

Chapter 22

Life Cycle Management

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Abstract This chapter gives an overview of Life Cycle Management (LCM)—a discipline that deals with the managerial tasks related to practicing sustainable development in an organisation. Just as Life Cycle Assessment, LCM advocates the life cycle perspective, and it applies this perspective in decision-making processes. The chapter shows that LCA can play a key role in LCM since LCA provides quantitative performance measurements. It also explains, which stakeholders need to be considered, how LCA and LCM relate, how LCA can be used to develop Key Performance Indicators, and addresses how LCM can be integrated into an organisation.

Learning Objectives

After studying this chapter, the reader should be able to

- Define Life Cycle Management (LCM) and describe its links to related approaches and terms
- Give an overview of the central elements of LCM and how LCM relates to Life Cycle Assessment (LCA)
- Identify central stakeholders and their areas of influence on decisions
- Describe factors needed to make LCM work in organisations
- Describe how to develop Key Performance Indicators for use in LCM practice
- Practice LCM activities and decision-making contexts by means of a case study

In general, this chapter takes the viewpoint of a Life Cycle Management practitioner.

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22.1 Introduction—What Is LCM?

22.1.1 *Definition of Life Cycle Management—And Distinction Against Related Terms*

Private individuals and managers in organisations constantly make choices in the context of all kinds of activities; be it shopping in supermarkets, choosing a holiday destination, selecting means for business travel or refurbishing a family home or equipping an entire office building. When working towards sustainable development, any such choice will imply the question, which option may be the preferable one in a holistic perspective. The way advocated and described in this book is to answer this question through taking a view on the life cycles of the involved products and systems. Practicing the above in managerial decision-making is Life Cycle Management (LCM); i.e. the making of managerial decisions with a sustainability-oriented, holistic view on the life cycles of the products, service activities and systems that the managerial decisions are dealing with.

Once adopted, Life Cycle Management means taking a constant view on many life cycles of products and systems, and practicing LCM thus influences decision-making processes in many contexts, in fact in more or less all activities an individual or an organisation pursues. Examples of decision-making in an organisation may be selecting engineering materials for products (e.g. for window frames), choosing suppliers providing materials and services, selecting logistics solutions (e.g. rail transport vs. air transport), designing or redesigning factories—or schools or residential houses—and even selecting among different options for public transportation systems to be established by a municipality—and all this potentially in different geographical regions.

LCM can, with full legitimacy and good reasoning, be practiced without a focus on environment and sustainability, e.g. for pure cost optimisations. However, it will always involve a view on entire life cycles. LCM in this chapter—and in common understanding—does build on the principles of sustainable development and Life Cycle Thinking (LCT). And LCM applies LCT in a generic and flexible way to business management, potentially employing any life cycle-based approaches and methods, such as:

- Life Cycle Assessment (LCA), [sometimes also referred to as ‘Environmental LCA’ (E-LCA)]
- Social LCA (S-LCA or SLCA) (Chap. 16)
- Life Cycle Costing (LCC) (Chap. 15);
- Ecodesign/Life Cycle Design (LCD)/Sustainable Product Design (SPD), Design for Recycling/Circularity and others (Chap. 23).

This also covers combinations and/or simplifications of such approaches as well as classic business tools, such as stakeholder analysis, SWOT (strengths, weaknesses, opportunities, and threats) analysis (with sustainability focus), etc. In the remainder of this chapter, the term ‘tool’ also stands synonymously for ‘method’ and ‘instrument’.

It is very important to acknowledge that it is always up to the individual organisation to decide which tools their particular Life Cycle Management approach should comprise—there is no ‘one-size-fits-all’ LCM approach. Rather, LCM draws upon the above outlined tools and approaches—something that can be called a toolbox (UNEP/SETAC 2007)—from which the organisation picks its individual set leading to their tailor-made LCM approach. This is because a large number of factors such as product type, business model, market presence, organisational maturity, level of ambition, value chain position, regulatory frameworks and others can play a decisive role for what a meaningful and feasible approach would be for a given organisation.

A prominent, already existing suggestion towards combining environmental, economic and social assessment is Life Cycle Sustainability Assessment (LCSA). The two principally possible methodological options to generate LCSA results are either to present three sets of impact category indicators next to each other (from LCA, LCC, and SLCA) or to develop methods for integrated inventory analysis and integrated impact assessment to reach integrated impact scores (Kloepffer 2008; Guinée et al. 2011). However, although principally targeted towards LCM, none of the two options seems immediately feasible for decision-support in Life Cycle Management for the following reasons: In the combined option, the resulting relatively large, combined number of indicators e.g. 20...30, may rather confuse than guide the decision-maker. The integrated approach, however, suffers from several methodological challenges, one of them being how to deal with location-specificity, which is crucial in both LCA and SLCA but not (yet) addressed to the extent needed. Thus, further research is required, potentially also integrating insights from, e.g. Multi-Criteria Analysis, Multi-Criteria Decision-Making, etc. (e.g. Linkov and Seager 2011; Prado et al. 2012).

Life Cycle Management is applicable in businesses and organisations of all kinds, sizes, markets and supply chain/value chain positions—be it manufacturers, retailers, service providers or other organisations—be they for-profit or not-for-profit, i.e. even a sports club can practise LCM. This chapter therefore uses the term ‘organisation’ as a placeholder for ‘business’, ‘company’ or any other product producing company and/or service-providing entity practicing LCM.

Since this is a Life Cycle Assessment textbook, one can appropriately say ‘LCM puts LCA into *practice*’ and also ‘LCA is a key tool in the LCM toolbox’. However, unlike Life Cycle Assessment, LCM operates *without* being a methodology consisting of a number of well-described distinct phases or steps (and LCM is not ISO standardised either). In addition, also contrary to LCA, LCM has no deterministic character, i.e. from a given starting point and given constraints it does not necessarily lead to the same conclusions, for instance the same recommendations. Rather, LCM is *a management concept* with an underlying life cycle-sustainability-oriented mind-set, and it comprises a number of different tools that can be applied in combination or separately, by different departments of an organisation or any stakeholder, and in a variety of decision-making contexts, such as choice of manufacturing processes in production development or supplier choice in the purchase department. LCM thus *pulls* Life Cycle Assessment and other

quantitative or qualitative decision-support tools into concrete *decision-making contexts*. This is explained in Example Box 22.1.

Example Box 22.1

A concrete LCM decision-making context is, for instance, whether or not to choose a certain new material that product developers—due to some technical properties—may find advantageous for a product type (e.g. for window frames). That material may also have adverse environmental properties, have a higher price per unit than alternative traditional materials, and may be more difficult to source and process in manufacturing than alternatives. In order to find out more on specifically the environmental properties of the material, either LCAs or other quantitative or qualitative assessments or data sources can be reviewed (in case they are at hand for the practitioner) or be actively commissioned. This would provide a basis for the material decision—and other factors, such as manufacturability, will have to be included in this decision context too. If it is decided to conduct an LCA, still some options exist as to how this LCA should be performed, e.g. whether a life cycle screening could suffice versus a full formal LCA, and whether to perform the assessment by own staff (that might even have to be hired/trained first) or by consultants (which may be expensive). Both choices influence the required time for the LCA, the incurred costs, and potentially other factors, e.g. the quality of the obtained LCA result. All this establishes the basis for the environment-oriented part of the decision of what material to select, and thus ultimately, all this may have an influence on the life cycle sustainability profile of the product, which the material is part of. In Life Cycle Management practice, the mechanical/technical, economic and manufacturing-related properties (as well as potentially additional ones) would have to be assessed as well—and communicated appropriately to individuals inside the organisation with different professional backgrounds, since the final decision is usually not made by one person alone.

The above example indicates the breadth of contexts that the LCM practitioner may have to take into account, incl. the variety of tools, like LCA, that can be employed in support of making life cycle-spanning decisions. Qualitative tools such as guidelines and checklists may be employed as well.

When looking at the LCA framework with its four phases and the Direct applications described in ISO 14040 (see Fig. 22.1), Life Cycle Management covers all of these Direct applications, such as Product development and improvement. LCM could thus be called the initiator/trigger or 0th phase for making LCAs, but also the result-user/-executor or 5th phase of the LCA, which is indicated by the double arrow in Fig. 22.1.

Life Cycle Management advocates taking a life cycle-wide view on business activities, and through this it can make the practitioner aware of two key

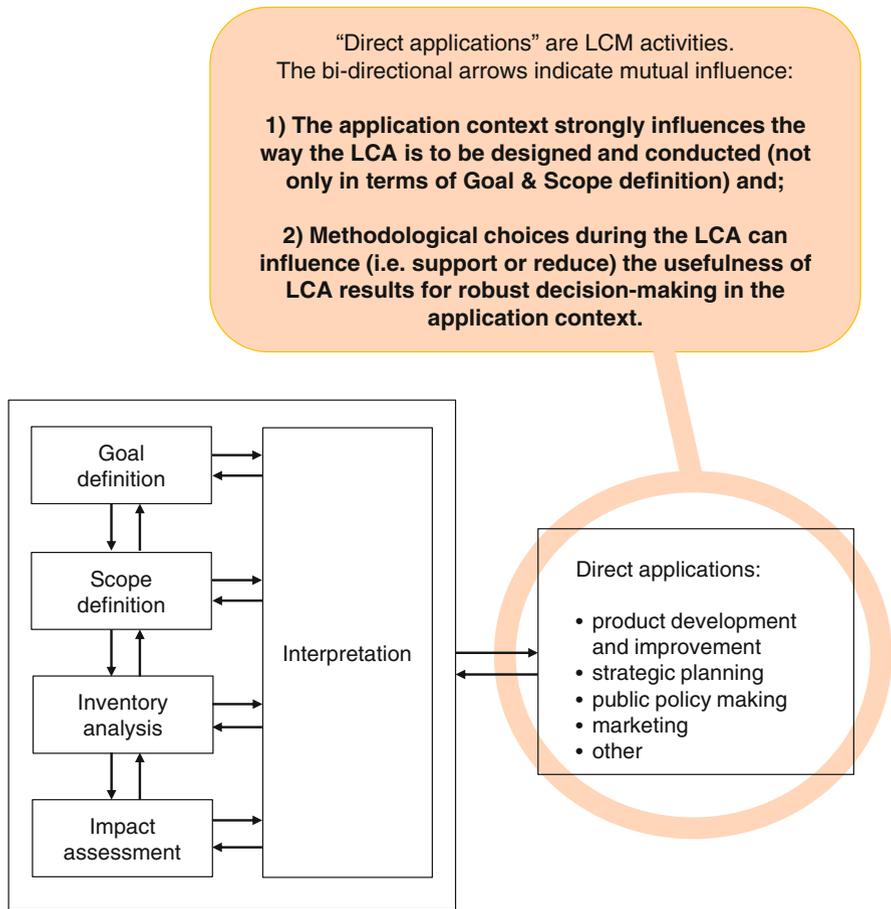


Fig. 22.1 The LCA framework of ISO 14040 augmented from an LCM perspective: key for successful support of LCM by LCA is that the LCA relates to the decision context of the direct application. Therefore, the direct application context could be called the initial 0th and/or 5th phase of an LCA (based on ISO 14040:2006)

circumstances: First, no life cycle stage can be neglected in the decision-making, since activities in any life cycle stage of a product or system (and thus decisions on whether or not to conduct those activities) can influence the sustainability profile of that product or system. Second, managing with a life cycle perspective initiates and sustains an organisational learning process of identifying what these influences may be, whether they are desired or non-desired ones, and which indicators to focus on. LCM thus enables identifying options and prioritising actions to reach more sustainable ways of running businesses.

In essence, Life Cycle Management deals with the *managerial tasks* related to practicing sustainable development in an organisation. It could thus also be referred

to as Sustainability Management—and is in some organisations also referred to as such, or as Responsibility Management, CSR management (CSR = Corporate Social Responsibility) or similar. However, the term ‘life cycle’ in the title underlines Life Cycle Management’s origins in the life cycle thinking (compare Sonnemann and Margni 2015, Chap. 2).

Sonnemann and Margni (2015) also provide the below, all-embracing definition:

“Life Cycle Management (LCM) is a management concept applied in industrial and service sectors to improve products and services while enhancing the overall sustainability performance of business and its value chains. In this regard, Life Cycle Management is an opportunity to differentiate through sustainability performance on the market place, working with all departments of a company such as research and development, procurement, and marketing, and enhance the collaboration with stakeholders along a company’s value chain. LCM is used beyond short-term business success and aims at long-term achievements minimizing environmental and socioeconomic burden while maximizing economic and social value.”

Since it is an overarching, cross-functional discipline, Life Cycle Management shares aim and focus with a number of other approaches and concepts, coming from the sustainability field, the managerial field and other fields. In practical application in the organisation, all such concepts are usually combined rather than pursued separately and exclusive to each other. Thus, applied Life Cycle Management often adds the aspect of sustainability to other more established management disciplines. An example is Supply Chain Management (SCM): Originally, this activity is about securing a required input flow of supply of raw materials and pre-manufactured goods, etc. into a manufacturing company with focus on the supplies being provided in time, and at required quality and cost. LCM adds the sustainability angle on this activity, for instance in the form of making sure that in addition to the other requirements also specified work conditions at suppliers comply with company standards and/or in the form that emissions from in-flow logistics do not exceed certain emission values.

Management approaches and tools, which LCM relates to in such a way, include e.g.

- Product (life cycle) Data Management (PDM);
- Sustainable Supply Chain Management (S-SCM);
- Corporate Social Responsibility (CSR) and Corporate Responsibility (CR);
- Environmental management (potentially according to ISO 14001, EMAS, etc.);
- Environmental Health and Safety (EHS);
- Compliance management;
- Corporate governance;
- Risk management.

In order to avoid possible confusion, it is pointed out below in what ways LCM in this chapter's context differs from the above and other quite similar terms and approaches:

- Product Life Cycle Management (PLM) is often used as covering product-related data management, as is Information Life Cycle Management and Product Data Management (PDM). LCM in the context of this chapter has a broader scope than such PLM/PDM, since it does not only focus on data management but on all life cycle activities in an organisation.
- In some companies, Life Cycle Management is referred to as an activity starting after launch of a product, i.e. subsequently to product development. In this chapter however, LCM covers product portfolio management, product development, and after-launch/after-sales activities until end-of-life of individual products and entire product types on the market.
- LCM in this chapter's context is not an activity that relates exclusively to the marketing life cycle (from product launch over market maturity until it is taken off the market). LCM rather relates to the physical life cycle(s) (cradle-to-grave) of a given palette of products that the organisation has a certain influence upon.
- Life Cycle Management is also often referred to as an activity of Asset Management, e.g. for large infrastructural installations with relatively long life times. Again, LCM in the context of this chapter has a broader scope than just this management of use/after-sales and end-of-life.
- Life Cycle Management also differs from environmental management systems and schemes, such as the European EMAS, the British BS7750 and the international ISO 14001, since these are designed for production (site) management. ISO 14001—according to ISO, one of the most widely applied standards for environmental management—in its 2015 revision now requires a view on life cycles of the produced products as well—in addition to the production focus. This, in turn, exemplifies a tendency towards integrated approaches rather than to pursue several single-issue-focussed management systems in parallel.

Instead of focusing on a certain part of the organisation or of the product life cycle, Life Cycle Management takes as a starting point an overarching perspective, and it thus influences—and is influenced by—many parts of the organisation (Fig. 22.2).

It is important to note already here that there are *internal* and *external* factors influencing the accomplishment of the managerial tasks. This will be elaborated later in this chapter (Sect. 22.2).

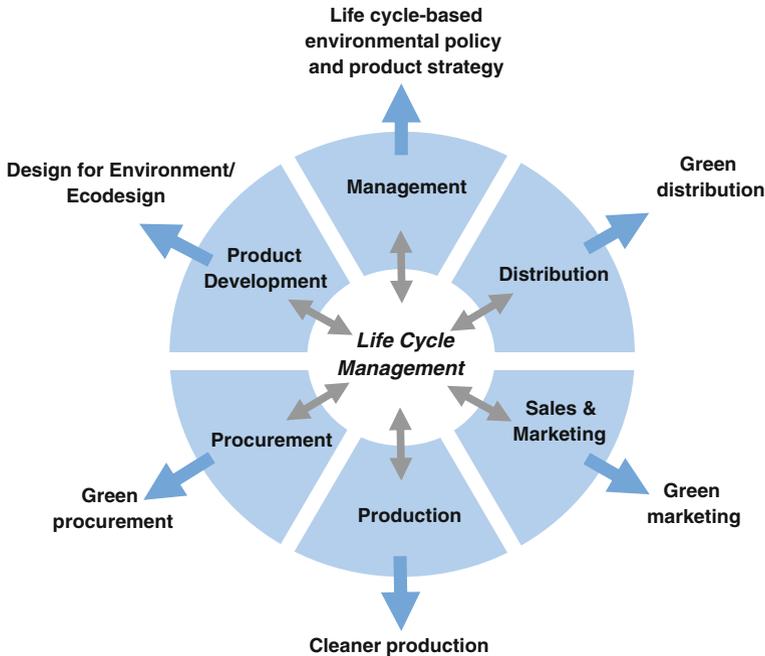


Fig. 22.2 Life Cycle Management as the central influencer and connector of different departments in an organisation and (shown on the circumference) examples of the outcome of its influence in each of those departments (based on UNEP 2007)

22.1.2 Brief History of LCM—Why Did It Arise? How Does It Evolve?

Life Cycle Management is a relatively young concept, which came up only about three decades ago. This timing can be explained as a logic consequence of two factors: First, the need of practitioners to operationalise the, then, new concept of Sustainable Development. Since the life cycle concept had been known and applied already since the mid-1970s (e.g. for military asset procurement; see also Chap. 15 on Life Cycle Costing), dealing with sustainability matters in a life cycle perspective was an obvious path to go. Second, a number of environmental incidents and catastrophes happened during the 1970s and 1980s. Immense disasters for instance with chemicals in the cities of Bhopal and Seveso, with oil tankers such as Amoco Cadiz and Exxon Valdez, with nuclear power plants such as Three Mile Island and Chernobyl as well as the controversial end-of-life treatment of the off-shore oil storage buoy Brent Spar all filled much in the public debate as well as in public and corporate consciousness in those years—and they were increasingly communicated through rising global news networks and environmental NGOs

(Non-Governmental Organisations). Therefore, the question of dealing with these issues in a strategically feasible and desired way—i.e. sustainably—became evident for governments, businesses, and the upcoming environmental NGOs alike.

A key initiator and driver for LCM discussion and development since 2002 is the UNEP-SETAC Life Cycle Initiative, which has issued a large number of publications, e.g. the LCM Guide (UNEP/SETAC 2007) and online material such as the LCM Navigator for SMEs (UNEP/SETAC 2008). The UNEP-SETAC Life Cycle Initiative has also been patron and sponsor for the bi-annual conference series on LCM that took place for the first time in 2001 in Copenhagen, Denmark. The LCM field is also promoted and elaborated by particular companies and, to a certain extent, also by business organisations and other NGOs, e.g. the World Business Council for Sustainable Development (WBCSD), through e.g. guidelines and models developed in their regime.

Life Cycle Management is today an established discipline, albeit pursued under many different names (as explained in Sect. 22.1). Current trends in LCM include:

1. Interest in mainstreaming LCM, i.e. getting it better integrated in standard procedure of organisations in many contexts (Sonnemann and Margni 2015);
2. Using LCM in organisational capability and maturity development support (e.g. Swarr et al. 2015; Pigosso et al. 2013);
3. Improving data flow integration and exploitation, e.g. in relation to socio-technical trends such as Internet-of-Things (i.e. the interconnectedness of various products, other than computers, through the Internet), and Big Data (i.e. the tracking, storing and making-available of large amounts of data; in fact relating to ‘PLM/PDM’);
4. Implementing LCM coherently and in the long term in ever-changing organisations. The 17 Sustainable Development Goals (SDGs) agreed upon in the UN General Assembly in late 2015, are increasingly understood as managerial targets that also drive future developments [e.g. in the SDG Compass (GRI/UN Global Compact/WBCSD 2015)];
5. Developing approaches to ensure companies’ long-term survival, e.g. if their business offerings rely on non-renewable resources.

22.1.3 LCM as Integral Part of a Management System

To manage means, in general, to have control of, to take care of and to make decisions about. The goal of Life Cycle Management is to contribute to sustainable development, through operationalising it in organisations. LCM does this through (1) requiring the practitioner to identify those sustainability matters that are relevant for the particular organisation (e.g. via conduction of LCAs and other assessments), and (2) connecting these with possible managerial actions (i.e. for instance advising on who shall do what and when). The subsequent managerial actions of

monitoring/checking and potentially initiating corrective or alternative actions are part of LCM in the same way as they are part of managerial procedure in general.

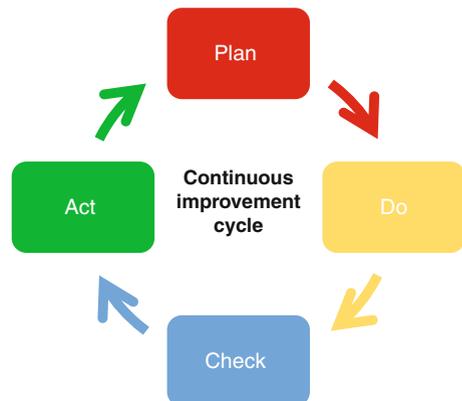
Similar to any other management concept, LCM can be integrated into a management system that the organisation may be using, and LCM can herein serve as a tool, e.g. for Sustainability Strategy Development. In its support of continuous improvement, LCM fits seamlessly together with widely applied management systems developed by ISO, such as ISO 9001 for Quality management and ISO 14001 for Environmental management, the latter having undergone a substantial revision in 2015, now emphasising its relevance not only in production contexts but also for product life cycle improvements, see ISO (2015).

The particular managerial tasks of Life Cycle Management, mentioned in Sect. 22.1.1, can be distinguished into four types:

1. Setting (measurable) targets—for the entire organisation or for parts of it, as part of, for instance, a strategy development process, as well as creating the basis for execution and planning, so that targets can be reached;
2. Executing the plan;
3. Tracking execution and performance; and
4. Taking corrective actions or setting new targets—depending on the performance.

In shorter terms, this sequence is described as Plan, Do, Check, Act or just PDCA (UNEP/SETAC 2007; ISO 2015), and in the sense of continuous improvement, the four phases will be repeated cyclically for an infinite number of times (see Fig. 22.3), each time at a slightly higher level of sophistication. Such a standard managerial activity cycle is practiced in many organisations and is a backbone concept in many ISO standards. Life Cycle Management follows those same four phases but distinguishes itself particularly in what the first and second phase deal with, namely target-setting for above sustainability matters and creating structures so that sustainability targets can be reached.

Fig. 22.3 A generic PDCA cycle of continuous improvement, consisting of the four phases plan, do, check, and act, which are run through continuously in management concepts such as LCM (based on ISO work, e.g. ISO 2015)



As a graphic representation of the different managerial factors' interconnectedness, Herrmann (2010) suggests an integrated model of LCM, the Total Life Cycle Management framework. It is developed to serve as a model defining relations with other management disciplines and as consistent frame-of-reference for LCM work and distinguishes two disciplines within Life Cycle Management: life cycle stage *spanning* management disciplines and life cycle stage *related* ones.

Disciplines spanning over several life cycle stages in this framework are:

- Social Life Cycle Evaluation;
- Economic Life Cycle Evaluation;
- Ecological Life Cycle Evaluation (i.e. Life Cycle Assessment);
- Information and Knowledge Management;
- Process Management.

Disciplines focusing on a certain life cycle stage are

- Product Management;
- Production Management;
- After-Sales Management;
- End-of-life Management.

The integrated model of Total Life Cycle Management is shown in Fig. 22.4.

As pointed out earlier, Life Cycle Management is no step-by-step methodology, but rather a management concept with an underlying mindset of thinking in life cycles and holistic contexts. Integrating this mindset into everyday practice of the organisation is key for a successful implementation of Life Cycle Management. This integration involves many different stakeholders as elaborated in the next section.

22.2 Who is Involved in LCM? Stakeholders and Their LCM Activities

The archetypical organisation applying Life Cycle Management is probably a company doing business with products of some kind (Note: The term 'products' in this chapter is generally understood as 'goods and/or services', but 'services' is sometimes mentioned for reasons of practical clarity). Such a company may or may not have, for instance, own product development activities, own production facilities, own logistics operations, etc. However, it may just as well be a different type of organisation such as an NGO, e.g. a consumer organisation or environmental activists group, or it can be a governmental organisation (e.g. an Environmental Protection Agency). The key common characteristic is that the organisation exerts influence on life cycles of products and/or their surrounding systems through its decisions. Using an LCA term, this could be called influence on the 'processes' taking place during the life cycle. For any such organisation, and

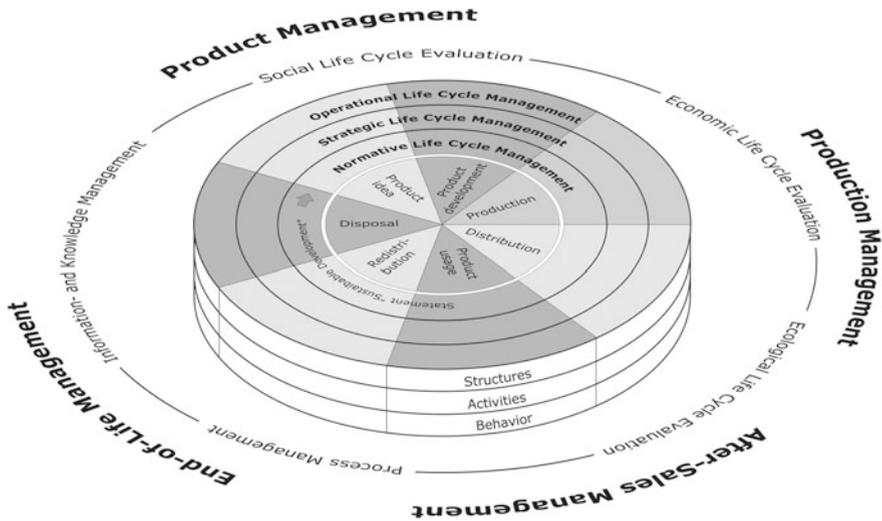


Fig. 22.4 A framework model for Life Cycle Management suggested by Herrmann (2010). This total Life Cycle Management model shows how sustainability as management philosophy can be unfolded in a consistent way in relation to management on different levels (normative, strategic, and operational level) and to the management objects (structures, activities, behaviour of/in the organisation). The model also shows, how the different levels and objects relate to life cycle stage-focused management disciplines (product, production, after-sales, end-of-life) and life cycle-spanning disciplines being information/knowledge management, social evaluation, economic evaluation, process management and—environmental life cycle assessment (reproduced with permission from the author)

that can be many, it may be meaningful to include Life Cycle Management in their management approach in order to exert the influence in a more structured, coordinated and informed way.

As an example, for a company producing a certain type of windows and seeking the environmentally preferable solutions, the decision context can, for instance, consist in having to follow EU and national regulation on particularly their type of windows, or that for certain markets specific end-of-life regulation may be given which may even be contrary to end-of-life regulation on other markets.

Life Cycle Management thus involves many stakeholders inside and outside the organisation with the organisation itself being a stakeholder too. All stakeholders have individual areas of influence; each can be a catalyst but also a potential unsurmountable obstacle for sustainability efforts, and each stakeholder may thus be able to substantially influence the success of such efforts.

The separation of external and internal stakeholders in the following two sections is only generic and exemplary. Depending on the size of the organisation, the function of some stakeholders may be internal or external. In small companies, the function of a legal department may, for instance, be fulfilled by an external law firm, whereas in larger companies, this function will be represented by an in-house

department. However, the point is that a stakeholder dealing with legal issues needs to be taken into account, since, e.g. legal issues may hinder the implementation of any concrete optional solution. Thus, the LCM manager has to integrate this factor when selecting optional paths for solutions.

22.2.1 *External Stakeholders*

Seen from the perspective of an industrial company, there is a variety of external stakeholders. Three types of such external stakeholders can be separated as having a more or less direct influence on the way a company runs parts of its business and thus as having a more or less direct influence on activities and decisions made in the company:

- Customers/Consumers—being the key targets of company activities;
- Governmental bodies and authorities in general—setting legislative frames and regulatory requirements around the activities;
- NGOs of various kinds characterised by not being formal governmental bodies or authorities and not being declared representatives of industry. This includes environmental organisations, standardisation bodies, think tanks and academia—setting societal agendas, providing scientific insight and influencing company activities through de-facto standards (e.g. a certain ISO standard may be a voluntary instrument, but can be a de-facto requirement for certain products and/or markets).

Competitors could be considered a fourth one, but are here part of the stakeholder type Industry, incl supply chain since this is where competitors exert their indirect influence on activities of a given company. Similarly, other industrial companies could collectively be considered a fifth stakeholder, e.g. as in branch organisations, but they would not exert influence on the activities other than as covered by already mentioned types of stakeholders. Last but not least, shareholders are not described as distinct stakeholder because they do not exert direct or indirect influence on a company's business offering.

Figure 22.5 shows these three stakeholders as well as a company/industry offering the product or service. The figure also indicates each stakeholder's direct or indirect influence on the product (or service), and thus their way of influencing the decision space of the company. Customer feedback on product performance, etc. is a very typical and direct source of influence on activities at companies, e.g. related to product design improvements. Authorities have a similar direct influence, e.g. via product-type-specific regulation (e.g. the European Directives and international trade requirements). NGOs, in contrast, have typically only indirect influence on products/designs but still potentially directly on the company itself (see note B in figure caption).

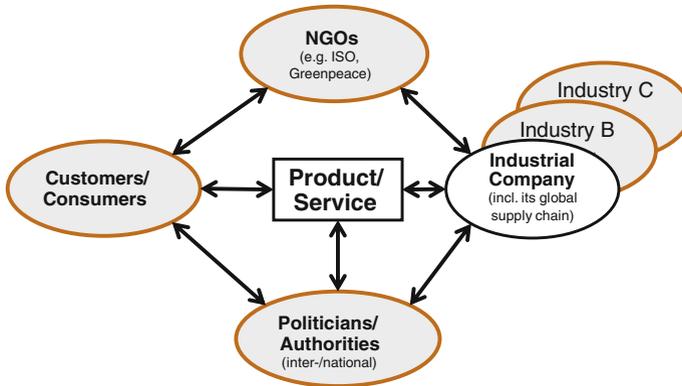


Fig. 22.5 The three generic types of external stakeholders influencing (directly or indirectly) the product/service business solution offered by a company: customers, politicians/authorities, and NGOs, as well as industry (incl. competitors and supply chain). Mutual relations indicated by arrows. *Note A* Investors and potential shareholders are not shown since they normally do not exert influence on the product/service solution. *Note B* Not all relations are indicated by arrows in order to keep simplicity in illustration, e.g. politicians/authorities' relation with NGOs

If the company for instance offers windows, a specific direct influence comes from international and national laws and regulations for buildings and from local authorities that the windows must comply with, and an incentive might come from potentially existing Green Public Procurement (GPP) schemes, as they exist, e.g. in Europe for some product types. The influences will differ depending on the different markets, i.e. regions, where the windows are intended to be sold. If the product shall be sold globally, obviously the number of influences (e.g. legal compliance requirements) increases highly. This means for Life Cycle Management work, that country/market-specific approaches may make sense, rather than trying to develop and apply one global approach.

22.2.2 Internal Stakeholders—Departments in an Organisation

Seen from a company perspective there are also a number of internal stakeholders, being the departments with their individual agendas and targets. Internal stakeholders can exert a great push and/or pull on the LCM function and the product/service offering of the company; and this can relate to all, both top management as well as workers in the production shop. A generic set of internal stakeholders includes the following ones (below and Fig. 22.6):

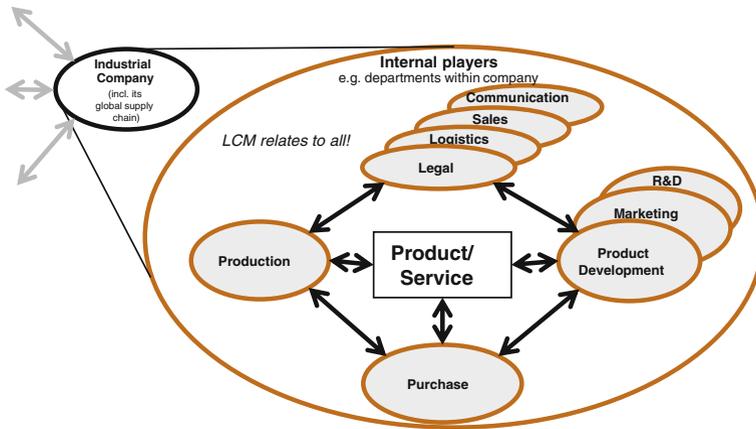


Fig. 22.6 The generic types of internal stakeholders of industrial companies, mutual relations between them and their (direct or indirect) influence on how the product/service is designed and marketed. LCM relates to all of them

- Marketing
- Research & Development (R&D)
- Product development
- Purchase
- Production
- Sales
- Legal
- Communication (to internal and external stakeholders)

Typically, *decision-making contexts* have many elements, and the LCM manager can take the role of pulling these different elements together in order to create a broad basis for decision-making. Looking at the window case, it may be that the company identified a particular material combination as environmentally preferable. However, if the production department has, e.g. difficulties in producing larger quantities at same quality levels, and or the purchase department would not be able to secure large enough quantities of it, the material combination would not be a feasible solution anyway. The same goes without saying for cost issues, although these also depend on the applied cost calculation model and business model. Only when having such a broad, combined view of influencing factors, truly holistic business decisions can be made. The LCM function closely interacts with such classic functions, like purchase, and advocates sustainability-related matters in that function’s decision context, e.g. a ban of sourcing of conflict minerals (i.e. minerals mined in conflict zones) or e.g. a design for easier disassembly.

22.3 How do LCA and LCM Relate to Each Other?—The Key Role of LCA in LCM

Augmenting the LCA framework of ISO 14040, Sect. 22.1 already introduced a relation between Life Cycle Assessment and Life Cycle Management in a graphic way. The present section elaborates this relation further and points out the key role that LCA can play for practicing Life Cycle Management.

On a framing note, it can be stated that Life Cycle Assessment and Life Cycle Management have a lot in common, but also have some clear differences. Both build upon life cycle thinking, both are a basis for decision-making, both only make sense within defined system borders, and both consider activities today or in the near future and address potential effects that may occur in the far future (which require the practitioner to make assumptions and build scenarios). However, contrary to Life Cycle Assessment, LCM (usually) neither establishes concrete cause–effect chains—and not at all in a quantitative way using algorithms and computer models—nor does LCM employ the concept of impact categories, and midpoints and endpoints.

Although, LCM can be practiced without employing LCA, and although LCA cannot support all decision-making in LCM (e.g. cost-related issues), the section shows that LCA offers support on two managerial key areas: status determination and target-setting.

22.3.1 *LCA Provides Environmental Quantifications Needed for LCM*

A classic saying goes: “What you cannot measure, you cannot manage!” Environmental Life Cycle Assessment is a prominent tool that enables such measuring and performance tracking for managerial purposes. Using Life Cycle Assessment, a practitioner can, for example:

- Determine in which environmental condition or state a given product system is, e.g. a product on the market (shown as its contributions to a number of environmental impact categories)
- Identify environmental hot spots in that system
- Compare potential alternative solutions (e.g. new design suggestions)
- Make scenario analyses and establish a ranking of such alternative scenarios.

Conducting Life Cycle Assessments requires both thinking backwards in time and thinking forwards/ahead—i.e. life cycle thinking. In addition, LCAs create outcomes in the form of insights and results, but also in the form of questions that arise along the way. The latter are dealt with through making assumptions on past and/or future conditions in the life cycle. However, LCA cannot provide suggestions for managerial actions that put such outcomes into practice within a decision

context. For instance, an LCA-based overview of impact potentials of different options may show one option as being preferable. However, by definition, the LCA cannot show, whether an environmentally preferable option, e.g. a certain engineering material for a window frame, would still be preferable, if other aspects were taken into account, e.g. the capability of a potential supplier to deliver that preferable material in the required quantity, quality, price and time frame. Exactly here, Life Cycle Management comes into play, since LCM can be used to integrate several aspects and related tools, including LCA, into one holistic, sustainability-oriented set of decision criteria (see Sect. 22.1.1).

22.3.2 Developing Key Performance Indicators for Application in LCM

Once an organisation has determined its mission, identified all its stakeholders, and defined its goals, it needs a way to measure progress towards those goals. Life Cycle Assessment is a crucial tool to conduct and support such progress measurements, since results from LCAs can be used to define performance indicators, which are a standard means used in management processes. Indicators are typically aggregated *indications* of the state of a given system at a certain point in time and/or of the performance of a system over a given period of time. One can distinguish several types of indicators; e.g. leading (target-setting) versus lagging (monitoring) indicators, result indicators versus performance indicators, and key result indicators (KRIs) as well as key performance indicators (KPIs), see, e.g. Parmenter (2015).

Irrespective of what type of indicator the Life Cycle Manager decides to use, LCA results can often crucially enrich such indicators or even entirely populate them, since they are quantitative by nature, thus LCA is a key tool in setting targets in LCM. An example of an indicator in LCM may be energy requirement of a manufacturing process—or of an entire production site (then often further specified as energy requirement per product produced, per year, per production line, etc.). This indicator can be populated using different units, for instance Mega Joules [MJ], kilowatt-hours [kWh] or other physical SI units. However, it could also be quantified in LCA-based units such as Global Warming Potential [kg CO₂-eq]. This could then support a comparison with and/or addition to other activities of the organisation. Transport and logistics activities of the organisation would, for instance, typically be monitored in terms of kilometres [km] (and as with production indicators, typically be specified further, e.g. per product). In the LCA context, one would additionally track employed means of transport (i.e. road, air, rail, ship) and potentially a particular vehicle type (e.g. five ton-truck, container vessel, bulk freight train, etc.). Using LCA, the transport activities would be quantifiable in kilograms of CO₂-eq as well, and a comparison with the above energy requirements of the production site or the entire organisation could be done—made possible through LCA.

Key aspects of managerial indicators are summarised below (compare, e.g. Gries and Restrepo 2011):

- They help an organisation define and measure progress toward organisational goals
- They are quantifiable metrics, agreed to beforehand, that reflect the critical success factors of an organisation
- They differ depending on the organisation, e.g.
 - A company may have as one of its KPIs the percentage of its income that comes from return customers, or revenue from eco-labelled products
 - A school may focus its KPIs on graduation rates of its students
- They must reflect the organisation's goals, must be key to its success/activities, and must be quantifiable/measurable (!)
- They need to be defined, incl.:
 - instructions on how to calculate them, => different individuals must always reach the same KPI value when calculating a particular KPI with the same background data
 - a definition that does not change from year to year (i.e. long-term definition needed);
- They can be used to set targets

When developing KPIs for any application context, the following needs to be observed:

- The landscape of data sources may be non-harmonised (e.g. not all source data may cover the same year, same location, etc.). This means: Observe 'data landscape' and availability of input data
- KPI inflation—Aim is *not* to measure what *can* be measured, but to measure what *should* be measured. This means: The fewer KPIs the better
- Pseudo accuracy: since 'Bad data in' leads to 'bad data out', this means: Interpret the KPI values related to their underlying data quality

In order to support the reader in developing KPIs genuinely meaningful for LCM work, and in reflection of current paradigm-setting developments in business and science, the remainder of this section deals with very concrete characteristics of environmental sustainability-relevant KPIs, points out problems and describes ways to address these.

Based on studying company reporting, one can distinguish two types of environmental sustainability-related KPIs seen today in many companies' communications: Intensity-based KPIs and company-wide KPIs, and e.g. (Bjørn et al. 2016a) pointed out problems that both types have:

- Intensity-based KPIs:
 - Examples: *kg CO₂-eq emitted per product* or *Emissions per \$ of revenue*

Main problems:

- Performance depends largely on the chosen reference (e.g. last year’s product model? Market average? Competitor’s product?)
- Total impact may still increase, if sales increase (which usually is a company target—depending on business model)

- Company-wide KPIs:

- Example: *kg CO₂-eq emitted per year*

Main problem:

- Misleading, for example if company is outsourcing and does not account for the outsourced activities

One can argue that an additional problem of both KPI types is, that they do not indicate how much impact reduction—or which concrete indicator value—would be enough in order to reach sustainable levels. Organisations such as the WBCSD and the Science-Based Targets initiative (SBT)—a collaboration established in 2014 between UN Global Compact, Carbon Disclosure Project (CDP), World Resources Institute (WRI), and the World Wide Fund For Nature (WWF)—have begun to address this missing link in suggesting methods to determine concrete targets for application in the company context. The SBTs relate to greenhouse gas emissions only, i.e. they only relate to this part of environmental sustainability, see e.g. www.sciencebasedtargets.org and Krabbe et al. (2015).

An example for such a KPI is given below, incl. related problems:

- Absolute-target-based KPIs

- “We as company x will by year y reduce our global emissions to z tons CO₂-eq per year”.

Problems with this absolute type of KPI are, however

1. When communicating such targets, the company is bound to them, since they are clear and trackable. This kind of lock-in is by many companies considered a risk and thus not pursued by many companies, even if they recognise Earth as a finite system in their reporting, compare, e.g. (Bjørn et al. 2016a).
2. The challenge of defining targets for other environmental impact categories than Global Warming (i.e. for impact categories where there is no international agreement and/or where targets are per se more difficult to determine, e.g. for regional and local impact categories).

The development of absolute KPIs is accelerated by the Two-degree-target agreed upon at the UN Climate Change summit COP21 in late 2015, where the global community committed to keeping greenhouse gas emissions at levels, so that average global temperature rise by the year 2050 stays well below 2 degrees centigrade above pre-industrial levels. It has also been shown, that such absolute indicators can be integrated into existing LCA methodology for other global impact

categories than Global Warming Potential, e.g. for Terrestrial Acidification (Bjørn and Hauschild 2015; Bjørn et al. 2016b). Ways of consistently breaking down high-level targets into targets for lower levels of decision-making are being suggested, e.g. by Rödger et al. (2016). In conclusion, the development of internationally agreed absolute indicator limits and their subsequent broad application cannot be seen to happen in the near future, but individual companies may adopt the principle and develop their own absolute indicators, as some companies already do.

The above examples and issues show that KPI development requires overview, understanding and utmost care by the practitioner in order to produce meaningful KPIs, which can trustfully be used as the central management instrument they are. This is even more important when applied within LCM, since it can be considered an even more complex field than many other management fields.

22.4 How is LCM Applied in Practice? A Brief LCM Case Study

Application of Life Cycle Management fundamentally incorporates that the practitioner makes choices *before* and *during* the application itself, rather than that she or he follows a predetermined procedure. The reason for this is that LCM is a management concept—as explained earlier in this chapter—and not a deterministic method or algorithm, with concrete steps or rules, that would lead to concrete, repeatable outputs, if triggered by same inputs. LCM application can be described as consisting of two elements:

1. Individually selecting one or several tools from the collection that may be called the ‘LCM toolbox’ (UNEP/SETAC 2007)—and;
2. Doing this in the concrete context of the given organisation—i.e. in collaboration with different departments and under recognition of a variety of factors, such as the organisation’s position in supply chains and the intended application field

Thus, there is never a one-size-fits-all way of applying LCM. Rather, each organisation needs to determine for itself and for the concrete product or activity, which combination of tools they consider appropriate for managing life cycle matters of that product or activity.

A typical starting point for applying LCM is product innovation and product development processes. From here, LCM activities often radiate back and forth to and from production and operations and to and from marketing and communications, especially sustainability reporting (see e.g. McAloone and Bey (2009)).

Taking the example of deciding among alternative materials for a new type of façade window frames, an LCM practitioner may come into play in the following, diverse decision contexts: Starting point would probably be that the window company has decided which markets, i.e. global regions and/or countries, the new

type of windows (and frames) shall be sold in, and in which target quantities and at which target sales price. In parallel, the design engineering/R&D (Research & Development) department has probably determined a number of technically feasible materials (e.g. a metal, a type of wood, and a composite material—plus maybe combinations of them). Although usually not practiced, the company might already here set a target environmental impact for the windows as LCM activity, and quantify this target in terms of a certain maximum Global Warming Potential the windows should not exceed (potentially further described, e.g. for modules of the window or for an annual production of all production sites or for one selected site, etc.). The target figure may be related to the window company's sustainability strategy and sustainability targets, which they may have published in their sustainability reporting. Supportive methods for such detailed target-setting are suggested, e.g. by Rödger et al. (2016).

Taking into account the different generic external and internal stakeholder types of customers, competitors, NGOs, governmental organisations as well as departments within the organisation (see Sect. 22.2), the company would check legal requirements and de-facto market requirements on the selected markets. This could refer to, e.g. legally banned materials or substances on that market for that type of product, but also to certain environmental labels and certifications that key competitors on that market have certified their products with. Or it could mean to apply for newly introduced, not yet widely applied labels that may represent a competitive edge on that market. Both, legislation and de-facto market requirements, are often quite different from country to country and especially from region to region, e.g. between Asia and North America. Obviously, if the chosen market is global this would require further decisions, e.g. whether or not to prioritise one label over others or to work towards certification against all labels on the global market, which of course has an impact on the cost of the product. Also, sustainability-related campaigns by NGOs, e.g. against specific labour practices or certain technologies, would be mapped as far as possible and analysed in terms of potential threats to sales of the product on the selected market(s). If a stakeholder campaign or similar activity is identified, decision options are either to ignore, to fight or to accept the respective stakeholder demand. An example of the latter is the following one from the paper and pulp industry: the global tissue paper producer Kimberly-Clark Corp. and Greenpeace agreed in 2009 on a new fibre policy and on a regular review process, ending a several-years Greenpeace campaign—an agreement to the benefit of all parties.

Back to the window example: In parallel to related information becoming available for the LCM decision-maker, the window producer's R&D department may practice ecodesign in making life-spanning scenarios for the product and taking design actions with focus on selected life cycle stages. The developers may, for instance, design the windows for easy disassembly (focus: end-of-life stage of the windows' life cycle) or design them in a modular way, allowing to easily attach and exchange components such as blinds, motoric actuators, etc. or optimise insulation capabilities—all this for the different materials under consideration (i.e. focus: use stage). At the same time, purchasers and designers could be supported in

choosing the exact material composition, e.g. the alloy of a metal and the supplier(s) selected to deliver raw materials and semi-manufactured goods (focus: materials stage and transportation stage). Furthermore, the production department as well as logistics and also service/after-sales departments could be drawn into the materials decision in order to, e.g. ensure manufacturability and secure availability, etc. (focus: manufacturing stage). Early in this process, the respective departments would also identify legal requirements on the target markets, such as safety norms, flammability norms and insulation capacity as well as potentially important voluntary requirements, which represent de-facto market requirements, such as certain environmental labels (e.g. certified wood, or eco-labels for the entire product).

Last, but not least, a core department responsible for business model options—i.e. the board of management—would be strongly involved, if a material choice should represent a strategic change, as for instance seen in the shift to aluminium used for car bodies which some automotive companies and suppliers have made. In the window case, this could be the shift to composite materials, requiring, e.g. entirely new production technologies and design options and constraints. In conjunction with potential regulative developments, e.g. as currently seen in Europe towards Circular Economy and the released action plan (EU Commission 2015), the window producer could consider a business model that incorporates take-back of their windows at their end-of-life—an option which then would have to be analysed for its environmental and economic viability.

22.5 What Does LCM Require and Yield in an Organisation? Application and Integration of LCM

Life Cycle Management costs time, requires learning curves at the different departments and—in essence—necessitates new thinking by all involved individuals. Such costs and obstacles often surface in many places and on many occasions, e.g. in the course of time-consuming data collection, life cycle modelling, communications, or when trying to determine, what in the particular company's context actually is meant with the term 'sustainability'. However, although very difficult to pin-point and quantify, LCM also yields gains, e.g. in the form of increased knowledge about the organisation's own processes and life cycle chains, incl. better insight into conditions at suppliers, due to the 'total' overview. LCM may also reduce risk and increase opportunities, as well as improve the ability to respond early to new legislation and market trends in the field. In that sense, LCM generally increases the resilience of the organisation that practices LCM, since it encourages taking both short-term, detailed views and long-term, helicopter-perspective views on company activities.

Sustainability matters are manifold and so are the organisations that work with them. LCM can, of course, be practiced in the multi-national corporation, in the

small or medium-sized enterprise, in the family-run company and in the one-person firm—and this irrespective of where on the Planet they are located. Since LCM is a translator of sustainability matters into business practice, LCM itself needs to be manifold and highly adaptable (a bit comparable to a Swiss Army knife which integrates many tools and makes them available in one pocket-sized product), so that pursuing LCM can produce improvements of the sustainability matters for any organisation and in any department of that organisation. Due to this necessarily multifaceted character, Life Cycle Management may well be perceived as diffuse. However, LCM *is the* means to put sustainability approaches into practice, since no measurement and assessment tool (such as LCA) can tell by itself what its results are to be used for or, e.g. what ranges of these results the organisation should deem desirable (beyond legal threshold values, if applicable, and also this context is not known to the tool).

Thus, having tools available in an organisation is not enough (even if these tools should in fact be easy and effective to use, which is not always the case): It requires an overall management concept, such as LCM, to reach a coherent, holistic approach, practiced in the relevant parts of the organisation. Last, but not least, the long-term survival—i.e. the long-term successful application—is key for any sustainability-supporting approach. Thus, the integration and anchoring of LCM in the organisation are just as important as the applicability of the tools it comprises. Addressing this key aspect, approaches to map and quantify organisational maturity and to build adapted capability have been developed and are increasingly in focus (as introduced in Sect. 22.1.2).

LCM can be integrated in an organisation in two principle ways: via projects and/or via functions (plus via combinations of both). The way of choice depends on the type of organisation and on preferences of the organisation. In project-based organisations, typically companies that design, produce and sell one-of-a-kind products or small series, most prominently construction companies, LCM can be integrated into the Stage/Gate process that the projects usually are managed by. Project managers and portfolio managers, in this case, need in to have a good understanding of the LCM concept and act as life cycle managers, unless a dedicated LCM specialist is included in the project team. This depends on the size of the project team and of the organisation behind, leading to the circumstance that often only larger teams and organisations have a dedicated LCM role in project teams—and this role can even be taken on by a consultant. In function-based organisations, typically mass-producing or batch-producing manufacturing companies (which our window company probably would be), and in combined structures, such as matrix organisations, Life Cycle Management can be integrated by establishing dedicated departments and/or appointing individuals and adapting set organisational processes, so that LCM aspects relevant in the particular company ultimately become integrated into day-to-day procedures.

In larger organisations, Life Cycle Management is typically not one outspoken activity or position, but it is in the vast majority of such companies embedded in

and dealt with by several departments and under many titles, often two to three departments (typically a corporate one plus the production-environmental department plus, maybe, a product-related one, see Sect. 22.1.1), rather than by one department alone. Ultimate goal in both principal integration situations is, that all project members and all departments are aligned and that, eventually, the LCM function becomes obsolete and a self-running part of all other functions. In either way of integration, the definition of KPIs is key in order to be able to set targets and track performance (see Sect. 22.3.2), e.g. at departments.

As explained earlier, any LCM approach is tailor-made in the course of finding the individually best-suited combination of tools that together represent the company-specific approach. Figure 22.7 shows an example of such a combined approach towards sustainability/LCM work at a company, integrating several elements.



Fig. 22.7 An example of an integrated approach (*screen shot of an intranet page*): The company Steelcase, globally providing office furniture and office space solutions, combined three elements/tools in their approach. Due to product type, material types, life cycles, markets and other factors, they chose to use both LCA, Materials Chemistry (i.e. cradle-to-cradle) and Reuse and recycling—already in 2007—and communicated this to internal and external stakeholders

22.6 Conclusions

This chapter described Life Cycle Management and the different aspects it involves—both from its contents and from its application and integration in organisations. Many examples relate to industrial companies but the principles are the same in municipalities and other organisations. In all contexts, Life Cycle Management has the below key characteristics:

- LCM is no step-by-step methodology or one-size-fits-all approach but a management concept that can and needs to be adapted to any organisation's context, i.e. LCM is always tailored to the specific organisation.
- LCM deals with the managerial tasks related to practicing sustainable development in an organisation—it could thus also be referred to as Sustainability Management.
- LCM requires collaboration between several departments within the organisation and with external stakeholders, such as supply chain partners.
- As with any other management discipline, practicing LCM requires setting targets and tracking performance. Such targets and related performance indicators can be set based on relative terms but may also be set as absolute terms.

Practicing LCM in a consistent way aims at ensuring that improvements in system performance can be achieved while also making sure that this does not lead to either sub-optimisations or burden shifting in the company/organisation as a whole and/or in the relevant life cycles.

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