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Assessing materials from an environmental perspective:

Designing a material selection tool for the product development process of an organisation: How to adapt the tool to a company's conditions and needs?

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Abstract

The overall environmental impact of a product is influenced by decisions made during product development, e.g. on alternative materials. Different tools exist on how to select materials. However they are seldom adapted to a company's needs. The research question of this thesis is dedicated to this issue: Designing a material selection tool for the product development process of an organisation: How to adapt the tool to a company's conditions and needs?

During the study, the author developed a tool with the aim to enable a company to rank materials from an environmental perspective. The study included 1) a review of currently used tools at other companies and organisations, 2) a needs assessment at the case company, 3) the development of the tool and 4) the testing of the tool on two metal finishing processes. The case company is IKEA of Sweden (IoS).

According to the study, main aspects to adapt a tool to a company's needs and conditions are 1) a clear purpose defining what the tool delivers to the company, 2) the integration of the tool in the company structure, 3) the accuracy of the results which depend on available input data and the expertise of the assessment group and 4) the simplicity of result delivery to the target group. The main limitation of the tool is the time needed for collection of data and assessment of materials. Main benefits of the tool are employees with better material expertise, the delivery of a framework to structure information and the input of the assessment results to the management group at the case company.

The study gives recommendations 1) to the case company, 2) to companies interested in developing a similar tool and 3) for further research.

The tool is considered to be a proactive approach for companies interested in a holistic approach to assess materials from an environmental and health perspective.

Executive Summary

The why and the research question

Decisions made during product development, e.g. on alternative materials, have a high influence on the overall environmental impact of a product. This thesis focuses on the development of company specific tools for material selection in product development. The main research question of this thesis is: Designing a material selection tool for the product development process of an organisation: How to adapt the tool to a company's conditions and needs?

The method

The study was carried out during June to October 2005 in collaboration with IKEA of Sweden (IoS) which stands for the product development of the home furnishing retail chain IKEA. The research included: 1) a research on similar tools at companies and other organizations, 2) a needs assessment at IoS based on interviews with employees and review of internal documentation, 3) the development of the material selection tool, 4) the application of the tool on metal finishing and 5) the analysis of the study and the testing results giving 6) general conclusions and recommendations.

The proposed material selection tool

The aim of the tool is to rank materials from an environmental and health perspective and to give thus clear recommendations to management and product development teams on material characteristics. The tool consists of two parts: 1) the material rating method which includes the environmental assessment using different criteria described below and 2) the user "interface" where different user groups can reach the assessment results which are summarized in an environmental class. Each class is divided into four categories, indicated in different colours. Green indicates the best choice from an environmental and health perspective and red the worst. A sheet with educational background information is added.

Input data to the tool comes from internal data (e.g. from material experts, Trading and from the LCA database Idemat) and external data (e.g. collected at branch organisations and research institutes related to the specific material).

The material selection tool includes a specific but clear and simple weighting process which makes it possible for the case company to choose focus areas. The eight criteria are based on IKEA's internal strategies and include: 1) Fraction of renewable material & well-managed renewables, 2) fraction of recycled material, 3) total material consumption, 4) probable end of life of material, 5) low emissions/ hazardous waste, 6) energy consumption, 7) no prohibited/ restricted substances.

Major results

According to the study, important factors to adapt a tool to a company's needs and conditions are:

1) The aim pursued with the tool: it must be very clear what the company wants to achieve with the tool in order to convince employees of its importance.

2) The integration of the tool into company structures: In the case of the case company this results in the usage of the tool at two different stages in product development. First, the

results of the tool are included in decisions of the management group and second, the results of the tool are used by the product development team.

3) The accuracy of the results has to be adapted to a company's expectations, to the available input data at the company and to the competence of the group of employees responsible for the material assessment.

4) The tool has to be adapted to the target group in that it must be simple to use. The target group must be convinced that the tool is useful to them. Besides this, the expert group doing the material assessment should be competent or the members should be given time and resources to improve their expertise. The discussion process during the material assessment is seen as a crucial factor to receive good results.

Major limitations and advantages of the tool

The major limitation of the tool is the time needed for the collection of input data and the material assessment. The advantages of the tool include 1) a common and detailed understanding among the assessment group members on environmental and health aspects of materials which can be fed into the product development process, 2) a framework for structuring internal and external information on environmental and health aspects of materials resulting in a holistic assessment of materials, 3) an input to management at the case company which can influence future decisions from an environmental and health perspective.

Major implications for other organizations

Other companies studied for this thesis mainly referred to hazardous substances for environmental assessment of materials. The suggested tool encompasses a holistic approach to environmental and health assessment. This is interesting to any company which wants to go beyond the normal. An interested company can however not take this tool and directly apply it. The tool is "tailor made" for the case company and the author suggests interested companies to follow the step by step list in the recommendations chapter.

Recommendations for the case company

General recommendations to the case company include the education of employees in both the LCA database Idemat and the inclusion of environmental and health aspects into material education of the product development team. Specific recommendations for the further development of the material selection tool relate to 1) the testing of the tool and its outcomes, 2) the administration of the tool, 3) the accuracy of the input data in relation to the reliability of the results and 4) improvement of communication between departments for access to information.

Recommendation to companies interested in developing a similar tool

The study includes recommendations for 1) the evaluation of conditions and needs at the company, 2) the evaluation of the present state at the company, 3) if the tool should be developed internally or externally and 4) the development of criteria.

Recommendations for further research

During the course of this study, no company was found using a similar material selection tool at such an early stage of product development. More research including more companies should be done on this issue.

The inclusion of social/ ethical and health aspects in product development are almost unexplored. This is a wide field for further research.

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1 Introduction

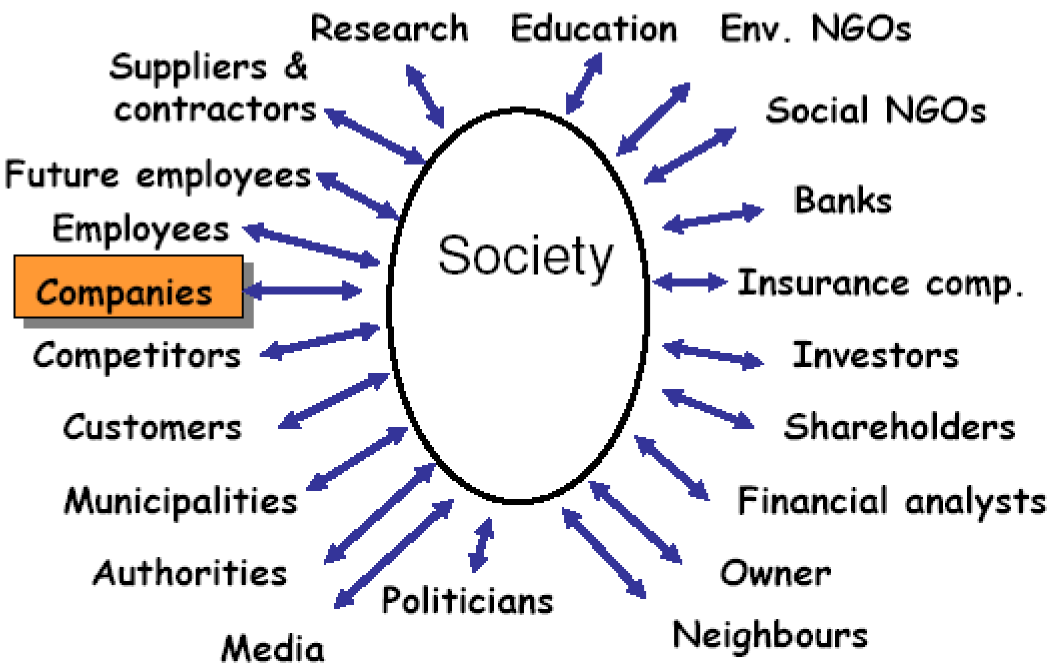
1.1 Background

"There are plenty of good designers who have no difficulty at all in producing the right answers, if only they are asked the right questions"

Bruce Archer[1]

Companies' role in society are about to change. While companies had an egocentric view seeing themselves as the centre of all actions, perspectives start changing to a picture which equals more the one shown in figure 1-1.

Figure 1-1: The company in society



Source: adapted from PP presentation Magnus Enell, ITT Flygt, Lund, February 2005

Companies are influenced by and influence society. More and more, companies have to take over responsibilities for actions taken due to e.g. legislation, competitors or pressure from customers, NGOs or government authorities. Efforts are triggered and supported by several Directives (e.g. RoHS[2] and REACH[3]) and policies such as Integrated Product Policy (IPP[4]) on EU level.

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[1] In Schmidt-Bleek & Tischner, 1995

[2] Directive 2002/95/EG (RoHS) prohibits the use of mercury, cadmium, lead, hexavalent chrome and flame retardants PBB and PBDE in new electrical and electronical products which are put on the market after 1 July 2006. The RoHS Directive is directly related to Directive 2002/96/EG on waste from electrical or electronic waste (WEEE), through WEEE Directive appendix 1A, see www.kemi.se for more information.

[3] The goal with the new European Directive REACH (Registration, Evaluation and Authorisation of Chemicals) is to facilitate the free movement of chemical substances in the EU and to protect health and environment. REACH demands that necessary knowledge on characteristics of chemicals and the risks related to the handling of those chemicals are assessed and that this knowledge is communicated to those handling chemicals or products in which those chemicals are included. REACH mainly demands that suppliers of chemical substances have to take a higher responsibility (www.kemi.se).

Issues that have come up during the last decade are related to companies' responsibilities 1) in social and ethical questions with child labour as the most prominent example, 2) environmental issues such as waste and emissions and 3) customer health issues related to the characteristics of a specific product. When looking at a specific product, companies should adopt a life cycle perspective which takes into account all stages within a product's life from the raw material extraction to product development, manufacturing, assembly, distribution, use and disposal as waste.

This thesis focuses on one essential part of the life cycle of a product, product development. Tischner & Charter (2001) state that around 80% of economic costs and environmental/social impacts are determined in the product planning and development period, in the very beginning of a project. For example, if a hazardous chemical is used, this will probably have an impact in the production, use and end-of-life period of a product. It is therefore obvious that product development and design play a key role within sustainable production. For example, Hawken (1999) states that around 90% of materials currently extracted from the earth through mining, logging and agriculture are wasted during extraction, transport, manufacture or end use.

The question is how to implement environmental, health and social/ ethical issues into product development. Much research has involved around these issues, bringing forward e.g. eco-efficiency, eco-design or Design for Environment (see e.g. McDonough & Braungart, 2002; Brezet & Van Hemel, 1997). Companies have started developing and implementing tools. However, there is confusion around what the aim of sustainable product design is and how to implement it in a usable and effective way. For example, researchers developed tools which were too complicated for companies to use while companies developed tools that were not strong enough to deliver a sufficient result.

Charter & Tischner (2001) state that product designers and developers are key actors when it comes to product development. However, designers generally have little knowledge on environmental issues as these aspects are not dealt with during their training. Therefore, environmental education has to happen "on the job". It has to be short and effective in order to be appreciated and used properly due to lack of time during product development.

Material selection is one crucial issue in product development. Therefore this thesis is narrowed down to the problem of material selection from an environmental perspective within product development. The problem is exemplified by one case company, IKEA of Sweden and a material selection tool is suggested for this company.

1.2 Objectives

As it is indicated in the background section, environmental issues should be integrated into product development in a very early stage. Especially the material selection during product development is of crucial importance for the future impacts of a product. This study is therefore dedicated to this issue.

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[4] IPP tries to minimize environmental impacts of products by looking at all phases of a products' life-cycle and taking action where it is most effective. IPP attempts to stimulate each part of these individual phases to improve their environmental performance. With so many different products and actors there can not be one simple policy measure for everything. Instead there is a whole variety of tools - both voluntary and mandatory - that can be used to achieve this objective. These include measures such as economic instruments, substance bans, voluntary agreements, environmental labelling and product design guidelines, see Swedish Environmental Protection Agency (2002).

The research question of this study is formulated as follows:

When designing a tool for the environmental assessment of materials used during the product development process of an organisation: How to adapt the tool to a company's conditions and needs?

The research question is tackled by going through several steps. First, the author looks at how other companies and organizations work with environmental aspects and performs a needs assessment at the case company. Second, the author develops a proposal for a material selection tool, based on the case company's specific conditions and needs and applies the tool on metal finishing processes. Finally, the author discusses how the study can be generalized.

1.3 Scope and Limitations

This study included developing a needs assessment, method, criteria and structure of a decision support tool for product developers and technicians. The results of this thesis are mainly based on a study undertaken at IKEA of Sweden (IoS) during June to October 2005. The tool has been applied by the author during the thesis period on metal finishing and will be further tested at the company after the thesis has been handed in.

The study includes literature studies and former studies conducted by the author with different companies. However major parts of the study are limited to insight knowledge of one large company working within the furniture business.

The criteria in the material selection tool are based on the environmental strategies of the case company. One important limitation is the fact that this thesis does not question these statements made in IKEA's strategies. This thesis deals with how to translate existing strategies of a company into a form which the product development team can work with. The reason for choosing this approach is that it seems as if often a company 1) has decided upon a strategy but lacks appropriate tools to carry out the tasks described in the strategy, 2) develops a tool but has no company-wide policy for enforcement.

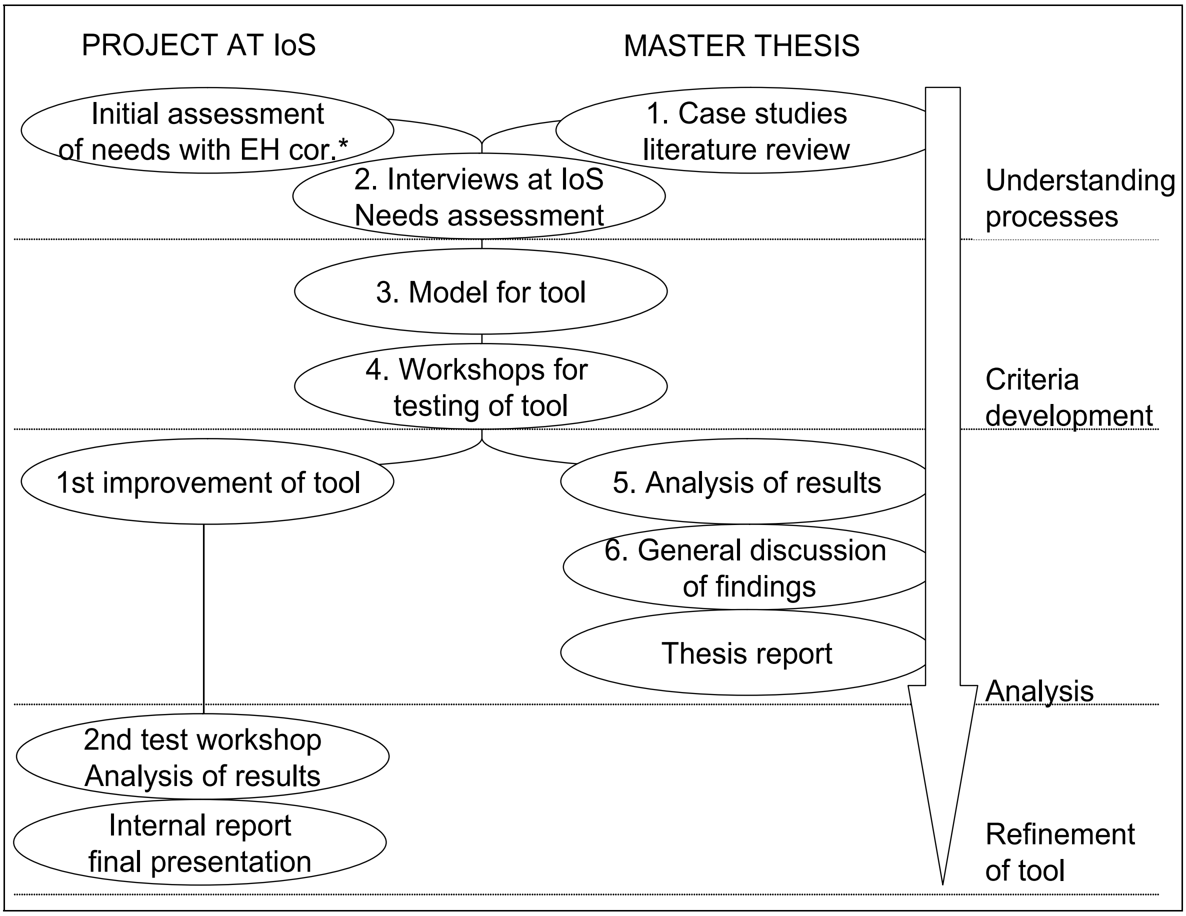
In this thesis, the keyword "environment" is defined according to ISO 14 001 (CEN, 1996): "Surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation. Surroundings in this context extend from within an organization to the global system."

The term sustainable product design which was referred to in the introduction includes an ethical and social perspective. However, this thesis does not take these issues into consideration. There are several reasons for this. The literature study, previous studies of the author and the needs assessment at the case company revealed that companies mainly work with social/ethical issues when directly working with suppliers. None of the companies had started to include these issues into product development. Research on how to implement these issues within product development has started as well only recently (Tischner & Charter, 2001). This means that there is not much written information and no other companies to study. If interested in this issue, one should have dedicated the whole thesis to the inclusion of social/ethical issues into product development. Thus, this is an important research topic for the future and it is clear that these issues are very important when working with supply chain management.

1.4 Methodology

As mentioned earlier, the case company in this thesis is IKEA of Sweden (IoS). The starting point of the study was IoS' interest in improving strategies of material selection during product development. This master thesis is therefore a joint initiative of IoS and the International Institute of Industrial Environmental Economics. Parallel to writing this thesis, the author developed and tested a proposal for a material selection tool adapted to the internal conditions of the case company. Figure 1.2 explains the research method and puts it into relation with the project at IoS:

Figure 1-2: Research methodology related to project at IoS



* Environmental & Health Coordinators in each Business Area

The thesis is divided into following parts:

1. Other companies and organizations are identified through literature study (key word search for material guide, material selection tool, EcoDesign tools), former research of the author (see Jakubaschk, 2005), and through IKEA's network. A tool is defined relevant for the study if it is currently used during product development at a company or if it is used to assess similar products as are purchased and sold at the case company. The main interest was to get an overview which other tools are used by companies and organizations at present.

2. The present approach to include environmental aspects in material selection at IoS is explored through an initial discussion with the EH coordinators at IoS, checking internal environmental steering documents (such as vision, environmental policy and strategies), interviews with product developers and technicians at different Business Areas (BAs) of IoS as well as with managers at the range and trading departments and material experts at IoS (see list of interviewees). Interviews were conducted with representatives of seven out of twelve BAs. The interviews aimed at gaining an understanding of the present situation at the case company such as the inclusion of environmental aspects in the product development process and the problems faced when doing so, the competence of the target group and the opinion of the target group on the need of a material selection tool. This information is analysed and leads to a needs assessment at IoS. The analysis of interviews was done according to a structure for analysing qualitative data in Rubin & Rubin (1995): 1) the structuring or grouping of answers according to interview questions or important concepts (themes that are taken up by different interview partners), 2) the filing of interesting quotes, 3) the analysis of data within and across these categories and 4) the scaling up of the answers to a broader understanding of the topic. This analysis and observations of the author lead to a needs assessment at IoS and to the identification of important factors to take into account when developing the material selection tool.

3. The next step is the development of a model for a material selection tool customized for the case company. The model is built on the needs assessment and important factors identified in step 2. The model is thus developed on empirical research and not through the comparison with already existing tools at companies or in research. The criteria are based on IKEA's and IoS' strategies identified in step 1. A proposal for ranking and weighting was developed through comparison with existing material guides developed by other organisations.

4. The material selection tool is then applied on and adapted to metal finishing processes with the aim to test the strengths and weaknesses of the tool.

5. The outcome of the case study is analysed and put into a broader context. This leads to recommendations for the case company and to companies which are interested in developing a tool with a similar purpose.

This process is a learning experience for both the researcher and the participating organisation. As seen in the figure, the project at IKEA continues after the handing in of the thesis. The proposal for the material selection tool is presented and discussed at a workshop open to all Business Areas in order to ensure the knowledge staying with the company.

1.5 Target Audience

The target group of this thesis are

- The employees at IoS Business Areas working with product development (e.g. range leaders & members of the management group at each BA, EH-coordinators, product designers, product developers, technicians)

- Students and professionals in this field

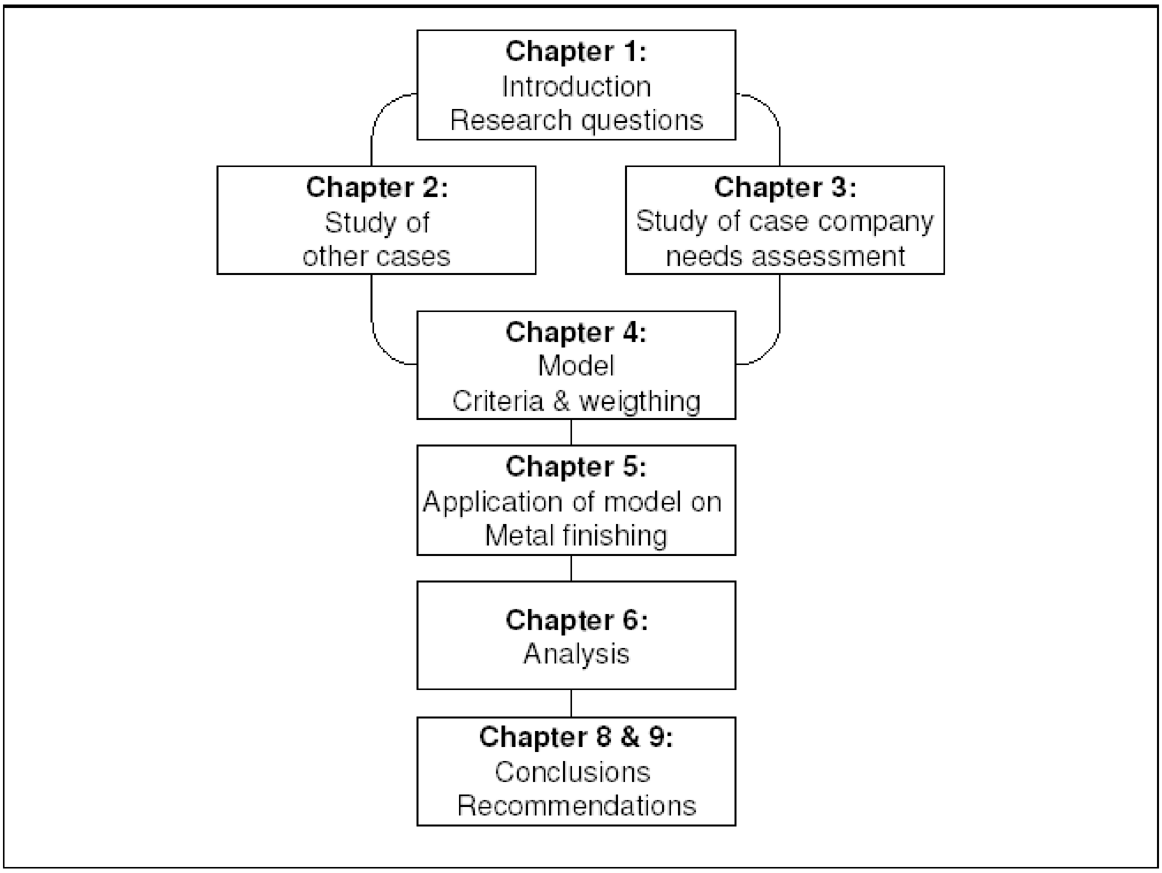
- Any other organisation interested in developing a similar tool.

1.6 Outline

Figure 1.3 explains how the methodology is translated to each chapter. Chapter 1 includes a background description of the study, research question, scope and limitations.

Chapter 2 looks at tools used by other companies and organisations. Chapter 3 summarises the information gathered at IoS and is the base for the adaptation of the tool to the company's conditions and needs. Chapter 2 and 3 are the backbones of the model for a material selection tool which is described in chapter 4. Chapter 5 analyzes the tool's usability to assess metal finishing processes. Chapter 6 puts the study into a larger perspective and evaluates how the results of the study could be used in other organisations. Finally, chapter 7 & 8 give conclusions and recommendations for both the organisation under study and other organisations interested in a similar guide.

Figure 1-3: Outline of thesis



2 Assessment of Materials – theory and practice

It is important for companies today to assess their impact on society and environment as mentioned in the introduction. Products - and thus materials in the product - which a company purchases or manufactures strongly influences a company's impact. This chapter gives an insight what kind of tools are currently used by companies and organisations for material selection. The aim of this section is to give an input to the development of the model for a material selection tool. Section 2.1 describes the assessment method Life Cycle Assessment (LCA). Section 2.2 summarises how companies presently deal with material selection during product development. Section 2.3 focuses on material assessment tools mainly used for building material and furniture as those are similar to the materials used at the case company. Section 2.4 presents PRIO, a tool developed by the Swedish Chemical Inspectorate which supports the environmental and health assessment of materials with focus on chemical substances. As the case company – similar to other companies – has a strong focus on hazardous chemical substances, PRIO might be a good add-on to the material selection tool. There are several tools developed in research. Two examples are the Method for Sustainable Product Development currently developed by the Natural Step[5] (Byggeth, 2001) and the Ecodesign strategy wheel (Brezet & Van Hemel, 1997). However, these tools are not further described here as the focus of this study is on tools presently used by companies and organizations.

2.1 LCA data, a base to assess harm to environment

Life Cycle Assessment (LCA) supports the evaluation of environmental impacts of a product/ material from cradle to grave based on a functional unit, e.g. one kg of material. In many cases, LCA data is the base for environmental assessments or for databases and tools. Therefore it is described here in more detail. For example, the case company uses a LCA database as a support tool during product development today.

According to Lindfors (1995), LCA is defined as *"a process to evaluate the environmental burdens associated with a product system, or activity by identifying and quantitatively or qualitatively describing the energy and materials used, and wastes released to the environment, and to asses the impacts of those energy and material uses and releases to the environment. The assessment includes the entire life cycle of the product or activity […]. LCA addresses environmental impacts of the system under study in the areas of ecological systems, human health and resource depletion. It does not address economic or social effects."*

An LCA consists besides others of an inventory analysis (detailed description of the product system, data collection and calculations, sensitivity and uncertainty assessment), an impact assessment including classification (where material and energy inputs are classified in impact categories) and characterization (where contributions to each impact category are assessed by quantitative or qualitative methods) and finally a valuation where the impacts of each impact category are related to each other in order to assess the total impact. Sometimes the impact assessment stage is left out; this method is called Life-Cycle Inventory, which means that the Inventory data is directly used for evaluation.

LCA methodology is not restricted to quantitative assessment. Partly because quantitative data are not likely to be available for all relevant parts (the strict LCA definition states that LCA shall cover complete life cycles) and partly because the weighting and valuation process in the end of the LCA is subjective and can be based on expert discussions or political opinion

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[5] For background on the Natural Step please see Robèrt (1994).

(Lindfors, 1995). Another important aspect to consider when using LCA data is that the assessment of the environmental impacts connected to the production, use, and disposal of a product need to take into consideration that the related interventions will be spread over different locations with different environmental characteristics. At present, LCA is limited as it cannot include local information in the analysis[6].

LCA is difficult and time-consuming to use (Hemel & Brezet, 1997) and is thus not much used by companies (Ny et al., 2005). It should as well be added that it is not possible to compare LCA indicators of different databases with each other or with other information, see e.g. EcoIndicator 95 and EcoIndicator 99 (Goedkoop et al., 2002). This fact is quite important in case a company works with materials which are not included in the LCA database.

Hemel & Brezet (1997) and Tischner & Charter (2001) point out that it is necessary for companies to follow a Life Cycle Approach (not to be confused with LCA) during product development. This means that developers and designers have to consider the impact that a potential design solution might have at all stages of the product's life cycle. However, the question is how to translate this demand in tools which the target group can handle.

2.2 Types of material assessment tools currently used at companies

The aim of this section is to present what tools companies mainly use at present. The type of tool is described, an example is provided and it is described how the tool is integrated into the respective company's structure (if information is available). Further, the target group of the tool is mentioned.

2.2.1 Negative lists

A negative list is a list of chemical substances or materials which are not allowed to be used at a company. SonyEricsson[7] is an example of a company using negative lists. The base for environmental work at SonyEricsson is the "Banned and Restricted Substances List[8]" (referred to in the following as "List") which includes all substances that the company and its suppliers are not allowed to use. The list applies for all products and work with the list is included in all stages of the product development process which means that the product development team is one main target group of the list. The result of the tool is the reduction or phase-out of hazardous substances such as nickel, lead, halogenated flame retardants and hexavalent chromium.

2.2.2 Positive lists

Positive lists are company-specific lists or databases containing chemical substances or materials which are allowed to be used at the company. The aim of a positive list is the same as for negative lists: to assure that a company's products are free from hazardous chemical

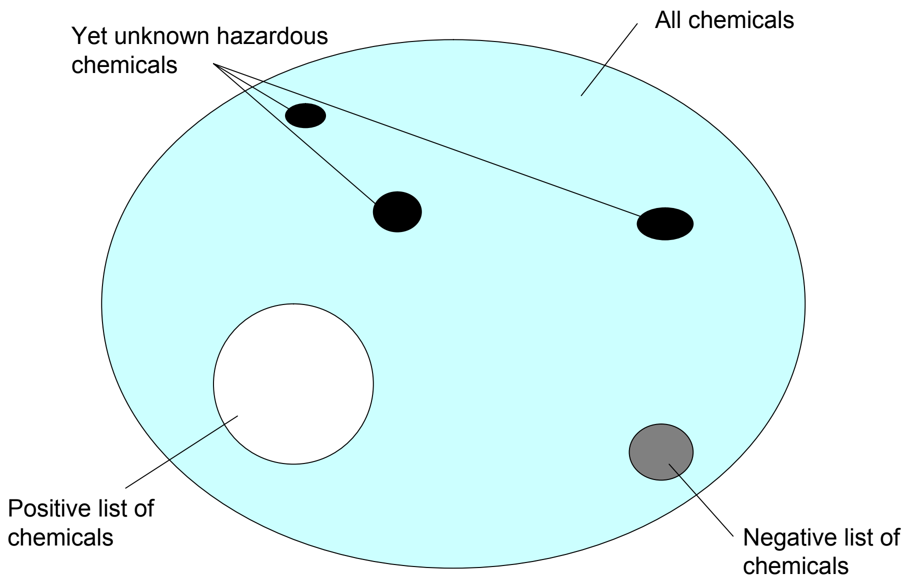
[6] SETAC, 1994, *"Integrating Impact Assessment into LCA"*, p 20, cited in Jönsson (1998).

[7] Sony Ericsson Mobile Communications was established in 2001 by the companies Sony Corporation and Ericsson. They provide mobile multimedia devices such as mobile phones and accessories, PC cards and M2M (machine to machine) solutions. The company is equally owned by the two parent companies and launched its first product in 2002. Globally, Sony Ericsson has around 5000 employees. Production of parts and components are almost to 100% outsourced

[8] Driving forces for Ericsson were international laws and conventions and pressure from competitors and customers (Jakubaschk, 2005), especially the EU Directive on the restriction of certain hazardous substances in electrical and electronic equipment (RoHS). The RoHS Directive bans the use of cadmium, mercury, lead, hexavalent chromium and two brominated flame retardants (PBDEs and PBBs) by 2006 with some exceptions; the requirements of RoHS have forced manufacturers to ask suppliers for submitting material declarations of components (van Rossem, 2001).

substances or materials. However, one could say that positive lists are a further development of the negative lists and assure a higher safety as is seen in figure 2.1. Negative lists of chemicals include those chemicals which have most severe impacts on health and environment and thus the company wants to avoid using them. However, negative lists do not take into account that many chemicals are used today for which no environmental and health assessment has been done yet. This is exemplified by the black spots in figure 2.1. Positive lists however, restrain a company to only use those chemicals substances which have been assessed carefully and thus these lists assure a higher security.

Figure 2-1: Comparison of positive and negative lists of chemical substances



An example for the use of a positive list for chemical substances is the so-called KemDatabasen at Skanska Sweden[9]. KemDatabasen is an internal database on all chemicals used in the company's projects and contains around 4000 chemicals. The database has five different grades for chemicals going from banned to "good environmental choice". The database is thus a positive list, including all substances that Skanska projects are allowed to use. Project engineers or managers on site of each project have to consult the database for any chemical used in the project – preferably before it has been purchased. If the chemical substance is not listed in the database, the environmental department assesses the chemical and the result of the assessment is added to the database. The assessment is done through comparison of the Material Safety Data Sheet (MSDS) with the restricted chemical list. The underlying criteria for KemDatabasen are lists of 1) chemicals which are banned or restricted according to legislation or internal decision or 2) harmful characteristics (e.g. carcinogenic). The e-purchasing tool is an Internet based electronic purchasing catalogue for all products purchased by Skanska Sweden and can be seen as a tool which uses the information of KemDatabasen as an input. The original aim of the e-purchasing tool is to reduce costs by

[9] Skanska Sweden which is part of Skanska AB, has around 12 000 employees. Its activities stretch from development and building to servicing the physical environment for living, working and traveling. The focus of environmental work at Skanska Sweden lays on the end products such as buildings, as these cause – according to LCAs made – the major part of environmental impacts (Jakubaschk, 2005)

standardizing the product range. However, additionally, products are ranked according to environmental aspects (currently this is restricted to chemical aspects according to KemDatabasen). For example, the A product range includes the most environmentally friendly products. The tool is used since last year and at the moment around 40% of all product purchase is done through the tool.

The company Manufactum[10] provides another example of positive lists. This company offers a wide range of products but uses exclusively "classical" materials such as glass, iron, wood, natural fibers, ceramics etc. It has so to speak a positive list of materials which are used during production.

2.2.3 Business ideas integrating material selection: niche markets

A different case arises when material selection is an important part of a company's business idea. Negative and positive lists are examples for companies which have been working in a conventional way for many years and which have during the last couple of years enforced their environmental work: environmental work is thus "imposed" on the core activities of the business. The following example should make clear that environmentally sound material selection can be handled in a more integrated way.

Hess Naturtextilien GmbH[11] is a retail company selling mainly clothing. The company's business idea is to sell environmental and social sound products. Thus when it comes to material selection, the company uses exclusively renewable, mainly organically grown, raw materials. It has strong partnerships with growers and about 90% of products are produced in Europe. During product development, Hess Natur uses a tool developed by the Wuppertal Institute in Germany called MIPS[12]. The tool helps to increase resource efficiency by at least 4 and consists of three parts: ecodesign, material flow management and product management. The company has as well produced a design manual which includes several tools for eco-product development, design and marketing. The company offers as well a special long-life collection which is based on a three-year guarantee. Like this, products are more durable and fewer resources are needed.

2.3 Material selection tools for construction and building materials

The aim of this section is to present material guides and eco-labels used for the assessment of building material and furniture in order to get an input how the structure of a material selection tool could look like, e.g. when it comes to criteria, ranking and weighting processes.

[10] The information for this section is retained from Burchhardt (2001) and www.manufactum.de. The German company was founded in 1989 and offers high quality products in a wide product category to a usually high price via mail order. Annual turnover was about 45 million € in 2001. There are no cheap, imported goods in the product range, most products are made by craftspeople and products are made to be durable. Many products in the range are no longer available anywhere else.

[11] The information for this section is retained from Paulitsch (2001) and www.hessnatur.com. The company, founded in 1976, is a mail-order business offering natural textile products. The company is Germany's largest supplier in the natural textile sector, has about 320 employees, 150 suppliers and partners worldwide and presents around 1800 articles each season.

[12] MIPS = Material Input Per Service unit: the measurement of material and energy consumption of a product or service, the material input in relation to the service provided by a product. The reference to service unit is made in order to be able to e.g. compare products with different life spans. The assumption is that any input becomes an output (waste) at some point and MIPS is a quantitative indicator for the input and the potential environmental impact thereof (Ritthof et al. (2002).

2.3.1 Material guides

Material guides are tools for environmental and health assessment of materials and the ones presented in this section are specifically developed for building materials. The criteria for material guides are oriented towards a holistic assessment, including all life cycle stages. The ranking in both examples is most often relative (e.g. going from high to medium to low emissions) but in some cases absolute threshold values are used, e.g. when it comes to the content of formaldehyde in a product. The material guides are developed by organisations or associations with a high interest in a better inclusion of environment & health aspects of materials into building projects. The guides are thus not company specific. The name "material" guide might be misleading because the guides actually rank finished products with each other based on product declarations from the producers. In the following, two examples are described.

Folksam Byggmiljöguiden 2004 (Folksam, 2004) has been developed by the Swedish insurance company Folksam. The insurance company is responsible for reconstruction after fire and water damages and purchases an enormous amount of construction material each year. The guide is thus a help to choose construction material with a good environmental and health performance. The annual assessment is based on product declarations and is done by independent experts. Criteria include the whole life cycle stage of a product from natural resources to work conditions during production and construction, use stage, waste and environmental and health aspects of chemical substances contained in the product. The material ranking extends from red (not recommended) to yellow (accepted) to green (recommended). The guide compiles information, compares materials for each material group and gives examples for recommended products.

A similar system to Folksam is MilaB (Miljöbedömning av Byggvaror)[13], a professional environmental assessment system which helps the construction and real estate sector to minimize environmental risks. As for Folksam, independent consultants assess construction material on the base of environmental declarations, ranking materials from "avoid" to "accepted" and recommended. The aims of MilaB are to set up a system for environmental assessment of construction material and make it available to members, set up criteria and influence the product development of construction material. The criteria include declaration of contents, raw materials, construction stage, use stage, demolition, waste and indoor environment[14]. The criteria are related to restricted lists of substances set up by the association, give threshold values and refer to labeling systems such as the EU flower, the Nordic Swan and a label of the Swedish Asthma and Allergy association. The criteria are given different importance during the weighting process. Even if not all criteria can be assessed, the weighting scheme allows an overall ranking.

2.3.2 Labelling systems

There are several eco-labellings defining specific criteria for product groups interesting for the case company. Examples are the EU flower[15] which developed criteria for furniture, indoor paints, mattresses and textiles, the Swedish Bra Miljöval for textiles or the European Association for ecological furniture retailers[16]. This association has created a control system

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[13] MilaB stands for Environmental assessment of construction material, see for more information at www.milab.nu.

[14] Information on criteria content and weighting process can be downloaded at www.milab.se

[15] http://europa.eu.int/comm/environment/ecolabel/index_en.htm

[16] Gesellschaft fuer Qualitätsstandards ökologischer Einrichtungshäuser mbH, http://www.oekocontrol.com

which includes differing labelling systems from different countries. Furthermore, the label includes testing of furniture of the retailers on included chemical substances. For all eco-labelling systems the assessment is very time-demanding and they are related to product declarations of ready products and even testing of the products.

2.4 PRIO, a tool developed by the Swedish Chemical Inspectorate

The main focus of environmental and health work at companies today is put on the phase-out and control of hazardous chemical substances. This is due to media and customer concerns and to emerging EU legislation such as REACH and RoHS which have been mentioned in the introduction.

The Swedish Chemical Inspectorate[17] has created a tool called PRIO (prioriteringsdatabasen) to reduce the risk of chemical substances on environment and health. PRIO is a web-based database of substances and their related characteristics. PRIO ranks chemical substances according to their characteristics into phase-out substances and risk-reduction substances. In the first group substances have environmental and health characteristics of such high concern that they should not be used. The selection of criteria is based on Swedish law and REACH. In the second group substances have characteristics which should be paid attention to. For each substance, the worst characteristic decides if it is considered a phase-out or restricted-use substance. PRIO gives information on the hazardousness of substances, not on the risk as the exposure data depends on how the substance is used. Table 2.1 shows the characteristics after which substances are assessed.

Table 2-1: Environmental and health characteristics of hazardous substances according to PRIO

Environment	Health
Phase-out substances:	**Phase-out substances:**
PBT/vPvB (persistent, bioaccumulating and toxic/very persistent and very bioaccumulating)	CMR (carcinogenic, mutagenic or toxic to reproduction
Ozone-depleting	Endocrine disruptive
Particularly hazardous metals (mercury, cadmium, lead and their compounds)	Particularly hazardous metals (mercury, cadmium, lead and their compounds)
Risk reduction substances:	**Risk reduction substances:**
Very high acute toxicity	Very high acute toxicity
High chronic toxicity	High chronic toxicity
Environmentally hazardous, long-term effects	Allergenic
Potential PBT/vPvB	Mutagenic, category 3

Source: www.kemi.se

One should keep in mind that there are about 130 000 chemical substances of which 30 - 50 000 are used on the world market. Only 3000 of those substances are classified and the hazardous characteristics related to health and environment are known. This means that no knowledge on hazardousness of substances is available in 90% of cases. The PRIO database can therefore only give examples and is by no means comprehensive.

[17] www.kemi.se, information on PRIO and its criteria can be downloaded from this website

There are a couple of databases which base their environmental and health assessment on PRIO characteristics. For example BASTA[18] and Sunda Huset[19] are web-based databases for construction material.

2.5 Summary

This section summarizes how the knowledge gained in chapter 2 can be used in the development of the material selection tool.

When it comes to LCA data, it should be noted that databases package data in LCA indicators which are not possible to compare with each other or with other data. As there is no LCA database including all materials which a company as big as the case company works with, it is not recommended to rely only on LCA databases as an input to material selection. This will be further specified in section 3.3.3 where the LCA database Idemat is presented, which the case company uses today.

Material assessment tools used at companies today focus mainly on hazardous chemicals. The tools which have been developed at companies can be divided into negative and positive lists of which positive lists constitute the safer alternative. No company is found during research which already uses a holistic material selection tool as proposed by the case company. Companies like Hess Natur follow a holistic approach. However this might not be applicable for the case under study because the whole business idea of Hess Natur is based on this approach which is not the case for the company under study. The tools used by the companies studied have been developed out of a need at the company and are well integrated today into the product development process and accepted by target group and management. This indicates that it is very important to listen to the needs of the case company in order to make the tool work well. The needs of the case company are therefore scrutinized in section 3.4.

The study of material guides and eco-labels for building materials and furniture gives input for criteria, ranking and weighting development of the material selection tool which will be indicated in chapter 4. However, the difference to a material selection tool as it should be developed for the case company is that there are no product declarations available and it is not possible to include criteria based on testing. The reason for this is that the material selection tool is used in a stage of product development when only the type of material is known but it is not known who will produce the material. The material guides can give examples for recommended products which is not possible in the case of the material selection tool. The material selection tool is on the one hand more company specific compared to the material guides. On the other hand the material selection tool is not a tool to assess a specific material of a specific producer but is a more general tool for the assessment of a specific type of material.

The PRIO database is a comprehensive tool to assess environmental and health impacts of hazardous chemicals and is used as a part of the material selection tool as explained in section 4.3.7.

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[18] www.basta.se

[19] www.sundahuset.se

None of the companies studied works today with a material selection tool as proposed by this thesis which makes it a new and proactive approach to rank materials from an environmental and health perspective.

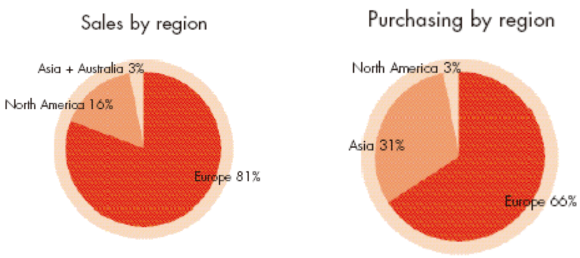
3 The Case Company: IKEA of Sweden (IoS)[20]

This chapter describes the case company, assesses the company's current conditions and needs and concludes with a needs assessment and reasoning for the introduction of a material selection tool at the case company.

3.1 Description of the IKEA Group and IoS

IKEA is a home furnishing retail chain selling low-priced products. The company was founded in 1943 by Ingvar Kamprad and IKEA are the initials of the founder and the initials of the farm (Elmtaryd) and the village (Agunnaryd) in Småland/ Sweden where he grew up. Sales totalled 12.8 billion Euro in 2004 and sales have risen more than 300 % from 1994 to 2004. The company has around 84 000 employees, mainly in Europe, North America and Asia. Most of the employees work within retail. Today, IKEA has about 1 500 suppliers with about 2/3 in Europe and 1/3 in Asia, mainly China. IKEA has a high interest in engaging in long-term relationships with suppliers and in decreasing the amount of suppliers to work with, e.g. IKEA had close to 2 500 suppliers in the mid-90's although its business was about half as big as today (Andersen, M., 2005). About 365 million customers visited an IKEA department store in 2003. The figures below describe the regions where most sales and purchasing are done and which are the major sales and purchasing countries.

Figure 3-1: Sales and Purchasing of IKEA by region



Top 5 sales countries	
Germany	20%
United Kingdom	12%
USA	11%
France	9%
Sweden	8%

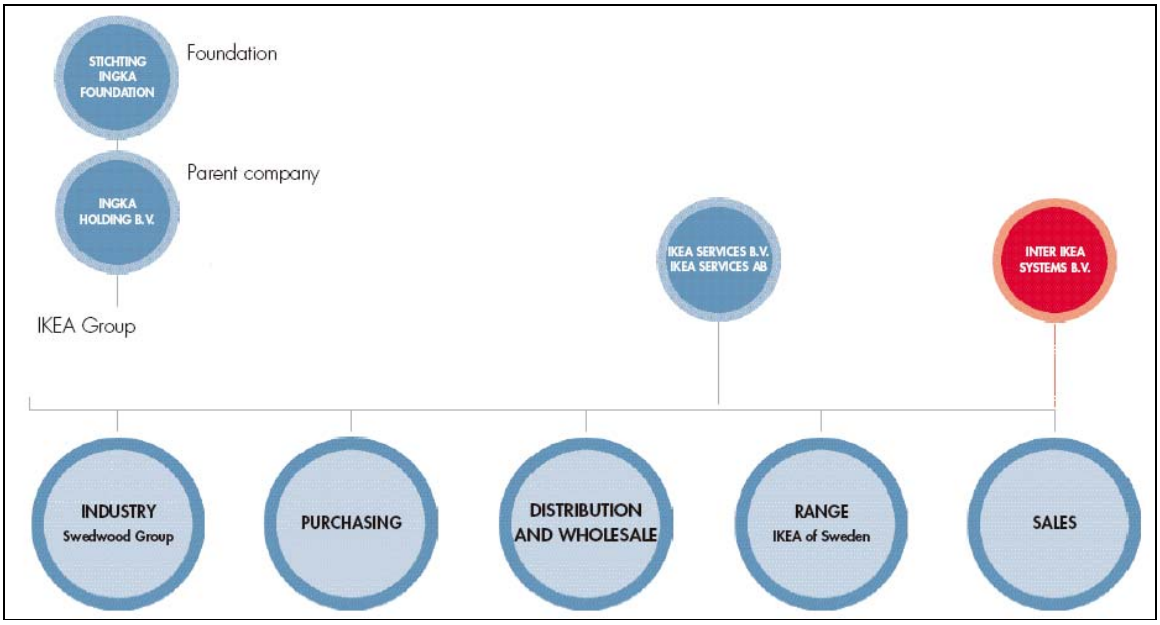
Top 5 purchase countries	
China	19%
Poland	12%
Sweden	8%
Italy	7%
Germany	6%

Source: IKEA Facts and Figures, IKEA 2003-2004

The IKEA Group is owned by a foundation, Stiching INGKA Foundation, situated in the Netherlands. The foundation owns as well INGKA Holding B.V. which is the parent company for the IKEA Group. Figure 3.3 shows the IKEA Group and the position of the case company: IKEA of Sweden (IoS).

[20] If not stated differently, information for this chapter comes from the IKEA website www.ikea-group.ikea.com and the brochure IKEA facts & figures 2003-2004.

Figure 3-2: The IKEA Group and the case company IKEA of Sweden



Source: IKEA Facts and Figures, IKEA 2003-2004

The IKEA Group is divided into several individual companies. Industry – or the Swedwood Group – produces wood-based furniture and wooden components in nine countries in Europe. Purchasing – or Trading – monitors the production of around 1500 suppliers through over 40 trading offices in the world. Distribution works with the transport of the products from supplier to customer while sales coordinates the retail in the IKEA stores. IKEA Services is a group of staff units which support the other companies within the IKEA Group. An example is the unit responsible for Social & Environmental Affairs. Inter IKEA Systems is the owner of the IKEA concept and trademark and they have franchise agreements with all IKEA stores.

IKEA of Sweden (IoS) develops the range of IKEA products which consists of around 10 000 products. This company is the case company for this study. IoS is responsible for the development of the IKEA product range which is sold world wide. IoS is divided into several Business Areas according to different product areas such as textiles or lighting.

3.2 Social and environmental work at the IKEA Group[21]

This section gives an overview of the social and environmental work which is currently done at the IKEA Group. Figure 3.4 summarizes the core values of the company.

IKEA states that it has an attitude of minimizing resource inputs and thinking economically. By today, a Code of Conduct and several company policies are developed and started to be put into action. In 2003, IKEA presented its first Social and Environmental Responsibility Report, followed by a second one in 2004. The aim is to publish these reports annually.

[21] all reports stated in this chapter can be downloaded at www.ikea-group.ikea.com

Figure 3-3: IKEA's core values

The vision

"The IKEA vision is to create a better everyday life for the many people"

The Business Idea

"Our business idea is to offer a wide range of well-designed, functional home furnishing products at prices so low that as many people as possible will be able to afford them"

This shall be achieved through:

- "A rational product range development and by adapting product design to production conditions.
- a rational distribution idea in combination with a caring meeting with the many people,
- a strict cost-consciousness in all areas."

Customer and Supplier in Focus

"We have decided once and for all to side with the many. What is good for our customers is also, in the long run, good for us. This is an objective that carries obligations.

We want to offer our customers low prices for well-designed and functional home furnishing products of good quality, manufactured under acceptable working conditions by suppliers that care for the environment. IKEA is a production oriented retailing company. We strive to build long-term relationships with suppliers that share our commitment to promote good practices, and who want to grow and develop together with IKEA."

Source: IKEA Sustainability Report 2003

IKEA has outsourced all its production which is why the company's social and environmental work with its suppliers is very important. In 2000, IKEA introduced "The IKEA Way of Purchasing Home Furniture" (IWAY)[22] which sets standards for environment, social and working conditions and purchase of wood in a four-step stair case model. It is based on relevant international conventions and all suppliers have to be committed to IWAY and to improve continually. The minimum requirements to be an IKEA supplier are stated in the IWAY standard. By August 2004, around 50% of European and American suppliers and 14% of Asian suppliers were IWAY approved (equals step 2 of the IKEA staircase model) (IKEA Sustainability Report, 2004). Section 3.4.2 goes more in depth and relates IWAY responsibilities to material selection. IoS has developed a new S&E strategy on which the criteria of the material selection tool are based.

Recently, IKEA has started with its work on Key Performance Indicators which allow the measurement of changes in several core areas such as IWAY compliance, forestry, transport and social & environmental performance of IKEA stores (IKEA Sustainability Report, 2004).

Besides this, IKEA is working with a number of organisations and NGOs concerning social and environmental issues. For example, the Business Social Responsibility (BSR), Greenpeace, Save the Children, WWF and UNICEF. To ensure a continuous work, IKEA has established several councils at higher firm levels such as the Social and Environmental Co-ordination Group (SECO) and the IWAY Council. SECO is responsible for work within this area and

[22] IWAY consists of three documents: The IKEA Way on Purchasing Home Furnishing Products (IWAY), The IKEA Way on Preventing Child Labor, The IWAY Standard (specification of the demands in the code of conduct)

includes the group manager for the support unit "Social & Environmental Affairs" and the environmental managers from each of the five operational areas within the IKEA Group. The IWAY Council is a forum for IWAY issues and consists of a number of senior IKEA co-workers and is headed by the IKEA Group president.

3.3 Present state of environmental aspects in material selection at IoS

This section analyses the interviews conducted at IoS during June and July 2005. The aim of the section is to gain an understanding of working procedures with focus on material selection and the attitudes of the target group. This information is essential for the development of the factors that have to be considered when developing the model for the material selection tool.

For citations and statements, employees are coded with letters, e.g. Source A. The list of employees interviewed is found in Appendix 1.

3.3.1 The Product Development process at IoS with focus on material selection

Each BA has a slightly different development process, e.g. samples and prototypes are developed at different stages, suppliers get involved at different stages and development processes take different amounts of time. However, the steps stated in table 3.1 are included in each product development process. It should be kept in mind that the main factors influencing material selection today are price, function (durability), aesthetics and quality as well as production suitability and supplier commitments. Therefore, this thesis deals only with one factor for material selection and the results and recommendations of this study must be evaluated in relation to these factors.

The main steps of each process are similar to the one drafted above. The main decision makers are the same at each BA: range leader, product developer, product technician and purchase specialist make material choices. There is no clear difference between BAs which develop furniture and those developing smaller products. The sampling and modelling process during the product development stage is different, though this is not of great importance when it comes to material choice.

The table makes clear that IoS relies strongly on the specifications issued by the management group. In this way, substances which are not wished to be found in IKEA products can be filtered away. However, environmental issues are not covered by the specifications but by the e-wheel method (see section 3.3.3).

Table 3-1: A generalised product development process

Stage in product development	**Explanation**	**Decision maker**	**Material choice?**
IoS Management	IoS management decides on restricted/prohibited substances in materials and products based on input of IoS's chemical and material experts resulting in specifications which are valid for IoS and thus for Trading	IoS management	Yes
Range coordination at IoS level	Decision on strategy for next years, influenced by trends, competitors, technical development and IKEA's range matrix[23]	Range leaders at IoS	Yes
Range strategy at BA	Same as above	PD[24], range leader	Yes
Design brief	PD briefs internal or external designer on function, price, look Designer delivers first sketches	PD, designer	Yes
Product development starts	Product development team[25] discusses how to translate the idea to a product 1) PT[26] works with translating design sketches to CAD drawings, is responsible for technical description and refinement of material choice, e.g. special quality, coatings 2) Purchase specialist starts looking for prices and quality of materials 3) possible suppliers or IKEA's model workshop make samples	PD, PT, purchase manager,	Yes, refine-ments
Wash council	At some early point during product development: to ensure that management group supports the product: product developer presents to management group	Management group	No
Product development continues	E-wheel and risk analysis quotation from suppliers packaging, labelling	PD team	At the most refinements
Product Council	Final approval of management group before product goes into production, in most BAs all choices have been made, production stop only e.g. in case of too high price	Management group	No
Project is handed over to Trading			

Source: Interviews conducted with BA employees in July 2005

[23] The IKEA matrix is a simple way for range leaders and product developers to find out gaps in their range both when it comes to styles and price levels.

[24] PD = product developer

[25] The product development team consists of a product developer, product technician, product support, purchase manager, packaging technician and communication manager.

[26] PT = product technician

3.3.2 The responsibilities of IKEA Trading: Limitations of the tool

This section has the aim to clarify the connection between and the differing responsibilities of IoS and IKEA Trading in order to make clear what issues should be taken up in a material selection tool at IoS.

When product development is accomplished, Trading takes over responsibility. Trading executes IoS' requirements stated in the technical description of a product. The technical description does not indicate country or supplier where the product should be produced. This is the task of Trading divided into different geographic areas. Trading has offices in all relevant purchasing countries which are in direct contact with the suppliers. The material selection done by IoS is usually not changed by Trading. Trading works on the demand of IoS which means that, the stricter the requirements, the stronger emphasis Trading can put when working with suppliers. In some cases, Trading has to make changes to the technical specifications, e.g. if additional testing on hazardous substances is needed in specific geographic areas or if conditions in the manufacturing country require additional treatment methods of the material (Source G). While Trading has to make sure that IoS requirements are followed by the suppliers, IoS has to ensure that the trading offices always are informed about new specifications and updates.

As mentioned in section 3.1, the core of IKEA's work with suppliers is the Code of Conduct "IWAY"[27]. IWAY requirements include:

- Environment (emissions, discharges, noise, ground contamination, chemicals, hazardous and non-hazardous waste),
- social & working conditions (fire prevention, worker safety, housing facilities, wages & working hours, child labor, forced and bonded labor, discrimination, freedom of association, harassment) and
- wood purchase (routines for procurement, purchase of wood from protected areas and plantations and purchase of high value tropical tree species).

IKEA has so far not included sub-suppliers into IWAY. Concentrating on materials, this means that only in cases where the material is produced at the supplier, IKEA can directly influence the material production process[28]. In summary this means that Trading does not cover environmental and health aspects during other life cycle stages (raw material extraction, use, end of life).

When it comes to social & working conditions, Trading has at the moment the highest responsibility and the material selection tool will not take into account these issues.

An important point is that in case IoS suggests materials with high environmental and health impacts, Trading can only try to minimize these impacts. It is therefore in the power of IoS to choose materials which are as environmentally and healthy sound as possible. This is the aim IoS should have with its interest in a material selection tool.

While IoS has the responsibility to develop an environmentally sound product, Trading has the responsibility to control suppliers for compliance with IWAY and to manufacture the

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[27] see www.ikea.com for download

[28] However, most often the suppliers buy the raw material at sub-suppliers. IWAY subscribes suppliers to communicate IWAY requirements to sub-suppliers but by today there is no control mechanism of this (Source B).

product. In practice, this means that IoS makes choices about materials in absence of knowledge on specific suppliers and data from Trading. This would imply that a material selection tool could not include specific supplier data and has thus to rely on general input data. At the same time, data on suppliers at Trading and knowledge at Trading on production processes, materials and differing conditions for materials depending on e.g. climate should be used as input data for a material selection tool.

3.3.3 Assessment of performance of present tools considering material selection

The first attempt of developing a tool at IoS which included material selection occurred in 1994. The tool was a checklist with a life cycle perspective which assessed following factors: materials, treatment, suppliers, use and end-of-life of textile products. It classified each factor into 3 different "environmental-effect-classes". The furniture component supplier Modul Service[29] developed a simple LCA tool in 1999 to assess environmental impacts of their products: Modul Miljöanalys. It is based on a method developed at Chalmers University (Sweden) and calculates an environmental number based on information on emissions from raw material production and transportation plus energy consumption during manufacturing and coating. The environmental impact is calculated for 5 environmental problems: the greenhouse effect, acidification, eutrophication, depletion of the ozone layer and ground-level ozone. The reason for choosing these impact factors was that data was available. Input data for energy consumption was received from suppliers and EU average data for energy production was used. Although the tool, in its simplicity worked well, the employees did not use the results and the tool was therefore soon abandoned. The responsible employee (Source F) states that the main reason was the fact that the tool was not anchored in the wider concept of the company.

The main backbone of IKEA's environmental work are **IKEA's internal specifications**, for example on chemical compounds and substances for which use is restricted or not permitted, so called negative lists. The specifications are based on IKEA values on health and environmental concerns and laws in selling countries. The decision to prohibit a substance is made by internal experts and verified by the IKEA top management group. For example, following substances are regulated under these specifications: Biocides, heavy metals (Cadmium, lead), PCP, PCB, Lindane, Formaldehyde, tinorganic compounds (TBT, DBT), several flame retardants, organic solvents, nonylphenol ethoxylates, PVC, CFCs & HCFCs, several arylamines.

An additional help for the EH-coordinators is **IDEMAT**[30]. However, according to employees (Source A, B, J) this tool is not yet widely used. One employee expresses that one reason is lacking education and therefore a lacking knowledge and interest on what can be achieved with the tool.

IDEMAT is a tool for material selection in the design process and was developed by Delft University of Technology. IDEMAT provides a database with technical information (mechanical, physical, thermal, electrical and optical properties) about materials, processes and components with emphasis on environmental information. It is possible to look up and compare information about materials, processes or components and to search for materials

[29] Modul started with producing all sorts of metal fittings, by today the company produces as well other components of IKEA products and works with all sorts of materials.

[30] See www.io.tudelft.nl/research/dfs/idemat for more information

that match specific criteria. The environmental effects of a material or process associated with the production of one kg of the particular material are shown in a graph. Additionally, Eco-indicator[31] and EPS-indicator[32] for that material give an impression of the environmental impact of that material. Background information is given for data sources, boundary of the analysis, input of raw materials and the emissions during the total production process (extraction and transport included). The procedure for information about processes is the same as for materials. An evaluation of the contents of the database showed however that environmental information is not available for all materials listed in the database; see Appendix 2 for a detailed list.

Since 2002, IoS works with the **e-wheel analysis method** during product development. The aim of this method is to minimise the environmental and health effects of IKEA products. The tool is based on a life cycle perspective and takes into account the raw material, manufacturing, use and end-of-life stages of a product. The method includes a checklist of questions and makes proposals for each life cycle stage with the aim to improve environmental and health aspects of the product. The basic idea of the method is that it is used iteratively through the product development process.

As the e-wheel method is important for the development of the material selection tool, a more thorough assessment of this method has been done in conclusion of the interviews made with IoS. As a general feature, it turned out that the e-wheel method comes in very late into the product development process[33]. Table 3.2 summarizes the advantages and disadvantages of the e-wheel method according to interviews done at different BAs and with environmental experts.

Table 3-2: Strengths and weaknesses of the e-wheel method

Strengths:
• e-wheel helps in educating the employees in the long run by asking questions about environmental and health issues
• e-wheel initiated the work with environmental and health issues directly during product development
• e-wheel is used in most BAs (even if it comes in late during product development)

[31] The EcoIndicators are based on a specific methodology developed by Pré Consultants (www.pre.nl). There are sets of indicators in Idemat: EcoIndicator 95 and EcoIndicator 99. The indicator methods differ in that EcoIndicator 99 includes more environmental aspects and the weighting system is different. Eco-indicators should support designers during the idea generation phase (in order to generate alternative product solutions) and during the concept development phase (in order to select best alternatives and development of concept. For an explanation of differences and more information please refer to Goedekopp (2002).

[32] EPS (Environmental Priority Strategy) indicator stands for the damage that is caused by the effects of the production of a material or by a process. This damage is expressed in financial terms. One ELU (Environmental Load Unit) corresponds approximately to one ECU

[33] One should note however that all BAs have the same IKEA environmental and health requirements to fulfill even if they accomplish it by other means.

Weaknesses:
• E-wheel is not concrete enough
• Interviewees state that they do not have enough knowledge to answer the questions listed in e-wheel
• E-wheel does not provide a common ground of assessment as there are no guidelines or ranking on how to answer the questions. This means that the method will give different results depending on who makes the assessment.
• E-wheel is supposed to be used iteratively during the whole product development process but according to interviewees, e-wheel is done quite late in the process of product development at a stage where the material choice is already done.
• E-wheel is used to minimise the risks that come up for a chosen material but it does not lead to the action of choosing alternative materials which would be better from an environmental point of view. It is thus used as documentation of the already concluded material choice.
• It is difficult to do the e-wheel method in a much earlier stage because not enough is known about the product. This is somehow a statement that bites into its own tail: IoS uses e-wheel in a stage where only documentation can take place of what has been done.

Some interviewees are convinced that the thoughts and questions raised in the e-wheel method are included in the product development process even if it is not documented by using the e-wheel method (Source C). Some BAs have rewritten the e-wheel questions in order to make them more sharp and adapted to the conditions at the department but have not come to a really satisfying result yet.

The question is thus what kind of method or tool could be employed in an early stage where it can be used to make right choices or to choose alternatives.

3.3.4 Knowledge & education of product development group

All representatives of the different BAs state directly or indirectly that they are conscious about environmental and health issues. It is obvious that IKEA's policies have "trickled down" to the employees, assuring them that they work for a company which works on improving its environmental and ethical performance. The interviewees are as well convinced that they include environmental and health aspects in product development, not only during e-wheel analysis but *"they have environment in the back of the brain which is different to other companies"* (Source C) puts it. However, one employee adds: *"We are all responsible to make our products environmentally friendly but one can discuss what is environmentally friendly"* (Source D) and expresses the feeling that she is aware of the fact that she might not know.

The range leaders and product developers interviewed do not have a deep knowledge on materials but they are aware of IKEA's S&E strategy and specifications.

Product technicians at each BA have a high level of knowledge on materials and surface coating methods. IKEA provides environmental and health educational programs. However there is a lack of knowledge among product technicians on environmental aspects of materials. It is not included in their formal training and internal training at IKEA does only put little emphasis on environmental and health aspects of material according to one of the responsible coordinators of material training (Source I).

Material experts at IoS have expertise knowledge on their specific material groups.

Environmental coordinators have most knowledge of the environmental aspects of materials. However, they feel the need for a material selection tool. It should be noted that range leaders, product designers and most technicians interviewed did not see the need for a material selection tool. At the same time, employees stated – as mentioned in table 3.2 – that they do not have the expertise to use the e-wheel method in a satisfactory way.

3.4 Needs assessment

This section summarizes the interview results and observations by the author in order to describe the reasons for the development of the tool and to assess the needs of the case company when it comes to the material selection tool.

3.4.1 Specification of needs at IoS for material selection

IoS's goal is to include environmental and health aspects in a better way into product development compared to the present. A part of this is the suggestion of a material selection tool customized to IoS's conditions and needs. The following list of wished characteristics of a material selection tool is an outcome of the initial discussion with the EH coordinators, interviews conducted with employees and observations by the author. This list is one of the basis on which the model for the material selection tool – described in chapter 4 – is developed. The list is separated into 1) needs related to the integration of the tool into the company and 2) needs related to the internal structure and the results delivered by the tool.

Needs related to the integration of the tool into the company:

- The tool should be based on IKEA's strategies and steering documents and it should be integrated into existing systems at the case company. It should be possible to use the results of the tool as an input to the e-wheel method.
- The tool should be simple to use and work with in daily life at IoS and it should be integrated already from an early stage of the product development process.
- The input data used should be company specific (reflect reality in IKEA's purchasing countries) and if possible data already available at the case company should be used
- The tool should be developed in close cooperation with the case company and updated internally at IKEA. This is to assure that detailed knowledge on strengths and weaknesses of the tool stay with the company's employees.
- The tool should be educating in a way that it includes relevant background information for each product group.
- The tool should make it possible to document the results.

Needs related to the internal structure and the results delivered by the tool:

- The tool should support decisions about alternative material choices from an environmental and health perspective and give a clear result to the product development team on which material is preferred.

- The tool should be usable to assess materials IoS wants to work with in the future and on which there is no company expertise available.

- The tool should use a life cycle approach, including extraction, production, use and end of life stages of a material.

- The tool has to provide a base for the assessment of materials which assures similar results independent on who makes the assessment.

The model developed in the next chapter will take into account these needs. If the tool cannot fulfill the needs it will be discussed why.

3.4.2 Reasoning for a material selection tool

As presented previously, IoS already has an array of tools, methods and specifications to work with and to follow. This paragraph gives the reasoning what value a material selection tool could add.

Currently, environmental and health issues are included at IoS in two ways: 1) the specifications which are set by the management group in collaboration with different experts at IoS and 2) the e-wheel method which supports the product development team in minimising environmental and health effects of IKEA products. Production at suppliers is controlled by the trading unit. Thus, IKEA's efforts focus on hazardous substances during production/ use and minimising environmental and health aspects during the construction of a product. However, a lot of information for environmental and health aspects is spread out among company departments and employees. Trading controls environmental and social issues at the suppliers, e.g. by environmental audits (Source G). In case IoS suggests materials with high environmental and health impacts, Trading can only try to minimize these impacts. It is therefore in the power of IoS to choose materials which are as environmentally and healthy sound as possible.

In the course of the project, it became clear that the criteria of the tool could serve as an input to councils at management level which so far set standards for material quality at IoS. In the future these councils could as well set standards for environment and health aspects.

An additional point is that the EH coordinators whose task it is to support the product development with environmental and health expertise do currently not have a common expertise on materials used at IoS. This means, that they have to rely on the scattered expertise which they can gather at different parts of the company. A material guide and an inherent method of material assessment can help the EH coordinators to gain common expertise.

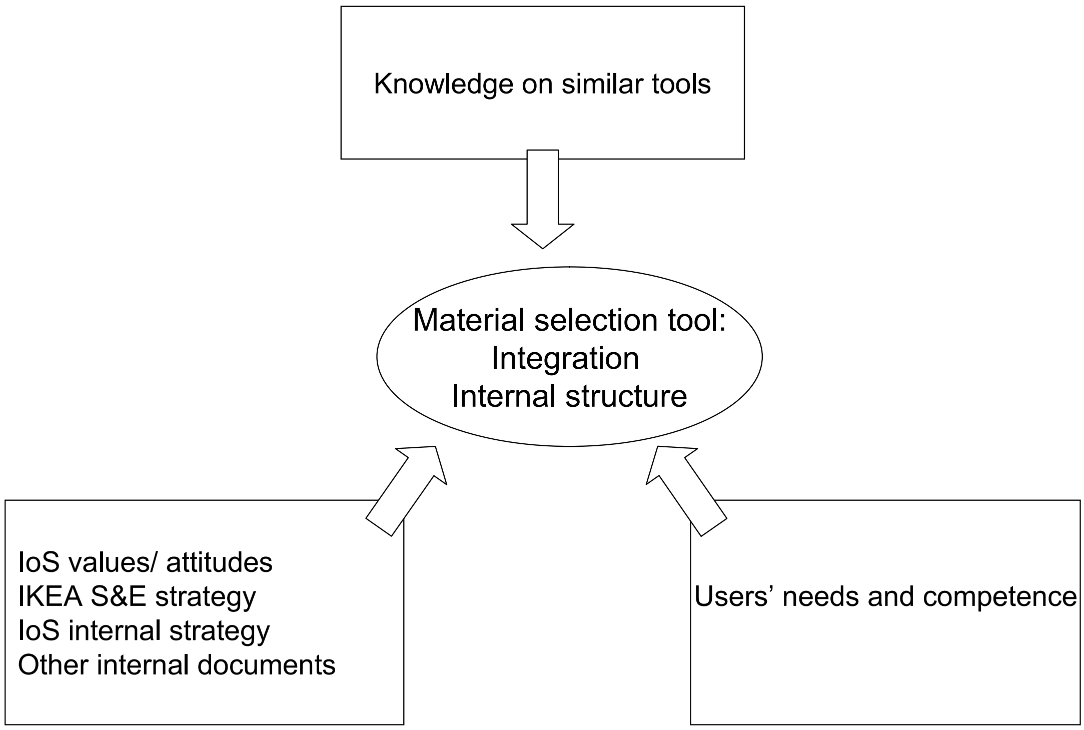
Thus, there is a gap as there is currently no tool or method which helps IoS to assess the input material of their products giving an overview of the environmental and health issues which are most important for IKEA. A material selection tool could bridge this gap. One could say that it is a method which helps IoS to sort the knowledge available at different places at IKEA and to make an assessment based on this knowledge.

4 A model for a material selection tool

This chapter presents the model for the material selection tool which is based on the previous chapters. Figure 4.1 explains how the model for the material selection tool has been developed: Chapter 2 provides knowledge on similar tools used by companies and organisations while chapter 3 provides input on IKEA's internal strategies and attitudes and the expressed needs of the case company.

The next sections describe the tool in more detail, starting with how the tool is integrated into the case company (section 4.1), followed by how the internal structure of the tool looks like (sections 4.2 and 4.3).

Figure 4-1: Model for developing a material selection tool



4.1 Integration into the case company

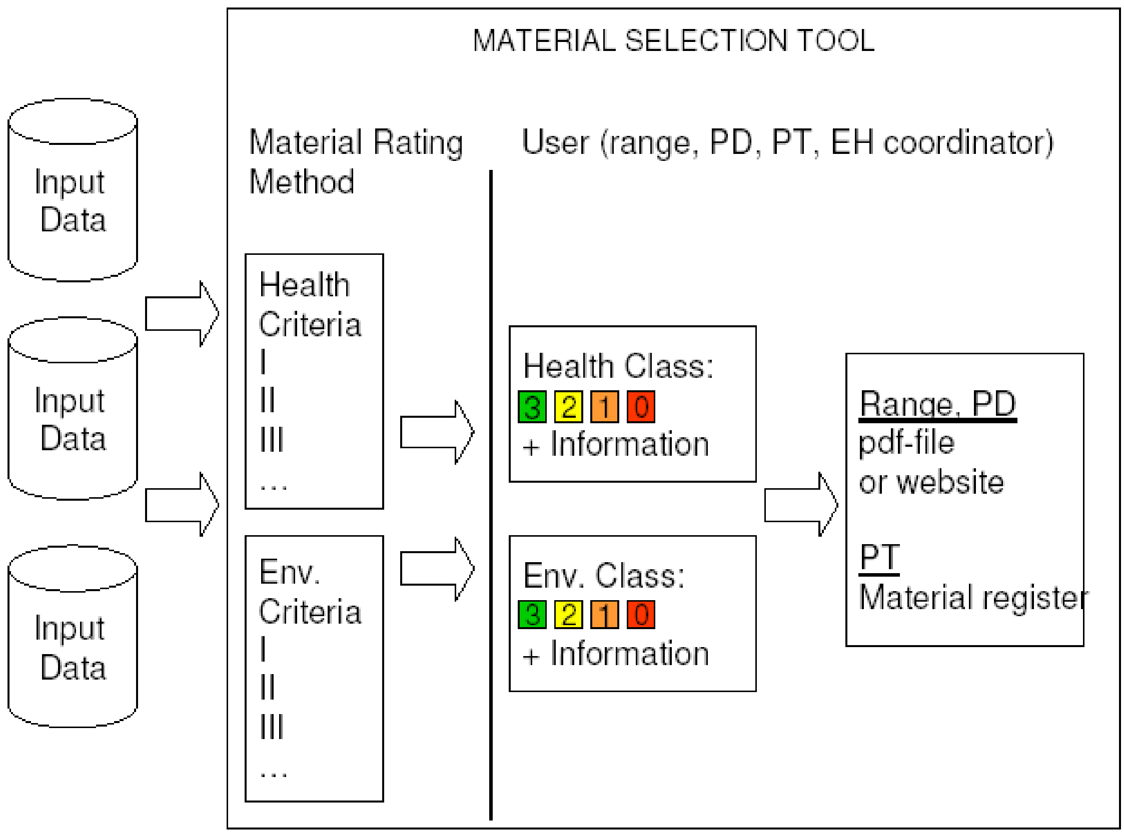
This section gives an overview of the factors which have to be considered when integrating a material selection tool into the case company's existing structures.

4.1.1 Structure of material selection tool

Figure 4.2 shows the proposed structure of the material selection tool. The figure shows that the tool consists of two parts: 1) the material rating method which includes the environmental and health assessment using different sets of criteria and 2) the user "interface" where different user groups can reach the assessment results which are summarized in an environmental class and a health class plus background information. As is explained in the next section, the input data most probably comes from different sources as is indicated in figure 4.2.

The author proposes that the environmental and health assessment is done by a group of EH coordinators, a material expert and an expert from Trading for the material in question. The criteria for this assessment are listed in the next section. Please note that the criteria for the Health Class indicated in the figure are not included in this thesis but are part of the project at IoS.

Figure 4-2: Proposal for the structure of a material selection tool



The assessments are done for each relevant material used by IoS and result in a classification of the material into a Health and an Environmental Class. Each class is divided into four categories, indicated in different colours. Green indicates the best choice from an environmental and health perspective and red the worst where:

0	Means that the material/process is not allowed to used at IKEA
1	Means that the material/process is accepted but should be substituted as soon as possible
2	Means that the material/process is accepted but it is possible to improve
3	Means that the material/process is best choice and recommended to use

Besides this classification, the assessment results should be summarized in an informational document accessible to the members of the product development team.

It is thus a clear result, simple to use as an additional input during product development. For example, it can be used as an input for the e-wheel method. As the assessment should always be done with the same core group of people (e.g. the EH coordinators), it is assured that a common ground for the assessment of materials is given and that the knowledge of those involved in the assessment constantly grows. Any further development and updating of the guide is in the hands of this core group.

The proposed material selection tool evaluates the potential environmental aspects[34] of materials used during IKEA's activities. Environmental/health impacts[35] which are potentially related to these aspects are mentioned in the matrix; however they are not taken into account during the ranking process. The reason for this is that environmental impacts depend on the characteristics of the affected environment. For example, waste water has a different effect when diluted in the ocean compared to a slow flowing river. It is insecure to predict the environmental impact of a potential environmental aspect without knowing where the activity causing the aspect occurs. It is assumed that the fact that one of IKEA's activities can give rise to a severe environmental impact, even if not known if it will occur and where, is enough reason for IKEA to avoid activities related to the aspect as much as possible.

In other words, this means that the material ranking tool includes a general hazard assessment but not a risk assessment. In order to be able to make a risk assessment it would be necessary to know about exposure data, e.g. in the case of chemical substances, concentrations and volumes used in a product. As the assessment for the material ranking is done in a stage where the intended use of the material is not yet clear, this is not possible. However, the material ranking tool helps in "thinning out" among materials currently used at IoS. IoS must then decide how to proceed with materials assessed as "bad" materials.

4.1.2 Input data

One of the most essential questions is from where to get the input data for the material ranking tool. It is suggested that IoS relates as much as possible on internal data at IKEA because this reduces the work load for those assessing the materials and improves the reliability of the method.

Internal data should come from the material experts, from Trading and from the LCA database Idemat to which the EH coordinators have access to. Additional data should be collected at branch organisations and research institutes related to the specific material. The results of the method depend on the reliability of the input data.

The case company has access to an LCA database; however it is not suggested to IoS to only rely on this database. The reason for this is that the Idemat data does not fit all IoS criteria. Another reason is that IKEA has outsourced its production and purchases mainly from Asian and Eastern European countries. LCA data is most often generated from European or North

[34] An environmental aspect is a part of an organization's activities, products, services which can interact with the environment. The decision on what is a significant environmental aspect is individual to each organization. Each aspect consists of various conditions (=activities, operations, products, services) which have an environmental impact (ISO 14001).

[35] An environmental impact is defined as any change to the environment – adverse or beneficial – which results wholly or partially from an organization's activities, products or services (= environmental aspect) (ISO 14001). Environmental aspects and impacts thus relate to each other in the same way as cause and effect.

American data and does thus not reflect IKEA's realities. One source which IoS should consider more in the future is a stronger link of IoS to information at IKEA Trading offices.

It should however be recognized that in many cases, general data is enough to come to a satisfactory assessment, e.g. in the case of hazardous substances which are used in specific processes. If no alternative processes exist, the probability is very high that the hazardous substance is used.

4.1.3 Education

IoS is interested in a tool which educates its employees. The proposed material ranking tool serves this purpose in two different ways. First, through the assessment, the expert group gains a common ground of knowledge in a way not available today. Second, through the use of the results during product development, the product development team will learn about the environmental and health performance of different materials – as in the accompanying information sheet, the team can find background information.

The main learning effect therefore occurs in the expert group and not in the product development team. This is a disadvantage of the material ranking tool. The advantage is however that the EH-coordinators will have a better and common ground in proposing alternatives for materials and that the product development team has a possibility to look up different materials and their characteristics during product development.

It should be noted that the proposed expert group at the moment probably does not have the necessary competence to do the environmental and health assessment. However, there is great interest among the EH coordinators to learn.

As mentioned earlier, environmental and health aspects are very rarely included into IoS's internal material education for the product development team. Here is a possibility for IKEA to improve in the future. The results of the material rating could be an input.

4.1.4 Documentation

There is an interest at IoS to make improvements visible and to document changes in use of materials in product development. The material rating method as such does not help in this work. The assessment for a material is done once and the result and background information has to be stored and documented. In case more information is available, a re-assessment has to be done and the ranking has to be updated.

4.1.5 Delivery of results to product development team

The product development team starting from range leaders to product developer, designer and technician is initially the main target group of the material ranking tool. The different employees can be reached in different ways.

The assessment results can be documented in different forms e.g. as Excel files in a folder to which all involved have access to or – more advanced – in a specific database. Range leaders and product developers might be reached through a summary of the results in a PDF file or on a website. Product technicians might be best reached through adding the assessment results for specific materials to the material register, which is a database used by product technicians when choosing terminology to write the technical specifications for Trading.

In any case, the EH coordinators will have the main responsibility to ensure the use of the assessment results.

4.2 Proposal for the weighting process

The intervals proposed in the ranking of each criterion should change according to IKEA's pace of improvement. The material ranking tool is an internal tool. It is not used to officially reflect IKEA's performance. It can be used as a tool for continuous improvement. Figure 4.3 exemplifies the proposed weighting process.

The first step is to do the ranking for all criteria which are explained in section 4.3. The result for each criterion is then filled into the row called "ranking". Criterion I in the example table receives e.g. the ranking 2. A company might consider that specific criteria are more important than others due to a company's strategies and values. In this case one criterion receives a higher importance compared to other criteria. In the example, criterion I and III are considered twice as important as criterion II. This means that the criteria count double in the overall ranking. When the row called "ranking" is filled in, the weighted average of all criteria is calculated. This is done by multiplying the ranking results of each criterion with the assigned importance of the criterion, e.g. for criterion I the calculation would be: 2*2 = 4. The weighted ranking results of all criteria are then summarized and divided by the number of criteria. In the example this gives: 6/5 = 1.2. Please note that the criteria with double importance count as two criteria in the calculation.

As it is in a company's interest to restrict materials which have criteria ranked as red an additional step in the ranking is needed. The very negative characteristics of a material should not be outweighed by positive ones. The second step of the overall ranking thus checks how many of the criteria are ranked as red (see bar chart in figure 4.3). In the example, the threshold for the number of "red" criteria is set at 1. This means that if there is more than one "knock-out" criterion, the overall ranking is set at 0. Therefore the final result in the example is 0.

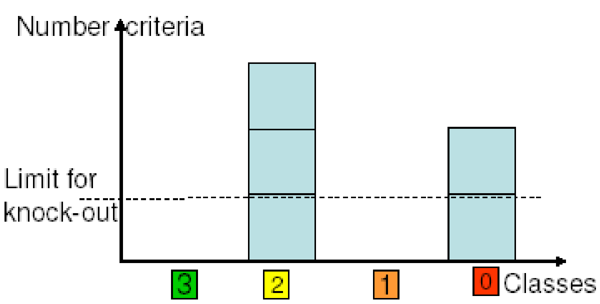
Figure 4-3: Proposed weighting process for material ranking

Step 1:

Criteria	Criterion I	Criterion II	Criterion III
A. Ranking	2	2	0
B. Importance of criterion	2	1	2
Weighting (A*B)	4	2	0

Average: 4 + 2 + 0 = 6 -> 6/5 = 1,2

Step 2:



Step 3: Final result

Class: 0

4.3 Criteria for environmental assessment of materials

The criteria are based on the internal strategies at IKEA[36]. The criteria and the ranking proposals are mainly based on suggestions for internal decisions at the company, based e.g. on regulations and customer demands. In many cases it is not possible to determine a strict scientific base for the ranking and it is necessary for IoS to set the ranking in a way which meets company internal goals. It should be noted that the ranking presented in this thesis is an interpretation of the author based on discussions with IoS employees. It does not necessarily reflect IoS's opinion or IoS' way of future work.

Each criterion is presented by aim, criterion definition, definition of input data and a proposal for ranking. It is not possible to suggest a ranking based on scientific knowledge. The specific company has to make internal decisions on how the ranking should be done. In this proposal, these decisions have been made by the author. The last criterion on transport is a proposal for the future, as it is not yet possible to retrieve sufficient input data at the case company.

Table 4.1 summarizes all environmental criteria and can be used as a result matrix when using the tool. Row A and B refer to the input data used for the ranked of the criterion. It is important to document from where the information for a ranking has been derived in case additional questions arise or the assessment has to be updated. Row C indicates the life cycle stages the criterion takes into account. In row D the actual ranking for the criterion has to be filled in. Row E indicates which importance the criterion has for the company. The environmental class gives the final result based on weighting calculations described in section 4.2.

[36] These strategies are internal and should not be disclosed to the reader.

Table 4-1: Proposal of criteria for environmental assessment of materials

Criteria	**1. Fraction of renewable material & well-managed renewables**	**2. Fraction of recycled material**	**3. Total material consumption**	**4. Probable end of life of material (recyclability & energy recovery)**	**5. Low emissions/ hazardous waste**	**6. Energy consumption**	**7. No prohibited/ restricted substances**	**8. Future criterion: Transport-ation**
A. Base data from: B. Year:								
C. Relevant Life cycle stages	Extraction	Extraction	Extraction Production Use	EoL	Extraction Production EoL	Extraction Production Use EoL	Extraction Production Use EoL x	Extraction Production EoL
D. Ranking								
E. Importance of criterion								

Environmental Class (Total ranking of criteria):

4.3.1 Fraction of renewable material

Aim

The aim is to trigger the increase of renewable material used by IKEA by ranking materials giving a high score to materials with high fractions of renewables and a low score to materials with low fractions.

Definition

The definition has been adapted from the IMPRESS[37] project at Chalmers University (Gothenburg) of which IKEA is part of (Flemström, K. et al., 2005).

Renewables are materials coming from living organisms, meaning materials that can be grown or extracted from grown substances. The process of creating new material is maximum 150 years. Examples are vegetable oils, wood, down, leather and cellulose material such as paper and plant fibers. IKEA has materials that are only partially made from renewable material. Some have been developed in order to increase the amount of renewable material in production. An example is the new material ”chip-plastic”[38] which is a mixture of chips and plastics.

Acquiring Input Data

Data for renewable material can be extracted from the IMPRESS database.

Additional criterion: Material from well-managed renewables

Renewable material is only to be valued as positive if it comes from sustainable sources. Therefore it is necessary to make an add-on to this criterion which takes into account this fact.

Aim

The aim is to trigger an increase of renewable material used which comes from well-managed sources by giving a high score to renewable material from certified sources and a low score to materials from unknown sources.

Definition

Apart from wood, IKEA does not yet have a definition for other well-managed renewable resources and there are no specific independent certification schemes which could provide guidance. However, work is done on these issues and it is therefore important to add the additional criterion in this context.

Acquiring Input Data

It is unclear where to retrieve input data.

Table 4.2 shows the proposal for the ranking of the combined criterion fraction of renewable material coming from well-managed sources.

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[37] The aim of the IMPRESS (Implementation of Integrated Environmental Information Systems) project is to coordinate environmental management methods and tools and to integrate them into corporate business processes, see http://www.imi.chalmers.se/impress.htm for more information.

[38] spånplast

Table 4-2: Ranking criterion 1: fraction renewable material & well managed resources

	Renewable			
Well-managed	0 (< 50% renewable)	1 (> 50% renewable)	2 (> 75% renewable)	3 (> 95% renewable)
0 (material from unknown sources)	0	1	1	1
1 (conventional plantation, no classification system available)	1	1	1	2
2 (material from source with known practices)	1	2	2	3
3 (material from certified/ well-managed source, e.g. FSC)	2	2	3	3

As well-managed is so far an additional criterion, it should not steer the criterion outcome, but give an extra plus to the renewable criterion. This is reflected in the ranking.

4.3.2 Fraction of recycled material

Aim

The aim is to trigger the increase of recycled material used by IKEA by ranking materials giving a high score to materials with high fractions of recycled material and a low score to materials with low fractions.

Definition

The definition has as well been adapted from the IMPRESS project. The material has been recycled through material recycling. Material recycling means the reprocessing in a production process of the waste material for the original purpose or for other purposes but excluding energy recovery. Post-industrial scrap, material scrap from the company's own manufacturing of products, is considered to be virgin raw material since it has not constituted part of any product that has been delivered to consumers. However, materials considered as scrap from the manufacturing at one company is considered to be recycled material if used at another company, also if it is paid for. Post-industrial scrap is thus only considered as virgin raw material if it is produced at the company's own manufacturing units. Feedstock recycling of polymers is included. It must be taken into account that the recycled material can be contaminated with hazardous substances. This is part of criterion 7 (on chemical substances).

Acquiring Input Data

Average fractions of recycled material in material are available through the IMPRESS project.

Table 4-3: Ranking criterion 2: fraction of recycled material[39]

3	80 to 100% recycled material
2	50 to 80% recycled material
1	Up to 50% recycled material
0	0% recycled material

[39] The ranking has been adapted to a similar ranking of the MiLab tool, see www.milab.nu

4.3.3 Total Material Consumption

Aim

The aim is to trigger IKEA to decrease the material with high material intensity by ranking materials giving a high score to materials with low material intensity and a low score to materials with high material intensity.

Definition

The definition includes the material consumption during extraction and production in kg per kg material.

As an example, the following ranking is based on a list of about 30 materials extracted from the LCA database Idemat. This is a very rough ranking and it is questionable if it makes sense to decide on general intervals for materials. If a more detailed view is required it is better to create intervals for different material groups. The ranking should thus be seen as an example. In any case, this criterion might be questionable because lighter materials earn a higher ranking. Second, because the material input is specific for different materials and even in case of good environmental performance, material input might be high. An example is cotton which needs about 8000 kg input material (mainly water) per kg (see Idemat database). In case of organically certified cotton, it might be an environmentally viable resource; however, the cotton would get a very low ranking for material consumption.

Acquiring Input Data

The data is available in the LCA database Idemat (see Appendix 2 for which materials environmental data is available).

Table 4-4: Ranking criterion 3: Total material consumption

3	< 20 kg/kg material (Very low material consumption)
2	< 100 kg/kg material (Low)
1	> 100 kg/kg material (High)
0	> 200 kg/kg material (Very high)

4.3.4 Material recyclability and energy recovery

This criterion is a combination of two factors which are important for the end-of-life stage of a material: the recyclability of a material and the possibility to incinerate a material with energy recovery. Both factors are presented in the following.

Material recyclability

Aim

The aim is to trigger the increase of material which can be reused and recycled, used by IKEA by ranking materials giving a high score to materials with high fractions of recyclable material and a low score to materials with low fractions.

Definition

The definition is partly adapted from the IMPRESS project.

1) Average recycling data (most possible recycling rate) for all materials. Materials containing hazardous substances as toxic, carcinogenic substances should not be material recycled.
2) Possibility for disassembly
    - If the material consists of several materials, these can be manually or automatically separated from each other
    - The material will probably be material recycled through a shredding process
    - Small amount of "contamination" exists in the material e.g. flame retardants in polyethylene (in line with IKEA specifications)
    - More than 90 weight % of the material can be separated.

The probability of an available collection system in the selling country is very important but it is not possible to make a statement on this at the stage of the material ranking method.

Acquiring Input Data

Average recycling data (European or global) are available through the IMPRESS project (excluding probability of available collection system).

Incineration with energy recovery

Aim

In case the material is not recyclable according to definition above, the material should be incinerated with energy recovery.

Definition

Energy recovery means the use of combustible waste to generate energy through direct incineration with or without other waste but with recovery of the heat. The definition of a material appropriate for incineration with energy recovery can be divided in two parts:

1. The material does not contain toxic substances such as heavy metals or halogenated substances. Combustion of materials containing halogens can result in toxic compounds, like dioxins and furans, which are difficult to separate and destroy in an incineration/combustion process. Combustion of materials containing heavy metals can result in spreading/distribution of the toxic compounds. The environmental impact of incinerating these materials is therefore high.
2. The energy needed for the incineration process of the material is lower than the combustion heat released; meaning that combustion of the material can generate energy through direct incineration with or without other waste but with recovery of the heat. This means that e.g. metals are not appropriate for incineration with energy recovery.

Acquiring Input Data

This is possible through logical thinking as most materials are combustible.

Ranking for recyclability/ energy recovery

The aim of this ranking is to ensure that the material does not get a positive weighting for energy recovery although it should be material recycled. The best ranking a material with

100% incineration with energy recovery can get is 0.5 point while it gets 3 points if it is 100% recyclable. Table 4.5 shows the ranking for this criterion.

Table 4-5: Ranking criterion 4: material recyclability & energy recovery

	Fraction recyclable		
Fraction Energy recovery of rest	<50%	> 50%	> 90%
< 50% (no)	0	1	3
> 50% (yes)	0.5	2	n.a.

4.3.5 Low emissions and hazardous waste

Aim

The aim is to trigger IKEA to decrease the material with high air and water borne emissions and hazardous waste during life cycle stages by ranking materials giving a high score to materials with low emissions/ waste and a low score to materials with high emissions/ waste.

Definition

This criterion includes air/water borne emissions and hazardous waste during the extraction and production phase of the material. It is hardly possible to come up with a definitive ranking. There are two possible ways for the expert group to do the ranking: 1) IKEA decides internally to focus on specific emissions which are related to environmental impacts (e.g. ozone depletion) IKEA wants to put emphasis on; 2) the expert group decides in each case individually on the severity of process specific emissions. In the second case, more knowledge is expected from the expert group.

Acquiring Input Data

Emission data (air and water borne) is available in the LCA database Idemat. Additionally, there is IKEA internal knowledge on waste water and hazardous waste.

Table 4-6: Ranking criterion 5: Low emissions & hazardous waste

	Emissions			
Hazardous waste	0 (high emissions)	1 (medium emissions)	2 (low emissions)	3 (very low emissions)
0 (hazardous waste)	0	0	0	0
1 (probability for hazardous waste)	0	1	1	2
3 (no hazardous waste)	0	1	2	3

4.3.6 Energy consumption

Aim

The aim is to trigger IKEA to decrease materials with high energy consumption by ranking materials, giving a high score to materials with low energy intensity and a low score to materials with high energy intensity.

Definition

At present a rough ranking of energy consumption of materials has been done based on data in Dahlström et al. (2000). It is a cumulative value for the energy consumed during manufacture of the material and takes into account manufacture of both virgin and recycled material. Dahlström et al. (2000) point out that the values are approximate values because production processes can differ very much from each other.

This is a very rough definition and does not take into account from which sources the energy comes from. However, in any general guide it is not possible to define this, energy sources differ from country to country, region to region and the fuel mix is in the end conclusive if the energy consumption is sustainable or not. Consider production process A using double as much energy as production process B, however energy in process A comes from renewable sources while process B uses energy from an old power station. Which one is to prefer?

Acquiring Input Data

Input data must be acquired in MJ/kg or in a unit that is possible to transform to MJ/kg as the ranking intervals are given in this unit[40]. Input data for energy consumption should either be available at IKEA suppliers or in general LCA data.

Table 4-7: Ranking criterion 6: Energy consumption

3	< 20 MJ/kg (Very low energy consumption, closed loop)
2	< 50 MJ/kg (Low)
1	< 100 MJ/kg (High)
0	> 100 MJ/kg (Very high)

4.3.7 Material does not contain prohibited/ restricted substances

Aim

The aim is to trigger the decrease of materials with a high amount of prohibited/restricted substance use during production and in finished material by ranking materials giving a high score to materials with no prohibited/ restricted substances and a low score to materials with those substances or substances from unknown sources.

Definition

This criterion is based on IKEA's specification on prohibited/ restricted chemical substances and the PRIO list on characteristics of chemical substances which was presented in section 2.2.3.

Acquiring Input Data

The input data needed is a list of materials and related production processes and associated chemical substances. This information is mainly available from industry sector organizations.

[40] Please note that it is not possible to use data from the LCA database Idemat because the Indicator for resource consumption (equally expressed in MJ/kg) does not reflect the energy consumption during production but the "surplus energy" in MJ/kg extracted material (only mineral resources and fossil fuels). This reflects the expected increase of extraction energy per kg extracted material when assuming that the quality structure (concentration of the material in the earth crust) is getting worse with time. The absolute number in MJ/kg has no real meaning and it is thus not possible to compare it with data in MJ/kg which is collected from other sources.

Ranking

The assessment of each material should include a list of major chemical substances used during production of/ included in the material. This list is then related to PRIO characteristics as far as it is possible (see checklist below) by using the PRIO database[41] or by asking experts in case the specific substance in the material is not listed in the database.

Table 4-8: Ranking criterion 7: No prohibited/ restricted substances

3	Supplier documentation is available and appropriate or it is not probable that the material contains prohibited/ restricted chemical substances according to IKEA's specifications or according to PRIO
1	IKEA specifications are fulfilled, Material probably does not contain "phase out" chemical substances according to PRIO, Material probably contains "priority risk reduction" chemical substances according to PRIO
0	Supplier information on the material is not known, the material probably includes harmful chemical substances according to PRIO and IKEA's specifications

4.3.8 Suggestion for future criterion: Transportation

Aim

The aim is to trigger IKEA to decrease the use of materials with high transportation intensity by ranking materials giving a high score to materials with low transportation intensity and a low score to materials with high transportation intensity.

Definition

This criterion cannot be put into use before information from which country/region material is from is available. The definition should include transportation from raw material stage until the material reaches the IKEA supplier. The criterion takes into account the means of transport (boat, railway, car, airplane) and the transport in km. This criterion can only be used if information is available on the supply country/ region of the supply chain from raw material to purchaser of finished material.

Acquiring Input Data

It is unclear where input data should be received from.

Table 4-9: Ranking criterion 8: Transportation

	Km			
Transport means	0 (very high amount of km)	1 (high amount of km)	2 (within one region)	3 (within one country, low km)
0 (> 70% car/airplane)	0	0	0	0
1 (40-70% car/ airplane)	0	0	1	2
2 (> 40% railway/ boat)	0	1	2	3
3 (> 70 % railway/ boat)	0	2	3	3

[41] The database is available at www.kemi.se and can be used free of charge.

5 Applying the material selection tool on metal finishing

The author applied the tool on two metal finishing processes: Chromating and galvanization. A short introduction to metal finishing and these two processes is given in Appendix 3. Section 5.1 summarizes the results of the application while section 5.2 analyzes these results.

5.1 Environmental assessment of chromating and galvanisation, using the material selection tool

This section assesses each of the criteria described in chapter 4.3, describing how the criterion's definition and ranking has to be adapted to metal finishing and describing the reasoning for the ranking result. If applicable, the reasoning is separated in process and product related aspects. The first two criteria in the general result matrix (table 4.1) are not used in this assessment.

Criteria 3: Total Material Consumption

It is possible to use the definition. The criterion focuses on the main materials used in the metal finishing process, in this case chromium and zinc. This information is available in the LCA database Idemat.

Chromating:

The raw material input for chrome is 9.68 kg per kg material.

Galvanisation:

The raw material input for zinc is 77.06 kg per kg material.

Ranking:

		Chromating	Galvanisation
3	< 20 kg/kg material (Very low material consumption)	X	
2	< 100 kg/kg material (Low)		X
1	> 100 kg/kg material (High)		
0	> 200 kg/kg material (Very high)		

Criteria 4: Probable End of Life of material: material recyclability and energy recovery

Energy recovery is not relevant for this criterion as metals are not incinerated. The definition of the criterion changes to the following two questions:

1) Does the metal finishing hinder recylability of the bulk metal?
2) How much of the coat metal can be recycled?

Metal finishing sometimes causes downgrading of the metals at recycling of products made of steel, aluminium and brass. Usually metal finishing is not recycled separately and changes thus the original metal contents of the bulk metal (EU Project Madame[42]).

[42] The EU project MADAME evaluates the total environmental effect of metal finishing processes in a life cycle perspective. The aim has been to create a common language on environmental issues for the purchase and design departments in large

Chromating:

1) About 80% of chromates will follow the product to recycling or scrapping. Chromating does not cause problems for recycling (EU Project Madame).

2) There is no information available, however the author assumes that the chromium is not recovered in its pure form but is recycled together with the bulk metal.

Galvanisation:

1) As there are technologies to recycle zinc from metal finished objects, zinc coating does not hinder recyclability of bulk metal. When steel is melted for recycling, zinc evaporates and is recycled through condensation; the condensed zinc is then used as raw material for production of zinc (Dahlhammer, 2000).

2) The recovery rate of zinc in galvanized steel scrap in Sweden is today at 30% and potential recovery rate is believed to be 60-80%. Tried and tested technology is available for recovery of zinc from galvanized steel (Landner & Lindström, 1998).

Ranking:

	Fraction of coat metal recyclable?			
Hinders recyclability of bulk metal?	0-10% (or no information available	< 50%	> 50%	
No	1 (Chromating)	2 (Galvanisation)	3	
Yes (or no information)	0	1	-	

Criteria 5: Low emissions/ hazardous waste

The definition is not changed.

During the **process** of metal finishing, about 20% of metal consumption ends up as hazardous waste and no economically sustainable recycling method exists for this waste at present (EU Project Madame).

An additional emission in the use and end of life phase of a metal finished **product** is the scattering of the coating in nature due to run off and leakage from waste heaps (SEPA, 1996). However, the products of the case company might not have a great impact during their life time as besides out-door furniture none of the products is mainly used outside during its use period.

companies on the one hand and small and medium-sized metal finishing companies on the other hand. The results of the project are summarized at www.syf.se/Madame/Results.asp.

Chromating:

<u>Emissions:</u>

Any releases of chromium (VI) from any sources are expected to be reduced to chromium (III) in the environment. The impact of chromium (VI) as such is therefore likely to be limited to the area around the source. The behaviour of chromium species in the environment can be influenced by environmental factors, such as pH and water hardness. (European Chemicals Bureau, 2005)

During the neutralization and reduction of Cr VI, sodiumbisulphide is used which leads to air emissions of sulphur dioxide (Nordänger, 1997). The hexavalent chromium substances are of low volatility and so emissions to air are unlikely from most processes. Specific information provided by manufacturers and users indicates that there are some releases to air from production and from some use steps; these are expected to be in particulate form (European Chemicals Bureau, 2005). Chromating results in a high amount of wastewater, water borne emissions are thus much more prominent compared to air emissions (Nordänger, 1997).

There is no information on scattering of chromate in nature during the use phase. However, as mentioned above, this might not be a great issue for the case company.

<u>Hazardous waste:</u>

Almost all metal contents in metal finishing bath that do not get stuck on the product (about 20%), will sooner or later become part of hazardous waste. The waste is stored and there is a risk of leakage and the metal contents are lost from the technosphere. It depends very much on the supplier how well cleaner production methods are employed to reduce this risk. In general, hazardous waste from chromating includes the used surface treatment baths; sludge from precipitation of used baths and concentrates from treatment/ recycling of bath (IKEA Trading). As specific supplier is not available, this general data is used.

Galvanisation:

<u>Emissions:</u>

Today's modern hot-dip galvanizing plant is completely closed and air and water emissions have decrease by 90% in Sweden compared to the 70's (Landner & Lindström, 1998). However, this does not give information on how plants in Eastern European and Asian countries work. Emissions of zinc and flux smoke to air can be reduced with the help of process modifications, e.g. dipping the work pieces in a separate bath with flux solution rather than having the flux lying on the surface of the bath with molten zinc (IKEA Trading).

Dispersal of zinc, corrosion and runoff from zinc-coated materials is big. Corrosion is mainly caused by sulphur dioxide in the air deposited on the surface of the material; oxidation forms readily soluble zinc salts, which can be washed away by rain. Corrosion rate is greatest at the start of the exposure, after which it gradually declines (Landner & Lindström, 1998). Obviously, corrosion depends on environmental conditions. Galvanised indoor products will not be subject to this problem, however for IKEA's Business Area for outdoor furniture, galvanisation is one of the main metal finishing processes employed. The washed-off metal is supposed to be higher at more polluted exposure sites than less polluted ones (Landner & Lindström, 1998). With regard to production in Asia and Eastern Europe, this is of interest when it comes to the storage of galvanised products.

Hazardous waste:

Waste is formed mainly from iron/zinc alloy in bath and zinc ash[43]. Hazardous waste occurs in the form of solid wastes from gas treatment and spent flux as both contain easily soluble zinc which is toxic to aquatic organisms. (IKEA Trading)

Ranking:

	Emissions			
Hazardous waste	0 (high)	1 (medium)	2 (low)	3 (very low)
0 (hazardous waste)	0 Chromating	0	0	0
1 (probability for hazardous waste)	0	1	1 Galvanisation	2
3 (no hazardous waste)	0	1	2	3

Criteria 6: Energy consumption

The definition was adjusted to 1) how high energy consumption during production of coating metal is and 2) how high the energy consumption during the metal finishing process is.

It is very difficult to assess the energy consumption of the **process** because it depends very much on the supplier. Influencing factors for energy consumption are among others rack or barrel plating, the thickness of the metal coating and the size of the products to be metal finished. A metal finishing process will typically contribute with 1-12 % of total energy consumption in a product's life cycle (EU Project Madame).

It is not possible to predict how the metal finishing can influence the energy consumption during use because nothing is known about the intended use of the material. However, usually the metal finishing influences the energy consumption of the product during transport or use, e.g. because the product weighs less or because of better conductivity, this is an important positive environmental impact. In the case of the case company only a decrease of energy consumption due to a decrease in the weight of the product can be taken into account.

Chromating:

Energy consumption of primary production of chromium is slightly higher compared to zinc (Landner & Lindström, 1998). Chromating consumes about 3% of total energy consumption in a product's life cycle, assumed that the product doesn't use any energy during usage. The chromating bath as such demands no energy besides the manufacturing of the chemicals used but the main energy consumption occurs during pretreatment (1/3) and drying (1/3), waste water treatment and the conveyor. (EU project Madame)

There is no information about energy consumption during production. However, it should be possible to relate information on the production process which could be received from material experts or IKEA Trading to an assumption on how much energy is used during production.

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[43] According to Basel Convention, zinc ash and similar are not hazardous waste unless they contain lead or cadmium.

Galvanisation:

Energy consumption in primary product of zinc is among the lowest for any base metal. (Landner & Lindström, 1998)

There is no information about energy consumption during production. The ranking for both processes is thus based on the energy consumption during the extraction of zinc and chromium.

Ranking:

		Chromating	Galvanisation
3	Very low energy consumption		
2	Low	X	X
1	High		
0	Very high		

Criteria 7: No restricted substances used during production/ use

Chromating:

The following table compares the PRIO checklist with the list of substances usually used during the chromating process[44]. The process includes phase-out substances with the characteristic CMR and risk reduction substances with the characteristics "very high acute toxicity" and "environmentally hazardous, long term effects". Therefore the ranking is 0.

Table 5-1: PRIO list for chromating

Environment	**Health**
Phase-out substances	**Phase-out substances:**
PBT/vPvB (persistent, bioaccumulating and toxic/very persistent and very bioaccumulating)	*CMR (carcinogenic, mutagenic or toxic to reproduction):* *Sodium chromate, sodium dichromate*
Particularly hazardous metals (mercury, cadmium, lead and their compounds)	Endocrine disruptive
Ozone-depleting	Particularly hazardous metals (mercury, cadmium, lead and their compounds)
Risk reduction substances:	**Risk reduction substances:**
Very high acute toxicity: *Sodium chromate, sodium dichromate, hydrofluoric acid*	Very high acute toxicity
High chronic toxicity	High chronic toxicity
Environmentally hazardous, long-term effects: *Sodium chromate, chromic acid, sodium dichromate*	Allergenic
Potential PBT/vPvB	Mutagenic, category 3

[44] This general information was taken from IKEA Trading which made a general summary of metal finishing processes. It depends on the bulk metal to be coated, which substances are used in the chromating bath, examples are given here for aluminum (sodium carbonate, sodium chromate, chromic acid, sodium dichromate, sodium fluoride, phosphoric acid), magnesium (chromic acid, nitric acid, hydrofluoric acid, sodium dichromate, calcium fluoride), zinc (chromic acid, fluorides, nitric acid) (Ekengren et al., 1993).

Galvanisation:

According to RIVM (1991)[45] "the risks associated with the current concentrations of zinc in the environment appear to be nil for man, and limited and localised for animals and plants. For humans, especially lactating women, the possibility of too low a zinc intake is greater than that of excessive intake."

The toxic effect of zinc in living organisms seems mainly to be associated with the fact that it competes with other metals, mainly copper and iron, for their binding sites, the usual result is that the organism shows symptoms of a deficiency in the displaced metals. Zinc concentration in the superficial, organic soil layer must be more than five times, and probably ten times, greater than the natural background levels before any adverse impact on soil biology or vegetation can be expected. Factors influencing effects of zinc in nature are hardness of water (toxicity of zinc in aquatic environment decreases with higher hardness), concentration of organic matter & phosphorus (bioavailability of zinc decreases). Organisms can gradually develop a higher tolerance. (Landner & Lindström, 1998).

According to IKEA trading during the galvanisation processes the substances zinc, zinc chloride, nickel (usually less then 0.07%) and aluminium are used. IoS has requirements on how high Cd content is allowed in zinc used for galvanising and on not using lead during the galvanisation process; according to IKEA Trading these requirements are fulfilled. However, there is a possibility that the process includes lead or cadmium. Lead is used to enable the easy lifting of precipitated hard-zinc (zinc-iron alloy) from the bottom of the molten zinc bath (Landner & Lindström, 1998).

Table 5-2: PRIO list for galvanisation

Environment	**Health**
Phase-out substances	**Phase-out substances:**
PBT/vPvB (persistent, bioaccumulating and toxic/very persistent and very bioaccumulating)	CMR (carcinogenic, mutagenic or toxic to reproduction)
Particularly hazardous metals (mercury, cadmium, lead and their compounds)	Endocrine disruptive
Ozone-depleting	Particularly hazardous metals (mercury, cadmium, lead and their compounds)
Risk reduction substances:	**Risk reduction substances:**
Very high acute toxicity:	Very high acute toxicity
High chronic toxicity	High chronic toxicity
Environmentally hazardous, long-term effects: *Zinc chloride*	Allergenic
Potential PBT/vPvB	Mutagenic, category 3

[45] Cited in Landner & Lindström (1998)

Ranking:

3	Supplier documentation is available and ok or It is not probable that chemical substances with harmful characteristics (according to PRIO) are used in process and are in the material and It is not probable that chemical substances according to IKEA's specifications are used during process and are in the material
1 Galvanisation	Supplier documentation is not known IKEA specifications are fulfilled Process probably does not contain "phase out" chemical substances according to PRIO Process probably contains "priority risk reduction" chemical substances according to PRIO
0 Chromating	Supplier information on the material is not known or the process probably includes harmful chemical substances according to PRIO and IKEA's specifications

5.2 Analysis of Results

This chapter summarizes the results of the environmental assessment for the metal finishing processes chromating and hot dip galvanization. As these are processes and not materials, the matrix had to be adapted and only 5 of 8 criteria are applicable. Table 6.1 shows the result matrix with ranking and weighting process.

The importance of each criterion has been weighted equally. The test has been done by the author in order to disclose the strengths and weaknesses of the method and is thus not based on a decision by IoS.

Table 5-3: Test results for chromating and galvanisation

Criteria	3. Tot. material consumption	4. Probable end of life of material	5. Low emissions/ hazardous waste	6. Energy consumption	7. No prohibited/ restricted substances
Base data/ Year	Idemat	Landner et al., 1998; EU project Madame	EU Chemical Bureau, 2005; IVF 1997; Landner et al.1998; IKEA Trading	EU project Madame; Landner et al., 1998; IKEA Trading (not yet)	IKEA Trading; Landner et al, 1998
Relevant Life cycle stages	Extraction Production Use	EoL	Extraction Production Use EoL	Extraction Production Use EoL	Extraction Production Use EoL
Ranking **Chrom.:** **Galv.:**	 **3** **2**	 **1** **2**	 **0** **1**	 **2** **2**	 **0** **1**
Import-ance of criterion	1	1	1	1	1

Chromating: 1) Environmental Class (Average): 6/5=1.2 2) Final result: **0**

Galvanisation: 1) Environmental Class (Average): 8/5= 1.6 2) Final result: **2**

The final result for chromating is 0 because 2 of the criteria are ranked 0 which according to the weighting process explained in section 4.2 leads to an overall weighting of 0 (prohibited). The final result for galvanization is 1.6 which could be rounded up to 2 (accepted). Table 5.4 shows if the general criteria and ranking had to be changed and if full information/ input data were available.

Table 5-4: Evaluation of test results: definitions, ranking, information changes

Criteria	Definition change?	Ranking change?	Information available?
Criteria 3: Total Material Consumption	No	No	Yes
Criteria 4: Probable end of life of material	Yes	Yes	Only partly for chromating
Criteria 5: Low emissions/ hazardous waste	No	No	Only partly for chromating
Criteria 6: Energy consumption	Yes	Yes	No absolute data
Criteria 7: No prohibited/ restricted substances	No	No	Yes

The assessment of criteria 5 and 6 was done without using absolute data. Definitions and ranking for criteria 4 and 6 had to be changed. Information was mostly available; however the data is not very detailed. For example, for criteria 7, data from IKEA Trading's Intranet site has been used. This gives information about the most common substances used but obviously cannot give information of what is actually happening at suppliers.

6 Analysis

This chapter focuses on the analysis of the results from this study and puts the study into relation with the research question which is:

When designing a tool for the environmental assessment of materials used during the product development process of an organisation: How to adapt the tool to a company's conditions and needs?

The research question is answered by describing several factors which are according to this study important for the adaptation of a material selection tool to a company's conditions and needs. While the discussion of the factors is of a more general nature, examples are drawn from the experiences made during the case study.

The factors are:

- The aim pursued with a material selection tool
- The integration of the material selection tool into company structures
- The expected accuracy of results
- The target group at the case company.

Section 6.5 of the analysis summarizes the limitations and advantages of a material selection tool, as found during the case study. Section 6.6 broadens the view of this study and shows how other organisations can benefit from the results of the study.

6.1 The aim pursued with a material selection tool

A company must be very clear for what purpose a material selection tool is developed, otherwise it is difficult to convince employees and management of the importance of the tool. In the case of IoS the purpose of the material selection tool was to enable IoS to rank company specific materials from an environmental and health perspective in order to give an input to product development which materials are better than others or which materials should be used while others should be avoided. For example, at the case company this work is already ongoing at different departments however the material rating method would include a higher number of criteria which are connected to the company's internal strategies. A clear aim of the tool is the starting point for any development.

It is as well clear that the tool should be mainly used to compare materials within specific material groups. However, the material selection tool can serve different purposes, either comparing materials within one material group or materials of different material groups with each other. It mainly depends on how the ranking of the different criteria is defined. In the first case, it is necessary to adjust the criteria to each material group in order to give a more detailed result. In the second case, it is necessary to find general criteria which fit all materials. In this case it is probable that materials with quite similar characteristics or from the same material group end up in the same class. It is suggested, to focus on the comparison of materials within material groups as this gives a more detailed result.

A review of the material guides and eco-labelling criteria presented in chapter 2 reveals that usually criteria are developed for specific material groups. For example, when comparing with material guides such as Folksam or MiLab (see section 2.3) both guides are developed for specific material groups (construction materials). Even if the general rankings proposed in section 4.3 might not be of direct use, the general criteria can be used as a base for criteria for different material groups: while the criteria in itself can remain the same for different materials, the ranking has to change.

The test results show as well that it is necessary to adapt the criteria to metal finishing. The adaptation is probably more difficult for processes compared to other material groups.

6.2 The integration of the material selection tool into company structures

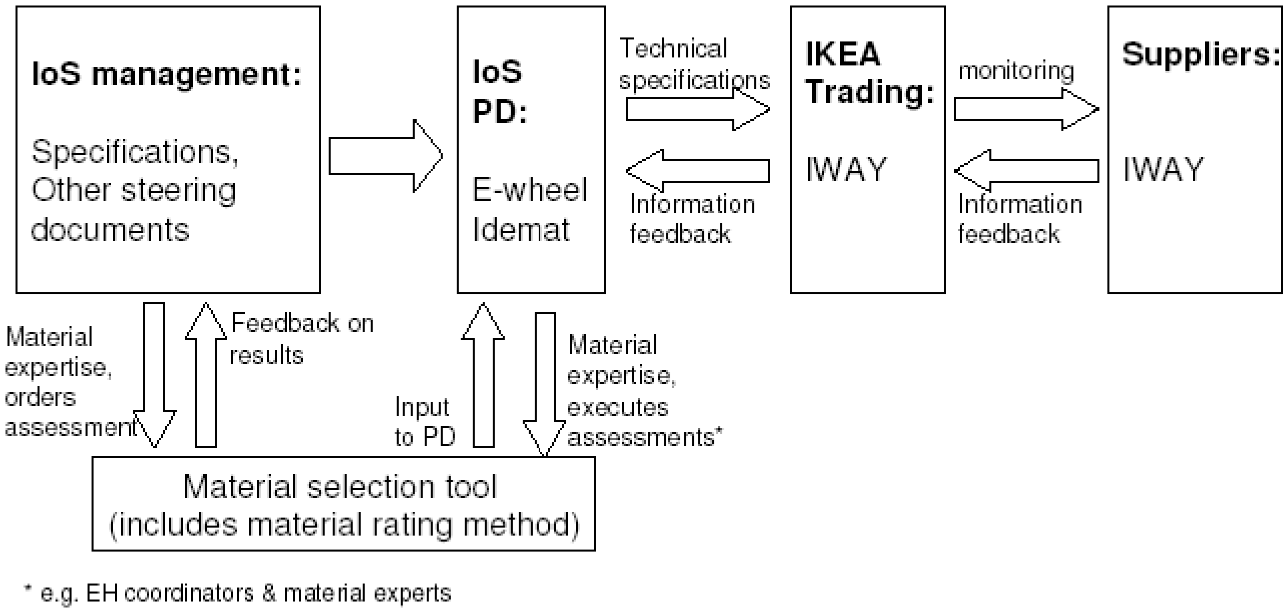
As already shown in chapter 2 of this thesis, the author wants to stress that without knowledge on existing structures, it is not possible to build a functional tool. For example, referring to the simple LCA tool developed by Modul Service (see section 3.3), the main reason for not applying the tool was that it was not developed to suit into existing company systems. In order to make this happen, one has to check the needs of the company, see section 3.4, and look at the tools and structures already used at the company, see sections 3.2 and 3.3. This knowledge helps in deciding on how the tool can be adapted to the needs and conditions at the company.

As an example, Table 6.1 shows at what stages in product development at the case company the material selection tool could be used. Table 6.1 shows that the tool mainly comes in at two stages: the management level and the product development stage where the e-wheel method is used. However, due to the fact that the tool delivers results to the management group and might influence their decisions, the tool indirectly influences all stages in product development. Figure 6.1 proposes how the tool is included in the organizational structure at the case company.

Table 6-1: Stages in product development at case company where material selection tool is used

Stage in product development	Material choice?	Material selection tool used?
IoS Management	Yes	Yes, tool is used as input at management level
Range coordination at IoS level	Yes	
Range strategy at BA	Yes	
Design brief	Yes	
Product development starts	Yes, refinements	Yes, tool is used as input to e-wheel method
Wash council	No	
Product development continues	At the most refinements	
Product Council	No	
Project is handed over to Trading	No	

Figure 6-1: The position of the material selection tool at the case company



As mentioned in section 3, the top management already issues specifications which are related to environmental & health issues with focus on chemical substances. The difference between those specifications and the new tool is that the tool takes into account more environmental criteria.

6.3 The expected accuracy of results

The accuracy of the results of the tool depends on the input data and on the structure of the tool (criteria, ranking, weighting system). Therefore the results from the application of the tool on metal finishing can be used as a first test. An expert for environmental assessments of metal finishing processes (Skogsmo, 26/09/05) assessed the test results and stated that the study is a start for an environmental assessment but more work and input data is needed to receive a detailed and reliable result. However, the test shows how the author came to the results described in section 5.2 and gives an indication if the tool can generate reliable results in the future.

6.3.1 The input data

The input data plays a great role in the assessment. As can be seen in table 5.2, in all but one case it was necessary to use additional input data from research reports in order to come to a result. In four out of five cases it was possible to use input data available at IKEA. This means that the assessment most probably has to be done using input data from several sources inside and outside of the case company. It is important that members of the assessment group gain a good knowledge on what information is already available at other departments of the company. The main idea is not to repeat work already done at other departments.

It is not clear at date how accurate the data must be as an input to the material ranking in order to receive a good-enough result. M.S Brown (18/08/05) suggests as a rule of thumb that business decisions must be made with data good enough to come to the right result in 80% of all cases. A company has thus to find a balance between the accuracy and the generality of the data used.

6.3.2 Criteria, Ranking, Weighting

The criteria of the tool reflect current strategies at IKEA and gives a more holistic perspective of environmental and health aspects. As discussed earlier the ranking intervals are not very precise however the ranking becomes precise due to relevant input data and through discussions of employees with different expertise, e.g. environmental coordinators and material experts. Applying the tool, it becomes clear that the use of knock-out criteria is very important for the accuracy of the overall result. For example, without using knock-out criteria, chromating would receive an overall result of 1 which does not reflect the real hazardousness of the process.

6.4 The target group at the case company

The target group of the tool should be convinced that the tool is useful to them. At the case company this is only partly the case today. While the product development team does not see the need, EH coordinators and material experts appreciate the tool.

The tool has been designed on the basis of meetings with employees which are included in the target group. The usability of the tool relies on the fact that each material receives a specific ranking from red to green. It is therefore very simple and fast to use during product development and for management as soon as the assessments have been done. However, it is doubtful if the main user group is going to be the product development team. The main beneficiaries might be the expert group as the members gain most knowledge which they then can use during product development.

6.4.1 The expert group

The assessment should be done by a group of people with different backgrounds and interests to help maintain the objectivity of the assessment. There is however always a danger that the group already has a "supposed" result in mind which it tries to verify during assessment. It is of great importance how the environmental and health assessment is done in order to decide if the tool is of use. The main aspect which makes the tool useful and creates reliable results is the **discussion process** among the expert group as this makes clear to the group where gaps of knowledge are. As the assessment for the example given in this study has been done by the author, it cannot be determined how well this works. The case company has to find out through testing of the tool after the handing in of this thesis. In many cases the author could not retrieve enough input data to come to a reliable result and the ranking has therefore been done by logical thinking. The discussion of the expert group is thus of great importance in order to establish a common understanding and reasoning for prohibition or allowance of specific materials and processes in cases where a clear result is not available.

A crucial factor is as well the **competence** of the assessment group. It is essential that the assessment team gets enough time to learn and discuss. Even if the assessment is done internally, experts might be necessary to evaluate specific questions. However, if the main assessment stays in the company, it is assured that the knowledge stays within the company, too. The expert group should believe in the analysis made but be critical to the results. One can say that one of the main aims of the tool is to make the expert group, especially the EH coordinators, more knowledgeable on environmental and health issues of materials and thus to enable them to contribute with more material expertise during product development, e.g. during the e-wheel method and to pass on this knowledge to others in the product development team.

6.5 Limitations and advantages of a material selection tool

The material selection tool is limited in several regards.

- It should be clear that the tool is an assessment of possible hazards as opposed to a risk assessment. This is because the intended use of the material and thus exposure data is not available at the early stage of product development at which the tool assesses materials.
- In most cases it is not possible to give clear intervals for the ranking process which might be considered as inaccurate and not safe enough. As explained further down this is not primarily a limitation but a characteristic of such a tool.
- The fact that input data is not based on information from producer country is a limitation of the tool. However, this is a problem which has its roots in the practices of companies having a large number of suppliers and it is thus not possible to tackle the problem with the help of a material selection tool. However, if more country specific input data is available in the future, it can be used by the tool.
- Even so working routines might improve with experience, a limitation of the tool is the time needed for collection of reliable input data and the material assessment. This might be greatest limitation for any company to work with such a tool.

The advantages of the material selection tool are many fold.

- A large advantage is that the employees gain greater expertise on materials. Further, this expertise has developed through discussions and grounds on a common understanding. This makes it easier for e.g. EH coordinators of the case company to stress environmental and health impacts of specific materials when discussing with the product development group as they know that all other EH coordinators are of the same opinion.
- A second advantage of such a tool is that it gives a framework to guide research for input data and to sort internal & external information. It enables thus a company to make an overall assessment of environmental & health aspects based on company specific strategies and values.
- As mentioned in the limitations, the tool does not provide clear ranking intervals. However, the accuracy of the tool comes from the input data used and the discussions among the expert group. The author believes that this approach gives a result which is accurate enough to be used by the company. Besides this, it is more assured that a more detailed knowledge persists.
- Even if time is needed for collection of data and the material assessment, this work is only done once for each material. Besides this the author believes that the use of the material selection tool can save a lot of work, stress and confusion among employees in the future which might arise due to stricter regulations, more competition or higher demands of customers.
- As the tool is used in a very early stage of product development and gives a general environmental and health assessment for materials it is possible to use its results even on a management level. The management group can thus include an environmental and health perspective in decision making of which materials should be used at IoS and which not.

6.6 How can other organizations benefit from this study?

The tool in this study has been specifically developed for the conditions at the case company. However, the experiences can be used in different circumstances. In the recommendations it is explained how other organizations could go about to develop a similar tool.

The main interest other organizations might have in this study is whether or not it is useful to develop such a tool. In the prevention ladder of Brezet & Hemel (1997), the selection of alternative materials is on the second highest rank, only topped by the development of new product concepts. Obviously, assessing environmental aspects of materials instead of finished products is an important step towards better prevention. Brezet & Hemel (1997) state that very few companies have reached this stage today. The advantage is that materials with characteristics which are unfavorable to the environment or human health can be excluded from a company's purchasing list. In the long run this might lead to a positive list of materials used at the company, an idea which Skanska Sweden has taken up with the e-purchasing tool (as explained in section 2.2.2).

Due to external policy drivers, companies have put a lot of effort into the elimination of hazardous substances in products. The idea behind a material selection tool goes beyond this as it suggests eliminating or substituting those materials which do not fit company-specific environmental and health criteria. This approach might be interesting to any company which wants to go beyond the normal. If looked at isolated from other tools at the case company, a limitation of the material selection tool is that it gives an indication of which material is favorable from an environmental point of view compared to another one but it does not give an indication on which material is best to be used in a certain product. Therefore, a material selection tool as presented in this study has to be accompanied by other tools which support this sort of decisions.

Other organizations might wonder if there are different ways of selecting alternative materials. One option could be a simple checklist for EH coordinators. On this base they could discuss advantages and disadvantages of different materials from the point of view of risk potential for the company including scientific and internal-political factors. This would be an even more qualitative approach, however including a common assessment of materials using the knowledge in the company and extending the environmental knowledge of the expert group. A second option would be the assessment of materials using information available in an LCA database. In this case, employees have to be educated in understanding and using the database and a limitation is that the LCA information is not customized to a company's internal strategies. It seems as if the material selection tool is a mid-way between these two approaches.

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7 Conclusions and Recommendations

7.1 General Conclusions

This thesis deals with the development of a tool for environmental assessment of materials which is adapted to a company's needs and conditions. The aim of the tool is to enable the case company to rank company specific materials from an environmental and health perspective. The tool is used both in an early and later stage of product development.

For the adaptation of the tool to a company's needs and conditions, several factors are considered to be important: 1) A very clear aim of the tool and a clear anchoring of the tool, 2) the integration of the tool into the present company structure, 3) the accuracy of the results needed to make it a useful tool for the company and 4) a clear target group which uses and benefits from the results of the tool. This includes the user-friendliness of the tool. The accuracy of the results depends mainly on the input data used together with the discussion among and competence of the expert group at the company.

The main limitation of the tool is the time needed for the collection of input data and the assessment of materials. However, the author believes that the limitations are outweighed by the benefits of such a tool. The main benefits are 1) better trained employees when it comes to environmental and health aspects of materials, 2) a framework for sorting and structuring internal and external information on environmental and health performance of materials and 3) the input of assessment results to the management level which might influence company decisions at a very early stage of product development.

For other companies, this study is useful as it points the way towards a more holistic tool for environmental and health assessment compared to the mainly chemical-substance-focused approaches discussed in section 2.2.2. During the course of the research, the author has not found a tool currently used at a company which has the same approach. It is therefore suggested that the tool is an example for a proactive approach of a company to tackle the problem of material selection during product development. This might be a way towards environmentally sound and healthy products. Especially for the future if external pressure, e.g. stricter regulations or customer demands, arise this tool might be very useful. The material selection tool developed in this thesis is however company-specific and only works in combination with the other tools used at the company. Therefore, any other company interested in the tool has to evaluate in which regards the material selection tool has to be adapted.

The material selection tool, as well as IKEA's other tools such as specifications and e-wheel method can be summarized as tools for eco-efficiency[46]. Its goal can be summarized as reducing the impact of companies on nature. McDonough & Braungart (2000) coined a different approach called eco-effectiveness: "Even the most rigorous eco-efficient business paradigm does not challenge basic practices and methods: a shoe, building, factory, car or shampoo can remain fundamentally ill-designed even as the materials and processes involved in its manufacture become more 'efficient' ".

[46] Eco-effectiveness is coined by the World Business Council for Sustainable Development (WBCSD) and is concerned with three objectives: reducing the consumption of resources and the impact on nature and increasing product or service value (Lehni, 2000).

The heart of this approach is "to work on the right things – on right products, services and systems – instead of making the wrong things less bad". Once working on the right things it is fine to use efficiency as one of the goals to achieve this. IKEA's challenge lies in choosing and going towards an approach of "doing the right thing". Any tool can just do as good as the aim it was made for.

7.2 Recommendations to the Case Company

This section describes specific recommendations to the case company. The recommendations can be divided into general recommendations and specific recommendations for the further development of the material selection tool.

General:

Besides the development of the material selection tool, this study points to two main areas in which employees should receive more education in order to improve IoS knowledge on materials: 1) the inclusion of environmental and health aspects into material education for product technicians and others of the target group, 2) the education of EH coordinators in the use of the LCA database Idemat.

Material selection tool:

1. In general, the case company has to examine if the knowledge gained through the use of the material selection tool is worth the time it will take for development and updating.

2. The general criteria have to be adapted to each material group used at the case company.

3. The results of the tool have to be tested on the usability for the target groups: management level and product development team.

4. The case company has to set up an administration for the tool: Who is responsible for further development of the tool, for the assessments, for the updating of the assessments and for documentation of the work?

5. Time and money efforts increase with reliability of data and IoS has to decide on how accurate the input data has to be. This is to decide during continued testing of the method.

6. The expert group should strengthen relations with other departments, e.g. IKEA Trading as it is important that members of the expert group gain a good expertise on what information is available at other departments.

7. Material experts at IoS have expertise knowledge on their specific material groups. This knowledge, although not specifically in environmental and health issues, should be used extensively as input for the material selection tool.

8. One aim of use of the material selection tool is the use of the results during the e-wheel method. The case company has to check if results of the tool are useful for this purpose.

9. In order to ensure that the common expertise on material increases among the members of the expert group, it is suggested that the assessments should always be done by the same core group of people. The expert group has to evaluate if the discussion help to gain common expertise.

10. The case company has to assess a wide range of materials. Before start, the company should decide on which material groups to prioritize.

7.3 Recommendation to companies interested in developing a similar tool

The tool developed during this study is of value for companies interested in a holistic assessment of materials from an environmental and health perspective. As personnel with a wide range of expertise at the respective company are needed, it is probable that mainly medium to large sized companies have the human resources to develop and maintain such a tool. Any company interested in this tool should however carefully evaluate already existing structures as this tool has been developed specifically for the organisational environment of the case company.

Other organisations can benefit from this study as some general steps can be deducted from the study on which steps should be taken by an organisation to develop a similar tool:

Step 1: Evaluation of conditions and needs at the company

The company has to carefully evaluate the necessity and the precise purpose of the material selection tool. Besides this, it is necessary to evaluate the needs of the target group which will use the tool. For example, the company has to evaluate the level of material expertise of the target group in order to set the results of the tool at the right detail level.

Step 2: Evaluation of present state at the company

In this step the company has to evaluate which strategies, values and attitudes of the company should be the base for the tool. This prioritization can be done by the environmental management group or by reviewing current strategies of the company. Second, the company has to evaluate which tools already exist at the company which might be related to the material selection tool. This is to make sure that no redundant tools are developed and to set the material selection tool in relation to present tools and structures at the company.

Step 3: Should the tool be developed internally or externally?

For this step it is important to evaluate if there is enough competence, learning interest and available time among employees so that the environmental assessment can be done internally. If this is not the case it might be better to outsource the development and maintenance of the tool. It should as well be evaluated which employees at the company have key competences (e.g. material experts, trading experts, environmental/health/chemical experts) and who can be made responsible for the development and maintenance of the tool.

Step 3: Developing the criteria

The criteria are developed according to the prioritized internal strategies, regulations and values identified during step 1. The company should evaluate which sort of input data related to the specified criteria is already available internally and to what extent the company has access to external environmental and health data (e.g. LCA databases, ongoing projects where the company is involved). The company has to make internal decisions to set the ranking intervals for each criterion and to set the importance of each criterion in relation to the other criteria.

Finally, the company has to apply the tool on several materials in order to test its functionality, the decision making process of the assessment group and the outcomes.

7.4 Recommendation for further research

IoS interest in a material selection tool is the base of this thesis. It would therefore be interesting to do a study on other companies' interests and needs of such a tool. In the course of the project, no companies were found which already use a material selection tool at the same early stage of product development. It would be interesting to do a more comprehensive study on tools of other companies: how are they adapted to company specific strategies and how are they integrated in the company organization.

In the beginning, it was thought to develop as well criteria for social/ ethical and health aspects. During the study it became clear that these research areas are almost unexplored and it was impossible to cover all of them. If working with social and ethical aspects, companies today restrict themselves to work with supply chain management and there has been done very little research on the integration of social/ ethical aspects directly into product development (compare e.g. to Tischner & Charter, 2001). Further research should be done on these issues. Companies and organizations have started to address health aspects. More research has to be done in how to integrate health aspects during the whole product life cycle into product development.

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List of Interviewees

At IKEA

The case company prefers not to mention the names of interviewees, therefore a list of the functions interviewees have at the company is included here:

EH coordinators at IoS: 3

Environmental & Chemical Expert, IKEA Trading China/Global

Environmental Competence Group at IoS: includes EH coordinators, ordered study, supported the study through several meetings

Environmental Specialist at IoS

Good & Healthy Product Coordinator at Modul Service

Material experts at IoS: 3

Product developers at IoS: 4

Product technicians at IoS: 4

Quality & Environment Coordinator at Trading

Range coordination at IoS

Social and Environmental Manager at Supply Chain

At other organizations

Brown, Michael S., Consultant Michael S. Brown Associates, Santa Barbara/ USA, telephone interview, 18 August 2005.

Flemström, Karolina, project leader IMPRESS at CPM, Chalmers University, Gothenburg, telephone interview, 15 August 2005.

Skogsmo, Jan, Chairperson Swedish Metal Finishing Association (SYF), IVF Gothenburg, telephone interview, 23 September 2005 and email contact (Re: ex-jobb material guide/ytbehandlingar hos IKEA of Sweden), 26 September, 2005.

Ståhl, Mattias, Consultant Kemi & Miljö, Stockholm, telephone interview, 15 September 2005.

Abbreviations

BA	Business Area at IoS
ECG	Environmental Competence Group at IoS
EH coordinator	Environment & Health Coordinator
IoS	Ikea of Sweden
IPP	Integrated Product Policy
IWAY	IKEA's Code of Conduct for relations with suppliers, IWAY stands for "IKEA's way on Purchasing Home Furnishing Products"
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
MIPS	Material Intensity per Product /Service, Design for Environment tool developed in Germany (Schmidt-Bleek & Tischner, 1992)
MSDS	Material Safety Data Sheet
PD	Product Developer
PRIO	Web-based tool designed by Swedish Chemical Inspectorate to minimise risks on health and environment due to use of hazardous chemical substances
PT	Product Technician
REACH	EU proposal for EU Directive on chemicals, REACH stands for Registration, Evaluation, Authorisation of Chemicals
REPID database	A database developed by CPM at Chalmers University during project with railway industry, contains data on recycled fractions of materials/ products
RoHS	EU Directive RoHS on the restriction of the use of certain hazardous substances in electrical and electronic equipment
S&E	Social and Environmental
Trading	Trading unit of IKEA Group, responsible e.g. for work with suppliers

Appendix 1: Questionnaire to Product developers & technicians

About interviewee:

Date, Name, Profession, Tasks at IoS, at IKEA since

About product development process:

1. Draw and explain the product development process at your BA
2. At what stage are product developer, designer, technicians, product council, suppliers, purchasers involved?
3. At what stage in PD do you make the decision which material is used?
4. What factors influence your choice of materials during product development?
5. Which materials do you mainly work with?
6. What kind of systems and tools are you using at what stage in PD?
7. Do you use the e-wheel method? If yes, who does the analysis? Do you see any problems in using it? If you do not use it, why not?
8. Who makes decisions/ has most influence (who can say no) during product development?
9. Who has responsibility if something goes wrong?
10. Do you interact with other BAs during product development? If yes, why?

About Knowledge:

11. Have you worked/ are you working with environmental or health aspects at IKEA?
12. What does environmental, health aspect mean to you in product development, how would you explain it?
13. (Has IKEA influenced your environmental behaviour? Give an example)

Inclusion:

14. At what stage of product development are environmental/health aspects considered?
15. Who at your department knows about environmental/health/ social issues?
16. How do you communicate environmental, health, social aspects to your suppliers (e.g. included in technical description)?

Additional questions

17. Do you feel responsible for the product you develop when it comes to safety, environmental, health and social aspects?
18. How do new ideas, e.g. on new materials or new technologies evolve at IKEA?
19. What problems do you see/ have you experienced to introduce env/health considerations in PD?
20. Would you use a material guide? What should be included, how should it look like to make it usable?

Appendix 2: Environmental Information available in LCA database Idemat

The information has been viewed in August 2005.

Textiles:

Environmental information available for carbon based textiles, e-glass fiber, cotton, synthetics (aramid, polyester),

No environmental information available for half synthetics (ethyl cellulose, viscose), ramie, nylon, silk, wool, synthetics (dyneema, nylon), vegetable (banana, coir, felt, flax, jute, ramie, sisal, starch)

Ceramics:

Environmental information only available for traditional ceramics (earthenware, porcelain, stoneware)

Glass:

No environmental information available other than ex/in energy.

Laminates:

Environmental information available

Ferro metals:

Environmental information available for cast iron, stainless steel, steel.

Metals non ferro:

Environmental information is available for aluminium, copper, magnesium, nickel, cadmium, chromium, cobalt, lead, manganese, molybdenum, palladium, platinum, rhodium, tin, tungsten, vanadium.

No environmental information is available for gold, beryllium, bismuth, mercury, silver, tantalum, uranium

Fuels:

Environmental information is available for coal, crude oil, diesel, kerosene, LPG, natural gas, petrol (for some only eco indicator 95).

Leather

Environmental information is available.

Liquids:

No Environmental information is available, liquids listed are: acetone, alcohol, glycerol, silicon oil, sulphuric acid, water.

Polymers:

Environmental information is available for:
ABS general purpose, HDPE, LDPE, LLDPE, PMMA, PP, PS, PVC soft & hard,

Elastomers (butadiene rubber, natural rubber, nitrile rubber, styrenebutadiene rubber,
engineering (PA 6, PA66, PB, PC, PET, PET bottle grade, SAN),
foams (PE exp, PS exp, PUR flexible & hard foam, reinforced (ABS GF30, PA6 GF30, PA 66 GF30, PC GF30, PET GF30, PP GF30 and
thermosets (EP, MF, PUR, UF).

No environmental information is available for:
agrobased polymers (e.g. cellulose, starch),
elastomers (chloroprene rubber, chlorosulph. PE, liquid silicone rubber, silicone rubber, urethane rubber).

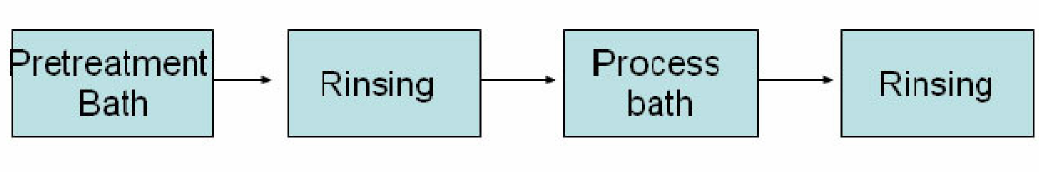
Wood:

Environmental information is available for all wood types class 1 (e.g. teak), class 2 (e.g. cedar), class 3 (e.g. African mahogany), class 4 (e.g. birch), class 5 (e.g. ash).

Appendix 3: Introduction to metal finishing

Metal finishing means the alteration of a material's surface properties in order to increase corrosion or abrasion resistance, alter appearance or enhance utility of the product (Noyes, 1993). Most operations are batch operations during which the work pieces are dipped into and then removed from baths containing various reagents for achieving the required surface condition. Figure 12 summarizes the main steps of a surface treatment operation.

Figure 12: Main steps of surface coating operations



Source: Ekengren et al., 1993

Surface treatment operations can be separated in different categories:

1) Chemical and electrochemical conversion (non-metallic coating): designed to deposit a coating on a metal surface that performs a corrosion protection and/or decorative function, in some instances it is a preparation for painting. An example is chromating. The coatings provide some corrosion resistance but the main function is as a base for the adhesion of paints, lacquers and oils to the metal surface. Chromate coating is applied to minimize rust formation and to guarantee paint adhesion.

2) Hot dip deposition: this process means that the object is dipped into a bath with the coating metal; an example is galvanization where the object is dipped into a bath with molten zinc.

3) Electroplating: this is done by passing an electric current through a solution containing dissolved metal ions as well as the metal object to be plated. The metal object acts as a cathode attracting metal ions from the solution which are then deposited on the metal object. (Noyes, 1993)

The surface treatment industry is related to a large amount of environmental problems. Metal and chemical substances are the base of the metal finishing industry. Potential problems are soil contamination, surface water contamination through spills, high amounts of waste water and hazardous waste in the form of sludge, improper storage/ transportation of waste and the improper handling of process chemicals (UNEP IEO, 1997). The environmental impacts of metal finishing operations depend on the type of process, local conditions and on the management at the individual plant.

In product development, the choice of the surface coating is usually done in a later stage and the main factors which decide on which coating is used are demands on the function and quality of the finished product, the availability of the material (supply, price), workability/ durability of the bulk material and demands of the expected environment in which the finished product will be stored, transported and used (Ekström, 1994).

Chromating

Chrome is extracted from chromite (Cr2FeO4). Chromating is an inorganic coating or passivating process. Items for passivating are generally dipped in the passivating solution, which consists of an aqueous solution of inorganic chemicals, traditionally based on chromium trioxide or sodium dichromate. No electricity is needed. Chromating is usually only one in a series of treatments to protect the base metal. The concentration of chromium chemicals in the solution can vary depending on the metal being protected. (European Chemicals Bureau, 2005)

Chromating is mainly used on electrolytic zinc-plated material in the fine mechanical and electronic, construction and car industry e.g. screw nuts, screws, components in cars, household devices and furniture. Chromating is used as corrosion protection for indoor use, has good adherence for paint, improves look of zinc and cadmium surfaces and is a protection for storing, transporting and handling of the base material (Nordänger, 1997). It is put on the base material through dipping, spraying or painting. The chrome source for chromating consists of different chemical combinations of Cr VI. The base materials which can be chromated are zinc, cadmium, aluminium, magnesium, copper, massing, tin and silver. During the chromating process, the chrome ions in the chromating bath bind with the metallic surface of the base material and create a film of chrome and metallic oxides on the base metal. Different chromating solutions are used for different materials and the results differ in colour, depending on the type of coating whished and the type of base material. For zinc, blank (blue), yellow, green and black chromating is used while for cadmium blank, yellow and green chromating is used. Aluminium is coated by yellow or blank chromating. The blank chromating process mainly used CrIII and a low amount of Cr VI. Cr VI is available in form of chromate, dichromate or chromatic acid.

Galvanisation

The metal part that is to be coated is dipped in a bath of molten zinc. Before galvanization, the metal part is often pretreated by degreasing or/and chemical cleaning/pickling. Fluxing agents are used on the surface of the piece of work to remove oxide that is formed between the pickling and the dipping in molten zinc. The fluxing agent also serves to dissolve zinc oxides which are formed on the surface of the zinc bath.

After the work pieces have been dipped in the zinc bath, they are cooled, which can be done either in air or in water.