Sustainable Design Engineering: Design as a Key Driver in Sustainable Product and Business Development

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Abstract

Sustainability has become a "hype" topic these days (Steeger 2004). However, although sustainable considerations are clearly on the agenda of many researchers as well as managers, the corporate sustainability map is still characterized by some considerable "blind spots" (Waldron et al. 2008). One of these blind spots is the role design plays in developing sustainable products, and how the efficiency and sustainability of new product development (NPD) is increased by consequently and strategically integrating the design function into the innovation process. Starting from this fundamental perception, the intention of this chapter is to outline a theoretical and practical framework for a new understanding of sustainable product design, which should not be driven by purely ethical or technical considerations only but needs to be grounded on business strategy and economic objectives likewise.

1 Some Fundamental Considerations on Sustainability and Sustainability Definition

Although the sustainability issue is, today, heavily referred to in political, societal, as well as corporate contexts, the term "sustainability" is vague, and very different concepts and understandings may be linked to this single term (Basiago 2006). As Stuart Hart puts it, there "can be little doubt that sustainability is one of the most frequently used but least understood terms of our time" (Hart 2005, p. 57). Fresner et al. (2006) have shown on the basis of an empirical study that indeed the sustainability term may create very different associations in

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the ecological (energy efficiency, resource-conservation, recycling-capability…), social (self-determination, fairness, health protection…), as well as economic direction (stability, profitability, independence…).

Whereas in the political and societal arena, sustainability is mostly used in the context of "sustainable development," i.e., in the sense of a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 16; Martinet 2009, p. 3), sustainability within the corporate context – especially the context of innovation management and engineering – needs a much more pragmatic conception. Even if changing legislation and societal factors are increasingly pushing more and more companies to integrate sustainability aspects into the management of their firms, sustainable corporate policies will only really increase if the true "value added" such policies incur is clearly highlighted (Schäffer 2011; Steeger 2004; Figge et al. 2001).

What Robert Solow (1993, p. 167–168) has generally claimed for sustainability policies of all kinds, i.e., that "if the sustainability means anything more than a vague emotional commitment, it must require that something be conserved for the very long run" and that "it is very important to understand what that thing is," is especially effective in business environments: "To integrate sustainability principles into their business strategies and to aid resource allocation decisions, managers must quantify the link between social and environmental actions and financial performance" (Epstein and Roy 2003, p. 79).

Over the last decades, different instruments have been developed to help companies to analyze and manage the added value sustainability brings to their business. These instruments reach from simple sustainability check lists to complex eco-balance sheets, eco-reports, and balanced sustainability scorecards as well as sustainability indexes and sustainability rankings (Burschel et al. 2004; Charter and Tischner 2001; Figge et al. 2001; Fresner et al. 2006; IÖW 2007; Schäfer 2005; Schäffer 2011; Schaltegger and Sturm 1992). Interestingly, many of these initiatives – although being clearly focused on business issues – link sustainability considerations mostly to very general strategic objectives such as increased corporate social and/or environmental responsibility. What is often missing is a view on sustainability which really brings it down on the shop floor and links it to the important areas of new product development (see Fig. 39.1).

Over the last 20 years, there have of course been multiple initiatives to increase a sustainability-oriented view on product development such as the IPP (Integrated Product Policy) framework, the introduction on new ISO standards such as the ISO/TR norm 14062 (environmental management – integrating environmental aspects into product design and development), extensive considerations in the area of product life cycle management, and other initiatives in the area of sustainable innovation (Charter and Clark 2007; EU 2005; ISO 2002; Eversheim et al. 1995). The design community has not took second place but clearly contributed to the increase of sustainability consciousness within NPD contexts. Guo Q. Huang's book "Design for X" and Ezio Manzini's diverse publications on "sustainable design" are just two examples out of many underlining that (Huang 1996; Manzini 2006). It is striking, however, that – whereas publications on sustainability management

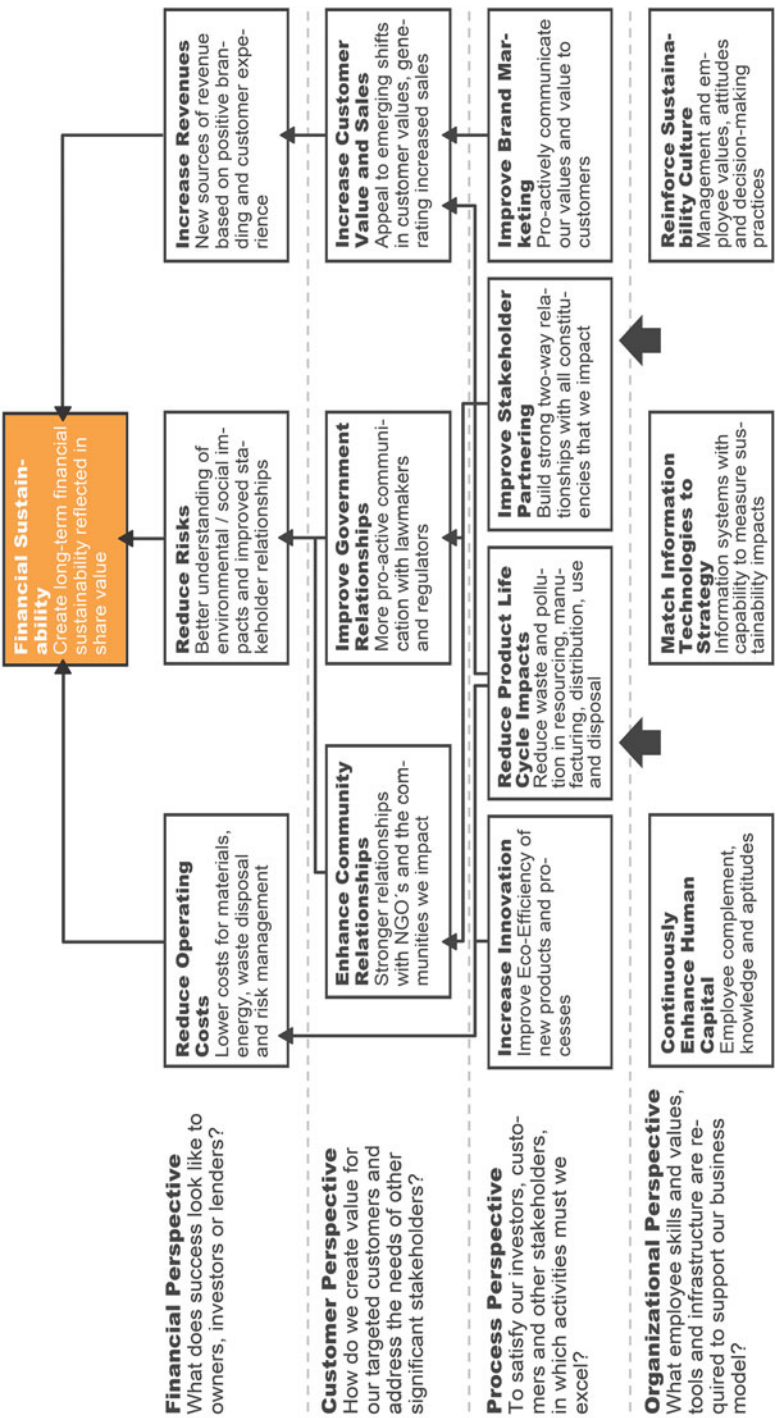

Fig. 39.1 Product innovation as an integral part of a holistic business approach to sustainability (Source: Montgomery 2009)

and/or sustainability economics often miss the link to product innovation – many treatises on design engineering and on ecodesign often do not clearly position a sustainability-oriented design to where it usually takes place, namely, in the business context.

Following a consequent business orientation, there is a clear need for a different definition of sustainable design engineering, taking the design process itself far beyond the will to just develop sustainable product design results (Manzini 1999). Without changing the processes itself as well as the business objectives behind, any intention to increase the sustainability of the products designed will consequently fall short. "The keyword is synergistic, synergy between form and function, between construction and production, between engineering and market etc." (Grimheden and Hanson 2005, p. 28). What has generally be defined by Martin Grimheden and Mats Hanson as the core idea of any design engineering activity especially applies for sustainable design engineering. The automotive industry is delivering good examples for that. From Toyota's hybrid cars to BMW's i-series, such revolutionary new product concepts would never have become reality if not the design process was recalibrated, bringing design away from a short-term project thinking to accepting it as a continuous improvement task fully integrated into a company's long-term innovation process based upon steadily evolving product roadmaps.

Instead of a one-sided approach to sustainability, a triangular understanding is needed according to which technical considerations (technology, materiality, safety, etc.), aesthetical aspects (shape, ergonomics, functionality, etc.), and business objectives (cost, market potential, revenues, strategic fit, etc.) are directly and continuously linked to one another, jointly focussing on making the results of new product development processes more efficient (in terms of energy-/material-/resource- as well as production-/recycling-efficiency), increasing a product's quality, reliability, and overall life span and most important its marketability and revenue power (see Fig. 39.2).

How can a company make sure that these objectives are clearly integrated into the processes of product conception and product development? Why is design an important factor within these processes? And which effects does a sustainability-driven design engineering have on the overall efficiency of innovation management? It is these important aspects of modern innovation management this chapter is focussing on.

2 Some Fundamental Considerations on Design

To clearly understand the economic power, a sustainable design engineering process has, it is important to conceive the role design is playing in modern industrial management. In fact, although design – just like sustainability – has become a hype topic these days, many companies still fail to take full advantage of the potentials

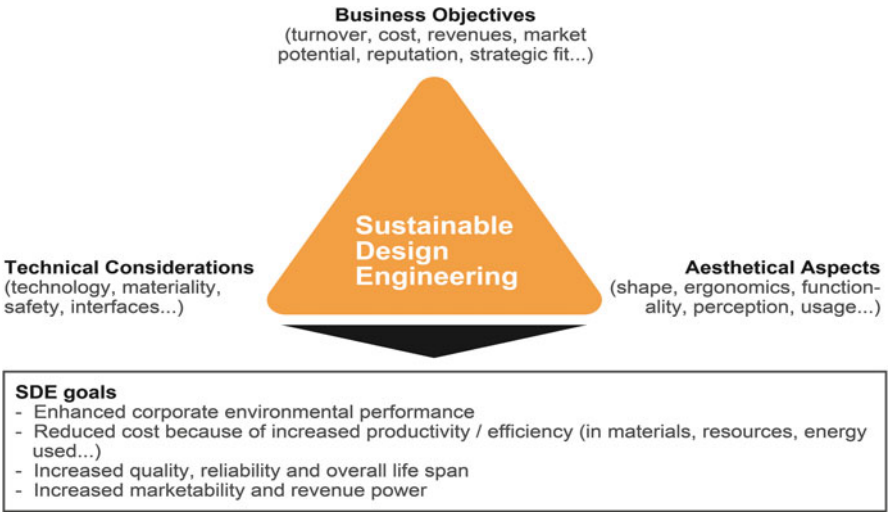

Fig. 39.2 A triangular approach to sustainable design engineering (SDE)

design offers for business success. Especially in capital goods' and technical goods' contexts, design is often perceived as an additional and purely aesthetical activity to be carried out by some outside "creatives" (Herrmann and Moeller 2005, 2006, 2009; Herrmann et al. 2009).

Following a strictly industrial understanding, design, however, plays a much more fundamental role within product innovation and development processes. It encompasses not only the outward form-giving but also the definition of a product's functionality, construction, user interfaces, ergonomics, and materiality, assembly/disassembly. Within modern design theory and everyday work, this broad understanding of design is often referred to as "design engineering" or "engineering design" (Grimheden and Hanson 2005; Seeger 2005; Skerlos et al. 2005).

However, industrial design has an even broader function than just bridging the gap between a product's internal technical live and its outward appearance. In a modern industrial understanding of design, the design activity is central to the process of product conception, i.e., not only its future technical, and aesthetical but also strategic configuration, thus having a significant influence on the future innovativeness, quality, degree of sustainability, as well as potential market success and revenue of a new product to be developed (see Fig. 39.3).

It is not only technical consumer goods companies such as Apple or Audi but increasingly capital goods manufactures such as Gildemeister (machine tools), Heidelberg (printing machines), Kuka (industrial robotics), or MAN (commercial vehicles) which are following such an understanding (see Fig. 39.4). Accordingly, they do no longer regard design as a "nice to have" add-on to an otherwise fixed set of management and engineering tools but clearly integrate it into their overall strategy and innovation systems (Herrmann et al. 2009).

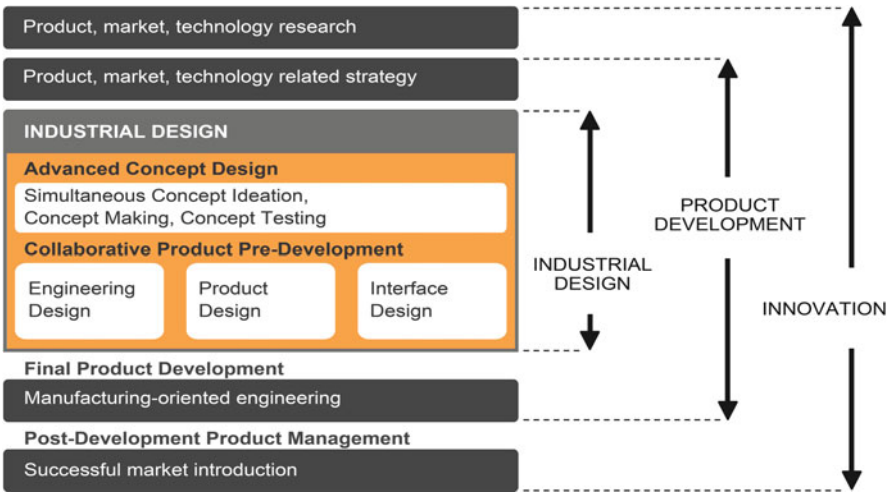

Fig. 39.3 A modern industrial conception of design (Source: Herrmann et al. 2009, p. 31)

Fig. 39.4 Dymatrix die-cutter – an example for strategic design engineering by Heidelberg (Source: Heidelberger Druckmaschinen AG)

3 The Role of Design in Innovation Processes

An essential prerequisite to fully understand the role of design within sustainable engineering therefore is the recognition of the importance design today generally bears for the success of innovation projects. Theory and praxis show that design

can serve as a lasting reinforcement factor in innovation processes and therefore also in making the results of these processes more sustainable. Design can already provide effective support in the idea-generating phase; it makes new product ideas tangible at an early stage, it is important in the development of marketable products, and it can help again to redesign existing products in such a way as to lower costs ("design to cost") and/or ("design to build") to increase the probability of market success (DMI 2004; Herrmann and Moeller 2009; Marsili and Ammon 2006; Mutlu and Er 2003). Design moreover possesses an important function in the context of product differentiation, and profiling and the communication of new product-line logic in terms of assortment coherence and system's intelligence. Above all, design makes the innovative qualities of a new product concretely perceivable. Important product aspects such as value, reliability, high engineering standards, etc., get apparent to the viewer – and thus the potential buyer – only by way of the respective product design (Herrmann and Moeller 2009). Unfortunately, these central aspects of design are often disregarded. According to a study carried out by the German Federal Ministry of Education, Science, Research and Technology, "design can influence the innovation process considerably more strongly than this is currently the case… Designers are not only able to accompany innovations, but to initiate those themselves and to develop clear visions of innovation. These potentials have not sufficiently been exploited so far" (VDI 1997, p. 74).

The special role design has as regards new product development may perhaps best be explained with reference to the key role design assumes within the early conception phase of an innovation. Designers in much of their work usually have a conceptual approach. They develop holistic product concepts before directly jumping into the nitty-gritty details of product development (Hardt 2004). If used in an appropriate manner such an in-depth conception work usually leads to better product solutions: "Product success depends on developing strong product concepts and ensuring organizational focus on those concepts through project selection… It is commonly thought that most of a product's quality, cost, and performance is decided during conceptual design, and that very little influence comes from the details of the design… Best practices within the categories of product strategy, detailed design and goals achieved an adoption rate of about fifty-eight percent, while best practices within the categories of product disposal, concept generation, concept screening, and concept design achieved an adoption rate of about thirty-six percent… We can see that organizations have not widely adopted… unconstrained examination of product concepts" (Dooley et al. 2002, pp. 2, 10, 18, 19). Unfortunately within engineering thinking, such conceptional aspects are often neglected (Pappas 2002). This explains why the designer's role within innovation processes can be of crucial importance for the later outcome.

If, on the contrary, conceptual aspects are not considered enough within NPD product development processes, the probability of later flaws and failures is considerably higher, not only but specifically as regards the sustainability of the products developed. As Hari Bapuji of the Asper School of Business at the University of Manitoba has illustrated on the basis of an extensive study of the toy industry, many of the products recall in that industry out of the last years did not derive from

manufacturing problems but from conceptual flaws in the early phases of the value chain. In order to prevent this from happening, the design function (and a conceptual approach linked to it) is crucial (Bapuji 2008).

4 Return on Sustainable Design Engineering (SDE)

As shown in Sects. 2 and 3 of this chapter, design generally plays an important role in product conception and development processes. But what is its contribution in making the results of these processes more sustainable? Following the above sustainability definition, design may contribute to a sustainable product development in that it either influences the efficiency/cost side (in terms of energy-/material-/resource- as well as production-/recycling-efficiency) or by increasing a product's quality/reliability/life span and most important its marketability and revenue power.

As far as the efficiency/cost side is concerned, designers probably have a considerable influence on the overall development cost. Although Hollins and Pugh (1990) have shown that the pure design concept costs only make up for approximately 12% of the overall product cost, design decisions heavily influence future cost (such as cost for assembly/disassembly, component cost, warranty cost, etc.) on the manufacturer's side as well as the potential cost of ownership on the client's side. By looking for ways how to design a technologically and functionally similar product solution differently, design can heavily alter the overall efficiency not only in terms of manufacturing cost but also with reference to energy-/material-/quality-efficiency.

Also as regards the revenue potential of a new product design solution is concerned, designers can make an important contribution to increase the marketability and thus return on investment (ROI) in product development and engineering. It has been a considerable problem in the past that more environmentally friendly and sustainable product solutions were often perceived as being less attractive. Through changing the design of the product (not only in terms of its look but also in terms of its usability, interfaces, ergonomics, functionality, etc.) design adds value in that it increases the marketability and sales potential of a sustainable product solution (see Fig. 39.5).

Here are the following three examples out of many underlining that: When Nokia launched its mobile phone 3110 Evolve (the first mobile phone made from recycled materials) in 2008, it looked by no way like a typical eco-product. On the contrary, its design had clear references to modern high-tech benchmarks of that time, therefore increasing its mass-market sales potential (Trivedi and Unhelkar 2008). Bosch Thermotechnology has over the last years not only increased the eco-friendliness of its products (e.g., by combining traditional heating systems with solar-thermic components) but also invested into an innovative design of its products, not only with reference to the exterior but also the interior life of its products, following the example of an advanced engine bay design within the automotive industry (Herrmann et al. 2009). Finally, MAN Nutzfahrzeuge Group, through a radical redesign of their cabs did not only increase drivers' comfort but have also lowered fuel consumption of their truck fleet (MAN 2007).

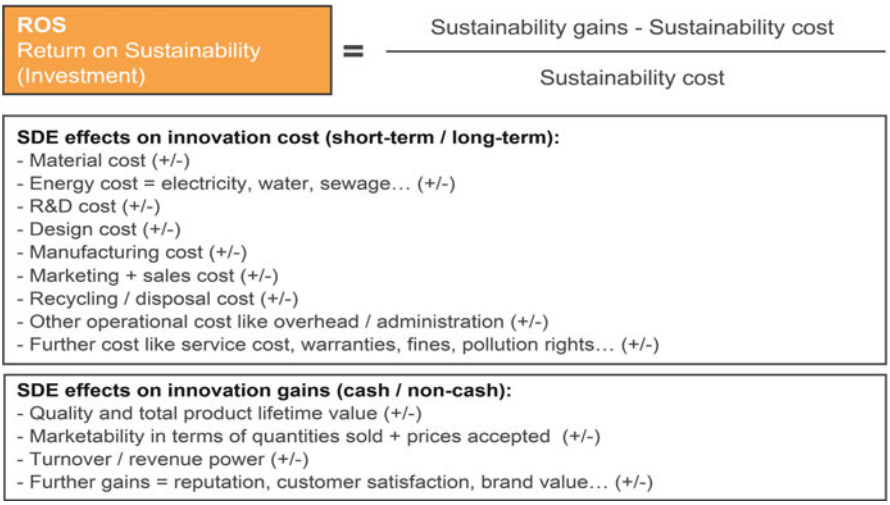

Fig. 39.5 Design contribution to an increased return on sustainability (ROS) in strategic design engineering

Apart from these immediate effects in terms of cost/efficiency, revenue, and market attractiveness, from a business point of view, it is of a considerable interest to see whether the increase of the quality, the reliability, and the prolongation of the product life cycle deriving from a sustainable product design positively influence the overall future income potential of a company. Such considerations are of a special importance because as a result of hypercompetition (D'Aveni 1994), it is often assumed that product life cycles are clearly shortening as a consequence of a general innovation pull and push and a trend toward disruptive innovation (Paap and Katz 2004). In contrast to that, the design discipline (even if it is often perceived as fashion-kind of thing from outside) has a long tradition in focussing on a sustainable, i.e., long-term oriented approach to innovation. Starting from the Deutsche Werkbund and Bauhaus movements to the more modern concepts of "Gute Form" (to just take the German example), many designers are clearly trained to look more for lasting aspects in product development instead of just focussing on short-term innovation and business turnover. As Brigitte Wolf, professor for strategic design at the University of Wuppertal, puts it: "The materialistic orientation of management is confronted with the often idealistic self-conception of design" (Wolf 1994, p. 12).

Such idealistic predeterminations, however, do not prevent the design discipline from justifying its rather long-term-mindedness on a quantitative basis. In fact, a company prolonging the life span of its products does of course also reduce the potential for selling new product versions or product series to the same clients within the same period of time. There are in fact arguments showing why a sustainable product and design strategy may nevertheless pay off. Many market and innovation leaders such as ABB, Bosch, Ergo, FSB, Gildemeister, Heidelberg, Miele, Porsche,

Siemens, USM, and Volkswagen have been successful in the past (and still are) because they did and do not only look for short-term successes by always throwing new products on the market but also because they follow a sustainable product and assortment strategy.

A long-term oriented product and design policy allows companies to raise the product longevity and therefore operating efficiency on clients' side to achieve an easier payback of increased development expenditure, to reduce disposal cost, to benefit from increased customer contentment and loyalty, to charge higher price premiums, to sell extra services, and last but not the least, to meet changing consumer tastes (such as the LOHAS – lifestyles of health and sustainability trend). Whenever the total delta of these advantages clearly outweighs the disadvantage of a reduced per-period repurchasing rate to the same clients, the net sustainability profit (sustainability returns - sustainability cost) will be a positive one (Arnold et al. 2001; Burschel et al. 2004; Epstein and Roy 2003; Figge et al. 2001; Schäfer 2005).

Of course, design does not automatically lead to all of these advantages. Apart from the fact that a designer may be equally short-term oriented as businessmen often are, design sometimes leads to consequences which do not positively but negatively influence the overall sustainability balance (id est a company's overall relation of environmental assets and liabilities). For example, in today's short-cycle market economies, products are often repacked or redesigned just to increase their marketing opportunities, which may deteriorate the overall sustainability balance (Bhamra 2009; Lewis et al. 2007). Again, here it is the responsibility of the respective product managers, designers, and engineers to clearly look for solutions which outbalance these effects (e.g., through ecologically friendly packaging solutions or a complete product redesign leading to reduced material usage) in order to keep the overall balance positive. A benchmark example for that is Apple: "Over the past decade, Apple's designers and engineers have pioneered the development of smaller, thinner, and lighter products. As our products become more powerful, they're using less material to produce and generating fewer carbon emissions. For example, although today's 21.5-inch iMac is more powerful and has a much larger screen than the first-generation, 15-inch iMac, it is designed with 50 percent less material and generates 50 percent fewer emissions. Even the iPad became 33 percent thinner and up to 15 percent lighter in just one generation, producing 5 percent fewer carbon emissions" (Source: http://www.apple.com/environment/).

5 Organizational and Strategic Conclusions

The arguments outlined above are of a considerable importance for the organization of design within the engineering and innovation context. Design should no longer be seen as an add-on activity to be brought in at the end of a product development process but be clearly treated as an integral part of innovation management, generally as well as especially within sustainability-oriented innovation contexts.

How different the results can be – depending on whether design is integrated early into the innovation process or not – has been clearly illustrated by Udo Lindemann, professor of product development at the Technical University of Munich, with the help of the following two examples from his own professional experience: "In the first case we had optimized a product from the technical and economic points of view; the construction work was near completion. Now the designer was invited to 'take a final look.' What was left for this 'poor guy' to do? Who would have consented to a reconstruction project in the form of an increased budget and accepted the delay in the product's launch? In the second case, the designer was involved before the machine concept was established. Following some intensive and vehement discussions, the outward appearance of the machine was determined with the resulting conceptual consequences. The later fair and market success confirmed that the decision to collaborate had been sensible" (Lindemann 2005, p. 298).

To fulfil the responsibilities and tasks directly deriving from playing an increasingly important role within innovation processes, the design discipline itself clearly has to change its nature and expand its competence profile. Apart from enlarging its technological know-how and apart from opening up to new forms of open collaboration and innovation (Sawhney 2002), it also must step-up its eco-competencies and its knowledge of sustainability methodology in the area of life cycle assessments (LCA), environmental effect analysis (EEA), house of quality/house of ecology approaches, and likewise (Fargnoli and Kimura 2006a, b; Tischner and Schmincke 2000; Charter and Tischner 2001). To facilitate design efforts in the area of sustainability, designers may refer to a set of helpful online tools, which have been developed over the last years, such as the "ecodesign pilot" in the area of hardware design (http://www.ecodesign.at/index.en.html) or the "Packaging Impact Quick Evaluation Tool (PIQET)" (http://piqet.sustainablepack.org) in the area of packaging design.

Last but not least, the design discipline will only be able to fully assume its key role within sustainable NPD processes if it moves away from a purely "project-oriented thinking" to a more strategic view on design, linking its own long-term oriented product and design strategies to other important strategy areas within the company (corporate strategy, market strategy, innovation strategy, technology strategy, product and assortment strategy, brand strategy, communication strategy; see Borja de Mozota 2003; Bruce and Bessant 2002; Herrmann 2004; Herrmann and Moeller 2008; Ritzen and Beskow 2001).

As Lennart Karlson has shown with the example of ABB (see Fig. 39.6), in corporate context, design work is usually embedded in a complex product development environment, with lots of different strategic and operational parameters (trends, scenarios, roadmaps, positionings, customer values, product specs, budgets, etc.) to consider (Karlson 2002, Karlson and Wisen 2002). Within such corporate environments, it is indispensable to clearly link design to these many strategic and operational parameters and to bindingly integrate sustainable design objectives within the overall stage-gate development processes to refrain them from remaining pure lip service.

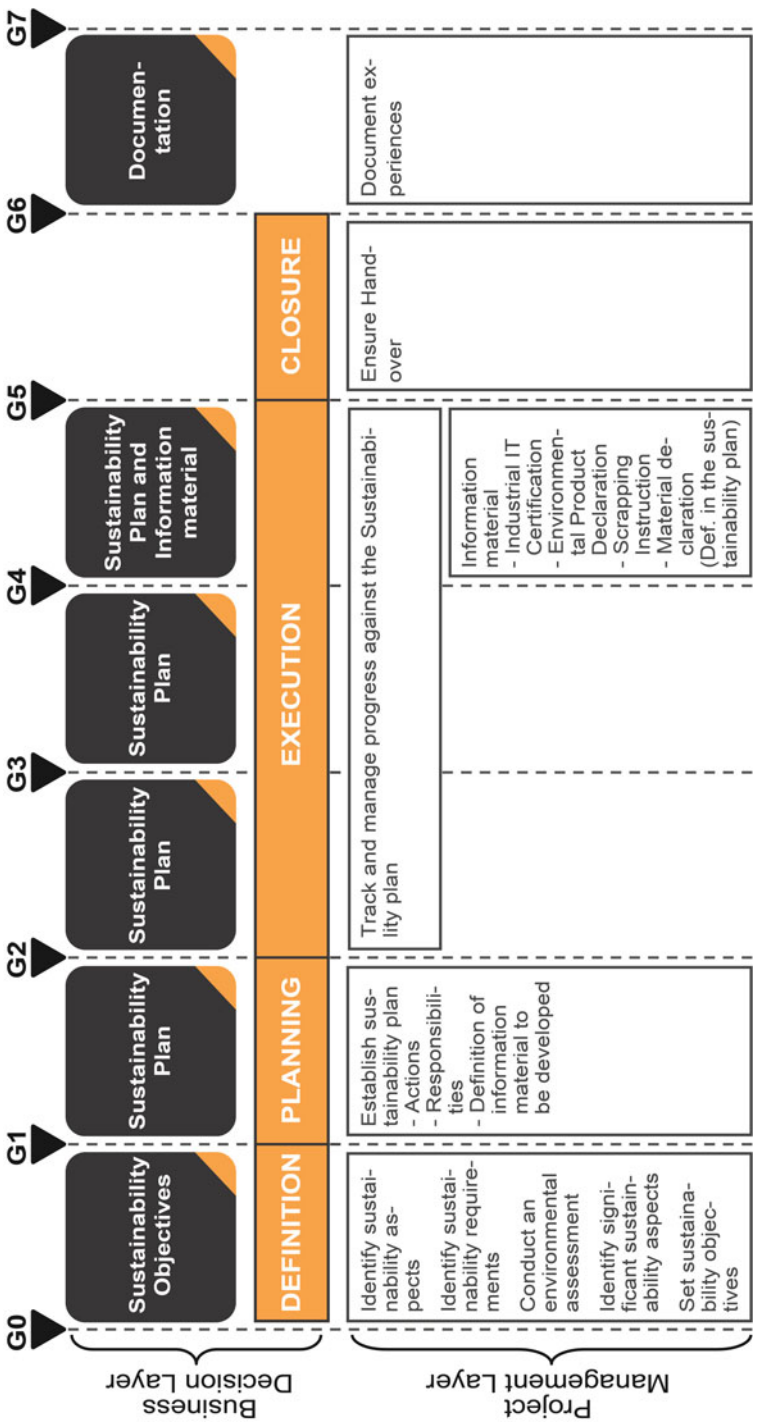

Fig. 39.6 Sustainability as part of a stage-gate-oriented design process at ABB (Source: Karlson 2002, p. 12)

6 Summary

Design is by no means a nice-to-have add-on to engineering but an integral part of it. Design can play an important role in making product innovation and engineering more sustainable. To fully assume this, it is, however, not sufficient to link design to some very general eco-objectives. It is on the contrary indispensable to really strengthen the ties of the design task and the design engineering activity to other strategic and operational activities within business and to clearly prove the positive effects a sustainable product design has on overall business. Moreover, the design work itself should be considered as a "strategic activity" sui generis. It is not very astonishing that those companies which follow a long-term orientation within their overall market approach usually also display a high consistency in their outward product design (and vice versa). It came of no surprise if in times of increased economic turbulences, the for long out-fashioned tendency to build on and maintain such "sustainable competitive advantages" (Porter 1985) instead of always chasing for new ones may gain new importance.

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