Part IV
Solutions for Sustainable Value Creation Networks

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Value creation is understood as the comprehensive, activity-based framework within which transformation processes like manufacturing take place. Yet the results-oriented, economic definition of value creation is seen to be too narrow in the context of sustainable manufacturing. Value creation is therefore defined here as the tangible and intangible transformation processes in the pursuit of the creation of useful products and of the accumulation of intellectual capital given consideration of the sustainability criteria, indicators, and associated global living environments.

Global value creation gained significant momentum with the increased use of new communication and transportation techniques, a phenome-non often termed processes of globalisation. As a consequence of this transformation, manufacturing enterprises are confronted with increasing complexity coupled with a growing intensity of competition. Increased specialisation on core competencies as a consequence of this enhanced competition has made the division of value creation among a number of enterprises necessary. The organisation of networks that are spread all over the globe appears to be an inevitable step in the recent development of manufacturing practices. In this context, manufacturing activity can be seen as a value creation network (VCN) connecting value creation modules (VCM), each one defined not only by monetary or economic parameters but by social and environmental aspects as well. Sustainability is possible when every module of a VCN, or, at best the whole VCN as a system, is directed at increasing benefits for society and the environment while maintaining economic profitability. In this context, examining VCNs in their totality is therefore just as important as enhancing the sustainability of individual manufacturing technologies.

In the following chapters, such design approaches are described for or-ganisations and networks. In this pursuit, we aim at peering beyond the individual value creation module. The first chapter, *Future of business models in manufacturing*, explains the development of the sustainable business model (SBM)-concept within a globalised world and gives a preview of the manufacturing world of the future by combining SBM research with future studies. Product Service Systems and Circular Econ-omy-based business models are presented as examples that have the potential of meeting current and future sustainability challenges by

applying a systems perspective on VCNs. The second chapter, *Industrial Symbiosis in value creation networks*, takes up the topic of Circular Economy with a specific look at how material is reused across industry and production lines. By applying the concept of Industrial Symbiosis, it presents a method that aims at closing material cycles not only within a company, but within a VCN and even across multiple VCNs that were originally independent from one other. The third chapter, *Integration of sustainability into the corporate strategy*, entails a concept for the restructuring of the entire organisation from tangible and intangible resources, business processes and the respective management disciplines. Finally, an integrated model-based framework is then presented that aims at enabling sustainability management and corporate sustainability performance measurement given the multidimensional requirements of VCNs and individual business fields.

Future of Business Models in Manufacturing

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Abstract In order to achieve systematic change in pursuit of sustainable manufacturing, both a strategic long-term perspective employing methods from future studies and a concrete implementation of the knowledge gained in sustainable business models are necessary. In this chapter, the concepts and exemplary methods for sustainable business model innovation are introduced with a special focus on sustainable manufacturing. Circular Economy-based business models and Product Service Systems are explained as examples of sustainable business models, along with a deduction of sustainability factors for both examples. The fruitful combination of future studies and sustainable business model development is illustrated in the example of a so-called *living factory*, a modular and adaptive production environment which integrates aspects of Circular Business Models and Product Service Systems.

Keywords Sustainable business models · Circular economy · Product service systems · Manufacturing scenarios

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1 Introduction

Bringing the topics of business models, future studies and sustainability research together, this chapter puts itself in a relatively new tradition of manufacturing science. Since the 1990s, the literature in the three fields mentioned above has been growing indeed, yet opportune combinations of them so far remain rare. This being the aim of this text, short introductions into each field will be made, so that existing literature can be conveniently linked to our own contributions to research on sustainable business models and future studies.

Given the challenges which current modes of production and consumption place on nature and society, it seems necessary to pursue a new way of conducting business. Transforming business models into sustainable business models and creating pathways for sustainable technology development thus constitute the main themes of this chapter. In Sect 2, a short introduction of the inner-workings and benefits of sustainable business model concepts and tools will be given, before two specific examples, namely Product Service System-based and Circular Economy-based business models will be elaborated on. A special focus will lie on the analysis of sustainability factors for those two cases. Section 3 focuses on the tools for creating successful sustainable business models drawing on findings from the area of scenario planning as an instrument of future studies. This last chapter also presents the *Living Factory* as an exemplary result of combining future studies with business model innovation.

2 Sustainable Business Models

In the simplest terms, the concept of business models can be explained by splitting the term into its components. A business can be seen as the activity of buying and selling goods and services for the purpose of earning money, while a model is a means of representing reality in a structured, simplified and intelligible manner. A business model can ergo be understood as a structured, simplified and intelligible representation of how a company buys and sells goods or services and in that process, earns money. With this logic, a business model is a qualitative instrument for strategizing how business should be done. With the rise of the internet in the early 1990s, how business is being conducted has changed immensely. Value creation and communication networks have spread around the globe and diversified partners and consumer segments. At the same time, due to this development, both value creation and the predictability of a business's success has risen to a new level of complexity. Meanwhile, the first conceptualisations of how companies conduct their businesses have appeared and the term *business model* has arisen (Zott et al. 2011) as a means of describing how a business now operates. In the pursuit of assisting companies maintain competitive advantage by means of understanding, comparing, assessing, predicting and changing the way of doing business, diverse

and even controversial concepts and approaches to business models have emerged in their wake. Mayo and Brown focus on the operational content, i.e. strategic purpose of a business by stressing the "key interdependent systems that create and sustain a competitive business" (Mayo and Brown 1999, 18). Morris, Schindehutte and Allen, on the other hand, propose a level-decision-approach by framing the supra-levels 'foundation,' 'proprietary,' and 'rules' levels á six sub-levels to lead business decision-making and to ensure that the individual decisions that are made within the company are internally consistent (Morris et al. 2005, 729). The three supra-levels cover the main areas of managerial decision-making in a company that answer increasingly specific questions at each level. At the foundation level, such basic questions have to be answered, as, how, for whom and by means of what sources of advantages, is value created? Furthermore, how exactly is profit generated? Meanwhile the proprietary level focuses on how the aspects of the foundation level are handled best and most uniquely. Finally, on the rules level, entrepreneurs should create guidelines and operating rules on how to strategize the foundation and proprietary of ones' business (Morris et al. 2005, 730f.). Osterwalder and Pigneur developed a value-based approach, in which the term business model entails a description of "the rationale of how an organization creates, delivers and captures value" (Osterwalder and Pigneur 2013, 14). This economic point of view allows an entrepreneur to develop and describe their business with nine core elements that involve this approach. These elements range from specific customer segments, revenues and partnerships to value proposition, activities and costs. Their business model approach is currently one of the most popular approaches for describing, developing and analysing business models.

Facing global environmental and social challenges, concepts like the business model of Osterwalder and Pigneur have been refined so that they include the reduction of negative impacts and the increase of benefits to both environment and society. Especially industries that thrive from non-renewable resources and those that create value mostly by employing cheap labour, serve as huge drivers of ecological imbalances and social inequalities. Concepts of sustainable business models are juxtaposed against the idea of 'business as usual' as they are meant to reflect upon their sustainability strategies and goals while earning money or replacing monetary earnings by environmental or social benefits in general. In that process, the meaning of value and the stakeholders involved in the business are redefined to be oriented towards the social and environmental perspective. In practice, that means that sustainability is not only implemented as a voluntary guideline, but as a fundamental part of each value proposition, value creation and value capture activity.

Product Service System-based and Circular Economy-based business models are examples of wide-ranging transformative models that include a product's entire lifespan into their considerations and are therefore viewed as the most effective sustainable business models. Their approaches require a perspective that is shifted from profit-oriented to enhanced benefits or reduced negative effects on environment and society.

2.1 *Product Service System-Based Business Models: Satisfaction, Functionality and Ownership*

The Product Service System (PSS) concept highlights the shift from traditional businesses based on the development and sale of physical products to a new business orientation based on functionalities and benefits delivered through a combination of products and services (Barquet 2015, 40f). Product Service Systems reflect on a long history of societal appreciation of service and ownership. After the world wars at the beginning of the 20th century, a noticeable development in the way people in the Western hemisphere organised their daily lives occurred which was interrelated with the changing socio-economic structures of that time. Domestic or commercial services like household servants or public laundry services were slowly replaced by self-service systems. In that process, a materialisation of services which is now fittingly represented by increasingly cheap goods like the washing machine, enabled households to complete housework at home without the help of external parties by buying a product instead of a service (Roy 2000, 291). Yet, all the while since the fifties, a convergence of product and service and a second reconfiguration of the product service-relation has taken place, which gives way to speculations about the renewed dematerialisation of the economic sphere and the emergence of a "new service economy in which profitability is based […] on the provision of services to meet essential human needs" (Jackson 1996 quoted in Roy 2000, 292). Innovative combinations of products and services that can satisfy the same or even more needs than the product by itself, have appeared. In addition to car-sharing as a more prominent example of PSS, more unknown forms are beginning to enter the markets. Philips and Turntoo have, for example, created a PSS that sells light-per-lux and lightening systems with installation, maintaining and disposal, as an alternative to the ownership of lightening infrastructure, like cables and light bowls (Ellen MacArthur Foundation 2016). Those systems relieve the consumer of maintenance, insurance and disposal expenses while satisfying similar needs (in those cases transportation and light) as the original business model in which selling the product would have sufficed.

Tukker argued that beyond the rising numbers of researchers interested in this new set of PSS, such business models have attracted the attention of entrepreneurs once it became clear that characteristics and quality of a product were insufficient at holding onto a business's competitive advantage (Tukker 2015, 77). Designing and selling a combination of service and product now stands as a prominent value proposition. Manzini and Velozzi see "selling satisfaction instead of providing a product" (Manzini and Vezzoli 2003, 851) as the crucial element of PSS business models. Various benefits abound for companies, like reaching out to new market sectors (Allen Hu et al. 2012, 354). At the same time, consumers favour customised offers and the exemption from the responsibility for a product's end of life. In that vein then, PSS are not necessarily inherently sustainable, as there is no evidence that simply replacing product selling for service offer is sufficient for leading to more sustainable solutions (Evans et al. 2007, 4226). Of course, the lesser need for

materials and resources during the manufacturing process on account of the higher span of consumers that can be reached with lesser products, the higher the efficiency employed. This might well therefore serve to reduce the negative effects on the environment. Yet this factor alone hardly suffices to qualify PSS as *sustainable*.

Following Tukker's classification of PSS-based business models, the conclusion can be drawn that the three main categories that are product-oriented services, use-oriented services and result-oriented services, all offer different opportunities but also include different limitations for the promotion of social and environmental well-being. Product-oriented PSS could optimise energy and resource consumption since service offers, e.g. as maintenance and repair, might increase the use phase of products. However, the traditional dynamic of selling as many products as possible and therefore causing negative environmental effects, remains firmly in place. Use-oriented PSS, which includes models of leasing, renting and pooling, might on the one hand lead to higher impacts due to less careful consumer behaviour, but on the other hand to extensive improvement of usage efficiency. The volume of impact reduction due to this efficiency increase varies between 30 and 50 %, in instances of car sharing, ski-renting, and laundry services and even up to 1000 % for drilling rental services. An even higher share of environmental benefits could be offered by result-oriented PSS, as this can be completely detached from product-oriented concepts. Examples could be payment-per-service unit-business models, like pay-per-copy copy shops or catering services, where a result is offered instead of a product. These models break the link between profit and production volume and reduce the incentive for large-scale production volumes and the accompanying resource consumption. Producing less to satisfy the needs of the same amount of consumers can significantly reduce the overall material usage. Nevertheless, using less materials, i.e. more durable materials, could be an incentive for result-oriented services (Tukker 2015, 86). To facilitate the identification of sustainable practices, a special set of five sustainability factors of PSS (see Fig. 1) was created. In combination, they target not only the environmentally thoughtful handling of resources, but also social justice and change.

(1) Design for Environment (DFE) is meant to include all stages of a product's lifecycle by following strategies of minimizing material and energy consumption and the selection of low impact materials and energy-efficient systems. What's more, cleaner technologies and environmentally friendlier materials and optimised distribution systems should be used.

Principles of disassembly, upgrading and adaptability should likewise be considered as end-of-life strategies. *(2) The identification of the value for each stakeholder* should take into account that longer lifespanmight decrease production, but cost savings can occur due to the reduction of material, the incentivizing of extended PSS lifecycles, and the profitability of new services. *(3) Promoting change in behaviour through educating consumers and PSS providers* can help to overcome the high symbolic value attached to owning a product and thereby increase the involvement of the consumers and employees as well as the satisfaction

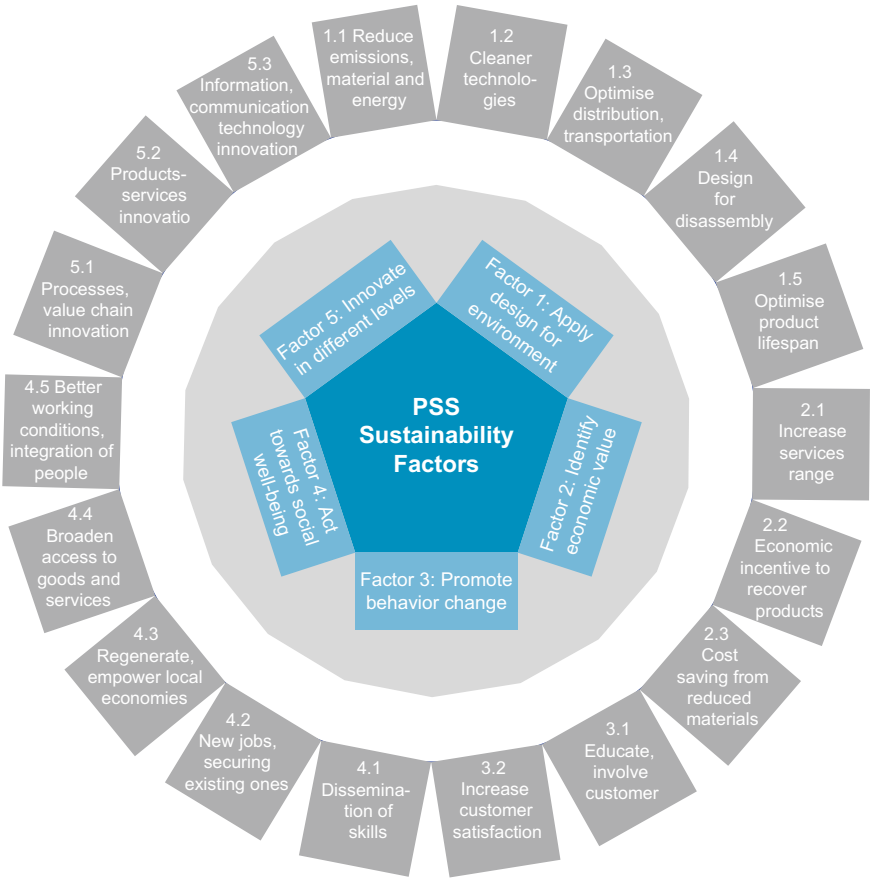

Fig. 1 Sustainability factors for product service systems

of the consumer's needs. Transparency, appearance, usability of the offer, price and time and cost saving can represent the means of this sustainability factor. As part of the *(4) Delineation actions to social well-being,* a PSS should also take responsibility for the creation and safety of jobs, for example, hiring and training employees to provide services. The fairness of the working-conditions (hours, wages, health and safety) and the tackling of social issues like the integration of social minorities or marginalised groups are also targets the attainment of sustainable PSSs. The empowerment of local communities and a broadened access to lower income segments should also constitute part of the actions for social well-being. *(5) Innovation in different levels* describes how innovations made in individual parts of the value chain might not be as sustainably successful as aligned and concentrated measures of innovation and optimisation. On-site assembly, remote controlling for maintenance and repair of products can be strategies for this factor (Barquet et al. 2016).

2.2 Zero-Waste or Reusable Waste: Circular Economic Business Models

Similar in their relevance and prominence in sustainable manufacturing are concepts of a circular economy that are based on the idea of following a product's whole life cycle and reducing resource input, waste, emission and energy leakage. Using nature as a model that cycles all its materials by means of natural decomposition and recreation, as promoted by *Industrial Ecology* thinkers like Keneth Boulding, Robert Ayres, Allen Kneese and Robert Frosch, involves putting money and hope into a product's durability and zero-waste policies.

Walter Stahel was one of the first scholars who, by introducing his concept of *Performance Ecology* in the 1980s, broached the issue of a closed-loop economy. Product-life prolonging measures like recycling, reusing, upgrading and remanufacturing coupled with a PSS-like idea of selling performance rather than the product, were to become the characteristics of his idea of a self-replenishing economy. William McDonough and Michael Braungart introduced their Cradle to Cradle (C2C) framework in the 1990s in Germany, wherein they argue that focusing on emission reduction is the wrong determination, as, emissions are the inevitable consequence of living. Instead, economy should focus on what they call materials-in-the-wrong-place-problems. Products should be designed and manufactured so that their materials could either be safely transformed in biological systems (*biological nutrients*), or be indefinitely recycled (*technical nutrients*), in case of substances that cannot be absorbed by nature. In the end, a cycled economy forms on account of the healthy waste that turns one process's waste into another process's resource. *The Blue Economy* as conceptualised by Gunther Pauli also stresses the importance of the question of how to create value from waste as a mean of providing for people's basic needs. The 2012 World Economic Forum shed new light on the idea of Circular Economy since the Ellen MacArthur Foundation introduced their publication *Towards the Circular Economy* and therein caused re-examination of previous ideas with a similar focus (Brennan et al. 2015, 223f).

A study of literature on circular business models (CBM) shows that they are generally considered to be sustainable. Five factors compounded out of 16 sub-factors seem to be critical for benefitting the environment and society while generating economic profit at the same time (see Fig. 2): *(1) Resource optimization* targets the saving of material, use of material and energy from renewable resources, dematerialisation, the creation of value from formerly considered waste and the creation of more value from each unit of resource (World Economic Forum 2014; Ellen MacArthur Foundation 2013a, b; Low et al. 2016; Geng et al. 2016; Schulte 2013; Winkler 2011; Guohui and Yunfeng 2012; Romero and Noran 2015). *(2) Improve environmental capabilities* consists of the reduction of negative emissions into the environment while increasing positive emissions to foster e.g. soil health and land productivity (World Economic Forum 2014; Ellen MacArthur Foundation 2013a, b). *(3) Risk reduction and control* can be achieved through design for

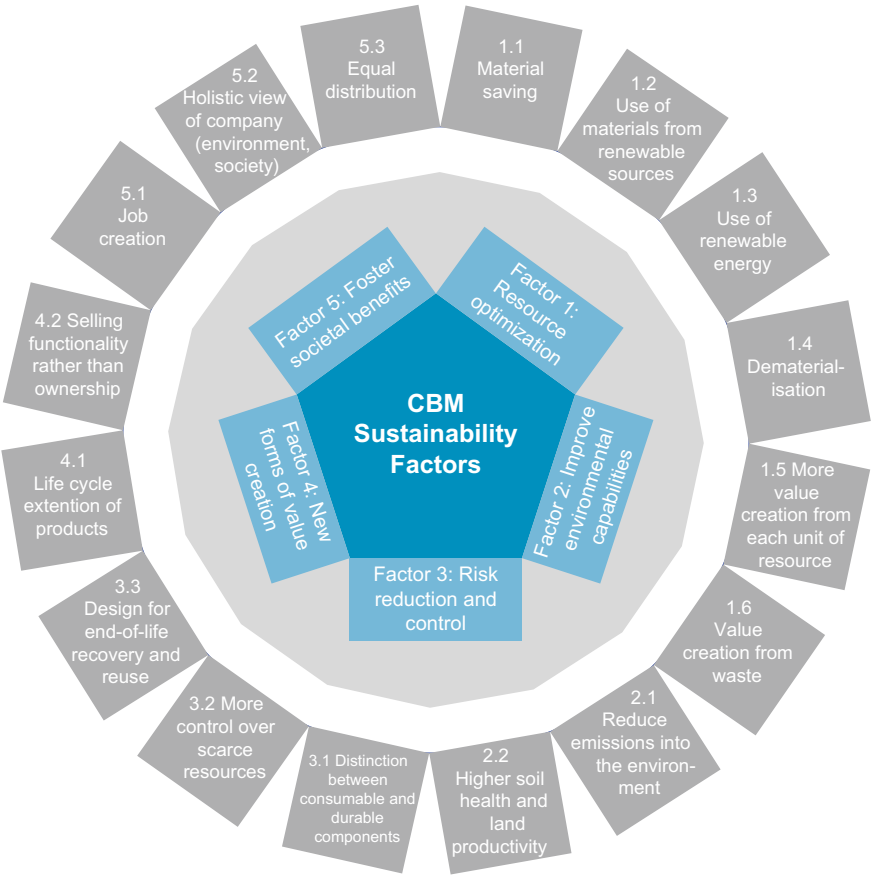

Fig. 2 Sustainability factors for circular business models

end-of-life recovery and reuse, whereby more control over scarce resources and a distinction between consumable and durable components can be attained (World Economic Forum 2014; Ellen MacArthur Foundation 2013a, b). *(4) New forms of value creation* can be reached by increasing the products' longevity, which then can foster new forms of consumption such as pay-per-use instead of ownership (Schulte 2013). *(5)* Finally, circular economic business models can *foster societal benefits* by creating new jobs, fostering equal distribution by fair wages and social thoughtful distribution of job opportunities, as well as by means of their holistic view of the company with regards to the environment and society (World Economic Forum 2014; Ellen MacArthur Foundation 2013b; Siemieniuch et al. 2015).

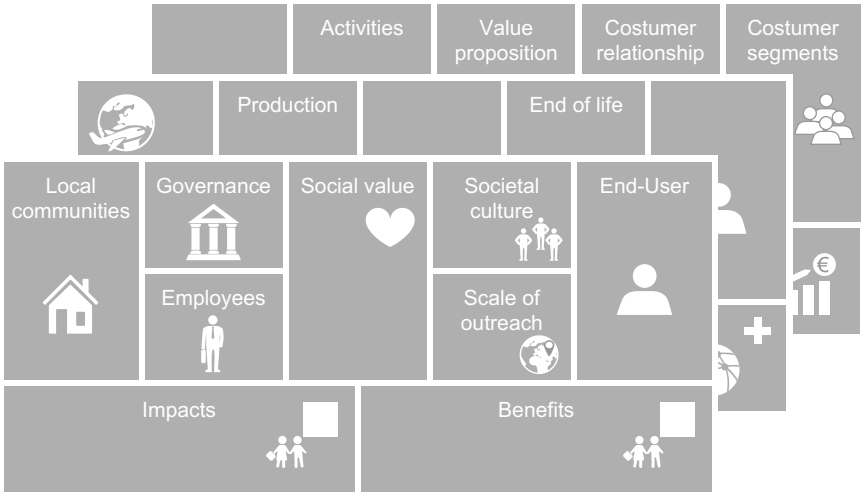

Fig. 3 Section of the three layered canvas business model tool (Joyce et al. 2015)

3 Developing Sustainable Business Models

Sustainable business model tools were developed to either adapt conventional business models or design new ones so that they fulfil the purpose of creating business that are environmentally and socially friendly as well as economically sufficient. Osterwalder and Pigneur developed the most common tool for business model design, called Canvas. In drawing up the nine core elements of their business model approach that was mentioned above (Costumer Segments, Channels, Costumer Relationship, Revenues, Value Proposition, Resources, Activities, Partners and Costs), entrepreneurs can easily conceptualise their business model (Osterwalder and Pigneur 2013). Criticism from environmentally and socially concerned academics and economists targets the focus on the economic perspective and benefits to the disadvantage of environmental and social issues. To meet this demand, the *three layered Canvas* (see Fig. 3) was later developed.

3.1 The (Three Layered) Canvas: A Tool for Sustainable Business Model Creation

Starting out with the idea that businesses will be more sustainable and also economically more successful when their business model innovations take a triple bottom line approach "people, planet and profit", as John Elkington imagined it in 1998, Joyce, Paquin and Pigneur designed a *triple layered canvas* that takes both

economic, social and environmental benefits and impacts into account (Joyce et al. 2015).

The authors used elements of *Environmental Life Cycle Assessment* to create the environmental layer of their concepts, which now include Functional Value, Materials, Production, Supplies and Outsourcing, Distribution, Use Phase, End-of-Life, Environmental Impacts and Environmental Benefits. Using a *Stakeholder approach,* they designed the nine elements of their social layer (Social Value, Employees, Governance, Local Communities and Suppliers, Societal Culture, Scale of outreach, End-Users, Social Impacts and Social Benefits). Vertical coherence enables the comparison and analysis of interaction and interference of specific elements, like for example value proposition, functional value and social value (Joyce et al. 2015).

3.2 Business Model Innovation Meets Future Studies

The desire to know the future can be observed continuously throughout time. Independent of geographic or cultural boundaries, the practices range from highly spiritual (divination or prophecy) to purely scientific (probability calculation or game theory), and build hybrid forms like Utopian concepts in the arts or social sciences. After the Second World War, scientific future studies took a turn to what is now called modern future studies (Son 2015, 122f.). Scenario planning was introduced in the 1950s as a method of demonstrating the extremes and a variety of hypothetical futures, and in that pursuit, a shift from forecasting to the manageability of the outcome with present measures emerged (Son 2015, 124). Nowadays, scenario planning is used as a tool for describing possible future outcomes and situations based on a complex net of influence factors. A fragmentation of future studies brought a variation of approaches and goals, such as explorative or normative scenarios (Bradfield et al. 2005). Abele and Reinhart, for example, created explorative scenarios for the German manufacturing industry in 2020 and described possible futures surrounding fields in which a high level of adaptability and competitiveness with regards to the global markets is required (Abele and Reinhart 2011). Using the pathways for sustainable technology development approach by Gausemeier, their findings were used to deduce the concept of a highly modern and versatile factory based on modular machine tools, the so-called “Living Factory” (see Fig. 4) (Gausemeier 2014). A Living Factory involves high versatility and mobility of production facilities that can be reached through the combination of modular machine tool frames, so-called LEG^{2}O frames, and business model innovation that makes use of a Product Service System and circular business model concepts. A detailed description and analysis of the LEG^{2}O frame is presented in the part *Sustainability-driven development of manufacturing technologies* in this book. Lightweight constructed and accuracy-tuned modular machine tools enable partial replacement and flexible combination. Applying a PSS-based system might mean renting or leasing the machine-modules, which are in the best case provided

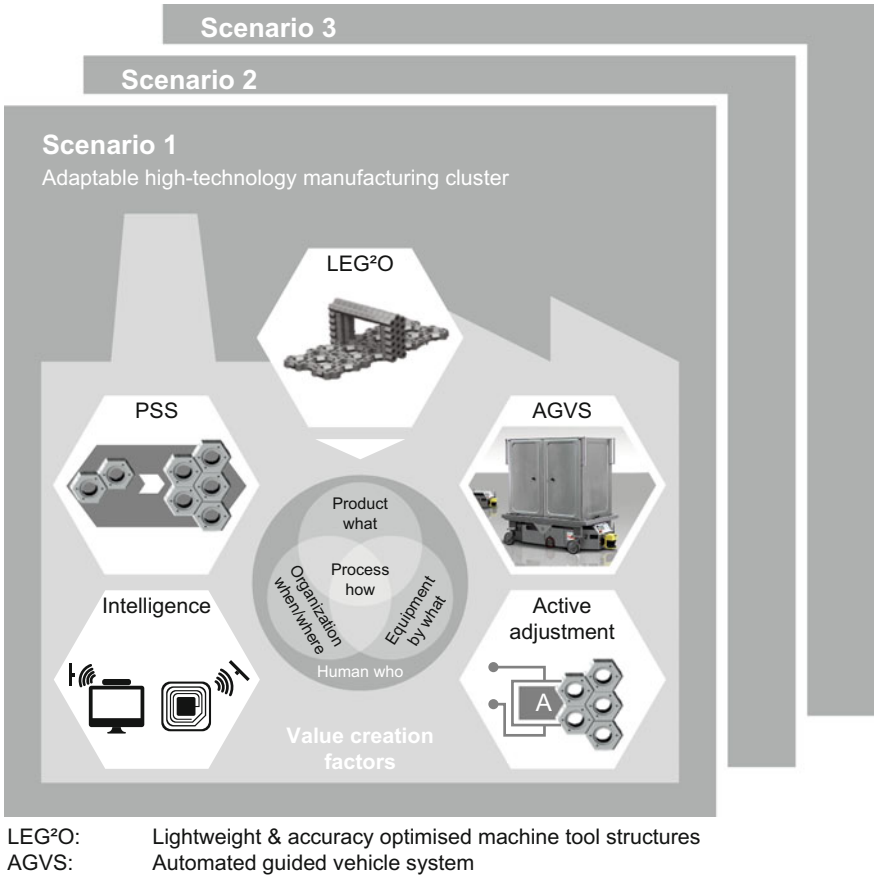

Fig. 4 Excerpt of an abstract representation of the living factory

according to the principles of a circular economy, along the lines of occupancy and requirement. A Living Factory can therefore adapt itself to fluctuations in demand and environmental and social conditions. Intelligent communication and information technology is used, including RFID tags and automated guided vehicles for logistics. Specifically, this means to reach a circular system in which machine-modules are offered by means of a central technology provider who can assist in building up the initial modular machines, and later on extend on them by adding additional building blocks, or updating them with new functionalities and smart blocks. Similarly, unused building blocks can then be taken back to be transferred to another customer. Outdated building blocks, meanwhile, can be updated, remanufactured or recycled for material recovery by the central technology provider.

4 Conclusion and Outlook

Business models such as Product Service Systems (PSS) and Circular Business Models (CBM), offer great potential for changing manufacturing according to the triple-bottom line approach of producing benefits for society, environment and economy and at the same time minimizing negative effects. However, the application of those business models will not necessarily fulfil economic, environmental and social needs. Adherence to such factors like the ones that were presented in this chapter, is nevertheless essential if a truly sustainable business model is to be created. Yet, getting to know these factors might stimulate enterprises not only to adopt sustainable business models, but also to implement sustainable practices and solutions.

Scenario planning can be seen as a useful tool for theoretically predicting the future's needs along with the success of a business model. The complex challenges that businesses and sustainability will face are well advised to be included in current business model innovation in pursuit of enhancing sustainability success and reducing risk of failure. Business model innovation and sustainable technology development mark the two major fields that require scientific progress, as, sustainable business models indeed rely heavily on both aspects. Both also include new ideas in the structuring of manufacturing processes as the example of the Living Factory shows. Modular machine-tools that are themselves produced and used according to circular principles need to be developed and tested. The transition from traditional business models to sustainable ones and how methods from future studies, e.g. scenario planning, can support these transitions are, furthermore, relevant subjects demanding deeper investigation. Another important aspect lies in the creation of indicators to measure the sustainability of business models. Building on the predominantly qualitative factors of developing quantitative approaches, has yet to be explored. The adoption of PSS and circular economy principles, moreover, can facilitate yet hardly guarantee that this version of business practice will result in a more sustainable performance. The need for future research likewise extends to the management of remanufacturing and (re-)consumption, which specifically requires a more transdisciplinary approach.

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Material Reutilization Cycles Across Industries and Production Lines

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Abstract The concept of Industrial Symbiosis aims at organizing industrial activity like a living ecosystem where the by-product outputs of one process are used as valuable raw material input for another process. A significant method for the systematic planning of Industrial Symbiosis is found in input–output matching, which is aimed at collecting material input and output data from companies, and using the results to establish links across industries. The collection and classification of data is crucial to the development of synergies in Industrial Symbiosis. Public and private institutions involved in the planning and development of Industrial Symbiosis rely however on manual interpretation of information in the course of creating synergies. Yet, the evaluation and analysis of these data sources on Industrial Symbiosis topics is a tall order. Within this chapter a method is presented which describes value creation activities according to the Value Creation Module (VCM). They are assessed before they are integrated in Value Creation Networks (VCNs), where alternative uses for by-products are proposed by means of iterative input-output matching of selected value creation factors.

Keywords Circular economy · Industrial symbiosis · Industrial ecology · Value creation networks · Input-output matching

1 Closing Material Cycles in Manufacturing

Industrial sustainability is a topic which can be addressed from a range of angles, including not only from the usual product and process perspective, but also on the level of Value Creation Networks (VCNs).

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The concept of a *Circular Economy*, which seeks to decouple global economic development from finite resource consumption, has attracted a lot of attention in recent years (Ellen MacArthur Foundation 2015). *Circular Economy* is an umbrella term for different material recovery techniques such as reusing, remanufacturing, and recycling (Ellen MacArthur Foundation 2015), as well as frameworks for closed material systems, such as the *Blue Economy* (Pauli 2010), *Industrial Ecology* (IE) (Frosch and Gallopoulos 1989), and *Industrial Symbiosis* (Chertow 2007). Within these frameworks, one can distinguish whether the material has been recovered from an intentionally manufactured product at the point of its end-of-life (EOL), or as a by-product (an unintended derivative of the production process). The waste framework directive of the European Commission specifies the hierarchy of waste from the least favourable option to the most favourable option (landfilling, energy recovery, recycling, reuse/remanufacturing, minimization, and prevention) (European Commission 2008). Since the term 'waste' conveys no or little value, the authors opt for the term 'by-product,' with its reference to originally unintended derivatives of manufacturing resulting separately from the desired product through industrial processes.

The term Industrial Ecology (IE) was coined by Frosch and Gallopoulos to depict the design of manufacturing entities analogous to natural ecosystems (Frosch 1992). As a sub-discipline of IE, Industrial Symbiosis is concerned with resource optimization among collocated companies (Jacobsen 2006). Industrial Symbiosis brings together traditionally separate industries into a collective approach for competitive advantage involving physical exchange of materials, energy, water, and/or by-products (Chertow 2000). In other words, Industrial Symbiosis aims at organizing industrial activity like that of a living ecosystem, where the by-product outputs of one process are used as valuable raw material input for another process. In an ideal Industrial Symbiosis, waste material (by-products) and energy are shared or exchanged between the actors of the system, therein reducing the net consumption of raw material and energy inputs, and thus the generation of waste and emissions (Sokka 2011). The geographic co-location of production plants with possible synergies in terms of waste streams, furthermore, serves to facilitate the exchange of the physical flows that are involved (Duflou et al. 2012). One aspect of the Factory of the Future, described by Herrmann et al. entails the symbiotic integration of factories into their surroundings (Herrmann et al. 2014). Cerdas et al. introduce the concept of a Circulation Factory, combining manufacturing with remanufacturing and recycling into an integrated system (Cerdas et al. 2015).

The term 'eco-industrial park' (EIP) describes, in a general sense, an industrial or a commercial area that is used by different companies. EIPs are networks comprising a variety of firms with an immediate geographical proximity to one another, where material exchange is carried out. An important precondition for an EIP is mutual trust, which seems to be a precondition to implementing common exchange relationships successfully (Bauer 2008; Hauff et al. 2012; Ludwig 2012). The EIP in Kalundborg, Denmark, is considered to be a seminal example in the literature on Industrial Symbiosis. The development of Industrial Symbiosis has been described as an evolutionary process in which a number of independent by-product exchanges have

gradually evolved into a complex web of symbiotic interactions between five collocated companies and the local municipality (Ehrenfeld and Gertler 1997).

Results have shown that significant environmental savings are related to Industrial Symbiosis in Kalundborg (Jacobsen 2006). For example, three million m^3 of water could be saved through recycling and reuse. The environmental benefits of Industrial Symbiosis have been quantified in numerous further cases (Kincaid and Overcash 2001; Chertow and Lombardi 2005). Although Industrial Symbiosis has developed into a notable research topic, its impact on actual industrial practice remains very modest (Chertow 2007). Efforts by public and private institutions have been made to improve the systematic planning and development of Industrial Symbiosis over the past decades (Lowe 2007). Practitioners moreover consider it crucial to finding ways of obtaining buy-ins from businesses—an essential step for success. Many practitioners have noted the significance of company champions (Chertow and Park 2016) as well as the importance of using the language of business (costs, revenues, risk, etc.) to generate this buy-in (Laybourn 2015). Duflou et al. argue that 'the most effective way of strengthening Industrial Symbiosis is to increase the economic motivation' (Duflou et al. 2012).

A significant method for the systematic planning of Industrial Symbiosis is input–output matching. It is aimed at collecting material input and output data of companies, and using the results to establish links across industries. As an outcome of the method, a resource input associated with one organization can be matched to a complementary resource output of another organization (Lowe 2007). In the case of a certain proximity of a match, an integrated input–output matching method can also be recommended for a further conversion or treatment process (Bin et al. 2015).

Regarding the support of input–output matching, a growing trend has surfaced, whereby the application of internet-based IT tools such as Synergie by International Synergies, or the Resource-eXchange-Platform as part of the ZeroWIN EU project have emerged to further promote coordination and exchanges. Additional tools include Knowledge-Based Decision Support System (Boyle and Baetz 1998), Dynamic Industrial Materials Exchange Tool (Shropshire et al. 2000), Match Maker! (Chertow 1997), Industrial Ecology Planning Tool (Nobel and Allen 2000), WasteX (Clayton et al. 2002), Industrial Ecosystem Development Project (Kincaid and Overcash 2001), Residual Utilization Expert System (Fonseca et al. 2005), Institute of Eco-Industrial Analysis Waste Manager (Sterr and Ott 2004), Industrie et Synergies Inter-sectorielles (Massard and Erkmann 2007), SymbioGIS (Massard and Erkmann 2009), and Core Resource for Industrial Symbiosis Practicioners (Laybourn and Morrissey 2009).

The collection and classification of data is crucial to the development of synergies in Industrial Symbiosis (Cecelja 2016). Public and private institutions involved in the planning and development of Industrial Symbiosis rely on manual interpretation of information in the course of personal communication and case-by-case analysis. Cecelja et al. (2014) report that in the course of their service offer, practitioners access and interpret data collected from the industry by combining it with further data stored in databases such as the following:

- Proprietary databases built to monitor the activity of industry, e.g. industrial sectors, industrial volumes, planning and marketing datasets, and occasional project management technologies, such as environmental records, quality management practices, or
- Custom-made databases that offer access to case studies, e.g. Crisp system (Grant et al. 2010).

Bin et al. propose a big data analytics approach for developing industrial symbioses in large cities. The authors suggest that data can be acquired from structured or unstructured sources. Structured sources include company registration, waste exchange registry databases, the national pollutant emissions inventory, geographical information systems (e.g. Google Maps), lifecycle inventory databases, etc. Examples of unstructured data sources are financial reports, information from company websites, online news, social media, online encyclopaedias, and journal corpus (Bin et al. 2015).

The evaluation and analysis of these data sources regarding Industrial Symbiosis is of course challenging to say the least. Firstly, data has to be interpreted in the context of specific knowledge domains. Secondly, the resulting implications have to be evaluated in combination with available data about the surrounding value creation network (e.g. materials, technologies and objectives, environmental effects, economic and social benefits). Given increasing numbers of network participants, their dynamic behaviour within the network (e.g. inclusion of new technologies, inclusion of additional stages for by-product pre-processing, pre-treatment, transportation, and storage) and the resulting complexity of material streams, it becomes quite apparent that a systematic and thorough analysis through manual manipulation of data is outright impossible (Desrochers 2004; Mirata and Emtairah 2005). Furthermore, Grant et al. criticize the available datasets as outdated and incapable of assisting innovation (Grant et al. 2010).

In order to involve businesses in Industrial Symbiosis, online platforms for facilitating exchange of by-products have been provided. Industry organizations such as the United States Business Council for Sustainable Development (USBCSD), or facilitators such as National Industrial Symbiosis Programme (NISP), allow businesses a secure and common platform for discussing potential synergies through symbiosis (Chertow and Park 2016). In recent approaches, novel concepts such as ontology engineering have been introduced in matching tools and platforms for Industrial Symbiosis, since they can help to put tacit knowledge out there—essential for the mutual, nonmarket interactions required for Industrial Symbiosis (Cecelja et al. 2014; Cecelja 2016). Halstenberg et al. suggest employing organisational data systems such as Product Data Management Systems (PDM), Product Lifecycle Management (PLM), Enterprise Resource Management Systems (ERP). Utilizing these data for Input-Output Matching tools and platforms can add functionality to existing approaches (Halstenberg et al. 2016).

2 Method Design for Sustainable Manufacturing by Analysis of Value Creation Factors

A number of different approaches exist which address the issue of Match-Making for Industrial Symbiosis. In this section, the method for designing in pursuit of resource efficient approaches stemming from the domain of sustainable manufacturing is presented, involving analysis of value creation factors. The method relies on the concept of the Value Creation Module (VCM), which will be explained in Sect. 2.1, followed by a description of the method (Sect. 2.2).

2.1 The Value Creation Module (VCM)

Any type of value creation activity can be characterised in terms of a so-called value creation module (VCM) (Seliger 2008). The VCM is depicted in Fig. 1. A VCM is composed by five Value Creation Factors (VCF): product, process, equipment, organisation and human. Networks and modules are conceivable at different levels of aggregation (Wiendahl et al. 2009) (e.g. grinding a turbine blade, assembling a turbine, building a power plant, and providing power for a community), each with sustainability indicators that are identical on all aggregation levels or relevant for the respective aggregation level. Effective and efficient VCFs must be identified, combined into promising VCMs and promoted.

Fig. 1 Value Creation Module (VCM) (Seliger 2008)

A **Product** represents a desired, manufactured output according to design requirements, specifications and standards (Laperrière and Reinhart 2014). A **process** is understood as a task that depicts how desired outputs are created from inputs. **Equipment** is the means to manufacture the products, e.g. machine tools, jigs and fixtures, tools and measuring equipment. The crucial precondition for factory operations are **humans**. They are the direct employees involved in value creation, using qualifications and training to that end (Westkämper 2006). The **organisation** represents the functional, spatial and temporal context in which manufacturing tasks are carried out and managed (Spur 1994).

2.2 *Description of the Method*

This sub-section highlights the procedure for the method of designing for sustainable manufacturing and thereby included resource efficiency by means of analysis of value creation factors. A flowchart of the procedure can be seen in Fig. 2. The goal of the method is to model and plan value creation networks in a sustainable manner with a specific focus on by-product exchanges in the sense of Industrial Symbiosis objectives.

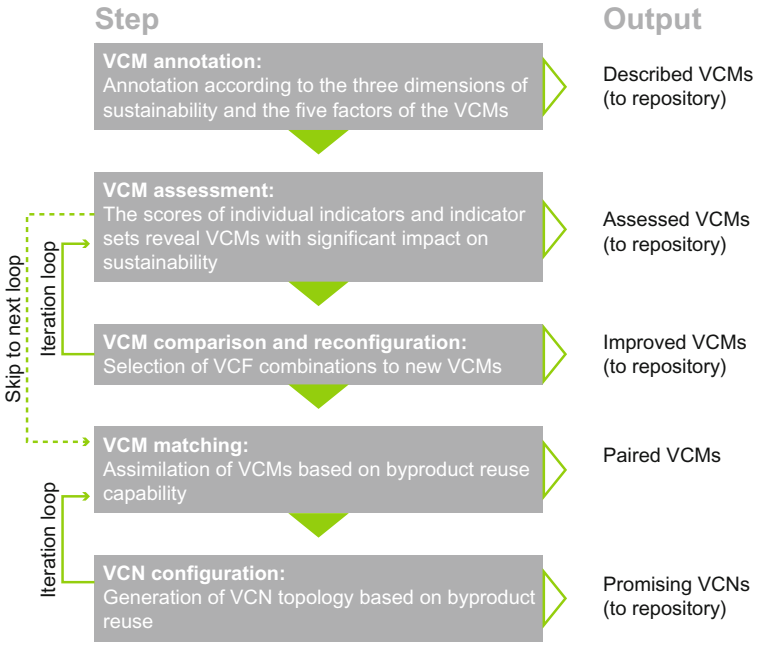

Fig. 2 Flowchart of the method for designing for sustainable manufacturing by means of analysis of value creation factors

Firstly, VCMs are annotated, assessed and improved. This part of the method focused for that reason, on the specific processes and not on their network. Secondly, the method focuses on the network level. Here the individual VCMs are matched in order to form Value Creation Networks (VCNs).

The VCM (see also Sect. 2.1) provides a structured framework for the **annotation** of value creation activities in the first step of the method. It allows the integrating of various levels of aggregation from a single manufacturing tool and operations via manufacturing cells and systems, whole factories with national and international entrepreneurial conglomerates or knowledge generating communities (Wiendahl et al. 2009). As this method prescribes, VCMs are annotated according to the three pillars of sustainability as well as according to the five VCFs (product, process, equipment, human and organisation).

In order to gain general knowledge on the sustainability performance of the VCM, a **VCM assessment** is performed in the second step. The scores of individual indicators and indicator sets reveal which of the VCMs have a significant impact on sustainability. In order to reduce dependency on detailed performance data, a qualitative approach is used. This approach enables a rapid cross-industry assessment of VCMs, capable of showing concrete improvement potential. The VCM assessment is based on the Bellagio principles and is requisite for a dynamic shift between module and network perspective.

The third step, **VCM comparison and reconfiguration** of alternatives, is then performed in order to eliminate shortcomings of VCMs which have been identified through the VCM assessment. In this step of the method, alternative comparison and VCM reconfiguration are conducted. Next, alternative comparison is performed by comparing the VCM assessment scores for two or more different VCMs. All VCMs are then described according to a VCM annotation structure, where elements and elements instances are utilised. This is made possible through similarity matching between these elements and elements instances. Depending on the similarity score of the selected comparison elements, the VCM can be reconfigured and its sustainability performance enhanced. The comparison criteria are selectable based on the VCM annotation and a reference VCM.

Once the comparison criteria and the similarity matching threshold have been determined, the highest scoring VCMs are presented, based on the individual indicator sets. The indicator set score is based on the VCM assessment. The VCM reconfiguration is a process for improving a reference VCM by VCF substitution. VCF of higher scoring VCMs are used for the process.

Figure 3 presents a comparison between two VCMs, ‘Bamboo frame manufacturing at PTZ’ and ‘SUW sharing platform’. The latter offers significant improvements in public reach, which when implemented as a ‘Help for self-help bamboo frame manufacturing in Vietnam’ presents an improved overall sustainability performance.

The method focuses on the network implementation of the previously annotated, assessed and reconfigured VCMs. All VCMs considered are now treated as black-boxes, and matched with the purpose of forming networks. A network can be formed and planned according to various goals. The method presented focuses on

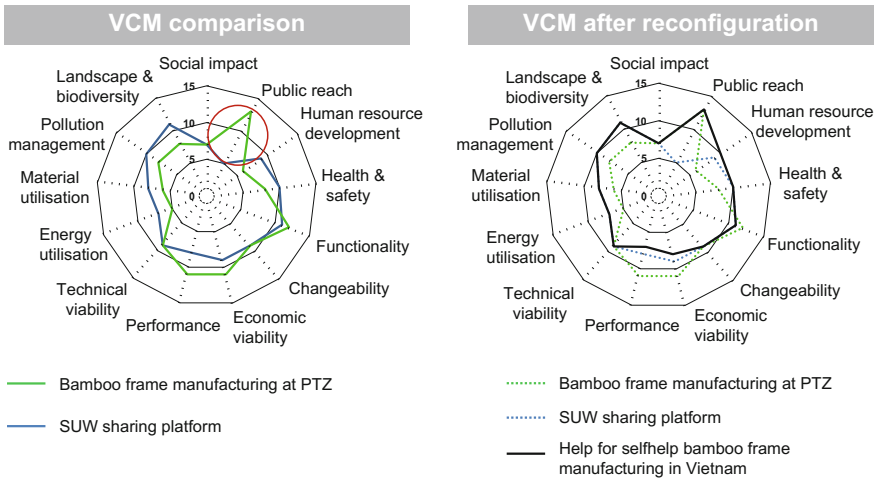

Fig. 3 VCM comparison and reconfiguration

the aspect of creating symbiotic relationships among companies in the sense of an Industrial Symbiosis.

The process of **VCM matching** begins with a classification of the by-product, all the while ensuring representation in a manner that is appropriate to the various industries. For example, a by-product can be classified as a biomaterial or a technical material (metals, ceramics, organic polymers, composites, semi-conductors and advanced materials). In the next step, the by-product is annotated in terms of quantitative and qualitative information. In this process, the VCM is described in a more detailed manner through information embedded in the VCM ontology belonging to the VCF taxonomies for product, process and equipment. The goal is an annotation which ensures that a by-product of one manufacturing entity is described in a suitable manner so that it can find a suitable fit with another manufacturing entity. The material type classification, economic factors, environmental considerations and known reutilisation possibilities are all required (e.g. stream behaviour, material cost, level of toxicity, reutilization possibilities) in that pursuit.

A **match of one VCM to another** is performed by comparing the respective in- and outputs. In order to establish possible usage, the by-product material stream is classified.

Moreover, in pursuit of identifying suitable relationships between VCMs within the considered VCN, an **input-output matching** approach is carried out to pair VCMs based on their by-products. For this purpose, a similarity algorithm is utilized. An important aspect of input-output matching is the range of matching since, depending on the type of description, different ranges are possible. In the case of a quantitative description, the pairing up can either be a 1-to-1 match or be located within a certain range. In the case of a qualitative matching, the inputs and outputs can be matched according to semantic descriptions.

According to the VCM matches identified, suitable **VCNs** have to be **configured** in the next step. From a single VCM, pairs of VCMs are generated and a network is formed by moving with the flow of by-products. Having the role of a broker in place—that is, a neutral network administrator who has the responsibility of creating a VCN and identifying open interfaces for new VCMs creation—is seen as a useful function for the arrangement of the different VCMs in a network. Three tasks are then performed in order to establish the networks. First, a joint effort opportunity is to be detected and promoted by a broker, made through an online platform. Then the main features best suited to describing the joint effort are to be classified. Finally, rough planning for the network is to be conducted. Possible network partners and their ideal locations can then be identified. A VCN topology is created by selecting one VCM to act as an anchoring point and other VCMs arranged accordingly.

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Integration of Sustainability into the Corporate Strategy

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Abstract In order to successfully achieve sustainable corporate development, enterprises have to define and implement a pragmatic strategy. In that pursuit, the discussion of motivation and reasoning behind incorporating sustainability strategies serves as a prelude to the thematic examination of challenges and courses of action in corporate strategy development and implementation. Especially in the context of sustainability, additional legislative and stakeholder requirement considerations make managing these tasks effectively, however, much more challenging. The firm's overall objectives thus become multidimensional and have to be broken down to the individual departments and business fields. Consequently, considerable effort has to be devoted to the planning, measurement and evaluation, steering and control as well as optimisation and communication processes of the holistically defined corporate value creation. Furthermore, a solution for enterprise sustainability management and its evaluation is necessary for ultimately balancing economic, ecological and social performance factors, to ensure optimized decision-making.

Keywords Sustainability management · Sustainability strategy · Integrated reporting

1 Organisational Framework for Sustainable Development

With respect to the increasing competitiveness, cost and price pressure as well as the limited availability of natural resources, efficiency—as the maxim of manufacturing—stands as an imperative. Nowadays, a new sense of responsibility

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towards future generations is emerging, as insights on the long-term effects of over-exploitation and environmental pollution are increasing. In the context of the evolution of this responsibility towards internal and external stakeholders, enterprises are confronted with the imminent challenge of adapting strategic orientation and operative value creation accordingly.

The linkage between the economic, ecological and social perspectives of the interaction of enterprises with their environment however, poses unique challenges in terms of potential internal conflicts of objectives. At the same time, it is questionable to what extent the attainment can be related to the three perspectives of sustainability. Thus long-term strategic orientation has to be recognised as a premise for sustainable development, so that potential short-term performance discrepancies are not misinterpreted as deficits, or implied as representing poor decision-making. This is assuming that sustainability is more than an ideological construct for the conscious influence and control of human and entrepreneurial behaviour. Instead, it has to be conditional to certain criteria and traceable or ascertainable. Numerous approaches for operationalising sustainable management are therefore focused on indicators, but remain, however, limited in their extent or integrity in order to avoid complexity.

The three-dimensional differentiated approach requires the simultaneous safeguarding of the economic, ecological and social capacity of the respective system and its environment for both the current and future generations (Dyllick and Hockerts 2002). Building on the definition of the German Bundestag, safeguarding economic performance is herein based on ensuring an adequate competitive situation as a driver of innovation and as a price-building mechanism, without however at the same time limiting the welfare of the individual involved. The preservation, and in some cases, the restoration of the capacity of natural systems, is thus the main objective of the environmental perspective. In that pursuit however, societal order is only sustainable if solidarity and social justice stand as the prerequisites to individual freedom and development in the process of determining the change of conditions and structures (Enquete-Kommission 1998).

Eco-effectivity strategies pursue absolute objectives in terms of reducing environmental pollution, as achieved through the use of renewable energy sources, recirculation of products, by-products and materials into product lifecycles or natural systems, as well as the limitation of environmental pollutants. Eco-effectivity thus refers to the degree of objective attainment, where the target is directly tied to the reduction of environmental or social burdens (Schaltegger 2000).

The fundamental strategy of efficiency is based on the objective of increasing resource productivity through the minimisation of resources deployed in relation to the maximised output with respect to the entire lifecycle. This is commonly achieved through product and process optimisation or innovation as well as procedures and product characteristics profiles that influence the operating condition and lifespan of the product (Enquete-Kommission 1998; OECD 2010). The Eco-efficiency strategy hence refers to resource efficiency in relation to production processes. The substitution of conventional materials—therein enabling the use of less material or the construction of lightweight structures, recyclable materials or

those that have lower pollution potential—serves to support the pursuit of eco-efficiency. Socio-efficiency can be expressed in an analogy, wherein value added is expressed in relation to social burden (Schaltegger 2007).

The analysis of a growing world population and simultaneous depletion of natural resources inevitably calls for confrontation with human consumer behaviour (Huber 2011). Sufficiency in an economic context here describes an alignment of consumer behaviour towards a sufficient consumption that accounts for resource depletion with existing technologies. Applied to the organisational level, this entails a limitation of production to a level below the possible growth boundary, so as to avoid overconsumption of natural resources (Huber 2000). The potential for growth of enterprises is not directly limited by the sufficiency strategy. The environmental and social impact is however minimised when implicit consideration of the long-term utilisation of products is taken into account. This represents an attempt at finding an optimal balance between economic value creation and the reduction of environmental pollution and social burden (Bergmann 2010).

Beyond process and product optimisation, the consistency strategy requires a structural change in the utilisation of resources and energy as well as restructured usage of natural drains. This explicitly calls for innovation capability with respect to new technologies, material as well as processes and products (Huber 2011).

This basic model can be extended by four fundamental principles, including responsibility, cooperation, and circular as well as functional orientation. These are possible operational principles held by economic actors, yet are in some cases redundant reiterations of the specifications of strategies and principles on a conceptual level (Dyckhoff and Souren 2008).

From a system theoretical point of view, cause-effect relationships are possible within and between the three dimensions of sustainability. These (inter-) dependencies may be positive or negative, respectively weakening or strengthening effects on the baseline objective of preserving ecological, economic and social capital. The dependencies may be characterised by place, time and reflexivity (Gleich and Gößling-Reisemann 2008). Hence, the effects of actions implemented may appear within the given system currently under consideration or surface in different systems. Simultaneous and delayed effects are often more difficult to detect however, as simultaneous effects may be interpreted as independent, while latent effects may go completely undetected.

2 Incorporating Sustainability Strategies

In order to meet the requirements set forth by the triple bottom line (Dyllick and Hockerts 2002) and the sustainability strategies, enterprises have to adapt their own corporate strategies. In this section, the reasoning behind implementing sustainability as part of the corporate strategy is examined, and the main motivational aspects are highlighted.

While the term strategy stems from a military context (Clausewitz 1935; Giles 1910), the conceptual integration into the context of corporate management in terms of strategic planning and later strategic management, was undertaken over half a century by scholars from varying fields (Will 2012). Originating from conceptions of efficiency as the main driver of productivity (Taylor 1911) and the relation of experience to cost-efficiency (Henderson 1973), competitiveness then took over the corporate strategy discussion, later expounded upon with differentiated business strategies (Porter 1985). The basis for developing a strategy can be dominated by external circumstances such as the market or environment. Moreover, the enterprise typically positions itself through the lens of its internal resource-based perspective —creating value and competitiveness through the deployment of core competencies (Prahalad and Hamel 1990). In that process, a basic definition of strategy as the long-term oriented behaviour of the corporation in pursuit of achieving defined objectives (Welge 2001) needs to be expanded, to account for meeting the corporation's (and its internal and external stakeholders) objectives *together* with safeguarding the same possibility for future generations. In so doing, economic, ecological and social capital have to be expanded, yet sustained for the future (Dyllick and Hockerts 2002).

Based on the historic development of the term and discipline, limitations set forth by sustainability strategies seem contradictory and require closer examination. Initially, the motivational aspects attached to integrating sustainability requirements into the corporate reality are analysed. As for the scientific development of this aspect, a main structuring characteristic lies in the origin of the motivation. Where early contributions were focused on external factors, internal motivation and connecting drivers have gained in significance. Figure 1 gives an overview of the main motivational factors and drivers for corporate sustainability (Bansal and Roth 2000; van Marrewijk and Werre 2003; van Marrewijk 2003; Schaltegger and Burritt 2005; Epstein and Buhovac 2014; Windolph et al. 2014; Lozano 2015; Engert et al. 2016).

Upon consideration of the motivations behind implementing sustainability into the corporate strategy, a new or adapted strategy has to be defined. In a procedural approach to strategy development, the main imperatives and courses of action are discussed in the following section. Here we propose considering the options to (1) adjust the corporate strategy to include objectives regarding economic, ecological and social performance; (2) to define a specific sustainability strategy as part of the corporate strategy and (3) to redefine the corporate strategy based on the premise of creating a holistic sustainability strategy (Figge et al. 2002). After the successful implementation of sustainability aspects in the strategizing phase, proactive management is needed in order to achieve the sustainability objectives.

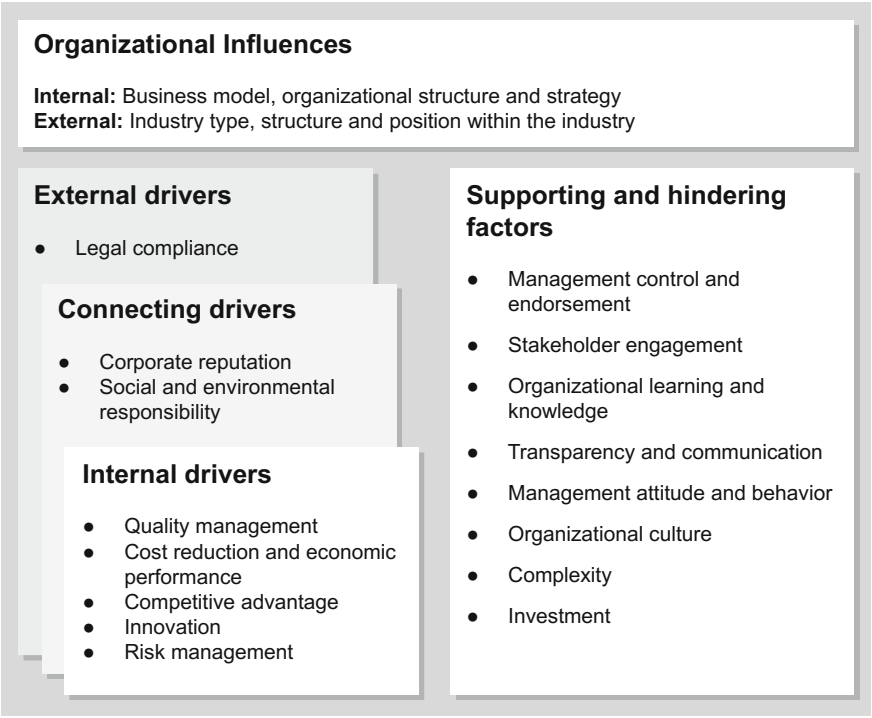

Fig. 1 Motivational factors and drivers for corporate sustainability

3 Management of Corporate Sustainability Performance

The management of organisations is described here in a stepwise approach (Fig. 2), addressing the building blocks of the business model, the corporate strategy, the business processes and the resources deployed. In order to improve the performance —in this particular context the sustainability performance—purposeful actions need to be planned, implemented and monitored. Overall, the dynamics of the business operation, decisions taken and the outcome, all need to be recognised in order to establish a comprehensive view of the cause-effect relations within and across the organisation's borders. Communication with relevant stakeholders takes on a key role in that process, as transparency requirements increase. Internal and external communication must become an established activity of organisations that aim to make information available about their performance beyond the standard financial data reporting.

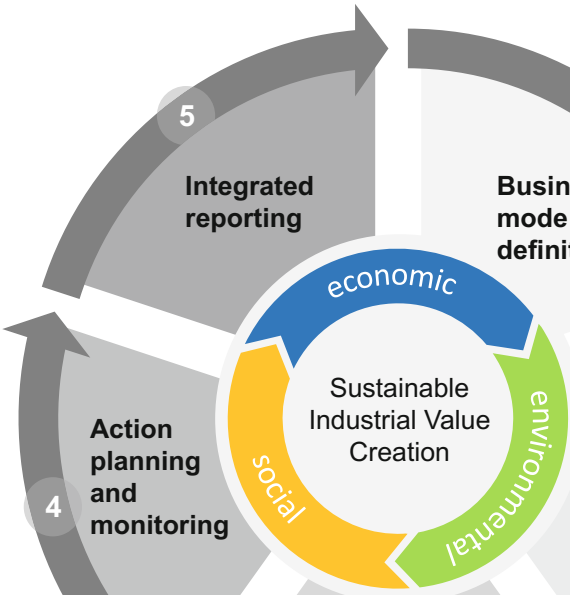

Fig. 2 Stepwise approach for the management of corporate sustainability (Galeitzke et al. 2016)

3.1 Definition of the Business Model and Business Success as the Baseline for Strategy Development

The path of sustainable corporate development needs to be outlined for any business with specific deliberation on its internal and external environment. To achieve sustained success, the organisation must pinpoint its concrete objectives and values. These should be, furthermore, clearly understood, accepted and supported by the employees of the organisation (ISO 2009). It is therefore necessary to explicate the business model and the enterprise's potential innovation as an integral or complementary part of strategy development.

To do adequate justice to the topic of sustainability as a whole, the following perspectives have to be considered within the process of business model definition/innovation:

1. Economic Perspective—While the traditional economic challenges are to increase the company's value and to increase the profitability of products and services, the challenge with regards to economic sustainability lies in making environmental and social management as economical as possible.

2. Environmental Perspective—All actions of an enterprise affect its ecosystem. Thus, companies are encouraged to reduce the absolute level of their negative environmental impact resulting from production processes, products, services, investments etc. to a considerable extent, where the largest possible decrease is desirable. The largest possible decrease is however desirable.

3. Social Perspective—In order to achieve sustainable value creation within the social dimension, the social issues of focus have to provide a real competitive advantage. Such advantages could be obtained by increasing revenues, or reducing risks or operational costs. In this pursuit, the tension between social and economic pressure is relieved as both society and businesses enjoy tangible benefits at the same time.

Combining fragments or modules of a company is a fundamental aspect in several business model definitions (Osterwalder and Pigneur 2011; Johnson et al. 2008; Wirtz 2010; Mitchell and Coles 2003), serving the purpose of creating products and services and thereby creating, providing and maintaining value (Wirtz 2010; Johnson et al. 2008; Osterwalder and Pigneur 2011). In this context, value creation is used for strengthening the customer relationship and competitive advantage (Wirtz 2010). These components of business model innovation can be summarised as illustrated in Fig. 3.

Nowadays innovation is a major key for sustainability due to the fact that the future society demands innovative products, processes and services, without losing out on efficiency (Clausen 2011). Product or incremental process innovations are neither a guarantee for success nor sufficient for coping with the emerging information, knowledge and time-competition (Stern and Jaberg 2010). Against this

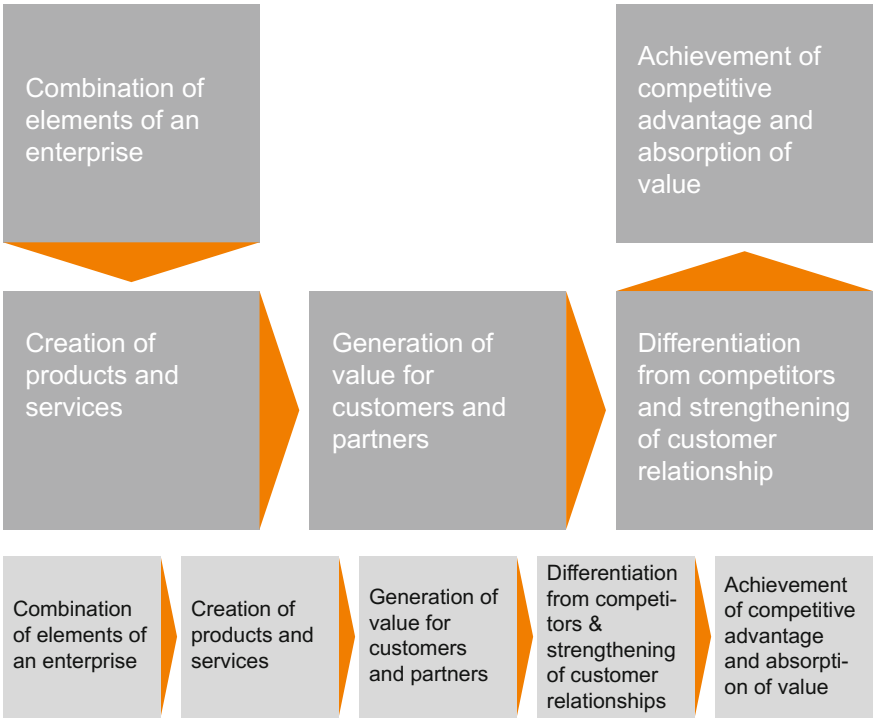

Fig. 3 Constituents of business model innovation definitions (Schallmo 2013)

background, the innovation of business models has arisen as a new discipline, providing organisations with supplementary guidelines for differentiation models in the market place in pursuit of securing long-term competitive advantage. Relating the business model concept to sustainability (Lüdeke-Freund 2010) defines a sustainable business model as "a business model that creates competitive advantage through superior customer value and contributes to a sustainable development of the company and society."

A business model basically defines the way in which a company operates. Sustainable Business model innovation can be an important leverage for change in a company to be considered sustainable and for coping with the emerging challenges in this context. This furthermore entails an expansion of the business model scope beyond green (FORA 2010), product-service-systems (Tukker 2004) or social issues (Yunus et al. 2010; Bocken et al. 2014). Brocken et al. developed a set of sustainable business model archetypes clustered by technological, social and organisational perspective for innovations as shown in Fig. 4 (Bocken et al. 2014).

These archetypes can be interpreted as an approach for business model innovation towards sustainability. They can initially assist in the process of embedding sustainability into existing business models or for the purpose of radical re-engineering of the business models and for delivering a sound starting point from

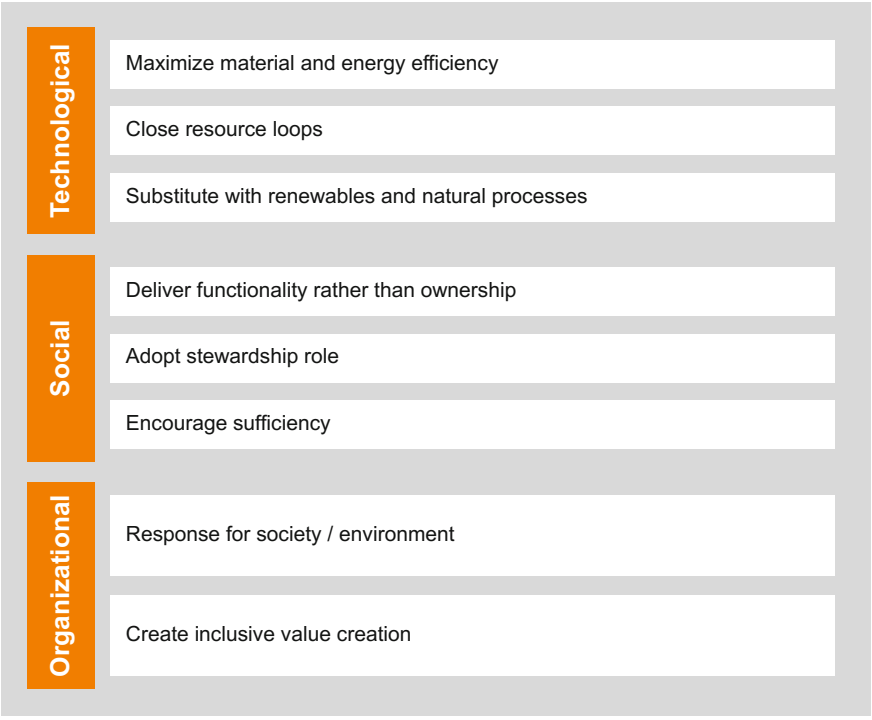

Fig. 4 Sustainable business model archetypes (Bocken et al. 2014)

which to broaden economic, environmental and social aspects in tackling the complementary process of strategy development.

3.2 Strategy Development

Today, enterprises are forced to align their own objectives with the needs of all their stakeholders. Particularly at a time characterised by shorter product life cycles, decreasing prices, new technologies, global markets and increasing sustainability demands, enterprises require an efficient process for their strategy development activities.

The term strategy was first recorded in the late 1950s in the economic doctrine of the Harvard Business School. As instruments of corporate management first evolved from the concept of strategy, the terms strategic planning, and consequently strategic management have been established. In English-speaking countries (Chandler 1962; Ansoff 1965; Schendel and Hofer 1979; Porter 1980), prominent pioneers provided crucial foundations. From this 50-year history of the strategy concept in the context of corporate governance, the following features of a strategy can be derived: the consideration of actions of other actors, proactivity and long-term orientation (Staehle and Conrad 1994).

Strategy in its initial context is generally used to establish conditions that will guarantee long-term economic success and thus the continuity of the company. For this purpose, a strategic success ensues, which ultimately leads to advantages over competitors (Rüegg-Stürm 2005; Grant 2005).

The development of a comprehensive strategy which not only concentrates on competitive benefits and thus on the economic value, presents itself however to be a much more complicated undertaking. With regards to the aspect of sustainability, the environmental and social dimensions have to be taken into account, and, moreover, the cause-impact relations likewise have to be adequately assessed.

Several companies appear to be active in the field of sustainability management. They may publish, for example, extensive sustainability reports. Yet their efforts nevertheless often remain unclear from a strategic perspective. Rather, the impression that sustainability issues are being tracked often tends to be the case, more than they are actually proceeding on the basis of a clear strategy (Baumgartner and Ebner 2010).

The development of a comprehensive enterprise strategy which meets all given requirements from internal and external stakeholders and specifically contains sustainability perspectives, is a process which requires a structured approach in the interest of keeping the complexity and uncertainty at a minimum level. The process of strategy development can be divided into four major phases as presented in Fig. 5 (Will 2012).

In the first step, information is preliminarily collected which describes the current situation of the company for establishing a general consensus on the initial

Fig. 5 Strategy development

situation (e.g. information about business environment, general corporate objectives or the corporate profile incl. development of earnings).

In the second step, the products and markets are categorised so as to quantify their respective contribution toward the overall business result. For visualisation, the findings can be represented e.g. in a product-market-chart. Based on this analysis, the current market situation of the company is evaluated. The aim of this step is to obtain a first rough estimation of the yield model to derive interesting advancements from the existing business model in the next step.

The major decisions regarding the incorporation of sustainability into the strategic decision-making process are derived in the step of assessing the strategic options for corporate sustainability. The starting point for the determining of suitable strategic options is captured in step 1, featuring the general corporate objectives and the current trends in the business environment. In addition, the current situation of the company examined in step 2 leads to the necessity of a fundamental decision on how exactly the company would like to deal with the challenge of sustainability without losing any growth potential. Baumgartner and Ebner (2010) recommend a set of profiles for sustainability strategy (Table 1) as a first means of orientation in the strategic decision-making process.

Each of these positions the company wants to occupy has to be evaluated by taking into account risks, chances and possible development scenarios regarding market penetration, product differentiation, market expansion or diversification. For the analysis of the relationship between sustainability and competitive strategy, (Baumgartner and Ebner 2010) propose two criteria: costs caused by the strategy, and the recipient of the resulting benefits.

Finally, a selection of a strategic option based on the assessment from the previous step has to take place in order to arrive at the detailed strategic objective as a conclusion.

Since an enterprise consists of several different units and elements which are interconnected on several levels (active vs. passive or strong vs. weak relationship), it is necessary to consider all influences and possible side-effects within the process of strategy implementation. In this context, many companies use enterprise processes as a common backbone for the different management disciplines with the objective of fast and consistent realisation of strategic issues at all levels of the enterprise (Jochem and Balzert 2010).

Table 1 Strategy profiles for sustainability based on Baumgartner and Ebner (2010)

Strategy profile	Explanation
Introverted	• Low standard of sustainability • Concentrates mainly on conformity and compliance with sustainability rules and guidelines
Conventional extroverted	• Aims to communicate sustainability commitment to society for increasing competiveness • Responsibility often located in public relation department • Focused on external presentation of sustainability
Transformative extroverted	• General orientation conventionally extroverted • Company is a driver for corporate sustainability in society • Most important are facts, which prompt sensitive reaction from society without proving fulfilment
Conservative	• Oriented towards internal measures • Focusing cost efficiency and well defined processes • Commitment to investment in appropriate technology, sophisticated health and safety, ecological sustainability • Process-based analysis and assessment of corporate sustainability • Society-related issues less important
Systemic visionary	• Highly developed sustainability commitment • Combines outside-in and inside-out perspective, based on internalisation and continuous improvement of sustainability issues • Aims in all sustainability aspects at good results • Stakeholders and market are equally addressed by sustainability commitment
Conventional visionary	• Oriented towards market impact • High level of maturity • Minimal lower maturity in processes, purchasing, no controversial activities or corporate citizenship due to lower impact to market situation as sustainability leader

The use of process management approaches for transferring complex strategies down to the operational business will be examined in the following section.

3.3 Process Definition and Modelling

Process definition and modelling is of great importance in the pursuit of achievement of the company's strategic and operational objectives. The aim is to improve the efficiency on the one hand, and the effectiveness of the company on the other hand, so that its total value can be increased. Processes and process management are connected to two essential signifiers for ensuring effectiveness and efficiency in the company. First, the corporate strategy determines the processes which are required and which strategic objectives are to be implemented alongside them. It forms the basis for process identification and target orientation. This involves changes in corporate strategy, entailing changes in the processes itself. Secondly, the customer

or stakeholder orientation determines what expectations and requirements have to be met through the processes. Therefore, the process definition extends from the requirements of the customer to the delivery of the process results to the client. It is important that the terms of the processes of corporate strategy and customer reference in the context of process management are coordinated (Jochem and Balzert 2010). Figure 6 illustrates the connection of corporate strategy and its operationalisation via an integrated management.

The comprehensive development and implementation of a corporate sustainability strategy which meets the requirements of the economic, environmental and social perspective, require a sound information basis from which to proceed. The various management disciplines involved have to be addressed in such a way that the attendant complexity is reduced to a minimum. A promising approach for visualizing and therein explaining the interrelation of varied enterprise objects lies in enterprise modelling.

In Vernadat's view (1996), an enterprise model is the basis for the understanding of a company, whereby the relevant structural and dynamic components and their interactions are described.

Enterprise modelling describes relevant processes and structures of a company or organisation and their mutual relationships. The applications are designed extend to the illustration of the enterprise architecture, the root cause analysis of

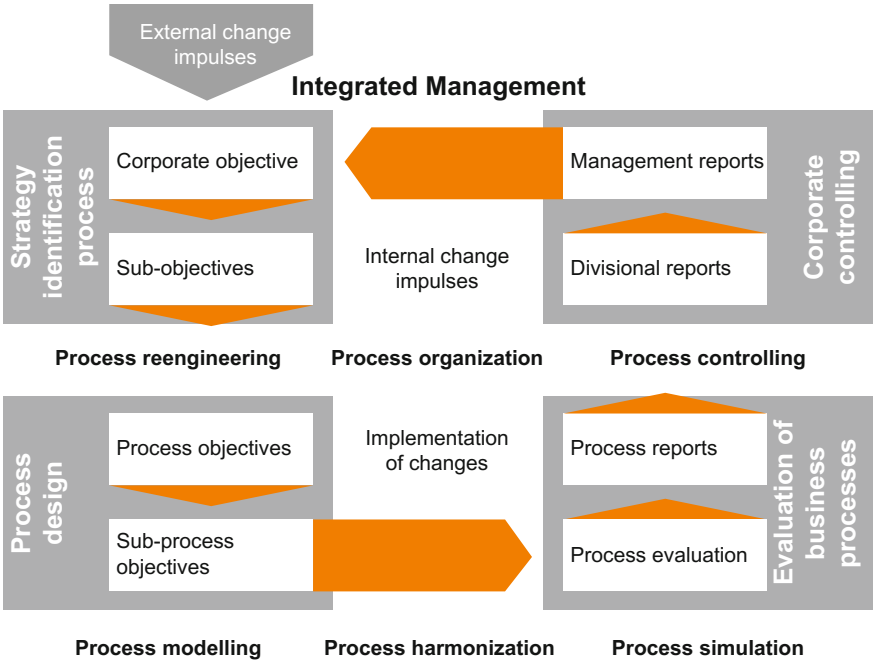

Fig. 6 Connection of corporate strategy and process management

operational problems, strategy development, process optimisation or the management of business collaborations, among other topics (Sandkuhl et al. 2013).

Thus, the process management commences with the alignment of the processes and the sustainability strategy, which means defining the value-adding processes and objectives to be achieved. In the following phase of process design, the defined processes will be designed in detail, modelled and optionally documented. In the course of the implementation of the processes in the organisation of the company, the evaluation of the processes is carried out in terms of target-achievement, and where applicable, harmonisation or standardisation can be required. Finally, the actual controlling of processes follows, related to the entire corporate controlling process, resulting in impacts on the strategic development.

Both the challenges and the opportunities which integrated mapping of process management and sustainability offers, lie mainly in the mastery of increasingly complex planning processes. Based on enterprise models that unite the perspectives of different strategic planning disciplines and also support them with integrated model-based planning and evaluation instruments, the objective of corporate sustainability is pursued holistically (Dyllick and Hockerts 2002).

An important and critical success factor remains however unconsidered within enterprise models. The implementation of a sustainable development strategy requires not only an excellent knowledge of the internal processes and structures, but also, for example, of relationships with customers and partners, i.e. intangible assets. The role of such assets in terms of sustainability is briefly introduced in the next section, along with an approach for the integration of these values into the development of corporate sustainability.

3.4 Resource Definition and Impact Analysis

In order to provide products or services, an organisation will combine different types of resources like human skills and knowledge, natural materials and social structures, by using machinery, infrastructures and financial assets. A sustainable organisation will maintain and, wherever possible, enhance these capital assets, rather than exhaust them ("capital stewardship") (Knight 2006; ARE and DEZA 2004). In turn, the design of the business processes constitutes the interrelation of the business operation, its resources and performance as well as the impact on the economic, social and environmental dimensions (Fig. 7). If, for instance, economic sustainability is interpreted as an expansion of the private welfare maximisation, enterprises have to ensure the long-term functionality and effective performance of their operation. Consequently, the design of the business processes needs to be directed towards the effective, efficient and beneficial use as well as towards the development of the capital assets involved. In this context, the capital-based approach refers to the relevance of different types of resources and makes a basic distinction between tangible and intangible resources. These are then employed in business processes to improve the organisational performance.

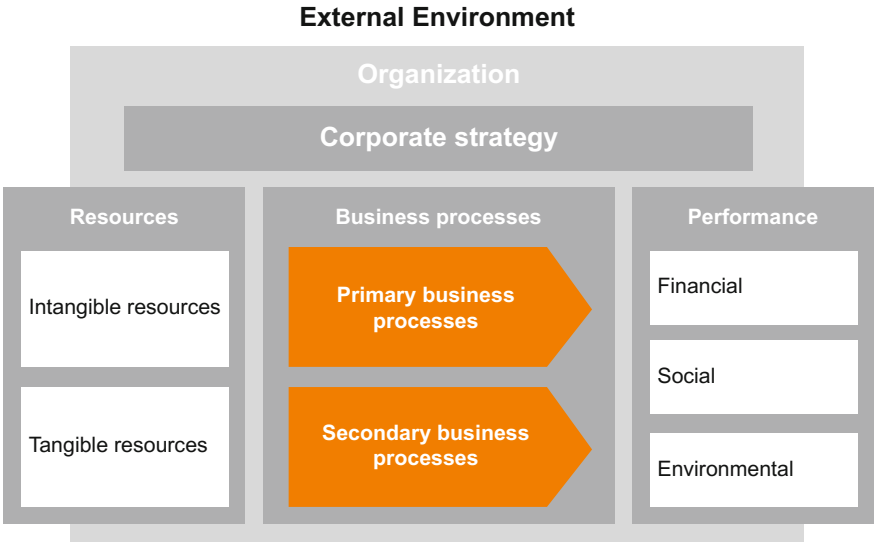

Fig. 7 Reference model for corporate sustainability

Tangible resources, meaning those resources that are material or substantial, are composed of financial, manufactured and natural capital (IIRC 2013).

Financial capital is the sum of available financial resources that are utilised to fund the organisation's operation. Thus, the product and service provisions are financially sustained through capital obtained via revenues, investments, debt, equity or grants.

Manufactured capital meanwhile comprises all physical objects that are employed by the organisation in order to produce and deliver its products and services. This physical part of the production system includes infrastructure and buildings, operating equipment as well as measuring, storage and transport utilities (Westkämper and Decker 2006). These objects can be obtained from third parties or in-house production.

On the basis of the classical understanding of "land" as a major factor of production, natural capital comprises all natural resources, processes and systems available (Harris and Roach 2013; IIRC 2013).

The classification of intellectual capital as an intangible resource follows the principle of the harmonisation of intellectual capital factors into standard repositories. Human, structural and relational capital are herein subdivided into standard success factors (Mertins and Will 2008) which map the most common types of intellectual capital. In order to comply with the system attached to modelling processes, the repository of intellectual capital factors needs to be adapted on a case-by-case basis. At the same time, considerations for directing this approach towards sustainable corporate development are taken in the following adaptation delineation.

The competence model forms the basis for the human capital factors. It was developed through empirical studies and quantifies specifics of enterprises analysed. Here a more generic approach is taken, which in turn is detailed through the consideration of role- and activity-based competencies. Human capital is thus defined as the sum of professional, social, personal and methodological competence. The peculiarity of these competences is dependent on the specific role occupied or on the activity itself, and in a wider sense, likewise on the strategic consideration of paradigms such as sustainable development.

The structural capital requires a distinct consideration of those capital factors that are activity-based (cooperation and knowledge transfer, product and process innovation), and the objectified factors (management instruments, explicit knowledge and corporate culture). While all factors are indeed structural factors of intangible resources, the implications on the activities of the model as condition transformation of objects such as "knowledge," need to be observed and incorporated into the process model creation.

In relational capital, a new configuration considers relations on micro-, meso- and macro-level in order to integrate social aspects in a distinguished manner. At the micro level, the external relationships of the enterprise with individual actors are considered, while cooperation partners, supplier-, customer- and investor-relationships constitute the meso-level as individual "dyadic" relationships (Provan et al. 2007). Relationships to public bodies (legislative, funding) and society moreover are considered within the macro-level of relational capital. This allows for a focused definition of all relevant stakeholders and the enterprise's relationships to those stakeholders.

At this point, an assessment of the cause-effect relationships can be implemented following a cross-factor impact assessment of all resource factors (Alwert et al. 2005). Identifying closed-loop interrelations is an attempt to address the system's theoretical discussion of the introduction, where weakening or strengthening dependencies are identified and expressed in relation to a specific analysis object (Galeitzke et al. 2015).

The definition of resources (tangible and intangible) builds the basis for analysing the interrelations within the different resource categories and helps to identify fields of action for improving on the sustainability performance of their deployment. The following section introduces an approach for action planning and monitoring by using extended enterprise models.

3.5 Action Planning and Monitoring Through Allocation in Process Models

The most brilliant sustainability strategies can turn into disasters if they are not entirely or only insufficiently implemented. A key factor for a successful implementation of the sustainability strategy lies in the planning of operational actions

and the availability of evaluations for monitoring and tracking qualitative and quantitative aspects. The measurement, control and communication of information on sustainability require the interaction between various actors, evaluation methods and operational data (Maas et al. 2016).

Figure 8 presents a framework concept for the description, analysis and monitoring of sustainability, specifically their interrelation with enterprise models.

Applying this framework, one can ensure that a systematic embedding of the individual sustainability strategies, objectives, their monitoring and its implementation takes place in the planning phase.

The enterprise model characterises the core area of the framework presented. It represents an enterprise within all its aspects of strategic objectives, products, organisation, processes, tangible and intangible resources and their interrelation to each other. Once the variables that contribute to the characterisation of sustainability are modelled, a detailed action plan for the achievement of the strategic objectives is required. In order to coordinate this multi-dimensional sustainability system, mechanisms for prioritising them, clustering mechanisms for mapping them to the different dimensions of sustainability, as well as mechanisms for describing the relation aspects between them, are all necessary. To make best use of the scarce resources of an enterprise, an initial selection is necessary. To that end, a two-dimensional prioritisation-matrix can be used. The matrix differentiates between the dimensions "need for action (urgency)" and "feasibility"—each of them assuming the characteristic values low, medium and high. The matrix (Fig. 9) can help identify which measures are urgent and how easy or difficult they are to implement (Kohl et al. 2014).

It reveals the urgency level of the actions, along with their feasibility. The optimisation of the energy use might, for example, be highly urgent, but need not be easily feasible due to contractual ties. Furthermore, the enhancement of the material efficiency could be highly urgent, but not very feasible, due to the complex processes along the value chain that can only be altered with the application of enormous effort.

As soon as the prioritisation is complete, a suitable set of indicators has to be derived. Due to that fact, numerous methods, guidelines and norms have been developed (Kohl et al. 2013; Neugebauer et al. 2015; ISO 2013; VDI 2016), which offer evaluation mechanisms, and finally, indicators for expressing the degree of target achievement. A further consideration is then omitted at this point. Once the suitable indicators are aligned with the planned actions and thus with the strategic objectives, the monitoring via the usage of operational data has to be realised. Business intelligence and reporting tools that are only capable of visualising performance indicators are no longer sufficient for capturing the complex requirements of a comprehensive sustainability approach (Schneider and Meins 2012). Moreover, a solution for network sustainability management and its evaluation is required for balancing economic, ecological and social dimensions (Wilding et al. 2012). In the context of sustainable development, economic, environmental and social aspects have to be presented in a context-sensitive manner. To provide task or role-oriented information, the framework supports a so-called "view concept." The views contain

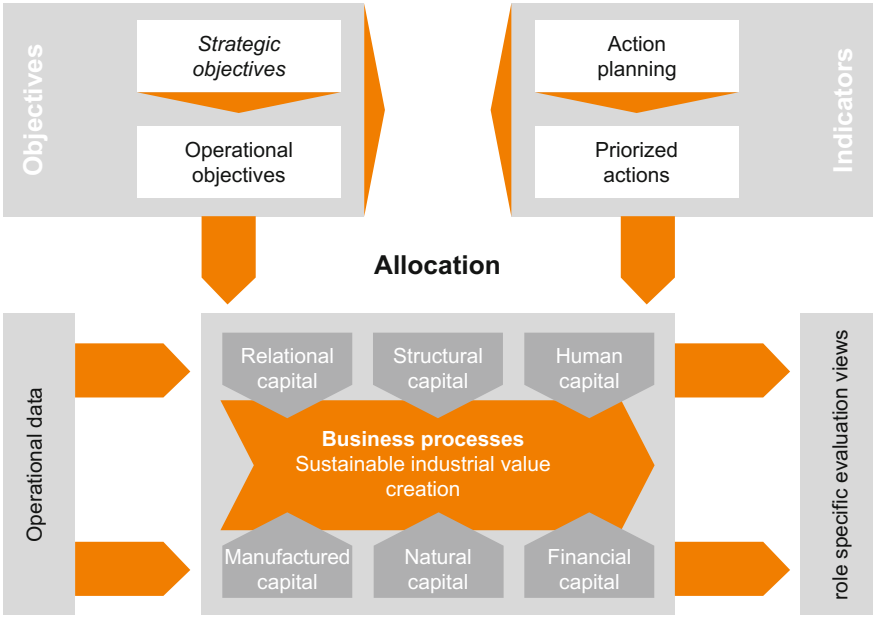

Fig. 8 Model-based framework the management of corporate sustainability performance

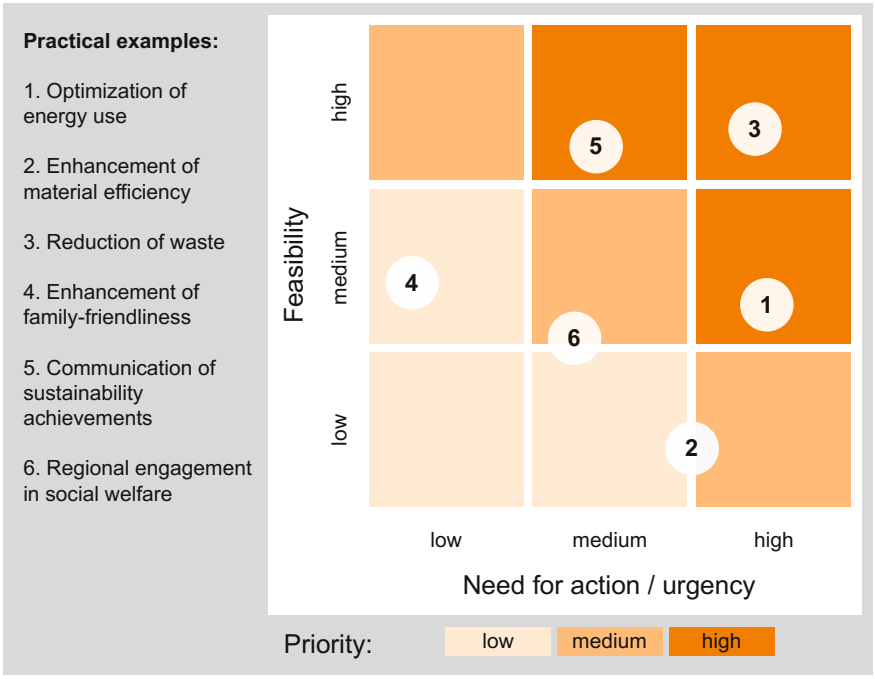

Fig. 9 Prioritisation-matrix (Orth et al. 2011)

the relevant information for typical application and modelling purposes. They offer a focused cut without changing the models themselves. An evaluation component offers role-specific model evaluation views, summarizing relevant indicators and enterprise information in a central system, and allows their evaluation according to model elements.

The framework also allows a derivation of integrated reporting which complies with national and international standards. All elements described in the section above and integrated into the integrated model-based framework, are represented also in reporting guidelines for the communication of sustainability. The following section briefly introduces the major approaches.

3.6 Integrated Reporting

Companies are exposed to a growing number of required reports for internal as well as external reporting purposes (e.g. Intellectual-Capital-Statements, environmental reports, corporate social responsibility reports or sustainability reports). Given this situation of information overload, a comprehensive integration of various reports seems to be worthwhile. An integrated reporting format would not only reduce the internal preparation efforts, but also contribute to the standards, as for example formulated in the EU directive "Accounts Modernization Directive" on non-financial enterprise reporting (Clausen et al. 2006). While large enterprises communicate non-financial data and information to their stakeholders, small enterprises so far lack the means to report on their effort and achievements in implementing sustainable strategies. This section highlights our research contribution on integrated reporting.

In 2011, Eccles and Saltzman (2011) defined integrated reporting as "a single document that present and explain a company's financial and nonfinancial—environmental, social, and governance (ESG)—performance." This definition highlights the content and origin of integrated reports. In addition to traditional financial information, contents regarding the sustainability of the company[1] are of note. Hence, in the following, the phenomena surrounding "sustainability reporting" will be discussed in detail before the connection to integrated reporting will then be drawn.

Sustainability reports document the environmental, social and economic engagements that enterprises are making in dealing with internal and external resources. They satisfy the increased need for information on the part of stakeholders. For sustainability reporting, criteria and an array of guidelines are already available. Worldwide attention has been paid to the Global Reporting Initiative

[1]The terms "sustainability", "environmental, social and governance" (ESG), "non-financial" or "corporate social responsibility" (CSR) reporting are frequently used interchangeably. They describe reports with different degrees of focus on environmental, social or corporate governance issues (Ioannou and Serafeim 2011).

(GRI). Since 2013, the meanwhile fourth version of the so-called "G4 Guidelines"—is available (Global Reporting Initiative 2013). Since the so-called "CSR directive" of the European Union was released, all reports published after the 6th of December 2016 have to be prepared "in accordance" with the G4-Guidelines (Guideline 2014/95/*EU*). When developing the guidelines, the GRI had several objectives in mind. One was to offer a bridge-builder for sustainability reporting on the path toward integrated reporting. The G4-Guidelines are therefore also applicable and implementable in integrated reporting (Soyka 2013).

The International Integrated Reporting Council (IIRC)—established in August 2010—consists of representatives from corporate, investment, accounting, securities, regulatory, academic and standard-setting sectors as well as from civil society (IIRC 2011). In September 2011, the IIRC released its first discussion paper, offering an initial proposal for the development of an "International Integrated Reporting Framework." More than 200 responses were received from a wide range of stakeholder groups. The (IIRC 2012) published the results in 2012. The current IIRC proposal considers arguments for integrated reporting, and describes guiding principles and content while offering preliminary suggestions for the development of an international "integrated reporting framework" (IIRC 2013).

Central to Integrated Reporting is the organisation's business model, i.e. "the process by which an organisation seeks to create and sustain value" in the short-, medium- and long-term perspective. This model is embedded into a system of inputs, business activities (the core of the business model) and outputs, as well as outcomes. In this context, value creation is not done by or within the organisation alone. It is influenced by external factors, e.g. the economic conditions and societal issues which represent risks and opportunities in the external environment. Furthermore, relationships to employees, partners, networks, suppliers and customers have an impact on the organisation's value creation process. All organisations depend on different resources and relationships for their success. In that process, the IIRC framework uses the concept of "multiple capitals" for explaining how an organisation creates and sustains value. According to the framework, an integrated report should display an organisation's stewardship not only with regards to financial capital, but also with other forms of "capital" (e.g. manufactured, human, intellectual, natural and social), along with their interdependencies.

According to the IIRC, integrated reporting explains linkages between an organisation's strategy, governance and financial performance and the social, environmental and economic context within which it operates. Based on this, the IIRC formulates suggestions for integrated reporting—consisting of seven guiding principles and nine key content elements. The guiding principles underpin the preparation of an integrated report, based on the interconnected key content elements.

The Guiding Principles are:	The Content elements are:
A. Strategic focus and future orientation B. Connectivity of information C. Stakeholder relationships D. Materiality E. Conciseness F. Reliability and completeness G. Consistency and comparability	A. Organisational overview and external environment B. Governance C. Business model D. Risks and opportunities E. Strategy and resource allocation F. Performance G. Outlook H. Basis of preparation and presentation I. General reporting guidance

The approach of the IIRC gives comprehensive understanding of tangible and intangible resources and suggests interdependencies between corporate action and results. Since the IIRC approach aims for a harmonisation of reporting, a special focus is set on the enterprise's external communication.

Originally, the approach was developed for large companies that are publicly traded. However, an approach for small- and medium-sized enterprises (SME) must be "downsized" or "downsizable" for the special purposes of SME (Bornemann

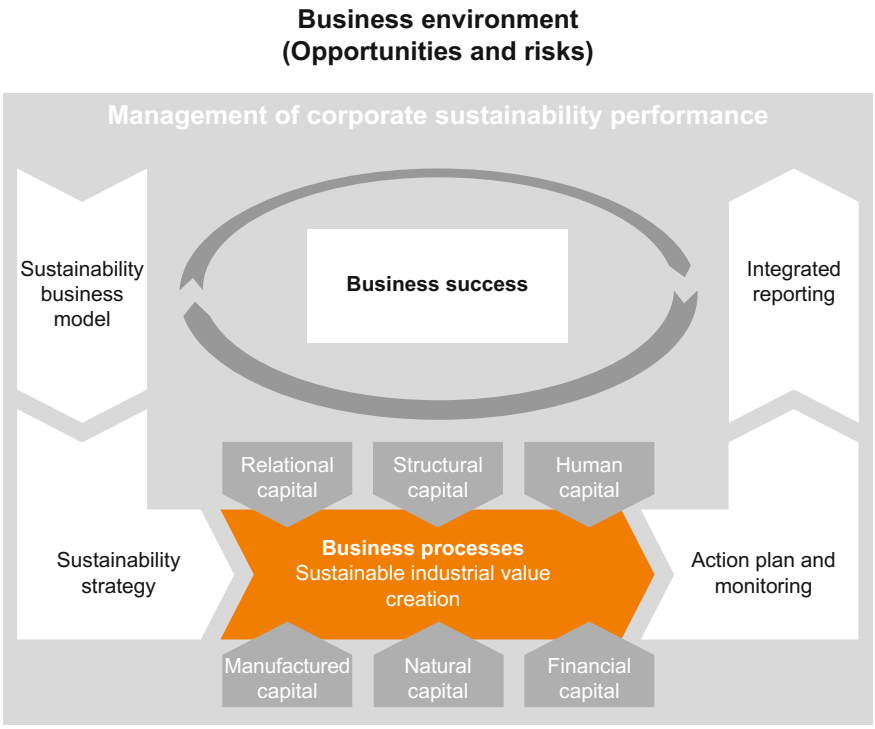

Fig. 10 Framework for management of corporate sustainability performance

et al. 2011). Because the IIRC approach principle is based on this, flexibility for an adaption is thus built-in.

In-line with the guiding principles and content of the IIRC, the authors have developed a reduced approach with a special focus on SME. This approach uses the five following principles and six content suggestions:

The Guiding Principles are:	The Content elements are:
A. Materiality	A. Organisational overview
B. Integrity	B. External environment
C. Connectivity	C. Business model
D. Consistency and comparability	D. Risks and opportunities
E. Communicative quality	E. Performance
	G. Actions and Outlook

To enhance the range in the distribution of the report, the approach also suggests using digital media. In addition, the formulated principles likewise profit from the use of digital media. When regarding, for instance, the consistency and comparability principle, the timelines of the KPIs prove to be much more doable in the digital approach than in the case of a classical print-version of a report.

4 Conclusion

The proposed integrated model-based framework for the management of corporate sustainability performance and the presented stepwise approach for implementing the discussed elements can be summarised as illustrated in Fig. 10. It can assist researchers as well as practitioners in gaining a clearer focus on the development and implementation of sustainability business models, sustainability strategies, performance management and reporting, regardless of whether transparency or decision support is taken as an a priori perspective. It also enables managers to improve their understanding of how the different management disciplines interact on sustainability topics and how to tackle increasing complexity in a context-sensitive and role-based concept.

Further steps in the area of sustainability performance management are nevertheless needed to extend the scope towards complete supply chains in order to manage, evaluate and control the performance of complex value-creation networks. Here, detailed concepts for an intuitive handling of data occurrence means that services for its selection, combination and aggregation, all have to be examined. In addition, several evaluation methods like the LCA already exist on the market, but connection mechanisms have to be developed to allow for reliable steering, controlling and monitoring. On top of the data-driven development needs, the knowledge transfer to the industrial community also has to be strengthened in order to improve and support the corporate sustainability orientation process as a whole.

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