

Mattias Lindahl & Johan Tingström

(Carsten Jensen - HRM/Ritline AB)

**A small textbook on
ENVIRONMENTAL
EFFECT ANALYSIS**



**Department of Technology
University of Kalmar**

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The authors disclaim all responsibility for the consequences that might arise when practising the Environmental Effect Analysis. The textbook and the method are still in progress.

Preface

In today's society products are being made and used to a constantly increasing extent. In addition there is also a never-ending flow of new products. Products that earlier generations would have never dreamt of. The new products are constantly trying to fill the needs and demands of our society.

These products are directly or indirectly causing environmental problems. The growing population's increasing use of, and need for, these products results in larger and more complex environmental issues.

A growing knowledge of the connection between products and environmental problems has resulted in an increasing interest in these issues, from both businesses and the public, during the last ten years. To reduce the effects on the environment they try to apply an holistic perspective to the products, i.e. regard the entire life-cycle of the product.

It is the early phase of the product development that, to the greatest extent, determines the total environmental effect of a product. It is therefore important that the environmental aspects are taken into consideration in this critical phase so that the effects on the environment can be reduced.

This book presents Environment Effect Analysis¹ (EEA), which is a qualitative method for Design for Environment, DfE. The method is designed for use in the early phases of product development. The advantages with the EEA method are that it is easy to learn, relatively fast to carry out and results in suggestions for concrete environmental improvements.

¹ The former name of the method was Environmental-FMEA, a name still used by some companies.

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1

Design for Environment (DfE)

1.1. Introduction

Design for Environment is in fact not different from ordinary product development. Therefore the book begins with a description of the traditional product development. The chapter also throws light on the profit gained from a good and efficient product development.

To be able to judge how effective a product development is you study time, cost and quality. These variables are independent of both what is to be produced and the size of the product or system. The customer and the executives usually want the products to be produced faster, at a lower cost and with a higher quality². A large part of the product development comprises the design phase. Professor Jan-Gunnar Persson, at the Royal Technical University i Stockholm, Sweden, has defined the design phase as:

“A creative process which on the basis of the customers functional and quality demands and the norms and security demands intends to

- *Create, verify and document a technical solution*
- *Manufacture production data*

With the aim: good economy for both user and distributor.”

1.2. Product development

Simplified, there are two different ways of working with product development, sequential or integrated. Sequential product development is the traditional method

² Ullman, D. (1997), The mechanical design process, McGraw-Hill, ISBN 0-07-065756-4, New York.

but for different reasons the product development has gone more and more towards a more structured and integrated way of working.

1.2.1. Sequential product development

Sequential product development (Figure 1) means that all the phases are carried out as a series of actions. A new phase is not started until the previous is finished. This method has however turned out to have a number of built-in disadvantages

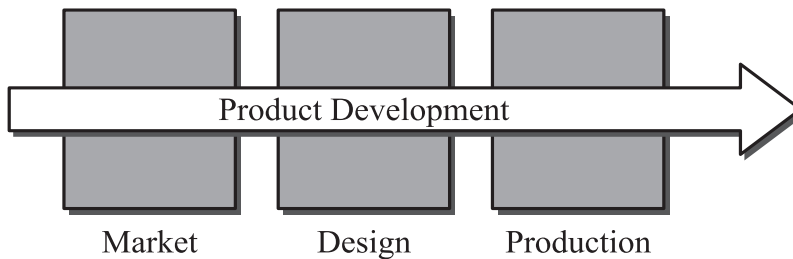


Figure 1. Sequential product development means that all the phases are carried out as a series of actions. A new phase is not started until the previous is finished.

The best known disadvantage is the “over the wall” problem (Figure 2). Obstacles easily arise between the different sections or phases of the product design which often results in important information not going to the place where it is needed. The lack of information gives rise to a number of different sub-optimizations (Appendix 2).

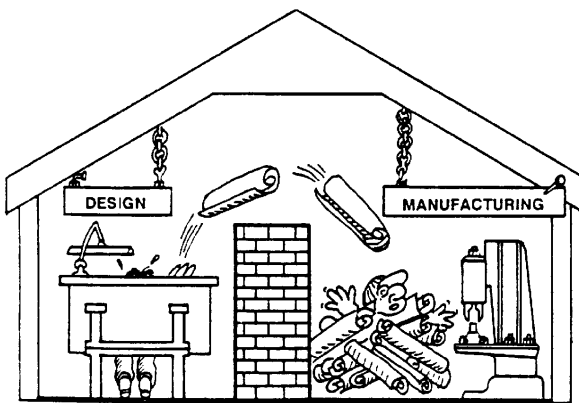


Figure 2. “Over the wall” problem. Information and data are sent to the next step in the chain without any feedback to ensure the proper use of the information/data [Unknown illustrator].

One other disadvantage is that there is a lack of understanding between the different divisions. This can result in misunderstandings; for example, which division is to do what. The result can be that working material is sent from one division to another and this causes problems for the receiver. One example of this could be that the design division sends blueprints to the production division that are not possible to produce. Another example is if the marketing division sells a product that the design division has never constructed before.

Furthermore, there is also a big risk that each division sub-optimizes its work at the expense of the whole. The responsibility for one's own work can easily become more important than the responsibility for the company as a whole.

Tasks can easily end up between two divisions and stay there because the situation is not dealt with since nobody knows where the responsibility lies.

Finally, if a product development is to work out well it is sometimes necessary to go back and ensure that the development results in what the market and the customers demand. In many cases this leads to a situation where many things have to be done all over again, which will take up extra time and resources.

1.2.2. Integrated product development

Integrated product development (Figure 3) is built on parallel processes during the development. Working this way leads to a shorter lead time, that is, the time it takes from when a customer desire arises to when there is a finished product. In the constantly growing competition this turned out to be a good way of working to be more efficient.

One of the first spokesmen for an integrated way was Fredy Olsson who, in 1976, in his doctor's thesis presented a structured and integrated method. Olsson's idea was after that developed by Andreasen³, among others, and is today the most frequently used method in product development.

An integrated way of working requires and encourages cooperation and communication between divisions and between co-workers. A large part of the work is done in interfunctional teams, consisting of people from the different divisions. The effect of this is that the characteristic problems for the sequential product development will not arise.

³ Andreasen, M M., Hein, L. (1988) Integrated Product development, IFS Ltd, ISBN 0-948507-21-7, London.

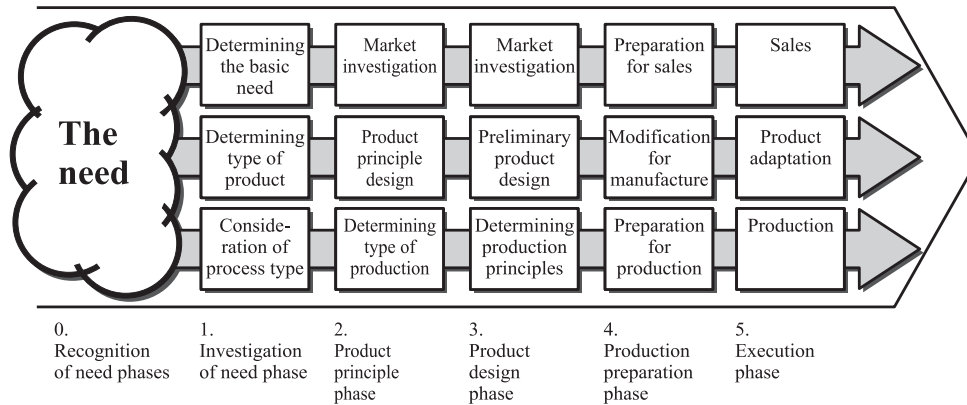


Figure 3. Integrated product development means that production development is done in parallel processes⁴.

1.3. Environmental adaptation

The growing awareness of the connection between products and environmental problems has resulted in increasing demands being made for reduced environmental influence from products. An example is the producer responsibility, which means the producer must take care of the product when it has served its time.

In product development the environmental demand has become yet one more parameter to consider. Different methods for DfE have therefore been developed to solve the situation. The purpose of DfE is to:

“take concurrent engineering one step further, whereby all life-cycle phases - needs recognition, development, production, usage, and including disposal or recycling - are considered simultaneously from the conceptual design stage through the detailed design stage in order to minimize environmental impact compared to benefit”.

A life-cycle of a product includes all the phases that can be connected to the product (the product system⁵), see Figure 4. All the phases cannot be included and in practice there are different limitations (Chapter 2.6.1.2).

⁴ Andreasen, M M., Hein, L. (1988) Integrated Product development, IFS Ltd, ISBN 0-948507-21-7, London.

⁵ A gathering of material and energy like coherent unit processes which together perform one or many defined functions.

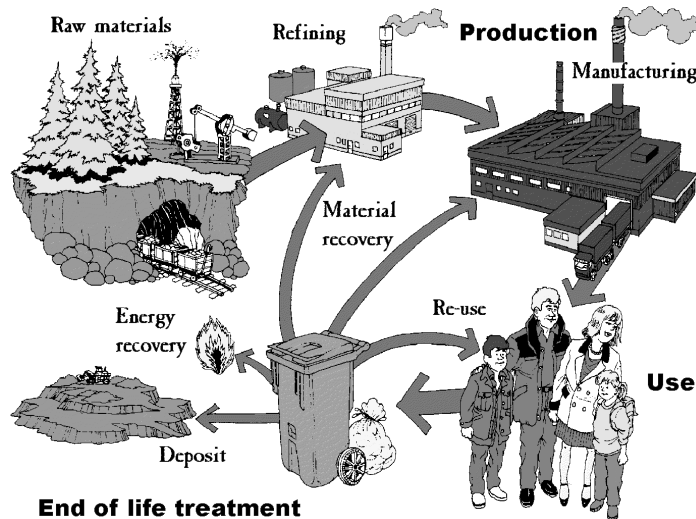


Figure 4. Different phases in the life-cycle of a product⁶.

Figure 5 shows the traditional focus of the product development and the more overarching perspective of the life-cycle. The boxes in the figure represent different processes in the life-cycle of a product. Across the different boundaries of the processes flow not only products but also information. Observe that the figure is simplified. In reality the connections between the different stages are far more complex.

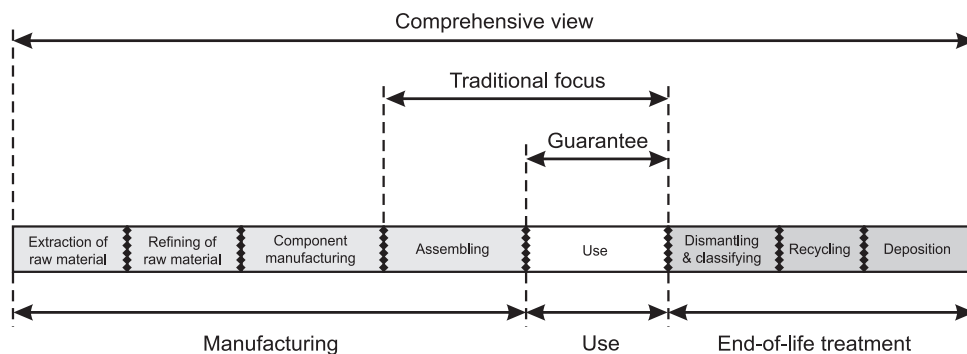


Figure 5. The focus in product development has traditionally been quite narrow but has recently become more overarching.

⁶ Magnusson, T. (1997) Handbok för miljöanpassad mekanik-konstruktion - En introduktion, Sveriges verkstadsindustrier, ISSN 1104-7178, Orginaltecknare Ulf Östlund HB

The overarching focus gives not only environmental gains but also economic ones. In many cases it is hard to tell what is what. The big advantage of the more widened perspective is that it decreases the risk of sub-optimizations (Appendix 2). Suboptimizing usually results in more expensive and less functional products or technical systems because, for example, it requires more material and energy to obtain the desired function. An increased consumption of material and energy reflects directly on the total environmental pressure of the product.

Design work is not linear with one starting point and an already set-out finish. It is an iterative process that can be described as a repeating cycle (Figure 6). The design work is generally controlled by the defined demands and desires that are to be obtained. Demands and desires can for example be:

- Reliability
- Safety
- Function and performances
- Environment
- Manufacturing aspects
- Design and shaping
- Cost

From a management perspective, the environmental issues have historically been seen as non-profitable and uninteresting. This old approach has over time, and with the increasing attention to environmental problems, made way for a more varied approach. To take into consideration the environment is no longer solely associated with increased costs and work effort. A company invests, hoping for the investment to bring profit in the future. To concentrate on DfE is an investment, and it can lead to the company saving money by decreased consumption of material and increased sales. The growing market for environmentally adapted products means that more and more customers choose the products that cause the least environmental effect instead of other products. There are therefore large opportunities for the companies to get back the money they invested.

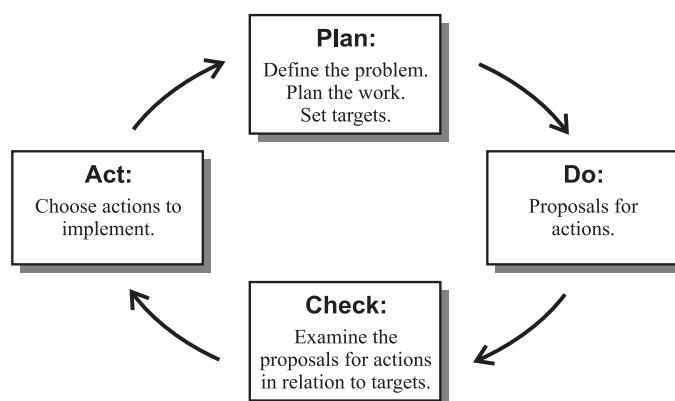


Figure 6. Designing is an iterative process.

1.4. Product planning

During product planning the possibilities for direction and change are greatest at the beginning of the project, that is, in the pilot study and the concept phase. The earlier the changes are made the less they will cost in time and work effort (Figure 7). A change to a drawing costs very little compared with having to do it when the production has started⁷. This is usually called the design process paradox. .

When the possibility for change is at its greatest, the knowledge of how the product will turn out is at its smallest. As the knowledge of the product grows the possibilities of making changes decrease.

The reason is that the decisions being made during the process of the product development, for example, regarding performance characteristics or actions, have to be unlocked. They mostly become out-of-date when the changes result in new fundamental conditions and demands. Much of the work done becomes worthless and has to be redone.

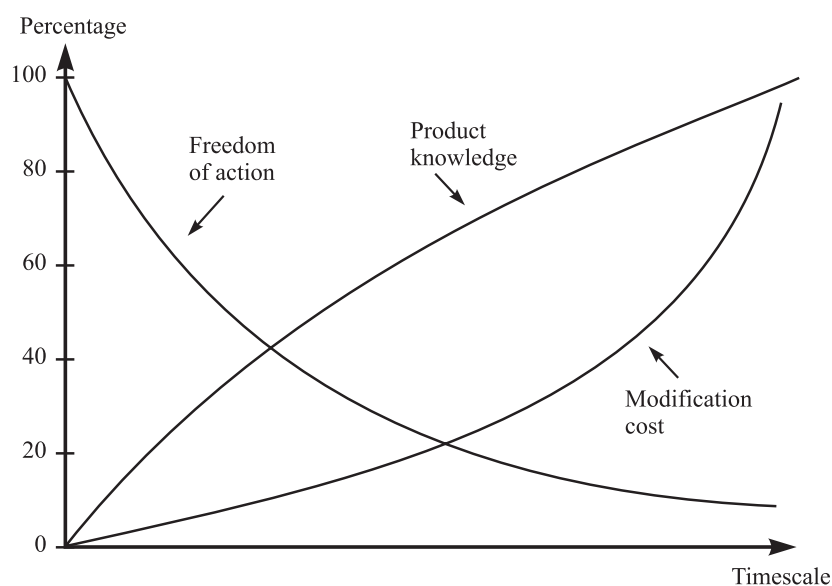


Figure 7. A principle figure, showing how the freedom of action in the process of product development decreases over time and how the knowledge and modification cost increases.

⁷ Ottman, J.A. (1994) Ignore Environmental Issues at Your Own Peril, Brandweek, p.17, May 9.

The aim of DfE to minimise the total environmental influence which a product causes during its life-cycle. Usually the process starts by listing and checking environmental demands and desires. A survey of the entire life-cycle of the product is to be carried out. Usually it is divided into:

- Production; What is the environmental influence of the production of the product?
- Use; What is the environmental effect of the product during its use?
- Final disposal; What will happen when the product has served its time?

When doing the survey, attention should be paid to the overarching parts, this is to avoid getting stuck in details. Figure 8 shows examples of data that can be of interest when considering the life-cycle of the product.

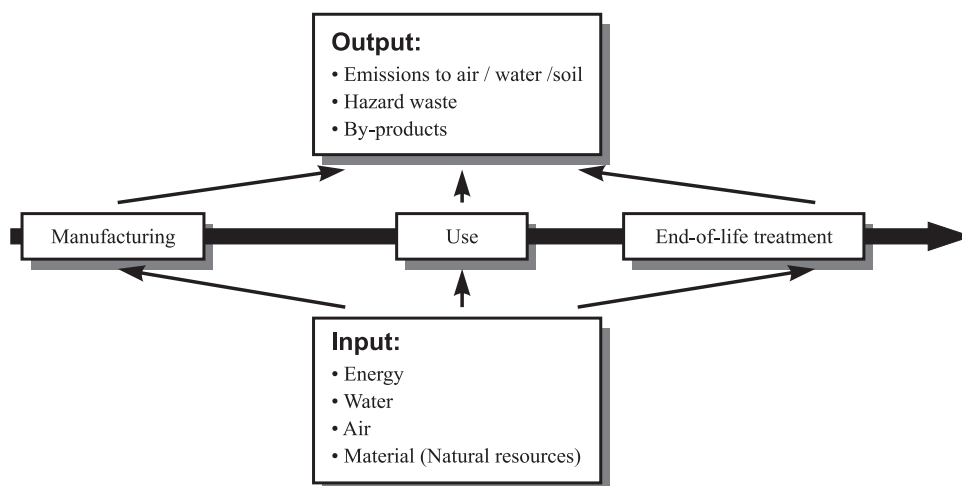


Figure 8. A survey of the environmental impact of the product during its entire lifecycle provides an idea of where to make the efforts to reduce its total environmental effect.

1.5. Product related demands and desires

The specification of demands should deal with environmentally related product demands and desires. To be able to follow up and evaluate the results it is advantageous if the demands and desires can be quantified. An example of a quantified demand can be that a substance, classified as environmentally hazardous, will decrease by 70% during the next two years or that the share of recycled material will amount to 50% in all new products. Sometimes you can't

find specific environmental demands for each product but what you can do is relate or compare the product to similar ones.

Examples of product related environmental demands are:

- **Environmentally hazardous substances:** A new product shall not contain or require environmentally hazardous substances for its production or use.
- **Share of recycled material:** Try to find new opportunities to use recycled materials. Where does it have to be virgin material and where does it not?
- **Waste, discharge and energy consumption during use:** Can you change any of the phases of the production or can something be left out?
- **Length of time:** How long before the product has served its time? Which parts will be worn, can they easily be replaced to prolong the length of time?
- **Disassembly:** Can the product be disassembled and how is that to be done in order to facilitate final disposal?
- **Recycling:** Can standardised components be used in new products or as spare parts?

2

Environmental Effect Analysis – EEA

This chapter contains a description of the methodology for Environmental Effect Analysis⁸ (EEA). EEA has been developed in an interactive process based on knowledge and experience from searches in the literature and case studies. The development has taken place in close co-operation with the industry, e.g. in a project founded by the Swedish National Board for Industrial and Technical Development (NUTEK).

To receive the latest information about the development of the method, please visit, <http://www.eea.nu>.

2.1. History

EEA development started in the mid-nineties, as a result of a great need for an easier and faster method for environmental impact evaluations than the ones at hand. An important demand was that the method should be pedagogical and recognisable for the designers, in order to ease the implementation and increase the level of acceptance. At the same time, the method had to be compatible with the ISO 14 001 (1996) standardized Environmental Management System (EMS).

At this time, the FMEA method had substantial support in the industry and was used by many enterprises working with quality management systems in their product development. Therefore, the EEA was developed with the FMEA as a prototype.

One of the companies that participated in the early development of FMEA was HRM/Ritline AB, a consultant company in Gothenburg, Sweden. This company, was among other things, involved in the development and design of car components. The company introduced an environmental management system according to ISO 14 001 during spring 1996. However, they felt that the Life Cycle Assessment methods were too complicated to achieve a rapid answer in an early

⁸ The former name of the method was Environmental-FMEA, a name still used by some companies.

phase of product development. Therefore they developed a less complicated method – the Environmental-FMEA (E-FMEA).

The ideas were presented to the Volvo Car Corporation, which saw a possibility of using the method in their product development. During 1997, the method was further developed by Volvo and adjusted to their activities.

At the end of 1997, the Association of Swedish Engineering Industries (VI) gave the Swedish Institute of Production Engineering Research (IVF) the assignment to develop a simple tool for DfE, based on the traditional FMEA methodology. The development was done in co-operation with Volvo Wheel Loader AB, and resulted in a method similar to the one already at hand. Later, the VI initiated a formalisation of the new method and started to implement the method among its member companies.

During 1998-99, a number of companies used the method in pilot studies. Furthermore, the University of Kalmar, Sweden, continued to develop the method for companies within a project financed by NUTEK.

The method has also been introduced internationally. After the international introduction, the name became an issue. Legal problems were foreseen in the USA, where the FMEA concept was already a protected name. In the fall of 1999 the name was changed from Environmental FMEA to Environmental Effect Analysis – EEA.

2.2. What is EEA?

The objectives of an EEA are to identify and evaluate significant environmental impacts of a product in an early stage of a development project. This is in order to be able to evaluate alternative materials, and processes as early as possible.

By doing so the negative environmental impact of the product's entire life-cycle may be prevented or limited in a simple and cost-effective way.

In an EEA, available competence, along with experience, is used to decrease the environmental impact from a tentative design in every step of the life-cycle. It is important to emphasise that the EEA focuses on the environmental requirements of the product and that the environmental examination is a teamwork between different functions in a company. One of the greatest advantages of the method is that it can and should be used in the early phases of a product development project.

When performing an EEA, the aim is to find so called *hot spots*, that is, the environmental effects that can be judged as particularly important to work with in order to decrease the environmental influence of the product. The EEA can be seen as a compass, by aid of which you can give priorities to the environmentally related work.

Another aim of the method is to function as a pedagogical tool. Everybody involved learns about the environmental effects and the environmental competence increases automatically.

In short, EEA is characterized by the following:

- It is a systematic study of the environmental effects of a product system, from extraction of raw material to the final disposal.
- It is based on environmental requirements.
- The level of detail, as well as the time frame for the EEA, can be varied depending on chosen definitions of goal and system boundaries, i.e. it is a flexible method.
- It is a qualitative method.
- Assumptions and sources of data are accounted for in a transparent⁹ and understandable way.
- It is intended for internal use and especially for product development.
- It is not possible to compare two different technical functions with each other.
- It can be a part of an environmental management system according to ISO 14 001 [1996].

2.3. Summary of EEA framework and methodology

EEA is a systematic process carried out by a multifunctional team. The analysis contains a number of activities that should be coordinated with other activities in the product development work. The different activities, preparations, inventory, analysis, implementation and follow-up are integrated in the project plan, which is established before the start of the project. The planning of an EEA should therefore, as far as possible, coincide with the rest of the planning of the project.

The preparation work includes the collection of relevant information regarding the current product, its life-cycle and environmental impact. Of special interest are, present and expected, future environmentally related requirements of the product. These requirements can be divided into three: authority demands, market demands and internal demands (controlling documents, internal environmental aims etc). Of

⁹ The account should be made in such a way that it is easy to understand how presumptions, sources of data and data are connected.

interest are also the materials used, the manufacturing process, the way it is used and the means of final disposal. If earlier life-cycle assessments have been made, they can give valuable input data for an EEA. It is important to emphasize that EEA data collection should cover all phases of the life-cycle but not necessarily in detail.

The EEA method uses a special form in order to structure the analysis, see section 2.4. When filling in the form, it is important to do it jointly within the EEA. This is partly because it facilitates the collection of life-cycle information and partly because it is necessary to reach a consensus within the group with respect to the information used. This is since the method uses qualitative, in other words subjective, data for the evaluation. It is also important because many different functions in a company can be affected by the improvement suggestions that come out of the analysis.

The analysis is made on the basis of the product's life-cycle, which can be divided into different phases (for example; Purchase/Procurement – Production – Use – End-of-life treatment). The composition of the EEA-team can vary but the design, market, purchase and management divisions should be represented. The examination should be led by somebody who has a thorough knowledge of the environment besides being very well informed about the products and product development of the company. The result of the environmental analysis is that a number of considerable environmental impacts, caused by the product, are pointed out. Based on the result, different corrective and preventive actions are suggested. One such action could be: Alter types of materials used.

When the suggested actions are carried out, a follow-up analysis is made. The environmental impacts are re-evaluated in order to check that actions introduced have given positive results, i.e. that they will lower the total environmental impact. The follow-up is carried out by the same EEA-team that has been used from the start.

The last step in the process is documentation. The documentation is important in order to be able to communicate the results and to simplify the EEA work in the next product development project.

To give the EEA a good chance of influencing the product development, it should be carried out in an early phase of the development project. Figure 9, shows a schematic diagram of a product development project, where the EEA is made right after the specification of requirements. In that way it is possible for the EEA to influence the detailed technical specification of the project requirements.

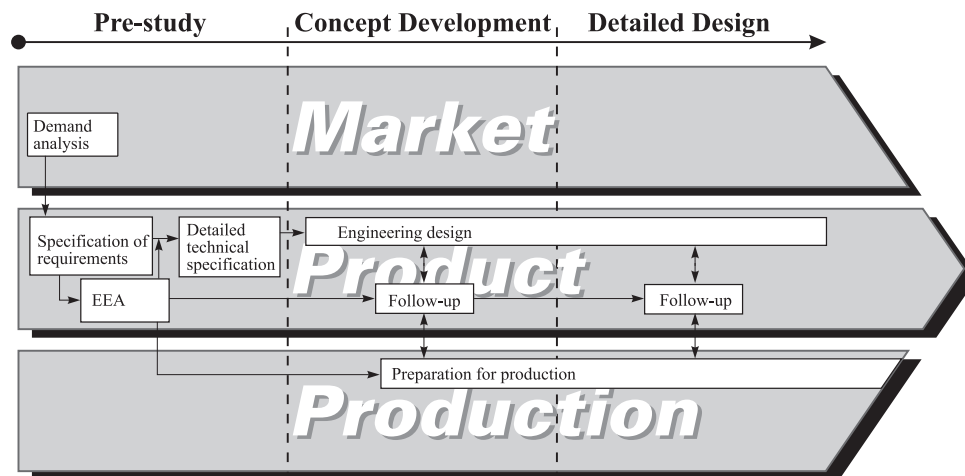


Figure 9. Schematic picture of a product development project where the EEA is planned right after the introductory technical/environmental specification of requirements.

2.4. EEA-forms

When an EEA is performed, a special form is used. Figure 10 shows an example of an EEA-form. The form may vary somewhat, depending on the type of evaluation that will be made and on the specific user needs. The form is divided into four different parts; the form heading, the inventory part, the valuation part and the action part, Figure 11.

The form is a tool to obtain the systematics, which is one of the greatest advantages of the EEA-method. The form also works as a medium of documentation, of great importance for the follow-up and evaluation of an EEA. A short description of the different parts of the form and how to fill them in follows below.

2.4.1. The form heading

The function of the form heading is to facilitate the future identification of the performed environmental analysis. Some companies have special demands and needs and it is therefore necessary to introduce changes and additions at times.

Figure 10. An example of an EEA-form.

Figure 10. An example of an EEA-form.

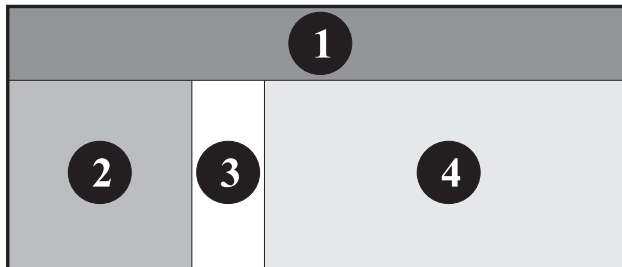


Figure 11. An EEA-form contains four parts; the form heading (1), the inventory part (2), the valuation part (3) and the actions part (4).

2.4.2. The inventory part

The inventory part contains two main areas, Life-cycle and Environmental Characteristics (Figure 12), within which you document the environmental analysis, Section 2.9.

Inventory			
Life-cycle		Environmental Characteristics	
No.	Life-cycle Phase	Activity	Environmental Effect / Aspect

Figure 12. The inventory part of the EEA-form.

2.4.2.1. Life-cycle

Number – One serial number for each activity, for the purpose of facilitating the identification during future work with the analysis.

Life-cycle Phase – Here the different life-cycle phases of the product are identified. Thereafter, information on which life-cycle phase the current activity belongs to is filled in. The choice of phases of the life-cycle depends on the limitations made and the extent of the EEA. The most common way to divide the phases of the life-cycle is:

- Purchase/Acquisition (I)
- Production (T)
- Use (A)
- End-of-life treatment (R)

Sometimes it can be advantageous to make a more detailed division of the phases of a life-cycle than above. One reason is to show in greater detail in what part of the life-cycle the most important effects with respect to environmental impact arise.

Another reason could be that the number of identified activities with related environmental effects is so large that it is difficult to discriminate between them. Especially for an outsider, / understanding could be facilitated by means of a more detailed division.

2.4.2.2. Environmental Characteristics

The next step in filling in the EEA-form is the Environmental Characteristics. This means identifying the environmental effects of each activity.

Activity – The life-cycle may be divided into different activities i.e. parts where something is performed or happens and where environmental impact is caused. Thus, for every step of the product's life-cycle the activities related to the environment should be identified.

Environmental Effect/Aspect – This refers to external and/or internal influences on the environment, caused by a human activity.

- Consumption of resources such as energy, materials, water and land.
- Discharges into the air, water and land.
- Generation of waste and by-products (hazardous and dangerous wastes and other waste according to the environmental legislation).

2.4.3. The evaluation part

When the inventory part is filled in, the next step is to evaluate and rank the effects with regard to their environmental significance. There are a number of different evaluation methods and available variations, see chapter 3. The main principle for most of the methods is to evaluate the different environmental effects based on various parameters. Controlling documents, public image, emission amounts, improvement possibilities and possibilities for employee influence are examples of parameters.

The evaluation part results in a list of what are known as *hot spots*, that is, those activities with the most significant environmental impact.

2.4.4. The action part

With the help of the evaluation part, those activities that should and can be measured are identified. In the action part different kinds of recommendations are

listed and decisions made, which in turn are analysed again to make sure that environmental improvement is achieved. Below follows a short description of the different columns in the actions part (Figure 13).

Actions		Valuation				Realization	
Proposals for Action							
Recommended Actions	Environmental Effect / Aspect	S	I	O	EPN / F	Remarks	Responsible

Figure 13. The actions part of the EEA-form.

2.4.4.1. Proposals for Action

Recommended Actions – Based on the evaluation part, adequate actions are suggested in order to eliminate or reduce the environmental effect.

2.4.4.2. Evaluation

In order to ensure that the recommended actions result in environmental improvements, they are evaluated once again.

2.4.4.3. Realization

Remarks – Remarks, references and comments, for example, a reference to suitable time for decision regarding a certain action or reference to a special document.

Identification of responsibility – Identification of the person or division within the company that is in charge of the action and responsible for its accomplishment.

2.5. Flow chart for performance of an EEA

An EEA is performed according to the principal structure in Figure 14. The structure shown, and especially all its feedback arrows, should not be interpreted too literally. EEA is an iterative process and in reality there is always feedback. Figure 14 only shows the main and most common feedback.

2.6. Goal and scope definition

The systems that are being examined are in general very complex. That is why it is so important to identify the goal of the analysis very early. Based on the goal, it is possible to define the right system boundaries. If this is not done early there is a

risk of examining wrong aspects of the system which will result in a low quality or a misleading analysis.

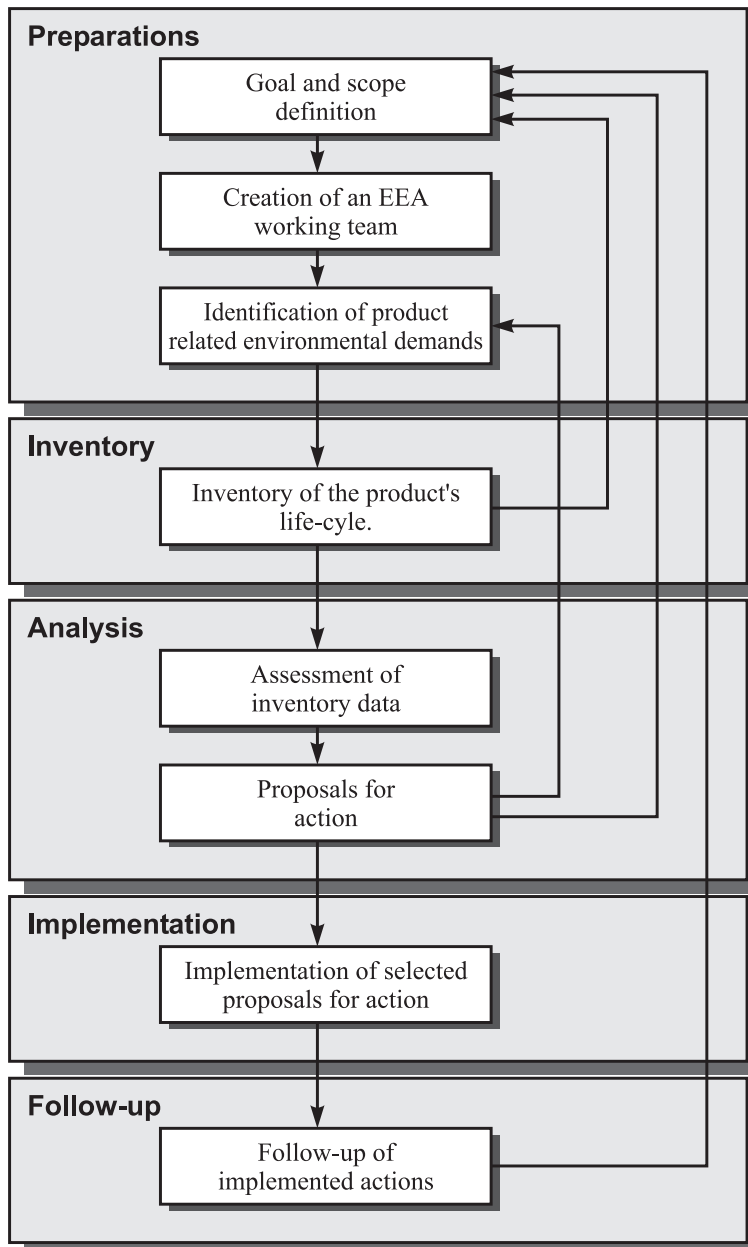


Figure 14. The EEA methodology flow chart.

2.6.1. Goal definition

The initial questions to be answered are why the analysis is performed and what purpose it serves. It is not until you know this that you can choose the right method of analysis. Unfortunately, however, it is common that the method of analysis is chosen before these questions are answered, which generally results in a poor result both with respect to quality, time and cost.

Let us assume, for example, that the purpose of the analysis is to determine the environmental impact of a new product in the product development process. At the start of the analysis there is no quantitative data on the product available. All that exists is a concept describing a solution to the product's function. To use a quantitative method in this case is seldom meaningful. When there is enough quantitative data to do the analysis properly it will generally be too late to obtain significant environmental improvements. Instead a qualitative method that gives results promptly should be implemented in the product development process.

The goal definition might have to be changed during the analysis. New information can result in altered conditions. To simplify the definition of an EEA-study a list of adequate questions that ought to be answered is given below.

- What is to be examined and why?
- What function(s) does the examined product system/systems fulfil?
- What requirements concerning collected data have to be fulfilled in order to fulfil the goal of the analysis?
- What assumptions and limitations have to be introduced?
- What resources, regarding time, money and personnel are allocated for the analysis?
- How are the results to be presented, which are the target groups?

2.6.1.1. Function

One fundamental condition for the right of a product system to exist is that it offers at least one function. The demand for different functions in society changes constantly. It is this never-ending demand process that stimulates the development of new products all the time.

Define the function of the product system

In an EEA, it is advantageous to identify the function of the current product system. In product development, both new and further development, it is always important to keep the function up-to-date. There is always a possibility that the chosen concept can be replaced by a better one.

The definition of the function should be made as short as possible and should be known by all personnel taking an active part in the analysis. A product system can have many functions, hence it is important to choose the most relevant for the analysis. Some examples of functions are: A hygienic customer package for a litre of milk, storage of 1200 mAh, storage of 1 Mb data.

Comparison between two products regarding function

It is not possible to compare the function of two different products using an EEA. The qualitative characteristics of the method means that there are no parameters that enable you to make a comparison between the products.

2.6.1.2. System boundaries

To define system boundaries and thereby demarcate the analysis is crucial for success. A product system is usually a very complex system containing both main processes as well as sub-processes¹⁰ which in turn may contain sub-processes and so on. If all these processes were to be included in the analysis, it would be endless and impossible to accomplish. Besides this, the importance of each sub-process decreases as they come further and further away from the main processes.

The definition of system boundaries is an iterative process and mostly it is not possible to exactly determine them already from the start. Below examples of the most common system boundaries are given.

- **Other natural systems** – Where is the start and the end of the life-cycle of the examined product system? A common starting point is usually some sort of extraction of raw material from nature. Examples of natural systems are storage resources¹¹ and flowing resources¹². What you define as the origin of the examined product system depends on what you want to examine.
- **Life-cycles of other product systems** – Different production systems are usually connected to each other in a very complex network and with a very large geographic distribution. One example is when a machine/process is used for production of more than just the examined

¹⁰ Processes that are subordinated to another process.

¹¹ Finite natural resources being stored in the earth's crust, for example fossil fuels and ores. The new production/The supply is so limited that it in principle is zero with regard to the human perspective.

¹² Flowing resources are created all the time and have generally the sun as their primary energy source. Examples of flowing resources are water- and wind energy, wood and wheat.

product, for example an oil refinery producing a number of different petrochemical products through one and the same process. In the analysis, it is therefore important to separate different life-cycles without making the result misleading.

- **Geographical** – Different components in a product system can, for example, be produced in different parts of the world, with varying infrastructure, production of electricity, waste disposal etc. The ecological capacity to assimilate pollution also varies between different geographical areas. It is therefore important to identify the geographical areas within which the product system is located and being used.
- **Time** – The life-cycles of different product systems have different lengths, which causes problems. If the product system has a very long life-cycle, it will in general be more complicated to estimate how the product system should be handled in the end-of-life treatment. The techniques of the end-of-life treatment that we have today might be replaced by improved techniques when it is time for the product system to be taken care of.
- **Production capital** – Production capital is for example the necessary means of production such as buildings, machines, vehicles and roads. Generally they are not included, since they do not influence the environmental effects of the product system in a crucial way.
- **Personnel** – to handle a product system requires people who have to eat, be transported and have a place to sleep etc. These activities cause some form of environmental impact, although this is generally not included in the analysis.

2.6.2. Quality demands for data

The quality of data in an EEA is very important for the relevance and reliability of the study. Compared with, for example, a Life-Cycle Assessment (LCA), the EEA-method makes no quantitative but only qualitative demands on the data.

In order to secure the data quality, it is important to document the sources and characteristics of the data used during the study. The characteristics of the data should above all cover:

- Time related aspects (How old is the data, is it still valid?)
- Geographical aspects (For what geographical area is the data valid, local, regional, national, regional or global?)
- Technical aspects (What is the status of the techniques used?)
- Specific/General aspects (Is the data being used specific or average?)

2.7. The EEA-team

In an EEA it is important to obtain knowledge from the entire life-cycle of the examined product system and this is one reason for establishing a broad EEA working team. The composition of the EEA-team should be multifunctional, which means that it should contain people with knowledge that covers as much as possible of the life-cycle. The number of team members should, according to experience, be around eight, all with different functions.

The participants in the team represent, with their knowledge, different functions of the team. The division of functions is not strict, it has to be adjusted to the situation, for example;

- One person may represent one or many functions, this is common in small and medium sized enterprises.
- One function is shared between two or many people, this is common when working with very complex products.

Below is a list of a number of different functions that should be represented in the team:

2.7.1.1. Co-ordinator

Assignment: Prepare and lead the EEA.

Qualifications: Should have experience of leading and structuring work and meetings. Have a thorough knowledge of environmental issues in general and of the company's Environmental Management System (EMS), environmental goal and internal environmental requirements in particular. Furthermore, the person should be well informed on the current and expected requirements and legislation of the authorities and how to find environmental information. Finally, the person should be familiar with the product development of the company.

Function: Usually the person is responsible for, or a co-ordinator of, environmental issues.

2.7.1.2. Project leader

Assignment: It is the project leader who plans the EEA as a part of the product development project and is the one convening the EEA-meetings. The person has the function of assisting the co-ordinator during the preparations and decides, together with the co-ordinator, which people/functions / should be a part of the team.

Qualifications: Have a thorough knowledge of the product planning and product development of the company.

Function: He/she is usually the project manager for the current product development project.

2.7.1.3. Purchaser

Assignment: An expert on the components suppliers needed in the product system.

Qualifications: Have a thorough knowledge of the suppliers' products, for example regarding materials, consumption of energy, issues and production waste. Also have knowledge of the environmental profile and the practical work of the suppliers. It is also important that the person has knowledge of the different ways of transportation being used by the supplier when transporting the components from the supplier to the company.

Function: An experienced purchaser.

2.7.1.4. Designer

Assignment: An expert in the design and materials selection for the product system.

Qualifications: Should be a technical expert on the current product system and have a thorough knowledge of the technical design, function and materials of the product and potential alternative technical solutions/concepts and materials.

Function: An experienced designer.

2.7.1.5. Production technician

Assignment: Expert on the production of the product system.

Qualifications: Should have a thorough knowledge of, for example, consumption of energy and chemicals, emissions and waste for the production process within the company.

Function: An experienced production technician.

2.7.1.6. Marketing controller

Assignment: Expert on customer demands and needs and the distribution of the product to the customer.

Qualifications: Should have a good knowledge in general of the present and future customer demands of the market. The person should also have knowledge of the distribution system to the customer and the means of transportation being used.

Function: An experienced seller.

2.7.1.7. Service technician

Assignment: An expert on the use phase of the product system.

Qualifications: Should have good knowledge of the installation, use, service/repairs, upgrading etc of the product system and the consumption of energy and materials, emissions and waste related to it. Knowledge of why products are finally rejected is also important.

Function: An experienced service technician.

2.7.1.8. End-of-life treater

Assignment: An expert in rejected product systems.

Qualifications: Should be wellinformed about how different types of products are treated during the end-of-life phase and the consumption of energy and materials, emissions and waste related to it. Furthermore what the recycled material/energy is used for.

Function: It is in general unusual that a company has an employee with this experience. In order to obtain their knowledge, it can be useful to co-operate with an established enterprise in the end-of-life treatment business. An alternative could be a service technician within the company, or from a company servicing the current product.

2.8. Identification of product related environmental demands

The identification of product related environmental demands is a very important and sometimes difficult part of the EEA. It can be hard to be certain that you have addressed the right demands. In order to simplify and clarify the identification of the environmental demands of the product system, you usually divide them into three groups, based on who makes them:

- Authority demands
- Market demands
- Internal demands

2.8.1. Authority demands

In this context, the environmentally-related demands of the authorities are defined in a wider perspective. Besides laws and decrees, authority demands also include requirements from other national and international committees/delegations in the environmental field. The demands of the authorities can in a simplified way be divided into two types, absolute and future requirements.

2.8.1.1. Absolute requirements

Absolute requirements are those laws, decrees, roles and recommendations that must be obeyed. The absolute requirements can be seen as the minimum level at which all businesses/organisations must maintain themselves. If it turns out that any of the requirements are not fulfilled, the company/organisation will be forced to make immediate improvements.

2.8.1.2. Future requirements

These requirements need not be met immediately but it is usually advantageous for the company to fulfil them nevertheless. By fulfilling the requirements already today, the company gains a lead over the competition compared to those companies who wait until the demands become absolute.

The laws, and decrees that have been decided upon but have not yet come into force also fall into the category of future requirements. So do other different recommendations/requirements from national and international committees / delegations.

2.8.2. Market demands

The ability to read the demands of the present and future market is usually seen as the most important indicator of whether a company is, or will be, successful. The more demands and functions the product system can fulfil, the better the

acceptance by the market. The market demand regarding the environment in general has its basis in the use phase.

The market interest in environmental improvements varies, but the interest has grown during the past decade. The interest in, and importance of, the environmental requirements also varies geographically. The markets where the environmental requirements are of most importance today (year 2000) are the northern European and American markets. The interest in other industrialised countries varies. The knowledge of, and the willingness to pay for, environmental improvements are lower in the developing countries, since they generally can't afford to give priority to the environment.

Although the market interest in environmental improvements varies, it does not mean that improvements shouldn't be considered. Experience from actual product development shows that it is enough if just a small part of the market starts to make demands in order to make the rest of the market follow. An example is the introduction of new environmentally improved washing powders and toilet papers.

A common market demand is that the used products should be recyclable. This influences the selection of materials to be used in the product. A material that doesn't have a recycling system might not be useful, even though it might be the best when it comes to fulfilling the function. Some larger enterprises, for example Volvo and Saab, have black-listed materials and demand that they are avoided in the products they make.

A more and more common demand is that materials and components that contain dangerous substances should be labeled. The purpose of this is to secure and simplify an environmentally correct end-of-life treatment of the materials/components.

2.8.3. Internal demands

The internal demands are made by the company/organisation itself. The most common source of the internal demands is usually the environmental management system (EMS) of the company/organisation. The EMS is introduced based on an environmental policy decided by the management. The policy describes how the company/organisation views the environment and how the product systems should be formed in order to minimise the environmental impact.

The EMS also contains a number of environmental goals and they also have their basis in the environmental policy of the company/organisation.

The internal demands can, with the right management approach, in some cases become the demands of the market and thereby give the company/organisation a strong advantage over the competition. A somewhat simplified example of this is the change from chlorine as a bleaching agent in the paper industry to bleaching with other methods. When one of the paper mills started to use a new method it didn't take long before the customers demanded chlorine-free paper.

2.8.4. Examples of environmental demands

Before doing an EEA it is important to analyse one's own product system and identify, for example, the existing authority demands. It is important not to use a standardised list because there is a big risk of missing out on new requirements.

The environmental demands which are effective for the product system are put together from the experience and knowledge of the EEA-team. Examples are presented in table 1, 2 and 3 below.

Table 1. Examples of demands of the authorities that can be made on a product.

• Description of consisting substances	• Emissions/waste from use
• Emissions/waste from end-of-life treatment	• Producer responsibility at end-of-life treatment
• Packing	• Environmental labelling/description
• Emissions/waste from production	• The product's energy consumption
• Regulated substances in the production	• Regulated substances in the product

Table 2. Examples of internal demands that can be made on a product.

• Environmental policy	• Standards, norms, guidelines
• Maximum consumption of substances/ energy during use	• Environmental goal, proposals for action
• Environmental labelling/description	

Table 3. Examples of demands of the market that can be made on a product.

• Description of consisting substances	• Emissions/waste from production
• Emissions/waste from use	• Internal EMS
• Packing	• Length of time/upgradeability
• Emissions/waste from end-of-life treatment	• Hazardous substances in the end of life treatment
• Hazardous substances in the production	• Performance of environmentally related standards
• Maximum consumption of substances/ energy during use	• Environmental labelling/description

2.9. Inventory

Generally the inventory is the most time-consuming part of an EEA. The aim of the inventory is to identify and document the life-cycle of the product system and relevant inputs and outputs.

The inventory is carried out by the EEA-team. It is important that everybody involved brings the necessary information at the time of inventory. The inventory contains two parts:

- A flow chart for the product system is drawn from the defined system boundaries.
- Data, such as the need of raw materials and energy, discharges and waste production, is connected to the different phases of the life-cycle and reported in the EEA-form.

2.9.1. Flow chart

The first step is to make an inventory of the materials and processes needed in order to obtain the function of the system. From this a flow chart is drawn for the product system.

Figure 15 show an example of a flow chart for the production of a lead battery. The boxes in the figure represent the different life-cycles (processes) of the product system.

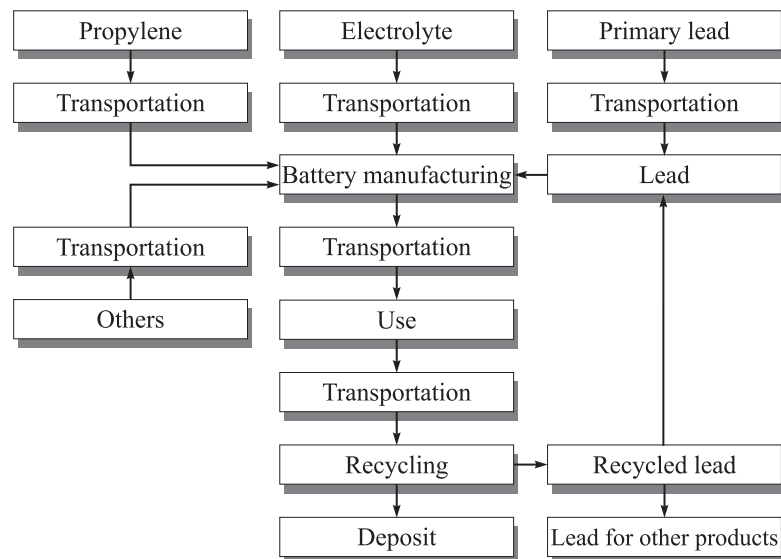


Figure 15. An example of a simplified flow chart for a lead battery.

2.9.2. Collection of data relating to the processes

Information regarding for example consumption of energy and material, waste and discharges is connected to the different phases of the life-cycle in the collection of data. It is advantageous if there is quantitative data, but this is not necessary. The data is reported in the EEA-form.

2.9.3. Sources of data

Besides the competence within the EEA-team, it is usually necessary to turn to other sources of information. It is not possible to state that some sources are better than others, it depends on the knowledge that is being looked for. When using sources of information, high reliability is very important as well as a thorough documentation.

2.10. Assessment of inventory data

When the inventory is completed the next step is to make an evaluation with the object of trying to decide what activities cause the most important environmental impacts and if it is possible to alter any life-cycles.

The assessment is made by the EEA-team and the results are reported in the EEA-form. There are a number of different evaluation methods available.

Usually the valuation results in a number of *hot spots*. The EEA-team decides which environmental effects should be considered as *hot spots*. It might be that an activity causing only a small environmental influence still gets considered as a *hot spot* because the environmental impact can easily be reduced.

When making the assessment it is important to observe and try to estimate the uncertainties in the data used. Besides the uncertainty of data quality, there are also uncertainties in the fact that limitations and assumptions have been made. Furthermore, there are uncertainties in the results depending on the method of evaluation that has been used.

The results obtained by an EEA give a rough picture of the reality. This is a general problem when working with methods of environmental analysis and also, for example, life cycle assessments, using quantified and more extensive data.

2.11. Proposals for action

The work to find proposals for action is led by the EEA-team but not necessarily carried out by them. The person in charge of the product development, in cooperation with the production development group, submits a number of proposals for action. The EEA-team evaluates the proposals according to the same method as the one used for the assessment of data and then finally decides what proposals to choose.

When working with the proposals for action it is advantageous to try to link several *hot spots* together with the aim of taking action against more than one at the same time. One example is to decrease the weight of an active product and thereby decrease the consumption of energy during transportation.

2.12. Implementation

The implementation phase is the most important phase. Too often, the obtained results are not implemented but are left in different files.

The responsibility for the implementation stays with the project leader but a good thing to do is to divide the responsibility for different actions. In the implementation, it is important to document possible problems if they arise.

2.13. Follow-up of the results

When the product development project is completed, it is important that a follow-up of the result of the EEA-study is made. The EEA-coordinator is usually responsible for the follow-up. It is important that the follow-up covers all types of experiences, not forgetting the experiences from the implementation of the proposed actions.

2.14. Reporting

In order to gain continuity and structure, an EEA has to be reported appropriately. How this documentation is made depends on the needs and the structure of the company. It can be either physical or digital. The advantage of digital documentation is that the information becomes more easily accessible. Important in all documentation is, however, the transparency, that is, that an outsider should be able to see how the work has been carried out and thereby be able to form his or her own opinion regarding the results of the analysis.

An EEA should contain:

- Identification of the product system examined.
- Information on the limitations of the analysis and estimates made regarding the product system and its life-cycle.
- Decisions regarding actions, the responsible person for each measure and when it is to be accomplished.
- A follow-up date for the environmental analysis.
- The EEA-form

3

Methods of evaluation for EEA

The evaluation is done with the aim of finding what is significant from different perspectives, in order to be able to concentrate the resources for solving these problems. A number of different methods are used today for the judging of environmental effects. Some of them are presented in this chapter. The methods work well and less well depending on what they are used for. It is too soon to recommend any method in particular. Further research and evaluation is needed. The oldest and most documented method of today is the SIO 1-3.

When judging environmental effects, according to the following methods of evaluation, it is important to know that everything starts out from normal operations in the production, normal use and normal final disposal of the product. Accidents and abnormal conditions in the operation are not taken into consideration.

Generally in environmental analysis a number of different environmentally-related parameters are examined, all with different units and amounts and with different environmental influence. Examples of parameters are emissions of carbon dioxide, nitric oxide and consumption of iron ore. In order to be able to handle, compare and communicate all the different values, some sort of valuation is necessary. In the valuation the different parameters are put in relation to each other in order to increase the understanding of the whole.

All forms of environmental evaluation involve some sort of subjective judgement. The methods are usually criticised because they don't make it possible to compare things that differ greatly from each other. The different parameters have to be handled and judged separately which leads to a situation where the different results will be very complex to evaluate and hard to understand. Therefore you have to make some sort of evaluation in order to obtain an understandable and communicative result.

3.1. The SIO 1-3 method

The SIO 1-3 method was developed by HRM/Ritline AB in Gothenburg, Sweden, and is the most frequently used method of today. It was the first method to be used for EEA and it is the basis of many of the other methods of evaluation.

The evaluation is done by grading the following criteria:

- Controlling documents (S)
- Public image (I)
- Environmental consequences (O)

These criteria are graded from one point to the maximum of three points. Adding these numbers forms the EPN-number. EPN stands for Environmental Priority Number, which is the indicator of how serious the environmental problem is.

$$EPN = S + I + O \quad (\text{Maximum} = 9)$$

The column EPN/F on the EEA-form also includes a criterion called F, improvement possibility, which focuses on the effort in time, cost and technical possibility needed to environmentally improve a product or a part of a product.

The result is put into a system of co-ordinates, Figure 16, where the EPN-number is presented on the X axis and the possibility of improvement on the Y axis (the scale on the Y axis goes from one to nine, one representing small possibilities of improvement and nine very large possibilities). The system of co-ordinates is used to facilitate the interpretation of the result and as guidance for the proposal for action.

3.1.1. Controlling documents (S)

The controlling documents start out from the external legal requirements. They can also include the internal demands found in the environmental policy of the company.

- 1 p) No requirements, environmental policy or law cover the referred environmental effect.
- 2 p) The environmental effect will, in the near future, be regulated either by law, managing documents or an environmental policy of the company itself.
- 3 p) The environmental effect is regulated by law or managing documents and/or runs against the environmental policy of the company.

3.1.2. Public image (I)

Independent of the size of the environmental influence of the company or its products, the public have their opinions. The public image of the company is an important parameter since the reputation of a company is very easily damaged.

- 1 p) Has no negative influence on the environmental reputation of the company.
- 2 p) Has no direct negative influence on the environmental reputation of the company but might affect the public opinion indirectly.
- 3 p) Has serious negative effects on the public opinion of the environmental reputation of the company.

3.1.3. Environmental consequences (O)

When evaluating the extent of the environmental consequences, the EEA-team has to agree upon how different objects are to be valued. Local versus global environmental effects, which of the categories of environmental influence are the most and least important ones and so on. The EEA-team also has to decide what is to be considered large and small.

- 1 p) No negative environmental influence lies within the field for which the EEA-team has the competence to judge.
- 2 p) Negative environmental influence is short-term and the probability for recovery is good, or of long duration but of less importance.
- 3 p) Negative environmental influence is of the kind, degree and extent that might cause long-term or permanent damage to the environment.

3.1.4. Improvement possibility (F)

Naturally the possibility of improvement depends on a number of different factors, some of them are available techniques, cost and time.

- 1 p) No improvement possibility.
- 2-3 p) Small improvement possibility.
- 4-6 p) Some improvement possibility.
- 7-8 p) Large improvement possibility.
- 9 p) Very large improvement possibility.

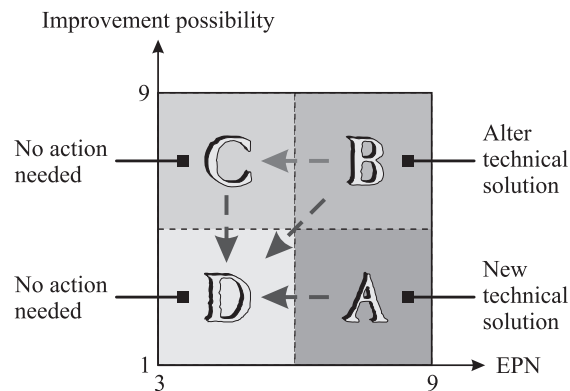


Figure 16. The matrix of valuation for the SIO 1-3 method.

3.1.5. Interpretation of the result from the system of co-ordinates

The system of co-ordinates is used to facilitate the interpretation of the result and as guidance. By filling in the valued environmental effects in the matrix (Figure 16) and studying their proportion, it becomes easier to find the *hot spots*.

The matrix is divided into four squares. These squares should not be seen as definite, the dividing lines can vary. The different squares stand for:

- A The activity and its environmental effect have a high EPN-value and the possibilities of improvement, that is to lessen the environmental effect of the activity, are small. You should change the technical solution or choose another concept so that the activity is changed or the environmental effects are reduced.
- B The activity and its environmental effect has a high EPN-value but also great possibilities of improvement. The activity or concept can be retained but you should carry out the improvements.
- C The activity and its environmental effect has a low EPN-value and great possibilities of improvement. No actions are required.
- D The activity and its environmental effect has a low EPN-value and the possibilities of improvement are small. No actions are required.

Depending on where the evaluated activities and their environmental effect end up in the matrix the EEA-team decides on which activities they are to work on and the necessary actions. A basic rule when selecting the hot spots is to strive for the left part of the system of co-ordinates and then work towards the left lower corner of the matrix. You should start in square A and work your way anti-clockwise to finally end up in square D.

3.2. SIO 1-9 method

SIO 1-9 is a variant of the SIO 1-3 method. This method gives a wider range and a more fair and accurate division. Controlling documents (S) have only the values of 1, 5 and 9 since there are, will be, or are not, any managing documents.

3.2.1. Controlling documents (S)

- 1 p) No requirements, environmental policy or law cover the referred environmental effect.
- 5 p) The environmental effect will, in the near future, be regulated either by law, managing documents or an environmental policy of the company itself.
- 9 p) Regulated by law or managing documents and/or runs against the environmental policy of the company.

3.2.2. Public image (I)

- 1-3 p) Has no negative influence on the environmental reputation of the company.
- 4-6 p) Has no direct negative influence on the environmental reputation of the company but might affect the opinion of the public indirectly.
- 7-9 p) Has serious negative effects on the public opinion of the environmental reputation of the company.

3.2.3. Environmental consequences (O)

- 1-3 p) No negative environmental influence lies within the field for which the EEA-team has the competence to judge.
- 4-6 p) Negative environmental influence is short-term and the probability for recovery is good; or of long duration but of less importance.
- 7-9 p) Negative environmental influence is of the kind, degree and extent that might cause long-term or permanent damage to the environment.

3.2.4. Improvement possibility (F)

- 1 p) No improvement possibility.
- 2-3 p) Small improvement possibility.
- 4-6 p) Some improvement possibility.
- 7-8 p) Large improvement possibility.
- 9 p) Very large improvement possibility.

Adding these numbers forms the EPN, Environmental Priority Number. The result is put into a system of co-ordinates (Figure 16) where the EPN-number is presented on the X axis and the possibility of improvement on the Y axis. The evaluation is done in the same way as with the SIO 1-3 method.

3.3. SIO 1-3 and SIO 1-9, The multiplier

If the values are multiplied instead of added together as they are in the SIO 1-3 and SIO 1-9 methods there will be two other variants of the SIO-method. Looking at it mathematically there is a certain difference. Assuming that, according to the usual SIO-method, there is a series of values with the sum of six. This gives many different possible series of values, for example $2 + 2 + 2$ or $1 + 2 + 3$. When multiplying these series the answers will be eight and six. The multiplier gives a wider range of the EPN-numbers. Apart from this, the same criteria are used for the valuation of the improvement possibility. The result is handled and evaluated in the same way as in the SIO 1-3 method.

3.4. The KEE-method

The KEE-method was developed by Mattias Lindahl, University of Kalmar and Carsten Jensen, HRM/Ritline AB. The method is divided into three parts where product-related environmental demands, ecology and improvement impossibilities are taken into consideration. This is the only method that takes into consideration the modification cost. Demands and ecology are compared with the modification cost and the possibilities of improvement.

3.4.1. Part 1 - Environmental demands

The demands (K) come from:

- Customers (k)
- Internal (i)
- Authorities (l)
- The public (a)

The customer demands (k) can adopt the values 0, 1 and 2.

- 0 p) No customer demands.
- 1 p) No knowledge of customer demands.
- 2 p) There are, or will be, customer demands.

Customer demands are, for example, consumption of energy or the weight of a product.

Internal demands (*i*) can adopt the values 0 and 1.

- 0 p) No internal demands.
- 1 p) There are, or will be, internal demands.

Internal demands are, for example, the policy of the company or production technology.

Authority demands (*l*) can adopt the values 0 and 1.

- 0 p) No legal demands.
- 1 p) There are, or will be, legal demands.

Legal demands are, for example, requirements of the product or the production site.

Public demands (*a*) can adopt the values 0, 1 and 2.

- 0 p) There are no public demands.
- 1 p) No knowledge of public demands.
- 2 p) There are, or will be, public demands.

Public demands are the demands made by environmental organisations and other concerned interested parties. It also includes the public image of the company in the environmental considerations.

The demands are added and then multiplied by 2, this is to gain balance in regard to the part of ecology where the maximum value is 9.

$$K = (k + i + l + a) \cdot 2 \quad (\text{Maximum} = 12)$$

3.4.2. Part 2 – Ecology

Ecology (*E*) consists of:

- Quantity (*m*)
- Seriousness (*s*)

Quantity and seriousness can adopt the values 1, 2 or 3.

Quantity

- 1 p) Insignificant quantity *or* Insufficient knowledge of the quantity.
- 2 p) Certain quantity *or* Nothing to compare or relate to.
- 3 p) Dominating quantity.

The judging of Quantity (m) has only been done on a few articles since it requires great knowledge of the production. When the knowledge is insufficient it is given the value 1, so that it will not influence the calculation.

Seriousness

- 1 p) Does not have a detrimental effect on people's health, disturb the ecological multiplicity or waste environmental resources.
- 2 p) Does either have a detrimental effect on people's health, disturb the ecological multiplicity or waste environmental resources.
- 3 p) Does have a detrimental effect on people's health, disturb the ecological multiplicity and waste environmental resources.

Multiplying these values forms E . The EPN-number is obtained by adding K and E .

$$E = m \cdot s \quad (\text{Maximum} = 9)$$

$$EPN = K + E \quad (\text{Maximum} = 21)$$

3.4.3. Part 3 – Improvement possibility

The possibility of improvement (F) consists of:

- Modification cost (k_f)
- Improvement possibility (p)

The modification cost and the improvement possibility can adopt the values 1, 2 and 3.

Modification cost (k_f)

- 1 p) The financial investment is high in comparison to the expected environmental improvement.
- 2 p) The financial investment is in proportion to the expected environmental improvement.
- 3 p) The financial investment is low in comparison to the expected environmental improvement.

Improvement possibility (p)

- 1 p) No or very small improvement possibility.
- 2 p) Certain improvement possibility.
- 3 p) Large or very large improvement possibility.

Multiply the values to obtain F .

$$F = kf \cdot p \quad (\text{Maximum} = 9)$$

The result is put into a system of co-ordinates (Figure 17) where the EPN-number is presented on the X axis and the possibility of improvement on the Y axis.

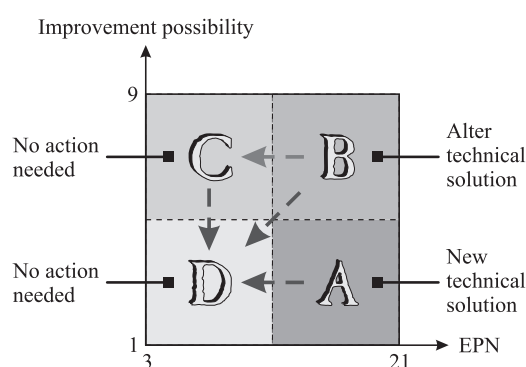


Figure 17. The matrix of valuation for the KEE-method.

3.5. The ULF-method

The ULF-method was developed by Herman Lindström and Christoffer Löfberg¹³. It is based on an evaluation system for environmental effects used for analysis of present situations or environmental investigations. It focuses on the environmental effects from a biological point of view and does not take public opinion into consideration. The evaluation is done by grading these parameters:

Scope.....	<i>Local</i>	(L).....	0,1,3
	<i>Regional</i>	(R).....	0,2,4
	<i>Global</i>	(G).....	0,3,5
Seriousness.....	(A).....		1,3,5
Risk of effect on the biosphere	(B).....		1,3,5
Range of time	(O).....		1,4,6
Quantity.....	(M).....		0,1,2,3

¹³ Lindström, H., Löfberg, C. (1999), Analys av EEA metoden som hjälpmedel för miljöanpassad produktutveckling, Institutionen för teknik, Högskolan i Kalmar. In Swedish only. (Free rendering: Analysis of the EEA-method as a tool in the environmentally adapted production development)

3.5.1. Extent**Local level:**

- 0 p) The environmental effect is small or non-existent.
- 1 p) There are certain environmental effects.
- 3 p) The environmental effect is substantial.

The effect of the environmental problem is totally dependent on the location of the source of the discharge. Examples are local air pollution from ground level ozone in cities and metal discharge in air and ground from smelting plants¹⁴.

Regional level:

- 0 p) The environmental effect is small or non-existent.
- 2 p) There are certain environmental effects.
- 4 p) The environmental effect is substantial.

The effect of the environmental problem is observed at a place other than the location of the source of the discharge. An example is the acidification in the Nordic countries, which is largely due to the discharge from England, Poland and others¹⁵.

Global level:

- 0 p) The environmental effect is small or non-existent.
- 3 p) There are certain environmental effects.
- 5 p) The environmental effect is substantial.

The effect of the environmental problem is not dependent on the location of the source of the discharge. Examples are the depletion of the ozone layer and the increased concentrations of greenhouse gases¹⁶.

The difference in the numbers of the values between the different levels is due to the fact that environmental influence on a global level is worse than influence on a regional level and influence on a regional level is worse than on a local level.

¹⁴ Brännlund, R., Krström, B. (1998) Miljöekonomi, Studentlitteratur, ISBN 91-44004745. In Swedish only. (Free rendering: Environmental economics)

¹⁵ Warfvinge, P.(1998) Miljökemi, KFS AB, ISBN 91-88558-18-5. In Swedish only. (Free rendering: Environmental chemistry)

3.5.2. Seriousness

- 1 p) Does not have a detrimental effect on people's health, disturb the ecological multiplicity or waste environmental resources.
- 2 p) Does have a detrimental effect on people's health, disturb the ecological multiplicity *or* waste environmental resources.
- 3 p) Does have a detrimental effect on people's health, disturb the ecological multiplicity *and* waste environmental resources.

In the evaluation the method has as its starting point the overarching environmental objectives for acceptable environmental influence of the Swedish government¹⁶.

3.5.3. Risk of effect on the biosphere

- 1 p) Only if there is an accident.
- 3 p) Small risk of permanent influence on the biosphere.
- 5 p) Large risk of permanent influence on the biosphere.

3.5.4. Range of time

- 1 p) The influence on the biosphere is presumed to remain for a short period of time (<30 years).
- 4 p) The influence on the biosphere is presumed to remain for an average period of time (30-200 years).
- 6 p) The influence on the biosphere is presumed to remain for a long period of time (>200 years).

The evaluation is among other things based on the different chemical speeds of turnover in the atmosphere¹⁶.

3.5.5. Quantity

The quantity can adopt the values 0, 1, 2 and 3. They are used for ranking order of the same environmental effect arising from different activities. For example: consumption of electricity arises at both assembly and welding. To obtain the EPN-number you add up all the parameters.

$$EPN = L + R + G + A + B + O + M \quad (Maximum = 31)$$

¹⁶ Warfvinge, P. (1998) Miljökemi, Tabell 2.4, sid 28, KFS AB, ISBN 91-88558-18-5. In Swedish only. (Free rendering: Environmental chemistry, Table 2.4)

3.5.6. Improvement possibility (F)

- 1 p) No improvement possibility.
- 2-3 p) Small improvement possibility.
- 4-6 p) Some improvement possibility.
- 7-8 p) Large improvement possibility.
- 9 p) Very large improvement possibility.

The result is put into a system of co-ordinates (Figure 18) where the EPN-number is presented on the X axis and the possibility of improvement on the Y axis. The evaluation is done in the same way as with the SIO 1-3 method.

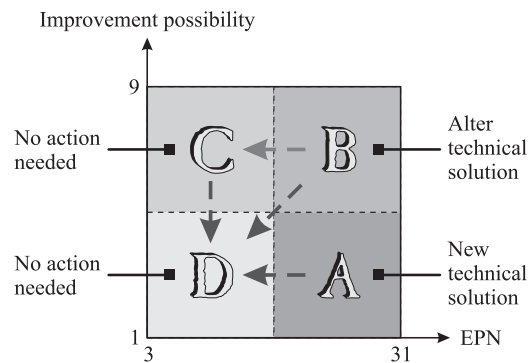


Figure 18. The matrix of valuation for the ULF-method.

3.6. IVF method

The IVF-method¹⁷ was developed by the Swedish Institute of Production Engineering Research (IVF). The method is based on the evaluation of the criteria; Demand/Desire, Quantity/Relative amount and Control/Possibilities of influence. The parameters can adopt the values 1-10 although some companies find it easier to use only the values 3-5. If there isn't sufficient information for an evaluation of one of the criteria it should be marked with a question mark (?), signaling that the matter should be investigated further. If the EEA-team can't agree on a value a rule of thumb is to always choose the higher value.

¹⁷ Magnusson, T., Franzén, B. (1999), Miljöeffektanalys – ett hjälpmedel vid miljöanpassad produktutveckling, Sveriges Verkstadsindustrier, Industrilitteratur AB, Stockholm. In Swedish only. (Free rendering: Environmental effect analysis – a tool for DfE)

3.6.1. Demand/Desire (k/ö)

This is where the importance of the demands coming from the authorities, the market and the company itself are evaluated.

- 1 p) All the present and expected demands/desires fulfilled.
- 2-3 p) Expected desires not fulfilled.
- 4-6 p) Present desires not fulfilled.
- 7-9 p) Strong present desires and expected demands not fulfilled; affects the image of the company.
- 10 p) Absolute demands not fulfilled.

3.6.2. Quantity/Relative amount (k/m)

This criterion shows the extent of the current environmental effect in comparison to other relevant comparable objects. Since it is a relative valuation, the EEA-team has to find a similar object to compare the current environmental effect with in order to be able to grade the quantity of the effect.

- 1 p) Insignificant quantity.
- 2-3 p) Small quantity.
- 4-6 p) Certain quantity.
- 7-9 p) Large quantity.
- 10 p) Dominating quantity.

3.6.3. Control/Influence possibility (k/p)

The Control/Influence possibility is evaluated according to the possibility to influence the activity in such way that reduces the environmental influence.

- 1 p) No possibility of influence.
- 2-3 p) Small possibility of influence.
- 4-6 p) Some possibility of influence.
- 7-9 p) Large possibility of influence.
- 10 p) Very large possibility of influence.

Multiplying all the values forms the Priority Number (PN).

$$PN = (K / \ddot{O}) \cdot (K / M) \cdot (K / P) \quad (\text{Maximum} = 1000)$$

The higher the priority number, the more urgent the need to take action. Observe that a high priority number is not necessarily synonymous with serious environmental influence. A high number can also reflect businesslike or practical considerations (demands from different interested parties, competitive advantages etc.) When doing a study of a product you should decide upon a maximum level allowed before any action is taken. Furthermore, you should take note if any of the parameters get the value 10, even if the total value is below the maximum level allowed. Action, if the maximum level is passed, can be to change the product, the design or the system it moves within.

4

Exercise

This exercise is about getting to know the EEA-method. It should be carried out in groups of three to five people. A paintbrush, perforator or telephone etc. can be used as objects for analysis.

1. Describe the scope and limitation of the analysis.
2. Fill in the EEA-form.
3. Identify the need of action for substantial environmental effects.

Discuss also the pros and cons of the method as far as time allows. Observe that this is an exercise and thereby has its limitations. The multifunctional aspect of the composition of the EEA-team is left out.

TOOLS

It is easier if the chosen object is a physical and touchable product. Follow the method of work described in chapter 2.

ENVIRONMENTAL ANALYSIS REQUIREMENTS

Start out from the requirements and desires below and do further supplements depending on chosen product.

- Heavy metals must not occur (cadmium, chromium, quicksilver etc.)
- All plastic details shall be labelled if there is room
- 25% of the plastic has to be recycled
- Maximum 5% of the weight can be landfilled
- Weight should be optimised

PRODUCT FACTS

If there is uncertainty about the product facts, assume that:

- The plastic details are made by moulded PP or PA
- Any colour/varnish has a solvent base
- Polished surfaces are often chromed
- Sheet and metal details can be recycled if they are easily separated
- No plastic material can be recycled today

WHAT THE RESULT AND PRESENTATION SHOULD CONTAIN

The result of the EEA-team should contain the following:

- The scope and limitations of the analysis
- The environmental requirements used in the analysis
- Identified activities and environmental effects (the filled-in EEA-form)
- Evaluation of substantial environmental effects
- Proposals of improvements for the substantial environmental effects
- Experienced pros and cons of the method

5

Definitions

Concept	Definitions
Activity	An activity is an event or phase where one or many environmental effects occur.
Waste	All output ending up in end-of-life treatment.
Data category	Defined flow of substance or energy such as discharge in air: carbon dioxide, lead. Discharge in water: lead _(aq) , Material resource: lead ore, Energy resource: electrical power.
Diffuse discharge	Uncontrolled discharge in soil, water and air.
Elementary flow	(1) material or energy brought into the studied system, being brought from the surroundings without any previous human alteration. (2) material or energy brought out of the studied system, being brought back to the surroundings without any succeeding human alteration.
Emission	Discharge of substance or energy into the environment.
Unit process	The smallest unit in a product system for which data is collected when doing an EEA.
Flow chart	A graphic description of the studied system in the shape of a process tree. All processes and flows should be marked on flow chart.
Input	Material and energy entering a unit process.
Inventory analysis	The phase of the life-cycle assessment containing the listing of inputs and outputs of a given product system during its entire life-cycle.
Life-cycle	All phases of a product system, from raw material acquisition or generation of natural resources to the final disposal.
Life-cycle phase	A stage in the life-cycle of a product system.
Environmental aspect / Environmental effect	External and / or internal influences on the environment, caused by a human activity.
Environmental impact	Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an environmental effect.
Product system	A collection of material- or energy-like coherent unit processes, together carrying out one, or many, functions.

System boundary	Boundary line between a product system and the surroundings or other products systems.
Transparency	Open, overarching and understandable presentation of information.
Output	Material and energy leaving a unit process.

Appendix

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Appendix 1

EEA-forms

- FORMS FOR THE SIO-METHOD
- FORMS FOR THE KEE-METHOD
- FORMS FOR THE IVF-METHOD
- FORMS FOR THE ULF-METHOD

[illegible]

[illegible]

Environmental Effect Analysis - EEA [The IVF-Method]																
Part Name		Part Number		Drawing Number		Function		Date		Issue						
Project		Supplier		Info				Follow-up Date		Page No.						
EEA Leader		EEA Participants														
Inventory Life-cycle	No.	Life-cycle Phase	Environmental Characteristics		Valuation				Actions				Valuation		Realization	
			Activity	Environmental Effect / Aspect	K / O	K / M	K / P	PN	Proposals for Action Recommended Actions	Environmental Effect / Aspect	K / O	K / M	K / P	PN	Remarks	Responsible

[illegible]

Appendix 2

Suboptimisation

Suboptimisation is to optimise one or many sublevels in a process without considering the total performance of the process. Avoiding suboptimisation means that the performance of the different sublevels might decrease while the total performance of the system increases. Suboptimisation is quite common and easily occurs in complex, difficult-to-grasp systems. Suboptimisation should be avoided.

Viewing a product from a life-cycle perspective reduces the risk of suboptimisation. Assume that a product has been surveyed and its environmental impact during the entire life-cycle has been identified and assessed. For the simplicity of the matter, the product has been divided into three parts; production, use and end-of-life treatment (Figure 19).

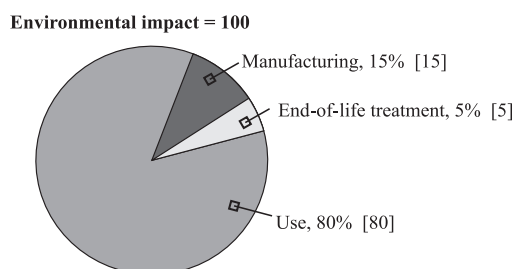


Figure 19. The area of the circle represents the total, assessed impact of the product during its life-cycle. In this example the assessed environmental impact is assumed to be 100.

Assume that the manufacturer does not know this yet and, according to the traditional way of viewing environmental problems, tries to decrease the discharge from the production. By changing the production process and altering materials the manufacturer manages to decrease the environmental impact to 12. The altered materials lead to consequences which result in the total environmental impact of the product's entire life-cycle increasing from 100 to 120 (Figure 20). For the company however, this might seem like an improvement, since the relative and actual environmental impact during the production process has decreased. The impression is that the company has done something good for the environment.

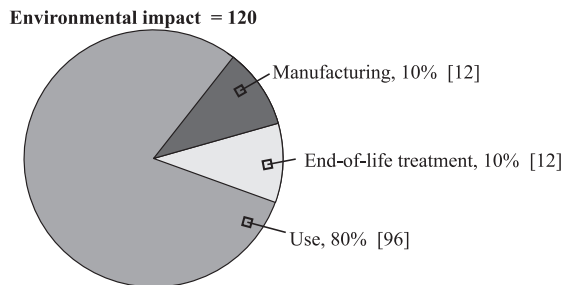


Figure 20. The environmental improvements in the production lead to consequences during use and end-of-life treatment which results in an increase to 120 of the area representing the environmental impact.

If the company on the other hand uses a life-cycle perspective and works for the decrease of the total, rather than their own, environmental impact, then the situation could be as described in Figure 21.

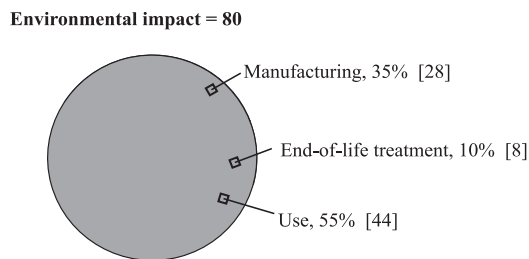


Figure 21. The environmental improvements result in the total environmental impact decreasing to 80 while the part of production increases to 28 or in relative terms 35 %.

For the company, in this example, there will be an increased environmental impact. However, the product as a whole now causes a smaller environmental impact than before. This is an optimisation on the basis of the total system and it has decreased the total environmental impact of the product during its entire life-cycle.



A growing knowledge of the connection between products and environmental problems has resulted in an increasing interest in these issues, from both businesses and the public, during the last ten years. To reduce the effects on the environment they try to apply an holistic perspective to the products, i.e. regard the entire life-cycle of the product.

It is the early phase of the product development that, to the greatest extent, determines the total environmental effect of a product. It is therefore important that the environmental aspects are taken into consideration in this critical phase so that the effects on the environment can be reduced.

This book presents Environment Effect Analysis (EEA), which is a qualitative method for Design for Environment, DfE. The method is designed for use in the early phases of product development. The advantages with the EEA method are that it is easy to learn, relatively fast to carry out and results in suggestions for concrete environmental improvements.

The authors are Ph.D. Students in Eco-design at the Department of Technology, University of Kalmar. The book have been economical supported by the Swedish Business Development Agency - NUTEK.

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