CHALMERS

Design for the Environment in context of environmental demands and business opportunities

A study of Autoliv Inc.

Master of Science Thesis

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Populärvetenskaplig beskrivning

Miljöanpassad produktutveckling handlar om att skapa resurseffektiva produkter till största möjliga nytta både för konsumenter och för samhälle till minsta möjliga miljöpåverkan. Bilsäkerhetskoncernen Autoliv har möjlighet att styra produktens miljöpåverkan mot maximal resurseffektivitet genom medvetna val tidigt i produktutvecklingsprocessen. Låg resursförbrukning, såsom lägre energiförbrukning och materialåtgång med bibehållen funktionalitet, kan i sin tur leda till sänkta kostnader under produktens hela livscykel. Dessutom kan detta stärka konkurrenskraften då kunderna erbjudas ett ökat mervärde för produkten. Inom ramen för detta diskuterar examensarbetet bl a:

- hur trender och omvärldskrav ser ut för miljöanpassad produktutveckling
- exempel på hur andra företag har valt att organisera sin miljöanpassade produktutveckling
- hur bästa miljöprestanda kan identifieras, vilken organisation som behövs och hur resultaten kan omsättas till konkreta åtgärder under produktutvecklingen

MASTER OF SCIENCE THESIS, REPORT No. 2006:10

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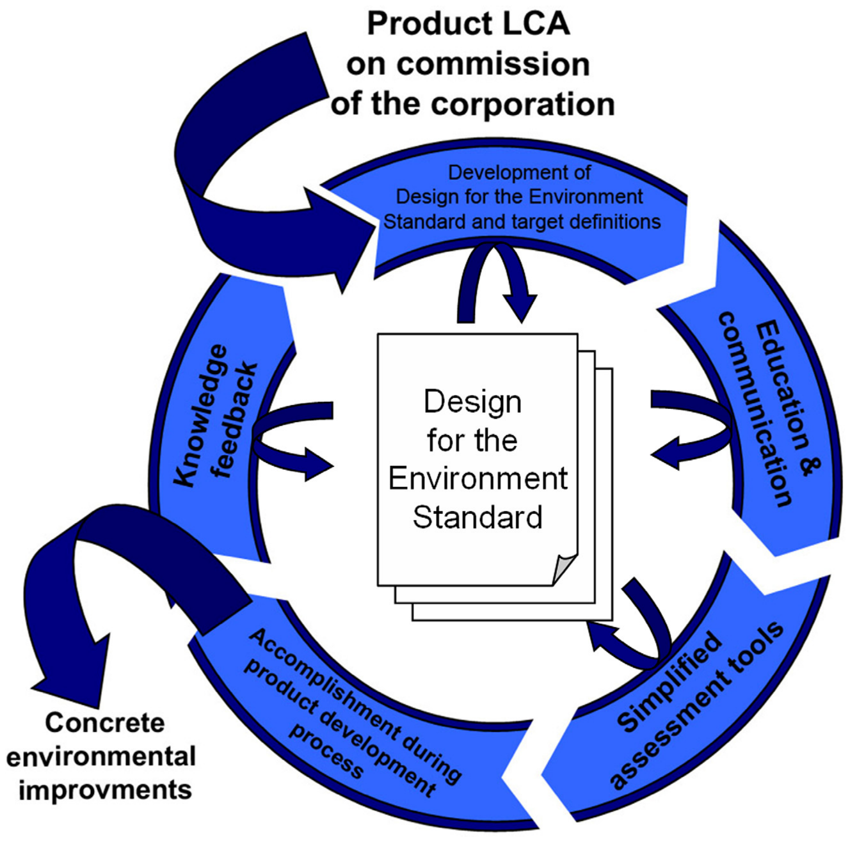

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Preface

The perspective of human being of the world is dynamic. The insight changed dramatically after Christopher Columbus 1492 discovered America. The imperial countries entered a new era, - the modernity that would last for 500 years[1].

During this period intellectual fundamentals for the society by the revolution of science were set and the modernity became based upon three fundamental presumptions of the nature - the nature is understandable, can be controlled and subordinated human being. None of these are still unrestrictedly valid. Nature is truly complex and can not be fully controlled. Stochastically coincidences always occur and make predictions uncertain, e.g. consider the scientists attempt to predict the consequences of the global warming.

The french gentleman, Antoine de Saint-Exupéry said[1]: *"-Nous n'heritons pas la terre de nos ancêtres. Nous l'empruntons à nos enfants!", "-We do not inherit the earth from our parents; we borrow it from our children".* It's an axiom; the human being is a part of the nature and the way she acts settle the rules for future generations. Everything has a price in the thermo dynamical coherence. Each act costs energy. In this nature's economy, our destiny is depending on how we balance our wishes with available resources. From a holistic perspective, a company sooner or later will have to deal with these prerequisites and contribute to a sustainable future as a part of the society. However, adaptive companies that constructively deal with these questions in time may also benefit from optimisation of resources and, ultimately finding profitable new inventions when old solutions turn out to be environmentally inconvenient. The Design for the Environment program can be a company's methodology to meet this dynamic future.

This thesis describes how environmental analyses can be converted into concrete actions in the product development process and how to implement a Design for the Environment program within Autoliv. It is the final moment of my education for a Master of Science in Environmental Science at the Department of Environmental Science and Conservation, University of Gothenburg, accomplished on commission of Autoliv Inc. during the period of 2002 to 2005.

I have come to owe many thanks to several persons during my thesis work. Special thanks to supervisor and examiner Ann-Marie Tillman, Professor at Environmental Systems Analysis, Chalmers University of Technology and instructor Torbjörn Andersson, Autoliv Development. A key to the thesis has been the interviews. Thus, I will thank the following for enthusiastically participation; Britt Andersson and Erik Bergman at Saab Automobile AB, Elisabeth Dahlqvist at Volvo Car Corporation, Eva Axelsson at AB Volvo Penta, Christer Wallin at Kendrion Holmbergs AB and Matti Weineland at Gustavsberg Vårgårda Armatur AB. Finally, I thank my family for forthcoming comments and understanding during the work of this thesis.

Gothenburg, February 2006

Johan Dahlström

[1] Sörlin, S. Naturkontraktet. Om naturumgängets idéhistoria. Carlssons förlag, 1991.

Abstract

Design for the Environment in context of environmental demands and business opportunities
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Design for the Environment or Green Design describes how to develop recourse optimised products with maximised performance for both consumers and society to a minimum of negative environmental impact. The thesis describes how environmental assessments can be transformed into concrete actions during the product development and is based partly on literature studies, partly on interviews with five companies. The interviews show that a proactive and structured Design for the Environment program is founded on knowledge about the environmental impact factors during the product life cycle and how these factors shall be treated. Knowledge transformed into clearly expressed targets and requirements founds a qualification to continuously develop the products' environmental performance. In turn, this requires both a working organisation and communication channels.

Autoliv advantageously performs life cycle assessments for representative product categories to identify the products' actual environmental impacts and possibilities for development. Since Life Cycle Assessment is founded upon knowledge based assessment, delimitations and the main procedure are important for the interpretation of the results. Therefore, experiences from the performance have a special value of knowledge.

To guarantee continuity in the corporate environmental work, an environmental affairs co-ordinator suitably is appointed. Its purpose will be, based on analysis results and external requirements, to structure and communicate the corporate requirements and knowledge to the product development organisations as well as collect its feedback. The communication can be facilitated by a corporate Design for the Environment standard completed with different training. The requirements of this standard are cross-linked with the two corporate standards that prescribe the Autoliv product development process. Most important are the connections in the two first steps of the product development process, where most possibilities to improve the product's environmental performance are found. Checklists, matrices or other simplified analysis tools can then also be time effective tools to utilise in the local projects. Most important in the final step of the development process is the feedback of experiences from the project.

An additional tool is Autoliv Material Data System. The information in the system can be used for monitor of hazardous substances and output of weight. In the long term, the system can also be an important tool for Life Cycle Assessments, as it can be utilised for inventory data input, as well as supporting selection of environmentally suitable materials.

As it appeared, among others during the interviews, environmental requirements aimed at product development were experienced as insufficient. Especially, follow up and validation have been poorly prioritised which inhibit development. Nevertheless, the foremost incitement to focus on Design for the Environment is to optimise resource efficiency, which in all steps gives the company both economical and environmental profits but above all contributes to a sustainable development of the society.

Keywords: Design for the Environment, Green design, Autoliv, Life Cycle Assessment, Swedish Automotive industry

Sammanfattning

Design for the Environment in context of environmental demands and business opportunities
A study of Autoliv Inc.

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Miljöanpassad produktutveckling handlar om att skapa resurseffektiva produkter med största möjliga nytta både för konsumenter och för samhället till minsta möjliga miljöpåverkan. Avhandlingen beskriver hur miljöanalyser kan omsättas till konkreta åtgärder under produktutvecklingsprocessen och baseras dels på litteraturstudier, dels på intervjuer med fem företag. Intervjuerna visar bl. a. att ett pro-aktivt och strukturerat miljöarbete i produktutveckling bygger på fakta om miljöpåverkande faktorer under produkternas livscykel samt hur dessa skall hanteras. Omsätts kunskaperna till tydliga mål och krav skapas förutsättningar för kontinuerlig utveckling av produkternas miljöprestanda. Detta förutsätter i sin tur både en fungerande organisation och kommunikationskanaler.

På Autoliv kan livscykelanalyser genomföras för representativa produktgrupper för att ge en bild av miljöpåverkan och utvecklingspotential. Då livscykelanalyser bygger på faktabaserad bedömning har tillvägagångssätt och avgränsningar betydelse för tolkningen av resultaten. Erfarenheterna från genomförandet har därför ett speciellt kunskapsvärde.

För att säkerställa en kontinuitet i koncernens miljöarbete utses lämpligen en miljöfunktion. Dess syfte blir att utifrån analysresultat och omvärldskrav strukturera och förmedla koncernens miljökunskaper och krav ut till produktutvecklingsorganisationerna liksom att återkoppla dess erfarenheter. Kommunikationen kan ske med hjälp av en koncernstandard för miljöanpassad produktutveckling kompletterad med olika former av utbildning. Standardens krav korslänkas då med de två koncernstandarder som beskriver Autolivs produktutveckling. Viktigast är kopplingarna i produktutvecklingens två första faser där möjligheterna att påverka produktens miljöprestanda är störst. Då kan checklistor, matrisverktyg eller andra förenklade analysverktyg också vara tidsmässigt effektiva verktyg att använda i de enskilda projekten. I slutet av utvecklingsprocessen är däremot återkopplingen av erfarenheter från projektet viktigast.

Ett kompletterande verktyg är Autolivs materialhanteringssystem. Informationen i systemet kan användas för övervakning av farliga substanser och viktsutfall. På sikt kan systemet även bli ett viktigt verktyg för livscykelanalyser, dels som källa till inventeringsdata, dels för att välja miljömässigt lämpliga material.

Att bilindustrins miljökrav mot produktutveckling upplevs som bristfälliga framkom vid bl. a. intervjuerna. Speciellt prioriteras uppföljning och validering lågt vilket hämmar utvecklingen. Ändå borde främsta incitamentet för miljöanpassad produktutveckling vara optimal resurseffektivitet som i alla led ger företaget både ekonomiska och miljömässiga vinster men framförallt bidrar till en hållbar samhällsutveckling.

Nyckelord: Miljöanpassad produktutveckling, Autoliv, Livcykelanalys, Svensk bilindustri

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Appendices

1 Purpose

The purpose of the thesis is partly to theoretically describe how environmental assessments can be justified and converted into concrete actions in the product development process. Partly propose a practical procedure to implement environmental performance in Autoliv product development process.

2 Methodology

A literature study has been done to give a general overview and deployment of established Design for the Environment tools and methods used to measure environmental performance. The study has focused partly on product concepts and tool aimed at the research, partly on methodologies and tools for product development. The study was mainly based on literature from publications in scientific journals like Journal of Cleaner Production and The journal of Sustainable Product Design together with reports from various institutes, both Swedish and international.

Interviews at five companies have been accomplished with one or two Design for the Environment responsible employees at each company, to supplement the literature study. The interview started out from a pre-made form and proceeded from 1,5 to 3,5 hours at each company. The results from interviews are important for the thesis as it describes how environmental aspects in product development process can be identified, evaluated and communicated to the organisation and how the improvements are verified in practice.

With help from internal standards and requirements in customer technical specifications, the product development process and environmental work within Autoliv has been described.

2.1 A critical review of the methodology

Since only one or two persons at the supplier companies were interviewed it is important to mention that the opinions expressed are the opinions of the interviewed person or persons. It is therefore possible that the opinions do not reflect the company as a whole. There might have been misunderstandings during the interviews but that was tried to be avoided by short summarizes at the end of or during every interview. Further, all interviewed have proofread the interviews and have had the possibility to comment. Nevertheless, interviews are always subjective since the dialogue is continuously interpreted by the people involved.

3 Introduction

The post-industrial environmental problems seem to be more complex and more diffuse as more all mankind learn and the time goes on. The time when a major environmental problem was similar with a leaking oil cistern on a backyard resulting in a locally contaminated rill, that was comparable easy to do something about is partly passed, at least in the Western world.

The industry has changed the environmental focus during the last decades from End-of-pipe approaches in the 80ies to the trend of Design for the Environment approaches from 2000 and after. Above prevention and control of local pollution from factories, the industry has to deal with more and more complex environmental problems, where the cause-effect chain can be very long and difficult to identify and understand [29]. Lack of understanding might lead to short perspective management decisions that prevail isolated environmental beneficial actions but necessarily not in sounding improvements.

The central question for this thesis is how the complex environmental problems are identified, communicated and handled within the engineering industry. Within a company, one idea to deal with these problems is the Design for the Environment program. Design for the Environment can be described as a process with methodologies to implement environmental aspects in the product development process in a structured manner. There are several reasons for an implementation of a Design for the Environment program. Common are satisfaction of customer demands, reduction of manufacturing costs and lightening of regulatory burdens [12]. However, an implementation of a Design for the Environment program is foremost a strategic planning that is related to a long-term perspective and investments may have a long payback time [12, 29]. For a local company, that requires carefully deliberated decisions based on, for instance, future legislative situations and the development of the world around.

Tools intended to support this process and achieve a more environmentally adapted product design includes a wide array of environmental assessment methods and management tools. The supply of tools covers quite simple checklists as well as very complex software tools including comprehensive databases. Many tools are based upon Life Cycle Assessments, LCA, which has been developed during little more than a decade. The science of LCA methodology and procedure has grown and developed significantly during these years and much has been published in scientific journals [3, 13].

The success of an implemented Design for the Environment requires a broad engagement of the company organisation where communication is important. There are many examples of disconnected information between people involved in the Design for the Environment development, like environmental departments, the "Design for the Environment program" employees that creates the tools and finally the rest of the development organisation [12, 24, 25, 26, 29].

Autoliv has actively taken part in the area of environmental problems for several years, foremost via the implementation work of environmental management systems within each single plant. As this work has proceeded, the understanding for significant environmental impacts has increased and, above the local environmental work within the production area, the company also has intensified the focus on environmental aspects in the product development process and the ideas behind the Design for the Environment program.

4 Background to the Design for the Environment program

During the last century, and especially under the last decades, mankind has realised that many social and ecological problems are common for all countries in the world. Global problems, like environmental pollution, population growth, anthropogenic climate change, and increasing demand are expected to be doubled in the next decades. The human way of living in the world has to be changed if the conditions of living for future generations should be guaranteed. Overexploitation on nature and nature resources together with pollutions caused by human activities affect these conditions of living. The demands not to abuse the non-renewable primary resources, on which our quality of life is based, has to be solved if the human being should have an future on Earth.

To manage all these complex and diffuse environmental problems, discussions have lead to the idea of sustainable development as a possible solution of the dilemma [1, 20]. This chapter describes the structure of some concepts aimed at measure of needs and assesses changes to meet a sustainable development. A development that forms the most fundamental conditions to work with Design for the Environment.

To obtain a sustainable development, there are several strategies and concepts developed and in this thesis, only a number of these related to Design for the Environment are presented.

The following text describes a generic model, over the foundation of a sustainable development and the connections with tools aimed at Design for the Environment. Thus, the model is applicable for many frameworks aimed at describe a sustainable development and the concept of The Natural Step Framework is chosen here only as an example of one model. In addition, some other concepts for sustainable development that supplement the following model are described in chapter 4.1.

The Natural Step has its origin in an international non-governmental organisation, with the purpose to facilitate an ongoing dialogue between scientists, decision-makers and public policy [1, 47]. The framework is mainly designed for qualitative problem analyses, planning of society and for the development of investment-programs in business corporations.

The tools and concepts to support the ideas of sustainable development have mainly the same purpose but the variety of deliveries has led to some confusion regarding differences and linkages between various tools, the qualities, and consequently, questions on how best to apply them. Comparing with results from similar tools can simply point at different directions or even contradict to each other. For a comprehensive planning in any complex system in general, K.-H, Robért et al. [1] describes the value of delineating five hierarchically different system-levels and maintain the distinction between the levels when planning, Figure 4-1.

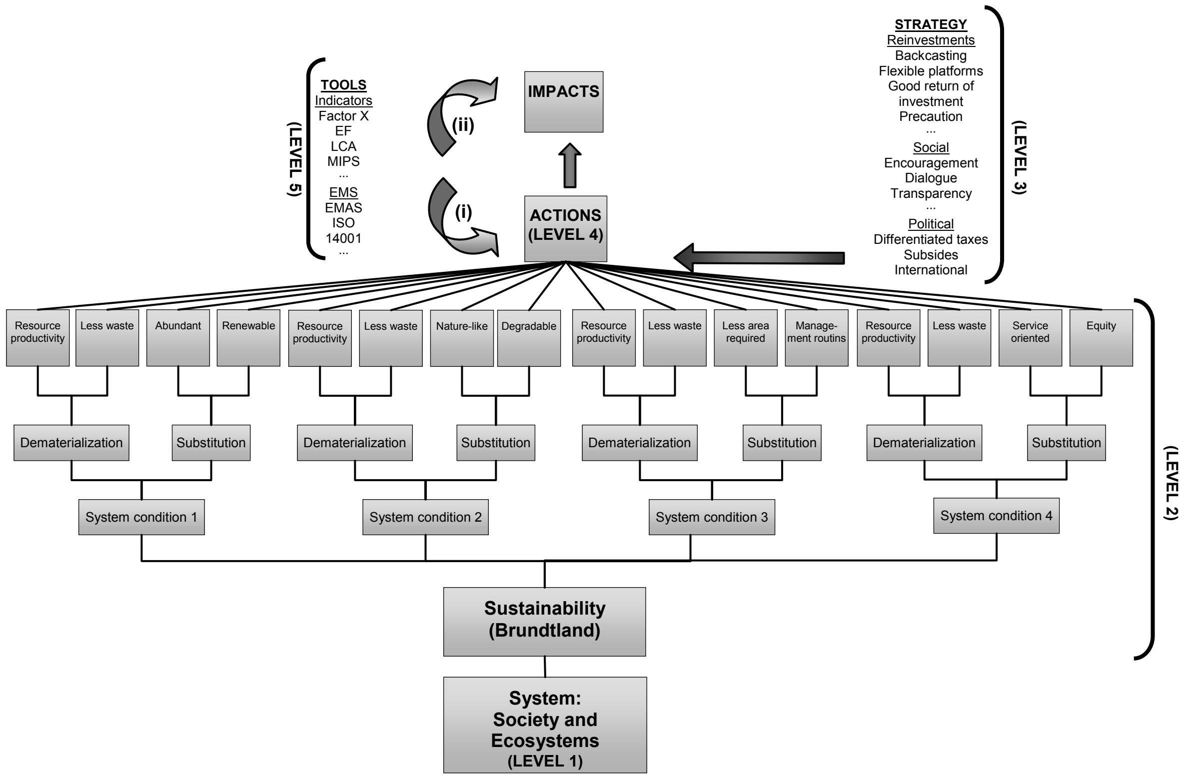


Figure 4-1: Description of five hierarchically system-levels according to K.-H. Robért et al. [1].

If this model is applied on the complexity of the idea of sustainable development, the five levels can be described as follow:

1. Principles for the *constitution* of the system, e.g. ecological and social principles.
2. Principles for a favourable *outcome* of planning within the system, e.g. *principles for sustainability.*
3. Principles for the *process* to reach this outcome, e.g. *principles for sustainable development.*
4. *Actions, i.e. concrete measures* that comply with the principles for the process to reach a favourable outcome in the system, recycling and switching to renewable energy.

5. *Tools* are needed for several purposes. To control actions on level 4, tools are used to conclude the relevance of actions with reference to principles for the process, e.g. indicators of flows and key-figures to comply with principles for sustainability. Examples are the Factor concepts, described in chapter 4.1. Further, the activities in level 4 have to be monitored and audited and tools for management purpose are for instance environmental management systems, described in chapter 5.2.1. Other tools are needed to assess impacts and the reduction of these, e.g. ecotoxicity and employment, as a consequence of strategically planned societal actions. Examples of these are tools for quantitative assessments of the objective of meeting the system conditions and for indication of progress, e.g. Life Cycle Assessment, described in chapter 5.1.1.

More in detail, level 1 describes the overarching system, which focuses on societies and all the surrounding ecosphere (i.e. the full space between the lithosphere and the outer limits of the atmosphere). Fundamentals like thermodynamics, biogeochemical cycles and societal exchange with, and dependency on, the ecosphere have to be understood on this level.

Level 2 states the implication of sustainability within the ecosphere, which was formulated a philosophical definition in the Brundtland Commission report: "To meet the needs of the present without compromising the ability of future generations to meet their own needs" [9].

The concept of The Natural Step Framework has its main focus on this level and describes non-overlapping conditions for social and ecological sustainability – the Four System Conditions. Three of these state the conditions of an ecological sustainability, while the fourth state the requirement to meet human needs, framed by the other three statements. The focus on both ecological and social factors is not unique for this concept only, and a working synergism between these it is generally considered to be fundamental for a true sustainable development [1]. Summarised, the four systems conditions state:

1. Concentrations of substances extracted from the Earth's crust may not systematically increase.
2. Concentrations of substances produced by society may not systematically increase.
3. Degradation by physical means may not systematically increase.
4. Society human needs are met worldwide.

These four conditions can then be subdivided in two basic mechanisms; *dematerialization*, i.e. reduction of material flows, and *substitution*, i.e. exchange of type/quality of flows and/or activities. Further, these two mechanisms can be divided into various means of e.g. increased resource productivity and less waste.

Level 3 focus on the process to reach a goal. Active measures have to be taken to move the society in the direction of sustainability; i.e. dematerializations and substitutions needed to comply with the four systems conditions on level 2. There are several important aspects to take into consideration, among others strategic investments, which require conscious selected targets and flexible development platforms as well as a good return on investments to meet a sustainable future. Others are social principles, which include communication together with transparency in the society and political courage to run, for instance, international agreements and economic development in right direction.

Level 4 connects to the previous level 3 but describes what actions those have to be performed to comply with the system conditions in level 2 within the ecosphere in level 1. Actions could here be the conversion to renewable energies.

Level 5 describes the tools to utilise for prediction, monitoring and audit the progress towards sustainability. There are two levels to consider:

(i) The first level focuses on a proactive evaluation on how actions comply with the overall plan and objectives corresponding with the system conditions.
(ii) The second level focus on how to monitoring identified dangerous impacts in the system; important since it is the direct target of the planning, i.e. specific show the result of a short-term action. Tools are needed to confirm out phase of, for instance, hazardous substances.

Sub-level (i) can be described as a concept, which defines how to achieve a sustainable development, including lifecycle thinking, Design for the Environment, and cleaner technology. The concept should guide the overarching approach to deal with environmental aspects [1].

There have been several concepts developed during the last decade, and all concepts have its origin in a particular professional discipline, that makes the approach and focus slightly different. The life cycle thinking considers the implication of any action in a cradle-to-grave perspective, while design for the environment deal with decisions in the product development process. The Cleaner technologies concept deals with the manufacturing and processing technologies together with End of Life Management, which mainly focus on the End of life phase. Despite the differences, there are a great deal of synergies between the concepts, e.g. the Design for the Environment focus mainly on the design phase, which is a part of the lifecycle thinking as well as the end of life management. Common for these concepts agrees to a systems approach, considering up-and downstream processes [29].

Obviously, there are advantages to principally work with the sub-level (i), to avoid environmental problems to even occur, but too often, identified and specific problems overshadow the principle level for long-term solutions, which should be based on prevention and proactive thinking. The need for action on a specific impact is many times urgent and generates much turbulence in the market, that the focus on taking measures to all the detailed problems, temporarily can disguise the underlying system-errors creating them. Thus, strategic tools should not only focus on known current problems, defined in sub-level ii, but also apply a sustainability perspective, according to sub-level (i), to prevent from culminate in unsustainable activities [1].

4.1 Examples of sustainable development tools and concepts

The Factor X describes a group of concepts that utilises metrics on various activities or flows, of which the environmental impact can or should be reduced by a certain factor to reach sustainability. The concept is considered to be a very useful and flexible to monitoring activities with the intention to meet dematerialization aspects of each four system conditions. Questions that can be answered are for instance; to what factor should technology-induced flows be reduced as a minimum to meet the capacity of the eco-system? This factor may differ widely depending on, for instance, the geographically location and vulnerability in different ecological systems. Another question that can be answered is; with respect to equity aspects, by what factor should materials flows be reduced in order to leave sufficient space for decent living conditions for the poor population in the world [1, 6]?

The Factor 4 is one example of Factor X and a policy strategy that refers to a hypothetical fourfold increase in resource efficiency, brought about by simultaneously doubling wealth and halving resource consumption. The concept has attracted much attention since it was introduced in a book in 1998 [1].

A second example is the Factor 10, which argues that in the long term, resource use in developed countries needs to be at least slashed tenfold if the world society is to approach sustainability. The reasoning behind this is that globally, consumption needs to be halved, but that the greatest reduction should come from those countries that are currently the most profligate in their use of resources. The policy strategy was formulated 1994 in Carnoules in France by the Factor 10 Club, by leading of professionals from governmental, industrial and academic institutions.

Another example of a concept that suggests a way to reach a sustainable development is the book Our Ecological Footprint, written by Mathis Wackernagel & William Rees [54]. It describes a way to identify and determine all dematerialization under the system conditions, considering the described level 2 of the sustainable development model, Figure 4-1. The outcome of various activities is measured and aggregated into units of area, i.e. the reduction or increase in an ecological area needed to support the activities [1]. These are then related to an estimation of the total life sustaining area of the biosphere, i.e. the accumulated "foot-prints" form an all activities related to the total carrying capacity of the exosphere. Some aspects, for instance persistent compounds foreign to nature, cannot be described in terms of "footprints", since these aspects have to be phased out in a sustainable world. The Ecological Footprint only includes those activities that are potentially sustainable in if not done in excess of the biosphere's regenerative capacity. The concept is an overall measuring tool to get humanity's impact on the Earth and a tool for measuring and visualising the resources required reaching sustainable conditions from households to nations [54].

As the knowledge of sustainability continuously improves, the results from all concepts should be considered to be preliminary, and should be kept in mind when they are discussed. For example, knowledge of hazardous substances concerning persistence, abundance and eco-toxicity is continuously improving.

5 Decision tools aimed at Design for the Environment

To meet the idea of sustainable development, tools for inventory and assessment of products´ environmental performance are needed. This chapter intends to give an overview of those groups of tools that are used within the area of Design for the Environment on the market today. It describes further the structures and needed qualifications for tools to be tolerably reliable foundations for good decisions. Different tools are used on various levels, both within research and in companies' product development. Depending on purpose, the tool has to be constructed to meet requirements so it can facilitate inventories and assessments and, particularly within the product development, not too time consuming and complex to use.

A great number of Design for the Environment tools have been developed to facilitate the handle of complex multidisciplinary information necessary to identify and assess the environmental impact from a product, a function or a process. They provide a wide range of support for decision, from the initial inventory of environmental impacts to impacts analyses and opportunities of improvement. Different tools have widely differing purposes. Some are more applicable to research with a long-time frame, whereas some meet requirements of fast decisions in the product development process, where the pressure of time often is a burden. Often, the precision of data stands in contradiction with time. Design for the Environment tools in the product design process have to be fast and therefore, preferably these should rather be based upon more thorough and precise tools. These are used to improve the deeper knowledge, suitably as research beside of the product development process [29].

With regard to the previous chapter 4, tools aimed at Design for the Environment, belong to level 5 and can support both impact assessments and actions to take into consideration when products are developed. However, these tools are more precise than the sustainable frameworks that belong in the hierarchical system, according to the level 4.

The Design for the Environment tools can be divided in two distinguished groups;

I. *Analytical tools,* which focus on the consequences of a choice
II. *Procedural tools* that focus on the procedure to reach a decision.

Independent of what tool, all have to be supported by technical elements, like mass balance models, dose-response models, evaluation models, quality assessment etc. Basically, technical elements can be defined as methods of obtaining data, data processing and presenting of information. Technical elements may supply information directly to the decision process, or to a variety of tools and vice versa, and tools may require information from more than one technical element. For instance, an LCA model consists of technical elements, dealing with the Life Cycle Inventory and Life Cycle Impact Assessment. In some cases, technical elements may also, standing alone, be used to support the decision process.

All technical elements are supported by *data,* which could be both qualitative and quantitative.

5.1 Analytical tools aimed at Design for the Environment

Analytical tools are required in different steps of the Design for the Environment process. The tools for this purpose can be divided in the main categories; quantitative LCA-types tools, and more qualitative or semi-quantitative matrices and checklists [29]. More complex LCA tools may be more suited for research separated from the main product development process. To facilitate, an analysis computational algorithm based on quantitative data can be used. The other two can be used both initially in the process but also continuously under the process. These tools may use both qualitative and quantitative data, often based on the results from the quantitative analytical tools [12].

In any case, common for all tools is the purpose to provide better technical information for good decisions with respect to the complete life cycle, a part of it or a specific environmental burden. However, important to remember is that, independently of what analytical tool is being used, there are always gaps in the data input, which gives assessments with various quality [14].

5.1.1 Life Cycle Assessment, LCA

The quantitative Life Cycle Assessment methodology and other in-depth analysis methods provide a picture of the environmental impacts from a product or a function, hereafter represented by product only, under a complete life cycle or a part of it. It can also be used to assess and give priority between different eco-design options. In a wide range of linear problems, good solutions can be found with a high level of sophistication and practicality. Basically, the LCA is divided in three procedural steps [24].

In the first step goal and scope is defined. A proper definition of the purpose is fundamental for the following steps of the analysis but also of importance for other reasons, for instance other interested parties that need to understand the results of the analysis. An LCA can be performed in many different ways, which also can lead to different results. On this level, aspects that might have an influence on the results are, for instance, the choice of system boundaries and allocations. Several products might share the same processes and the load of those, expressed in the relation to one function only, is the implication of an allocation. Finally, a functional unit is selected based on what to be studied. This is used to enable comparisons between various alternatives or products.

In the second step, the Life Cycle Inventory, LCI, a flow model of a technical system is constructed and input data to this model are collected. The model that describes the mass and energy balance over a system is incomplete in the meaning that only environmentally relevant flows are considered. To fulfil an inventory, there is a need for great knowledge of the product, for instance its materials together with manufacturing processes, how long will the product be used, how it is used etc. The data collection is one of the most time consuming processes of the analysis but gives gradually often a rather comprehensive picture of the environmental impacts of the object. As the knowledge of the system increase, allocations and system boundaries, as well as functional units, might have to be redefined [4]. To meet the needs of data input in the inventory process, there are several software tools and databases developed for this purpose.

It could be enough to end up the analysis with the inventory, but if a decision should be taken upon the results, also the third step could be accomplished. This third step, the Life Cycle Impact Assessment, LCIA, aims at a description of the environmental consequences of the environmental loads quantified in the inventory phase. This is made by aggregating of the environmental loads into fewer environmental impacts like effect on biodiversity, acidification, eutrophication, etc.

The assessment process is in turn divided into three mandatory steps; impact category definition, classification, and characterisation and some optional as normalisation, grouping, weighting, and data quality analysis. However, in practice, most of the conventional tools and methods used for this purpose have often many of these steps already covered by the main methodology and normally, the practitioner has to deal with foremost the classification, characterisation and the weighting procedures. Classification simply means that the result parameters from the inventory are sorted and assigned to the defined impact categories. In the characterisation step, the environmental objects of impact are quantified with the help of equivalency factors, which means that for instance, eutrophication compounds are added up on their bases of their equivalency factors. Summed, these are an indication of the total size of eutrophication impact from the studied object scenario. The weighting process can be either a qualitative, quantitative or a mixture procedure where the relative importance of the different environmental impacts is weighted against each other [4].

The International Organisation for Standardisation, ISO, has harmonised efforts on a global level and published a series of international standards for LCA practice in ISO 14040-14043 [3, 12]. The ISO standard states a framework but even if many of the established LCA tools on the market are based upon the standard series, the tools are still based on different basis of valuation. Accordingly, the result of the methodology depends on conscious assumptions and allocations and this always has to be considered when the final results are to be considered.

5.1.1.1 Ready-made Lifecycle Impact Assessments methods

To facilitate the accomplishment of an LCA, ready-made Lifecycle Impact Assessments, LCIA methods can be used. The advantages with these tools are the pre-made indices available for various aspects that are aggregated to a single index number, hereafter called eco-points. All indices indicate their relative environmental harm, and the total environmental impact of a system can therefore more easily be obtained by multiplying all environmental loads of the system by their corresponding indices and then sum them up.

$$\text{Total environmental impact} = \sum_{i} \text{Load}_i \times \text{Index}_i$$

where i = environmental impact category, e.g. eutrophication, acidification etc.

The determination of the relative harm of different environmental impacts is based on value-bound procedures and different weighting principles, which are reflecting different social values and preferences [4]. Thus, the value of eco-points schemes is that they can provide quick analyses of the overall environmental effect of products and how different elements of the design contribute to this. However, a disadvantage is that the eco-points are ultimately dependent on subjective weightings of different environmental effects and that these are not always transparent to users. Hence, eco-points are particularly well suited to identifying areas for attention and exploring, rather than making choices between different alternatives [16].

In the following text, the two described LCIA methods have such index lists. However different methods are based on different basis of valuation and the result of the methodology depends on conscious assumptions and allocations and this always has to be considered when the final results are to be considered.

EPS – Environmental Priority Strategies in product design [4, 62]. The EPS methodology to perform LCA is built on prepared ELU-index, Environmental Load Unit, for both materials and processes available in a relationship database. The ELU is defined as "1 ELU is similar to the willingness to pay of 1 EURO to re-establish the impact to the environment generated by our way of living based upon the reference point; the calculated declaration of value in year 1990". Thus, each index can be described to be built upon an own LCA, locked in a fix routine, visualised in figure 6-0. Basically, the assessment is founded on a principle of assessment, which is built upon five different objects of value for the impact of the following

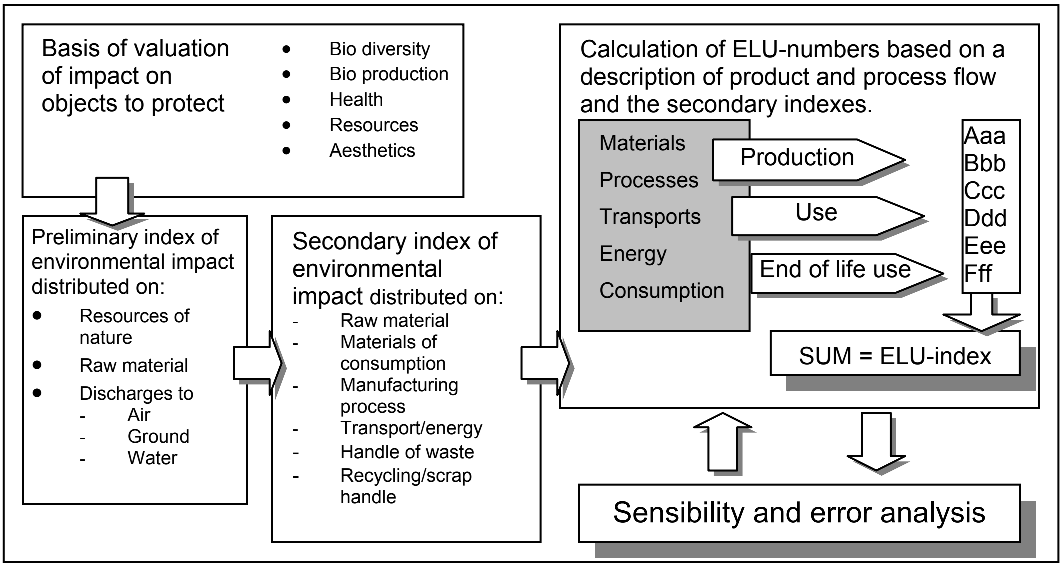


Figure 5-1: Flow description for the assessment of ELU-indices, Carl-Otto Nevén, Assess Ecostrategy Scandinavia AB, year 2000 [62].

objects of protection; bio diversity, bio production, health, resources and aesthetics. From these objects of value, preliminary indices of environmental impact are assessed, based on natural resources, raw material and discharges. In the next step, preliminary indices are redistributed into secondary index of environmental impact, which are assessed based on the activities connected to the development of the object. Finally, ELU numbers are summed up in an ELU-index, according to a description of the product and production flows of the object. Volvo, the Confederation of Swedish Enterprise and the Swedish Environmental Research Institute originally founded the system in 1990 [23]. The methodology follows the ISO 14040-43 standard for LCA. The assessment methodology has also been continuously developed, among others with help from the Nordic Product Ecology project under 1994-1995. The purpose has been to develop a relationship database and give suggestions how to work with integration of Design for the Environment. The work should be based upon lifecycle assessment, customer orientated product development process and cost related product development process based upon Life Cycle Costing analysis, which is an analysis over the cost accounting under a product's lifecycle.

The concept was sold a couple of years ago, and the EPS methodology is now marketed, together with the computer software tool, EPS 2000, by Assess Ecostrategy Scandinavia AB.

Eco-indicator'99 – PRé Product Ecology Consultants, Amersfoort, The Netherlands [4].

The Eco-indicator is built upon single score indices like EPS methodology and is also aimed at especially product development applications internal a company. One major challenge in the inventory process is to obtain reliable and comprehensive data, which sometimes even can appear to be impossible. Spatial and temporal knowledge may sometimes be lacking. The constructors of Eco-indicator'99 have compensated this by developing a model for assess an average of damage in a geographical area, i.e. Europe.

The Eco-indicator method is accomplished in several steps where the first use natural science to calculate the environmental impact generated by the environmental loads from a product life cycle. Impacts aspects are human health, ecosystem quality and resources. Compared with EPS, the impact categories basically consider the same aspects, except from the aesthetics.

What to consider as an environmental problem varies regarding of what country and culture that is studied. The environmental impacts are weighted according to this and three cultural perspectives are represented in the method; the perspective of the individualist, the hierarchist and the egalitarian. The individualist and the egalitarian are their opposites, where the view of the individualist only accept proven cause-effect relations as environmental impacts while the other only practise the precautionary principle which imply that nothing is excluded and in between stands the hierarchist. The egalitarian perspective will lead to the most complete but on the other hand also the most uncertain set of indices. The Eco-indicator method can use these three cultural perspectives individually or as an average.

When the indices of the method were produced, a panel of experts was consulted. 365 members of a Swiss LCA interest group were questioned about their opinions about environmental damage. As earlier discussed, there are cultural differences between countries and the result from this consultation was not representative for all Europe but considered as useful for the first set of indices.

Environmental Themes **–** The methodology builds on classification and characterisation, which in one step are weighted [4, 5]. The weight factors can be determined in different ways but in the original Dutch study, an expert panel defined the weighting factors, using the following impact categories:

- Global warming
- Depletion of stratospheric ozone
- Acidification
- Eutrophication
- Photo-oxidant formation
- Ecotoxicological impacts
- Human toxicological impacts
- Waste
- Resource exhaustion

The methodology has been adapted to Swedish conditions with some direct substitutions of weighting factors, which have been derived from reduction targets in Swedish public environmental policy. These indices have a short-term focus, while another set of indices also calculated for Swedish conditions have a long-term focus with intention to also consider need reduction to not exceed critical overload levels.

5.1.1.2 LCA databases

As stated earlier in the text, it can be enough to stop the analysis after a fulfilled inventory. This phase also requires the most efforts when an LCA is performed. To facilitate the inventory, several databases are available. In general, these databases consist of three parts:

- The data
- A structure to organize the data
- A software system which handles both the data and the structure

The database structure is the physical result of a modelling where the data from the reality is mapped into a conceptual model [19].

Some of the databases are only direct inputs to LCA software while other can be standing alone concepts as well as they are standardised and can be used in several software. Next follows some examples.

IDEMAT is a computer database for designers, developed by the section for Environmental Product Development of the faculty of Industrial Design Engineering at the Delft University of Technology in the Netherlands. It provides technical information about materials and processes in words, numbers and graphics, and puts emphasis on environmental information and specific engineering aspects like metals, alloys, plastics, wood and energy and transports. The information in the database is presented on six or less pages. On one page information is shown on mechanical, physical, thermal, electrical and optical properties. This page also contains information about possible processing technologies and applications for a material, important remarks, the cost price and environmental info. Together it shows details of about 40 aspects in numbers or words. The environmental "properties" are shown in a graph showing the environmental effects, associated with the production of one kg of the particular material.

In the following pages, the background information is given like sources of the information, boundary of the analysis, input of raw materials and the emissions during the total production process. The procedure for information about processes is the same as for materials.

SPINE, Sustainable Product Information Network for the Environment, was developed to make communication of LCA data between software and databases possible and is a relation database structure. The main concept of the SPINE data model is activity. An activity can be, for example, extraction of raw material, using a product, or recycle of it. An activity has inputs and outputs, which can be described as flows [19]. Activities can be connected to each other by their flows. Thus, it becomes possible to build a model of a studied system where all activities can be reused and connected to each other. The database involves formats, methods, and models in order to enable an effective and efficient handling of environmental information.

The Centre for Environmental Assessment of Product and Material System, CPM established in 1996, has developed the system. The purpose was to establish a comprehensive knowledge base to support the industry needs in the field of environmental assessment [55]. The centre is research collaboration, in the area of environmental assessments and informatics, between Chalmers University of Technology and several Swedish based multinational member companies.

The definition of a life cycle inventory data set, according to SPINE, addresses five different information areas; identification of the technical system, methods used to obtain the data set, details on data acquisition, flows of material and energy, and recommendations when using the data. The definition of a life cycle inventory data set is described in the figure 5-0.

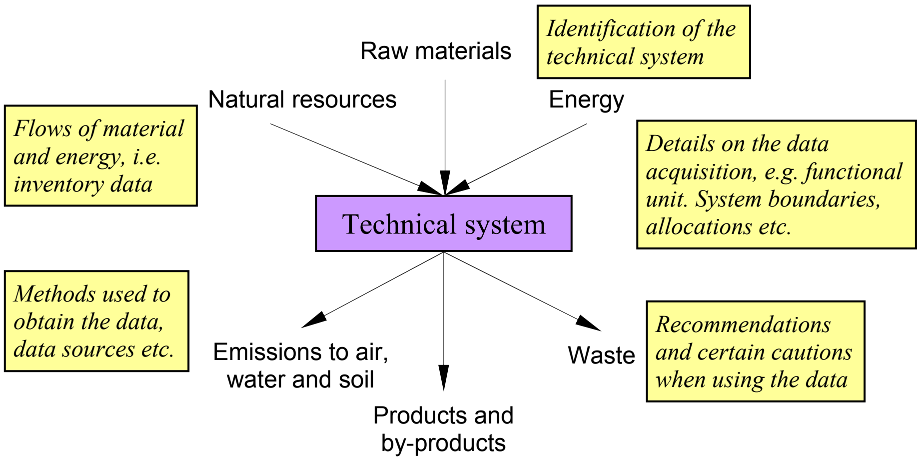


Figure 5-2: The definition of a life cycle inventory data set according to SPINE [55].

The concept is based on quality aspects, flexibility and transparency. The data documentation can be used other LCA software or as stand-alone software, SPINE@CPM that is structured by the life cycle inventory data documentation format SPINE. This software aims at facilitate handle of the documentation of data, describing all different types of technical systems, independent of whether it is large or small, real or hypothetical.

The format contains large text fields, which enables a great deal of relevant information to be included, compared to many other Life Cycle Inventory Data documentation formats that utilises, e.g. limited pre-defined text options. The flexible format also enables a transparent documentation of complete life cycle inventories where each included activity that is described separately, as a technical system, may be identified easily.

5.1.1.3 LCA software

Analyses can be performed manually on paper or with help from computer software systems. Some of these use different Ready-made Lifecycle Impact Assessments methods [21]. In some systems the assessment methodologies can be exchanged, while other only use one “build in" methodology. Other software has built in possibilities to change both assessment methodology and different inventory data from different LCA databases. That enables a user to compare the results from different point of views, which facilitate the evaluation of the results.

For a novice user, the background estimations and limitations might be difficult to understand and thus the results may become hard to interpret, which should be remembered when these sorts of methodologies are used [24]. The knowledge about the software presumptions is important to take in considerations when actions are taken upon the results. However, tools that are built upon lists of indices facilitate the assessment, regarding both time consumption and work efforts. The following examples are only a selection of all available tools aimed at this purpose on the market.

EPS 2000 – Assess Ecostrategy Scandinavia AB, Gothenburg, Sweden [45].

When the first version of EPS software was developed, special emphasis was placed on making the system easy to use by its incorporation into a simple application on a standard computer program [19]. The main menu gives the designer access to different calculation procedures that enable to inventory information associated with activities and environmental impacts. The system also gives instructions on how to calculate environmental load indices. As default, all environmental impact information is expressed in an eco-point schema called Environmental Load Unit, ELU. Sensitivity and error analysis can be applied on an assessment result that gives information on the relative importance between different ecological scores. The SPINE database can be used in EPS 2000, as well as it is possible to make comparison between other eco-points schemes like Eco-indicator.

SimaPro – PRé Product Ecology Consultants bv, Amersfoort, the Netherlands [53].

The system was first developed in 1990. It enables complex products with complex life cycles to be compared and analysed and is widely used by many multinationals, consultants, institutes and universities [47]. As an input to the system, several databases can be used like IDEMAT 2001, Industry data and Data archive. SimaPro allows comparisons with the eco-point schemes Eco-indicator and the EPS-indicator for materials, processes or components, which enables a quick overview of different assessments of the environmental impacts. [24, 47, 49].

ECO-it – PRé Product Ecology Consultants bv, Amersfoort, The Netherlands [53].

The ECO-it software enables to model a complex product and its life cycle. The software calculates the environmental load, and shows the parts of the product different contribution. ECO-it aims at product and packaging designers. The software uses Eco-indicator'99 scores to express the environmental performance of a product's life cycle.

Eco-scan is a commercial package that can handle a number of eco-point schemes. The schemes are similar in that they cover all life cycle stages - production, distribution, use and end of life [16]. For each stage, the user selects appropriate materials, processes, usage, and transportation details from the options provided in the software. The package then calculates an eco-score for each of these elements, based on a number of points for a given quantity or usage.

5.1.2 Simplified tools for environmental assessment

The accomplishment of an LCA is often too time consuming and complex to be used directly in the product development process. Traditional LCA methodology is foremost suitable for basic research or within core engineering prior to the formal product development process [12, 24]. In the beginning of a project in the product development process different matrices methods and checklists are often preferred. These tools have their strength in that they provide a quick overview and proportionately easy assessment mechanism but lose in lack of details and accuracy. Matrices relate two or more factors to each other; the vertical part often considers the different life stages while the horizontal part considers the interventions, extractions and emissions. The data that have to be considered can be qualitative or semi-quantitative. In parallel with the matrices, checklists can be used as well as later under the process.

5.1.2.1 Environmental Effect Analysis or Environment-FMEA

The Environmental Effect Analysis is a qualitative methodology that is used preferably early in the product development process. The purpose is to identify, structure and prioritise important aspects that can results in environmental impact during the life cycle of a product or a function. The priorities are made from the severity of the environmental impacts, requirements to consider from authorities, customers and other interested parties and sometimes also the feasibility [2]. The feasibility has to be used with conscious caution, since what is feasible is not always the most important environmental aspect to consider.

The method is based upon the same principles as the traditional industry standard, Failure Mode and Effect Analysis, FMEA, which is used to identify weaknesses in a construction, before they appear in reality. There are several similarities between the two methods, which both are intended to be applied in a systematic working procedure carried out in a group and aim at identifying serious effects or sever impacts. Both are also built upon a continuous improved educational level with a systematic follow-up structure. The main differences beside of the focus on environment are extension of point of view, where the E-FMEA takes the entire life cycle into consideration [39].

An Environmental Effect Analysis is performed in a group of people with representative knowledge from various functionalities within the company, which should enable to consider the product's environmental impact from different point of views. To get a good result, it is important that at least some members of the group have enough competence to handle questions like environment in general as well as more specifically, Design for the Environment but also questions about the product and production [2].

The main process starts with definition of targets with the work and the function of the product. Thereafter system boundaries are defined and relevant requirements of the concept are identified and discussed. Depending on what system boundaries that have been defined, a part or the complete life cycle can be considered. However, if only a part of the cycle is discussed, still precautions are recommended to be taken so no significant environmental aspect in any part of the rest of the cycle is missed.

The identified aspects are assessed in the meaning that their environmental impacts are compared to each other and are given a score, for instance a number between 1 and 10. The quantification of the aspect is defined, also with a number from 1 to 10. The feasibility of the aspect can be considered in the same way as the impact and the quantification but, as mentioned, an aspect with a severe impact should still be considered even if it is no possibility to do something about it. Finally, the assigned scores for each aspect are summarised together. Multiplication, addition or other method of calculation can be used, depending of assessment methodology.

The results from the analysis can then be used during the product development process to develop alternative materials, processes or technical solutions based on the environmental impacts prioritised in the environmental effect analysis.

5.1.2.2 The Eco-design strategy wheel

The Eco-design strategy wheel is in fact a checklist aimed at the earlier part of the product development process to visualise a product's environmental characteristics. It is however placed in this chapter to not confuse the reader in the next chapter that rather describes checklist that are related to customers' technical specifications to Autoliv.

The intention with the Eco-design strategy wheel is that a project team within the product development process should use the checklist as a guideline for constructive discussions to identify environmental aspects to consider during the process. The tool can also be used later in the process to review the initial decisions [12].

The tool is divided in 8 improvement areas, which are called ‘eco-design strategies’ sectors. Seven of these cover a critical part of the product’s impact to the environment while the 8: th focus on the optimisation of the product. A checklist belongs to each sector for mainly qualitative assessment but also in some cases for quantitative elements and suggestions together with opportunities to bring inspiration and help the user to see the product from different point of views.

At a local Autoliv company, an adapted version of tool has been introduced. The tool is used twice, the first time early during the concept phase. At this stage, the intention is that the design engineers shall consider environmental aspects of the concept while changes still are comparably easy and economically feasible. Later on, when the product is ready for production launch, the same tool is used as a review tool to conclude environmental performance of the product and bring input to future projects. The tool is presented in appendix IV.

As indicated in Figure 5-3, some strategies will influence the product mostly at component level, some at product structure level and others at product system level. For instance, substituting a material with a more environmentally suitable one may have foremost consequences for the design of a specific part of the product, while the selection of energy source will probably lead to changes both on component and product structure level.

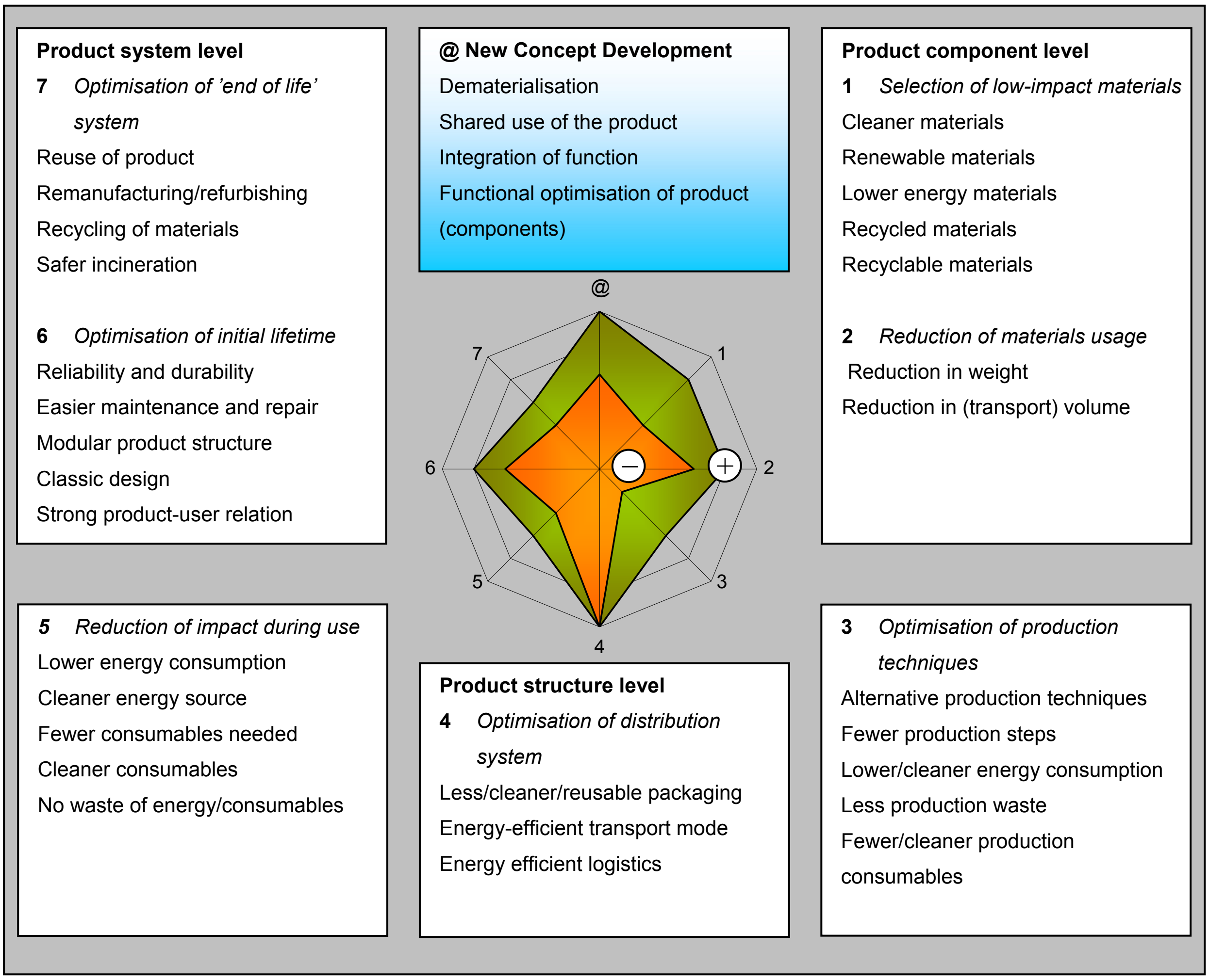


Figure 5-3: The EcoDesign Strategy Wheel [25]

Suppose that the lifetime should be extended, more radical changes may be required beyond the product component or structure level and the changes may include also repair and maintenance system under product system level [25].

The ‘new concept development’ strategy is characterised by the symbol ‘@’ to emphasis it's special character. The ‘@’ symbol refers to the innovative and eco-efficient email system, an invention that saves both paper and money. The symbol should provoke employees in the product development process to reconsider their actual product concepts and observe the product in different point of views.

After the team has come to their final decision, the outcomes of the environmental assessments are presented in the strategy wheel, which visualise environmental bottlenecks in the product. The wheel can also be useful to select between two concepts (orange and green in the figure) by visualising the profiles of the two alternatives in the same wheel [2, 29].

5.1.2.3 MET matrix

MET matrix, the matrix over Material cycles, Energy and Toxic emissions, was first developed by the TNO Industry Centre in Delft, Netherlands in 1995. The aid is a qualitative and structured methodology to analyse and assess the environmental impact over a product’s life cycle [2]. It can either be used as a simple basis for environmental prioritises by members of a project team under the main product development process or as an assessment foundation for indices in LCA software. Under the three groups, eight environmental effects are taken into account. The material category includes exhaustion of resources, the energy category has sub-categories, which includes green house effects, acidification, smog and eutrophication and toxic emissions category includes ozone depletion, human toxicity and eco-toxicity. If needed these environmental effect can be separately investigated which facilitate and increase the transparency [17].

However, the MET-matrix can also be filled in on paper form and represent then a more simple aid to analyse a product concept under the product development process. Then it is a qualitative and fast methodology to analyse and assess the environmental impact over a product’s life cycle [2].

Members of a project team perform the MET analysis under the main product development process, preferable together with someone that has more specific environmental knowledge. The MET matrix is effectuated in four main steps. In the first step, a general discussion is performed with help from a checklist about the functionality of the product. In the next step, functional unit and system boundaries are defined. Thereafter, in the third step, all material, energy and toxic discharges for the entire product life cycle are listed in a matrix as indicated in Figure 5-4, where on the vertical axis, the different life cycle stages of a product are considered. On the horizontal axis, the different types of environmental impact per life cycle are to be marked. The methodology is accomplished with an evaluation of identified environmental aspects, which are considered most significant.

The MET Matrix		**Materials cycle** Input/Output	**Energy use** Input/Output	**Toxic emissions** Output
Production and supply of Material and components		...	...	...
In-house production		...	...	...
Distribution		...	...	...
Utilization	Operation	...	...	...
	Serving	...	...	...
End-of-life system	Recovery	...	...	...
	Disposal	...	...	...

Figure 5-4: A simple way to document the most important facts is to use the MET matrix [29].

5.1.2.4 Checklists aimed at Design for the Environment

Most checklists are generally tools of a quantitative nature. Typically, the checklist consider issues in the process of the product development like product performance including for instance energy consumption, product parts including the materials and the function of the product. Thus, these lists could be quite long and therefore several checklists are available on the market for various purposes within the product development [3]. One example of a checklist tool for Design for the Environment is the Life Cycle Design Checklist [29]. This checklist is organised according to 13 improvement areas, which are called ‘design principles’. The list has also an assessment system included, called ‘ABC rating Scheme’. With help from this scheme, the user can get an indication of the expected environmental relevance of each criterion for a specific design. The checklist can look as described in figure 5-5.

Criteria for Saving Resources	Relevant for the product	Characteristics	Rating (Tick off Characteristics) A	B	C	No data available
Material Input	☐	Evident reduction	☐			☐
		Size of the product in accordance with function		☐		
		Over-sized (not necessary for function)			☐	
Recycled material	☐	Fully refurbished product	☐			☐
		Use of recycle parts		☐		
		Completely new product			☐	
Use of recycled materials	☐	High percentage of recycled materials (70-100 %)	☐			☐
		Medium percentage of recycled materials (30-70 %)		☐		
		Low percentage of recycled materials (< 30 %)			☐	
Evaluation						
		A = Ideal situation				
		B = Acceptable situation				LCD
		C = Urgent need for action				

Figure 5-5: Example of Life Cycle Design Checklist [29]

Another example of a Design for the Environment list is the Eco-Design Checklist [8]. The list is meant to be a support for qualitative environmental analyses by listing relevant questions that are needed to be asked to avoid environmental bottlenecks during the product life cycle. Thus, the checklist can be a complement to other Design for the Environment tools under the product development process like MET-matrix or the Eco-Design Strategy Wheel. When a problem is identified, the checklist can also be useful for suggestions of improvements. The checklist starts up with a need analysis where a main question is to what extent the product fulfils its main and auxiliary functions. This question is preferable answered before the environmental aspects are considered. The rest of the checklist consists of five headlines, which mirror a product life cycle with relevant questions for each part of it.

5.2 Procedural tools

While analytical tools focus on the facts and the reasons for the environmental impact, procedural tools focus on procedures to guide the process to reach and implement environmental decisions in a process. The procedural tools can however consist of decision procedures in which an analytical tool may be used. For instance LCA may be used as a foundation for decisions in an environmental management system. Next follows some examples of procedural tools.

5.2.1 Environmental management systems

There are different environmental management systems standards certificate available on the market but the most established standards are the ISO 14001 from the International Organisation for Standardisation [41], and the EMAS, Eco-Management and Audit Scheme, provided by the European Union authorities [44]. EMAS requires an official environmental declaration from the certified company each year and is an ordinance only valid within the Union, while the ISO 14001 is a global standard. Both require that direct environmental impact is measured but EMAS also enforce measurements of indirectly generated environmental impact like for instance increased pollutions from cars as a result of increased fuel consumption caused by increased weight.

The overall purpose with an Environmental Management System is to provide company organisations with a system and methodology to structured focus on environmental impacts generated by the company.

Some actions have to be taken like for instance, the set up of environmental policy, accomplish inventories to identify significant environmental impacts and assure conformance with environmental legislation. The system can be integrated with or into other management systems requirements, and should assist a company to achieve their environmental goals and objectives. The success of the system depends on a commitment from all levels and functions within a company organisation and especially from the management team.

The certificates require continues improvements but it is up to the local company to set the goals and the time frames.

5.2.2 Guidelines

A complement to checklists and matrices are different guidelines. These can describe and explain aspects and procedures to consider during a complete life cycle or a part of it. However, the guidelines are not requirements but aim at a support for the user to reach targets and requirements set by customer and consumers or identified by the analytical tools used in the product development process.

In 2002, the International Organisation for Standardisation, ISO, released a technical report aimed at Design for the Environment [40]. The report can be considered as a guideline for the implementation of an environmental management in the product development process and is an aid for people involved in these work efforts.

Also Autoliv Sweden, a company within the Autoliv group has produced a guideline aimed at Design for the Environment attached in Appendix III. The intention is that it should be used in parallel with other tools like the Design for the Environment checklist; an Autoliv Sweden internal produced routine. The list consists of a questionnaire with relevant Design for the Environment questions performed in a Microsoft Excel file. The routine and checklist is attached in Appendix IV. After the form has been fulfilled, the results can be considered immediately in a graph, similar to The Eco-design strategy wheel, described in chapter 5.1.2.2.

5.3 Checklists and design requirements within the automotive industry

To meet expectations on a product within the product development process, there are several features and requirements to consider like costs, assembly, usefulness etc. If the customer is a single company the requirements can in many cases be very precise, while if the product is directly aimed at consumers, the requirements might have to be founded upon various inputs, like marketing analyses. To assure that no requirement is forgotten, engineers often use checklists as an aid. It could be aspects to consider for Design for the Environment in general as well as assure compliance with customer requirements. Other applications can be in the pre-phases of a project where it can be used as an idea generation method. Checklists can be presented by a number of various ways, for instance flow diagrams, forbidden lists, etc. [29]. The way questions are asked and what contents they have indicate whether the checklist has a qualitative or quantitative approach.

Within producing companies, there are often many developed checklists to be used for support to and review of the product during development process. If a Design for the Environment approach is supposed to be implemented, it can be an advantage to add new questions to already established checklists and procedures. There are also pre-made checklist available on the market like the eco-design checklist [8]. These sort of checklists can provide a complement to other Design for the Environment tools used in the product development process like the Eco-design Strategy Wheel or the MET-matrix methodology. In the following chapters, common environmental product development related customer requirements are described. The examples are partly collected from the internal standards within Autoliv or from technical specifications to suppliers by Saab Automobile AB [43], respective Volvo Car Corporation [52], here abbreviated to Saab respective Volvo.

5.3.1.1 Restricted and forbidden chemical substances use lists

Lists over restricted or forbidden chemical substances are very common within the car manufacturing industry. The purpose of the forbidden substance lists is that all specified substances must not be allowed in any product in the car above stated thresholds. Restricted substances can be used but have to be reported and sometimes approved if their concentrations in the homogenous material exceed the thresholds.

The lists can be more or less precise in their listings of substances. Some lists like the Ford and Volvo hazardous substances list, RSMS, [52, 51] have aggregated substances in representative groups, which might give a first impression that the items of the list are quite few. Both Saab and Volvo require declaration of conformance with respective hazardous list via IMDS, which further described in chapter 10.2.

Other lists like the forbidden and restricted list of Renault is rather precise and explicit declare unique CAS-RN[1]. These sorts of lists might enable the user to identify a specific substance. However, these lists can be large and maybe hard to overview for an inexperienced user.

Also Autoliv has a restricted and forbidden substances use list, the Autoliv standard 5 Substance Use Restrictions, AS 5, which is mainly a consolidated list based upon the customers hazardous lists. The list was developed to facilitate the decisions for the employees within the product development process when several customers' lists had to be considered [34]. The AS 5 list is described more in detail in chapter 11.2.

5.3.1.2 Target Life requirement

Both Saab and Volvo have defined targets for the life of the product. The target gives constructors instruction about requirements like resistance to climate and environmental stress but is also important for the environmental impact of the product [43, 52].

5.3.1.3 Recycleability/Recoverability requirements

The Recycleability/Recoverability requirements are of great importance for the car manufacturers since they have to prove compliance with the End of Life Vehicle directive described in chapter 10.1. At Saab, all products shall meet all requirements stated in a Recycleability/Recovearbility Guideline, GMW3116. Further the technical specification states that the product shall be recyclable both for cars sold within and outside Europe. Some input to the compliance calculations are submitted from the suppliers via a material database, IMDS, described in chapter 10.2.

Volvo requires "recycling of the complete car must meet or exceed the following requirements: - Max. 15 % scrap waste per car, based on average per manufacture from 2002 (at the least) and the weight of the vehicle" [52]. This requirement follows the local Swedish legislation.

5.3.1.4 Weight requirements within Autoliv

The weight requirements are normally set by the car manufacturers. Autoliv has decided to pay much attention to the weight of the product since an internal analysis has shown that the weight has a significant negative environmental impact due to increased fuel consumption. The product's weight reduction has to be considered individually by each company within the group [60]. The aspect is also important to the car manufacturers, which normally have a weight target at each single project, see further the interviews, chapter 6.

A practical case describes how the customer requirement, here collected from the technical specification of Volvo, is adapted in the product development process at Autoliv [43, 52]. The theoretical weight is communicated by the car manufacture to Autoliv by the technical specification in the beginning of a new project. The specification states, "if weight is to be saved by using different materials of different quality of materials, the supplier is to make suggestions". Thus, the supplier is supposed to take measures to reach the target. Later on in the product development process the actual weight is declared and submitted via the material database, IMDS. IMDS and the internal Autoliv product development process are further described in chapter 10.2, 9.2.4 respective 11.1.

[1] Chemical Abstracts Services Registry Number, an international numbering system for chemical substances

5.3.1.5 Labelling to enable recycling

To facilitate separation and treatment of plastic parts when vehicle is scrapped, Volvo requires the plastic material to be labelled in accordance with the directive in STD 5052,41, and in conjunction with new design or tool changes. All plastic parts above the weight of 50 gram or more should be labelled [43].

Saab states that all plastic parts shall be identified and marked according to standard STD 3483 [37].

5.3.1.6 Environmental labelling

The environmental labelling tool provides guidelines for the use of environmental labels and declarations. The purpose is to provide communication of information on environmental aspects of products and services to encourage the demand and supply for those products that generates less stress to the environment. From the International Organisation for Standardization, a group of standards are provided for three different types of environmental labels; type I, ISO 14024, type II, the ISO 14021 environmental claims and type III environmental labelling scheme standardised in standard ISO 14025 – environmental labels and declarations [56].

Type I is a multiple criteria-based third party environmental labelling programme, aiming at simple yes or no decisions whether products will get a label or not [29].

Type II is called self-declared environmental claims and is based upon the company's own environmental product declarations which not necessarily have to be certified by external third parties. The declaration is a simple record that describes the environmental impact during its life cycle. Type II declarations can be a way to show known environmental impacts to interested parties like customers and in that way meet the request for information [2]. The type II declaration can also be a tool for the internal product development process where the present declarations are used to find improvements for future products.

The type III is a certified Environmental Product Declaration, EPD, which requires more detailed information than the type I declaration on a number of criteria attached to the product. The provision on a label does not require a decision regarding a definitive yes or no which also tells it apart from the type I labelling. The declaration is founded upon a LCA and it has to be certified by a third party. The purpose with a type III declaration is to meet the demands of quantitative environmental information that can be used by an interested party, for instance a purchaser at a customer, to compare with other similar products [2].

5.3.1.7 Material Guidelines

The technical specification [43] at Saab states, "that no toxic materials that can be accessed without vandalising the Module shall be used". Forbidden substances in cars produced by Saab world-wide are specified in the standard GMW3059, described in chapter 5.3.1.1, which includes for instance Asbestos, Methylenechloride, Trichlorethylene and Polyvinylchloride. Above this standard, the selection of material is described in the Recycleability/Recovearbility Guideline, GMW3116, which includes for instance recommendations of qualifications for recycleability of materials, plastics compatibility chart etc.

6 Design for the Environment program and organisation

The chapter overarching describes prerequisites and organisational structures needed for an implementation of a Design for the Environment program. Examples are given how to organise and communicate, from a corporation staff to a product development organisation and, if applicable, further to suppliers.

Considering present legislation, an implementation of a Design for the Environment program still is foremost a strategic planning and must be considered as a proactive commitment. Therefore, it is naturally related to a long-term perspective and thus investments may have a long payback, as it is a part of the reputation building and a sales argument [12, 29]. For a local company, that requires carefully deliberated decisions that take aspects like future legislative situations and the development of the world around into consideration. Nevertheless, there are also several short-term reasons to implement a Design for the Environment program. Satisfaction of customer demands, reduction of manufacturing costs, new angle of approaches that may lead to new business opportunities and lightening of existing regulatory burdens are some examples. Furthermore, international business associations often emphasise self-regulation as superior to regulation as a part of liberalise trade and investments and these arguments are also applicable for Design for the Environment [18].

The framework of Design for the Environment could be considered as a process within other internal processes of a company, which in turn are embedded in a product chain. In that perspective, shaping of the Design for the Environment organisation has great importance to be a working part together with the rest of the company organisation. To be efficient the organisation has to found an innovative, effective and competent work environment and both communication and system optimisation must work [3, 12, 29].

Different kinds of environmental systems and infrastructures can then support and facilitate necessary decisions. This chapter only overarching describes outlines how to build a Design for the Environment program and organisation since it has to be tailored in respect to each circumstance of the company.

Changes in work procedures or implementation of new support tools demands recourses. For instance determination of work time to co-ordinating environmental responsiveness must be balanced by the possibility of commercial viability [6]. Thus, what changes in organisation structures and resource efforts are appropriate to get the most benefits from the implementation of a Design for the Environment program?

A European study of some successful companies shows that a clear strategy is important to develop and characterise the implementation [29]. The strategic planning guides all other decision processes, where communication, marketing, and operational decisions interact with design and development, which in turn, interacts with capital investments. To the strategy belong some important aspects to consider as visualised in figure 6-1.

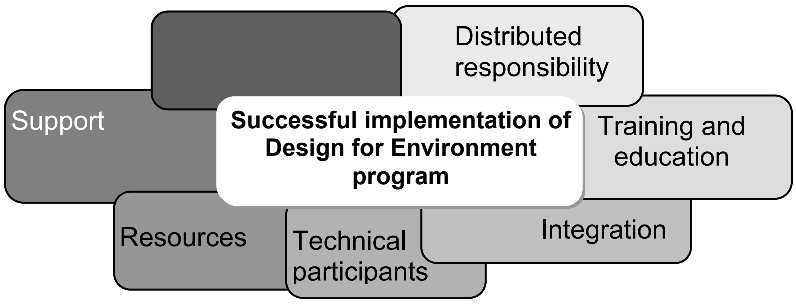


Figure 6-1 Devising an effective strategy for implementation of a Design for Environment program [12].

A environmental vision or a policy of a company describes the direction of the environmental strategy like for instance, does vision focus on the production or the product, are there any limitations and so forth. The strategy can be of two types, a priori statement to guide actions or a posteriori results of actual decision behaviors. Both can be proactive although the priori statement represents a more conscious decision process [18]. The policy shall constitute the target for the organization and the respect for the policy of the management strongly influences on the priorities of the organization. To acquire reliability and progress in line with the policy it is appropriate that the management also establish time frames for the accomplishment of decided undertakings [6, 12, 29].

Resources are necessary for the integration of a Design for the Environment program and to provide knowledge that supports the organization in specific areas such as materials selection and thorough analyses [6, 12]. Resources can be different kinds of tools like those described in previous chapters, but also appointed employees with dedicated roles. Particularly important for the support is a different kind of expertise that has knowledge and time for more thoroughly investigates a problem or a case. There are different ways to arrange this expertise role. Some companies have large centralized staff that supplies the organization with complete instructions while others have small, specialized teams on corporate level supported by additional resources on product development level. Independently the size of the central resources the corporate level must be able to communicate both requirements and support to the product development employees.

A disposition of the corporate role can include programme co-ordination, technical support, product assessment, and information transfer [12]. The corporate environmental authorities can communicate to diverse organisational groups as described in Figure 6-2.

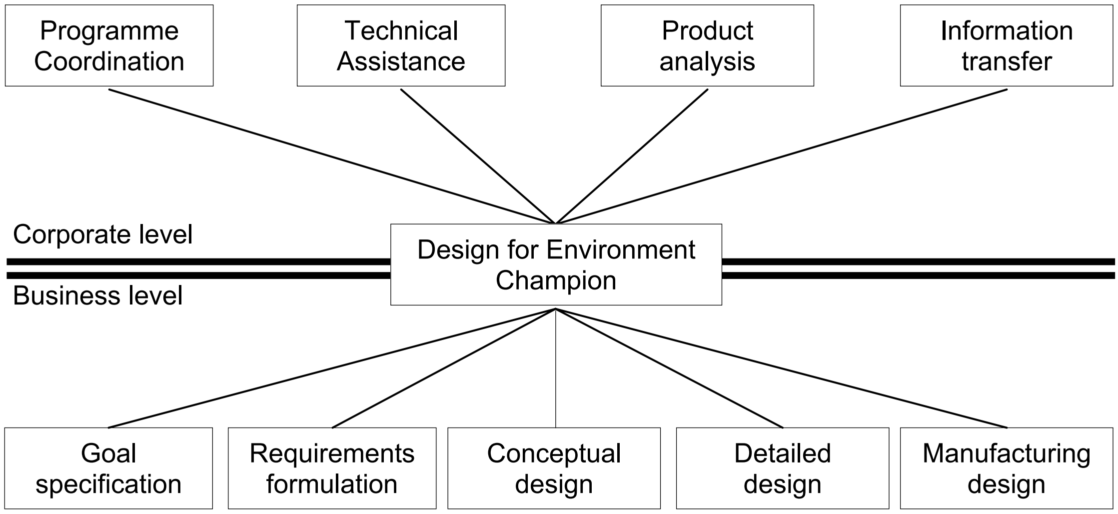


Figure 6-2: An example of an organisational structure for effective Design for the Environment implementation [12].

The Design for the Environment Champion role coordinate different objects and serves as links between support functions on corporate level and design efforts among the product development teams.

As a Design for the Environment program is fundamentally multidisciplinary, the communication between coordinating expertise and the product development organization is crucial. Environment, economy etc. must be combined with technical aspects, distributed properly to responsible and integrated as a part of the daily decisions [6, 12]. In that perspective work procedures are critical for reaching work goals and form normally a foundation for the development process. Different work procedures are very often already established for various purpose, e.g. quality and development systems. Established procedures could beneficially being integrated with environmental criteria. This kind of new requirements brings a need for training and education and the employees must be incorporated in new ways to consider the product and its life cycle. The communication channels must work on all levels, from the corporate authorities to each employee within the development organization. New tools and procedures must make sense to the product development organization and meet usefulness as well as reliability.

6.1 The suppliers of the companies

Not to forget is that most companies do not produce all parts themselves but bay it from suppliers. This provided, a significant part of the product's environmental impact may be generated by the supplier.

One important aspect of working with sustainable development is to "green" this supply chain, i.e. work with environmental management also within the supply chain [28]. The diffusion of environmental management via the supply chain is a very important factor for the improvement of industrial performance.

However, the concepts of "greening the supply chain" are usually understood as screening suppliers for their environmental performance and then doing business with those who have the best environmental performance. The concepts may include working with suppliers on green product designs, holding awareness seminars, helping suppliers establishing environmental programs etc. According to Wixe [28]; "there have been instances when companies have been held responsible for the environmental liabilities of their suppliers. Therefore concern for the environmental performance of suppliers has […] become characteristic of responsible business practice".

Customers and stakeholders do not always separate a company and its suppliers and this have made it necessary for companies to assume responsibility for also the environmental performance of the suppliers.

Bowen et al (2001) [7] have identified three types of "green supply activity":

- Product-based green supply: Includes recycling and packaging initiatives and efforts to reduce waste that require co-operation with a supplier.
- Greening the supply process: Includes building environmental criteria into the vendor assessment system, use of a scoring system to rank suppliers on their environmental performance, use of environmental supplier questionnaire, use of environmental criteria in the selection of strategic suppliers, supplier environmental awards and requiring suppliers to have an environmental management system.
- Advanced green supply: Includes use of environmental criteria in evaluation of buyers' performance, use of environmental criteria in risk-sharing and reward sharing agreements and joint clean technology programmes.

The most common type is the product-based green supply since these efforts have the most direct potential to cost savings according to Bowen et al (2001).

7 The Interviews

A number of interviews have been performed to get a more real and practical picture of how companies have solved the approach of the connection between theoretical inputs and more practical product development. Five companies were selected after the following criteria: the company should have some years of experience from environmental work in the product development process. The environmental work within in the company should also be relevant to the environmental work within Autoliv.

The two car manufacturers of Sweden, Volvo Car Corporation and Saab Automobile were selected since they, as customers to Autoliv, have requirements how Autoliv should perform their product development. As all car manufacturers of the world, they are also subject to the public debate, due to the fact that cars generate great negative global impact on the environment.

Volvo Penta was the third company to interview. The global company is a part of the corporation AB Volvo and produce engines and power systems to customers in selected marine and industrial applications. The company has historical connections with Volvo Car Corporation and hence it was of interest to find out whether environmental procedures had to be different depending on customer requirements. The environmental activities within Volvo Penta also had a good reputation.

To cover more of the Autoliv production chain, the company Kendrion Holmberg AB, a supplier to Autoliv, was selected. The company is a part of the Kendrion group and supplies components containing both steel and plastics to Autoliv.

Finally, Gustavsberg Vårgårda Armatur AB was selected. The company is located in the same town as Autoliv Sverige AB, the local Autoliv plant in the municipality of Vårgårda but produce totally different products; taps and joint of pipes to water pipe line systems. The arguments to choose this business were several, first of all, to get a broader sampling and not get too focused on the car industry only. The company was also known to have experiences in the Design for the Environmental work.

The prepared interview form that supported the interviews is available in appendix II.

7.1 SAAB Automobile

Persons interviewed: Britt Andersson and Erik Bergman, Environment Concerns Materials (ECM) at Saab Automobile AB the 11th of December 2002.

7.1.1 Presentation of SAAB Automobile AB

Saab Automobile AB, hereafter called Saab, is an international automobile company with about 8000 employees. The head office is located in the city of Trollhättan in the western part of Sweden. The company has affiliated companies in Sweden where Saab Automobile Powertrain AB in Södertälje has production of engines, and in Gothenburg where transmissions are produced, but also in Finland, Norway, Denmark, Finland, United Kingdom, Germany, France, USA, Australia, Switzerland, and Italy. Saab sells about 130 000 cars per year and is active in more than 50 countries worldwide. The most important markets are the USA, United Kingdom, Sweden, Germany, Italy, Australia, France, The Netherlands and Norway. International and diplomat sales account for considerable volumes and could be regarded as one of the top markets.

Saab was established as an independent company in 1990, following a joint-venture agreement between Saab-Scania AB and General Motors. As from January 28, 2000, General Motors owns it.

7.1.2 The environmental work at SAAB Automobile

Hazardous materials and fuel consumption have been in focus since more than a decade and the environmental aspects are supposed to be handled as any other aspect in the product development process.

A further basis for the environmental work at Saab has been the ISO 14001 environmental management system, which Saab received in 1999. However, by time, other environmental procedures have become more in focus for the work with Design for the Environment and the system has today less importance for those departments that are involved in the design process.

It is not an expressed intention from the head office that Saab should be a leader within the development of Design for the Environment and therefore, new legal requirements and internal enthusiasm are the main influences that push the work forward. For instance, all car manufacturers in Europe have agreed to a long-term requirement to reduce fuel consumption by 25 percent. The implication for Saab is that the car models should have average fuel consumption lower than 8.1 litres per 100 km (189 CO_2/km) by 2005. Saab must also be able to offer cars, complying with Environmental Class 1, which is a pollution limit criteria set by the Swedish National Environment Protection Board.

Two important sources of information are ACEA, European Automobile Manufacturers Association [48], and their national associated Swedish organisation, Bil Sweden. In all these discussions the Information Department and the Department for Monitoring of Law requirements and Safety are the communicators, and they are then supposed to spread information and agreements out to the rest of the organisation.

Other interested parties of the environmental design work at Saab are customers such as bigger companies, the police authorities and taxi companies. Their requirements are not often expressed directly, but the Information Department gets input in sort of questions about cars environmental performance etc. Thus, Saab’s impression is that consumers are rarely interested in environmental aspects when they select a car and it seems like other aspects, for instance, performance and quality are much more important. However, what have come to the interviewee knowledge are questions from the customers like health aspects, risk for allergy in contact with chromium dressed skin and exposure of brominated flame retardants etc, but they do not feel a demand from consumers as it looks presently. They conclude that their impression is also confirmed by Saab’s market analyses with Design for the Environment focus, which shows that it is enough to be on an average level compared with the competitors, when it comes to environmental performance.

7.1.3 The Environmental organisation of SAAB

On corporate management level, Saab has one environmental manager. The environmental manager is in charge of an environmental department with two employees who handle authorisations and environmental issues in the production etc. The Environmental Management System is lead by a project leader at the Department for Environment and Health. This department also has the major responsibility for work environment and prophylaxis etc.

There are two departments that are working directly with environmental issues connected to the product development process. The first, with seven employees, focus at materials and recycling. The second has five employees and focusing at emissions from the materials and from the engine. They also focus on weight of the product that has influence on the fuel consumption. The departments are separated from each other in that meaning they have their own targets. The interests from the different departments are not co-ordinated in an overall plan for the environmental impact of the car and therefore priorities may be standing in contradictions to each other. In these cases, the differences of opinion are solved by discussion.

After the fusion with General Motors, Saab has obtained further knowledge, which supports the product development process. On component level the design responsibility is partly converted to the supplier who shall incorporate environmental requirements in all Saab project tasks. Further, to remain as a business partner in the future all suppliers to Saab must hold an ISO 14001 certificate before year 2003

7.1.4 The product development process and its connected environmental aspects

In the first step of the product development process, the Marketing Department formulates what performance the car is supposed to fulfil in their requirement specification. Since the environmental requirements are not structured and put into routines, they could be formulated in different manners, or even excluded. However, requirements are often formulated in general terms like "the car shall have little impact on the environment".

In the next step, the marketing department vision is adopted and converted to more concrete targets when a Vehicle Technical Specification is formulated for the entire car. These targets and requirements are mainly based upon earlier experiences and are reviewed prior each new project. Further in this step, environmental requirements are always formulated in a checklist document, which then becomes the requirement specification for the development process. When a revision of the Vehicle Technical Specification environmental checklist for the entire car is accomplished, the Performance Responsible and other people with important knowledge have a meeting where a Design for the Environment “brainstorming” is performed. The “brainstorming” at Saab could be described as a group of people with different knowledge that meet and discuss risks and improvements of a non-existing concept. The results of this discussion are then converted into requirements in the checklist. This procedure is not co-ordinated in any routine but is very important for the improvement of the requirement specification document that is used by the product development employees. However, the Performance Responsible is responsible for ensuring that all targets and requirements are defined and reached. Thus, this role has also responsibility to follow and revise all projects for the entire car concept, from drawing to a finished product and is therefore obliged to present when new concepts are introduced. The strength with this one role co-ordination is that it is proportionately easy and flexible to add aspects and rewrite the requirement specification document.

In the third step, the specification for the entire car is divided in different system levels, called Sub-System Technical Specification, SSTS. For example, this specification could be the concept of Safety Restraint System, which includes products like airbags, retractors and appurtenant electronics. Thus, all environmental requirements for the complete car are broken down in sub-systems. Also in this step the Performance Responsible role has main responsibility for the environmental performance.

Component Technical Specification is then formulated. This specification is further broken down into component level and could for instance be a driver airbag, analogue with above example. The design and production of the components are often out-sourced to the supplier, who has to consider the aspects on the local component drawing. In the continuous steps of the product development process, the design is developed in a tight communication between the responsible suppliers and people responsible for design at Saab. During this phase of the process, both technical and system responsible employees should have checkpoints meetings to verify that the product is developed in accordance with the drawing and applies to all formulated requirements, both for the Sub-System Technical Specifications and the Component Technical Specification. The environmental requirements are a part of written routines and should thus be a part of the gates in the product development process.

This development process continues just until before the start of production when all targets and requirements have to be reviewed and validated. To assure the compliance with the Component Technical Specification, a Production Part Approval Process, PPAP, described further in chapter 11.1, is required. Practically, this approval process is a thorough documentation made by the supplier that proves the compliance with the drawing and all technical specifications set by Saab. When the PPAP is approved at Saab, all technical specifications are gathered and evaluated to make sure that a release of the complete car is possible.

There are several environmental aspects to consider in each project. Hazardous substances not to be used in the product are listed in the General Motor's standard, GMW 3059, which continuously emphasised focus as new chemical legislation are introduced or are planned to be in a short period of time.

The focus on recycling requirements according to standard GMW 3116 has become very important after the legalisation of the European Union End of Life Vehicle directive, described in chapter 10.1. The directive requests to what percentage materials have to be recycled and what percentage that can be incinerated. To establish a market for recycled materials, Saab has also requirements on amount of recycled material content in parts produced by the company.

All plastic parts have to be marked according to the Saab standard, STD 3483. Further, no material should cause allergies and must comply with the chemical forbidden and restricted substance list of General Motor, GMW 3059. The only material restricted for use is the PVC plastic and it has to be substituted in all carry-over details and should not be introduced in new parts.

The main weight targets on the car concept are formulated in the PFE routine, Performance, Fuel and Economy, which is an important aspect, both for the fuel economy and the impact to the environment.

In resemblance to most of the car manufacturers in the world, Saab collects information about the weight of each component, its composition of materials and possibly hazardous substances from the supplier via the internet based system, IMDS, described in chapter 10.2. Before a start of production, the specification for the entire car has to be approved by the Performance Responsible. Crucial before the launch, is the compliance with the European End of Life Vehicle directive since non-compliance with the directive might lead to fine. Further, weight targets and hazardous substances compliance must be confirmed together with all other environmental requirements. Except from IMDS, there are no written processes to bring feedback of the results back to new concepts, but the gained knowledge is verbally conveyed.

7.1.5 Environmental edification of knowledge at Saab

The environmental knowledge about the product is based upon gained knowledge from LCA made by other companies than Saab and input from people involved in the environmental work. Possible input benefit from own accomplished LCA has been discussed but is considered to be too time-consuming and too extensive in relation to the demands, and inputs from external analyses are sometimes used instead.

7.2 Volvo Car Corporation

Person interviewed was Elisabeth Dahlqvist, Environment department at Volvo Car Corporation, 5th December 2002.

7.2.1 Presentation of Volvo Car Corporation

The company Volvo was founded on Hisingen in Gothenburg in 1927. At this time it was quite common for car manufacturers to find components in industrial catalogues, purchase them and then assemble a car. The quality, which resulted from this procedure, was not particularly high and many of these manufacturers quickly disappeared.

However, quality was of paramount importance to the men who founded Volvo and the basic idea was to design and draw the components for the car internally. Suppliers were then selected to produce these parts in accordance with specifications, thereafter the company made the assembly work with the aid of experienced car builders. Still, quality is one of Volvo's core values together with safety and environment.

In 1928, Volvo also introduced production of trucks. Trucks, and subsequently buses, dominated Volvo's production during the first decades in terms of numbers [58]. Till year 1999, AB Volvo was one group with production of among others, buses, trucks, engines and cars. This year, Volvo Car Corporation was bought by Ford Motor Company and becomes a part of the Premier Automotive Group together with Jaguar, Land Rover, Lincoln and Aston Martin.

The production of all components, such as engines and transmissions, is based in Sweden. The cars are built in three different lines; Sedans, Versatiles, including Cross Country, Coupés and Cabriolets. The company has three major assembly plants, in Gothenburg and Uddevalla, Sweden and in Ghent, Belgium and smaller assembly plants in Malaysia, Thailand and South Africa, which are serving the local markets. In Born, the Netherlands, Nedcar produces Volvo S40 and Volvo V40.

Today, the corporation has 28000 employees from which 5500 are employed at the Torslanda plant in Sweden. Here are also the headquarters and all corporate functions located. Their sales and service network covers more than independent companies constitute 100 countries but much of the network that are working with Volvo Car Corporation as a business partner. The four largest markets are USA, Sweden, Germany and UK.

7.2.2 The environmental work at Volvo Car Corporation

External requirements come from many directions. In addition to meet regulatory law requirements, the company acts actively when new requirements are to be developed within the authorities. The benefit is the possibility to adapt new requirements before it has become a valid requirement and thus act in a more controlled manner.

Other requirements come from customers and consumers. These requirements are often not as concrete as the legal requirement but are instead expressed by inquires. To understand needs from the market the company accomplishes marketing research. As a result of these marketing researches, a need for more objective environmental information about the car has been identified. Therefore, Volvo Car Corporation as the first company in the world accomplished an Environmental Product Declaration, EPD, which provides interested parties with a holistic overview of what impact a Volvo car has to the environment throughout its lifecycle. Thus, the EPD enables a customer to make more correct and efficient comparisons between different cars and model configurations.

The need varies from country to country but are also culturally related which entail that the company above conventional concepts also try to offer cars that works with alternative fuels. One example is the Bi-fuel car that works by compressed natural gas (methane), stored at a pressure of 200 Bar. The car has been delivered to, among others, major taxi companies in Germany with the environmental benefits as an argument.

The decision to have environment as a core value confirms that environment is important to the company and the engagement from the corporate management team is, depending of the issue, often active or even proactive and overall, the general the interest in environmental questions is fundamental from their side.

After Ford Motor Company's purchase of Volvo Car Corporation, the company has got access to much knowledge, which facilitates the development of new, more technical and complex but also environmentally adopted solutions, which further strengthen the core values.

Since 2002, the company has an environmental management system for the entire corporation under one single umbrella certificate in accordance with the ISO 14001 standard, but parts of the company has been certified since several years. The certificate is important for the general environmental work within the main company but also to involve all employees and push the company to continuous improvements. After the end of 2002, ISO 14001 certification or EMAS is requirement for all suppliers to Volvo Car Corporation and the company does not accept new suppliers without a certified system.

7.2.3 The Environmental organisation of Volvo Car Corporation

On corporate management level, the Deputy CEO[1] communicates environmental related issues within the corporate management team. The Environment Manager has direct communication with the Deputy CEO, and spreads the information within the organisation, in general and specifically, mostly by e-mail or verbal communication. As the department is responsible to supervise the development of environmental issues in the product development process, it has a central role in the product development organisation.

The environmental department is divided in three divisions; weights group, fuel consumption group and unwanted materials and recycling group. Totally there are 25 employees who are either responsible for environmental aspects in the projects or specialised on different important environmental aspects, devoted to do basic research early in the concept phase of the product and follow up on projects during the lifecycle.

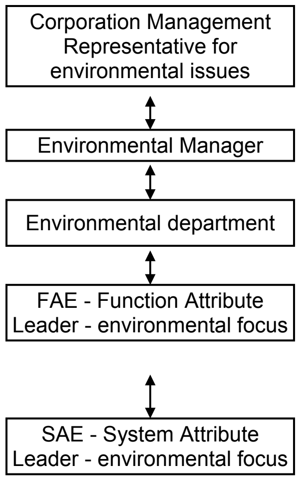


Figure 7-1: Environmental information flow within VCC

Results from assessments made by the environmental department, together with requirements from authorities and customers are then converted to internal requirements and targets for the product development process. These are brought out to the product development organisation by the Function Attribute Leader role, which represents the environmental department in each project, with responsibility for the co-ordination of the environmental requirements for the complete vehicle. The requirements and targets are then broken down and cascaded to a group of key persons called System Attribute Leader, who participate as a team member of each project. The System Attribute Leader is responsible to the environmental requirements and targets in each single project and ensures that it meets these or can show acceptable reasons for an exemption from the requirements.

[1] Chief Executive Officer

7.2.4 *The product development process and its connected environmental aspects*

For selected systems/components in each car project, a Design for the Environment assessment called E-FMEA, Environmental Failure Mode and Effect Analysis, has to be done in accordance with Volvo Car Corporation standard VCS 5034,59 Environmental Impact Analysis, E-FMEA [39]. When the analysis is to be carried out, representatives from the environmental department, for instance the Function Attribute Leader or the System Attribute Leader, together with people with technical knowledge including representatives for spare parts, production experts, purchase people and possibly suppliers join in a meeting.

Information about material content and processes are necessary input to fulfill an E-FMEA and is collected from several channels. Examples of sources of information are conclusions from results and experiences from LCA and other analyses, accomplished both external and internal the company, together with legal requirements. Also marketing analyses performed by the Communication department can give valuable input.

The collected knowledge is used during the E-FMEA process and the results are then transformed into technical requirements called FKB, Function Requirement Description, which are stored in a database. A schematic process flow of monitor and specification of requirements development is described in figure 7-2.

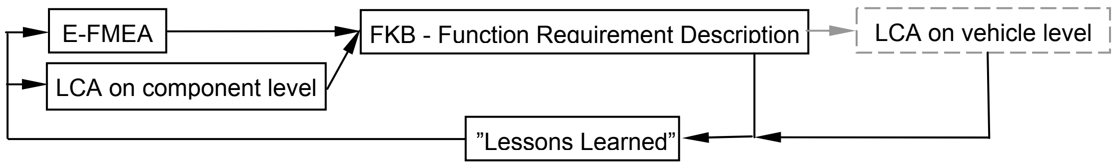


Figure 7-2: Continuous improvements of the products' environmental requirements at Volvo Car Corporation

Further, the identified environmental aspects from the E-FMEA are converted into technical specifications. For example, an identified environmental aspect is that the car's engine generates carbon dioxide by combusting fuel. Aspects that have impact to the fuel consumption are depending on several aspects as air friction, the weight of the car etc. Thus, the technical specification must specify limits on air friction, maximum weight etc.

There are several requirements that always are a part of the database, for instance the ban of hazardous substances not to be used in the product. These are listed in the Ford Group's Restricted Substance Management Standard, RSMS, applied internally to Volvo Cars Corporation and to its suppliers. This list of banned substances becomes more in focus since new chemical law requirements are continuously introduced. The focus at recycling requirements has become even more important after the legislation of the European Union End of Life Vehicle directive, described in chapter 10.1. In the Function Requirement Description database the requirement specific instructs what materials that have to be material recycled and what may be incinerated. All plastics have to be marked according to Volvo Car Corporation standard and no material should course fogging phenomenon or cause risk of allergies. Like for Saab, the weight targets on the car concept are important both for the fuel economy and the impact to the environment.

To ensure tracking of all substances and materials used in the production of the car, the company use the International Material Data System, IMDS. All supplied materials and theirs chemical compositions together with the weight of the product, have to be declared by the suppliers. The system also keeps track of restricted substances and ensures that no banned substances are used in the products. To be able to recycle more fractions of the car in the future, more complete information will be required on the chemical content of plastics, glass, textiles etc and IMDS will be a tool to collect this data from suppliers. At Volvo Car Corporation, the data is downloaded into an internal database, called Material DataBase, MDB, which helps the company to meet environmental targets and requirements. Regularly control of all targets and requirements in the Function Requirement Description database during the product development process are reviewed in Characterisation Attribute Meetings, scheduled in connection with the gates in the product development routine.

7.2.5 Environmental edification of knowledge at Volvo Car Corporation

In the beginning of 1990th, the company began to develop an LCA system for weighting of life cycle inventory data, together with the Federation of Swedish Industries and the Swedish Environmental Research Institute, IVL. The system was named Environmental Priority Strategies in product design, EPS, further described in chapter 5.1.1.3, with the purpose to enable quick, comprehensive analyses, for instance the environmental performance between two product concepts [23]. The development of the EPS system, as the EPS-indices, is handled by CPM, described in chapter 5.1.1.2. Computer software called EPS was also developed to make it easier to perform quick calculations. Some years ago the software was sold out and today the company Assess Ecostrategy Scandinavia AB markets it.

Lack of information, collection and handle of input data are difficult problems that must be solved to enable reliable assessments. Thus, tools that can facilitate these procedures are crucial.

For Volvo, EPS is still an important tool to assess environmental impacts. The tool is used before the start of a project to identify environmental aspects as well as during and after a finished project to review initial decisions and build knowledge to future projects. The experiences have shown that Volvo can obtain most benefit from the assessment of new concepts or solutions, which then founds requirements for future similar projects. Additionally, important input to the assessments is a local SPINE database, containing both internal and external data from CPM. SPINE is more detailed described in chapter 5.1.1.2. Beside SPINE, the material data system, IMDS can be an important tool to gather information.

Above available tools, it is very important that the people of the product development organisation feel that they are involved and have knowledge about Design for the Environment. Therefore all employees continuously get appropriate environmental education.

The Environmental Product Declarations, EPS made by Volvo Car Corporation should enable stakeholders to understand what impact the product generates to the environment. The declarations are also a tool for Volvo Car Corporation to validate environmental improvements as time goes on. The better results in the EPD, the better total environmental performance of the product.

When the LCA and Design for the Environment program was first introduced, some people felt a frustration since improvements did not happen fast enough or even at all. The understanding that all environmental aspects of importance have to be transformed into measurable and realisationable requirements are one of the most important learned lessons for Volvo Car Corporation. The Design for the Environment should be treated like other requirements and integrated in the product development process. Therefore, it is important that people involved understand the requirements and their backgrounds. To spread and receive feedback on the environmental work within the product development process, the environmental department arranges workshops. People with key positions, like System Attribute Leader, SAE, and Function Attribute Leader, FAE, are invited to discuss and learn about various aspects within the Design for the Environment program.

7.3 Volvo Penta

Interview with Eva Axelsson, Environmental Manager at Corporate Strategy and Core Values, AB Volvo Penta, the 13th of December 2002 in Gothenburg, Sweden.

7.3.1 Presentation of Volvo Penta

Volvo Penta is one of five divisions within the group of AB Volvo. AB Volvo is one of the world's largest producers of trucks, buses and construction equipment with a leading position in the fields of marine and industrial power systems and aircraft engine components. After the selling of Volvo Car Corporation in 1999, the Volvo Group has focused exclusively on transport equipment for commercial use, which creates the conditions for increased synergies and improved competitiveness.

Volvo Penta supplies technically advanced engines and power systems to customers in selected marine and industrial applications e.g. leisure boats, workboats, power-generating equipment and forklifts. With an amount of export to more than 90 percent of the company business and with dealers in some 120 countries, Volvo Penta is the most widely spread company within the Volvo Group and has one of the industry's largest dealer networks.

The company is divided in three business segments. The product line in the Marine Leisure business segment comprises petrol and diesel engines of 10 hp to 770 hp, plus complete drive systems and accessories. The Commercial Marine business segment offers diesel engines with power outputs of 100 hp to 770 hp, and complete drive systems for propulsion and auxiliary equipment. The Industrial Engines business segment offers engines and drive systems for many different applications, like generator equipment and propulsion systems for trains.

The production is located in four major sites whereof two are Swedish plants, in the towns of Vara and Skövde. In Vara, 3- and 4-litre diesel engines are produced, while Volvo Truck Corporations engine factory in Skövde produce 5-16 litre diesels. This factory is also one of the most automated factories in the world. Lexington, Tennessee, USA produces all gasoline engines for the marine leisure market. This is also the site where all Aquamatic drives are produced. Finally, company has a plant in Wuxi in China, which is a joint venture between AB Volvo Penta and Wuxi Da-Hao Power Company. The factory assembles diesel engines and generator packages. There are also two development centres, one in Gothenburg, Sweden, which is the head office, with development focus at diesel engines respective in Chesapeak, USA, which is the head office locally for USA and specialised in the development of petrol engines and drives.

Like in common with the rest of the Volvo group, Volvo Penta has quality and environmental care as core values but also safety. The core values should drive the development of new product offerings, but also be the arguments for customers to choose the company.

The origin of Volvo Penta goes back to 1868 when Sköfde Iron Foundry and Mechanical Workshop was founded. Manufacture included cast-iron goods and hardware such as boilers, pots and pans, ploughs and threshing machines. The name Penta comes from the famous B1, which was designed by Edvard Hubendick. The engine was called Penta, Greek for five, because of the five men who attended the meeting at which the first drawings were presented. In 1982 the company became an independent subsidiary of the Volvo Group [59].

Today, the company has 1400 employees where of 570 are employed at the plant in Gothenburg, Sweden.

7.3.2 The environmental work at Volvo Penta

Environment is a core value for the Volvo group that is important for the company to stay up with. The environmental care in all operations shall be an integrated part of the company. Therefore, the entire organisation in Sweden including the plant in Vara and the American production unit in Lexington is certified according to ISO 14001. Within AB Volvo, the Corporate Management Team considers the environmental aspects important and the CEO each year proclaims an environmental challenge to all business areas. This challenge is the basis for the Volvo Group environmental objectives.

New emission requirements, especially on engines in off-road vehicles and for commercial marine use has resulted in a significantly increased cost to enable the company to handle the environmental aspects within the development process. The company also expects other strengthened requirements on emissions levels for marine engines that require further environmental focus. For instance, there are planned to introduce new emission limits in year 2006/2007 for inboard engines on leisure boats.

Customers' awareness and requirements are however low and the market seems to be rather rigid. Many of the sold engines will be used onboard ships which are often on international water, far from national laws and hard to reach also via international agreements between countries. Other engines are designed for a use in buildings like hospitals, to generate power just in case of power failure. Engines' fuel consumption onboard ships can sometimes be considered primarily because of economical reasons, which however indirectly promote also the environment. Otherwise, most interests focus at esthetical aspects like low noise level and visual smoke.

Marketing analyses have shown that the consumers only rarely consider the environmental impact of the products at the purchase. One reason could be that Volvo Penta mostly manufacturer engines for a small market that is not in focus for consumers and a public debate. This can explain why customers are unwilling to pay for environmental improvements. Instead, the pressure by the authorities is more important and future changes in legal requirements will drive the development for environmentally improved products that should benefit the company.

7.3.3 The Environmental organisation of Volvo Penta

The company has one single fulltime role responsible for the co-ordination of the environmental work, i.e. the Environmental Manager who has Design for the Environment as one responsibility. Further there is one person responsible for the environmental management system at each plant.

The AB Volvo Corporate Management Team has an expressed interest in the environmental work and they state much of the requirements to the product development organisation. Normally, the Managing Director receives the requirements and transfers it to the Environmental Manager, who implements it into environmental targets for the organisation. Some of the targets, which can be both quantitative and qualitative, are then implemented in the product development program.

The department for monitoring of law requirements also supervise product environmental requirements from the authorities.

7.3.4 The product development process and its connected environmental aspects

The product development in Gothenburg is specialised on diesel engines and shares the development of gears with the development centre in Chesapeak. When Volvo Penta initiates a new project, the engine often already exists and they rather optimise it for a specific purpose, like an application adapted to conditions onboard a ship.

In the pre-investigation of a new concept, the Product Planning Department write the general outline for the product, like dimensions and general requirement specifications.

When Product Planning Department has finished the suggestion of concept, it is taken over by the product development organisation that meets the written general outline with a technical specification that shall balance targets of the concept with a realistic cost.

At this stage, a checklist for assessment of environmental aspects is performed, similar to the E-FMEA model at Volvo Car Corporation. Input to this checklist comes from several directions and information is received from different networks, earlier results from LCA, and customers and authorities requirements. To follow up environmental aspects during the development of the product, the checklist consider a number of aspects in several steps according to the Global Development Process, which is the valid product development process routine with in the Volvo group, see principal flow in figure 7-1.

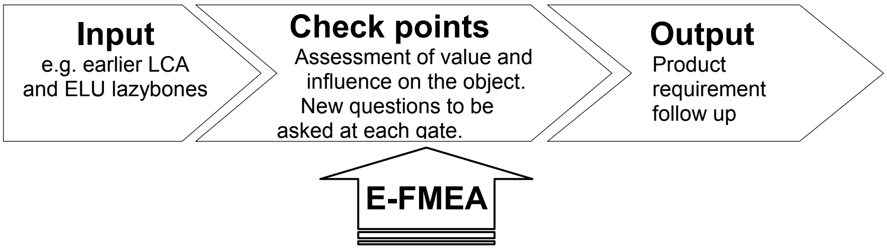


Figure 7-3: Building of environmental requirements within Volvo Penta

To assist the product development organisation, there are plans to introduce lazybones and guidelines, for example lists of EPS-index for various applications. The principle of EPS-index is further described in chapter 5.1.1.3. The environmental aspects of the product identified in the checklist for assessment of environmental aspects are also included as an environmental feasibility list for the product, but transformed into requirements. The requirements may various from different concepts but some aspects are normally always included, like compliance with the Volvo Corporate Standards of forbidden and restricted chemical lists, Volvo STD 100-0002 and Volvo STD 100-0003 and interval of change of oil. Other requirements can be weight aspects that facilitate installation and limitations of noise and air emissions.

7.3.5 Environmental edification of knowledge at Volvo Penta

Most important for the development of the environmental requirements is the Checklist for assessment of environmental aspects, which forms the foundation of the requirement specification within the product development process. To support the checklist with reliable input, some LCAs have been accomplished. Performer of these LCAs has been Volvo Technology Corporation, who has used the EPS system. Presently, the opinion is that the company has enough input to decide what to focus on during the product's life cycle.

Other sources of input are the SPINE database and material data from supplier. The chemical forbidden and restricted lists, Volvo STD 100-0002 and Volvo STD 100-0003 are communicated to all suppliers of production material together with other environmental requirements on e.g. management systems.

To review the conclusions of preliminary analyses, measurements are performed on finished products. For marine and industrial engines, there are emission level requirements and to measure the performance of these combustion engines, a specific test cycle is accomplished. For the company is important to act proactive and continuously try to influence and impels the market and authorities to promote more environmental adopted products.

7.4 Kendrion Holmbergs AB

Interview with Christer Wallin, Quality and Environment responsible, Kendrion Holmbergs AB, the 19th of December 2002 in Anderstorp, Sweden.

7.4.1 Presentation of Kendrion Holmbergs AB

Kendrion Holmbergs AB was founded in 1938 and has since then grown into an organisation with 250 employees whereof 7 are involved in the product development process. The company has a long tradition in manufacturing safety parts for the automotive industry and has manufactured components for safety belts since the 1950s.

Focus today is on safety parts and systems for the automotive industry, together with parts and belt systems for child seats in cars. The business is divided into two different business areas, automotive and child safety, and locally in Sweden, Kendrion Holmbergs is a big supplier to Autoliv since several years.

The company offers complete services to customers, and works with a network of external toolmakers, from product development with prototypes and tool shop to pressing, injection moulding, over moulding, tube forming, coating and assembly in semi- or fully automatic assembly lines. The main product ranges are brackets and pillar-loops, pretentioners and torque locks.

7.4.2 The environmental work at Kendrion Holmbergs AB

Kendrion Holmbergs is certified according to ISO 14001 since 1997 and the certificate is mandatory for all companies within the Kendrion group, but also a customer requirement. The certificate is important for the environmental work at the company and should it come to an end, most environmental activities risks to stop.

The company has recently closed the chromatin line to meet coming requirements from authorities and is working actively with out phasing of surface treatments with content of hexavalent chromium (Cr VI).

7.4.3 The Environmental organisation of Kendrion Holmbergs AB

The company has two employees working half time with the Environmental Management System related questions like chemicals in production, handling of waste, permissions of discharge etc. Environmental aspects in product development process should be handled within the product development team but no specific person is appointed to monitor the environmental work within the project.

7.4.4 The product development process and its connected environmental aspects

The internal routine for the product development process is divided in four steps. For all new products, customer requirements shall be analysed and the project team members shall have a ”brainstorming”, which means that the team members should get together and discuss what improvements that could be done with the product. Considered aspects could for instance be weakness and strength of the product, but also potential environmental impact and adherence to customer requirements. The product development routine also refers to an appendix, which imposes a structured environmental analysis early in the first pre-investigation phase. However during the interview, no documents could prove that these activities had been performed in the practice.

Nevertheless, direct customer requirements had been focused and each reviewed project had submitted both material compositions and weight of the product into IMDS in a late step of the product development. Further, chemicals of the product in opposition to the Autoliv standard 5 Substance Use Restrictions, AS 5, had also been declared for each project.

7.4.5 Environmental edification of knowledge at Kendrion Holmbergs AB

No environmental analysis has been performed to the knowledge of the interviewed person. The company is a sub-supplier and supply to one or several suppliers. Therefore, the company is rather far from a final consumer product and thus the environmental discussions driven by consumers. Possibly as a result of this, the internal requirements of the company are only occasionally reviewed. This may in turn lead to an unstructured control to internally handle external requirements, for instance customer requirements. Further, the process to identify significant environmental impacts was not founded in a structure analysis methodology.

Compliance with customer environmental requirements for studied products was not identified early during the development process as required by the internal routine. However, this was partly compensated by a deep engagement by some employees involved in the product development process. Thus, customer requirements identified later on in the process was considered and mostly corrected when it is possible.

7.5 Gustavsberg Vårgårda Armatur AB

Interview with Matti Weineland, Quality and Environment Manager at Gustavsberg Vårgårda Armatur AB, the 26th of November 2002 at the local plant in Vårgårda, Sweden.

7.5.1 Presentation of Gustavsberg Vårgårda Armatur AB

Vårgårda Armatur was founded Gustav Hedblom in 1920 when he began to manufacture taps. In 1987, AB Gustavsberg bought the company, and it became possible to provide more complete concepts both sanitary equipment for bathrooms and taps for household requirement and a system of connections and ball valves for the plumber.

AB Gustavsberg has an old history and was founded during 1640s by Gustav Gabrielsson Oxenstierna who also has given the company its name, Gustavsberg. Originally, it was factory for brickwork but today the company manufacturers WCs, washbasin ware and bath tubs. In 1991, showers were included in the product set by the purchase of Koralle, a leading manufacture of showers in Europe. Gustavsberg is thus one of the leading manufacturers of bathroom and plumbing products in Sweden. After the fusion with the German Villeroy & Boch group the company belongs to one of the largest manufacturers of bathroom products in Europe.

The Vårgårda Armatur has 210 employees whereof 10 are involved in the product development process. Most of the development of new products is made locally at Vårgårda Armatur and the company has design authority for the development of taps within Villeroy & Boch Corporation even if some design is made in co-operation to get uniform product concepts.

The plant has an almost complete product line where raw material becomes finished taps and screw-pipe joints in one building. The product line starts with incoming pig brass casting. The brass is melted and moulded together with a core of sand and resin and the castings are after-treated depending on product. All cores and flashes are removed and taps are chromatin and polished, followed by assemble of plastic details.

7.5.2 The environmental work at Gustavsberg Vårgårda Armatur AB

The products of Vårgårda Armatur are used directly by end consumers and their responses to new concepts have great impact on what can be produced. The only regulatory environmental requirement directly connected to the final product, states that the taps should not have negative impact to the drinking water, e.g. contaminate the water. Other regulations are instead connected to the main production. For instance, there are comparatively many chemicals in the production, which have to be monitored to follow regulatory requirements.

The interest among private consumers about the product's environmental impact is proportionately low, and the company rather push these forward than vice versa. However, major customers, like landlords can have interests in reducing the water consumption from taps.

The company is certified according to both EMAS and ISO 14001 since 1998. Today it is a fundamental requirement to have a certified environmental management system but Vårgårda Armatur tried to be the first in Sweden since they believed that it could be a marketing advantage. Unfortunately, the response from consumers was poor. However, it was an initiator for a more proactive Design for the Environment work within the company and it has opened contact networks with research institutes in Sweden that have been useful for the company.

7.5.3 The Environmental organisation of Gustavsberg Vårgårda Armatur AB

The company has an internal organisation for handling of environmental issues connected to the product. The local Plant Manager is responsible for communicating environmental issues within the Company Management Team and communicates through the Quality and Environment Manager to the organisation. Both the Quality and Environment Manager and the Plant Manager administrate environmental related issues in production, e.g. the handle of chemicals. To the Quality and Environment Manager’s help there is a Quality and Environment Department with three employees.

All employees have a fundamental environmental education at the company’s expense but to maintain the environmental work, the Quality and Environment Manager is involved in most of the product-related discussions at the company.

Within the company, the Quality and Environment Manager communicates most environmental issues via an information board, geographically located in the production of the plant or, in the local staff magazine. The Quality and Environment Manager also attends active in each product development project and has the main responsibility for the follow up of aimed targets.

7.5.4 The product development process and its connected environmental aspects

The product development process has three different levels, project, mission and activity, depending on the complexity of the task. The definition of project is a detailed described task, which is planned to be extensive in time and cost consuming. It will require several qualifications by the project members and includes uncertainties. A project is time limited and is run by a stand alone temporary organisation. The mission is defined as a time-limited task, which requires co-ordination, planning and check control but the scope is limited whether the activity is defined as part of the normal business.

The product development process is divided in four gates; three gates that consider the procedure before start of production, while the fourth is a follow-up and review phase of the project, after the product has been launched. However, the most important step for the environmental aspects is the phase before the first gate, where the environmental specifications are discussed. In the routine, there is no structured way of handling the environmental aspects at each project but the Quality and Environment Manager attend in the beginning of each project and at each gate, to follow up the decisions. Normally, there are between 5 to 10 projects ongoing simultaneously. Important drivers for environmental aspects are requirements from the authorities, major customers together with internal initiatives where often considered aspects are water and hot water consumption during the use of the product, amount of materials in the product, transportation and content of lead in the brass alloys. However, the Quality and Environment Manager comments that the company is still in an up building phase and the education of the product development organisation is ongoing. This is made by information via the information board and e-mail communication to involved people. In discussions with research institutes, key persons are supposed to attend as much as possible to gain new knowledge about Design for the Environment.

7.5.5 Environmental edification of knowledge at Gustavsberg Vårgårda Armatur AB

The company has performed several environmental investigations for various purposes with help from the EPS-system and Eco indicator 95, described in chapter 5.1.1. Among others, the investigations have shown that the water consumption during the use of the product, has a major impact to the environment and the company is constantly researching and developing water saving techniques. By concepts like eco-flush and mixer taps equipped with patented water saving technology, significant savings can be made compared to the old technology. Conclusions from an LCA have resulted in the single lever mixer tap that saves water without affecting the normal use. The mixer tap has two flows, comfort flow and full flow. Pulling the lever to the highest position, the tap provides 100 percent flow. When it is released it will immediately return to the 60 percent comfort flow with help from a spring in the tap which saves water and helps the user to limit the water consumption. Thus, both energy and water can be decreased which saves costs without compromising the comfort.

A new patented invention built upon the same idea as the lever mixer tap, but not released to the market, is a hot water saving tap which additional to the water consumption saver, also has a spring that limit the heat water flow. Also this invention is a result from a deeper environmental analysis, showing that the consumption of hot water has the major environmental impact during the product life cycle. It is the company's wishes that also consumers in Sweden will see these advantages and choose this solution.

The company has performed one Environmental Product Declaration, EPD. The major benefit for the company has been the internal understanding of the product's environmental impact, which has helped them to see new innovation opportunities. The original intention was also that retailer and other major customers should educate their own employees to facilitate the possibility to compare the environmental performance of taps from different competitors. However, the education of employees has not yet been fully accomplished and the understanding for the new environmental knowledge is generally still limited. Presently, Vårgårda Armatur tries to spread gained knowledge to customers. Unfortunately, the response has so far been rather poor.

8 Description of Autoliv

Autoliv is a worldwide manufacture of automotive safety, with a wide range of products. The business idea aims at development, production and marketing of systems worldwide for mitigation of injuries to automobile occupants and pedestrians, and for avoidance of traffic accidents.

The corporation comprise 80 subsidiaries and joint ventures in 29 countries, and over 20 crash test tracks in nine countries whereof eight test tracks can be used for full-scale testing, for example head-on collision test with two vehicles, figure 8-1. In January 2003, the company had 31800 employees whereof about 2500 are involved in the product development process or in research.

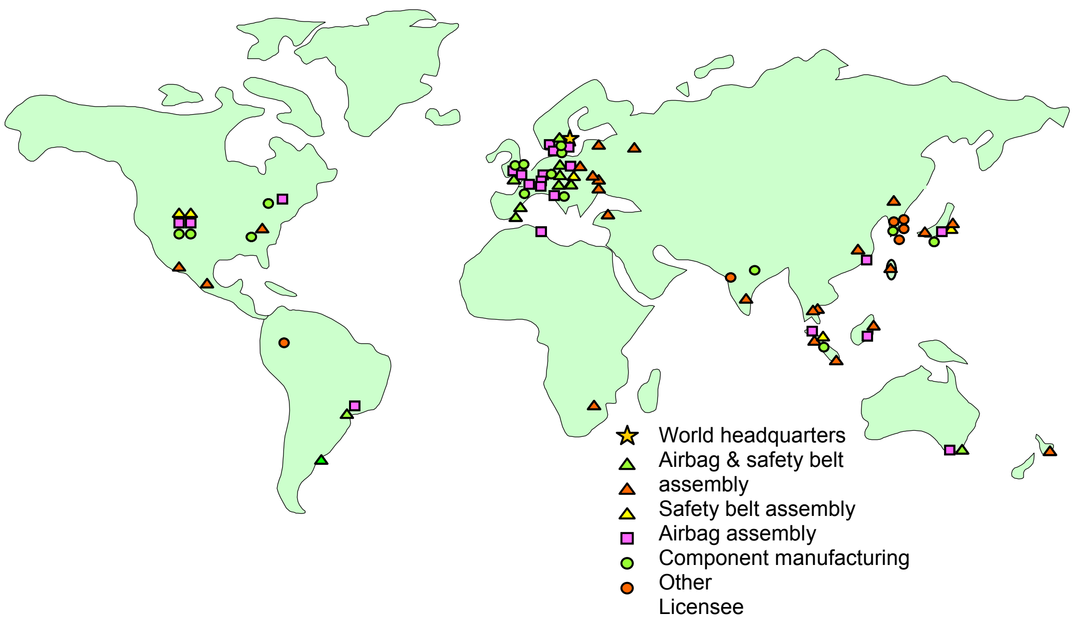


Figure 8-1: The geographical location of Autoliv in the world.

The market for safety products can today be regarded as oligopoly, i.e. only a few big actors with big volume of production are active. The reason is partly fusions between actors on the market, partly that the market tier is entailed with big development expenditures.

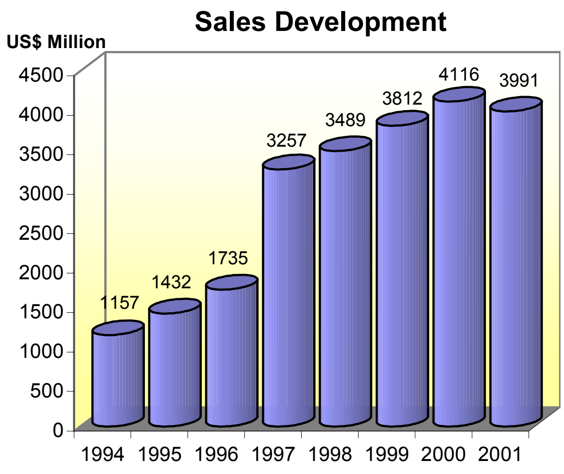
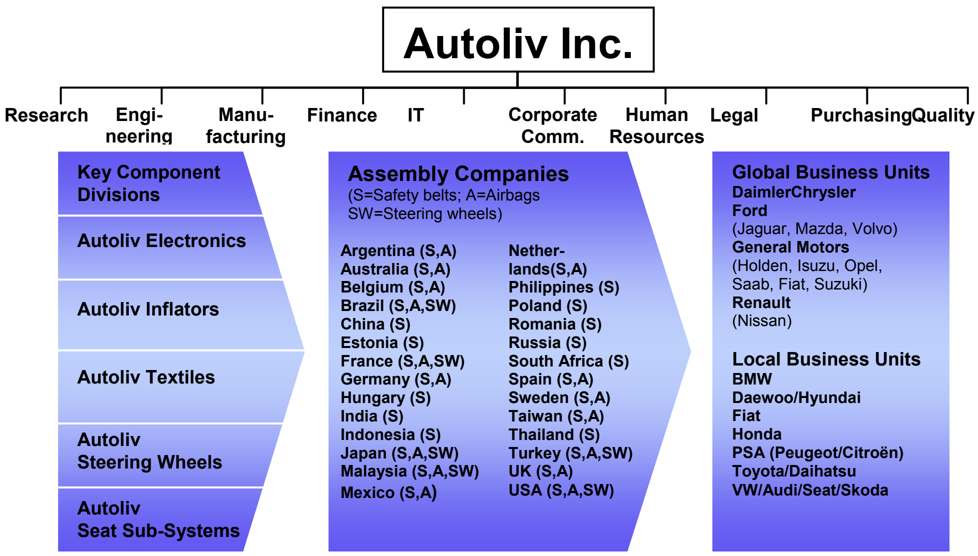


Figure 8-2: Sales development of Autoliv [46]

Autoliv has been successful in this competition, and was first with the inventions of, for instance, the side-impact airbag, the Inflatable Curtain for head protection in side impacts and the Anti-Whiplash Seat. Other products that are not yet launched to the market are for instance Roll-over Protection Systems, Night Vision Systems and Pedestrian Protection Systems. The company has expanded considerable during the last two decades on a market that also has increased as the awareness among people of the risk of car accidents matures, figure 7-3. Today, Autoliv is listed on the stock exchange in both USA and Europe and airbags account for 50% of that market, safety belts for almost 30% and electronics for nearly 20% [46].

8.1 Description of the Autoliv organisation

Autoliv has final assembly of restraint systems in 29 countries, located close to major customers' plants for just-in-time supply. The company also has six specialised component groups where the production is concentrated in relatively few locations for achieving economics of scale. The component companies are generally located in the same countries as the assembly plants.



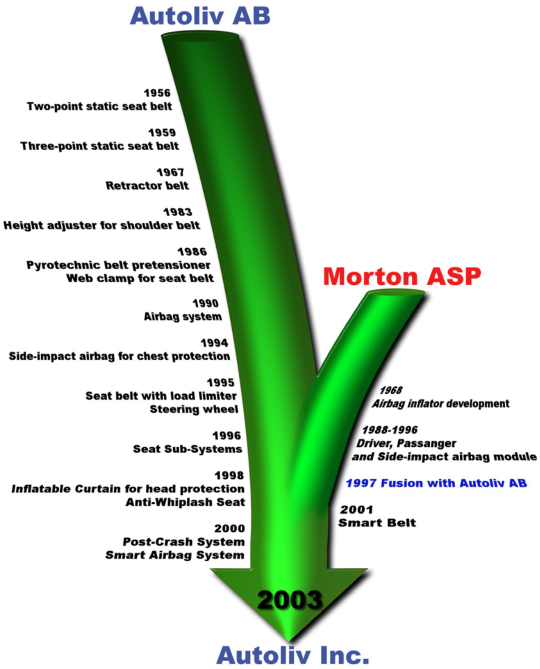
In France, Germany, Spain, Sweden, the UK and the US, the local management is regionally responsible for some operations in other countries than their own. As a result, the main customers have the advantage of dealing with the Autoliv in their home market also when they have or are going to establish production in other markets. Together with two regional co-ordination offices, this organisation contributes to low corporate overhead and short response times for the customers. Thus, the global headquarters has only 35 employees.
The Business Directors of Autoliv and their organisations co-ordinate all activities with major customers on a global basis.

8.2 History of Autoliv

The company has developed from a small family business to a worldwide corporation with over thirty percent of the world market.

Autoliv was started the business operations in 1953, by the brothers Stig and Lennart Lindblad, who founded the Lindblad's Auto service in Vårgårda, Sweden. In 1956, they started to produce safety belts to Volvo Car Corporation.

The production of safety belt made the essential foundation till the middle of 1980th. Throughout the 1980's and the 1990's, the company expanded through a number of acquisitions of both airbag and safety belt manufacturers and 1994, Autoliv was listed on the Stockholm Stock Exchange. Through the merger of Autoliv AB and Morton, the group changed name to Autoliv Inc.



8.3 The Markets of Autoliv

Autoliv supplies to all major car manufacturers in the world and most car-brands but no customer group accounts for more than 20% of Autoliv's sales. The contracts are generally divided among a car manufacture's different car models where Autoliv normally act as a development partner for the car manufacturer.

The company estimates that it currently has approximately one third of the global market for car occupant restraint products that makes Autoliv to leader of automotive safety in the world [46]. The markets accounted for customers in the North American to 33%, Europe 53% and Japan 9% of Autoliv's sales in year 2001. The most important countries were the United States, Germany, France, Japan, Spain, Great Britain and Canada. Sweden accounts for almost 4% of sales.

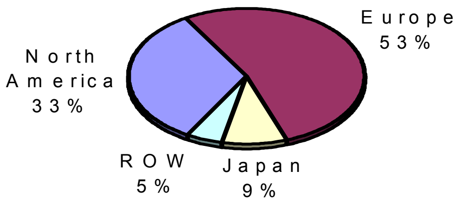


Figure 8-3: Autoliv world sales market

The market for airbags in the world has intensive growth during the 1990's and in 2001, the number of frontal airbag units was almost 90 million and the number of side-impact airbags nearly 40 million, which is continuously increasing market. Also the safety belts market has quickly increased and the group holds approximately one quarter of the total safety belt market.

There are several reasons to successful expansion of Autoliv but important are the increased public focus on car safety together with the acquirers of competitors and new contracts. In Europe, Autoliv has estimated that currently over 90% of the new light vehicles have a driver airbag and 80% also have an airbag for the front seat occupant. Installations of side-impact airbags began in 1994, but already in 2001 two thirds of all new vehicles in Europe had such systems for chest protection.

In Japan, where development started later than in Europe, penetration rates for frontal airbags are already as high as in Europe, while cars equipped with side airbags are just over 10%. Autoliv placed a local assembly of airbag modules in Japan in 1998 and has today a strong position in the airbag inflator market and rapidly growing sales of airbag modules.

In the rest of the world, penetration rates vary greatly from country to country, but the average is still less than 50% for both driver and passenger airbags. Cars with side airbags represent a minority.

8.4 Manufacturing

The component production is concentrated in a relatively few locations, while assembly plants are located close to the customers. The customer typically delivers final products up on request, popular called "just-in-time", sometimes several times per day. For some customers, Autoliv has also begun to establish sequence centres inside or in direct vicinity of a customer's car factory. These centres make final assembly and feed Autoliv's products into the car assembly line.

Since major automobile manufacturers are continually expanding production into more countries, also Autoliv has to increase manufacturing capacity where the major vehicle manufacturers have or are likely to set up production facilities.

The manufacturing is highly automated, which allows for low-cost production in high wage countries where its largest customers are located. In accordance with its cost containment program Autoliv has, during several years, moved and allocated production to low labour cost countries such as Poland, Estonia, Mexico, Thailand, and Taiwan. Consequently, the company currently has over 20% of its employees in such countries.

8.5 The products of Autoliv

The purpose of the Autoliv products to protect the occupants, which is will be described with some representative Autoliv products and theirs market shares in different areas of the world.

All product development of equipment for automotive safety that is managed within Autoliv is, just like all other development, about from an idea that is founded in human needs, with help from experience and competence further develop new and better products. People involved in the product development process, assume three cases; design of systems aimed at preventing a crash, or secondly, if the accident still happened, mitigate its consequences and the third, with help from retroactive systems, for instance automatically alert emergency agency [46].

The fundamental protection of a car is built in the construction of the chariot, but the safety can be much improved by well-performed occupant protection systems where Autoliv has their profession. The company not only offers safety belts and airbags but also seat structures, child seats, anti-whiplash systems and various detection and alert systems.

A basic concept works as follow, if an accident is not possible to avoid, the crash sensors will give signals to the electronic controlled unit that is the heart of the crash protection system. The unit analyses what sort of accident that has triggered the sensors and sends signals, first to the safety belt pretensioners which reacts with tighten the belt on the occupant with help from a little pyrotechnical powder charge. Thereafter, while the impact on the chariot proceeds, various airbags are deployed in various extensions, depending on the actual accident. Finally, the system can alert emergency agency with for instance information about the art of accident and the location of it.

The development has changed from separate systems like single airbags to more complete and complex, concurrent units that can adapt to different accident situations. For instance, the electronic crash transmitters in the car can decide the violence of the crash and adapt the safety belt and the airbag system thereafter.

Now follows a presentation of Volvo XC90 that is an example of a vehicle with many representative safety products from Autoliv.

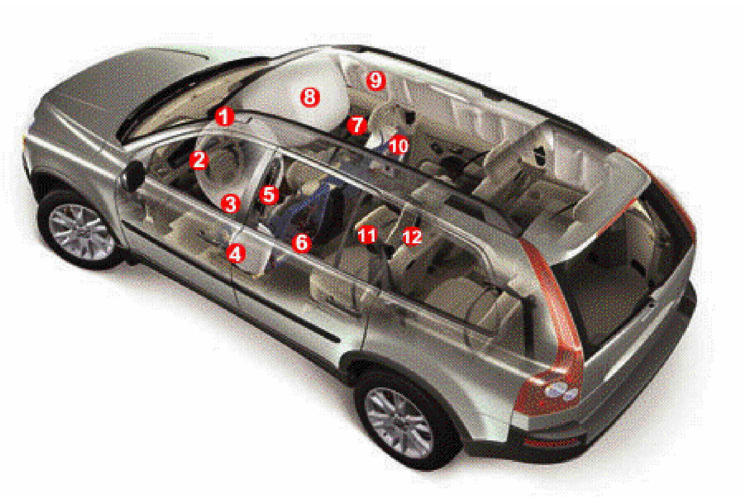


Figure 8-4: Example of where to find Autoliv products in a car

The decision to start to produce steering wheels (2) involves that the driver airbags can increasingly being delivered integrated with the steering wheels to offer more integrated products. This improves the performance of the product as well as it makes it more compact and less resource consuming.

The automatic height adjuster (5) for the front safety belts assures that the shoulder belt is correctly positioned to provide the best possible restraint characteristics for different-sized occupants. The seat structure (6) promotes a stronger seat structures to prevent a person to slip under the safety belt in a car crash.

To further improve the conditions for an occupant to maintain in the seat under a crash, Autoliv has developed the belt-in-seat (12), which is a unique recliner to allow the shoulder belt to be attached to the backrest of the seat instead of the car structure. The invention should be especially effective in maintaining clearance between the head and the roof in rollovers.

The integrated child seat (11) is a foldable seat, which makes it possible for children to use the vehicle's safety belt system, which is more efficient than a separately attached belt.

Neck injuries from rear-end collisions was a new phenomenon when it appeared the first time during the 1970th. The reason turned out to be a too rigid seat structures which not collapsed in a rear-end collision [10]. The solution was a controlled collation with a mechanical construction. The Autoliv innovation, the Anti-Whiplash Seat (AWS) (10) was introduced in 1998, is estimated to reduced the risk for neck injuries in rear-end collisions by more than 50%.

The Safety belt Systems (7) is one of the oldest concepts of Autoliv, produced by Autoliv since 1965 and estimates to reduce the risk for serious injuries in frontal crashes by 40-50%. As an example the safety belts in the Volvo XC90 have:

a) Pretentioners that tighten the belt at the onset of a crash, using a small pyrotechnic charge, so that the restraining of the occupant starts as early as possible.

b) Load Limiters, which pay out some safety belt webbing before the load on the occupant’s chest becomes too high. In the front seats where there is a risk of hitting the steering wheel or the dashboard, the excessive energy is instead absorbed more uniformly by the frontal airbags. The load limiters in the Volvo XC90 are of a new design with two stages to provide an even load on the occupant's body from the combined safety belt and airbag system.

Autoliv also offers several different airbags to the occupant’s protection in a car. The most common is the driver airbag (3). The latest generation of vehicle's frontal airbags have two stages to adjust the deployment to the crash severity estimated to reduce driver fatalities in frontal crashes by approximately 25% when the driver is using the belt.

The Thorax Bags (4) are estimated to reduce the risk of serious chest injuries in side-impact crashes by approximately 20%. Autoliv and Volvo introduced this type of bag in 1994 but it is now available in most cars.

A Passenger Airbag (8) is the biggest airbag in the car and the estimated reduce of fatality in a frontal crash is approximately 20% for belted occupants. Autoliv has been a pioneer in airbag technologies since the early 1980's.

The Inflatable Curtain, IC, (9) has two purposes, one to reduce the risk for life threatening head injuries in side-impact collisions, which has been decreased by more than 50% after the introduction in cars. The other is to protect the occupant from injuries in a rollover accident. This is an Autoliv innovation and it was introduced in 1998 and is now available in most cars.

Despite of all these protection systems, people still are injured and to fast get help after a severe crash, the car can be equipped with the on-call-system (1). The system has a cellular phone that automatically calls an On-Call Emergency Centre and provides the rescue team with the location of the vehicle from the vehicle's GPS navigation system. This is a reactive post-crash system and it can also be used to trace a stolen vehicle.

9 Autoliv Product Development Systems

Autoliv Product Development System forms the framework for the product development within the group. This chapter describes these procedures.

As Autoliv Inc. has developed and grown to one of the major global suppliers to the world's automotive vehicle industry, an increasing amount of the company's business demands the ability to co-ordinate the development activities between different group companies across the world. To meet the need for a common procedure within the company, a framework of activities with common project phase nomenclature and key document contents has been established [31]. The framework is divided in two Autoliv standards, pre-Autoliv Product Development System Procedure AS 108 [32] and Autoliv Product Development System AS 100 [31]. The entire development procedure is visualised in Figure 9-1.

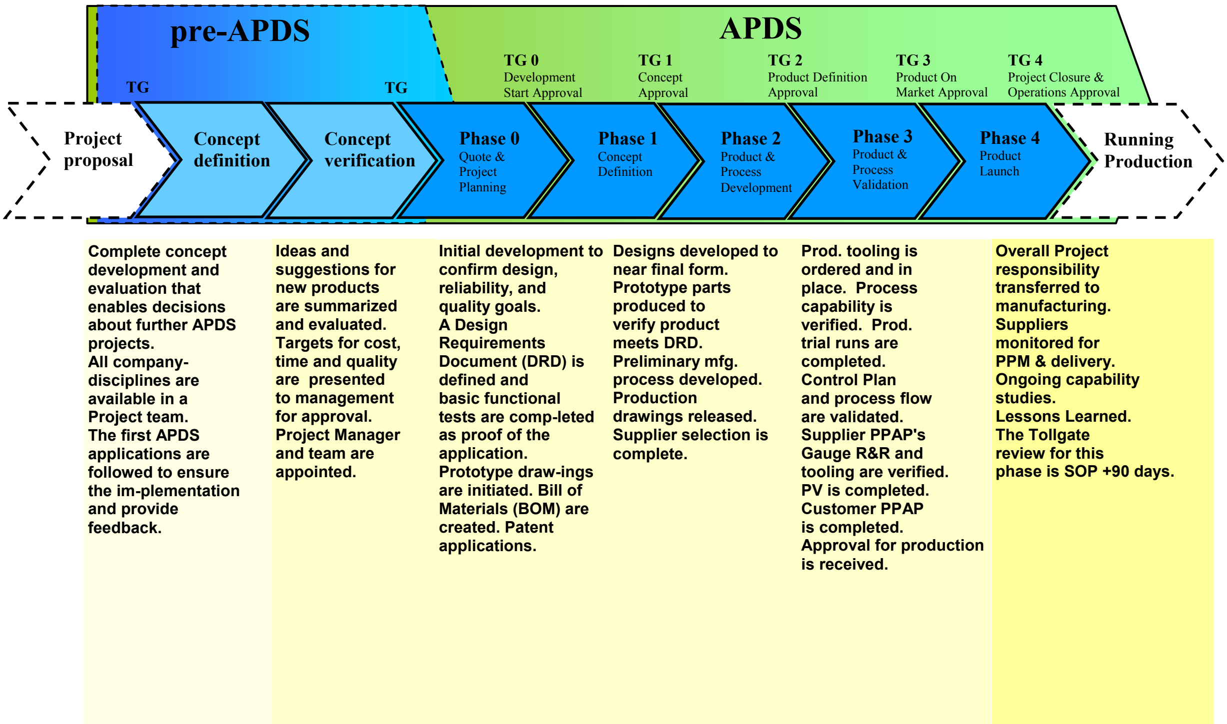


Figure 9-1: Visualisation of the standardised development procedures at Autoliv [31, 32]

9.1 Pre-APDS

The pre-development procedure, pre-APDS, shall settle the prerequisites of a potential concept, and is antithesis of the later following development procedures independent from fixed launch plans. The structured development is particularly a tool for the core engineering within the corporation [32].

The process is divided in two steps, the concept definition and the concept verification. The process is initiated by a project proposal from an idea or concept that might has been developed both internally or in cooperation with customers. Within each project a Design Requirements Document has to be created with input from all relevant processes and instances of the organisation. The document is established at this stage but is brought up to date continuously during the later parts of the development. It contains the Autoliv and customer criteria for a project, including product description, design goals and requirements, possible processes from supplier to customer. Further, applicable statutory and regulatory requirements and incomplete, ambiguous or conflicting requirements have to be resolved before the document is released.

In addition to requirements, selected by the customers through their knowledge and analyses, critical and significant product and process characteristics has to be identified also locally by the project team. For this purpose, the team can use the following tools and methods:

- Product assumptions based on analysis of customer needs and expectations
- Identification of reliability goals/requirements
- Identification of special process characteristics from the anticipated manufacturing process
- Failure Mode Effect Analysis, FMEA that are split into two separate assessments, Design FMEA (DFMEA) and Process FMEA (PFMEA). It is a systemised group of activities intended to:
    1) Recognise and evaluate the potential failure of a product or process and its effects,
    2) Identify activities which could eliminate or reduce the chance of the potential failure occurring and
    3) Document the process.
- Design of experiments
- Test and simulations, are performed according to a design verification plan that is a methodology for developing a test plan that itemises all tests and evaluations necessary to ensure that functional and reliability criteria and target requirements are defined in specific measurable terms. The test plan, includes the test description, acceptance criteria, target requirements, test responsibility, test state, sample size, and timing requirements, and is developed on all new products by the responsible design/development engineer. The results from the testing is reported in a design verification report, that provides a means for reporting test results and progresses, made toward design targets specified by the plan. It also provides the data to verify that the design stage output meets the design stage input.

All identified characteristics are documented on the FMEA form, drawings, the control plan and all associated process documentation. The Project Team Leader maintain a summary of all these critical design aspects in the project, including all critical and significant characteristics and their origin as well as where they will be controlled. As the outcome from the pre-development process shall found a confidence that the project can be brought further in the development process, the project shall show how to meet performance, cost, reliability, manufacture ability and robustness targets. Thus, the results from pre-APDS are used as a platform for the later development process.

9.2 APDS

APDS is divided in five phases, which have defined deliverables that must be completed before the project is allowed to continue into the next phase of the development process [31]. A project goes from initiation in phase 0 to product launch in phase 4. Each phase ends up with a Tollgate, a checkpoint meeting, which has to be carried out before the project can leave to the next step. All through the process, there are totally five checkpoints that must be passed, and in between, the APDS defines in detail what activities to be undertaken and verified in each step of the development project.

Each local Autoliv company shall adopt the standard routine and have in place its own detailed product development procedure. This is necessary to be able to meet all requirements on the product, such as design, manufacturing, environment, quality, timing and cost goals established by Autoliv and the customer. The procedure identifies certain key documents to be maintained in a common format in the English language, which enable simplified project key data transfer and global project status monitoring.

The development system is mandatory when new products are to be designed and when full product validation is required for the assembly where any modified components are used. The process is run as a project and the local Autoliv Company identifies a cross-functional project team with representatives from at least: Engineering, Quality, Sales and Manufacturing departments and representatives from the supplier direct or indirect via Purchase department. The team takes the responsibility for all the required project activities according to the development standard and the local procedure from initiation and approval in phase 0, through product launch in phase 4, ensuring that all requirements are met prior to Tollgate Review.

The Managing Director at each Autoliv company is responsible for that the procedure is observed and to establish a Tollgate Review Board locally. The review board has members from the local top management in at least the following areas: Engineering, Manufacturing, Purchasing, Quality and Sales. This team reviews and approves or disapproves all the activities in a project at the Tollgate Review in the end of each phase. The Managing Director is also responsible to follow the projects very closely and to appoint a chairman of the Tollgate Review Board.

Environmental guidelines and restrictions shall be observed by the project both during development and in future production. Besides the material restrictions, the weight reduction of new products or components has a priority, however without compromising the safe function of the products. Materials and substances planned to be used should first be verified against the Forbidden and Restricted Substances Lists, described in chapter 11.2. The form "Declaration of Conformance to AS 5" or "Approved Waiver" is included with the supplier PPAP submission, described in chapter 11.1, submitted as early as possible in the project to allow for actions if rejected. Below follows a more detailed description of each step.

9.2.1 APDS Phase 0 Project Initiation and Approval

The goal of phase 0 is the timely response to market conditions combined with a disciplined focus of the developmental resources. Ideas and suggestions for new products are summarised and evaluated and cost targets are established for the project, along with the initial market, customer and product information.

The Project Team Leader together with the project team assesses the feasibility of the proposed design and the team must be confident that the proposed design can meet aimed targets like manufacturing, assembling, testing, packaging, delivery of sufficient quantities and on schedule. It must also be capable to meet cost targets and in compliance with both Autoliv quality and environmental requirements. This information is presented to the first tollgate review board for project approval.

9.2.2 APDS Phase 1: Concept phase

In this phase, the concepts are developed to create design, reliability, quality and environmental goals. A Design Requirements Document is defined and basic functional tests are completed for proof of concept. Prototype drawings are initiated, along with a Bill of Material. Concept samples can be delivered at the end of Phase One.

9.2.3 APDS Phase 2: Product and Process Development and Design Verification.

Designs are developed to near final form, ensuring a design freeze at the end of this phase. Prototype parts are produced to verify that the product meets the established Design Requirements Document. Further the Design Verification is completed and the report is documented. A preliminary manufacturing process is developed; the component structure is finalised and production drawings are released. Supplier selection is nearing completion.

9.2.4 APDS Phase 3: Product and Process Validation

All production tooling are ordered and installed. The process capability is verified and production trial runs are completed. Further, the Control Plan and process flow is validated. Supplier declares in writing performance and capability by the Production Part Approval Process, PPAP's (further described in 11.1). A review of the Product Verification Design is held and the run of the product verification is completed including any resulting action items and the supplier approval is received from the customer.

9.2.5 APDS Phase 4: Product Launch

The overall project responsibility is transferred to manufacturing responsible. The design authority after production launch is defined. Capability studies are performed to monitor the process for continuous improvement and suppliers are monitored for product failures and delivery performance. Any process or design changes that affect the supplier's approval process submittal are performed according to the supplier Production Part Approval Process (PPAP) and Process and Design Change Management procedure, and is approved by the customer, as required. A final review of design verification procedures and risk assessments are performed to verify with the ongoing production.

If already existing products are to be modified, this is handled according to the process “Major Engineering Change”. The Technical Manager at the local company decides whether the work shall be initiated according to APDS or if it shall be done as an Engineering Change only.

For Autoliv companies supplying directly to external customers as Original Equipment Manufacturers, or tier 1 suppliers, the project must also be of a certain magnitude and standard project naming is applied when the project is initially created in the corporate Product Data Management system, further described in chapter 11.3.

In the Tollgate Review the project status is presented based on the previous review together with any outstanding issues highlighted for approval, disapproval or counter measures as decided by the Tollgate Review Board.

Upon satisfactory completion the Tollgate Review Board makes a formal sign-off that is an approval to continue to the next phase. In the case that all requirements are not completed satisfactorily, the board may decide on a countermeasure plan that allows the project to proceed. The Tollgate Review Board must approve the results of this plan separately.

A project review at tollgate must also take into account the status from any sub projects and that they have reached at least the same tollgate level. Example: An airbag module project can not be released from phase 1 to 2 prior to the inflator and cushion projects has both reached at least phase 2.

The conclusion of the Tollgate Review in the end of each phase must be summarised in an APDS – Phase Approval Summary Sheet. Enclosed is an example of such a sheet that could be used. Any other approval forms used must have at least that content. The completed APDS Phase Approval Summary Sheet must be retained in the project file.

10 Environmental requirements on Autoliv

Cars are responsible for a great deal of the environmental impacts both locally and globally in the world and therefore the manufacturers have to take responsibility and continuously improve the cars. As Autoliv has grown from a small company to a corporation with activities all over the world, the environmental responsibilities also have increased. The corporation is confronted with both regulatory and customers requirements and is thus expected to take their responsibility to contribute to a sustainable development. This chapter describes some examples of environmentally related requirements that the Autoliv has to deal with.

The end of life directive is directly aimed at the car manufacturers but affects also their suppliers. Beside the ban of some hazardous substances, the directive forces the manufacturers to raise the level of reuse and material recycling from scraped cars.

The Internet based material database IMDS enables the car manufacturers to analyse the material composition of a car. The database can among others be a tool for the car manufacturers to meet regulatory requirements.

The environmental certification, ISO 14001 shall assure that the holder of the certificate meets legal requirements and has a continuously procedure for environmental improvements.

10.1 End of Life Vehicle directive

In 18 September 2000, a new directive within the European Union gained legal force by the European Commission's approval of directive 2000/53/EC, the End- of Life Vehicles directive, ELV [38]. The main purpose of the directive is to reduce waste from vehicle with weight less than 3,5 tones. The member states of the union should take measures to ensure that the car manufacturers take the responsibility to set up systems for the collection, treatment and recovery of end-of life vehicles. This shall be done gradually up to a recovery rate of 95 weight-% that must be reached not later than the year of 2015. In all cases, the producers have to meet all, or a significant part of, the costs of the implementation of all requirements.

The directive imposes a proactive development and states "…fundamental principle that waste should be re-used and recovered…" Practically an effect is that also a market for recycled material will have to be promoted. The directive further states; "It is important that preventive measures be applied from the conception phase of the vehicle onwards and take the form, in particular, of reduction and control of hazardous substances in vehicles, in order to prevent their release into the environment, to facilitate recycling and to avoid the disposal of hazardous waste…"

The very fist step, valid for all cars put on the market after 1 July 2003 is thus to ensure that all materials and components of vehicles are free from the heavy metals lead, mercury, cadmium and hexavalent chromium (Cr^6). The prohibition has however some exceptions for certain applications and concentrations which are stated in an Annex of the directive.

All new cars, put on market after 2005, have to be type-approved before they are put on market, in order to ensure that the components of the car in theory can be recycled to an to a minimum of 95 % by weight per vehicle. In this percentage an amount of minimum 85 % must be either re-usable or material recyclable. The rest 10 % must be at least possible to incinerate and only 5 % are allowed to be landfill. Further, the member states shall ensure that the last holder of the car can deliver the end-of life vehicle to an authorised treatment facility without cost.

In January 2006, the reuse and recovery of all real end-of life vehicles have to be increased to a minimum of 85 % whereof 5 % may be incinerated.

To meet the requirements of the directive and enable dismantling, reuse and recycling of end-of life vehicles and their components, the requirements have to be integrated in the design and product development of new vehicles. This leads in turn that the car industry needs more information about the material composition of all components. For this purpose, IMDS, described in the next chapter, can be used to assure that the cars comply with the directive.

10.2 International Material Data System, IMDS

The international material data system, IMDS is an Internet based automotive industry material data system with the purpose to meet the obligations placed on car manufacturers, and their suppliers, by national and international standards, laws and regulations [50]. Most of the world's car manufacturers are members of the system together with parent companies and subsidiaries. On their behalf, the company EDS administers the system where all materials used in a car are archived. One purpose with the material database is that it shall facilitate the recycling of old cars as well as improve the possibility to coop with new chemical requirements in future.

All material information in IMDS is based on a list of basic substances from a database that contains more than 3000 different substances.

The raw material suppliers declare their material compositions based on basic substances, which can then be sent to a specific recipient or published for any use by all IMDS users. The component suppliers, e.g. a plastic moulder, then declares the material composition and weight of their parts by using these materials, see example in figure 10-1.

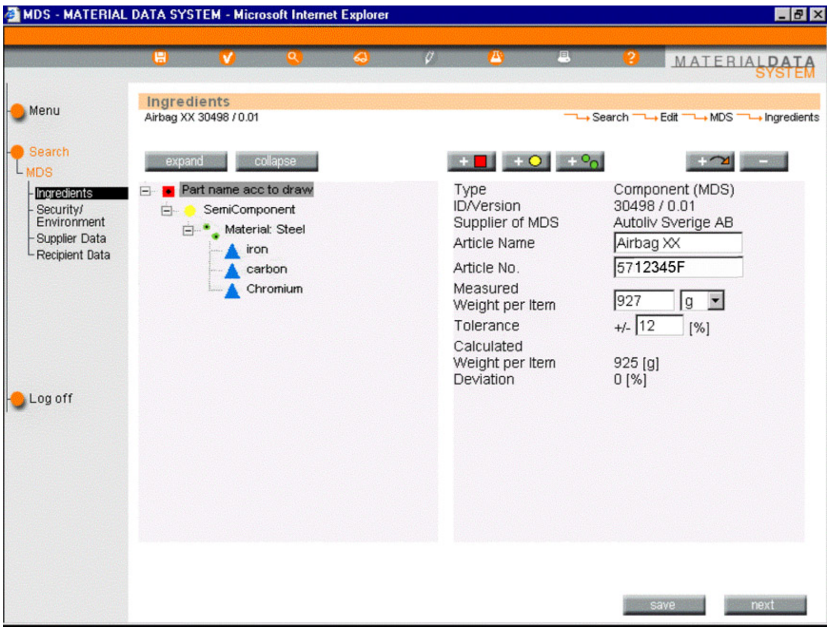


Figure 10-1: Weight and materials are examples of information stored in IMDS

When the parts are sent further to the customers, these can then become parts in an assembly when they are added in the next customer component structures. The final recipients are the car manufacturers who download the information into their own systems.

In theory this process flow works, but so far the entering of data into IMDS has proceeded quite slowly because many raw material suppliers will not declare their material since they consider the composition of the material as business secrets. In turn, this lack of material declarations in the system stops component users to enter their component and material compositions. Obvious the communication between car manufacturers and raw material suppliers must be improved and negotiations are needed to enable a working system.

If the lack of material in the system is solved, IMDS can be a useful tool also internally for small component suppliers since it can help the users to better understand the materials and the chemical compositions. Functionality in the system auto selects substances of concern that are listed by different the car manufacturers. These functionalities enable small companies to more easily identify dangerous substances in his products and ensure compliance with customer requirements.

The PPAP documentation, described in chapter 11.1, is a tool for many car manufacturers to secure that the supplier has met the required product and production performance. As a part of this documentation, the supplier has to report in IMDS by fill in used materials, their chemical composition including hazardous substances and the weight of the product and component. Declaration of recyclability is optional to declare. The gathered information wills help when the car manufacture has to type approve new cars for the European market in accordance with the End of Life Vehicle directive. It will also to show if the product comply with the hazardous substances list that the customers requires conformance with. To meet the requirement of material, weight and probably later on recyclability, Autoliv submits IMDS-declarations.

To meet the car manufacturers' requirement to input all material data of all products produced by Autoliv, the company has seen a need to improve the internal product development process and integrate IMDS into the internal Product Data Management system. The tool that enables a download from IMDS, editing of data internally and finally upload to IMDS is called Autoliv Material Data System, AMDS. After the launch it will probably be a useful tool to meet the requirements of the car manufacturers but also internally for the design engineer to select proper material in the environmental point of view, see further description of AMDS in chapter 11.3.

10.3 ISO 14001

To be supplier to the car manufacturers, it is almost a prerequisite to hold an ISO 14001 certificate since most of the major customers require it. For instance General Motors announced that, by the end of 2002 all suppliers had to implement an ISO 14001 Environmental Management System to remain as supplier to the corporation [52]. Another major car manufacture with the similar requirements is Ford Motor Company with all sister subsidiaries, like Volvo Car Corporation [51]. At Autoliv, the certification procedure is co-ordinated in the Autoliv Standard 30 [33].

10.4 Financial stakeholders

Also finical institutes have interests in the environmental activities within Autoliv. Connecting environmental activities with economical and social aspects has become important for many operators that have started to focus on sustainable conditions.

Some financial institutes have audited Autoliv where they have considered aspects like generated carbon dioxide per amount of sold product, business activities, resource use efficiency etc [36].

11 The environmental work within Autoliv

To meet expectations from customers and public, of a responsible and environmentally adapted organisation and process, Autoliv use standards and tools to support people and facilitate the compliance. This chapter describes these tools and how they work, which are parts of a more comprehensive implementation of a Design for the Environment program.

The environmental work starts out from the corporate environmental policy that is presented in full text in appendix 1. A proactive life cycle perspective empathised in the policy and expects the companies within the group to incorporate the ideas in their local environmental work procedures. The local companies shall also assure that the employees have an appropriately knowledge to apply the corporate policy in their daily work. A part of this commitment imply that Autoliv has continuously certified its plants according to ISO 14001 since 1997, and currently 46 plants are certified including all major facilities in North America and Europe. The remaining plants are predominantly joint venture companies in Asia but certifications are planed also for these.

An analysis [15] has shown that the internal manufacturing does not have a significant environmental impact but rather generated by the suppliers. Autoliv has therefore decided to mainly focus the environmental efforts at the product development process and environmental aspects connected with this. Presently, Autoliv has five prioritised environmental areas; weight reduction, increase of recycles ability, no use of forbidden substances, reduction or elimination of restricted substances and local plant actions to save the environment [46, 60].

The weight reduction is not a quantitative target, set by the Corporate Management, but a recommendation to consider during the product development process within each plant. The aspect has been communicated on Corporate Management meetings where local Plant Management Directors have attended. All information and discussions from the meetings have been entered in the minutes and distributed to each attendee for follow-up internally at each company.

The use of recycled materials has been handled and communicated in the same manner as the weight reduction.

The prohibition of hazardous substances and reduction of restricted substances are handled via the Autoliv Standard 5 [34]. The requirement of compliance with this standard should be implemented at each local product developed organisation within Autoliv and its suppliers.

Most of the plants are only assembly plants and the majority of the components and materials are thus purchased. Therefore, the significant environmental impact of manufacturing in the plants is relatively little. Internally, the factories pay attention to aspects like energy consumption, chemical impact index, freight, etc. in accordance with the certificate instructions.

Suppliers are recommended by Autoliv to hold a third party certified Environmental Management System like ISO 14001. They must also declare material compositions into the material database IMDS and conformance with Autoliv Standard 5.

However, the company believes that the most important aspect to consider in this work is weight reduction of the final products, since this decrease not only the need for raw material, but also the weight of the vehicle and thereby lowers the fuel consumption during the vehicle's lifetime. One example of the weight reduction is Autoliv’s buckle pretensioner, in which the weight has been reduced by more than 50% since the introduction in the 1980s. Since more than 10 million buckle pretensioners are produced every year, the total annual weight savings exceed 5000 tons for this product alone [46].

Public information about the environmental performance of the company is reported in the Autoliv annual report, which in briefly describes how the company has performed during the last year. Above that, the company does not normally perform any separate reporting except from requested information to the authorities. The argument for not attend in surveys like Dow Jones Sustainability Group Index, is based upon priorities with other environmental work such as hazardous substances elimination. The company is of the opinion that it is waste of money and resources to report separately and it does not bring the environmental work further.

11.1 Autoliv Standard 1 (AS 1) and Production Part Approval Process (PPAP)

The main purpose with Autoliv Standard 1 is to define the Autoliv Quality System Requirements for suppliers. The standard is an Autoliv requirement, applicable for all production material and components then these are included in a purchase order or on a drawing [30]. The standard states what and how requirements shall be to communicate with the supplier and who has the responsibility to assure that each product conforms to the defined technical specifications. Therefore, this is in the first place a tool for the purchasing department and used as a master plan for supplier compliance control. For this purpose, the standard has a checklist that shall be used when requirements are communicated with new suppliers but should also be used as review tool when purchase employees are visiting established suppliers. For the environmental work the standard has an important function to submit environmental requirements to the suppliers.

One part of the AS 1 requirement handle the Production Part Approval Process, PPAP, which originally comes from the quality management standard QS 9000, a joint requirement by Chrysler Corporation, Ford Motor Company and General Motors Corporation. The purpose with the process is to determine that the supplier properly understands all customer requirements and that the process has the potential to produce products, which meet stated requirements all the way from development to production. Thus, PPAP procedure is used both to declare conformance to the customers requirements as well as a tool for Autoliv to require corresponding declarations from the suppliers.

The PPAP has five levels of declaration requirements, where aspects to consider in the declaration are stated in a local routine at each Autoliv company. Some aspects are common for all companies as a part of the QS 9000 standard, but the local company has also the possibility to input specific requirements, for instance requirements from a local customer. The default level for declaration is level 3, which is a full declaration by the supplier of all Autoliv requirements.

One part of these declaration requirements is related to environmental issues. Above that suppliers have to comply with regulatory environmental requirements, a fulfilled declaration in IMDS, described in chapter 10.2, and a written conformance or a waiver request in accordance with the AS 5 standard, described in next chapter 11.2, is a prerequisite of approval. AS 1 also expect the suppliers to plan for and implement an Environmental Management System, preferably ISO 14001.

11.2 Autoliv Standard 5 (AS 5)

The Environmental Policy of Autoliv Inc. states that the company has committed to continuous improvement in the field of environmental activities and environmental management systems shall be implemented at all Autoliv companies. As a part of these activities the company has developed Autoliv standard 5 Substance Use Restrictions, AS 5, which was introduced in 1998 [34]. The standard is applicable to all materials, components and products used under the manufacturing and in parts delivered from Autoliv Inc. and supplied to. Further, the standard is to be viewed as a minimum and in any cases where there are more strict requirements prescribed by local legislation or requested by the customer, those requirements are valid and must be adhered above AS 5.

The standard is part of the Autoliv quality management systems and it is linked to Autoliv Inc. Standard AS 1 - Supplier Quality System Requirements. The AS 1 standard should be consulted as part of the environmental requirements when suppliers are selected. The standard list is divided in two parts, forbidden respective restricted substances and is a consolidation of analogous customer lists. Unless otherwise specified the limit is 0,1% for both forbidden and restricted substances.

The supplier shall comply with the standard and is must declare conformance to it or inform Autoliv about any deviation at the time a part or material is ordered. The conformance must also be declared together with documentation of the Production Part Approval Process (PPAP). Depending on what to declare, the AS 5 form to fill in can be a “Declaration of Conformance”, which certifies that the materials, components or products do not use substances listed on the Forbidden or Restricted Substances Lists. Are there any deviations, the supplier must declare those materials, components, products or processes that contain listed substances. Materials, components, products and their processes that are in conflict with the Restricted Substances List shall be reported in a specific form submitted with PPAP. Materials, components, products and their processes containing substances on forbidden list must not be used. However, a waiver can request an exception if the substance is considered necessary due to safety or other requirements. These parts shall then be kept under surveillance and less hazardous alternatives shall be introduced when technically and economically feasible. Justification and a plan to eliminate the use, including timing and substitute substances, must be provided and the waiver must also show that precautionary measures are taken to minimise any damaging effects to humans or the environment. The request is submitted as early as possible in the project to allow time for actions if needed.

The Quality Manager for the local company is responsible for ensuring that the standard is applied within the company while the Purchasing Manager is responsible for ensuring that the standard is implemented and applied by suppliers.

Requests regarding restricted substances used in the manufacture, internal the plant are submitted to the local Quality Manager, whether waiver requests regarding substances in components, materials and products are made by the local project team. Requests regarding restricted substances used by suppliers to Autoliv are made reported and sent via PPAP, described in chapter 11.1.

If the project identifies a restricted or even forbidden substance, the project can not proceed until a waiver is accepted first by the customer and, if it is a forbidden substance, also approved by a corporate environmental affairs coordinator internal Autoliv.

11.3 Autoliv Material Data System, AMDS

As a result of new customer requirements of IMDS and the ELV directive, described in chapters 10.1 respective 10.2, Autoliv has decided to incorporate new data in the existing Product Data Management system that is already used worldwide within the Autoliv group. The system is a specification and communication tool for the product development process. The extended functionalities of the existing system is called Autoliv Material Data System, AMDS and will enable Autoliv to download data for each supplied part from IMDS and build assemblies structures internally. Finally the data can be reloaded as controlled information to the customers or used for internal purposes as described in Figure 11-1. The tool is believed to facilitate for the organisation that can more easily reach material and weight data. It can therefore be an important tool for the environmental work within Autoliv in the future.

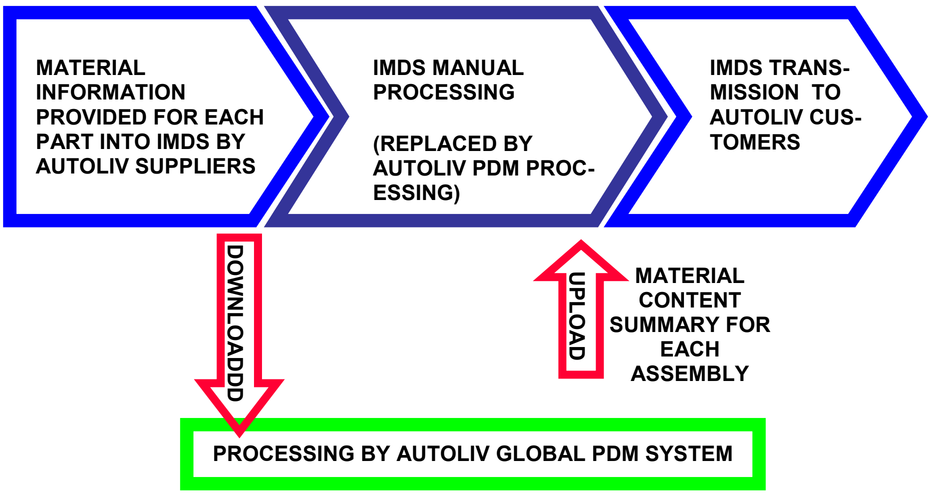


Figure 11-1: Processing of material information, using IMDS and internal Product Data Management system [60].

The development of AMDS opens new possibilities for the members of a single project as well as for the corporate staff as it enables a better overview and control of critical environmental data both during the development process and production. In turn that can be an important part of the common understanding and focus at the internal design for an environmentally adapted development.

For a specialist on Design for the Environment or a management team it can be easier to set up and monitor environmental targets for the product development process.

For a single project team, the access to material and weight data may leads to a higher consciousness and knowledge within the project. In turn that facilitates for the team to take environmental decisions into consideration at an early stage of a project but the data can also be used later, to verify the conformance to different kinds of requirements.

11.4 Autoliv Standard 65 – Lessons Learned in Autoliv

Each project within all Autoliv plants locally produce a large amount of know-how knowledge and lessons, originated from positive or negative experience's encountered during daily operations. This knowledge is not typically related to Design for the Environment but the methodology is exceedingly interesting also for these purposes.

Transformation of knowledge from earlier projects is valuable since it could avoid reinventing solutions that already are available within the group. However, these lessons and know-how are split in individual memories of people or possibly collective memories of local plants.

In order to improve and increase the availability of this knowledge within the group, a formal decision has been taken to implement a global Lessons Learned Process [35] supported by a computer database system named Lessons Learned System. This database is available for all employees within Autoliv and should be regarded at least in the beginning of project to avoid pitfalls and take impressions from success stories.

11.5 Customers requirements aimed at Design for the Environment

In the development of Autoliv, environmental aspects are often performed up on request from the customers. Weight and characteristics of materials in products are the overall concern for the car manufacture industry, which also largely involves all suppliers. These aspects have become even more important after a joint agreement between the European Automobile Manufacturers Association and the European Commission. This agreement states a long-term requirement to reduce the carbon dioxide to 140 g $CO2$/km by year 2008, which practically imply decreased fuel consumption by an average of 25 percent [42].

The environmental requirements are mainly communicated via Technical Specifications when a new product shall be developed. Examples of environmental requirements are described in chapter 5.1.2.4, based on two Technical Specifications from Saab Automobile respective Volvo Car Corporation.

12 Analysis

The analysis considers how the environmental activities work presently, both within Autoliv on corporate level and further to a single company and its suppliers. These conclusions are considered when the environmental activities are discussed how complies with, on one hand; the corporate policy and the environmental intentions from the head office, and on the other hand; existing requirements from customers and more in general, the society that is in change to a sustainable development.

In these perspectives, follows a discussion how a Design for the Environment program can be connected to the product development of Autoliv and what benefits the corporation can get from these changes. The interviews and theoretical studies are utilised to complement the argumentation and point at actual examples. As both customers and a supplier have been interviewed, it is possible to follow how environmental targets and requirements are communicated and evaluated, from the car manufacture and two steps down in the supplier chain.

12.1 Analysis of the existing environmental work at Autoliv

The fundamental principles of the environmental work within Autoliv starts out from the environmental policy that is a part of the Autoliv standard valid for the entire group and shown in full text in appendix I.

The policy states that “Autoliv’s environmental activities shall be pro-active…” and “One of Autoliv’s competitive tools shall be to develop products and manufacturing processes, which over their total lives are energy efficient and minimise environmental impact…”

The corporation states a responsibility for the environmental impacts of the entire product life cycle, independently wherever they appear. The policy continuous with “Autoliv companies shall ensure that their employees are appropriately trained and motivated to apply this policy in their daily work”. Suppliers and sub-contractors shall be influenced to apply the principles of this environmental policy.” The implication of the policy is promising and can constitute an appropriate foundation for a Design for the Environment program. Thus, from the policy point of view it is interesting whether this policy is implemented in reality, in the first place on corporate level but also secondly, on the single local company level. What practical actions are taken presently to support the policy and what can be improved?

Autoliv has prioritised five environmental objects [46, 60]:

- No use of forbidden substances,
- Reduction or elimination of restricted substances
- Weight reduction,
- Use of recyclable material
- Local plant actions to save the environment

The global standard, AS 5 for forbidden and restricted substances was established 1998 and is described in chapter 11.2. The standard is applicable for Autoliv and their suppliers. Of the five prioritised environmental objects, this is both the most structured requirement and most emphasised by the customers. An explanation to this focus on hazardous substances may be a result of the society’s consideration that has been expressed both in terms of political targets and legislation. Within Autoliv the process is structured in a written standard and has also been paid most attention both on corporate level and among local companies. Identified restricted substances shall be monitored and phase-outs planes followed up. Nevertheless, users of the standard, despite long time of implementation, often have difficulties to understand and interpret the list. To decide whether a chemical compound complies with the standard or not, thorough chemical knowledge is often needed. Presently, these processes are made manually and more effective tools should advantageous be developed to facilitate the administration. Thus, the product development management system has been developed to also enable handle of material data. That will probably facilitate these procedures and reduce workload for the Autoliv organisation.

Weight reduction is an important factor for the reduction of fuel consumption during the use of the car and accordingly, the environmental performance. This has theoretically been shown in one accomplished LCA within Autoliv [15]. The corporation has also expressed the importance of the weight reduction as a prioritised undertaking when new products are developed. However, the implication by giving priority to weight is not yet clear. Relevant questions are for instance how this undertaking is communicated and measured. There are no quantified targets and no deadlines. The importance of weight reduction has been verbally emphasised by the corporate head office at Corporate Management meetings where participants from local companies have attended [60]. These meetings have also been recorded and minutes have been submitted to each company. However, compared with the handle of the hazardous substances, there are no clear instructions or written standards in place, nor quantitative targets have yet been established on corporate level.

Use of recyclable materials is emphasised in the 2000/53/EC End- of Life Vehicles directive. A first step to enable material recyclability is to ensure that the material is free from contamination substances [11]. Autoliv has not yet taken any structured measures to focus on increased use of recyclable materials. Instead, the given priority to the use of recyclable materials has been communicated in the same manner as the weight target.

An action to save the environment on each local plant is the corporate requirement that all business units must hold an environment management system, preferably ISO 14001. It is also recommended that all Autoliv suppliers hold certificates [30].

12.2 Environmental drivers for Autoliv

Important drivers for the environmental work within Autoliv are beside legal regulations, like the End of Life directive [38], the customer requirements. The two studied customers, Volvo Car and Saab Automobile communicate environmental targets and expectations on Autoliv's product development via the Technical Specifications that is established for each new project. In the long term, if the targets of the final environmental performance of the car shall be reached, it is reasonable to believe that the external supplier requirements follow the internal requirements at the customers. It is therefore of interest how these requirements are handled and thus, Technical Specifications from both Volvo Car and Saab Automobile have been analysed. The results show that the requirements between them are quite similar.

The weight targets are crucial for the final fuel consumption. Each assembly at the supplier shall have a weight target, which then is followed up by the customer. However, Autoliv has no customer requirements that request them to further cascade the weight target to the sub suppliers. An unchanged weight compared with similar previous products or even higher weight can be justified by new functionalities and accepted.

Length of life requirement has impact on the environmental performance as the car manufacturing requires resources and generates pollution. Thus, foremost benefits from a long length of life are reduced need for resources. However, this must be balanced with the fact that the technique becomes better with higher environmental performance. Autoliv tests and evaluates the length of life performance in their technical centres.

Control of hazardous materials and substances are already in focus and considering new legislation like the End of Life Vehicle directive and the quite new request for declarations of material information in systems like IMDS, the future focus of the society will probably be even more intensive.

Labelling of plastic parts must be done in accordance with customer requirements and is a part of a much more complex process how to recycle a product at the end of life of the product. The majority of all materials in each European car will have to be material recycled in the future and these materials must be possible to identify in some way. Depending on how materials from scraped cars will be handled, the labelling requirement might be important. Both the specifications from Volvo Car respective Saab Automobile refer to Design for Recycling Guidelines, which seem to be very comprehensive. To enable successful recyclability, some basic principles in these guidelines are stated; the number of different materials shall be as few as possible and easy to separate. However, even if it is stated that the guideline targets must be reached, there is no process to follow up the results of the designed products. These requirements may easily become in conflict with other requirements, like for instance, easy assemble of many different materials with help from adhesives and thus, there is a risk that the recycling guidelines are not prioritised. However, the introduction of the End of Life Vehicle directive will strengthen and structure the authorities' requirements. In turn, it is reasonable that the car manufacturers also will pay more attention to recyclability guidelines of the Technical Specification when the law is fully implemented.

Above the mentioned requirements, both Ford Motor Company and General Motors, including their incorporated car manufacturers, required their suppliers to hold an Environmental Management System before the end of 2002 to remain as a supplier. Therefore, Autoliv decided that all major plants within the group should hold a certificate before this date. Today, a majority of the plants in the Autoliv group are holding a certified Environmental Management System.

Although it is more or less an industrial practice to hold a third party certified Environment Management System within the automotive industry, there are still many companies that end up with a focus only on the production plant [40]. One reason can be that ISO 14001 does not explicit force the company to consider indirect environmental impacts during the life cycle [41] and traditionally much attention has been paid on the local production [40] as it is up to the company to define significant environmental impacts. Considering the interviewed companies, several of the interviewee stated that they believed that their ISO 14001 certificate had comparable little importance to the development of the Design for the Environment program in the product development process. Instead, the certificate had been either an early ignition to a later and more sophisticated environmental work, often with focus on product development, or a supplementing tool for a structured environmental work. Thus, there are necessarily no formal connections between an Environmental Management System and a Design for the Environment program. A report from NUTEK, Swedish Business Development Agency [22], concludes analogous and question whether the ISO 14001 rather should have a product focus than a production focus.

12.3 Analyses of the interviews

Human impact on the global environment is an increasing concern all over the world. As a reaction a trend can be seen, especially in Europe, that industries and consumers try to influence by making conscious choices through the selection of more environmentally adapted products. These changed trends of consumption pattern in addition with new legal requirements have had impact on many businesses, which respond by changing their marketing strategy [24].

The interviewed car manufacturers are in focus from much different kind of interested parties. One of the most important are the end-consumers and their influences, in combination with other interested parties of the society that force the car manufacturers to continuously observe trends and demands. The expectations of social and environmental responsibility on car manufacturers are increasing and it does not only affect the car manufacturers but also their suppliers, which was shown during the interviews with both Volvo Car Corporation and Saab Automobile.

The European End of Life Vehicle directive aims at the car manufacturers and it will probably have important influence on the environmental work in the future. Although, most parts of the directive do not directly aim at the suppliers they are producing many components, and therefore also the suppliers will probably have to be involved. However, instead of a direct aimed legislation, the supplier may get parts of the directive as customer requirements.

A voluntary commitment between the European car manufacturers and the authorities are the amending of carbon dioxide reduction. The car manufacturers undertaking will also necessarily lead to new technical solutions that also must include the design responsible suppliers.

Hereby follows an analysis of the interviewed companies. Generally, the impression is that the development of the environmental work within product development is on various levels among the interviewed companies because of both internal and external reasons. In later chapters, the companies are reviewed in relation to both each other and Autoliv. The purpose is to give a picture how they have performed and what benefits Autoliv can gain from their work with Design for the Environment.

Saab Automobile had established an environmental organisation. The environmental requirements were formulated early in each new project and followed up later on. Responsible employees monitored and supported the project team during the development process. However, the procedures were not fully established in written routines. Further, there was no procedure to evaluate the final environmental performance of the products and no evidence that the products were continuously improved.

Volvo Car Corporation had a well-established environmental organisation and specially appointed employees who ensured that set environmental targets were reached both for separate parts and for complete cars. They also had a staff that accomplished advanced Life Cycle Assessment to evaluate that the environmental performance was continuously improved. However, the environmental targets for the product development were secret because of commercial reasons.

Volvo Penta believed that the pressure from the market was low and environmental requirements rather came from the authorities or internally within the Volvo group. The internal environmental organisation was small, centralised and gave a well-structured impression. Some analyses have been accomplished to validate continuous improvements.

Like Volvo Penta, Gustavsberg Vårgårda was selected to extend the point of view and compare whether presumptions in other marketing sectors could give valuable input to the environmental work within Autoliv. Since their products are directly aimed at a private consumer market, the response from new or changed products comes back quite directly. The performed environmental assessments have lead to new products and thus, the environmental benefits have become an additional commercial argument. The environmental interest from customers has so far been low, and the company has to convince the market about the products' better environmental performance and economy.

Kendrion Holmbergs showed a theoretical environmental procedure during the product development process but in reality it was not followed. Instead requirements stated by Autoliv were unstructured followed upon request in connection with the PPAP reporting much later on under the development process. Too late to identify and allow any environmental improvements. Conclusions from the interview show that both Autoliv and its customers must improve the transfer of environmental requirements and make sure that the results are reliable.

12.4 Design for the Environment tools

In the practice, a project team has to make many decisions and the environmental aspects are one part of these. Often can one improvement lead to an impairment of another. The team must be able to compare environmental aspects with others and prioritise among them in the daily process [29, 21]. However, it is not unusual that environmental aspects are considered to be more abstract than others. Maybe, a reason can be that the cause-effect chain might be hard to comprehend.

Considering conclusions from the theoretical literature studies and experiences from the interviews, one important key to a successful introduction of a Design for the Environment program is that involved employee get accurate and enough knowledge and also supporting documents about environmental aspects to enable action. For this purpose, tools are needed that can assist the team to make well-founded decisions. However, to perform a reliable assessment of environmental impacts during a life cycle is a complicated task that takes time. Nevertheless, the more comprehensive and precise assessment, the better founded are the conclusions. Thus, the tools used in the product development process must not only provide both reliable input and facilitate the main decision process but most also be time effective.

In this thesis, some common tools are described for different purposes. Some are suitable mostly apart from the main development process or at least in very early stages of the development process, while others are aimed at later steps. Therefore, advanced LCA tools, foremost used for research, are separated from the more simplified tools like matrices and checklists that are preferably used in the common development process. Volvo Car, Volvo Penta and Gustavsberg Vårgårda Armatur AB had all accomplished LCA based on the EPS methodology. These assessments were also supplemented with indices and inventory data from Eco-indicator and SPINE. These companies had also accomplished Environmental Product Declarations partly to be granted trustworthiness from the stakeholders, but also to validate progress. Thus, the results from these advanced tools had formed a foundation of knowledge when less complex tools were used during the development of the product.

Which tool that suit a company depends on the need and the local culture at a company [21]. Among the interviewed companies both checklists and matrices were used. Gustavsberg Vårgårda and Saab used checklists or a "brainstorming" to get a foundation for the further environmental work during the development process while Volvo Car and Penta used Environmental Effect Analysis. Common for the utility of all these tools was the accomplishment initially of each new development project. Thus, each decision became well founded when environmental targets and requirements should be defined later on.

12.4.1 Selection of Design for the Environment tools for Autoliv

Considering both experiences from the interviewed companies and literature, it seems to be a benefit to keep more advanced LCA tools separated from the product development process. As the advanced tools are more precise they also become more complex and time-consuming.

Beside the final result, the analyses often give many experiences during the accomplishment that help to build up important knowledge within a company. Such experience is useful to predict significant aspects to consider without accomplishing a thorough analysis. Based on long experiences from performing LCA Volvo Car used that approach. LCA on a similar group of products give predictable results and thus, Volvo only accomplished LCA on new product categories and major changes on existing concepts.

Autoliv has not accomplished any LCA on corporate level and not structured any rules for such activities. Nevertheless, some single companies have accomplished a limited number of LCA [15]. How the benefits from the results and the experiences from the accomplishment have been evaluated has been a local decision at the responsible company.

Without a common structure that describes how to accomplish LCA within Autoliv, valuable knowledge may be is lost. Especially important is a common procedure to evaluate results and experiences, together with a structure to communicate this knowledge to the product development organisation. As mostly external individuals, like students, have made the local analyses, important knowledge and experiences from the accomplishment might have been lost, such as assumptions and other prerequisites. That makes the results difficult to evaluate. Furthermore, each new analysis has to start from the beginning to build up for instance contacts, inventory data etc. These finalised analyses become difficult to compare as all of them may be built from different approaches.

Due to lack of structure and targets it is a question whether these analyses may be neither useful nor reliable in a corporate perspective. However, any documented experiences may be useful for the corporation to establish structured LCA procedures. Thus, as a first step, Autoliv should accomplish comparable analyses of a limited number of representative product categories to get a comprehensive understanding of the environmental impacts from different products categories. Provided that these LCA are done with help from computer software, the results from the inventory can be applied on other basis of evaluation, which in many perspectives is an advantage. A first reason is to get a more harmonised and thorough understanding of the relative importance of each aspect, several methodologies should be applied. This since the results of an LCA is partly influenced by the utilised assessment methodology. Secondly, as environmental science is a relatively new science, research continuously make new findings that leads to existing environmental basis of valuation continuously have to be revised. Consequently, accomplished assessment becomes obsolete by time and must be regularly revised to remain reliable.

Provided that experiences and knowledge from advanced LCA is applied, less complicated tools, like for instance Environmental Effect Analysis or MET-matrix, can be a valuable support to assess and prioritise environmental aspects during the product development process. However, also in this process, a certain level of Design for the Environment related knowledge and experiences has to be reached to gain the full benefit from the tools [22, 29]. To get the most from any of these less complex tools, it should be a part of the implementation of the Design for the Environment program. Only then, it can enable and assist the employees to take relevant environmental aspects into consideration in their daily work. The tools have to be intuitive and pedagogical to use since the project team members have several other aspects to consider and the time frame is often limited.

Environmental Effect Analysis uses the same principles as the FMEA, which is already used by Autoliv. In that perspective, the basic methodology is already familiar within the organisation. However, a question is whether the knowledge will be enough to acquire the most benefit from the tool. The accomplishment of the Environmental Effect Analysis required environmental expertise both at Volvo Car and Penta.

The MET matrix is described in this thesis but was not used by the interviewed companies. After the list of identified environmental aspects is accomplished, the aspects are assessed to decide which of the three topics Material cycles, Energy and Toxic emissions that shall be given most priority in relation to each other. The assessment requires some knowledge and the prerequisites are thus similar to Environmental Effect Analysis.

Another alternative is the pre made checklist. Checklists have the benefit that they are delivered in a structured format that facilitates the fill in and doesn't require deeper environmental knowledge. However, checklists are in comparison with, for instance Environmental Effect Analysis rigid and do not permit the people involved freely identifying and assessing environmental impacts and opportunities. Therefore a combination between an Environmental Effect Analysis and a checklist could be a useful solution for Autoliv.

A variant of checklist, based on the Eco-design strategy wheel, has already been implemented at one local Autoliv company, appendix IV. The purpose of this checklist is foremost to get the development employees conscious about aspects and activities during the life cycle that have relatively significant environmental impact and help them to prioritize. Although the results must be presented at certain tick marks under the development the results are not yet connected to any formal targets or requirements. Instead, the structured format intends to help the organization to understand the overarching environmental impacts and when possible, reduce or improve them.

For Autoliv, the development of the internal material data system AMDS, described in chapter 11.3, can be an important tool to get a comprehensive overview of the material composition and weights of the products. The system will facilitate the identification of materials with contents of forbidden or restricted substances in accordance with AS 5. The possibilities to change design or substitute materials increase if the identification is done earlier in the development process. It will be possible to monitor weight and different materials on optional level that will make it feasible to set up targets both for single companies and the corporation, which directly support two of the prioritised corporate environmental aspects. However, maybe most important, the information will let the product developers to be more conscious of the material and its composition. This knowledge can be used to find better design solutions that improve the environment performance. In the long term it can also be a useful input for future Life Cycle Inventories and Assessments.

12.5 The interviewed companies constitution of Design for the Environment program

Saab Automobile has two departments working directly with environmental related issues during product development. However, the environmental procedures in the development process have only partly been co-ordinated in written routines.

Experiences from previous design together with legal law requirements, gained knowledge from competitors and other external interested parties are collected but Saab has not performed any LCA. Many experiences are achieved during the accomplishment of an LCA and it could be discussed whether Saab retrieves this knowledge from external reports or not.

Identified claims and expectations are converted into more structured specifications, which are manually monitored and followed up by a role, Performance Responsible. Since this single role is defined for each car concept, it makes it possible to keep an overview of the identified environmental aspects and bring back experiences to future projects.

A number of environmental requirements are specified in the supplier specifications. The supplier shall declare the material compositions and weight of all used materials. For this purpose, the material database IMDS is used. The system enables Saab to ensure that none of the General Motor's listed hazardous substances or the only banned material, PVC plastic, are used. Via the system, Saab can also control the declared weight of each product that helps the staff to accomplish a theoretical calculation of recyclability of the car. To further improve recyclability during the product development, Saab uses Recycling Design Guidelines that also is a requirement in the technical specification for the suppliers. However, except from optional recyclable materials information in IMDS and labelling of plastic parts with recyclability symbol on the drawing, there is no documented evidence that the supplier actually have used the guideline.

Different from Saab, Volvo Car Corporation believes that the environmental performance has importance for the consumers' purchase of cars and environment is thus a business argument for them. To define relevant environmental aspects, the company has developed structured methodologies to identify, assess, prioritise and follow up important environmental aspects by both tools and routines. On a regular basis they perform internal environmental assessments for all new projects or major design changes. Together with earlier experiences, legal requirements and customer demands this becomes valuable input when the more simple assessment tool, the E-FMEA is applied to each project. The results from the E-FMEA constitute the foundation for the environmental requirements in the Technical Specification, which shall be considered both internally and by the suppliers. The realisation of the environmental requirements is driven and monitored by special staff for both overarching car concept and single projects including suppliers. The environmental improvements of the products are measured in a structured manner by the accomplishment of public Environmental Products Declarations. By performing these on regular basis, the company can be informed whether actions lead to progress or not.

Volvo Penta has limited the environmental staff to one single Environmental Manager and one environmental responsible at each plant. In the early concept phase a tool, similar to the E-FMEA at Volvo Car, is utilised to perform assessment of environmental aspects. The results form the foundation of requirements for the further development process. Input comes from internal performed LCA based on EPS methodology and SPINE, together with relevant legislation and customer requirements. After the development of the product is finished, the result can be evaluated by measurements of emission levels and Environmental Product Declaration.

The environmental activities within the product development at Gustavsberg Vårgårda Armatur AB are small enough to be controlled by one person. Thus the Environmental Manager attends in the beginning of each new project and can help to bring both knowledge and ensure that proper environmental aspects are defined. Beside of legal regulations, customers together with internal requirements are considered.

The company was very early to be certified in accordance with ISO 14001. This founded their understanding for the environmental aspects within a company. In addition, they have performed several assessments with help from the EPS-system and Eco Indicator 95. They have also performed an Environment Product Declaration, which they think should be of interest when customers are becoming more conscious about the environmental impact.

Kendrion Holmbergs has not initiated a Design for the Environment program. The internal product development routine imposes a meeting that shall identify environmental requirements from customers and other interested parties. However, since these meetings only occasionally occur, separate activities later on and upon request have taken place to unstructured handle the requirements. Even if the company so far has been able to satisfactory fulfil the few environmental demands of Autoliv, the company loses valuable experiences and the chance to improve the process for the future. Gathered knowledge stays isolated among the involved employees since the activities are not documented and there is a risk that the same problem occurs twice.

12.6 Constitution of Design for the Environment program at Autoliv

A vision has to clearly state purpose and designations of responsibility to enable realisation of its goals [12]. Autoliv Corporate Environmental Policy stipulates a responsibility for the environmental impact of the products during the entire life cycle. However, to go from words of the vision into concrete results is a difficult step. The following chapters describe and discuss prerequisites and suggestions that are needed to adapt the organisation and the development process to a Design for the Environment program.

To succeed in the efforts to achieve a good environmental performance of the product's lifecycle, it is especially important that the environmental aspects are well founded and considered as early as possible in the beginning of the product development process. Provided this, it enables a flexibility to make changes and improvements on the product without too big costs and workloads [40].

Much literature emphasise that a successful implementation of a Design for the Environment process is a full integration into the product development process together with a well-founded participation by the employees and the management [3, 12, 29]. The existing five corporate prioritised environmental aspects are differently coordinated. Two of them are implemented as written standards in the Autoliv product development system but still the process can be improved, which is described later on in this chapter. The best-established aspect that also has the clearest objective is the reduction or prohibition of hazardous substances distributed by the corporate standard AS 5 described in chapter 11.2. The standard is linked to the product development and describes a structured process with coordinated responsibilities both within the organisation and at the suppliers. The experiences from this work could be used as a model for further integration of the other prioritised environmental aspects that are not yet clearly coordinated.

Except from people involved in the procedures of handling hazardous substances, Autoliv has not appointed any formal staff for a Design for the Environment program on corporate level. Nevertheless, external expectations and requirements actually demand internal activities like, for instance the material declaration in IMDS or the requirement of increased recyclability in accordance with the European End of Life Vehicle directive. Considering the global concern for increasing environmental impacts from the car manufacturing industry these sorts of requirements are not isolated demands but likely a beginning of the society's expectations for environmental measures within the sector. In that perspective it would be justified to establish a permanent corporate Design for the Environment team.

Naturally there are pros and cons and a decision for the corporation to take whether resources shall be set up temporarily for separate activities or formal established to proactively meet future environmental expectations on Autoliv. Mobilising staff from parts of the organisation that can be at service for separate projects might temporarily seems to be a flexible solution and may in a short perspective also possibly save money. On the other hand, there will be no opportunities to build up efficient processes but also more important, knowledge that can be used as a competitive and proactive development, since the team will be dissolved after each finished project. Studied literatures advocate that a Design for the Environment program must be a proactive process as it has a long time frame [3, 12, 29, 18]. The fundamental principles of strategy build upon preservation of the trademark, future expected demands from stakeholders and authorities together with optimisation of processes rather than isolated actions upon request. Their conclusion is also supplemented by the experiences from the interviews that a structured and conscious organisation performs better than a loose that acts up on request. Environmental work that is kept separated from the main process tends to lose the purpose to improve the products, since environmental aspects are not consequently considered when the actual decisions are taken in the daily work. It is thus important that those people that shall be a part of the Design for the Environment program also are involved in its development and the requirements should be formulated in a technical manner to be understood and accepted by the product development organisation.

Provided that a Design for the Environment program is implemented, how should an organisation be organised to get the most from it? A majority of the employees do not need thorough knowledge but should get enough support and knowledge to found suitable decisions via more simplified checklists and other tools and, whenever needed, a possibility to consult expertise. All the interviewed companies except from Kendrion Holmbergs had more or less a centralised core environmental organisation. These staffs had the commission to observe the world around environmental development, perform deeper analyses and support the development organisation in different ways. In other words, their primary task was to facilitate the establishment and maintenance of an environmental design on the product development level.

Autoliv has much in common with the interviewed Volvo Car Corporation, Volvo Penta and Saab Automobile in perspective to size and customer relations. A centralised organisation at Autoliv would derive advantages from copying the principles of well performing parts of the organisation structures as well as suitable tools. It is fundamental to have knowledge about all activities that have significant environmental impact and how these shall be improved to increase the environmental performance. All three had built their environmental strategies upon internal Life Cycle Assessments and Environmental Product Declarations. The assessments had given them specific results applicable for their own production processes and products but more important is the gained knowledge from the accomplishment of the inventories and the assessments. The understanding for boundaries, assumptions, quality of data etc. gives experiences and a consciousness that supports the environmental organisation when decisions shall be taken in the future work.

Autoliv has not yet any global co-ordination for environmental assessments. In the policy Autoliv assumes responsibility for the environmental impact during the life cycle of the products. Based on the discussion in chapter 12.4.1 the success of a serious strategy builds on knowledge and experience, which are given by thorough analyses such as LCA. As the outcome will be of use for the entire corporation, responsible for these assessments can advantageously be a corporate function that ensures identification and accomplishment of needed analyses. The corporate function, here called Environmental Affairs Coordinator, shall also take responsibility for that the results and experiences are structurally spread within the development organisation.

How the knowledge is integrated and communicated to the business units is thus the next crucial step for the success of the Design for the Environment program. The interviewed companies used simplified tools to communicate and implement the knowledge among the employees of the development process. These and a number of other different tools like e.g. checklists and matrices have been presented in this thesis, all with their pros and cons. Isolated these tools do not contribute much but must be put in a correct context. Thus, most important is not to define a tool specifically but rather a thorough assessment accomplished early in the development process and that the results from it is understood and considered under the continuous steps. Both the customers Volvo Car Corporation and Saab Automobile refers to different guidelines in their Technical Specifications like the Recycling Design Guide [37], Guidelines for Environmentally Conscious Design [43], to support an environmental adapted development. Though these guidelines were a part of the technical requirements, there were no descriptions how these have been met in the documentation to customer, i.e, PPAP. Apparently, the understanding of these guidelines may be vague within the development organisation. Thus, at least in the beginning of the implementation of the Design for the Environment program, all simplified tools must be combined with foremost direct support, education and training for understanding and practice of such guidelines.

Both experts and employees in the product development process need training and education to get inspiration and knowledge. Especially important is that the top management gets the education and commits to the purpose and the implementation procedure of the Design for the Environment program [22, 25]. Many employees within Autoliv have received a basic environmental education, as a part of the ISO 14001 certificate. This has given the organisation a certain understanding for the complexity of the environmental aspects. However, specific education aimed at Design for the Environment has not yet been accomplished.

An important input to the environmental assessments will be achieved from the Autoliv Material Data System, where material and weight will be stored and developed. Presently the system will be useful for instance to help the user to identify materials that contains banned substances and control complies of weight with the customer expectations. The system has requisites to be further developed by connecting the material data with the experiences from the corporate performed assessments. In this manner the design engineer should be able to consider the environmental load in a lifecycle perspective for each material and thus be guided to find proper material for any application. To enable such programming, the Environmental Affairs Coordinator must co-operate with those responsible for the Product Data Management system, Matrix, described in chapter 11.3, which in turn must interact with the Design for the Environment program.

The experiences from the interviews and literature have shown that clear, measurable customer environmental requirements are crucial for the development of the internal environmental work. Autoliv is not an exception and the requirements of the car manufacturers have highest priority. Analogues, well-defined requirements are very important in the communication between Autoliv and the suppliers, which also has been stated in the environmental policy of Autoliv. To maintain the same level of the prerequisite environmental performance also the suppliers need knowledge how to design and develop an environmental adapted product. As different suppliers have various prerequisites it will probably facilitate for them if Autoliv requested them to use a simple Design for the Environment tool, like E-FMEA or any other of the described matrices or checklists in chapter 5.1.2 and 5.1.2.4. The manufacture often has the greatest knowledge about the product. However, they may lack insight of Design for the Environment methodologies and knowledge. From the interview with Kendrion Holmberg, it became clear that the present requirements (IMDS, AS 5 and ISO 14001) from Autoliv were not efficient enough to ensure that environmental aspects were structurally considered and improvements were done. With their knowledge several improvements that gain the environment and may reduce cost could be done, according to Kendrion Holmbergs. For instance, theoretically a drawing made by Autoliv can prescribe that a piece of steel should have a thickness of 2 millimetres. Although the suppliers with their experiences know that 1.8 millimetres would meet the requirements but also save weight, suggested changes in the drawing is not encouraged or even a risk to be seen as a troublesome supplier.

The result from a simplified environmental tool could suitably be submitted together with for instance a Feasibility Analysis for Purchased Parts, in phase 1 when the contracting between Autoliv and the supplier is made. Accomplishment of such assessments at the supplier as soon as the supplier is involved in the development process can thus give input for important improvements.

12.6.1 Autoliv Product Development System

The Autoliv Product Development System sets the rules for the product development process within Autoliv by the core development standard pre-APDS, [32] and the application development standard APDS, [31]. Therefore, it might be a natural platform to also constitute the framework for an implementation of a Design for the Environment program. In the following chapters existing environmental requirements in the standard are discussed and possible opportunities are suggested.

12.6.2 Pre-APDS

Since no procedure to identify significant environmental aspects and requirements is in place, this analysis can only point out how such procedure could be organised.

The project team has the obligation to create a detailed project plan, where all relevant activities and responsibilities are considered. In this process it would be adequate to use a simplified tool for environmental assessment that gives thorough and structured qualifications to consider important environmental aspects. Well-founded data for this assessment may come from different sources like Design Requirements Document from finished projects, Lessons Learned [35] documentation, advanced Life Cycle Assessments, customer expectations, other corporate targets etc. Suitably these results could be documented in the Design Requirements Document as targets that are transformed into measurable requirements in the latter APDS phase 0.

As many projects are developing together with a customer like a car manufacturer, it might be constructive to also involve them at certain situations. Some environmental design solutions are true rationalisations while other may be more environmental effective but increase the cost. However, the customer may be prepared to pay more for unexpected improvements that can be positive sales arguments or meet other obligations.

12.6.3 APDS Phase 0 - Project Initiation and Approval

The first step of this development step starts up with an analysis of necessary qualifications of a product concept idea. The project team shall take over from the core engineering and must among others ensure that the product can be manufactured to a target cost but still meet all other requirements.

Presumed that an environmental assessment is in place and accomplished during pre-APDS, the results shall be transformed into measurable requirements. These environmental requirements should cover customer requirements, legislation and the demands from the internal assessments and are also suitably stored in the Design Requirements Document. To get a smooth transition from the core engineers to the development team both sides should attend when the requirements are defined. Similar procedures are practised at the interviewed companies Volvo Car and Penta, Saab Automobile and Gustavsberg Vårgårda Armatur, who had appointed staff for this purpose and participated at such meetings. To facilitate the transform from targets to requirements, different kind of support might be needed. If the support should come directly from environmental specialists or via guidelines has to be determined. To put a requisite pressure to fulfil the transformation and define correct requirements, the results should be presented at Tollgate 0.

12.6.4 APDS Phase 1 - Concept Definition

During this phase, the standard prescribes several decisions that have to be made finally. The product concept includes a final decision of environmental aspects like selection of material, dismantle possibilities, and material recovery. However, to reach desired results all these aspects should have been considered already in the previous phases and here rather reviewed and validated when the Design Requirement Document shall be completed.

The material selection has often a significant impact on the products environmental performance and aspects that could be considered are weight of different materials, material length of life, the content of recycled materials in the product, product recovery, hazardous substances etc.

Experiences and knowledge from earlier similar Autoliv projects are important for the continuous improvement of the product development and therefore, the project is requested to verify that such are gathered. At this stage a review is valuable as it assures that the project is keeping the focus. One task is to verify that no hazardous substances or forbidden materials are being used, which is controlled via the Autoliv Material Data System.

The checkpoint “Communicate to potential supplier the project targets” might be crucial for the final environmental performance of the product. Today Autoliv has two required environmental targets and one recommended. The required targets are declaration of material, substances and weight in IMDS, together with compliance and declaration of hazardous substances according with AS 5. Further Autoliv has a recommendation that the supplier should implement an environmental management system, preferably ISO 14001. Above this, the importance of the supplier’s participation and environmental knowledge during the development process has been emphasised. A suitable assessment tool can facilitate for the supplier to achieve the demanded knowledge and responsibility that should be expected by Autoliv. The assessment is best done in association with the purchase order and results can be reported together with the Feasibility Analysis as conformance evidence.

12.6.5 APDS Phase 2 - Product and Process Development and Design Verification

In the present version of AS 100 [31], many important environmental aspects are considered first at this phase. For instance, the hazardous substances are inventoried here, both in the engineering and the manufacturing point of view. The checkpoint question "Are all planned materials accepted by customer and in accordance with AS 5?" should rather be regarded as a point of review since most technical decisions are already taken. Nevertheless, the listed checkpoint aimed at chemicals used under the manufacturing process can be relevant, since manufacturing aspects are established first under this phase.

"Does the design comply with all environmental requirements?" and "Is the design in harmony with all known and expected legal requirements?" are aimed at the engineers in the standard but are in this step primarily most important to the manufacture processing and environmental aspects connected with this.

Purchase department is responsible for two important environmental related questions. "Proposed supplier selection in line with corporate guidelines and requirements?" and "Proposed suppliers must give Project Management capabilities and conform to AS 1". To assure compliance, the purchase department should rather consider these two questions already in phase 0 and the supplier at phase 1 if the environmental assessments are reported in the Feasibility Analysis in phase 1. In phase 2 these questions are relevant for an audit review.

12.6.6 APDS Phase 3 - Product and Process Validation

The design should now be completed and production tooling is ordered and now in place. A more complete production process should be established, the capability is verified and production trial runs should be completed. The suppliers declare the PPAP's, and the tooling equipment is verified. A pre-product verification design review is held and completed, including any resulting action items and finally, PPAP should be sent and approved by the customer.

Above manufacturing aspects, there are principally only environmental questions, related to verification reviews and declarations left. Certainly, it is important to continuously observe changes of legal and customer requirements but, in reality, the most fundamental decisions are already made and should principally only be reviewed in this phase if not a reconstruction is decided.

Connected with the supplier PPAP, IMDS material declaration should be declared as latest at this phase, and the customer can receive the complete IMDS declaration when the customer PPAP is sent. Ideally, if the communication with the suppliers has worked out well, this declaration is a pure confirmation of conformity from previous requirements in earlier phases and not an object for any action. However, in practise the IMDS declarations contain insufficiently declared material data and are not unusually inconsistent in compare with AS 5 restricted substances declaration.

Packaging aspects of the product are considered under phase 3, which should include environmental aspects. Depending on distance and means of conveyance, the packing material could be discussed whether returnable or disposable packing should be used. The decisions may be supported by guidelines or similar based on conclusions from accomplished Life Cycle Assessments.

12.6.7 APDS Phase 4 - Product Launch

In the final step of the product development process the product concept shall be transformed to regular production and project responsibility is transferred to employees responsible for manufacturing.

At this stage, all question marks of considered environmental aspects identified under the product development process should have been solved. The suppliers PPAPs have been approved in phase 3 and therefore, environmental aspects like the Bill of Material, weight, transportation distances etc. are in place.

Design Verification Documents are reviewed and delivered as a Lessons Learned to future projects in pre-APDS. Thus, it is time for sum up and a review to accomplish Lessons Learned documentation and feedback. Today, there is no structured way to communicate experiences from the environmental procedures specifically. However, all external environmental requirements should be considered when the Lessons Learned process is completed.

A future implementation of a Design for the Environment program should also include experiences from the internal environmental target process. Advantageously the experiences are used as input in new projects when the simplified assessments are accomplished and environmental requirements are established.

13 Conclusions

Outmost the purpose with implementation of a Design for the Environment program aims at reaching a sustainable development. However, to be more manageable and obtain a hearing, this diffuse vision must be broken down in more intelligible targets and incitements. Autoliv has agreed with a proactive environmental policy, which prescribes that the corporation assumes responsibility for the product from the time it is developed till the time it shall be scrapped, or metaphorically "from the cradle to the grave". The question is how the policy has been applied in practice to realise the commitments and what measures that can be taken to further improve the practical activities?

To a company like Autoliv, the arguments for an introduction of Design for the Environment could be the need to satisfy customers' expectations as the requirements continuously increase and in a proactive manner meet future legislation. The investments in a Design for the Environment program have turned out to be profitable for many companies, among others Volvo Car Corporation. A conscious design may lead to resource efficiency, reduced energy consumption etc. that in turn involves costs decrease or even, *vis avi* an increase of profit. Thus, both more cost effective and better products can be developed when environmental aspects are considered.

However, although the global focus on environmental devastation there the car manufactures with theirs suppliers are responsible for a great deal of the negative environmental effects, too little has been done to restrain the problem that are rather increasing. Weight targets, recyclability, reduction of energy consumption etc. promoted by environmental management systems are common requirements in the automotive industry but often poor focused and rarely followed up. Except from the End of Life Vehicle directive, lack of governmental pressure have allowed the car manufactures to remain in a reluctant position that infect in turn also the suppliers. Nevertheless, the future must bring severely increased requirements if the society shall be able to convert the present consume-waste society into a sustainable. The winners in this process are likely those who quickest can change their products to adapt the new conditions. Thus, strategic investments in a Design for the Environment program today are in that perspective reasonable new business argument tomorrow. These aspects must be considerable strategic arguments also for Autoliv as a global supplier to the automotive industry.

13.1 The existing environmental work at Autoliv

Autoliv has five prioritised environmental objects; no use of forbidden substances, reduction or elimination of restricted substances, weight reduction, use of recyclable material and local plant actions to save the environment. Presently the environmental focus is above all on substance restrictions, which are co-ordinated foremost in the later phases of the development. Also weight reduction is emphasised in the text but not connected with any explicative activity plane.

The decision to require all facilities within the corporation to hold an Environmental Management System is a local plant action to save the environment. Partly this is a result from strong customer requirements. However, the system is of less importance for the environmental procedures in the product development process as the focus is on production rather than on the product and its life cycle.

In parallel with the corporate expectations and legislation, the customer requirements constitute the final environmental requirements on a development project. Their environmental focus has been intensified after the European Commission's End of Life Vehicle directive [38] gained legal force in 2003. Although the directive only aims at the car manufacturers, the environmental requirements have been severed also for the supplier.

13.2 Design for the Environment program

Engaged and competent employees are the most important key for a successful outcome of a Design for the Environment program. As the implementation of a Design for the Environment program to large extent is an iterative process, a great deal of the outcome depends on the decisions of the employees. Therefore, a well established, structured and conscious organisation likely performs better than a loose that acts up on request. A key to success is also to gain acceptance from the development organisation and especially from the top Managers. Thus, the Design for the Environment program should be implemented in the common development process and treated in the same manner as other requirements.

Assessments on different levels are an important part of the program and experiences combined with education are essential for the outcome of the program. Life Cycle Assessment methodologies are the most common used tools to predict and assess environmental impact when products are developed. The accomplishment of an LCA gives much experiences and reliable prerequisites for further conscious environmental decisions. Accordingly, the accomplishment of a representative number of analyses to identify and assess significant environmental aspects should be done. As the results and experiences are relevant both for Autoliv as a corporation and for single facilities, the analyses are beneficially accomplished on commission of the head office and the results are then centrally distributed. Then, Autoliv founds a thorough base that, in next step, gives reliable instructions how to act to get the best environmental performance out of the product development.

On corporate level, a staff is needed to accomplish Life Cycle Assessments, identify and suggests corporate Design for the Environment targets, communicate results and support the development organisation. An appointment of a Corporate Design for the Environment role suitably coordinates the corporate activities.

After this first screening in order to accomplish these advanced analyses, such analyses shall only take place when new product categories are introduced or there are significant changes on existing concepts. However, a number of methodologies with different eco-points schemes should be applied on each analysis. The reason is that eco-points are always dependent on subjective weightings of different environmental effects and it is important to avoid that the assessment results are influenced only by one single methodology. The results of the analyses shall then found targets and requirements for the company, both on corporate level and within each development project. Advantageously these are quantifiable to facilitate continuous measurement.

13.2.1 Training and skills

One part of the implementation is training of the organisation. To enable the employees to act skilled and understand Design for the Environment aspects and procedures, all involved in the product development process, including the top management, need different levels of training and education. A way to improve communication and knowledge is to arrange joint meetings between the environmental staff and the development organisation. Topics can be results from advanced Life Cycle Assessment, new expectations from customers or the society.

Although knowledge about the Design for the Environment program must be common within the development organisation, local appointed employees might be necessary to coordinate and interpret the requirements from the corporate staff but also follow up the results. The appointed employees could be given enough skills and experiences by participating in the development of the Design for the Environment program, i.e. Life Cycle Assessments, definition of requirements and arrangement of joint meetings.

A tool that will probably facilitate the Design for the Environment process is Autoliv Material Data System, a material data system unique for Autoliv that utilise data from the car manufacturers International Material Data System, IMDS. So far it has been difficult to follow-up environmental requirements of products on corporate level, basically due to a too heavy work effort. The new system will enable Autoliv to handle material and weight aspects in a controlled manner where the quality continuously can be more easily secured, as it becomes a part of the existing Product Data Management system. Compliance with the AS 5 standard [34] from a single project up to corporate level as well as the possibility to supervise weight is a thorough environmental progress for the entire group. It both enables internal monitoring and externally strengthens Autoliv to communicate reliable environmental progress. By time the system may also supply helpful data for analyses, both on project and corporate level.

13.2.2 Design for the Environment program's integration in product development

Many requirements and instructions are communicated via standards within Autoliv. The two standards, pre-APDS [32] and APDS [31], set the rules for the product development process and define when and by who all activities shall be accomplished. Likewise, the results of the Life Cycle Assessments and other acquired experiences should be delivered as a Design for the Environment standard. The standard is suitably released separately, as its main purpose will be to define what and how to use simplified assessment tools and appropriate guidelines. However it must also define when, by whom and how relevant environmental project targets are identified and quantified to provide a strong connection with the two development standards. Targets and requirements are distributed in parallel as they continuously shall be updated.

A project is initiated by a concept definition in the beginning of pre-APDS. At this time fundamental foundations for a development project is established and important technical decisions are made meanwhile the degrees of freedom are still high. In principal the environmental parameters under the lifecycle of the product are not different from others that have to be considered, and therefore it is logic to also define the environmental targets and prerequisites at this stage. Although the present pre-APDS does not hinder consideration of environmental aspects since there is no procedure in place to structure and facilitate an incorporation of Design for the Environment targets for the organisation.

At early concept phase of pre-APDS, it will help the core development organisation to assess environmental performance and structure results that are converted to project specific requirements and fulfilled during the product development. As most of the interviewed companies used simplified tools to identify and adapt more general requirements into the development project, also Autoliv should take advantage of the results and experiences from the advanced Life Cycle Assessments. Early in the existing development process, Environmental Effect Analysis might be a useful tool since it has similarities to the already established FMEA at Autoliv. An alternative is checklists, where environmental aspects are considered and structured more mechanically. A checklist tool is probably easier to use than the Environmental Effect Analysis, but on the other hand, it might have a negative effect on the creativity. However, both tools can complement each other where the checklist can be used to structure Environmental Effect Analysis and communicate new findings from the corporate advanced analyses and latest updates from previous Lessons Learned [35]. The Environmental Effect Analysis stands in this solution for the innovative part of the discussions. By using such tools, the development employees will be promoted to learn about environmental impact and how to deal with materials and design. Then, a structured procedure, reliable knowledge among the employees and comprehensive tools, facilitates the proactive environmental development. Further, it enables to make time effective decisions already on an early concept level and take appropriate actions.

Both positive and negative results from the assessment and experiences from the development process are suitably documented in the Design Requirements Document. These targets should then be transformed in APDS into measurable requirements at phase 0 when the concept is transformed into a project.

At phase 1 the concept is finally selected. The project should already have considered the environmental aspects, as it becomes much more difficult to change anything on the concept when reaching this step. Instead, it is important at this phase to involve selected suppliers. Presently, the environmental requirements on the supplier are declaration of material and weight data in IMDS. Autoliv also recommend the supplier to hold an Environmental Management System, preferable ISO 14001. However, experiences from the interviews show that the Environmental Management System itself does not guarantee a proactive environmental work within product development. Rather the suppliers meet these requirements depending on commercial incitements. Nevertheless, since a significant part of the product is manufactured by the supplier, they become a major source of material and energy consumption. Like Autoliv, the suppliers must have a structured methodology combined with knowledge to succeed. Therefore, they must have the possibility to subsidise the environmental obligations. The communication Autoliv *vs.* the suppliers may be facilitated if the suppliers use the same simplified tool as Autoliv. As the implementation of tools takes effort and time, Autoliv can help their suppliers to more clearly define expectations and how the suppliers can help Autoliv in their efforts to succeed with the Design for the Environment program. The results can not only be used to validate the suppliers' compliance with the requirements but also as a base for dialogue during continuous development. In the end, these efficient utilisations of energy and material reasonably lead to better products and decreased cost.

In the final two steps of APDS, the project should execute the defined requirements and validate the results. In phase 4, after the product is put into production and the project is to be closed, Design Verification Documents is reviewed and stored for other projects and relevant experiences are shared within Autoliv as Lessons Learned.

Abbreviations

ACEA	European Automobile Manufacturers Association
ALV	Autoliv
AMDS	Autoliv Material Data System
APDS	Autoliv Product Development System
AS 1	Autoliv Standard 1
AS 5	Autoliv Standard 5
AS 65	Autoliv Standard 65
CAS-RN	Chemical Abstracts Services Registry Number
EF	Eco Footprint
ELU	Environmental Load Unit
ELV	End-of Life Vehicle
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Manage System
EPD	Environmental Product Declaration
EPS	Environmental Priority Strategies in product design
FMEA	Failure Mode and Effect Analysis
IMDS	International Material Data System
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MET	Material cycles, Energy and Toxic emissions
PDM	Product Data Management
PPAP	Production Part Approval Process

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Environmental Policy[1] for Autoliv Inc.

Autoliv shall implement its business decisions in an environmentally responsible and caring manner relative to its employees, its customers, and communities and countries where it operates.
Autoliv's environmental activities shall be pro-active and aimed at pollution prevention and continuous improvement while complying with legal, regulatory and other requirements. Autoliv companies shall establish appropriate environmental policies and environmental management programs for their operations, and up-date them in response to new research and the latest findings.

One of Autoliv's competitive tools shall be to develop products and manufacturing processes, which over their total lives are energy efficient and minimize environmental impact, without compromising the safe function of the product. Autoliv companies shall ensure that their employees are appropriately trained and motivated to apply this policy in their daily work. Suppliers and subcontractors shall be influenced to apply the principles of this environmental policy.

Autoliv companies shall maintain a constructive dialogue with environmental authorities and other concerned parties.

Stockholm, August 2002[2]

Lars Westerberg	Hans Bohman
Chief Executive Officer	Environmental Affairs Director

[1)] Reprint form Autoliv Standard 31
[2)] Initially established 1996

Intervju-underlag

Förutsättningar:
- Den intervjuade måste ha kunskap om företagets produktutveckling och miljöarbete
- Företaget har bedrivit miljöarbete under en längre tid och har erfarenheter man är beredd att dela med sig av

Företagets namn: ____________________

Intervjuad person: ____________________

Datum: ____________________

Allmänt om företaget

1. Företagets storlek
2. Antal anställda
3. Omsättning
4. Geografisk lokalisering
5. Marknadsområden

Organisation

6. Hur ser företagets miljöorganisation ut?

	Ja	Nej
• Separat miljöavdelning	☐	☐
• Miljöansvariga på olika avdelningar	☐	☐

7. Hur är produktutvecklingen organiserad?

	Ja	Nej
Centralt styrd	☐	☐
Utspritt och lokalt	☐	☐
Outsource PU	☐	☐

8. Beskriv hur produktutvecklingsprocessen ser ut

Visa hur flödet ser ut
Krav vid grindar etc

9. Vid vilka steg i produktutvecklingsprocessen kommer miljöaspekter in?

Konkreta exempel

10. Hur ser miljöaspekterna ut? - konkreta exempel i rutiner och dagligt arbete

11. Vem för in miljökraven respektive driver i projekten?

Utdelat miljöansvar i varje projekt?
Central miljöansvarig (expertfkn)?

Företagets miljöarbete – när var hur

12. Vem ställer miljökrav på företaget och hur starkt upplever ni kraven?

☐ Myndigheter (utöver lagkrav) ____________________

☐ Kunder (företag) ____________________

☐ Konsumenter ____________________

☐ Finansiella intressenter ____________________

☐ Ekonomiska drivkrafter ____________________

13. Har företaget miljöledningssystem (EMS)?

☐ Ja, sedan ________ ☐ Nej (gå vidare till fråga 12)

Vilket system: ____________________

14. Varför har företaget miljöledningssystem (EMS)?

15. Hur vill du beskriva företagsledningens inställning till miljöarbete?

Proaktivt ☐ Aktivt ☐ Stöttande ☐ Passivt ☐

16. Hur kommuniceras miljökrav ut i produktutvecklingsorganisationen?

Mätbara, kvantitativa krav?
Vem skickar ut?
Vem tar emot?

Från ledningen

Myndigheter

Externa intressenter (kunder, konsumenter)

17. Hur ser miljökraven ut - vad handlar kraven om? Exempel?

Produktutveckling?
Allmänt - ej spec. definierat

Från ledningen ______________________________

Myndigheter ______________________________

Externa intressenter (kunder, konsumenter) ______________________________

Andra intressenter ______________________________

Miljöarbete i produktutveckling

18. Hur tas kravspecifikationer på projekten fram?

Vem gör det faktiska arbetet ______________________________

Hur är kravspecifikationen utformad –guidelines eller ”skall-krav”?__________

19. Vilka utgångspunkter finns för kravspecifikationerna på projekten?

Är de konkreta?

20. Vem styr framtagningen av kravspecifikationen?

Kund

Interna företagsmål

Andra intressenter

21. Brukar det finnas miljökrav i kravspecifikationerna? (Om nej; varför inte!?)

Hur ser de då ut? ______________________________

22. Har ni stött på hinder när ni tagit fram dessa miljökrav i kravspecifikationerna?

Vilka? ______________________________

23. Hur har ni löst dessa hinder?

Mätning och analysering av miljöpåverkan – kunskapsuppbyggnad

24. Har ni gjort miljöanalyser?

25. Varför/varför inte har ni gjort miljöanalyser?

26. Vem utförde miljöanalyserna?

27. Vilka metoder/verktyg använde ni er av?

28. Var ifrån hämtas indata till miljöanalyserna?

29. Hur har ni omsatt dessa resultat till konkret praktiskt miljöarbete?

30. Visa konkret hur produkterna har förbättras map miljöprestanda

31. Vilka problem har ni stött på under utvecklingen av miljöanalyserna?

32. Hur löste ni dessa problem?

33. Vad har ni lärt er från dessa miljöanalyser?

34. Hur återkopplas resultaten från miljöanalyserna till produktutvecklingsprocessen?

KONSTRUERA FÖR LIVET

En miljöhandledning för produktutvecklare

Autoliv Sverige AB

Innehållsförteckning

Handledningen är skriven 1999 av Johan Dahlström, Kvalitet- och Miljöavdelningen, Autoliv Sverige AB, Vårgårda, i samarbete med Dan Persson, Produktutvecklingschef och Jörgen Ohlsson, Kvalitet- och Miljöchef. Skriften baseras på ”Miljöhandledning för konstruktörer”, Volvo Personvagnar (Utgåva 0).

Inledning

Syftet med denna handbok är att ge dig som konstruktör en vägledning till hur vi på Autoliv skall bistå våra kunder i deras strävan att minska bilens totala miljöpåverkan. Handboken fungerar dels som en snabb introduktion till miljöområdet men också som en checklista på de miljöaspekter du bör ta hänsyn till för att skapa en konstruktion med bra miljöegenskaper.

Tänk på att du som konstruktör har mycket stor möjlighet att påverka produktutvecklingen så att produkten får så liten påverkan på miljön som möjligt under hela dess livscykel.

"Konstruera för livet" är en kortfattad skrift vilket innebär att vi här inte går in på några djupa analyser. Du hittar en del råd och tips som du kanske upplever som motsägelsefulla. Din roll som konstruktör är dock att balansera konstruktionen mellan olika krav och att söka mer kunskap när du behöver.

Handboken är lämplig som underlag vid konstruktionsgenomgång, då miljökriterier bedöms.

Dan Persson
Produktutvecklingschef

Jörgen Ohlsson
Kvalitet- och Miljöchef

Kapitel 1

Autolivs Kvalitets- och Miljöpolicy

"Autoliv Sverige AB och dess anställda skall leverera produkter och tjänster i rätt tid, med en konkurrenskraftig kostnad och en kvalitetsnivå som strävar mot noll fel, till både interna och externa kunder. Verksamheten skall präglas av ett högt miljömedvetande."

Detta innebär bland annat att:

- ✗ PRODUKTERNAS OCH TJÄNSTERNAS KVALITETSNIVÅ skall vara så hög, att den utgör ett köpargument, samtidigt som negativ miljöpåverkan minimeras och föroreningar undviks.
- ✗ SAMTLIGA ANSTÄLLDA skall veta vilka krav som gäller från intern eller extern kund, samt kunna ställa krav på interna och externa leverantörer.
- ✗ LEVERANSER AV NY PRODUKT, eller användandet av ny process får ej ske, innan accepterad kvalitets- och miljönivå uppnåtts, och samtliga säkerhetskrav är uppfyllda.
- ✗ SOM MINIMINIVÅ gäller att samtliga tillämpliga lagar, föreskrifter och övriga berörda krav skall följas. Utöver detta åtar vi oss att löpande minska företagets totala miljöpåverkan, inklusive att ställa krav på våra leverantörer.
- ✗ MARKNADSAKTIVITETER som skapar orimliga kundförväntningar, får ej förekomma.
- ✗ NYA (OCH FÖRÄNDRADE) PRODUKTER alltid skall vikt- och materialoptimeras, så långt det är realistiskt möjligt, då detta är vår mest betydande miljöaspekt.
- ✗ SAMTLIGA KÄNDA KRAV skall finnas dokumenterade. På Autoliv; i olika krav-spec:ar.
- ✗ VI SKALL UTNYTTJA energi och råvaror effektivt, samt hantera restprodukter och kemikalier med minsta möjliga resursförbrukning och miljöpåverkan, så långt det är tekniskt möjligt och ekonomiskt rimligt.
- ✗ STÄNDIGA FÖRBÄTTRINGAR skall genomsyra företaget med alla dess processer.
- ✗ DENNA POLICY SKALL vara känd av samtliga anställda, samt tillgänglig för samtliga intresserade. Policyn finns i Kvalitetshandboken, Kvalitet- och Miljöavdelningen

Lars-Gunnar Skötte
Verkställande direktör, Autoliv Sverige AB

Särtryck ur kvalitetsmanual, utgåva 14, 980907

Kapitel 2

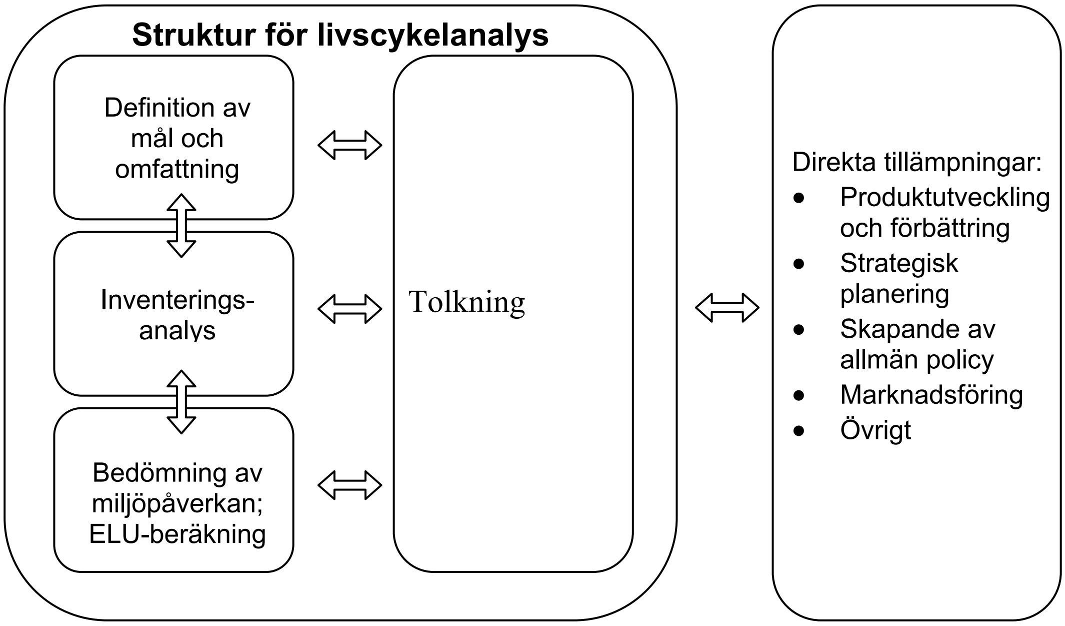
Minimera den totala miljöbelastningen

Gör en livscykelanalys, LCA

Genom att bedöma miljöbelastningen under hela konstruktionens livscykel: produktion, användning och slutanvändning, kan uppskattning göras var förbättringsåtgärder skall sättas in och vilken av flera konstruktioner som är att föredra miljömässigt. Dessutom blir livscykelanalys, LCA, ett allt viktigare verktyg vid marknadsföring, t.ex. vid ett miljöanspråk, i miljömärkningssystem eller i miljövarudeklarationer. Genomförande av LCA sker i en process med fyra steg:

1. Målbeskrivning – vad är det som söks? Hur omfattande skall analysen vara?
2. Inventering – datainsamling av produktens miljöpåverkan, energibehov, volymer etc under produktens tänkta livstid.
3. Beräkning av miljöbelastningstal (ELU) – kan beräknas både för ett material och en process.
4. Produktförbättring

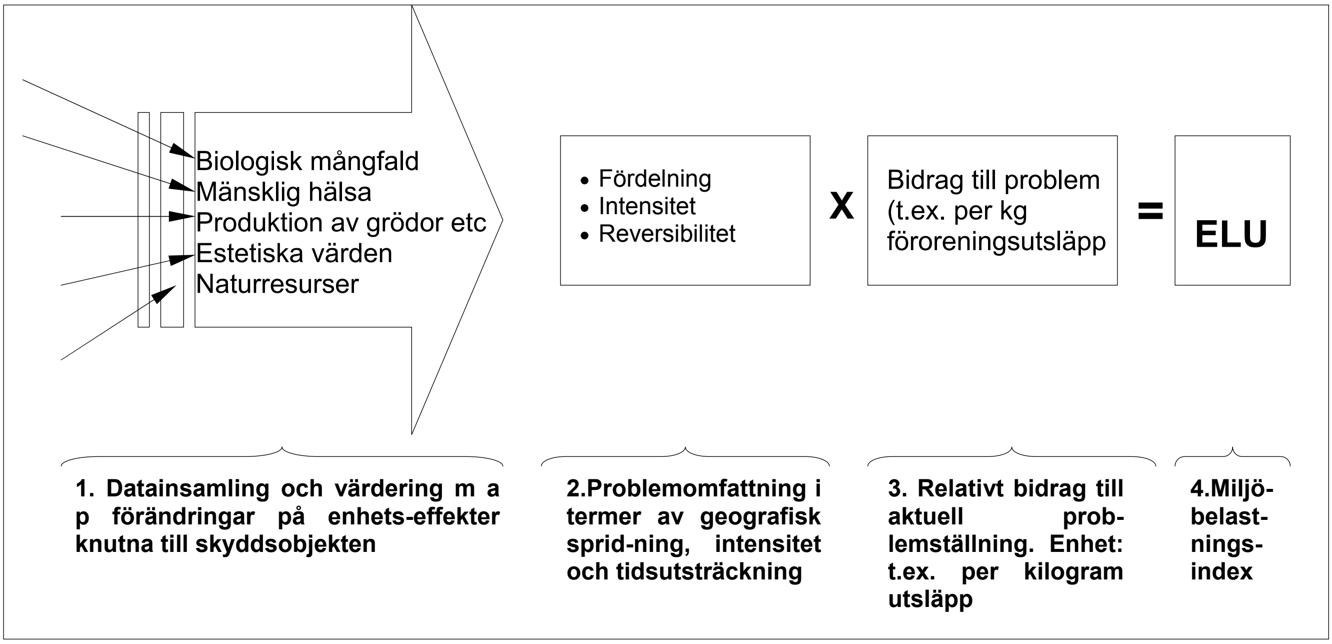
Metoden är standardiserad genom ISO 14 025, hösten 1999. Därför kommer den att göra sig allt mer gällande som ett viktigt instrument vid jämförelse av miljöpåverkan hos likvärdiga produkter. Idag tillämpar de flesta större företagen LCA. Analysen kan göras olika omfattande varför det är viktigt att innan genomförande göra lämplig avgränsning med avseende på målet med analysen. En principskiss för LCA visas i figur 1.



Figur 1: Incitament och modell för genomförande av LCA processen

Uppskattning av miljöbelastningstal (punkt tre) kan göras kvalitativt men det finns också PC-baserade verktyg för att kvantifiera miljöbelastning. Ett program som används är EPS 4.0 (Environmental Priority Strategies in product design). Förloppet illustreras i figur 2. Eftersom det förekommer även andra synsätt skall EPS värderingar ses som en del i beslutsunderlaget. EPS-systemet utgår från fem grundläggande miljöfaktorer:

- Biologisk mångfald (biodiversitet)
- Mänsklig hälsa
- Produktion av grödor etc
- Estetiska värden
- Naturresurser



Figur 2: Tillvägagångssätt för beräkning av miljöbelastningsindex

Vid och inför en konstruktionsgenomgång kan det vara användbart att göra överslagsberäkningar på ELU-värden för att vara säker på att valet av material eller process ger så liten miljöpåverkan som möjligt. Sträva efter ett så lågt ELU-värde som möjligt! Eventuella förslag på alternativa material kan finnas i Autolivs Vita Lista vilken återfinns under G:\Miljo.

Som underlag för beräkning av miljöbelastningstal ligger dels två viktiga principer:

- Principen om hållbar utveckling – ”vi skall inte nyttja naturresurser mer än att kommande generationer skall ha möjlighet att nyttja den på samma sätt”

- Försiktighetsprincipen – innebär att ett misstänkt miljöstörande ämne inte får användas förrän det kan bevisas att det är ofarligt

  och dels:

- Politiska krav, såsom t.ex. Agenda 21

Observera, det är viktigt att komma ihåg att en LCA-analys inte till alla delar gör anspråk på att vara vetenskapligt underbyggd metod utan innehåller moment med godtycklig värdering.

Exempel: Beräkning av miljöbelastningsindex (ELU)

En konstruktör skall konstruera ett lock till en airbag. Till denna vill han använda en blandning av polypropen, PP, och etenpropengummi, EPDM. En lämplig blandning visar sig vara 65 % PP och 35 % EPDM. Till varje lock beräknas det åtgå 0,13 kg material.
***Exemplet är starkt förenklat** och faktorer som transport, elförbrukning, slitage av maskiner etc tas inte med, vilket i verkligheten måste beaktas och kan utgöra en väsentlig del av den totala belastningen på miljön. Värdering av dessa faktorer är mycket viktig men svår och delvis subjektiv.*

ELU-värde per kg är beräknat till:

PP	3,1
EPDM	3,0

Alltså: 0,13 (0,65 • 3,1 + 0,35 •3,0) = 0,39845 dvs: ELU: 0,39845 per airbagslock

Om konstruktören väljer att använda ABS-plast istället för PP blir ELU per lock: 0,44915 då ABS har ELU 3,7 per kg. Ambitionen är att ELU-värdet skall bli så lågt som möjligt. I detta exempel är det sålunda miljömässigt lämpligare att använda PP än ABS.

Miljöeffekter att ta hänsyn till i konstruktionens livscykel

Produktion av material och produkt

- Förbrukning av material, vatten, energi – tär på jordens resurser
- Emission av miljöfarliga ämnen utgör ett hot mot vår hälsa
- Användning av återvunna material och spillmaterial spar jordens resurser

Användning av produkten

- Orsakar utsläpp av koldioxid, kvävedioxid, kolväten mm
- Tär på jordens resurser
- Buller
- Material och materialtillsatser kan t ex ge kontaktallergi och luftföroreningar i kupén

Skrotning, resthantering

- Material och materialtillsatser kan ge luft- och vattenföroreningar vid förbränning eller deponering
- Återvinning, (material, energi) –spar jordens resurser

Kapitel 3

Val av material

Välj material så att konstruktionen:

- **optimeras mot låg vikt**
- **får så låga ELU-värden som möjligt,** dvs elimineras från ämnen som är skadliga för natur och hälsa
- **inte innehåller ämnen som finns med i Autoliv Standard 5 (AS 5)**, dvs Forbidden Chemical Substances List (Svarta listan) respektive Restricted Chemical Substances List (Grå listan)
- **blir enkel att separera för återanvändning eller återvinning**
- Generellt är det svårt att säga om ett material är miljömässigt bra eller dåligt. Svaret beror mycket på omständigheterna men här följer några tumregler:

Polymera material

Välj i första hand någon av de två **termoplasterna** polyeten (PE) eller polypropen (PP). Tillverkningen av de båda termoplasterna ger låg miljöbelastning. Vid en fullständig förbränning bildar de vatten och koldioxid. Om PE och PP inte uppfyller de tekniska kraven, försök att använda någon annan termoplast. Märk dock att det finns olämpliga termoplaster, t.ex. PVC vars miljöpåverkan är starkt omdiskuterad. Som exempel har PVC genom sitt innehåll av klor den otrevliga egenskapen att bilda saltsyra vid förbränning och skall därmed undvikas.
Vid tillverkning av några termoplaster används cancerogena monomerer t.ex. styren. Halten monomerer i sådana plaster skall vara låg då de dunstar till omgivningen med tiden.
Ur återvinningssynpunkt är termoplaster lämpliga då de relativt enkelt kan gjutas om för andra ändamål.
Härdplaster har den fördelen att de i jämförelse med metaller kan spara vikt och därmed bidra till minskad bränsleförbrukning. Däremot är de i regel svåra att återvinna. Det gäller också gummimaterial som dessutom kan innehålla klor eller fluor vilka kan bilda miljöfarliga föreningar.
Termoelaster (TPE) kan vara alternativ till bland annat gummi. Denna grupp kännetecknas av att alla uppvisar gummiliknande egenskaper men till skillnad från gummi kan TPE smältas om likt termoplasterna vilket är till stor fördel vid återvinning. Dessutom kan materialförlusterna minskas vid tillverkning (F. Johansson, 1998).

Textilier och läder

Textilier skall uppfylla Öko-Tex standard 100. För konstfiber, t.ex. polyamid, gäller även råden i föregående stycke (Polymera material). Undvik att använda fenolhartsbaserade bindemedel eftersom de kan öka risken för allergier och ge dålig lukt. Använd inte heller flamskyddsmedel som innehåller brom eller klor.

Metaller

Stål, förzinkad plåt och zinkgjutgods är de metaller som traditionellt förekommer i bilkonstruktioner. Ofta kan det vara en miljövinst att använda höghållfast stål eller lättmetaller som aluminium och magnesium, som tack vare sin låga vikt bidrar till att minska bränsleförbrukningen. Det är också viktigt att sätta samman olika metaller på ett sådant sätt att risken för korrosion minskar och materialet kan återanvändas/återvinnas.
Användning av mer sällsynta metaller som t ex rodium kräver en speciell hänsyn eftersom naturtillgångarna är begränsade och dess påverkan i naturen inte är fullständigt kartlagd.
Tungmetaller som t ex kvicksilver, kadmium och bly är sedan länge uppmärksammade skadliga metaller och skall inte användas.

Undvik ytbehandling

Ytbehandling sker ofta i processer som kan vara miljöstörande eller som innebär att återvinning försvåras.

Polymera material
Väl om möjligt infärgning av plaster istället för ytbehandling.

Metaller
Legeringar, t.ex. stål, utsätts lätt för korrosion. En ytbehandling är därför ofta nödvändig. Om en korrosiv metall visar sig lämpligast är det viktigt att välja en så mot miljön skonsam ytbehandlingsmetod som möjligt. Var mycket restriktiv med följande ämnen: koppar, krom, zink och nickel.

Ett exempel på förbättring inom Autoliv är den minskade användningen av gulkromatering med sexvärd krom, Cr(VI), då Cr(VI) finns med i AS 5 Restricted Chemical Substances List (grå listan). Processen har ersatts av något dyrare men miljömässigt relativt lämpligare svartkromatering där Cr(III) till viss del ersätter Cr(VI).

Se upp med additiv

Additiv används för att förändra eller förbättra egenskaper hos material. Ämnen som finns på Autolivs AS 5 Forbidden Chemical Substances List (svarta listan) **får inte** användas i produkten men förbudet gäller också dess omgivning t.ex. som tillsatsmaterial vid tillverkning etc. Ämnen som finns upptagna på Autolivs AS 5 Restricted Chemical Substances List (grå lista) **bör inte** användas. Visar det sig att ”gråa” material måste användas i en ny konstruktion är det lämpligt att detta sker i kommunikation med aktuell leverantör. Var restriktiv med additiven då återvinning kan försvåras eller bli omöjlig.

Brandhämmande additiv
De flesta plastmaterial brinner och underhåller förbränning efter att de antänds. För att hämma reaktionsbenägenheten hos plasten tillsätts flamskyddsmedel. Additiven återfinns i allt från de flesta elektriska apparater till stoppningsmaterial i möbler som skumplaster. Traditionellt används sk halogenerde additiv, dvs ämnen med klor- och bromföreningar eftersom dessa spelar en aktiv roll vid minskad brännbarhet hos plaster. Tyvärr bildas aggressiva syror när ämnena kommer i kontakt med vatten. Som en följd av detta bildas korrosiva gaser (plast bildar bl a vatten vid förbränning) som angriper metaller och kan orsaka större sekundärskador än själva branden. Vidare är halogenerade flamskydds-medel i olika grad cancerogena (bevisat; särskilt vissa bromerade), allergiframkallande, bioackumulativa och neurotiska. Var därför restriktiv med användningen av flamskyddande additiv, undersök om tillsatserna verkligen är nödvändiga eller om ett alternativt mindre brandbenäget material kan användas. Ett exempel på ett icke önskvärt additiv är de bromerade flamskyddsmedel som ofta används i kretskort.

Undvik att limma

Användningen av lim gör att man försämrar möjligheten till materialåtervinning. Dessutom har det negativa effekter på arbetsmiljön (t ex användning av isocyanater i vissa lim eller lösningsmedel). Undvik om möjligt att limma. Är det nödvändigt med limning, använd då i första hand smältlim, i andra hand kontaktlim och sist två-komponentlim som härdar, t ex epoxi eller PUR.

Öka användningen av naturmaterial

Naturmaterialen, t.ex. bomull kan vara fördelaktiga ur miljösynpunkt eftersom de kommer från förnyelsebara tillgångar och inte fossila vilket t.ex. är fallet för konstfiber. Tänk på att göra avvägning mot transporter för naturmaterial jämfört med lokalt producerade konstgjorda material, t.ex. konstfiber. Kontrollera att materialen inte innehåller kemikalier som finns uppsatta på Autolivs AS 5 Forbidden Chemical Substances List (Svarta listan)/ Restricted Chemical Substances List (grå lista).

Minska materialemissioner

Det får inte förekomma att material avger hälsovådliga eller illaluktande ämnen i kupén. En varnande indikation på att negativa ämnen kan komma att spridas i kupén är om det uppstår en stark lukt från ett provmaterial. Vissa material avger ämnen som reagerar med andra material i bilen. Ofta handlar det om olika additiv som avges, t.ex. mjukmedel. T.ex. kan vindrutan utsättas för sk fogging, vilket innebär att avgivna ämnen, t.ex. additiv, från plaster eller liknande i kupén kondenserar och bildar en dimmig yta. Erfarenhet är kanske bästa botemedlet mot fogging då det är svårt att förutsäga vilka ämnen som reagerar med vilka.

Kapitel 4

Konstruera för låg resursförbrukning under tillverkning

Effektivisera resurserna

När nya produkter och processer utvecklas är det viktigt från både ekonomi- och miljösynpunkt att minimera resursutnyttjandet. Genom val av material och konstruktion påverkar man i stor grad resursförbrukningen vid tillverkningen. För att minimera resursutnyttjandet är det därför viktigt att ta hänsyn till produktionsförhållandena.
Genom att välja råmaterial som framställs nära produktionsorten och konsumenten kan såväl stora ekonomiska som miljömässiga vinster göras.

Minimera materialförbrukningen

Undvik produktionsteknik som kräver efterbearbetning eller reningsteknik efter som det blir både kostsamt och energikrävande. Sträva alltid efter att utnyttja råvaror effektivt. Produktionsspill skall alltid minimeras genom återvinning av råvaran i produktion. Avfall från produktion minimeras bäst genom att:

- Spillet minimeras
- Använda returemballage
- Använda slutna system

Några nyckeltal hämtade från ”Miljöhandledning för konstruktörer”, Volvo PV

Ett extra fästmedel betyder ökat avfall och hundratusen kronor i ökad resurskostnader.

En extra variant på extriörkulören betyder ökat avfall och 10 miljoner kronor i ökade resurskostnader.

En extra variant på interiörkulören betyder ökat avfall och 30 miljoner kronor i ökade resurskostnader.

Minimera energiförbrukningen

Energiförbrukningen är en avgörande faktor i kostnads- och miljösammanhang.

Det gäller att undvika konstruktionslösningar som kräver energislukande processer och långa transporter eftersom transport och energiomvandling av bränslen innebär stor miljöpåverkan och priserna på energi och fossila bränslen sannolikt kommer att stiga.

Minimera vattenförbrukningen

Oavsett den lokala tillgången på vatten bör man minimera utnyttjandet eftersom det alltid medför att vattnet förorenas i någon grad. Vattnet måste ledas till ett reningsverk där ytterligare kemikalier tillsätts för reningsprocessen och det för i sin tur med sig kostnader och ökad miljöbelastning. En lösning kan vara att införa slutna system för t.ex. kylvatten vilket kan vara både ekonomiskt lönsamt och ge stora miljövinster.

Minskad resursförbrukning har ofta fler fördelar

Att minska åtgången av material är fördelaktigt då miljöpåverkan liksom kostnader från transport, emballage etc. minskar. Nedan följer några konkreta exempel:

Exempel 1: Polylup är ett smörjfett. Här på Autoliv skedde tidigare levererans i tunnor med fettet inneslutet i plastpåsar. I varje tömd tunna återfanns en mindre mängd fett vilket totalt uppgick till 20 kg per månad. Efter ombyggnad distribueras nu fettet från en central pumpstation ut till respektive användare genom ett rörsystem. Påfyllning av centralenheten sköts av leverantören som tillämpar refill-system. Vinster som uppstått är minskat avfall i form av såväl fett som emballage. Då hanteringen kan skötas av en enda person uppstår färre maskinstopp vilket spar tid. På så sätt har vinster gjorts både i avseende på ekonomi och miljö.

Kapitel 5

Konstruera för låg bränsleförbrukning

Minska vikten

Vikten på våra produkter är den viktigaste styrparametern för miljövänlig konstruktion på Autoliv. Stäva därför efter att alltid använd lätta material både vid konstruktion och distribution.
Optimera konstruktionen efter dimensionerade kravnivåer och undvik överdimensionering.
Integrera detaljer och funktioner.
Se även till att leverantören lever upp till ovan ambitioner.

Förbättra hjälpapparaternas verkningsgrad

För alla elektriska funktioner, behöver motorn leverera energi till hjälpapparaterna. Den energi de förbrukar påverkar bränsleförbrukningen.

Inverkan av bilens vikt: 1 kg motsvarar 0,005 l/100 km

Detta släpper en bil ut:
Den största delen av avgaserna består av koldioxid (CO_2) som bidrar till växthuseffekten. Hur mycket koldioxid som släpps ut står i direkt proportion till bilens bränsleförbrukning. En del av avgaserna som bildas vid förbränning, består av kväveoxider (NO_x), kolväten (HC) och koloxid (CO). Dessa emissioner regleras i lag.

Så mäts bränsleförbrukning:
För att mäta en bils bränsleförbrukning används speciella körcykler. Cyklerna varierar mellan olika marknader. Drivande idag är Europeiska Unionen varför alla numeriska fakta här hänvisar till EU Combined. Vilka faktorer som påverkar bränsleförbrukningen gäller förstås generellt.

EU Combined är numera den körcykel som också används i Sverige när blandad bränsleförbrukning anges.

Kapitel 6

Konstruera för låga emissioner

Under en bils hela livscykel avges olika ämnen till omgivningen:

- **Produktion** – t ex lösningsmedel i lacker och lim. El och transporter till produktionen ger varierande mängd föroreningar till miljön.

- **Användning** – avgaser, bränsleångor, ”gaser” i material och spilloljor.

- **Sluthantering** – om bilens plastkomponenter, oljor m m förbränns och bryts ned frigörs komponenter till luft och vatten. Om plastkomponenterna kan återvinnas reduceras den direkta miljöpåverkan.

Produktionsfasen

Undvik material som kräver ytbehandling eftersom det bildas avfall och processen ofta medför emissioner till luft och vatten. Vid ytbehandling, använd processer som minimerar emissioner. Målning, rengöring och limning medför ofta att lösningsmedel avdunstar. Pressning och svetsning ger upphov till stoft och oljedimma. Uppvärmning av ugnar och processbad ger upphov till koldioxid och kväveoxider. Betning, avfettning, passivering och fosfatering avger emissioner till vatten som kräver behandling i ett industriellt, kemiskt reningsverk.

Användningsfasen

Minska bilens bränsleförbrukning (se kap 5). Se till att materialet inte luktar (kan vara hälsovådliga ämnen). Undvik ämnen som utvecklar särskilt skadliga gaser vid brand, t.ex. PVC-plaster eller andra klorhaltiga kolföreningar.

Sluthantering

Minska mängden miljöstörande ämnen i materialet (se kap 3). Konstruera för återvinning (se kap 7).

Kapitel 7

Konstruera för återvinning

Vid konstruktionsgenomgång skall frågor om produktens tänkta påverkan på miljön grundligt undersökas för att; dels få en allmän överblick på den miljöpåverkan produkten kommer att orsaka under dess totala livscykel, dels ha möjlighet att i ett tidigt skede byta ut material eller processer för att åstadkomma ett så lågt ELU-värde som möjligt. För att underlätta denna process och undvika negativa överraskningar kan nedan prioritets ordning vara till hjälp.

Prioritet 1

Undvik skadliga material och ämnen

Alla material och substanser som i sluthantering måste tas omhand för demontering och utfasning ur kretsloppet har negativa effekter på ekonomi och miljö:

- Skadliga material har en hög miljöbelastning och medför höga kostnader när de måste tas omhand.
- Skadliga material kan förorena övrigt material som är lämpligt för materialåtervinning.
- För att energiutvinning skall vara ett fungerande alternativ till återvinning får inte några ämnen avge sådana emissioner att det finns risk att störa energiutvinningsanläggningarna så att tillåtna emissionsvärden överskrids.

Genom att undvika skadliga material vid utveckling av produkter bidrar man till en bättre ekonomi och miljö. AS 5 Forbidden Chemical Substances List (svarta listan) och Restricted Chemical Substances List (grå listan) sätter upp minimikrav och är ett bra underlag för vilka kemiska ämnen som inte skall användas eller vars användning skall begränsas. Studera också gärna Autolivs Vita Lista som ger alternativa förslag till ämnen i AS 5.

Prioritet 2

Underlätta dränering och demontering av farligt avfall

De system i våra produkter där vätskor och material enligt lag måste tas omhand i resthanteringen, bör vara säkra och enkla att demontera. Det innebär:

- Nipplar för dränering av vätskor.
- Behållare med en plan och markerad lägsta punkt.
- Märkning för håltagning om dräneringsnipplar saknas.
- Farligt avfall som vätskor, system för krock-kudde osv skall vara åtkomliga och anpassade för demontering.

Tabell 2: Underlätta för återvinning/återanvändning av plastmaterial, metall och glas

Område	Påverkar	Att eftersträva
Materialval (se kap 3)	• Destruktionskostnader • Demonteringstid • Möjlighet till återvinning	• Undvika störande material • Minimera användningen av olika material • Kompatibilitet • Sorterbarhet
Märkning (se kap 3)	• Identifiering av material • Demonteringstid	• Lättläst storlek • Placering lätt att hitta
Fästelement	• Demonteringstid • Möjlighet till återvinning	• Integrerade snäppfästen • Demonteringsvänlig • Litet antal och enhetlighet
Ytbehandling (se kap 3)	• Möjlighet till återvinning	• Undvika ytbehandling • Ytmaterial kompatibelt med bärare
Lim, tejp, etiketter	• Demonteringstid • Möjlighet till återvinning	• Lim, tejp, etikett kompatibelt med bärarmaterial alternativt lätt borttagbart
Användning av återvunnet material	• Marknad för återvunnet material, kundnytta	• Användning främst i icke synliga tillämpningar med låga påkänningar

Prioritet 3

Återvinn material i processen

Vid all tillverkning skapas produktionsspill, en resurs att ta tillvara. När nya produkter utvecklas skall tillverkningen vara resurssnål för att utnyttja naturresurserna på ett optimalt sätt. Att hushålla med miljömässiga resurser är att också hushålla med ekonomiska, i form av sparade materialkostnader, kostnader för omhändertagande osv.

Arbeta så här med att återvinning inom processerna:

- Utforma komponenter och tillverkningsprocesser för att minimera produktionsspill.
- Ta vara på produktionsspill för återanvändning.
- Sträva efter så högvärdig materialåtervinning som möjlig för produktionsspill om det inte kan användas inom processen.
- Utnyttja materialets energivärde.

Prioritet 4

Design av komponenter för att underlätta materialåtervinning

Generellt gäller råd i tabell 2.

Plastmaterial

Sträva efter homogena konstruktionsdelar och undvik så långt som det är möjligt att blanda olika plaster. Sörj för att produkten blir lätt isärtagbar, dvs undvik lim- och svetsfogar och ingjutna eller inpressade metallinsatser. Om limning är nödvändigt, använd ett lim som är blandbart med det material det sammanfogar. De flesta lacker är osmältbara efter att de härdat. Dessa resulterar i att plasten blir omöjlig att återvinna. Använd därför lack som är blandbar med plastmaterialet i fråga eller plaster som inte kräver extra ytbehandling. Märk upp alla termoplaster med återvinningssymbolar. Konstruktionen blir då lätt att återvinna.

Vid val av härdplast respektive termoplast finns två viktiga faktorer att tänka på. Härdplaster har i regel lägre vikt än termoplaster men går i gengäld inte att återvinna vilket är möjligt med termoplaster (se kapitel 3). Detta beror på en komplex kemisk struktur hos härdplasten.

När plasten härdar binds molekylerna samman i alla riktningar och bildar en enda stor molekyl. Molekylerna kan tillföljd av begränsad rörlighet inte kristallisera och materialet smälter inte vid uppvärmning, utan sönderdelas.

Termoplaster kan däremot smältas om flera gånger då de svaga bindningar som håller samman molekylen släpper vid uppvärmning med ökad rörlighet hos molekylerna som följd. När plasten svalnat återuppstår bindningarna vilket gör plasten lätt att omforma och återvinna.

Metaller
För att få en större lönsamhet i återvinningsfasen:

- Konstruera så att det är möjligt att demontera högvärdiga metaller – främst Cu, Al och Mg – innan fragmentering.
- När olika metaller sammanfogas skall de i möjligaste mån vara lämpliga att tillsammans återvinnas i högvärdig legering.

Glas
För att underlätta återvinning av glas:

- Glaset bör hållas fritt från främmande material.
- Fastsättningen skall vara anpassad för att underlätta demontering.

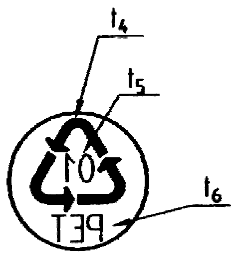
Märk plaster med återvinningssymbol

Alla termoplastkomponenter skall vara noggrant uppmärkta med tydlig återvinningssymbol redan vid konstruktion, framför allt för att underlätta vid källsortering av produkten men även för att ge information till kommande användare.
Enda undantaget för märkning är då plastkomponenten har så liten yta att ingen läslig återvinningssymbol får plats. Aktuella märkningsstandarder gäller ej för härdplaster utan omfattar endast termoplaster. Det finns idag flera olika standarder för återvinningssymboler för plaster på marknaden. I avvaktan på märknings-/sorteringsföreskirfter från EU rekommenderas att använda någon av nedan följande märkningsstandarder. Nedan information är hämtad från Plast- och Kemikaliebrascherna.

Förpackningar
– enligt den tyska industrinormen DIN 6120

Plastbeteckning gäller enligt kombination av internationella standardsymbolen för plast ”tre pilar”, och förkortning enligt ISO 1043-1. Som standard finns tre olika modeller i tre olika storlekar. Modell I är individuell med endast ”tre pilar” symbolen, medan modell II har kodsiffra, som står för en plast, inuti triangeln och slutligen modell III som ser ut enligt figur 3 nedan.

		(mm)		
Typ	Ø (mm)	t_4	t_5	t_6
1	12	0,1	-	-
	16	0,12	-	-
	20	0,15	-	-
2	12	0,1	0,12	-
	16	0,12	0,12	-
	20	0,15	0,15	-
3	12	0,1	0,1	0,1
	16	0,12	0,12	0,12
	20	0,15	0,15	0,15



Figur 3: utseened på återvinningsstämpel

Tabell 3: Standardstorlekar för återanvändningsstämplar samt kodsiffror med tillhörande förkortning för plaster. *) står för övriga plastsorter.

– enligt AMERICAN SPI

Märksystemen gäller enligt ISO 1043 – 1, ISO 1043 – 2, ASTM D 1600, ASTM 4000 eller SAE I 1344

Övriga plastartiklar
– enligt VDA 260 (tyska bilindustrin och SAAB)

Exempel: > PA 66-GF 30 <

Betekningar enligt DIN 7728 del 1, ISO 1043 del 2, DIN 7723 och SAAB STD 199.

Anmärkning: Detta system tillämpas av bl a den tyska bilindustrin, SAAB Automobile AB (STD 3493) och Scania AB.

– enligt DIN 54 480

Beteckningar enligt DIN 7728 del 1, ISO 1043 del 2, DIN 7723 och SAAB STD 199.
Triangel utformas enligt DIN 30 600.

Anmärkning: Volvo AB tillämpar en egen märkning, STD 5052,41, som innefattar återvinningstriangeln enligt DIN 53 480 men med siffersymbloer enligt en amerikansk standard som ansluter sig till DIN n6120 men saknar positionen ”0” före sifferangivelsen. Beteckningarna under triangeln ansluter till VDA 260 både vad gäller DIN 53 480 och Volvo STD 5052,41.

– enligt Volvo, 5052, 41

>PET<	HDPE >PEHD<	>PVC<	>PELD<	>PP<	>PS<	Other*

*) Other kan vara   other >ABS<   other >PA6/12<   Other >PP-MD30<

Märkning enligt Volvo STD 5052, 411, Volvo STD 5052, 412, ISO 472, ISO 1043-1:1987, ISO 1043-2:1988, ISO 1087:1990.

– enligt SAAB STD 3493 (SAAB Personbilar)

Exempel: > PA 66-GF 30 <

SAAB STD 3493 (ansluter till VDA 260 i översatt version) beteckningar enligt DIN 7728 del 1 och 2, ISO 1043, SAAB STD 199.

– enligt SAAB Scania - VDA 260

Exempel: > PA 66-GF 30 <

Anmärkning: använder VDA 260 i icke översatt version.

Övriga produkter
– enligt SAE (amerikanska bilindustriföreningen)

PBT

Bokstavshöjden: 3,0 mm.
Beteckningar enligt ISO 1043, ASTM D 4000 eller SAE J 1344

– enligt ASTM (Amerikas nationella standard)

ABS   PVC/PA (för sampolymerer)

Beteckning enligt ISO 1043, ASTM D 1600, SAE J 1344

Kapitel 8

Samarbeta med leverantörerna

Enligt Autolivs miljöpolicy skall vi sträva efter att ha leverantörer med djup kompetens inom utveckling och tillverkning av de komponenter och system de levererar. Genom att ha diskussioner med leverantören innan allt underlag är färdigt kan vi ta hänsyn till synpunkter om tillverkningsbarhet och kvalitetssäkring.
Leverantörerna är experter på sina processer. De kan ge värdefull information t ex om hur krökningsradier och placering av hål påverkar utnyttjandegraden av råmaterialet. Genom att ställa krav bidrar vi till att utveckla leverantörernas kompetens.

Ställ krav på företaget

Autoliv kräver av sina leverantörer att AS 5 efterlevs. Vidare ställs krav på att leverantörer av produktionsmaterial har miljöstyrningssystem som t ex ISO eller EMAS. Båda systemen kräver ständiga förbättringar.
Med målsättningen ”bästa branschstandard" fordras att leverantörerna strävar efter minsta möjliga miljöpåverkan med hänsyn till vad som är möjligt inom respektive bransch. Autoliv förutsätter att leverantören bevakar vad som sker i omvärlden.

Ställ krav på produkter och tjänster

Gemensamt för alla produkter är att de inte får innehålla kemikalier från AS 5 Forbidden Chemical Substances List (Svarta listan), att kemikalier från Restricted Chemical Substances List (grå listan) övervakas och att dessa ersätts med mindre farliga ämnen så snart som möjligt. Undvik att föra in ”grå-listade” ämnen i nya konstruktioner.
Övriga produktkrav är nära förknippade med respektive produkt, dit all uppföljning måste knytas. Kraven förmedlar en förväntan om vilka områden som måste utvecklas av Autoliv respektive leverantören. Det är viktigt att leverantören är villig att diskutera produkten och tillverkningsprocessen så att det gemensamma arbetet ger nya produkter med lägre miljöpåverkan.

Var medveten om konsekvenserna. Vid t ex specificering av ytbehandling ställs givetvis krav på leverantörens kompetens men också att företaget har giltiga miljötillstånd för verksamheten. Utökar man eller byter ytbehandlingskraven kan leverantören vara tvungen att söka nya tillstånd.

Referenser

Böcker och avhandlingar

”Miljöhandledning för konstruktörer”
Volvo Personvagnar (Utgåva 0)

Patrik Gillgren, Johan Josefsson
”Livscykelanalys av ett airbagsystem”
Luleå Tekniska Universitet, Institutionen för Material- och produktionsteknik, 1998

Standarder

ISO 14020-serien –	**Miljömärkning**
ISO 14020	Environmental Labels and Declarations – Self-declared Environmental Claims *Handlar om symboler och vänder sig till företag som vill använda sådana för sina miljö-uttalanden*
ISO 14024	Environmental Labels and Declarations – Environmental Labelling Type I – Guiding Principles and Procedures *Vänder sig främst till miljömärkningsorganisationer och motsvarar dagens symbolmärk-ning, t.ex. svanen.*
ISO 14025	Environmental Labels and Declarations – Environmental Labelling Type III – Guiding Principles and Procedures *Handlar om miljövarudeklaration baserat på livscykelanalys.*
ISO 14040-serien –	**Livscykelanalys (Life Cycle Assessment – LCA)**
SS-EN ISO 14040	Miljöledning – Livscykelanalys – Principer och struktur
ISO 14042	Environmental Management – Life Cycle Assessment – Life Cycle Impact Assessment
ISO 14043	Environmental Management – Life Cycle Assessment – Life Cycle Interpretation
ISO 14049	Illustrative Examples on How to Apply ISO 14041
ISO 14060	Guide for the Inclusion of Environmental Aspects in Product Standards (EPAS)

Tidskrifter och kompendier

Tekn. Doktor Folke Johansson
”Termoelasterna har intressanta egenskaper”
Uppfinnaren nr 2, 1998

Ordlista

Betning	Betning är en metod för att avlägsna oxidationsprodukter. Beläggningen löses bort från ytan med en sur eller basisk vattenlösning *(betbad)*. Betbadets sammansättning, pH-värde och temperatur anpassas till metallens och oxidens kemiska sammansättning.
Bioackumulativ	Kemiskt ämne lagras i vävnad hos djur och växter där det anrikas allt högre upp i näringskedjan.
EMAS	Eco-Management and Audit Scheme. Är en EU-förordning som dels kräver ett miljöledningssystem, dels en offentlig miljöredovisning. EMAS gäller endast länder inom EU.
EPS	Environmental Priority Strategies in product design
Fosfatering	Fosfatering är en ytbehandlingsmetod som fäller ut tunna, stabila skikt av zink-, järn- eller manganfosfat särskilt på stålytor men också på zink, kadmium och aluminium. Behandlingen leder till en för bättrad vidhäftning av färg och ett bättre korrosionsskydd.
Halogener	Halogenerade kolväten är kolväten i vilka man ersatt en eller flera väteatomer med halogenatomer som fluor, klor, brom och jod. Denna ämnesklass innehåller många viktiga ämnen med användning inom industri och vardagsliv. Till de halogenerade kolvätena hör bland annat vissa lösningsmedel, köldmedier, brandskyddsmedel, DDT och PVC. Dessa ämnen är mycket stabila mot kemiska och biologiska angrepp och den storskaliga användningen av dem på senare tid har lett till diverse miljöskador.
Härdplast	Härdplaster består av polymerer som är sammanbundna till en enda stor molekyl, med huvudvalensbindningar i alla riktningar. De kan till följd av begränsad rörlighet inte kristallisera och materialet smälter inte när det värms upp, utan sönderdelas. Återvinning är mycket begränsad.
ISO	Internationella standardiseringsorganisationen. ISO 14000 serien är ett standardsystem för miljöledning upprättad 1996. Serien omarbetas kontinuerligt.
Korrosion	Ett ämne som utsätts för oxidation
LCA	Livscykelanalys eller Life Cycle Assessment. En sammanställning och utvärdering av inflöden till och utflöden från ett produktsystem över hela dess livscykel liksom utvärdering av de potentiella miljöeffekterna hos ett produktsystem över hela dess livscykel.
Monomer	*Mono* – en, *mer* – del. Den kemiska grundenhet, varav en polymerkedja är uppbyggd.
Passivering	Passivering minskar korrosionshastigheten hos en metallyta genom bildning av korrosionsprodukter på ytan.
Plast	Def. en eller flera polymerer tillsammans med ett eller flera additiv.
Polymer	*Poly* – fler, *merer* – delar. Naturliga eller syntetiska organiska eller oorganiska ämnen vars höga molekylmassa kommer sig av mångfaldigt upprepade grundmolekyler. Naturliga polymerer är t.ex. proteiner, stärkelse och cellulosa.
PVC	Polyvinylklorid
Termoelast	Kännetecknas av elastiska egenskaper. Hårda, smältbara block fungerar i fast tillstånd som fysikaliska tvärbindningar. Mellan dessa finns mjuka, elastiska segment som ger de elastiska egenskaperna. Elstens styvhet kan regleras med vulkanisering eller strålning.
Termoplast	Termoplaster är uppbyggda av linjära eller förgrenade polymerer. Den sammanhållande kraften mellan dem är svaga sekundära bindningar s k van der Waals-bindningar, som släpper vid upphettning och ger molekylerna ökad rörlighet varvid materialet mjuknar. Vid avkylning stelnar det igen och kan därför smältas om upprepade gånger. Inom termoplasterna skiljer man på amorf och delkristallin struktur.
Öko-Tex standard 100	Europeisk standard för textilier. Erbjuder garanti till konsumenter att textilen inte innehåller ämnen som kan vara skadliga för hälsan. Finns på adress: IFP, Institutet för Fiber- och Polymerteknik, Box 104, 431 22 Mölndal

Appendix IV

AVDELNINGSINSTRUKTION AI-400-1530

Benämning:	**Miljögenomgång i utvecckningsprojekt / Environmental review in development projects**				
Utfärdare/ Sign:	Johan Dahlström /	Orginaldatum:	2002-10-28	Sida:	1 (1)
Godkänd/ Sign:	Johan Löfvenholm /	Revisionsdatum:	2002-10-28	Utgåva:	1

Syfte

Mäta miljöprestanda för produkter som utvecklas på Autoliv Sverige AB, då detta är vår mest signifikanta miljöaspekt.

Objective

To monitor environmental performance of products developed by Autoliv Sverige AB, since this is our most significant aspect of environment.

Omfattning

Samtliga produktutvecklingsprojekt inom Autoliv Sverige AB.

Scope

All product development project within Autoliv Sverige AB.

Rutin

Varje projekt skall vid två tillfällen under projektet utföra miljögenomgång, i fas 1 och fas 4. Miljögenomgången skall genomföras med hjälp av projektgruppen där minst en representant för projektet från operation samt marknads-, inköps- respektive teknikavdelning skall deltaga.

Genomförande sker med hjälp av "Miljögenomgångslista", se bilaga 1. Notera att samtliga fält måste fyllas i. Editerad datafil sparas därefter under lämplig projektmapp.

Efter avslutad andra miljögenomgång och godkänd TG 4 skall kopia e-postas till Miljö- och kvalitetsavdelning för konsoliderad mätning av miljöprestanda .

Routine

Each project shall, in two occasions, perform environmental analysis, within phase 1 and phase 4. Environmental analysis shall be performed with help from the project team, there, as a minimum, one representative from operation together with marketing-, purchase- respective design department have to participate.

The analysis is performed with help from "environmental analysis", appendix 1. Please, be notified that the form has to be completely filled in. Edited computer file should be saved under appropriate project folder.

After finished second environment analysis and approved TG 4, the computer file shall be copied and e-mailed to the Environment and Quality department, for a consolidated measure of the environmental performance.

Hänvisningar

SI-1002	Projektdrivningsrutin
Bilaga 1	Miljögenomgångslista

References

SI-1002	Project Management
Appendix 1	Environment analysis form

Ansvar

Ansvara och genomföra miljögenomgång:

- Projektledare

Redovisning av resultat från miljögenomgång vid TG 1 & TG 4:

- Projektledare

Ansvara för att Miljö- och Kvalitetsavdelning delges kopia på miljögenomgångslista efter godkänd TG 4:

- Projektledare

Responsibility

Responsibility and accomplish Environment analysis:

- Project Manager

Report result from environment analysis at TG 1 and TG 4:

- Project Manager

Responsibility to submit copy of environment analysis to Environment and Quality department after approved TG 4:

- Project Manager

Appendix IV

Bäste användare !

Verktyget Miljögenomgång i projekt har tre huvudsyften:

1) Tidigt ge projektet input till potentiella miljöförbättringar
2) Sent i projektet verifiera utfall
3) Input till Autoliv Sverige AB miljömål varför denna fil efter godkänd Tollgate 4 skall skickas till miljöavdelningen.

Där samlas följande data in:

- Slutresultat på hela miljögenomgången
- Utfall vikt kontra satt målvikt
- Förekomst av substanser enligt Autoliv Inc. Standard Substance Use Restrictions, AS 5
- Återvinningsprestanda

För att resultatet skall bli representativt är det viktigt att så många projektmedlemmar som möjligt är med och ger sin input.
Minst krävs närvaro av en representant från operation, marknads-, inköps- respektive teknikavdelning.
Lämpligt tillfälle kan därför vara ett projektmöte där alla redan är samlade.

Räkna med att en genomgång tar 0,5-1,5 timmar beroende på hur väl förberedda alla är.

Användning av checklistan

* Notera att verktyget Miljögenomgång är avsedd att fyllas i direkt i datorn under mötet. Förslagsvis används därför dator med projektor för att alla skall kunna följa med.
* Till varje frågeställning finns ett kommentarsfält där noteringar för t ex åtgärder och ansvariga personer kan skrivas ned. Fältet kan också användas för att motivera valet av svarsalternativ.
* För att underlätta ifyllnad finns hjälpkommentarer till ett antal frågor. Dessa indikeras med en röd triangel och visas när användaren svävar över med muspekaren.

Kontakta utfärdare av rutinen om ni har förbättringsförslag.

Lycka till !

Appendix IV

AI-400-1530, Bilaga 1-1. 2003-XX-XX

Miljögenomgångslista - Tollgate 1

Vänligen observera, samtliga fält är obligatoriska

Autoliv
AUTOLIV SVERIGE AB

Projektnamn		Projektnummer	Projektstart
Ansvarig projektledare			Projektslut
Datum	Deltagare		

Vikt

Målsatt vikt: ________ [gram]

Målvikt satt av: KUND ☐ AUTOLIV ☐

Identifierade AS 5 substanser i konceptfas - Fylls i under Bilaga 1-3, AS 5

X. Optimering av funktion

Funktion uppfylld av produkten ☐ N/A - ny produkttyp i sitt slag

- 3 p ○ Funktion från tidigare produkt uppfylls **immateriellt** eller att **borttagande av onödiga funktioner** medför **färre/mindre** produkter
- 2 p ○ **Integrerar fler funktioner** än tidigare produkt (färre produkter för samma funktioner)
- 1 p ○ **Samma funktion** som tidigare produkt
- 0 p ○ Integrerar **färre funktioner** än tidigare produkt (funktionerna uppfylls nu av ytterligare en produkt)

Kommentar:

1. Val av lågpåverkande material

Rena material

- 3 p ○ **Inga härdplaster eller kompositer, < 3 olika termoplaster** resp. **< 3 metallsorter,** är **fri från ämnen listade i AS 5** och **ytbehandlas ej**
- 2 p ○ **Härdplaster/kompositer**, material med substanser från **AS 5, Restricted Chemical Substances avskiljs lätt** från produkten **vid demontering.** Ytbehandling sker **ej**
- 1 p ○ **Härdplaster/kompositer,** material med substanser från **AS 5, Restricted Chemical Substances avskiljs ej lätt** från produkten **vid demontering.** Ytbehandling **sker**
- 0 p ○ **Härdplaster/kompositer,** material med substanser från **AS 5, Forbidden Chemical Substances avskiljs ej lätt** från produkten **vid demontering.** Ytbehandling **sker**

Kommentar:

Råvarutillgång

- 3 p ○ **Förnyelsebara plaster** respektive **återvunna metaller** används **i huvudsak**
- 2 p ○ **Förnyelsebara plaster** respektive **återvunna metaller** används **i mindre omfattning**
- 1 p ○ **Icke förnyelsebara plaster** gjorda av fossila bränslen respektive **återvunna metaller** används **i huvudsak**
- 0 p ○ **Jungfruligt material** används **i huvudsak** alternativt utgörs **> 5 vikt-%** av produkten av **sällsyntare metaller** så som koppar, tenn, zink, guld eller platina

Kommentar:

Energiåtgång ☐ N/A - ny produkttyp i sitt slag

- 3 p ○ Vid framställning av material till produkten åtgår **< 80 % energi** jämfört med framställning av material till tidigare motsvarande produkt. (Beakta även leverantörens energikonsumtion)
- 2 p ○ Vid framställning av material till produkten åtgår **< 95 % energi** jämfört med framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)
- 1 p ○ Vid framställning av material till produkten åtgår **lika mycket energi** som vid framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)
- 0 p ○ Vid framställning av material till produkten åtgår **större mängd energi** än vid framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)

Kommentar:

Återvunnet plastmaterial

- 3 p ○ Produkten består **i sin helhet** av **återvunnet** plastmaterial
- 2 p ○ Produkten består **delvis** av **återvunnet** plastmaterial
- 1 p ○ **Återvunnet** plastmaterial **kan inte** användas i produkten
- 0 p ○ **Återvunnet** plastmaterial **kan användas** men **gör det inte**

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-1. 2003-XX-XX

Miljögenomgångslista - Tollgate 1

Vänligen observera, samtliga fält är obligatoriska

Autoliv
AUTOLIV SVERIGE AB

2. Optimering av produktionsteknik

Produktionsavfall (avser utsläpp till mark, vatten eller luft) ☐ N/A - ny produkttyp i sitt slag

3 p ○ Produkten ger upphov till **< 90 % produktionsavfall** jämfört med tidigare produkt (Beakta även produktionsavfall hos leverantören)
2 p ○ Produkten ger upphov till **< 100 % men > 90 % produktionsavfall** jämfört med tidigare produkt (Beakta även produktionsavfall hos leverantören)
1 p ○ Produkten ger upphov till **lika mycket produktionsavfall** som tidigare produkt (Beakta även produktionsavfall hos leverantören)
0 p ○ Produkten ger upphov till **mer produktionsavfall** än tidigare produkt (Beakta även produktionsavfall hos leverantören)

Kommentar:

Förbrukningsämnen

3 p ○ Endast i naturen **lätt nedbrytbara ämnen** åtgår vid tillverkning (t ex propylenglykol, väteperoxid) - (Beakta även leverantörens tillverkning)
2 p ○ I naturen **nedbrytbara ämnen** åtgår vid tillverkning (t ex mineralolja utan specialtillsatser) - (Beakta även leverantörens tillverkning)
1 p ○ Ämnen från **AS 5, Restricted Chemical Substances åtgår** vid tillverkning (Beakta även leverantörens tillverkning)
0 p ○ Ämnen från **AS 5, Forbidden Chemical Substances åtgår** vid tillverkning (t ex kromateringsbad) - (Beakta även leverantörens tillverkning)

Kommentar:

3. Optimering av distributionssystem

Förpackningsmaterial (emballage)

3 p ○ **Returemballage** som **återanvänds** används vid transport av produkten
2 p ○ Emballage som används vid transport av produkten **återanvänds inte men kommer återvinnas i sin helhet**
1 p ○ Emballaget **återvinns delvis** efter transporten
0 p ○ Emballage av **högkvalitativa eller miljöbelastande** material används vid transport av produkten och **återvinns ej**

Kommentar:

Logistik in

3 p ○ **> 80 %** av alla komponenter till produkten **tillverkas** och **transporteras inom landet**
2 p ○ **> 50 %** av alla komponenter till produkten **tillverkas** och **transporteras inom landet**
1 p ○ **> 30 %** av alla delar till produkten **hämtas utanför Europa**
0 p ○ **> 10 %** av alla delar till produkten **hämtas utanför Europa** till någon del **med flyg eller lastbil**

Kommentar:

Logistik ut

3 p ○ Produkten är avsiktligt konstruerad så att den kan **packas effektivt i returemballage** vid transporter
2 p ○ Produkten är konstruerad avsiktligt så att den kan **packas i returemballage men är skrymmande** vid transporter
1 p ○ Produkten är konstruerad avsiktligt så att den kan **packas effektivt i engångsemballage** vid transporter
0 p ○ Produkten är **skrymmande** och kan **ej packas effektivt i engångsemballage** vid transporter

Kommentar:

Transportvolym ut

3 p ○ Produktens volym **reducerad** så att antalet transporter under tillverkning kan **minskas med >10 %**
2 p ○ Produktens volym **reducerad** så att antalet transporter under tillverkning kan **minskas med <10 %**
1 p ○ Produktens volym innebär **ingen förändring** i antalet transporter
0 p ○ Produktens volym medför **ökning** av transporter

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-1. 2003-XX-XX

Miljögenomgångslista - Tollgate 1

Vänligen observera, samtliga fält är obligatoriska

4. Reduktion av miljöpåverkan under användning

Materialvikt - påverkar fordonets bränsleförbrukning ☐ N/A - ny produkttyp i sitt slag

3 p ○ Produktens **vikt reducerad med >10 %** jämfört med tidigare motsvarande produkt
2 p ○ Produktens **vikt reducerad med <10 %** jämfört med tidigare motsvarande produkt
1 p ○ Produkten har **samma vikt** som tidigare motsvarande produkt
0 p ○ Produktens vikt **högre än** tidigare motsvarande produkt

Kommentar:

5. Optimering av resthantering

Optimering av livslängd ☐ N/A för **pyrotekniska** produkter

3 p ○ Produkten antas ha **längre** livslängd än fordonet och kommer sannolikt att **återanvändas** när fordonet skrotas
2 p ○ Produkten antas ha **samma** livslängd som fordonet
1 p ○ Produkten antas ha **kortare** livslängd än fordonet men är **enkel** att byta ut
0 p ○ Produkten antas ha **kortare** livslängd än fordonet men är **svår** att byta ut

Kommentar:

Materialåtervinning

3 p ○ **> 90 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
2 p ○ **> 50 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
1 p ○ **< 50 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
0 p ○ Materialåtervinning hade varit möjlig med annan konstruktion/andra material

Kommentar:

Energiåtervinning - endast komponenter där materialanvändning/materialåtervinning ej förväntas ske ☐ N/A - inga **brännbara** material

3 p ○ **Alla** aktuella, brännbara material i produkten är **fria** från AS 5 substanser och kan energiåtervinnas
2 p ○ **Alla** aktuella, brännbara material i produkten kan energiåtervinnas men vissa **innehåller AS 5, Restricted Chemical Substances** vilket kan försvåra energiutvinning
1 p ○ **Endast vissa** brännbara material i produkten kan energiåtervinnas och **vissa innehåller AS 5, Restricted Chemical Substances** vilket kan försvåra energiutvinning
0 p ○ Energin i produktens material kan **inte återvinnas** eftersom ett eller flera material **innehåller AS 5, Forbidden Chemical Substances** vilka vid förbränning kan orsaka miljöfarliga utsläpp

Kommentar:

Deponi

3 p ○ Inga delar av produkten bedöms hamna på deponi
2 p ○ Vissa av produkten material bedömns hamna på deponi men är **fria** från AS 5 substanser och kan **enkelt** separeras från resten av produkten
1 p ○ Vissa av produktens material **innehåller AS 5 substanser** men kan **enkelt** separeras från resten av produkten
0 p ○ Vissa av produktens material **innehåller AS 5 substanser** som är **svåra** att separera innan deponi

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-2. 2003-XX-XX

Miljögenomgångslista - Tollgate 4

Vänligen observera, samtliga fält är obligatoriska

Autoliv
AUTOLIV SVERIGE AB

Projektnamn 0	Projektnummer 0	Projektstart 0
Ansvarig projektledare		Projektslut
Datum	Deltagare	

Vikt

Målvikt satt av: KUND ☐ AUTOLIV ☐

Målsatt vikt: [gram]

Faktisk vikt: [gram]

Identifierade AS 5 substanser i produkten - Fylls i under Bilaga 1-3, AS 5

X. Optimering av funktion

Funktion uppfylld av produkten ☐ N/A - ny produkttyp i sitt slag

- 3 p ○ Funktion från tidigare produkt uppfylls **immateriellt** eller att **borttagande av onödiga funktioner** medför **färre/mindre** produkter
- 2 p ○ **Integrerar fler funktioner** än tidigare produkt (färre produkter för samma funktioner)
- 1 p ○ **Samma funktion** som tidigare produkt
- 0 p ○ Integrerar **färre funktioner** än tidigare produkt (funktionerna uppfylls nu av ytterligare en produkt)

Kommentar:

1. Val av lågpåverkande material

Rena material

- 3 p ○ **Inga härdplaster eller kompositer, < 3 olika termoplaster** resp. **< 3 metallsorter,** är **fri från ämnen listade i AS 5** och **ytbehandlas ej**
- 2 p ○ **Härdplaster/kompositer,** material med substanser från **AS 5, Restricted Chemical Substances avskiljs lätt** från produkten **vid demontering.** Ytbehandling sker **ej**
- 1 p ○ **Härdplaster/kompositer,** material med substanser från **AS 5, Restricted Chemical Substances avskiljs ej lätt** från produkten **vid demontering.** Ytbehandling **sker**
- 0 p ○ **Härdplaster/kompositer,** material med substanser från **AS 5, Forbidden Chemical Substances avskiljs ej lätt** från produkten **vid demontering.** Ytbehandling **sker**

Kommentar:

Råvarutillgång

- 3 p ○ ~~**Förnyelsebara plaster** respektive **återvunna metaller** används **i huvudsak**~~
- 2 p ○ **Förnyelsebara plaster** respektive **återvunna metaller** används **i mindre omfattning**
- 1 p ○ ~~**Icke förnyelsebara plaster** gjorda av fossila bränslen respektive **återvunna metaller** används **i huvudsak**~~
- 0 p ○ **Jungfruligt material** används **i huvudsak** alternativt utgörs **> 5 vikt-%** av produkten av **sällsyntare metaller** så som koppar, tenn, zink, guld eller platina

Kommentar:

Energiåtgång ☐ N/A - ny produkttyp i sitt slag

- 3 p ○ Vid framställning av material till produkten åtgår **< 80 % energi** jämfört med framställning av material till tidigare motsvarande produkt. (Beakta även leverantörens energikonsumtion)
- 2 p ○ Vid framställning av material till produkten åtgår **< 95 % energi** jämfört med framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)
- 1 p ○ Vid framställning av material till produkten åtgår **lika mycket energi** som vid framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)
- 0 p ○ Vid framställning av material till produkten åtgår **större mängd energi** än vid framställning av material till tidigare produkt. (Beakta även leverantörens energikonsumtion)

Kommentar:

Återvunnet plastmaterial

- 3 p ○ Produkten består **i sin helhet** av **återvunnet** plastmaterial
- 2 p ○ Produkten består **delvis** av **återvunnet** plastmaterial
- 1 p ○ **Återvunnet** plastmaterial **kan inte** användas i produkten
- 0 p ○ **Återvunnet** plastmaterial **kan användas** men **gör det inte**

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-2. 2003-XX-XX

Miljögenomgångslista - Tollgate 4

Vänligen observera, samtliga fält är obligatoriska

2. Optimering av produktionsteknik

Produktionsavfall (avser utsläpp till mark, vatten eller luft) ☐ N/A - ny produkttyp i sitt slag

3 p ○ Produkten ger upphov till **< 90 % produktionsavfall** jämfört med tidigare produkt (Beakta även produktionsavfall hos leverantören)
2 p ○ Produkten ger upphov till **< 100 % men > 90 % produktionsavfall** jämfört med tidigare produkt (Beakta även produktionsavfall hos leverantören)
1 p ○ Produkten ger upphov till **lika mycket produktionsavfall** som tidigare produkt (Beakta även produktionsavfall hos leverantören)
0 p ○ Produkten ger upphov till **mer produktionsavfall** än tidigare produkt (Beakta även produktionsavfall hos leverantören)

Kommentar:

Förbrukningsämnen

3 p ○ Endast i naturen **lätt nedbrytbara ämnen** åtgår vid tillverkning (t ex propylenglykol, väteperoxid) - (Beakta även leverantörens tillverkning)
2 p ○ I naturen **nedbrytbara ämnen** åtgår vid tillverkning (t ex mineralolja utan specialtillsatser) - (Beakta även leverantörens tillverkning)
1 p ○ Ämnen från **AS 5, Restricted Chemical Substances åtgår** vid tillverkning (Beakta även leverantörens tillverkning)
0 p ○ Ämnen från **AS 5, Forbidden Chemical Substances åtgår** vid tillverkning (t ex kromateringsbad) - (Beakta även leverantörens tillverkning)

Kommentar:

3. Optimering av distributionssystem

Förpackningsmaterial (emballage)

3 p ○ **Returemballage** som **återanvänds** används vid transport av produkten
2 p ○ Emballage som används vid transport av produkten **återanvänds inte men kommer återvinnas i sin helhet**
1 p ○ Emballaget **återvinns delvis** efter transporten
0 p ○ Emballage av **högkvalitativa eller miljöbelastande** material används vid transport av produkten och **återvinns ej**

Kommentar:

Logistik in

3 p ○ **> 80 %** av alla komponenter till produkten **tillverkas** och **transporteras inom landet**
2 p ○ **> 50 %** av alla komponenter till produkten **tillverkas** och **transporteras inom landet**
1 p ○ **> 30 %** av alla delar till produkten **hämtas utanför Europa**
0 p ○ **> 10 %** av alla delar till produkten **hämtas utanför Europa** till någon del **med flyg eller lastbil**

Kommentar:

Logistik ut

3 p ○ Produkten är avsiktligt konstruerad så att den kan **packas effektivt i returemballage** vid transporter
2 p ○ Produkten är konstruerad avsiktligt så att den kan **packas i returemballage men är skrymmande** vid transporter
1 p ○ Produkten är konstruerad avsiktligt så att den kan **packas effektivt i engångsemballage** vid transporter
0 p ○ Produkten är **skrymmande** och kan **ej packas effektivt i engångsemballage** vid transporter

Kommentar:

Transportvolym ut

3 p ○ Produktens volym **reducerad** så att antalet transporter under tillverkning kan **minskas med >10 %**
2 p ○ Produktens volym **reducerad** så att antalet transporter under tillverkning kan **minskas med <10 %**
1 p ○ Produktens volym innebär **ingen förändring** i antalet transporter
0 p ○ Produktens volym medför **ökning** av transporter

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-2. 2003-XX-XX

Miljögenomgångslista - Tollgate 4

Vänligen observera, samtliga fält är obligatoriska

4. Reduktion av miljöpåverkan under användning

Materialvikt - påverkar fordonets bränsleförbrukning ☐ N/A - ny produkttyp i sitt slag

3 p O Produktens **vikt reducerad med >10 %** jämfört med tidigare motsvarande produkt
2 p O Produktens **vikt reducerad med <10 %** jämfört med tidigare motsvarande produkt
1 p O Produkten har **samma vikt** som tidigare motsvarande produkt
0 p O Produktens vikt **högre än** tidigare motsvarande produkt

Kommentar:

5. Optimering av resthantering

Optimering av livslängd ☐ N/A för **pyrotekniska** produkter

3 p O Produkten antas ha **längre** livslängd än fordonet och kommer sannolikt att **återanvändas** när fordonet skrotas
2 p O Produkten antas ha **samma** livslängd som fordonet
1 p O Produkten antas ha **kortare** livslängd än fordonet men är **enkel** att byta ut
0 p O Produkten antas ha **kortare** livslängd än fordonet men är **svår** att byta ut

Kommentar:

Materialåtervinning

3 p O **> 90 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
2 p O **> 50 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
1 p O **< 50 vikt-%** av produkten kommer kunna materialåtervinnas, dvs material med **AS 5 substanser, samt härdplaster/kompositer** kan avskiljas. Inga kvarvarande material stör återvinning
0 p O Materialåtervinning hade varit möjlig med annan konstruktion/andra material

Kommentar:

Energiåtervinning - endast komponenter där materialanvändning/materialåtervinning ej förväntas ske ☐ N/A - inga **brännbara** material

3 p O **Alla** aktuella, brännbara material i produkten är **fria** från AS 5 substanser och kan energiåtervinnas
2 p O **Alla** aktuella, brännbara material i produkten kan energiåtervinnas men vissa **innehåller AS 5, Restricted Chemical Substances** vilket kan försvåra energiutvinning
1 p O **Endast vissa** brännbara material i produkten kan energiåtervinnas och **vissa innehåller AS 5, Restricted Chemical Substances** vilket kan försvåra energiutvinning
0 p O Energin i produktens material kan **inte återvinnas** eftersom ett eller flera material **innehåller AS 5, Forbidden Chemical Substances** vilka vid förbränning kan orsaka miljöfarliga utsläpp

Kommentar:

Deponi

3 p O Inga delar av produkten bedöms hamna på deponi
2 p O Vissa av produkten material bedömns hamna på deponi men är **fria** från AS 5 substanser och kan **enkelt** separeras från resten av produkten
1 p O Vissa av produktens material **innehåller AS 5 substanser** men kan **enkelt** separeras från resten av produkten
0 p O Vissa av produktens material **innehåller AS 5 substanser** som är **svåra** att separera innan deponi

Kommentar:

Appendix IV

AI-400-1530, Bilaga 1-3. 2003-XX-XX

Autoliv Restricted/Forbidden Substances, AS 5

AS 5 återfinns under Autoliv Corporate Standards i Lotus Notes databaser

Projektnamn 0	Projektnummer 0	Projektstart 0
Ansvarig projektledare		Projektslut
Datum	Deltagare	

TG 1	TG 4	Material/ytbehandling			Substans				
		Standard/Norm	Materialnamn	Vikt [gram]	CAS-nr	AS 5 Forbidden Substance	AS 5 Restricted Substance	Substansens namn	Substans i material [vikt-%]
☐	☐					○	○		
☐	☐					○	○		
☐	☐					○	○		
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Appendix IV

AI-400-1530, Bilaga 1:4, 2003-XX-XX

Resultat - Projekt:
Värdering av produktens miljöprestanda under dess livscykel

Autoliv
AUTOLIV SVERIGE AB

Projektnamn	Projektnummer	Projektstart
0	0	0
Ansvarig projektledare		Projektslut
	0	0

Tollgate 1

Datum: 0

Viktat miljöprestanda 0

Forbidden material NEJ
Restricted material NEJ

Tolkning av viktad miljöprestanda

2 - 3	Bra miljöprestanda under produktlivscykeln
1 - 2	Godkänd miljöprestanda under produktlivscykeln
0 - 1	Dålig miljöprestanda under produktlivscykeln

Tollgate 4

Datum:

Viktat miljöprestanda TG 4

Forbidden material NEJ
Restricted material NEJ

Viktmål uppnått: TG 4

Formel Viktat miljöprestanda (X)+3(1)+2(2)+(3)+4(4)+3(5)/14