Chapter 2
Life Cycle Management: Implementing Sustainability in Business Practice

Guido Sonnemann, Eskinder Demisse Gemechu, Arne Remmen, Jeppe Frydendal, and Allan Astrup Jensen

Abstract Life cycle management is a business management concept applied in industrial and service sectors to improve products and services, while enhancing the overall sustainability performance of the business and its value chains. Life cycle thinking and product sustainability is operational for businesses that are ambitious and committed to reducing their environmental and socio-economic burden while maximizing economic and social value. In this regard, life cycle management is used beyond short-term business success and aims at long-term achievements. The term "life cycle management" has been confused with other uses in engineering and manufacturing (product life cycle management) and in software development (application life cycle management), in buildings, plants, information management and so on. There is a need to clarify this term and its definition more than a decade since the concept was first introduced. This chapter aims at elaborating the concept and definitions of life cycle management as currently found in literature and as extending it from focusing on implementation of life cycle sustainability assessment into business practice to include it as part of sustainable consumption and production strategies and policies. Methods and tools used and the general framework for life cycle sustainability management covering environmental, social and economic aspects in business practices are discussed in detail.

G. Sonnemann (✉) • E.D. Gemechu
University of Bordeaux, ISM, UMR 5255, 33400 Talence, France

CNRS, ISM, UMR 5255, 33400 Talence, France
e-mail: guido.sonnemann@u-bordeaux.fr

A. Remmen
Aalborg University, Aalborg, Denmark

J. Frydendal
Ecolabelling Denmark

Danish Standards Foundation

A.A. Jensen
Nordic Institute of Product Sustainability, Environmental
Chemistry and Toxicology (NIPSECT), Copenhagen/Frederiksberg, Denmark

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1 Life Cycle Management and Life Cycle Sustainability Management: A Clarification of Terms

A web search on life cycle management (LCM) results in a link to the UNEP/SETAC Life Cycle Initiative's website as well as the official UNEP website on life cycle management and the publication of the UNEP/SETAC Life Cycle Initiative on *Life Cycle Management: A Business Guide to Sustainability* (Remmen et al. 2007), to which the authors of this chapter as co-initiator and co-authors of the UNEP publication will refer to. Moreover, links of LCM events from the first held in Copenhagen to the recent conferences in Gothenburg (http://lcm2013.org/) and the upcoming event in Bordeaux (http://lcm2015.org/) are among the top ten search results jointly with references to product life cycle management (PLCM) and information life cycle management (ILCM).

These considerations are the motivation for the authors to use Life Cycle Management: Implementing Sustainability in Business Practice as the title for this chapter.

Looking at some of the existing definitions of LCM that are summarized in Table 2.1, LCM seems to be a concept with a broad variety of approaches and methodological tools. Companies apply it in a number of different ways in order to achieve the desired outcomes, as far as it relates to their sustainability performance. The theoretical background for LCM has been developed by a SETAC Working Group (Hunkeler et al. 2004). Yet there is no universal definition of LCM.[1]

LCM is mainly a business management concept for sustainable products that can be applied in the industrial and service sectors with the aim of improving specific goods and services and enhancing the overall sustainability performance of the business and its value chains in general. It makes life cycle thinking and product sustainability operational for businesses that are ambitious and are committed to reduce their environmental and socio-economic burden, while maximizing economic and social values. In this regard, LCM is used beyond the short-term business success; rather it aims at taking businesses forward towards long-term achievements and sustainable value creation. So LCM requires a holistic view and a full understanding of interdependency of businesses in order to support relevant decisions and actions so as to improve sustainability performance that takes into account both the environmental and social benefits and at the same time offer a number of value creation opportunities to the business.

[1] Seemingly similar, but unrelated, terms include product lifecycle management (PLM), application life cycle management (ALM) for software, and data lifecycle management (DLM).

Table 2.1 Different definitions of life cycle management (further developed based on the work by Seuring 2004)

Reference	LCM definitions
Linnanen (1995)	Life cycle management consists of three views: (1) the management view – integrating environmental issues into the decision making of the company; (2) the engineering view – optimizing the environmental impact caused by the product during its life cycle; and (3) the leadership view – creating a new organizational culture
Fava (1997)	Life cycle management is the linkage between life cycle environmental criteria and an organization's strategies and plans to achieve business benefits
Finkbeiner et al. (1998)	A comprehensive approach towards product and origination related environmental management tools that follow a life cycle perspective
Heiskanen (2002)	LCA-based ideas and tools can be viewed as emerging institutional logics of their own. While LCA makes use of many scientific models and principles, it is more a form of accounting than an empirical, observational science. Thus, the life cycle approach implies a kind of "social planner's view' on environmental issues, rather than the minimization of a company's direct environmental liabilities"
Hunkeler et al. (2004)	Life cycle management (LCM) is an integrated framework of concepts and techniques to address environmental, economic, technological and social aspects of products, services and organizations. LCM, as any other management pattern, is applied on a voluntary basis and can be adapted to the specific needs and characteristics of individual organizations
Baumann and Tillman (2004)	LCM is "the managerial practices and organizational arrangements that apply life cycle thinking. This means that environmental concerns and work are coordinated in the whole life cycle instead of being independent concerns in each company"
Remmen et al. (2007)	LCM is a product management system aiming to minimize environmental and socioeconomic burdens associated with an organization's product or product portfolio during its entire life cycle and value chain
UNEP/SETAC (2009)	"… a business management approach that can be used by all types of businesses (and other organizations) to improve their products and thus the sustainability performance of the companies and associated value chains" "It can be used to target, organize, analyze and manage product-related information and activities towards continuous improvement along the life cycle"
Jensen (2012)	"… a systematic integration of life cycle thinking in modern business practice with the aim to provide the societies with more sustainable goods and services and to manage the total lifecycle's of an organizations product portfolio towards more sustainable production and consumption"

The definitions of LCM are thus wide and its concept needs further development, to which this book aims to contribute with theoretical and practical contributions, in particular from industries and businesses. New aspects include, for instance, activities on mainstreaming and capacity building as well as the use of LCM in the context of emerging economies, SMEs and regional development. The focus on the earlier definitions of LCM was mainly linked to the management view of only the environmental aspect of a product or a company – environmental LCM (Fava 1997;

Finkbeiner et al. 1998; Linnanen 1995). However, recent definitions of LCM cover environmental, social and economic issues (Hunkeler et al. 2004; Remmen et al. 2007) along a product life cycle, which is in line with recent developments in the area of life cycle assessment (LCA) that further expand the context of LCA to include social and economic elements under the life cycle sustainability assessment (LCSA) framework (Finkbeiner et al. 2010; Klöpffer 2008; UNEP 2011) to cover, for instance, new challenges related to the criticality of materials (Sonnemann et al. 2015). Hence, the implementation of LCSA into real world decision-making processes both at product, process or individual organizational level is to be ensured through the application of a broader LCM concept that aims at maximizing the triple bottom line. Finkbeiner (2011) referred to it as life cycle sustainability management (LCSM) for the first time.

2 Life Cycle Management: Concepts and Definition

As indicated in the *Business Guide to Sustainability* by Life Cycle Management (Remmen et al. 2007), which itself is based on Remmen and Münster's (2003) report to the Danish Ministry of Environment and the pioneering SETAC publication on Life Cycle Management by Hunkeler et al. (2004), LCM has been developed on the basis of fundamental concepts related to sustainable development, which are the triple bottom line and life cycle thinking. The most popular definition of sustainable development is the one from the United National World Commission on Environment and Development "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission 1987). This definition is based on two key concepts "needs" (the essential needs of the world's poor, to which overriding priority should be given) and "limitations" (the restriction imposed by technologies and socio-economic factors on the ability of the environment to meet the needs of present and future generation).

The triple bottom line (3BL) is a framework that integrates the "three dimensions of sustainability: economic, environmental and social" (Fig. 2.1) (Remmen et al. 2007). They are also called the three Ps: people, planet and profit. Businesses traditionally used to account only the economic aspect of their "bottom line" through profit they gain or lose. However, the modern accounting broadens the definition of bottom line to a full cost accounting by including the environmental cost on ecosystem service and a cost on the society. The consideration of 3BL in the conceptualization of LCM allows companies to broaden their focus from only economic aspects to the environmental and social dimensions.

The goal of life cycle thinking is to avoid burden shifting by assessing a product's use of natural resources and its impact on the environment, the economy and society throughout its entire life cycle. The life cycle of a given product involves a number of stages from the extraction of raw materials through processing, manufacturing, distribution, use, recycling, reuse or final disposal (Fig. 2.2). Life cycle thinking

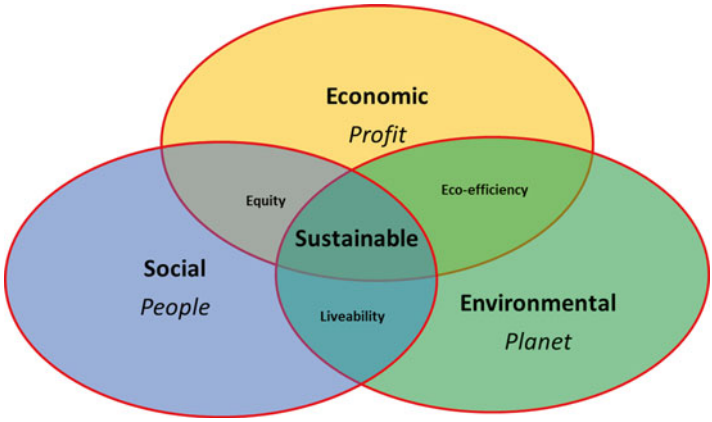

Fig. 2.1 The three dimensions of sustainability

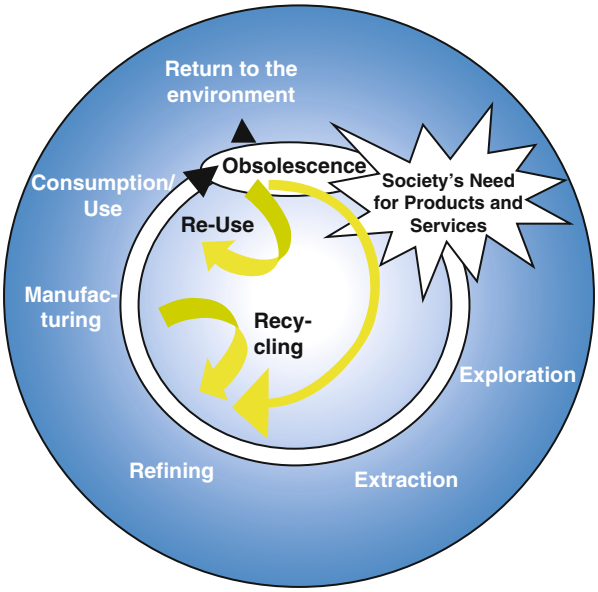

Fig. 2.2 The life cycle of products and services

enables to consider the environmental, social and economic impacts associated with the production or consumption of the product by taking into account all the stages of the product life cycle. It provides a means of ensuring that improvements in one stage are not creating a greater cumulative impact by simply shifting the burden to another stage of the life cycle. Therefore, it also allows companies to see the influence of their choices with regard to sustainability and help them take decisions, so trade-offs can be balanced positively to impact the economy, the environment and society.

In this context, LCA as an ISO standardized analysis is just one decision-making tool used to assess and identify the environmental aspects and potential environmental impacts of a product over its life cycle (ISO 2006a, b). Life cycle sustainability assessment (LCSA) is the combination of LCA, life cycle costing (LCC) and social life cycle assessment (SLCA) to assess the three dimensions of sustainability for products (Finkbeiner et al. 2010; Klöpffer 2008; UNEP 2011). In addition, also other tools such as material flow analysis (MFA), input–output analysis[2] and environmental risk assessment (ERA) are used by organizations to address their sustainability challenges.

LCM allows organizations to put life cycle thinking into modern business practice by using these tools. However, LCM is also about the systematic integration of product sustainability in company strategy and planning, product design and development, purchasing decisions and communication programs (Remmen et al. 2007).

A particular aspect of LCM is the question of who has which responsibilities in the product life cycle with regard to sustainability and who can do what under which circumstances. Evidently a retailer like Wal-Mart has more power to initiate change within the supply chain than for instance a supplier of automotive parts. Furthermore, the existence of sector wide collaborations like the Global e-Sustainability Initiative (GeSI) shows that there is space for joint work of companies of one sectors to address supply chain challenges, which in the case of GeSI have been addressed for instance by E-TASC (Electronics – Tool for Accountable Supply Chains), which a web-based tool utilized by companies to manage their own factories, communicate with their customers and assess their suppliers on corporate responsibility risks.

A related facet of life cycle (sustainability) management is how it is embedded in sustainable consumption and production (SCP) policies. SCP is understood as the "The use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations" (Norwegian Ministry of the Environment 1994). It means that SCP is a holistic approach that has at its core a life cycle perspective, which is the attitude of becoming mindful of how everyday life has an impact on the environment and society.

According to UNEP (2012), SCP focuses on the sustainable and efficient management of resources at all stages of value chains of goods and services encourages the development of processes that use fewer resources and generate less waste, including hazardous substances, while yielding environmental benefits and frequently productivity and economic gains. Such improvements can also increase the competitiveness of enterprises, turning solutions for sustainability challenge into business, employment and export opportunities. SCP also encourages capturing and reusing or recycling valuable resources, thereby turning waste streams into value

[2] See "LCA Compendium", volume "Special Types of Life Cycle Assessment" (editor: Matthias Finkbeiner), chapter 6 "Input–output and Hybrid LCA" by Shinichiro Nakamura and Keisuke Nansai.

Fig. 2.3 SCP policies along the product life cycle (UNEP 2012)

streams. The fundamental objective of SCP is to decouple socio-economic development from environmental degradation.

SCP policies cover all the areas highlighted in Fig. 2.3. A core element linked to SCP is resource efficiency that is about ensuring that natural resources are efficiently produced and processed, and consumed in a more sustainable way, as well as about reducing the environmental impact from the consumption and production of products over their full life cycles. By producing more wellbeing with less material consumption, resource efficiency enhances the means to meet human needs while respecting the ecological carrying capacity of the earth.

That means SCP is based on a life cycle approach but the link to how it is put into business practice using multiple tools mentioned above is not addressed in the same way as in LCM. Therefore, the question on how tools like LCA are actually used in public policy making and hence might influence business operations has been covered under the heading of LCM in the past. Overall there seem to be high expectations of the future use of LCA in SCP policy areas such as sustainable public procurement and eco-design directives as well as consumer information. However, there are still certain challenges to overcome such as the lack of good quality and available data, the lack of valid and internationally recognized calculation principle, more capacity building and resources.

3 Systems and Tools for Life Cycle Management

Being an integrated management framework of concepts, techniques and procedures, LCM connects different operational concepts, policies, systems, methods, tools and data that incorporate environmental, economic and social aspects and looks how they are interconnected and how to best address these throughout the product or process life cycle. As indicated in the previous section, a wide range of methods, tools and concepts can be used in LCM. Analytical tools are life cycle assessment (LCA), life cycle costing (LCC), social life cycle assessment (SLCA), organizational LCA (OLCA), hotspot analysis, different forms of footprinting such as water footprint and carbon footprint, cost benefit analysis (CBA), material flow analysis (MFA), substance flow analysis (SFA), input–output analysis (IOA), environmental risk assessment (ERA), etc. Procedural tools include auditing, checklists, eco-design, eco-labeling, etc. and supportive tools such as weighting, e.g. by Delphi expert panels, uncertainty analysis, sensitivity analysis, etc. could be applied. LCM also includes design concepts such as design for the environment, design for sustainability, design for recycling etc. It also refers to policies and strategies such as circular economy, sustainable consumption and production, integrated product policy (IPP), resource efficiency, eco-efficiency, dematerialization, industrial ecology, etc. as well as organizational systems or programs such as extended product responsibility (EPR), product development process (PDP), certification, environmental communication, value chain management, etc. All these analytical and procedural tools as well as policies, strategies and systems/programs are part of LCM (Nilsson-Lindén et al. 2014; Remmen et al. 2007; Sonnemann and Leeuw 2006). The initial ideas for this integrated approach of using multiple tools and methods stem from the ChainNet project (Wrisberg and Udo de Haes 2002).

The choice of policies, strategies, systems, programs and different types of tools represented in Fig. 2.4 mainly depends on the principal goals and the level of ambition of each company. Companies use LCM to support their goals of providing products that are as sustainable as possible. Companies need to go beyond their organizational boundaries and be willing to expand their scope of collaboration through external communications to all stakeholders of their value chain as it makes them more visible, may improve their public image, improve their relations with stakeholders and may increase their market penetration through mapping their product chains and develop criteria for product enhancement and value creation. Life cycle information may be included in:

- Communication to shareholders and stakeholders in general by, for example, green accounting and annual environmental or sustainability reports
- Communication with customers through such items as life cycle based environmental product declarations, LCA data, product environmental performance indicators or product profiles
- Communication with public authorities via product information schemes and green public procurement guidelines
- Communication with the public, consumers (including professional purchasers in businesses) and retailers using product brochures and various eco-labeling systems and information campaigns

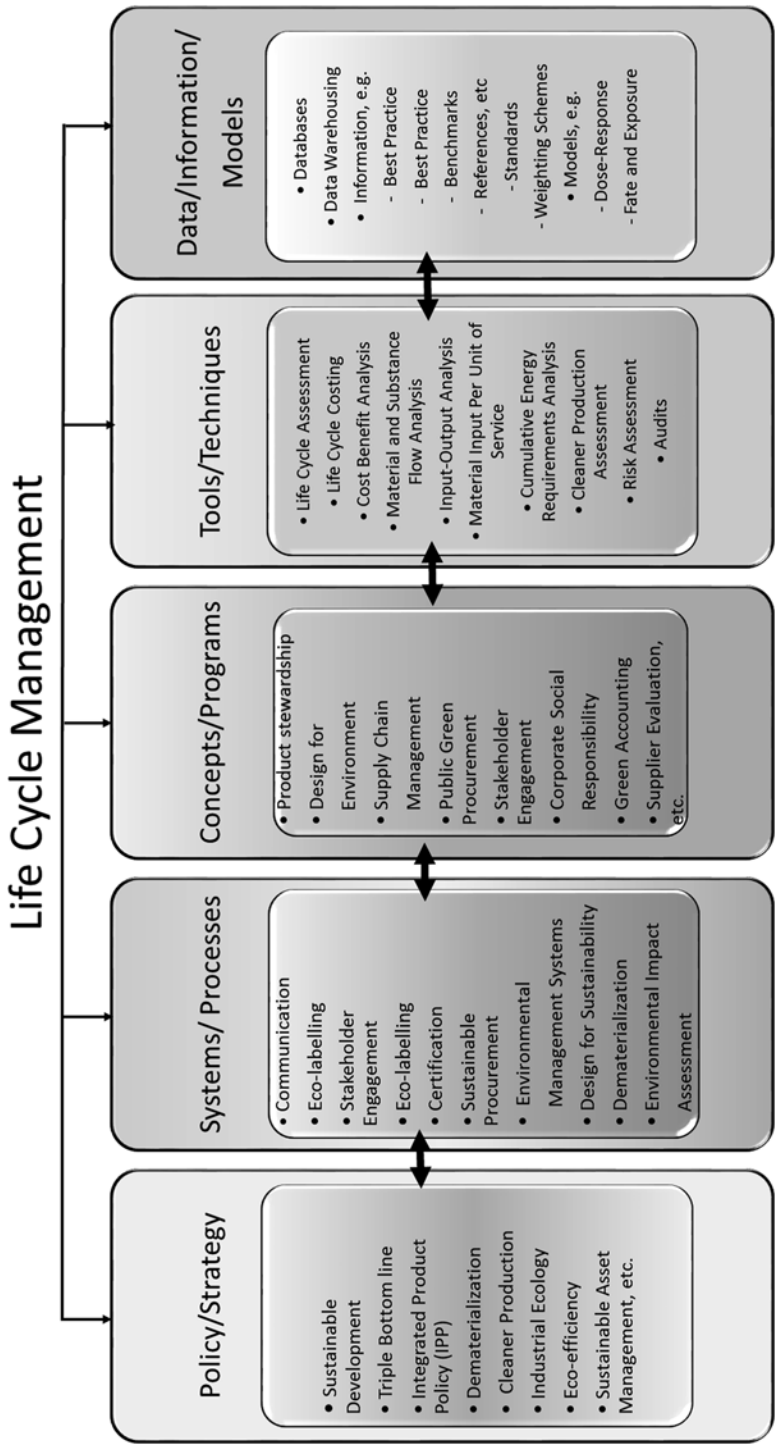

Fig. 2.4 Choice of policies, strategies, systems, programs and different types of tools within the life cycle management context (Based on Remmen et al. 2007)

- Communication with suppliers, including SMEs, using company codes or manuals of conduct, audit or supplier evaluation systems

Larger companies often combine supplier communication with offering training exercises.

4 Organizational Challenges

LCM can be applied in all organizations from a very small-scale local vendor to large and multinational companies. However, the application procedure and its organization may vary in each company. This is mainly due the fact that the relevance of different aspects of sustainability varies from company to company, and it depends on factors such as the type of product system involved in the company, specific social and environmental issues they would like to address, their geographic scope and supply chain complexity and so on. As a life cycle approach, LCM is a dynamic process in which companies may begin applying it with specific goals and objectives depending on the resource they have. They may begin with using LCA as a tool to evaluate their environmental performance of a single product and find an alternative solution to reduce the environmental burden from this product. Through time they can adjust their goal and move forward step-by-step from one project to a more advanced and sophisticated life cycle management practice, with a process in place for multiple products, which require advanced tools and data-intensive programs. Another point of departure for a company could be to benchmark their products or services against ecolabel criteria to determine relevant aspects to consider in a life cycle perspective and to find inspiration for improvements. This, of course, requires that ecolabel criteria exist for the products or services in question.

One of the critical reasons for companies to be engaged with LCM practices is their pursuit for continuous improvements, covering economic, environmental and social aspects. Nowadays, companies are influenced by external and internal factors so that they envisage such improvements and develop strategic policies, apply a number of tools and establish programs that integrate LCM into the core operations of their business. Business strategy, market opportunities and requirements from the finance sector, as well as national legislations, trade block related regulations and international agreements are the key drivers behind the implementation of LCM. Evidently, companies have to apply it based upon high-level management decisions, only then LCM becomes an integral part of the organizations' policies and strategies in the short term and long term. However, it can also be implemented with a pioneer in one of the multiple departments of an organization.

Successful implementation of LCM demands continuous support from top level management such as:

- Providing the required resources for the sustainability initiative including time and educational resources

- Participating actively in setting up the strategic sustainability goals of the organization
- Communicating explicitly throughout the organization regarding the sustainability aims in an effective and clear manner
- Involving actively the employees with regard to ideas and suggestions for the use of life cycle approaches

However, in order for LCM to be accepted and get continuous support from top level management, it needs to highlight the economic benefits the company can profit from its implementation in addition to the social and environmental performance improvements.

A successful implementation of LCM also needs full participation by a range of employees in order to ensure that the initiative will be deeply rooted in the organization and that the focus will be on concrete improvements to a product's sustainability profile, rather than mere talk and data collection. Furthermore, broad participation ensures that the LCM program does not 'die' if a key employee involved leaves the organization.

Leading companies will undertake initiatives to increase market share and enhance the potential for product innovation. A business striving for increased resource efficiency may see a strategy for product sustainability as an opportunity to reduce costs. In more conservatively operating companies, intrinsic factors will include reduced penalties and risks since taking a life cycle approach can help identify important opportunities and risks. Other organizations may seek to gain competitive advantage through innovation, brand value enhancement and strategic positioning in the market.

In the case of product design and development processes, for example, design decisions take place within the broader corporate management structure. An integrated management system – covering quality, environment and health & safety – with policies, goals, performance measures and a strategic plan that supports continuous improvements will be a driver for integration of sustainability performance metrics and measures. In this context, life cycle (sustainability) management offers a framework that allows management to organize and align the various applied concepts and tools in such a way as to exploit the synergies and interrelations between them.

Another key factor for the success of LCM practices in an organization is the involvement of all departments. Such an initiative could impact all functions and departments of a company. For instance, an implementation of a new design idea may need the support from procurement and marketing departments. Any decision that changes the material composition of a product not only affects its quality, price and environmental profile but also raises questions regarding procurement of new material, potential new markets, consequences to the production process, new logistical demands, etc. Therefore, communication and sharing ideas within and across departments in an organization is key to LCM. Communication and interaction helps generate a range of news ideas and helps push ideas into realization. It is important to recognize also the environmental and social initiatives, which already exist in various

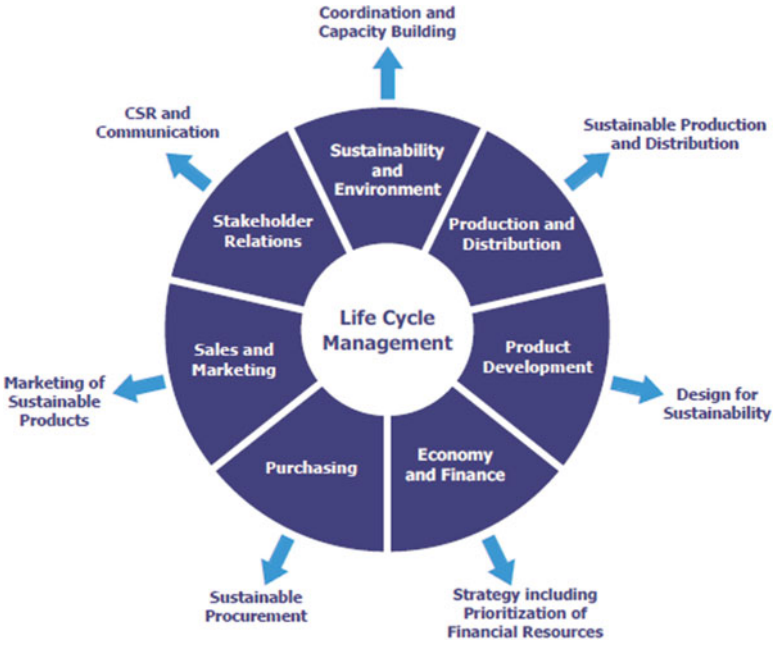

Fig. 2.5 All functions play an important role in life cycle management. The figure shows examples of how different departments in an organization can contribute to an LCM program (Remmen et al. 2007)

departments. Involving all departments means learning from what has done before. A life cycle perspective requires that all departments or functions work together, including product development, purchasing, production, logistics as well as marketing. All functions (illustrated in the following as departments) must therefore participate with ideas for initiatives and solutions, based on their particular expertise.

Figure 2.5 illustrates how different departments in a company can contribute to the establishment and running of LCM initiatives. In most cases, large, multinational companies have environmental, social responsibility and sustainability departments that could coordinate the implementation of LCM. These departments are typically responsible for reporting developments within environmental and sustainable policy and they can provide valuable inputs through training of employees in the other departments. However, it is crucial that the whole company is motivated and 'speaks the same language'.

However, most small and medium-sized enterprises (SMEs) do not usually have such departments. Therefore, the coordination of LCM activities could also be managed by forming a cross-organizational or cross-functional team with a representative from each relevant function, where a motivated employee (the pioneer) can act as coordinator and at the same time make sure that everybody has the necessary tools and materials to inspire and carry out the activities. The relevance for putting LCM into business practice of each department is summarized in Table 2.2.

Table 2.2 Departments in an organization and their relevance for life cycle management in practice (Based on the work from Remmen et al. 2007)

Department	Main activities
Production and Distribution	• Assess the environmental and social impacts associated with production processes and thus suggest an alternative solution to reducing resource consumption and the related impacts • Provide a novel ideas and data for product and process improvements • Identify and suggest a solution to reduce the impacts associated with the energy consumption connected to the transportations of raw materials, intermediate and finished products

Product Development and Design	• Move environmental and social considerations higher up on the design criteria list
	• Develop a new product with the starting point of social, ethical and environmental considerations– for example a new clothes collection based on organic cotton and fair trade
	• Make the existing product more sustainable, for example by replacing an environmentally harmful substance with a less harmful substance
	• Shift from producing a product to supplying a service – the sale of answering machines shifts to an electronic answering service delivered by the phone company
	• Assess the environmental and socioeconomic aspects of a product from two different angles based on a definition of the product system:
	  • A product life cycle perspective with assessment of the environmental and socio-economic impacts of a product system with tools such as Life Cycle Assessment (LCA) or Life Cycle Costing (LCC)
	  • A stakeholder perspective with assessment of impacts based on the stakeholders' view such as legal requirements, market demands, and competitors' products. Quality Function Deployment (QFD), interviews, etc. are commonly applied tools

Economy and Finance	• Provide a good financial performance to allow the company to see its impact on driving the company towards sustainability and LCSM • Assess the life cycle avoided costs due to the implementation of LCSM project, for example, by tracking both the annual cost reduction and commutative savings from prior years
Purchase	• Play an important role in selecting the optimal raw materials, semi-products and products for production, by applying some tools that integrate environmental and social considerations together with other factors such as price, quality, and functionality • Encourage environmental considerations at their suppliers via questions and demands an overview of the supplier's environmental and social initiatives as well as policies; documentation of the impacts from the previous life-cycle stages; overview of working conditions at suppliers and sub-suppliers; and/or specific environmental and social data regarding raw materials, secondary materials, etc.
Sales and Marketing	• Ensure a good flow of information to and from the customers such as consumer behavior and preferences, product's eco-friendly use and disposal, etc. • Promote the eco-friendly product e.g. by the use of ecolabels
Stakeholder Relations	• Identify and engage stakeholders (employees, suppliers, customers, etc.) so as to anticipate their opinions on the business, products and services and to identify what really matters to them

5 Conclusion and Outlook

In this chapter, the authors propose to consider the term life cycle sustainability management to clearly differentiate the term from other disciplines using also the term life cycle management. The current literature is summarized, in particular Remmen et al. (2007) and Finkbeiner (2011) on Life Cycle Management and Life Cycle Sustainability Management, focusing on putting life cycle thinking into business practice using relevant tools, including life cycle sustainability assessment (LCSA) to cover the three dimensions of sustainable development. The authors show that different companies have different ways of engaging their departments in LCM practices; they also use different tools and set different priorities.

A particular effort is made to explain life cycle (sustainability) management as part of sustainable consumption and production (SCP) strategies and policies. Strategies to change consumption and production patterns need to take into account the varying responsibilities of different actors in the value chain, including the consumers. Overall, there seem to be high expectations of the future use of LCA in SCP policy areas such as sustainable public procurement and eco-design directives as well as consumer information.

With regard to the future, management science will increasingly be brought into the topic of LCM, as shown for instance through recent work done by, inter alia, Nilsson-Lindén et al. (2014), and that there is an important need for capacity building and a great potential for mainstreaming. With regard to capability development using the LCM Capability Maturity Model (UNEP/SETAC 2013) is a good way to help companies to catch up with leading ones in the area of LCM. The next steps in companies are to move from projects to processes to establish the LCM team as a business partner for the long term. For mainstreaming to happen, professional communication targeting the opinion leaders and collaboration among life cycle experts and networks around the world are important elements for sustainable value creation.

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