

Chapter 13

Principles of EcoDesign in Sustainable Supply Chains

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13.1 Introduction

It is often said that the majority of environmental impacts of products occur during the design stage, so efforts to make supply chains more sustainable should inevitably include the product design process. In this chapter, we put EcoDesign in the broader product design context and discuss some aspects of implementing EcoDesign in companies. We then introduce ten “Golden Principles” (10GP) of EcoDesign and provide an illustration of how they can be used to analyze and redesign a product.

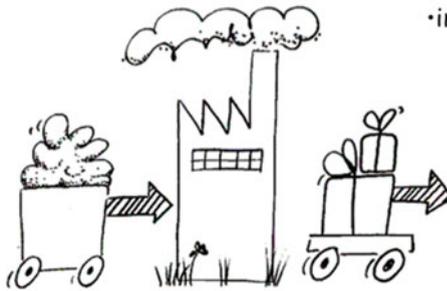
How does EcoDesign fit in the context of sustainable supply chains? If we simplify the concept of supply chain management (SCM), it is a matter of flows: flow of money, goods, and information throughout the life cycle, from extraction of materials via manufacturing, sales, use, and recycling.

Today, information might be the most important element in SCM in order to achieve a true eco-effective product. Figures 13.1 and 13.2 illustrate the shift. Some 50 years ago, the products were made in a physical plant. Material was imported, the products were made from start to finish within the plant, and in the end the full product was delivered out through the factory gates. Today, companies are not characterized so much by fixed physical locations as by moving activities where material, components, and money meet in different locations; what keeps things together is information.

This shift puts strong demands on information in order to achieve sustainable SCM (or eco-SCM). It is then necessary to understand the nature of “eco” in the industrial environment. Figure 13.3 shows all the necessary elements of a product design project and it is important to understand that “eco” is not the dominant part

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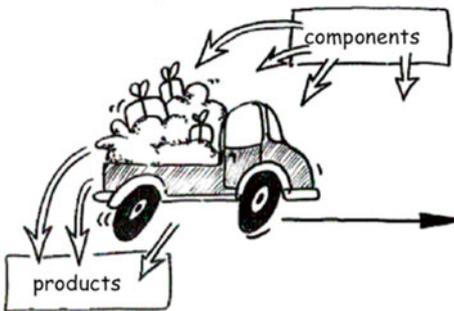


- material flow
- local responsibility
- inhouse production

Ownership of material and products!

Fig. 13.1 Yesterday products were made in a plant and ownership of material, manufacturing resources, and products was strongly connected to the company (Luttrupp 1998)

-delivery



- immaterial flow
- brand labels
- outsourcing

Immaterial ownership of material and products!

Fig. 13.2 Today, extraction of materials, manufacturing of components, and assembly of product altogether is a moving activity. Ownership of material and products are more of a virtual element (Luttrupp 1998)

but still a major one. However, there must always be a compromise between all the demands placed on the forthcoming product. Pugh (1991, p. 5) refers to this as the “Design Core”:

Total design may be construed as having a central core of activities, all of which are imperative for any design, irrespective of domain. Briefly, this core, the design core, consists of market (user need), product design specification, conceptual design, detail design, manufacture and sales. All design starts, or should start, with a need that, when satisfied, will fit into an existing market or create a market of its own.

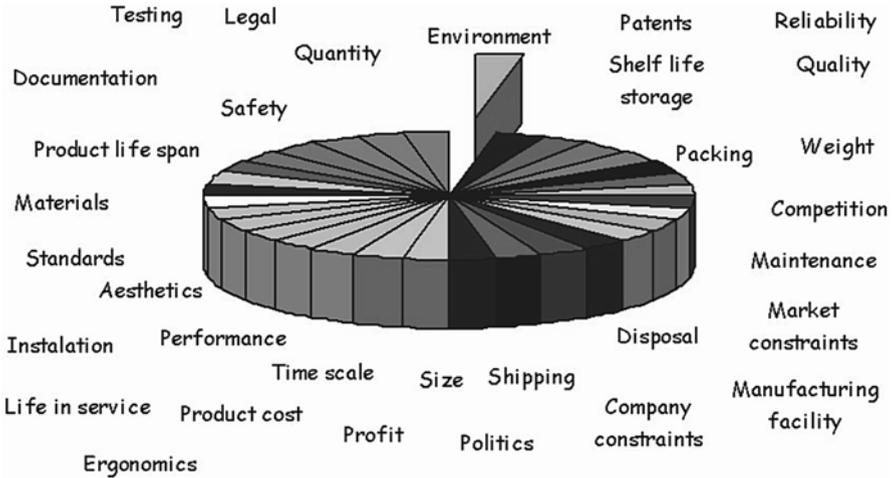


Fig. 13.3 An illustration of all the necessary elements in product development (PD). Entering environmental concern into this compromise makes it also EcoDesign (Luttropp 1999)

The circle diagram in Fig. 13.3 illustrates all these demands connected to the forthcoming product.

Even if environmental demands are important and crucial, there are a lot of other demands to be considered as well.

This means that Eco-performance, as defined by Züst (1996), is one of several very important elements, which has to be balanced in the design core against other functional and economic requirements. Environmental considerations have to be incorporated into the design core without taking over (Züst 1996).

Recycling and other environmentally imposed actions have to be related to all the other elements in the design core without taking over, since environmental demands will rarely have top priority. Functionality of the product and profit to the company are examples of two aspects which always have very high priority, almost always higher than environmental demands. Without customers buying a function and companies making profit, there will be no business, no matter the environmental issue. Consequently, EcoDesign (also referred to as Design for environment) may be defined as a practice by which environmental considerations are integrated into product and process engineering design procedures, while maintaining product, price, performance, and quality standards (Graedel and Allenby 2003). EcoDesign has been extensively studied in the academic literature. We refer to Hatcher et al. (2011), Ilgin and Gupta (2010), and Ramani et al. (2010) for some reviews. The readers may also refer to Bovea and Pérez-Belis (2012) for a review of the main EcoDesign tools. The importance of EcoDesign is also recognized among companies, although there may be confusion about the terminology. Short et al. (2012) ask firms in Sweden and the UK whether design for sustainability should be part of their product development process, and the vast majority of firms responding (97% of large firms in Sweden and 89% of large firms in the UK) agree that it should. When

asked whether they practice a design for sustainability approach, the proportion who said “yes” dropped, while even less confirmed that they use an EcoDesign approach. The conclusion is clear that there is widespread agreement about the need to incorporate sustainability in product design, but less understanding of the corresponding approaches and terminology. This conclusion is in line with Karlsson and Luttropp (2006) who highlight that answering to why we do EcoDesign is more basic than how.

This chapter mainly focuses on this latter question by discussing some aspects of implementing EcoDesign practices in companies. We organize the rest of the chapter as follows. Sect. 13.1 discusses the importance of design knowledge as a basis for successful implementation of EcoDesign. Section 13.2 presents the key actors to include in the EcoDesign process. Section 13.3 presents the 10GP of EcoDesign and discusses these principles in the context of sustainable SCM. In Sect. 13.4, we show how to apply the 10GP for analyzing and Eco-redesigning two products. Finally, Sect. 13.5 presents some conclusions. Design knowledge—a base for sustainable SCM.

Education and experience are two main elements in design knowledge. Many designers have a basic practical experience from youth by disassembling family goods like toys, clocks, radios, vacuum cleaners, etc. and mending bicycles, schoolbags, sports equipment, etc. This gives a natural sense for gravity, strength, and motion. Later, this practice is combined with formal education in engineering matters. Most machine engineering educations are based on classical technical elements like mechanics, materials, thermodynamics, etc.

This is visualized in Fig. 13.4 by the expression $(1 + 1 = 2)$: one plus one is two and nothing else! On this level, “law and order” is predominant and technical students with a new diploma have a preference for facts and correct answers rather than tricky questions. After a few years of practical work, engineers come to amplify their technical knowledge with experience and their real competence improves as a combination of education and experience. Questions have been raised that don’t have a single correct answer. This is visualized in Fig. 13.4 with the statement “ $1 + 1 = (1:3)$ ”. One plus one equals something between one and three, rather than a single number (Luttropp 1998).

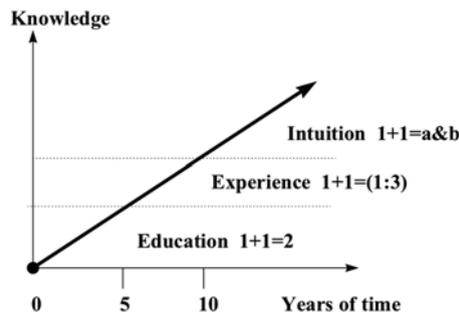


Fig. 13.4 The transformation of education and experience into intuition, the highest form of knowledge (Luttropp 1998)

Later, technical experience and education merge into intuition, reflected by “ $1 + 1 = a \& b$ ”. Design knowledge is, at this point, more experienced as “feeling” than a set of technical laws and physical conditions. Technical competence is transformed into technical “wisdom”. This status is monitored by Bragd in her study of the development of the Volvo XC90 car and expressed as “Tinkering” (Bragd 2002).

13.2 Managing the EcoDesign process

To succeed with EcoDesigning, integration of environmental competence into the product design process is essential, and early integration is the most effective. The nature of competence varies between persons involved in EcoDesign and four different competencies can be observed: consumers, designers, managers, and environmental specialists.

Designers need basic knowledge in environmental design and a network with environmental specialists. Research carried out by Ehrenfeld and Lenox (1997) shows that a good network including environmental specialists is essential for success in designing environmentally friendly products. Designers should not be the specialist on environmental matters since the design core (see Fig. 13.3) contains a lot of demands apart from environmental requests. There is an obvious risk that being an environmental specialist makes the designer less skilled in other areas.

Consumers ideally need a good basic knowledge of environmental matters in order to be a “good” customer. Choices by ordinary people often determine where on the agenda environmental issues will appear (if at all).

Managers need basic knowledge about environmental matters concerning acquisition, design, legislation, etc. Managers are the key to EcoDesign since designers cannot decide on environmental improvements on their own; it must be agreed on by management as a part of broader decisions about product economics and development.

Environmental specialists need deep knowledge of the environmental field and a good competence in current environmental analysis tools. Life Cycle Assessment (LCA) is well-known (see also Chap. 2 by Guinée and Heijungs (2017)), but many others exist. A specialist should also be well-trained in relevant Eco-design guidelines and checklists, standards such as ISO 14000, and should have a good view of current research related to EcoDesign. A basic task for the specialist is to transform environmental demands into operational design requirements with a connection to economy, legislation, acquisition, etc. One of the best ways to get competence in, for example, LCA is to actually perform a full LCA as a part of the learning process. Every product has one or two main functions, which are the reason why the product is on the market. Environmental aspects can therefore rarely be higher than second or third priority. A vacuum cleaner that does not suck up dust is of no use no matter how environmentally friendly it is. Every designer has to fulfil the main functions first and environmental demands second. An environmental dialogue must be present in the company, and environmental specialists are a major resource in these actions.

13.3 The Ten Golden Principles of EcoDesign in the context of Sustainable Supply Chains

The 10GP by Luttropp and Brohammer (2014) are a tool developed to foster cooperation by uncovering the intuitive design knowledge present in a product design group. The 10GP is an enhanced version of the Ten Golden Rules (10GR) that has been used in the EcoDesign education at KTH (Royal Institute of Technology) in Stockholm by the author since the early 2000s. The Ten Golden Rules were developed by Luttropp as the “lowest common denominator” of ten of the most common issues that must be addressed in EcoDesign (Luttropp and Lagerstedt 2006, p. 1400). Each of the Ten Golden Rules is generic and needs to be customized to the context; the same is true for the 10GP. For instance, the first Golden Rule is “Do not use toxic substances and utilize closed loops for necessary but toxic ones.” As Luttropp and Lagerstedt (2006, p. 1402) point out, this could be customized to:

- Identify which toxic substances are currently used in the product with which you are working;
- Try to find a nontoxic substitute that fulfills functional and economic requirements of the product;
- Ascertain if closed loops are already established or can be developed and utilized for recycling the materials including the toxic substances.

Luttropp and Lagerstedt (2006) provide a detailed discussion of how the rules were adopted and customized at Bombardier, using an iterative and participative process. The 10GP, discussed next, are an enhanced version of these Ten Golden Rules.

In this section, we discuss the 10GP of EcoDesign in the context of sustainable SCM. For each of the Golden Principles, we explain how it applies to EcoDesign, and why it is important in the context of EcoDesign. After introducing the Golden Principles, we provide an illustrative example of how a keyboard and a cordless drill were analyzed and redesigned using this approach.

GP1: Clarify product characteristics, functional and immaterial.

How: Identify which functions of the product are important and determine which are directly linked to particular materials or material streams. The material stream is then effectively a function of the function of the product.

Why: In redesigning a product, it is important to find a balance between the functions the product (and hence the embedded materials) aims to provide and the corresponding environmental impact of those materials.

GP2: Manage human resources in a responsible manner without consuming them.

How: Keep track of and note how human resources are used throughout the life cycle, both inside and outside the company. For example, designers can avoid using FeNdB magnets when ordinary magnets are sufficient for the current application since the extraction of neodym (Nd) is creating problems for the work environment.

Why: Even when employees may not be perceived as the top priority in a supply chain, the firm must ensure that the human resources along the life cycle are healthy, as otherwise the market will perceive claims of sustainable SCM as being hollow and thus potentially counterproductive.

GP 3: Minimize hazardous substances and arrange closed-loop systems for the present ones.

How: Ask suppliers for a bill of materials (BOM), which is necessary for any attempt to remanufacture the product. In practice, it is often hard to get a complete BOM since with semi-virtual products that are manufactured in accordance with Fig. 13.2 no single entity has the entire BOM.

Why: Firms may face questions about RoHS compliance as well as REACH reporting or possible toxic content of their product. Just asking and continuing to do so starts a process towards a more visible knowledge of the total material stream.

GP 4: Ensure efficient use of material resources with little generation of waste and efficient transportation.

How: Use recycled materials in manufacturing and measure/report how much goes into the process.

One element in LEAN is effective transportation of materials and in this sense a part of SSCM. Another LEAN element is low waste, which is eco-effective. From an EcoDesign perspective, it is important to use recycled materials in products if possible. Many companies claim use of recycled materials. With a less effective production process, it is then possible to compensate by bragging that recycled material is used when it is in fact production spills. The challenge is to find materials that have been in use and then returning into new products

GP 5: Ensure that GP-related costs are offset by an increase in GP-related income.

How: Firms should try to keep account of both the additional costs and income that is related to EcoDesign. (This is analogous to the requirement in Six Sigma to quantify costs and benefits of individual projects.)

Why: Products designed following EcoDesign principles can provide various benefits to firms, including enhanced brand, which can carry over to the broader portfolio of the firm. Without careful accounting, those benefits will not be attributed to the EcoDesign process, making eco products appear more costly than is appropriate.

GP 6: Minimize energy consumption in use, especially for active products.

How. Ask what types of energy and how much energy is used throughout the life cycle; in the production of raw materials, manufacturing, transportation, power in use, recycling, etc. Questions on these matters result in awareness and in turn often act as a driver towards smaller/more efficient use of resources.

Why. Active products are products with power consumption in use phase as most significant environmental impact. Typical active products are refrigerators and classical cars. For these products, a lot is to be gained by lowering the power consumption in use phase. Furniture are mostly inactive with most significant environmental aspect out of use phase. So, it is gainful to keep this product in the use phase as long as possible.

GP 7: Avoid mixing materials and adopt a clear and obvious structure of attachment joints and fraction borders.

How: Simplify the material composition of products and implement recycling-friendly features in products (sometimes referred to as Design for Environment, Design for Disassembly, etc.). Plan from the start of a product development process for a supply chain for recycled material at the same time as the classical forward supply chain for virgin materials.

Why: The recycling of materials is a critical issue in sustainable supply chains. An improved so-called material hygiene (MH) (a pedagogical concept aimed at managing compromises to optimize materials use in products) leads to cleaner, more efficient and useful material streams.

GP 8: Optimize the usage lifetime of products and promote repair and upgrading.

How: Firms should ensure that there is a system that takes care of discarded products. They should try to maintain relationships with the product owner so that recovery rates can be maintained at a level as high as possible.

Why: The shorter and shorter lifetime of products is perhaps the most important challenge in EcoDesign. Doubling the useful lifetime will reduce the need for recycling processes by 50 %.

GP 9: The product must be surrounded by a corresponding environmental culture.

How: Make sure that everyone involved also acts in an environmentally correct manner. Details such as reusable packaging may circulate backwards in the value chain with discarded products or spillage.

Why: Environment is often seen as a somewhat ethical issue, which means that in a sustainable supply chain one must also secure that the company culture is supporting the sustainability. It is important to “walk the talk”. If the company is not supporting sustainability and just the products, the company can easily be perceived as hypocrite.

GP 10: Ensure that the information IN the product, ON the product, and FOR the product is correct and sufficient.

How: Make sure that the information on the product clearly displays how to use it in an energy-efficient manner. Try to publish as much information as possible on bills of material, transportation routes, etc.

Why: This will be regarded as respectful to the concerned eco-consumer and drive towards more sustainable supply chains.

13.4 Golden Principle Analysis

One might be concerned that these EcoDesign principles are difficult to implement in practice, especially when firms are facing many competing priorities. That is not the case. To illustrate that, we provide two examples below of projects conducted by graduate students in the EcoDesign course at KTH Stockholm. The students analyzed and Eco-redesigned a keyboard (Alm et al. 2014) and a cordless drill

Table 13.1 Product characteristics for each of the 10 Golden Principles for the reference product; a keyboard

Golden principle	Reference product characteristics
1. <i>Function</i> —Clarify the product characteristics	Mainly functional value. Price motivates purchase. Some immaterial value in terms of brand perception
2. <i>Human resources</i> —Manage human resources in a sustainable way	The company has low-wage workers in China, but also have an outspoken agenda for Supply Chain Responsibility where procurement receives responsibility training, direct employment of migrant workers, limited weekly working hours, etc.
3. <i>Toxic</i> —Minimize hazardous substances and arrange closed-loop systems for the present	The keyboard contains a small WEEE-core. Otherwise little toxic substances is used
4. <i>Material resources</i> —Ensure lean production and efficient transport	The production in this company is highly optimized. Transport is mainly by ship which is relatively effective
5. <i>Economy</i> —Ensure that GP-related costs are offset by an increase in GP-related income	The product is profitable today
6. <i>Energy</i> —Minimize energy consumption in use, especially for active products	The energy consumption during use is very low relative to the other stages of the life cycle
7. <i>Material hygiene</i> —Avoid mixing materials and adopt a clear and obvious structure of attachment joints and fraction borders	The reference keyboard has a relatively low level of material mix
8. <i>Lifetime</i> —Optimize the usage time of products and promote repair and upgrading	The reference keyboard is assumed to be used during half its lifetime
9. <i>Context</i> —The product must be surrounded by a corresponding environmental culture	The company has a clearly stated agenda for sustainable operations
10. <i>Information</i> —Ensure that information IN the product, ON the product, and FOR the product is correct and sufficient	The reference product is labelled with energy consumption and some plastic parts have material labels

(Andren et al. 2014). The products were analyzed according to the 10GP to identify relevant areas of improvement. Tables 13.1 and 13.2 and Figs. 13.5 and 13.6 describe the reference product characteristics for keyboard and the drill is present in Table 13.3 and Fig. 13.7.

13.4.1 Keyboard

The product's performance for every Golden Principle is illustrated in Fig. 13.5. The green rings indicate the areas that are mainly targeted for improvements by the suggested redesigns that follow in Table 13.2.

Table 13.2 Possible improvements of the reference product keyboard

Golden principle	Redesign implications
1. <i>Function</i> —Clarify the product characteristics	Connecting a take-back program with component reuse to the product
2. <i>Human resources</i> —Manage human resources in a sustainable way	No improvements by redesign
3. <i>Toxic</i> —Minimize hazardous substances and arrange closed-loop systems for the present	The circuit board is reused. This should have positive effects since it is the most toxic part
4. <i>Material resources</i> —Ensure lean production and efficient transport	Reusing circuit board reduces the amount of material that is used
5. <i>Economy</i> —Ensure that GP-related costs are offset by an increase in GP-related income	The cost might increase slightly but the increase can be offset by a reduction in the environmental footprint due to reuse
6. <i>Energy</i> —Minimize energy consumption in use, especially for active products	No improvements by redesign
7. <i>Material hygiene</i> —Avoid mixing materials and adopt a clear and obvious structure of attachment joints and fraction borders	The number of materials that is used is reduced when the metal plate is removed. The detachable circuit board and break point makes the fraction borders more obvious
8. <i>Lifetime</i> —Optimize the usage time of products and promote repair and upgrading	The lifetime is not extended but the detachable circuit board facilitates repair and upgrades without changing the entire product
9. <i>Context</i> —The product must be surrounded by a corresponding environmental culture	No improvements by redesign
10. <i>Information</i> —Ensure that information IN the product, ON the product, and FOR the product is correct and sufficient	Adding labels for detachable circuit board, the break point, and all plastic parts can simplify recycling. HP can also market the redesigned keyboard as partly reusable

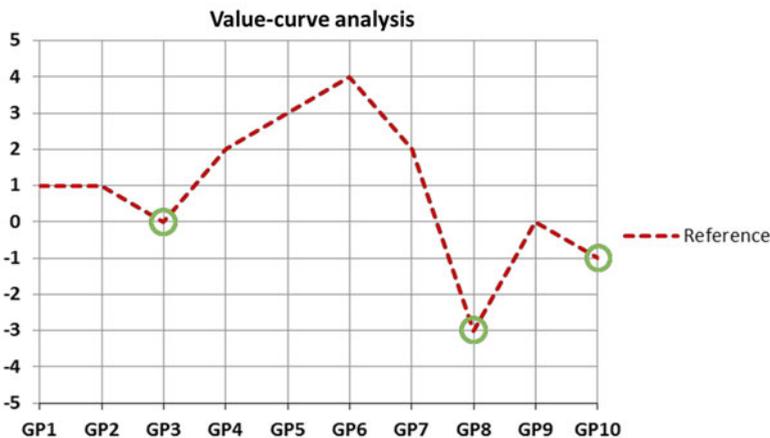


Fig. 13.5 GP value-curve for reference product

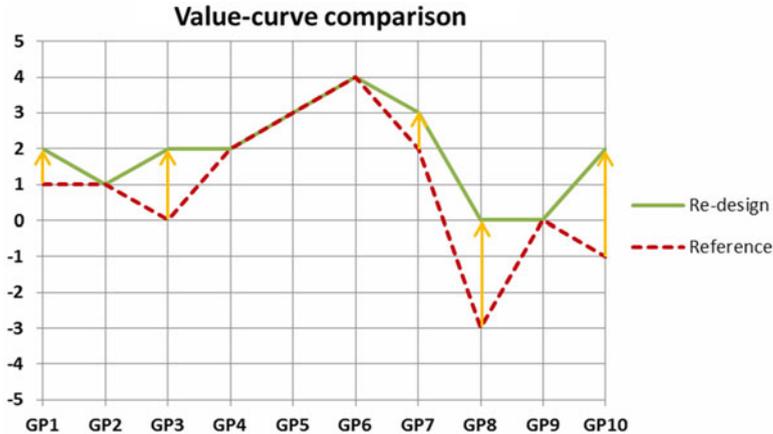


Fig. 13.6 GP value-curve for improved product

After implementing the redesigns, the value-curve analysis is redone. The GPs that have improved are indicated by yellow arrows in Fig. 13.6.

13.4.2 Cordless Drill

The main goal with the improvements of the drill was to lengthen the lifetime and make the disposal and recycling as simple as possible.

When analyzing the 10GP potential, improvements could be identified. By summing up the good and bad qualities of each golden principle, a clearer picture was made and major problem areas could be recognized. In the diagram illustrated in Fig. 13.7, four areas are marked as the major problem areas; the toxic substances, the material hygiene, the lifetime of the product, and the lack of information.

All of the big problem areas seemed to consist of similar suggested improvements. Changing the rechargeable battery to disposable batteries could solve problems in several of the principles. The existing battery in the cordless drill is a rechargeable 12 V NiMH-battery. The disadvantage using that type of battery is that it has to be maintained in order to not deteriorate. The customer, being a regular household-member, will, as mentioned earlier, only use the product a couple of times a year. This means that the user probably won't charge the battery as often as it should be charged or maintain it as it should be maintained, and there could be a problem of the battery deteriorating. By changing the battery to disposable batteries, either several AA batteries, or other standard type batteries of higher voltage, the problem may be solved. Another improvement that could be seen in several of the principles is the change of the plastic materials in the construction. The polystyrene used in the majority of the parts today has the disadvantage of being weak and easily crack, despite having addi-

Table 13.3 This table show possible improvements for the reference product drill

Golden principle	Description	Suggested improvements
1. Function	+ The main function, drill and screwdriver meets the expected qualities	Add more value to the product by adding special properties
	+ Equipped with a special property, a holder for drills	
2. Human resource	– Production mostly located in China, poor working conditions assumed	Move the production or ensure human resource treatment
3. Toxic substances	– If not frequently charged the battery loses potential	Possibly change to disposable batteries
	– Waste electric and electronic equipment (WEEE), high demands on recycling	Information about waste treatment
	– Additives in plastics	Change to plastic materials without additives
4. Production resources	– – Long distances	Move the production
	+ Easy to package	Change the design to contain less parts
	– Production of unnecessary parts	
5. Economy	++ Cheaper than most drills on the market	Possibly a higher price if justified
	+ Cheap materials	
	– Could be more expensive in order to live up to the 10G	
6. Energy	+/- Rechargeable battery	Possibly change to disposable batteries
	+ Battery using low wattage	
	– Battery has to be maintained	
7. Material hygiene	– – The chuck is made out of different materials but not separable for recycling	Redesign the chuck
	+/- Low mix of materials though two types of polymers are used	If possible, decrease the number of plastics
	– Difficult to disassemble due to many attachment joints	Decrease the number of parts and joints
8. Lifetime	– If not maintained the battery will deteriorate	Change to disposable batteries
	– Polystyrene, weak plastic	Change plastic material
9. Context	– Assumed poor environmental awareness	Move the production or ensure an environmental policy
	– No services available	Allow service
10. Information	– No material labels	Label the materials (especially the polymers)
	– No eco labels	Label WEEE-waste

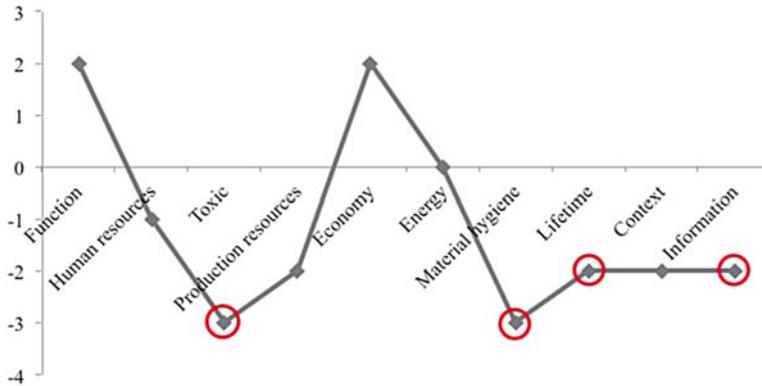


Fig. 13.7 The product's performance for every Golden Principle is illustrated with this graph. The red rings indicate the areas that are mainly targeted for improvements by the suggested redesigns that is given in table 13.3.

tives, which itself is a drawback in a recycling perspective. An improvement in this case could be a material change, to use a polymer with better material properties and better recycling potential. Another disadvantage of the product today is that it's difficult to disassemble. To simplify the recycling process, the design should be changed to consist of less parts and joints. The chuck was identified as a problem-part and should either be redesigned or delivered with better recycling information. The plastic materials and WEEE-cores should also have material and recycling labels.

13.5 Summary and Conclusion

The products business feasibility is basic and implies that environmental design research and developed methods never will get acceptance from designers without taking these elements into account.

The level of EcoDesign is set by the competence of the product developers. It is therefore necessary to understand the nature of EcoDesign knowledge and to launch EcoDesign tools that make it possible for designers to communicate on intuitive level.

Designers and managers have to cooperate in balancing environmental aspects, market opportunities, technical possibilities, and economics.

The situation can be described in four points.

- Environmental aspects must be integrated with technical possibilities, market, and economics
- Designers and managers have to keep up an environmental dialogue
- Environmental demands must be transformed into operational design requirements
- Environmental subjects are fairly new, time and education will do a part of the trick

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