR)
- Politecnico di Milano
- Riversimple
- University of Cambridge
- VTT Technical Research Centre of Finland

Furthermore for the accompaniment of the development process of this CWA was also acknowledged

- CEN European Committee for Standardization (CEN-CENELEC Management Centre)
- DIN German Institute for Standardization: Secretariat

The formal process followed by the Workshop in the development of the CEN Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN-CENELEC Management Centre can be held accountable for the technical content of the CEN Workshop Agreement or possible conflict with standards or legislation. This CEN Workshop Agreement can in no way be held as being an official standard development by CEN and its members.

The final review/endorsement round for this CWA was started on 2012-12-04 and was successfully closed on 2013-12-10. The final text of this CWA was submitted to CEN for publication on 2013-12-13.

This CEN Workshop Agreement is publicly available as a reference document from the National Members of CEN: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom. Comments or suggestions from the users of the CEN Workshop Agreement are welcome and should be addressed to the CEN-CENELEC Management Centre.
1 Scope

The current trans-national manufacturing product and service delivery solutions cannot be sustained in the emerging eco-sensitive business environments, where growing trade volumes and commercial operational patterns impose significant environmental and social challenges on companies and society. More specifically, increase in international trade and transport of raw materials, energy, intermediate products and services, wider range of stakeholders engaging with industry, resource limitations and emphasis on social responsibilities of companies has raised the need for businesses to integrate sustainability more fully into their purpose and processes. The challenges related to sustainability include social and environmental concerns such as labour practices, community involvement, waste and packaging, climate change and partnerships, further propagated by demand, global competition, consumer preferences and behaviour.

Manufacturing includes production and wider industrial activities across the value network that involves interdependencies and relationships amongst stakeholders. The European "Vision for 2020" report calls for understanding manufacturing as a network of complex and development-oriented relations. Hence, the constant evolution of manufacturing networks - coordination and cooperation between the capabilities and configurations - become vital for growth. External (macroeconomic stability, trade policies) and internal forces (process innovations, cost benefits, competition, corporate culture, organisational structure) have both led companies to change production systems and locations to maximize benefits. The expansion of manufacturing operations/activities and the changing business environment, which affects the wider society and environment, highlight the requirement for manufacturers to look for new approaches to manage sustainability impacts effectively – from sourcing and production, to distribution, product logistical support and afterlife.

The increasing demands for sustainability have created new challenges as well as emerging opportunities for society and business. In the current manufacturing setting, much of the opportunity to address novel challenges rests on the ability to manage complex value networks for sustainable value creation. Sustainable value creation is the key contribution of business to sustainability, i.e. to create long-term sustainable (social, environmental and economic) value. However, individual businesses, alone, will not be able to deliver sustainable value and the changes required at the value network level. Collaboration among stakeholders across the network to deliver sustainable value is necessary to develop common approaches for sustainable production and services.

Companies have begun to look for new approaches to understand and manage sustainability at the value network level. If the network partners are not capable of managing the future challenges around regulation, reporting and compliance assurance, scarcity of resources, then the ability to manage business risks and opportunities could be dramatically affected with serious impact to the business. Companies need to be pro-active in thinking about the opportunities that the sustainable economy will present. This will need firms to develop new products and markets and optimise their value networks for sustainability.

Thus the CEN Workshop Agreement (CWA) “Framework for Sustainable Value Creation in Manufacturing Networks” covers Good-practices for developing business models, governance models, sustainable solutions and performance management for existing and new sustainable production and service networks.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Definitions often attempts to be very precise, thus they may capture the concept in question rather narrowly. By reading several definitions for the same concept, a richer understanding of the concept may be obtained. In the definitions below, the preferred definition is stated, but in some cases alternative definitions are included as notes.

2.1 Accountability
is a state of being answerable for decisions and activities to the organisation’s governing bodies, legal authorities and, more broadly, its stakeholders
2.2 Business architecture
is conceptualised to structure the responsibility over business activities prior to any further effort to structure individual aspects (processes, data, functions organisation, etc.) [2]

2.3 Business ecosystem
is the network of organisations – including suppliers, distributors, customers, competitors, government agencies and so on – involved in the delivery of a specific product or service through both competition and cooperation

EXAMPLE The idea is that each business in the "ecosystem" affects and is affected by the others, creating a constantly evolving relationship in which each business must be flexible and adaptable in order to survive, as in a biological ecosystem [3]

2.4 Business model architecture
is a common understanding of the company organisation considering the value stream from a strategic viewpoint to high level description of business processes

NOTE Such a common understanding is a mechanism to support transformational changes within the company.

2.5 Business model
is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific company or a company network

NOTE Therefore it has to be considered which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences [4].

2.6 Business model elements archetypes
are common patterns within one element

EXAMPLE It is common to have a web-based B2C channel.

2.7 Business model elements
are the components that join together to describe a business model

2.8 Business model innovation
involves changing "the way you do business", rather than "what you do" and hence must go beyond process and products [5]

2.9 Business model innovation for sustainability
is defined as the process of re-defining the core purpose and how the firm delivers aligned economic, social and environmental sustainability

NOTE Innovations that change the value proposition (create positive benefits, or significantly reduce negative impacts) for the environment and/or society, through changes in the way the firm and its value-network create and deliver value, and make money from delivering value [6].

2.10 Business modelling
is the process of systematically analysing or developing the elements of a business model
2.11 **Business modelling framework**
A process/tool for assisting in analysing or developing a business model

**EXAMPLE** Osterwalder and Pigneur Canvas

2.12 **Capability matching**
Describes the ability to deploy resources and abilities of organisations for collaborative purpose

2.13 **Carbon footprint**
An indicator of total greenhouse gas emissions caused by an entity

Note 1 to entry: It is the overall amount, expressed in terms of CO2 equivalents, of carbon dioxide and other greenhouse gas (GHG) emissions associated with a product, using LCA methodology.

Note 2 to entry: A carbon footprint is only one ecological footprint; other indicators include e.g. water footprint and services footprint.

2.14 **Corporate social responsibility (CSR)**
Is the continuing commitment by business to behave ethically and contribute to economic development while improving the life of workforce and their families as well as the local community and society at large [7]

2.15 **Environment**
Surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation

Note: Surroundings in this context extend from within an organisation to the global system.

**SOURCE:** ISO 14001:2004, Environmental management systems - General guidelines on principles, systems and support techniques [8]

2.16 **Framework**
Structure expressed in diagrams, text and formal rules which relates the components of a conceptual entity to each other


2.17 **Key Performance Indicators (KPIs)**
Represent a set of measures focusing on those aspects of organisational performance that are the most critical for the current and future success of the organisation [10]

2.18 **Life cycle assessment**
Compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle


2.19 **Life cycle costing**
Represent cumulative cost of a product over its life cycle
2.20 Maturity
Maturity can be seen as an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired or normally occurring end stage [13]

2.21 Maturity model
Maturity model can be defined as staged roadmaps for assessing the capabilities of a company/organisation with respect to a specific management domain [14]

2.22 Methodology
Methodology represent a set of instructions (e.g. provided through text, computer programs, tools) that is a step-by-step aid to the user


2.23 Network
Network is a group of three or more organisations connected in ways that facilitates achievement of a common goal [16]

2.24 Organisational governance
Organisational governance is a system by which an organisation makes and implements decisions in pursuit of its objectives

[SOURCE: ISO 26000:2010-11, Guidance on social responsibility] [1]

2.25 Performance management
Performance management is defined as the process of analysing performance-related information (generated through performance measurement), making decisions based on this information, planning and implementing actions to improve or maintain the state of performance, and feeding back information intended to improve the process of performance measurement

2.26 Performance measurement
Performance measurement describes the process of acquiring performance-related data through a given set of measures and generating information by relating the data to a specific context

2.27 Product life cycle management
Product life cycle management is the process of managing the entire lifecycle of product from the design, production, support, and use to final disposal [17]

2.28 Product Service System
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 [18]

2.29 Social responsibility
Social responsibility can be described as a responsibility of an organisation for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour that - contributes to sustainable development, including health and the welfare of society; - takes into account the expectations of stakeholders; - is in
compliance with applicable law and consistent with international norms of behaviour; and - is integrated throughout the organisation and practised in its relationships

Note 1 to entry: Activities include products, services and processes.

Note 2 to entry: Relationships refer to an organisation activities within its sphere of influence.

[SOURCE: ISO 26000:2010-11, Guidance on social responsibility] [1]

2.30 Stakeholder
are an individual or group that has an interest in any decision or activity of an organisation

[SOURCE: ISO 26000:2010-11, Guidance on social responsibility] [1]

2.31 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

NOTE Sustainability has an economic, an environmental and a social dimension.


2.32 Sustainable business model
is the value logic that encompasses economic, environmental and social goals while aligning the interests of all stakeholder groups

2.33 Sustainable manufacturing
is the ability to smartly use natural resources for manufacturing by creating products and solutions via a network of suppliers, partners and collaborators that due to new technologies, regulatory measures and coherent social behaviour are able to satisfy sustainability - economical, environmental and social objectives

[20]

2.34 Sustainable manufacturing network
is an organisational form which (i) targets to gain future competitive edge to all participants through interaction and collaboration, and thereby (ii) is able to balance the three key aspects of sustainability (environmental, economic and social aspects)

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

2.36 Sustainable value
is perceived to be generated from embedding economic, social and environmental sustainability into firms

Note 1 to entry: Sustainable economic value: Profit, ROI, Growth, Financial resilience and Long-term viability

Note 2 to entry: Sustainable environmental value: Resource use no greater than rates of regeneration and renewal, Emissions and waste levels within the ability of the environmental to metabolise safely, Protection of bio-diversity and positive benefits for the environmental to counter past excess
Note 3 to entry: Sustainable social value: Poverty alleviation, Community development, Social equality, Health and safety and long-term meaningful employment

2.37
**Triple Bottom Line**
is a concept which considers a balance between economic, environmental and social issues in organisations [21]

2.38
**Use Case**
is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially the boundaries between phenomenon and context are not clearly evident [22]

2.39
**Use Case Scenario**
is a description that illustrates, step by step, how a is intending to use a system, essentially capturing the system behaviour from the user's point of view

NOTE A use case scenario can include stories, examples, and drawings [23].

2.40
**Value chain**
is the entire sequence of activities or parties that provide or receive value in the form of products or services

Note 1 to entry: Parties that provide value include suppliers, outsourced workers, contractors and others.

Note 2 to entry: Parties that receive value include customers, consumers, clients, members and other users.


2.41
**Value**
is the set of benefits derived by a stakeholder from an exchange

2.42
**Value network**
generates economic [environmental and social] value through complex dynamic exchanges between one or more enterprises, customers, suppliers, strategic partners and the community [24]

3 List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>B2C</td>
<td>Business to Customer</td>
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<tr>
<td>CEN</td>
<td>European Committee for Standardization</td>
</tr>
<tr>
<td>CSR</td>
<td>Corporate Social Responsibility</td>
</tr>
<tr>
<td>CWA</td>
<td>CEN Workshop Agreement</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and communication technology</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardization</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
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<tr>
<td>LCA</td>
<td>Life Cycle Assessment</td>
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</table>
4 Sustainability governance in manufacturing networks and the governance model

4.1 Introduction

Since manufacturing activities are presently organized through networked processes, effective and appropriate network governance is needed in order to ensure sustainable development and performance. As networks consist of independent actors with their own targets and decision-making models, the main differences between company and network governance models are related to legal aspects, decision making processes and control mechanisms. Network governance is necessary for ensuring that participants engage in collective and mutually supportive action, that conflict is addressed, and that network resources are acquired and utilized efficiently and effectively. Governance involves the use of institutions and structures of authority and collaboration to allocate resources and to co-ordinate and control joint action across the network as a whole [25].

Sustainable value integrates economic, social and environmental goals, and therefore, from a network perspective, the scope of a company needs to go beyond customers, immediate partners and shareholders, and consequently consider relationships, exchanges and interactions [26]. Sustainability governance at network level should enable clear identification of network actors and stakeholders, who are influencing and can be influenced by the sustainability of products and services during their life cycle. The interests of the main actors of a network (lead producers, their suppliers and customers) need to be considered. In addition also the interests of other involved actors (external stakeholders) need to be taken into account. Sustainability governance requires also tighter collaboration with the various stakeholders.

4.2 Methodology and tools

The model [27] presented here illustrates the sustainability governance within a manufacturing network as a process that guides the activities of all involved actors toward sustainable development and performance over product life cycle. The Sustainability governance model consists of three main tasks that are analysing, organising, and developing (illustrated in Figure 1). These tasks are in accordance with company-level approaches but highlight the need for multilevel network governance. The governance model illustrates a process that integrates i) requirements and commitments of stakeholders within the manufacturing networks as well as ii) business models and the self-interest of manufacturing network companies. At the manufacturing network level the common targets guide the joint development work.
The governance model process begins with the analysing task. In the analysing task, in order to guide the activities of involved actors toward the sustainability objectives, companies must first determine the key players in the manufacturing network and the boundaries of the business model. Therefore, the network analysis requires visualisation of the connections (business relationship, ownership, etc.) between the actors. Also, in order for the network-members to understand the network’s value for each member, the objectives, interests, and expectations of each should be covered. Consequently, it is important to assess the requirements and expectations of the stakeholders. On the basis of these analyses, companies are able to identify sustainability impacts over the product life cycle and the requirements imposed for the actors involved.

In the organising task, the analyses of involved actors, their requirements, and the total impact direct the organising and management of sustainability at network level. Shared targets and collaboration models are formed both inside the manufacturing network and with respect to other stakeholders within the business ecosystem. Alignment of business models and integration of processes in accordance with the sustainability objectives should be carefully considered. Exploring the business models of all actors is important also in order to ensure their commitment to network and common targets that have been set. Different collaboration models are required for different situations, for example, the sustainability objectives should be considered when one is deciding with whom to collaborate and how.

In the developing task, in order to ensure continuous improvement as well as renewal, progress should be evaluated via shared indicators and new targets should be transparent, based on the achievements. Actors will be able to renew actions, operations, and business models together in pursuit of sustainability goals and sustainable manufacturing network. Thus also the future structure and performance of network is shaped by all involved actors, and also governing the network level activities is more or less self-organized and emerging.

4.3 Recommendation for use

Sustainability should be integrated into companies as well as networks’ core strategies. The sustainability governance model presented serves this purpose and can be utilised for supporting the alignment of business models and processes with sustainability objectives. The model supports management in analysis and decision-making related to strategic collaboration for sustainability. The workbook “Towards sustainability
governance in manufacturing networks* offers various methods and tools on network-level co-development and also network-level case examples of their use. The workbook describes the network governance process and the relevant tools so that they are of help to businesses that want to be more sustainable and that want their network partners to develop alongside with them [27].

5 Sustainable business modelling

5.1 Introduction

This chapter of this CWA is about sustainable business modelling process and toolset. The objective of this document is to provide companies of varied scale/size (start-ups, SMEs, MNCs) and industry with guidance on developing sustainable business models.

The following sections will provide a brief overview of the process and toolset, which were described in various deliverables and publications of the FP7 project called "SustainValue".

5.2 Methodology and tools

The premise for the research carried out is the recognition that for industry to address sustainability challenges, such as the impact of climate change, threat of resource limitations, concerns over economic stability and growing public pressure for socially responsible business, a significant shift in the way businesses are conceived and operated to generate sustainable value (environmental, social and economic) will be required. Business model innovation and redesign is essential in generating real (long-term, multi-dimensional) sustainable value. Hence, to integrate sustainability into the core of the business a comprehensive consideration of the broader range of stakeholders across the system is necessary to rethink the value proposition of the company for society. This requires design and development of process and tools that explicitly include a multi-stakeholder view of value, which is integral towards business model innovation for sustainability. Hence, the SBM process and the portfolio of tools were developed with the aim to assist companies to deliver sustainable value (social, environmental and economic) through business model innovation and redesign for sustainability.

5.2.1 Sustainable business modelling process

The SBM process below [28] consists of five steps and each step is accompanied by a selection of tools that will assist companies in understanding and delivering sustainability. The proposed process considers network-centric perspective towards addressing sustainability [28]. It is an iterative process, in that as changes occur in one step it not only impacts on the following step but also on the preceding ones and occurs over a period of time.
Figure 2 — SBM process

Step 1
Purpose and objective of the business: setting the scene

Step 2
Identify potential stakeholders and select sustainability factors

Step 3
Idea generation: explore and develop new opportunities for sustainable value proposition

Step 4
System level change: business model/solution selection

Step 5
Configure and coordinate: define and develop the value creation and delivery system, and the value capture mechanism
Table 1 — Explanation

<table>
<thead>
<tr>
<th>Steps</th>
<th>What does it mean?</th>
</tr>
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<tbody>
<tr>
<td>Step 1</td>
<td>This step is about ‘setting the scene’. It involves developing an understanding of the rationale of the business and its values, whilst identifying the company’s position and drivers for engaging in sustainability, along with anticipated threats and opportunities for environmental and social sustainability.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Identify stakeholder types in the value network/s and broader sustainability priorities that will assist in exploring the new sustainable value proposition. The previous step on understanding the business purpose and current and future position on sustainability helps towards determining sustainability priorities. Additionally, in this step the challenges and priority areas for sustainability can be identified along with stakeholders with whom engagement needs to be established.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Generate a new sustainable value proposition towards designing a sustainable business model with focus on the value network. This step is concerned with understanding and analysing various forms of value across the network to develop the new sustainable value proposition.</td>
</tr>
<tr>
<td>Step 4</td>
<td>Transformation and/or development of the value proposition. This step involves the selection of one or a combination of feasible business models or solutions for the transformation of the new sustainable value proposition or propositions (step 3) so as to seek ways/paths to capture opportunities for value creation, while minimising negative value and maximising positive value in the network.</td>
</tr>
<tr>
<td>Step 5</td>
<td>Analysis and design of the value creation and delivery systems, and the value capture for the selection/s from step 4. It includes the identification and potential development of the value delivery and capture system (key activities, channels, resources) for pursuing sustainability whilst analysing the cost incurred through the life cycle to assist in evaluating the options. This step builds on steps 2 and 3 on the understanding of stakeholder value and value exchanges in the network.</td>
</tr>
</tbody>
</table>

5.2.2 Toolset

The following tools have been specifically designed or identified to focus on generating business model innovation for sustainability from a system/network perspective. The tools mentioned below support the SBM process. The following descriptions of the tools are included in reports of the SustainValue project as already mentioned above.

— System SWOT analyses and PESTLE/STEEPLED are proposed for step 1 of the SBM process. They are already available (on the shelf) and have been used in industry. They are included in this step as they support in defining the business purpose, industry-related requirements, norms and opportunities including the company position on sustainability (current and future) and its drivers.

— Corporate sustainability continuum [29] is proposed for step 1 of the SBM process. It represents the progress of a company on the path towards sustainability. It will help companies in reviewing their current and future path for sustainability, which will potentially be an input to the analysis, carried out in steps 2 and 3.
Figure 3 — Corporate sustainability continuum

- Value mapping tool [30] [31] is proposed for step 1, 2 and 3 of the SBM process. This tool assists in stimulating innovation and ideas, whilst mapping various forms of value and analysing changes from a multi-stakeholder perspective across the industrial network for creating new sustainable value propositions.
Scenario management tool is proposed for step 2 and 3 of the SBM process. This tool is included in these two steps as it supports the understanding of the current system (particularly key internal and external factors and forces influencing a company) and identifying requirements for the future that will affect the development and transformation of a novel sustainable business model.

Global Reporting Initiative (GRI) and Sustainability Accounting Standards Board (SABS) are proposed for step 2 of the SBM process. These guidelines are already available (on the shelf) and have been used extensively in industry. Although they serve more as check-lists, it is nonetheless considered helpful in providing guidance for identifying sustainability factors and priority areas.

Sustainable business model element archetypes [32] [6] are proposed for step 4 of the SBM process. This approach supports in the transformation of the new sustainable value proposition by providing a selection of groupings and mechanisms that help in delivering business models innovation for sustainability.
### Table 2 — Sustainable business model element archetypes

<table>
<thead>
<tr>
<th>Maximize material and energy efficiency</th>
<th>Non-finite benign resources / processes</th>
<th>Create value from waste</th>
<th>Deliver functionality rather than ownership</th>
<th>Encourage efficiency</th>
<th>Adopt a stewardship role</th>
<th>Re-purpose business for society/environment</th>
<th>Develop scale up solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Low carbon</td>
<td>Renewable energy sources</td>
<td>Cradle to Cradle, Circular (closed loop) economy</td>
<td>Maintenance, extended warranty</td>
<td>Consumer education</td>
<td>Ethical (fair) trade</td>
<td>Not for profit, Hybrid businesses, Social enterprise</td>
<td>Collaborative approaches (sourcing, production, crowd funding, lobbying)</td>
</tr>
<tr>
<td>Additive manufacturing</td>
<td>Zero emissions solutions</td>
<td>Industrial symbiosis</td>
<td>Rental, lease</td>
<td>Demand mgmt. Cap &amp; trade</td>
<td>Resource stewardship</td>
<td>Social / environmental regeneration</td>
<td>Licensing, Franchising</td>
</tr>
<tr>
<td>De-materialise products / packaging</td>
<td>Eco-minicry</td>
<td>Reuse, up-cycle, remanufacture</td>
<td>Pay per use</td>
<td>Slow fashion</td>
<td>Consumer care</td>
<td>Ease of pyramid</td>
<td>Open innovation (platforms)</td>
</tr>
<tr>
<td>Increase functionality</td>
<td>Green chemistry and slow manufacturing</td>
<td>Extended Producer Responsibility</td>
<td>Private finance Initiative (PFI), DBEIO</td>
<td>Product longevity</td>
<td>Choice editing</td>
<td>Biodiversity protection</td>
<td></td>
</tr>
</tbody>
</table>

— **Sustainability Impact Calculation (SIC) tool** is proposed for step 4 of the SBM process. This tool is included in this step as it supports in evaluating the sustainability impact across the life cycle and in the selection of sustainable solutions.

— **Osterwalder and Pigneur business model canvas** [33] is proposed for step 5 of the SBM process. This tool already available (on the shelf) and has been used by the developers in industry. It supports in the coordination and configuration of the key activities, resource, partners and channels and the value exchanges and value capture for the stakeholders across the network.

**Figure 5 — Business model canvas**

— **Strategic roadmapping tool** [34] is proposed for step 5 of the SBM process. This tool supports the transformation and implementation of the output from the value mapping tool and archetypes (business model/s selection). Such a roadmap plots the identified additions to the value proposition and business model elements on a timeline from the current date to a projected end-point (which could be considered as the long-term sustainability vision).
Life Cycle Cost (LCC) estimation tool is another tool proposed for step 5 of the SBM process. This tool includes in this step as it 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. LCC tool calculates and estimates the costs and effects of products during products' life cycle. With the tool user can compare five different solutions according to their annual and life time costs. This will assist in the development of the creation, delivery and capture of value. The tool is developed for power supply systems but the same approach can be used for any product.

5.3 Recommendation for use

Companies can select and use the tools as per the requirement of their business and its operations. The objective is to assist companies in the analysis and design of future oriented and novel forms of business that will deliver sustainability through a clearly defined sustainable business modelling approach – process and tools.

6 Sustainable solutions development

6.1 Introduction

In this chapter a framework is described which serves companies and value networks to analyse and optimise their processes in order to increase the sustainability of their solutions. 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 company's divisions have the potential to tremendously improve employees' contentedness. Further on, changes in the company's business model, for instance increased striving for ecological sustainability, are also supported by the presented framework. Which aspects 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.

On the whole, it may be asserted that:

The framework is a support to the analysis, communication and optimisation of the business processes, as well as the interfaces between different organisational divisions, with the purpose to increase the sustainability of company and value network offered solutions.

Further on, considering the theory that envisions business strategies, business models and business processes as interlinked elements which approach the same issues but in different business layers and at different organisational levels:

The framework is a tool recommended to help business process optimisation towards sustainability; as a tool, it aims at implementing the innovation required by a (new) business model of a company, while considering all the required organisational interfaces within the company as well as beyond the company's boundaries.

The tacit assumption behind the following elaboration is that sustainability can be realised through changes in any business activity. 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 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 optimise 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.
6.2 Methodology and tools

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 a development of sustainable solutions. In the following chapter 6.2.1 the Development Methodology for Sustainable Solutions will be conceptualized based on the identified requirements and on outlined theory deficits. The concept of this methodology will be called “Development Framework” and will be summarised in chapter 6.2.2. Each element of the Framework will be described in Annex 1 in detail.

6.2.1 Development Process as a Multi-Disciplinary Challenge

In the project SustainValue 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. Furthermore relevant development methodologies have been analysed to characterise necessary requirements. Based upon all found requirements and an understanding of the development methodologies, specific requirements for a development process for sustainable solutions have been methodically described. 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". Furthermore current methodologies of innovation (management) and solution engineering have been compared against the named requirements. This study reveals various methodologies which could be used to support innovation and solutions engineering within manufacturing industry during development activities.

![Figure 6 — Requirement towards sustainable solutions and gap analysis of current methodologies](image)

According to the gap analysis system boundaries must be broadened from an individual company to a value network level, which covers the whole life cycle. The methodologies 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 takes place. Hence, to realise the development on a network level, an interdisciplinary approach with interaction of all involved stakeholders during the development process has to be realised.

According to these conclusions the Development Methodology for Sustainable Solutions should cover several phases of life cycle and the activities of the relevant stakeholders, here called dimensions (see also next Figure 7).
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-services-systems – here called conceptual dimensions. To cover also activities of stakeholders, that act during the life cycle more operationally, and allow also sustainable innovation and development from their perspective, all planning activities have to be regarded in the Development Methodology for Sustainable Solutions – here called operational dimensions. These activities require a multilevel approach to sustainability, in order to understand the self-interests of involved actors and ensure their commitment (see next Figure 8).

Figure 7 — Interdisciplinary approach over the whole life cycle

Each of those activities in the named dimensions will be described with stages and gates, according to the stage-gate-model [35]. 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
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 3).

**Table 3 — Concept of detailed description of the stage-gate model**

<table>
<thead>
<tr>
<th>Method</th>
<th>e.g. Strategy Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage/Gate</td>
<td>Content</td>
</tr>
<tr>
<td></td>
<td>Functions, Responsibilities, Authorities (FRA)</td>
</tr>
<tr>
<td></td>
<td>Interfaces</td>
</tr>
<tr>
<td></td>
<td>Tools (D3.4)</td>
</tr>
<tr>
<td>Stage 1</td>
<td>e.g. Analysis, positioning</td>
</tr>
<tr>
<td>Gate 1</td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
</tr>
<tr>
<td>Gate 2</td>
<td></td>
</tr>
<tr>
<td>Stage ...</td>
<td></td>
</tr>
<tr>
<td>Gate ...</td>
<td></td>
</tr>
</tbody>
</table>

Consequently the Development Methodology for Sustainable Solutions covers stages and gates for every development dimension (see as an example in Figure 9).

**Figure 9 — Example of Stage-Gate-Model for all development dimensions**

Based upon the research 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. Each of them is then included in one of the three above mentioned primary dimensions, being part of either of central initiation, conceptual or operational dimensions:

- Strategy Development
- Business Model Development
For each dimension well established approaches have been identified and partly adjusted. 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. Further, the most innovative part 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 10).

6.2.2 General Development Framework

An innovation can be a new commercialised idea which is significantly better than an earlier solution. Innovation can be related to products, services, technologies, business and organisational models, operational processes, or operational methods. 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 aims at providing a framework flexible to applications 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. In this concern, it is preferable to use, more generically, the framework wording.

On the whole, the main innovations of this all-embracing framework are herein summarised.
The Framework emphasizes all the important connections and interfaces between the different methods and organisational units required for the development of sustainable solutions.

The Framework subdivides each method into specific stages and gates, making it possible to find existing interfaces or to define new necessary interfaces for an improved cooperation, as it would be required in order to reach 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 11 — Development Framework for Sustainable Solutions**

### 6.3 Recommendation for use

This development methodology, also named as “framework”, is supposed to be a tool and a guideline for companies or value networks to evaluate and optimise their current business processes. In this framework, which serves as a rough generalization over prototypic companies, three groups – central initiation, conceptual dimensions and operational dimensions – 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 realise sustainable solutions and to optimise 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 optimise their business processes towards sustainability, starting at any point in their process chain.

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, but also for a small company, the development framework is a useful tool in order to develop more sustainable solutions.

The experiences, done during the project in industrial contexts, helped then to provide proof for the mission of such framework in terms of its use in the company, summarised in the following phrases (already presented at the beginning of this document):

— “the framework is a support to the analysis, communication and optimisation of the business processes, as well as the interfaces between different organisational divisions, with the purpose to increase the sustainability of company offered solutions”;

— “the framework is a tool recommended to help business process optimisation towards sustainability; as a tool, it aims at implementing the innovation required by a (new) business model of a company, while considering all the required organisational interfaces within the company as well as beyond the company’s boundaries”.

7 Sustainability Performance Management

7.1 Introduction

While the contributions included in this CWA may be value outside the scope defined, it refers specifically to small and medium-sized enterprises (SMEs) which are active in any manufacturing sector. The focus has been on companies which are embedded in a manufacturing network, i.e., the companies are assumed to depend on contributions from suppliers or other manufacturing companies for collaboration within the same tier.

The objective of this CWA is to provide companies with guidance in their effort to increase the sustainability of their business. The recommendations and suggestions made in this document are intended to be applicable to companies from a wide range of industries. They can be implemented as a whole or in part; however, it is recommended that modifications to the original concept are applied with caution so as to maintain the original intention of the concept.

For companies to improve their sustainability performance it is necessary to identify the central levers that have the power to change performance to the better and to the worse. We suggest central levers that influence the sustainability performance outcome of a firm within a three-parted framework. The framework reflects the direction of causal logic of performance impact and thereby represents a powerful visual and conceptual tool that

1) helps management communicate priorities as to what the areas are within the organisation that require increased attention in order to achieve desired performance targets, and

2) supports understanding as to how the company’s being part of a manufacturing network impacts on its sustainability performance.

To support the performance improvement process, we introduce a measurement approach that complements the framework and helps operationalize it. The measurement approach consists of (mainly quantitative) Key Performance Indicators (KPIs) and of a qualitative maturity assessment that is necessary to evaluate qualitative elements of the framework.

7.2 Methodology and tools

7.2.1 Sustainability Performance Framework

The framework consists of eight performance levers associated with two performance categories, and one additional category to cover the three dimensions of the sustainability performance outcome (cf. Figure 12).
Figure 12 — Sustainability Performance Framework [36]

The first category of the framework is termed **Network Conditions**. It refers to the impact other firms in the manufacturing network have on the focal firm. It consists of the three elements Objective Alignment, Partnership Health, and Capability Matching.

"Objective Alignment describes how well organisations are able to align their organisational objectives with their value-adding partners to find common ground for progress in sustainable business development. Partnership Health characterises the 'chemistry between organisations', e. g. the level of trust and collaboration between network partners. Capability Matching describes how well the capabilities of network partners fit and thus how well they will be able to communicate, innovate, and change [36]."

The category Network Conditions is based on the assumptions that the majority of manufacturing companies is not entirely free in the choice of options they can pursue but are, in fact, dependent on the support from their manufacturing network if they intend to achieve any significant improvement in sustainability performance. If one of the three elements of the category Network Conditions indicates low performance, chances are the focal firm is unable to achieve significant improvement in the second performance category called Internal Performance Levers. The impact of the Network Conditions on elements from the category Internal Performance Levers varies; however, we propose that, overall, firms are likely to experience limits in their ability to make decisions leading to better sustainability performance [36].

The category **Internal Performance Levers** refers to five performance elements that lie within the boundaries of the organisation, yet are not completely independent of outside effects, as explained in the preceding paragraph. The five elements are Strategy & Business Model, Product & Service Development, Performance Management System, Governance, and Organisational Culture. We propose that these elements are direct drivers of the company's sustainability performance and thus represent central levers for its improvement and deterioration.

The third category, **Outcome**, refers to the measureable result in terms of sustainability performance. It is suggested that sustainability performance which can be measured quantitatively with the help of KPIs is a function of the previous two categories Network Conditions and Internal Performance Levers. Because sustainability is measured in terms of the three distinct, yet interrelated, areas - environmental, social, and economic - this category is also referred to as Triple Bottom Line Assessment.
7.2.2 Measurement Approach

For the measurement approach, we distinguish between qualitative and quantitative values. Quantitative values – as part of the category Outcome – can be aggregated and represented by KPIs. The values in the category Outcome can be captured quantitatively because they are tangible. In contrast, the performance values of the elements in the two categories Network Conditions and Internal Performance Levers are intangible, which poses a challenge to the measurement process. For this reason, a maturity model has been developed that attempts to assess the performance of the intangible elements through a set of questions and predefined answers. The maturity assessment process is explained in detail in Holgado Granados et al. 2013 [37].

![Figure 13 — Recommended Measurement Approach](image)

**Figure 13 — Recommended Measurement Approach**

7.3 Recommendation of use

The CWA intends to encourage SMEs to adopt a wider perspective on sustainability performance and how it can be improved. The framework and the measurement approach can be used in combination and are specifically designed for this purpose. Adoption of the framework without comprehensive performance measurement can still prove valuable as it can inform management decisions with respect to resource allocation and new paths to explore. The objective of the performance framework introduced here is to support “understanding and communication of structure and relationship within a system for a defined purpose” [38]. That is, the framework intended to support the performance management (the "system") of the organisation. The "defined purpose" of performance management is to support goals of the organisation as defined in the organisational strategy. Put in different terms, the performance management system helps the organisation operationalise its strategy. The performance framework put forward in this document provides the underlying structure of the performance management system to help the organisation achieve sustainability goals.
Annex 1
(informative)
Tools that may be used in the development framework

**Analytic Hierarchy Process (AHP)**

Analytic Hierarchy Process (AHP) is a structured technique for organising and analysing 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 organisation’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 organisation, 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 optimisation 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, storyboarding, 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 analysing a system bottlenecks and subsequent performances at the system level (productivity, delivery speed, etc.) under dynamic and stochastic conditions. Although analyse 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 organisation (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 organisation 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 organisations 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, organising, 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 organisation of a project with consideration and emphasis beyond the project lifecycle 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 to 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. RCFA 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 co-operation.

**Sustainability Accounting Standards Board (SASB)**

The Sustainability Accounting Standards Board (SASB) is a US non-profit organisation 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 optimisation, 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 co-operation 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.
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