CHAINET Definition Document

Final version

European Network on Chain Analysis for Environmental Decision Support

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Preface

CHAINET is a Concerted Action in the EU Environment and Climate programme (ENV4-CT97-0477). CHAINET started in December 1997 and has a duration of 2 years. The tasks of this Concerted Action are to set up a network linking environmental stakeholders in three fields of human activity (referred to as "cases") with experts on different environmental analytical tools, and to interactively write a guidebook on the use of these different tools. The guidebook will provide a toolbox for chain analysis, linking demand for environmental information with supply of relevant information. In addition it will give information on the application of the toolbox in three different cases, indicating specific directions for design and development. These tasks will be achieved through the organisation of meetings (network meetings, preparatory meetings and workshops), the establishment of a homepage on the internet and the production of reports in collaboration with CHAINET members.

The network is open to all interested parties. The overall coordination of CHAINET activities is being undertaken by CML, Leiden University (Nicoline Wrisberg). CHAINET has a Board with members from eight different European institutes:

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1. Introduction

1.1 Background

European policy has committed itself to the goal of sustainable development. Following this commitment, the European Union has placed its activities within a framework of environmental controls based on the best knowledge available at any particular moment in time. This includes a continuing movement away from an 'end-of-pipe' philosophy of environmental protection (one which, in any case, tended merely to shift problems from one environmental issue to another or from one societal sector to another), towards a new paradigm in which environmental considerations encompass the whole material and energy supply chain and consider the full social and economic structure. This has profound implications for both government and business.

Innovation and investment in new cleaner technologies will play a pivotal role in sustainable development. However, we now recognise that moving towards sustainability requires the redesign of entire systems of production, consumption and waste management in order to avoid shifting of problems[1] as often occurs with isolated measures; so the aim is not just the piecemeal improvements of separate parts. In particular, both smaller and larger improvements need to be placed in a systems perspective that specifically takes into account indirect effects in the chains of production and consumption involved. This chain perspective brings in to view the net effects on a system as a whole. *Chain analysis* aims to determine the overall environmental effects of any specific change to a particular system, as a chain or network of human activities, e.g. processes related to a substance, a product, a company or a region. It is necessary in order to avoid shifting of problems and to provide insights into improvement options and the managerial steps that are necessary to achieve them.

The present European Community programme of policy and action on environment and sustainable development identifies many of the elements needed for this chain perspective. However, a recent review of this programme recognised a number of areas that are still lacking, including a pragmatic, operational set of tools to assist chain analysis.

Decision-making in environmental management requires the assessment of a complex set of issues. It is an evolving art, given the dynamics of socio-political factors and our developing understanding of ecosystems. Within this context, a large number of *tools* have either been specifically developed or adapted from other decision contexts, as aids to public and private sector environmental management strategies and operations. The more commonly recognised methodologies include Cost Benefit Analysis (CBA); Cost Effectiveness Analysis (CEA); Material Flow Accounting (MFA); Life Cycle Assessment (LCA); Risk Assessment (RA); physical and financial input output analysis (IOA). Further aids to decision making, such as Multi Criteria Analysis (MCA), may be applied.

Each methodology has its own specific characteristics and is more or less suited to address particular environment-related issues. The choice of the approach depends on, inter alia, the physical object under study, the scope of the decision problem, its definition in space and time,

[1] e.g. shifting emissions to other times, locations, media, environmental problems,

the availability of data on environmental impacts, and the uncertainty associated with the estimation of the costs and benefits. However, it is not clear for which problems a specific tool is the most appropriate, or whether more than one tool should be applied, especially in determining the net overall effects of any given decision. At the same time no single tool can depict all sorts of ‘problem shifting’. This situation hampers the use of tools as a support to decision making and could result in the use of an incomplete or inappropriate analysis, with the ultimate risk of drawing the wrong conclusions.

1.2 Goals of CHAINET

CHAINET has three general goals:

1. To link the different scientific tool communities and stakeholders, with respect to the following tasks:
    - the fostering of communication between environmental scientists and stakeholders;
    - the joint identification of environmental problems in the three cases;
    - the collection and exchange of experiences and insights present within the European scientific, industrial and public sector communities.
2. To link demand for environmental information with supply of relevant information, with respect to the following tasks:
    - the establishment of common data needs and common strategies for data gathering and data exchange;
    - the establishment of a toolbox for specific decision contexts;
    - the identification of areas which demand a simplification of tools, combination of tools, or further development of tools;
    - the determination of the factors leading to effective use of environmental chain analysis tools as a driving force for product design and technological development, and for policy support.
3. To investigate how tools can be applied in three different cases - the supply, use and waste management chain for automobiles, for consumer electronic goods and for domestic clothes washing - indicating specific directions for design and development, through:
    - a description of the state-of-the-art results from existing environmental analyses;
    - a focus on relevant tools for the analysis of environmental impacts in the three cases;
    - the formulation of guidelines regarding the application of chain analysis tools for these cases and, when possible, to make further generalisations on the application of these tools in the decision-making process;
    - the formulation of tool assisted research and development programmes in the areas concerned.

The first goal requires a *communication network* for environmental tools. The last two goals are to be delivered in a *guidebook* on environmental analytical tools for decision support in design and comparison. The last two goals will also generate priorities for research and development, with special reference to the EC fifth framework programme.

This guidebook will include a catalogue of tools for environmental improvement and will assist the decision maker in identifying the right tool for the right decision context. The decision maker may be any stakeholder - from consumers, governmental bodies to business - who may consider environmental aspects in decision making. Its focus will be on environmental improvement options within a product chain. The guidebook will be widely disseminated to decision makers in the public sector, however, it will be primarily targeted at businesses. The guidebook will be of special interest for the different stakeholders in the supply, use and waste management chain for automobiles, consumer electronics, and domestic clothes washing.

Box 1 gives an overview of the content of the guidebook, which will consist of two parts. The first part will contain a general methodological overview including guidelines for when to use specific tools or combination of these tools; the so-called *toolbox*. This part will aim to determine the strengths and weaknesses of using particular tools in specific circumstances, and to identify the research needs in order to iron out the most important uncertainties associated with any particular methodology.

The second part of the guidebook will illustrate the toolbox by way of -the three cases noted above, addressing their complete supply, use and waste management chains. The cases will focus on the relevant combinations of tools for the particular problems arising in each chain.

The network for environmental tools will be developed throughout the two year duration of CHAINET. At the end of this period a proposal will be made for how to set up a more permanent organisation within the research community for the development of environmental decision support tools.

1.3 The aim of this Document

The aim of this Definition Document is to specify the subjects and tasks of the CHAINET programme. In particular, it identifies and defines the cases to be addressed and the tools to be investigated; and it also sets out the planning and goals of meetings and workshops. Comments on an earlier draft received from CHAINET members at the inaugural meeting in Windsor May 26, or subsequently in written form, have been incorporated into the text. The Document serves as a standard framework for the case-specific working groups, including case reports and workshops.

Section 2 describes the context, concepts and characteristics of the toolbox. Section 3 outlines the cases and the core questions that each working group has to address. Section 4 describes the organisational structure of CHAINET. Finally, Section 5 provides a timetable associated with each phase of the work programme and outlines the final outputs of the project.

Guidebook

Part 1

1. Introduction:
   description of decision making processes.
2. Demands for environmental information:
   characterisation of general decision situations and the related requirements for tools in terms of methodology, data and applicability.
3. Supply of environmental information:
   environmental information in decision making processes: analytical tools, procedural tools, including communication and management aspects.
4. Description of tools:
   short description of analytical tools, their methodology, data and applicability characteristics, and combination possibilities.
5. Guidelines for use of chain tools:
   linking demand for environmental information with supply of this information.
6. Success factors:
   identification of success factors for using tools and recommendations for overcoming barriers related to their use.
7. Research needs:
   related to tools for environmental decision support, including needs for simplification of tools and development of new tools.

Part 2

1. The supply, use and waste management chain of automobiles:
   - state-of-the-art - environmental problems in the chain
   - state-of-the-art - dealing with the problems (which tools to use)
   - directions for product design and technological development
   - research needs
2. The supply, use and waste management chain of consumer electronic goods:
   - state-of-the-art - environmental problems in the chain
   - state-of-the-art - dealing with the problems (which tools to use)
   - directions for product design and technological development
   - research needs
3. The supply, use and waste management chain of domestic clothes washing:
   - state-of-the-art - environmental problems in the chain
   - state-of-the-art - dealing with the problems (which tools to use)
   - directions for product design and technological development
   - research needs

Box 1: Content of the Guidebook

2. Demand and supply of environmental information

This chapter provides the framework for the toolbox for chain analysis in support of sustainable development.

2.1 Introduction

As mentioned in the introduction, European policy has committed itself to the goal of sustainable development, which requires a paradigm shift in *governments, industry* and *households*. It requires changing attitudes, responsible environmental management and innovation of new technologies, services and products. Several mechanisms can contribute to sustainable production, consumption and waste management:

- For a given basket of production, consumption and waste management activities, **environmental management**, e.g. improved housekeeping or better location choices, can substantially reduce the environmental burdens.
- For a given type of production, the environmental burdens be can substantially reduced by choosing the right **technologies**.
- For a given type of consumption, the environmental burdens be can substantially reduced by choosing the right **product** or **service** to supply the consumption function desired and the right technologies for production and waste management of this product.
- For a given budget to spend, the environmental burdens can be substantially reduced by the choice of **life style**/consumption pattern, e.g., by traveling less and spending the income thus saved on culture and sport instead.

Decisions related to production and consumption are mainly guided by considerations of private welfare, within a number of constraints set by public environmental policy. Within the private sector choices on environmental management, technology and product development are first of all, the decision domain of industry, while choices related to product purchasing and life styles are the domain of consumers. Public bodies may take decisions influencing each of the four mechanisms. However, so far environmental policy has to a large extent been directed at end-of-the-pipe technologies and on zoning regulations. Thus, in actual decisions in the economy - on locations, on budget spending and on technologies, - environmental considerations have up to now played only a rather limited role. Substantial environmental improvements can only be realised if such decisions are based on relevant information about the environmental consequences they may have. Thus, adverse environmental effects thus can be prevented before they have occurred, shifting from end-of-pipe measures to integrated measures.

However, as indicated in Figure 1, for a decision making process aiming at the overall goal of sustainable development for human societies, environmental information has to be integrated with economic, social and technological aspects. Explicit goals, targets and actions will be needed to meet the overall aim of sustainable development. It should be noted that this is not the subject of CHAINET. CHAINET is concerned with environmental assessment tools, as an aid to decision-making, providing information to guide the directions for meeting the goals and targets. CHAINET will focus on the overlap of the scientific circle of the diagram with the two other circles, which mean that the natural science based tools considered need to be compatible with technology, social and economic aspects in order to promote sustainable development.

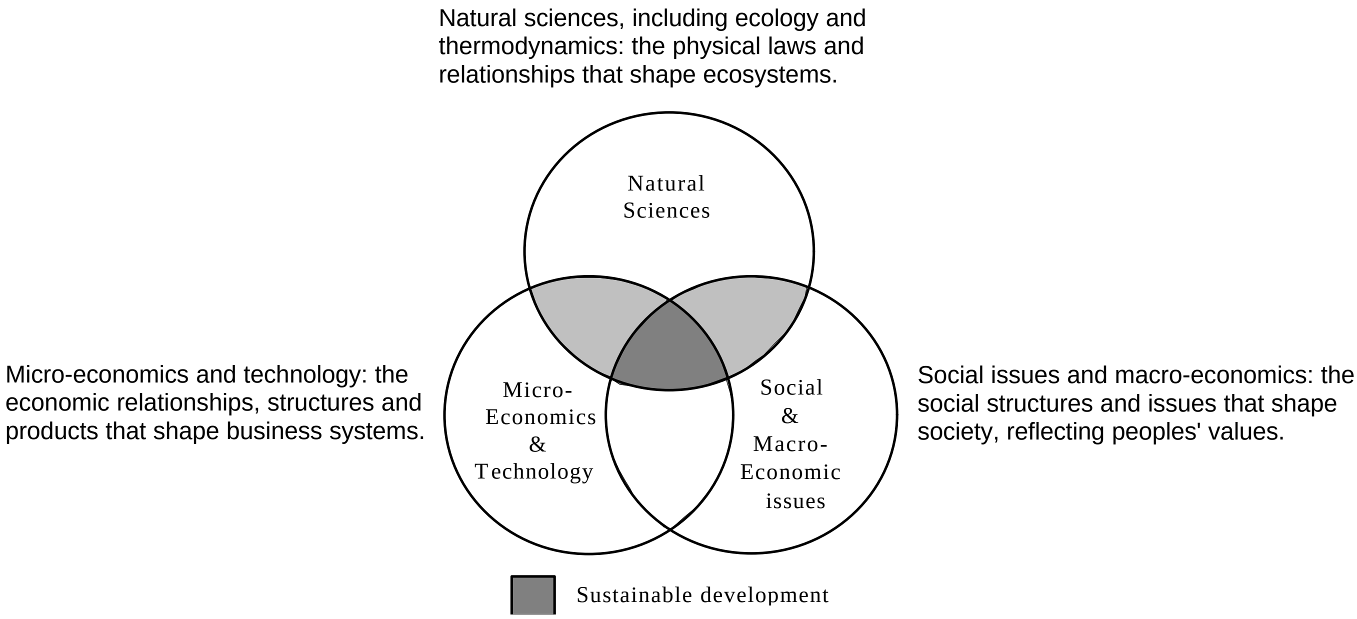
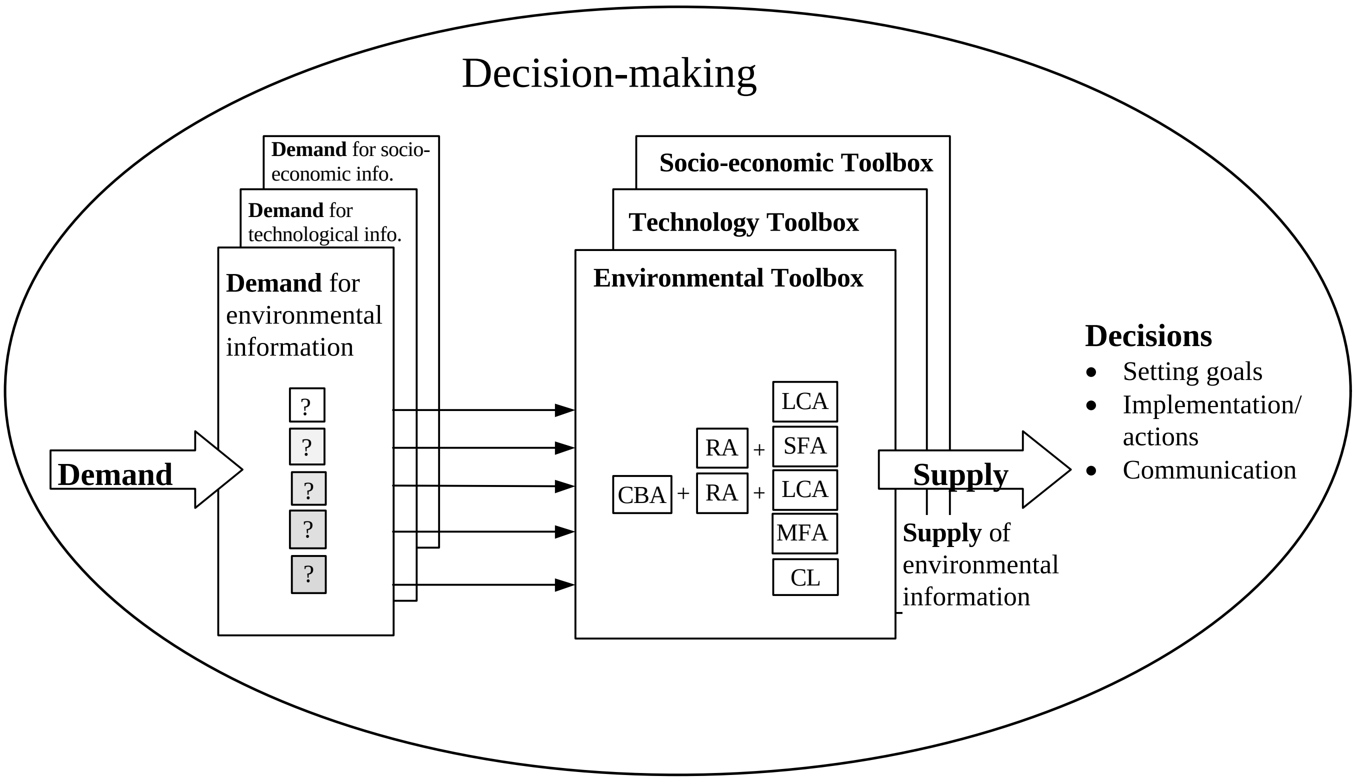


Figure 1: An interdisciplinary framework for decision-making as described by the LCANET working group on Positioning and Application of LCA. Adapted afterCowell et al. (1997).

The supply of tools and concepts providing environmental information for decision making support is both large and diverse. Developments have taken place independently of each other; driven largely from the information supply side. However, in a decision oriented approach, distinct demands for environmental information accord with the different decision contexts. CHAINET will link the *demand for environmental information* with the *supply of environmental information (via the relevant tools*). Figure 2 shows how different demands for information will be linked with different supplies of information to be used to support decision making, including the formulation of goals, their implementation and communication

The basic idea is that a certain demand for environmental information, characterised by the decision maker and the type of question, implies a specific requirement for tools both in terms of methodology and applicability. The toolbox will be established by specifying the requirements related to different demands for environmental information, and by examining how these can be met by the supply of a certain tool or combination of tools. Thus, the demand for environmental information will be characterised by the type of decision maker and the type of question whilst the supply of tools will be specified according to their characteristics with respect to methodology, data and applicability.



LCA: Life Cycle Assessment, RA: Risk Assessment, SFA: Substance Flow Analysis,
CBA: Cost-Benefit Analysis, MFA: Material Flow Accounting, CL: Check List

Figure 2: The role of an environmental toolbox in decision making.

2.2 Demand for environmental information

The type of environmental information required for supporting decision-making differs according to the context in which decisions are made. The demand for environmental information can be characterised by the *stakeholders* involved in the decision making, their *motives* and the *type of decision that need to be made*.

2.2.1 Stakeholders and their motives

In the LCANET Concerted Action, the working definition of a *Stakeholder* was *an individual or group with a legitimate interest in the decision*, (Udo de Haes and Wrisberg, 1997, p.44). Possible stakeholders were identified, classified broadly as: *governments and regulators* (supra-national, national and local); *consumers*; *industrial operators*, *suppliers* and *sub-contractors*; *neighbours*; *investors*; *NGOs*; *employers* and t*rade unions*. In CHAINET, with its focus on tools for assessing the environmental implications of human activities, the interest is in identifying the “toolbox” which can provide the environmental information needed by all stakeholders to assist them in making a particular decision.

The nature and extent of the environmental information depends on the level of interest of the stakeholders and the strategic level of the decision. A broad distinction can be made between the following levels of interest, as summarised in Table 1:

- compliance with legislation and making agreements between parties (environmental legislation, covenants, international treaties),
- market oriented considerations (green consumerism, competitive advantage, pressure from customers),
- pro-active economic considerations (waste reduction, cost effectiveness, anticipation of future policy measures, environmental liability),
- ecological/societal considerations (aiming at sustainable development).

For the business community the levels can be translated into a company's environmental strategy. Fava et al. (1998) propose a comparable structure of five levels of environmental strategy indicated in appendix 3.

Levels of interest	Demand for environmental information from government	Demand for environmental information from business	Demand for environmental information from NGO's and consumers
Compliance with legislation ↓	• Compliance with regulation • Environmental impact/risk of a substance/activity	• Environmental impact/risk of a substance/activity • Compliance with regulation	• Compliance with regulation • Environmental impact/risk of substance/activity
Market oriented considerations ↓	• Green procurement	• Marketing • Green procurement • Communication with other stakeholders	• Green procurement
Pro-active economic considerations ↓	• Development of waste management policy • Development of transport policy • Comparison of eco-efficiency of take-back systems	• Comparison of substances/ products/technologies/activities • Comparison of production at location A with production at location B • Development of substances/ products/technologies • Comparison of eco-efficiency of take-back systems	• Comparison of products/activities, e.g. reusable versus one-way? • Energy saving strategies
Ecological/ societal considerations	• Development of environmental substance/ product/activity related environmental policy • Factor 4/10 improvements	• Strategic planning • Factor 4/10 improvements	• Choosing life styles • Contribution to sustainability

Table 1: Examples of demands for environmental information.

As shown in Table 1, different stakeholders may have the same demand for environmental information. However, they may still have different requirements with respect to the supply of environmental information. This has to do with stakeholders different perceptions of what is important; the stakeholder's concerns and preferences. These in turn relate to his/her view on nature/ecological systems and his/her attitude to decision making, risk and justice. Various typologies of stakeholder views have been suggested by different social scientists. The Cultural Theory (e.g. Douglas and Wildavsky, 1982; Schwarz and Thompson, 1990; Earl et al., 1997) distinguishes between four different stakeholder views, see appendix 4. This theory has already been used to explain and interpret societal changes, politics, attitudes towards technology, risk perception, and it has also been drawn upon to improve risk management Hofstetter (forthcoming). It may also be used to understand differences in requirements towards environmental tools.

2.2.2 Types of decision questions

The type of *question* may be specified according to the following dimensions (explained further below):

- **Design of new systems versus a comparison of existing systems,**
- **Decision subject**,
- **Level of improvements**.

Design versus a comparison of existing systems. Directions for environmental improvements can be achieved by:

- guidance as to the direction of **design**, e.g. design and development of new products and technologies, and
- an assessment of the environmental effects of an object as **compared** to the current situation or to alternatives, e.g., comparison of the environmental burden of production at location A with production at location B, or a comparison of different ways of providing a given function.

Decision subject. The subject of the decision may be a material, process, product, technology, activity, lifestyle or infrastructure. Environmental improvement may take place at different levels of aggregation, ranging from a small scale improvement (as in, for example, redesign of a simple product), to a large scale improvement of a specific technology or infrastructure.

Level of improvement. The level of improvement is related to the levels of interest, understanding and resource availability. For a given decision subject environmental improvements may take place by small steps or by large changes, and the environmental information required differs accordingly. Different levels in environmental improvement have been suggested, such as (according to Stevels, 1997):

- Level 1: Incremental improvement, which will result in improvements in the order of 5-10%;
- Level 2: Complete redesign of existing concepts, which will result in improvements up-to 30-50%;
- Level 3: Alternative fulfilment of functionality, which may result in improvements of up to 50-75%;

- Level 4: Change of functionality, which may result in more than 75% (factor 4) improvements.

These levels of improvement are a combination of technical innovation and social and institutional innovation. The higher levels of design require changes in society, (as indicated in Table 3), and require the engagement of multiple stakeholders.
The Table also indicates the link to the time horizon. The optimisation of existing systems concerns decisions with a short-term horizon, while the change of product systems and improvements to existing technologies concern decisions over a medium-term horizon. Fundamental changes of several technologies or concepts pertain to long term decisions.

The different levels of improvements also require different types of information. Level 1 may require operational information and may be easily implemented in a company. Level 4 requires strategic information and may require interaction with numerous stakeholders in the chain in order to be implemented. This distinction between *operational versus strategic* information is directly related to the tools required: the data (on existing processes but also on new technologies), and the way these are modeled (linear versus non-linear; static versus evolving steady state or dynamic). Decisions concerning the short-term require operational information, while long-term planning requires strategic knowledge. Operational information describes small changes of small scale systems with a short time horizon. Strategic information refers to large and possibly qualitative changes of large scale systems with long time horizons.

Level of improve-ment	Goal	Example	Time horizon	Change of consumer lifestyle	Infra-structure change
level 1	Incremental improvements	current better TV	0-2 years	-	-
level 2	Redesign of existing concepts “green limits”	"green TV"	0-5 years	+	-
level 3	Alternative fulfilment of functionality	LCD TV	0-10 years	+++	+++
level 4	Sustainability	?	0-30 years	++++	++++

Table 3. Levels of Improvement after Stevels, 1997 and Stevels and van der Wel, 1998.

2.3 Supply of Environmental Information

The characteristics for the demand for environmental information have been described in section 2.2. This section concerns the supply of environmental information for decision support in the form of environmental analysis. The information from an environmental analysis, together with information on technology and on social and economic aspects, will be used to support decision making (see Figure 3). This is an interactive process where the results from one analysis can lead to the demand for more information.

A relevant distinction between concepts and tools has been made by the LCANET working on Positioning and Application of LCA (Cowell et al., 1997). *Concepts* are defined as an idea on how to achieve sustainability, such as life cycle thinking, design for the environment, and cleaner technology. *Tools*, on the other hand, are operational methods supporting the concepts. Tools can be further categorised according to their focus as *analytical tools*, when the focus is on computational algorithms or checklists aiming at finding a better decision; or as *procedural tools* when the focus is on procedures to guide the best way to reach a decision.

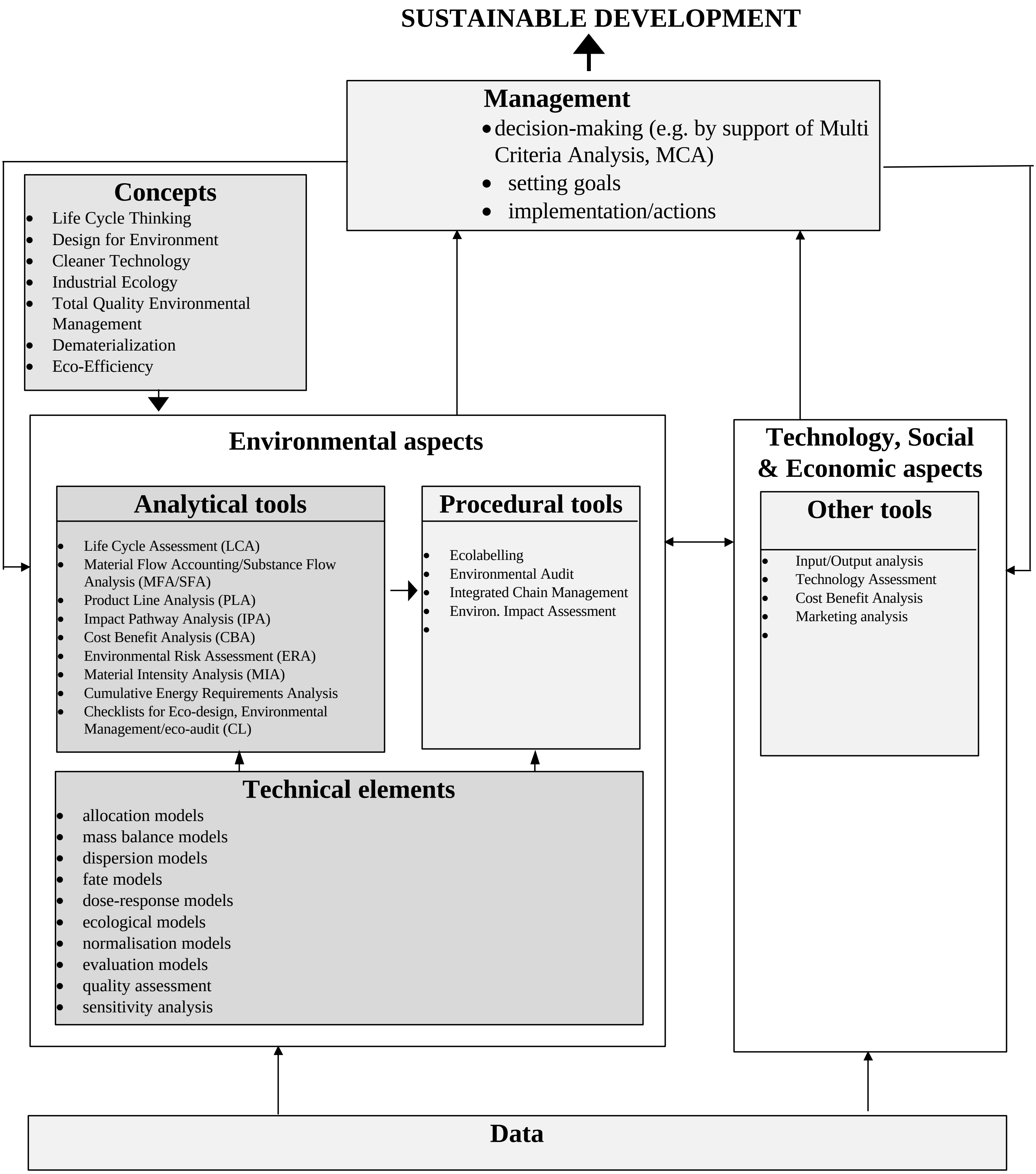


Figure 3: The relation between concepts, analytical tools, procedural tools, technical elements, data and other elements in the decision making process.

Procedural tools consist of decision procedures in which an analytical tool may be used. For instance, Risk Assessment may be used in Environmental Impact Assessment and Life Cycle Assessment may be used in eco-labelling.

In addition, *technical elements* can be distinguished as methods of obtaining data, data processing and of presenting information. Examples include material balances, dispersion modeling and dose-response models. A technical element may supply information to a variety of tools, and any one tool may require information from more than one technical element. The relationship between concepts, tools, technical elements and data and their relation to the decision process is indicated in Figure 3. CHAINET will focus primarily on *analytical tools, on technical elements and on data*. Appendix 2 provides a short description of some of the tools to be addressed in CHAINET.

The question as to whether one tool or a combination of tools is suitable for a certain demand for environmental information, depends upon the supply side's technical characteristics as well as the applicability of the tools. The following sections consider the characteristics of analytical tools with respect to their methodology, data and applicability for decision support, as well as their compatibility.

2.3.1 Technical characteristics of analytical tools

The analytical tools which will be considered in CHAINET are shown in Figure 3. These may be characterised according to the following dimensions, partly as suggested by the SETAC-Europe working group on conceptually related programmes (SETAC CRP, 1997) and Udo de Haes et al. 1998:

- **Modes of analysis**:
    - region based mode versus function based mode. In the first mode, the system consists of economic processes within a specific region; and in the latter mode the system includes processes which are upstream or downstream with respect to a given primary process,
    - descriptive mode versus effect oriented mode. The former describes how a situation is, while the latter describes the effects of changes resulting from decisions.
- **Object of analysis/basis for comparisons,** related to flows (e.g. product, function, substance, material, total mass, value) or processes (e.g. activity, sector).
- **Quantitative versus qualitative,** analytical tools may be specified at different levels of detail.
- **Spatial focus** (e.g. localised versus non-localised).
- **Type of modelling,** modelling of processes and reaction mechanisms (steady state, dynamic, dynamic equilibrium, optimum).
- **Types of environmental interventions** (e.g. extraction of resources, emissions, land use).
- **Type of impact assessment** (level in cause-effect network from environmental intervention up to the damage level).

These dimensions will be used in the cases (see section 3) to characterise and compare analytical tools and to draw conclusions with respect to their suitability for specific types of questions.

Analytical tools consist of different technical elements and are supported by data as shown in Figure 3. Tools are overlapping or competing if they use the same type of technical elements and/or data. Tools are complementary if they use different types of technical elements and/or data. The analytical tools will be positioned in relation to technical elements and data needs in order to determine their compatibility and common data needs and common strategies for data gathering, processing and exchange.

The technical elements, that will be considered depend upon the chosen tools, see Figure 3. Data requirements will be primarily characterised by economic/technological process data such as emission factors, material requirements, energy use and land use; and environmental process data such as dispersion, persistency and toxicity. Economic/technological process data will be specified according to their temporal and spatial aspects. The environmental process data will also be specified as to whether they are location specific or not.

2.3.2 Applicability of tools

A tool's suitability for a given decision context is, besides its methodology and data characteristics, determined by aspects such as:

- **uncertainty, accuracy, reliability and validity**, determining the confidence in the outcome of an analysis
- **transparency**, over assumptions and choices in the methodology and the data
- **complexity,** with respect to the understanding and use of the tool
- **credibility,** of the tool
- **resource requirements**, in terms of time, expert knowledge and money
- **practicality**, of the tool
- **compatibility with** other types of information/analysis concerning **technology, social and economic aspects**.

We will refer to these aspects as the applicability of a given tool.

3. Cases

The demand and supply of environmental information will be established for three cases: the supply, use and waste management chain for automobiles, for consumer electronics and for domestic clothes washing. These cases are described in more detail in the following sections. The cases have been selected in such a way that they provide a broad range of applications and different stages in the life cycle, involving different stakeholders. Since chain analysis requires an all encompassing view over the life-cycle, these three cases inevitably overlap. For instance, the environmental impact of the supply chain for automobiles overlaps with the one for washing machines. Likewise, the waste management chain may to some extent be identical for automobiles and electronic consumer goods.

Working groups will be set up for each case. The working groups will establish a case specific toolbox through a problem analysis by identifying relevant analytical tools, and by implementation and communication requirements. Figure 4 provides an overview of the core questions to be addressed by the working groups.

Demand side questions	**Supply side questions**
• Which sectors are involved in the supply, use and waste management chain? • Which processes are involved? • Who are the stakeholders involved? • What are the environmental problems of concern? • What are the demands for environmental information and what are the levels of interest? • Which environmental improvements have priority? • Where can problem shifting arise and how can it best be addressed?	• What is the system boundary? • What are contributions from the different tools? • What are the distinctions in the use of tools? • Are the tools competing? • What are the data requirements? • Which are the unknown/uncertain aspects of the problem? • How does the tool choice depend on data availability and quality? • Which other types of information are required? • What are the implementation and communication needs? • What are the factors of success?

Figure 4: Questions concerning the cases that each working group will have to address.

The aims of each case are:
- to identify the principal environmental impacts and demands for environmental information in the supply, use and waste management chain selected for study;
- to identify appropriate tools to comprise the “toolbox” for the case in question, and how they could be used in combination to promote new ways to provide reduced environmental impact.

These aims feed into the overall aims of CHAINET. The results of the three cases will be integrated into the guidebook and used to find ways to improve communication along the supply, use and waste management chain and with the full range of stakeholders (see Section 2.1). In addition, the first of the two aims will provide some input to planning by the European Commission of technology, product and service-oriented research in the next Framework programme.

A small Preparatory Group for each case will provide initial proposals on how the case might be structured, with a list of relevant “public domain” information. The work will be pursued by Working Groups which for their first task, will consider the following aspects:
- to describe the state-of-the-art; ongoing research projects and related platforms
- to make a problem definition by addressing the core questions of the demand side, starting with naming the stakeholders and the type of environmental decisions they have to take
- to put the case into the framework of the demand side (c.f. 2.3),
- research needs in relation to the demand side.

The second task will be concerned with the identification and assessment of:
- tools suitable for the identified demands, including analytical tools and implementation and communication aspects, including procedural tools,
- research needs in relation to the supply side.

The last task concerns the identification and assessment of:
- factors linking the supply side with the demand side
- factors leading to effective use of environmental chain analysis.

Box 2 provides a preliminary overview of analytical tools, which may contribute to the case problems described in Section 3.1 to 3.3.

3.1 Automobiles

Introduction

A modern car consists of about 10,000 components of more than 40 different materials. There is a growing acceptance of the use of Life Cycle Assessment by car manufacturers, in order to evaluate the total load of an automobile on the environment. Basic work has already been undertaken by different car manufacturers to make visible environmental loads of single components or complete products. The present approach in car manufacturing is considering environmental improvements at level 1 and level 2 (see section 2.2.2) of current components, products or concepts. This is revealed, for instance, by reductions in fuel consumption by using lighter materials and by streamlining the car, or by improvements in the recyclability of car components. This work can be used and taken into account in CHAINET’s activities addressing questions such as:
- what are the most important environmental problems of an automobile and what is the best soultion?
- how deep should the approach go to consider the life cycle of an automobile? Which tools should be used for adequate decision making?
- how to achieve environmental efficiency and an optimal function for the fulfilment of the need of transportation by an automobile?

Furthermore, the assessment and formulation of the consumer needs question the design of products in the most fundamental way. In society there is a constant tendency to encourage an increase in product use per person, in order to raise the level of individual material welfare. As a consequence, the level of environmental pollution increases as well. In order to reduce the environmental impact of both, production and consumption, not only technical aspects must be taken into account like energy and the reduction of material consumed for the production of a product and during its lifetime, but also the question of how much individual and public transportation is necessary and sustainable for the environment.

Structure of chain and parties involved

The supply chain of automobiles includes various material chains, such as steel, plastics, glass, fabrics as well as supply chains for highly complex components such as electronic devices and electro-motors. The use chain includes the supply chain of fuel, road infrastructures and repair services. The waste management chain concerns different recyclers, such as steel and plastic as well as the cement industry for combustion of tires and shredder waste. Some residues may be disposed on the landfill.

In order to integrate the environmental aspects of the whole chain all stakeholders should be involved; especially those whose decisions influence the design and use of automobiles.

Main environmental problems

- Energy use in relation to the various materials and components is a common key factor in the production of materials and components.
- The manufacturing of cars consist of many different production steps, involving a large number of differnt chemicals, including painting. This may be a main facor in relation to the environmental impact in this phase of the life cycle.
- Environmental impacts of automobiles in use: During the lifetime of automobiles consumables are needed like petrol, oil, water, harmful substances etc. and emissions are produced like CO_2, NO_x, H_2S etc.
- Waste management: The number of parts, the variety of materials, the amount of units and the complexity of design structures are directly connected with the recyclability, the dismantling and reuse of parts and materials and the disposal of waste and waste components. Also the life of an automobile should be considered in this context.

Tools for analysis

A number of different tools will be required for the analysis of this complex interaction of chains related to the supply, use and waste management. LCA will be required for the identification of dominant impacts in the different life stages, however, it will not be sufficient to catch effects related to the flows of heavy metals, such as Copper and Cadmium. Such assessments may require Substance Flow Analysis in combination with Risk Assessment. Tools like Material Flow Assessment and Cumulative Energy Requirement Analysis may be required in relation to the search for possibilities of increasing the eco-efficiency of the product chain.

Main directions and incentives for improvements

The main goal is the overall minimisation of environmental impacts. Eco-efficiency could be established with respect to the specific kilometre per person per year connected with the environmental impact to achieve this goal. Possible solutions are related to the need of less energy, a reduction of the number of parts used, the number of different materials, repairability and minimal costs for disassembly and disposal. The solutions which will be discussed will most probably be environmental improvements at level 1 and 2 (see section 2.2.2).

Environmental pressure groups are demanding for automobiles with a lower consumption of energy, less emissions and better recyclability. The European Union is preparing a Directive for automobiles to improve disassembly, selection of materials and recycling of parts and materials.

3.2 Electronic consumer goods

Introduction

Environmental considerations in production and product development are becoming of increasing importance in the consumer electronic industry due to legislative pressure, cost savings and emerging green markets. This is apparent from the widespread integration of eco-design (sometimes also called Design for the Environment, or DfE) into this business. Initiatives have been taken within companies, but there has also been cooperation between companies, for example, to set up a common LCA methodology for this purpose. The product developments are taking place in the context of rapidly changing technological surroundings.

The present eco-design programmes are limited to step-by step improvements of the present products (level 1), and sometimes to more radical redesign based on existing concepts (level 2). One of the obstacles encountered in eco-design is related to the “transition” situation, when investment in new production systems are required, renders still functioning systems obsolete. The question is how to take into account the economic and environmental costs of such a ‘destructive’ transition phase. The design of product alternatives by developing new concepts, or by replacing products with services (level 3) is more difficult to achieve for various reasons. New concepts require close cooperation with other stakeholders in the chain. This cooperation refers not only to standard supply chain management, but also to the supply of new services and creating infrastructures, which contribute to drastically improved environmental performance. Furthermore, one needs to be relatively certain that the new design is significantly better than existing products when drastic changes and large investments are involved. Methods for such an assessment are largely lacking.

At the same time, the consumer electronics industry in Europe is confronted with increasing responsibility as to the environmental impact of its products, including the take back of products at the end of their service life. In some countries this responsibility is legally codified, as in Germany in the “Elektronikschrott-Verordnung” and the “Kreislaufwirtschaftsgesetz”. Different European countries are tackling the take back issue differently, and in none of these cases has organisation been based on a systematic analysis of the resultant environmental benefits.

Structure of chain and parties involved

Consumer electronics cover a broad range of products, ranging from telephones and TVs to audio apparatus, printers and PCs. In many other products, electronics parts are increasingly important, as in cars, washing machines, door locks, etc.

The supply chains involved in electronic consumer goods include chains for materials such as plastics and various components. Typical components are printed circuit boards, capacitors, resistors, integrated circuits, solder, cables, transformers, electric motors, switches, coatings, batteries, mounting, housing, connectors, flame retardants, LCDs, monitors with their coatings, magnetic tape, and a broad range of mechanical parts. The chains involved in supply, use and waste management of consumer electronics mostly have a high degree of vertical

integration. Most producers have production facilities for major components and for assembly. However, smaller parts originate from all over the world, involving large numbers of often smaller producers.
The electricity chain is the most important in the use phase. The markets of most consumer electronics products are truly global, although for regional markets adaptations in products are made for technical and marketing reasons.
Waste management activities of discarded products cover the full range from local incineration and landfill, through to small scale re-use and recycling to even globally centralised recycling activities, as for TV tubes. Public regulations, both in the EU and in Member States, are of increasing importance in waste management of discarded products.

Main environmental problems
The environmental problems involved in the chain are quite diverse; relating to the many different types of components involved and often to energy requirements in the use phase. Raw materials extraction of, for example, heavy metals and rare earthes is a focus of environmental concern as is use of chemicals, especially acids, salts, and organic solvents, in the production of electronic components like integrated circuits. In their useful life, electronic products may loose some organics to air. Usually it is energy requirements that dominate this phase, either from the grid or from batteries. In waste management it is the large number of often small amounts of elements and species which are of prime concern, involving noble metals, heavy metals and rare earthes, and a broad spectrum of organic materials.

Tools for analysis
Because of the complexity of most consumer electronics, improvements in one respect often lead to deterioration elsewhere. Improvements themselves often result from broad strategic considerations and from relatively simple rules of thumb. LCA can analyse diverse effects at different stages in the life cycle. However, the different metals involved cannot adequately be covered by LCA if their overall control through several use cycles is to be established, possibly involving other sectors. SFA (Substance Flow Analysis) of these metals is then a more adequate tool, both from an environmental and from an economic perspective. The technical complexity, with many degrees of freedom, and the related economic complexity, require decision support with tools combining environmental and economic analysis. Eco-efficiency as a general aim to improve the environment at lowest costs possible, can be established at a physical level, as the amount of function per unit of environmental burden, or by involving more economic types of indicators, as in the costs per unit of environmental improvement. The tools involved are Cost-Benefit Analysis, Cost Accounting and LCA. The domains of the tools overlap, and their relative positions are to be clarified. Where the function of a product becomes variable, LCA cannot be used now. How to support such basic long term questions is one main subject for the group and for the concerted action as a whole.

Main directions and incentives for improvements
General strategies relate to reducing the numbers of materials, the amounts of materials as through miniaturisation and prolonged life, improving processes, avoiding materials and technologies with relatively high environmental burdens, reducing energy requirements and hence cooling requirements in the use phase, and increasing the secondary use of energy, materials, parts and components. It is not clear how piecemeal changes can contribute to long term environmental improvements. The life times of products in the sector are quite different. TVs tend to be used for decades, until the end of their technical life, (depending on the type of consumer). Pcs, on the other hand, will last only for a few years, being replaced by

functionally improved types long before the end of their technical life. Strategies for improvement then will have to differ. Benchmarking is possible here, but not at higher levels involving changes in functionality. Information technology is a main area where functionalities are changing rapidly and options for fundamental environmental improvements probably exist. High speed data transport, e.g., might allow for extreme simplification of home appliances, homes being connected to nets of servers with data and programmes. The tools for analysing such deep changes are still to be developed, at least operationally, but guidelines for this development may be specified.

For firms markets and costs ultimately decide their future. Extra market demand for environmentally improved products is limited. It is one factor in the good name of firms' brands, and is related to employee's morale and the firm’s status with regulators. Costs is a mixed item. To some extent, cost reduction and environmental improvements may coincide. Where this is not, or not fully the case, other motives are involved. Apart from demand factors government policy makers create incentives. Measures like take back requirements are one way to create incentives, next to more traditional command and control techniques and financial incentives. Markets being global, the role of product requirements is limited, mostly related to waste management. Local waste management policies may be quite diverse, leading to different and possibly conflicting requirements on product design. Creating uniform incentives for "the right" improvements is a common task, with a central role for policy makers. For the stakeholders involved in creating effective and efficient real improvements, a common view based on clear communication is a requirement.

3.3 Domestic washing of clothes

Introduction

Cleaning soiled clothes in the home is an example of a service which can be provided by a variety of means. The current conventional way to obtain this function is by wet washing with liquid or solid detergent in an electrically powered washing machine. A range of environmental tools, including LCA and RA, have already been deployed in developing cleaning agents and machines with reduced environmental impacts. Thus there is already a body of work which can be drawn on to address such questions as:

- how can a detergent and its constituents be selected?
- how can a machine be designed for reducing environmental impact during use and over its service life (including end of life treatment)?
- how can the above considerations be reconciled?, e.g. by
    - reducing the washing temperature;
    - balancing machine service life against technological developments,
- to what extent are environmental performance criteria dependent on local conditions, including:
    - sensitivity of the local environment,
    - wastewater treatment,
    - energy generation,
    - degree of soiling,
    - consumer behaviour.

However, the above questions all relate to the current practice of domestic washing of clothes purchased with little attention to environmental performance.

- What different future technologies could be feasible?
- Do the established environmental tools inhibit consideration of radically different ways to deliver the service?
- Are large scale, factor 4 to10 improvements possible, through complete redesign of existing clothes washing concepts or by an alternative fulfilment of this service or by broadening the basis to cover the overall environmental impacts of “clothing the human body”?

Partly to investigate the possibilities for future service provision, the case can consider “institutional” washing arrangements, for example in hotels, hospitals and other residential institutions.

Structure of chain and main environmental problems

There are at least three ways in which environmental impacts arise from the activity of fabric washing, associated with the different supply chains which intersect in this service:

Cleaning Agents: Surfactants, zeolites and other constituents of detergents have their own supply chains, while treatment of the waste water from the washing process depends on the composition of the cleaning agents used.

Machines: Washing machines also have their own supply chains, including post-use management of used machines. The environmental impacts at the point of use depend on machine design, for example through energy and water usage.

Fabrics: The fabric which is washed represents a third supply chain, with its own impacts (which may differ completely between synthetic and natural fibres).

The interactions between these supply chains are complex. For example, the service life of a garment depends on its use, on the material from which it is made and on the way in which it is washed. Washing conditions depend on the fabric, how it is soiled and on the detergent used. Efficiency of washing and efficiency of rinsing to remove cleaning agents are both aspects of “fitness for purpose” and impose constraints on water usage, for example.

Tools for Analysis

Because of the complex interactions along and between the supply chains, it is clear that no single tool will suffice to give a complete analysis of the environmental impacts of providing this service. Use of LCA for all three supply chains is established, as is use of RA for detergents. Understanding of consumer behaviour is also essential, for example in whether recommended changes in washing conditions are actually used, and in the extent to which fashion or damage are the prime determinants in the service life of machines and fabrics. Possible future developments in the provision of this service may depend on social acceptability. Therefore, this case will need to look beyond conventional quantitative environmental analytical tools.

Main directions and incentives for improvements

Given the intersection in this service of supply chains which are normally treated separately, long-term improvements are likely to result from considering all supply chains together. This will depend on better communication between the various commercial agencies, as well as with the consumer; the incentives being in the economic and environmental benefits which can result from applying the Clean Technology approach to this cleaning service (Clift, 1998).

Automobiles	**Electronic consumer goods**	**Domestic washing of clothes**
• LCA in relation to the identification of dominant impacts and eco-design • Check-lists for eco-design. • SFA in combination with RA in relation to assessing the eco-efficiency of take-back. • MFA and CERA in relation to the search for possibilities of increasing eco-efficiency of the product chain	• LCA in relation to the identification of dominant impacts and eco-design • Check-lists for eco-design. • SFA in combination with RA in relation to assessing the contribution of end-of-life processing to the eco-efficiency of product chain management. • Cost-Benefit type of analysis in relation to transition phases.	• LCA in relation to the identification of dominant impacts and eco-design. • Check-lists for eco-design. • RA in relation to the assessment of detergent constituents, including the influence of local conditions • Consumer research in relation to understanding consumer behaviour and social acceptance.

Box 3: Preliminary indication of relevant analytical tools for the case problems.

4. Organisation and programme

The overall organisation of CHAINET is illustrated in Figure 5, which distinguishes the key institutional structures and the lines of responsibility. Further details are described below.

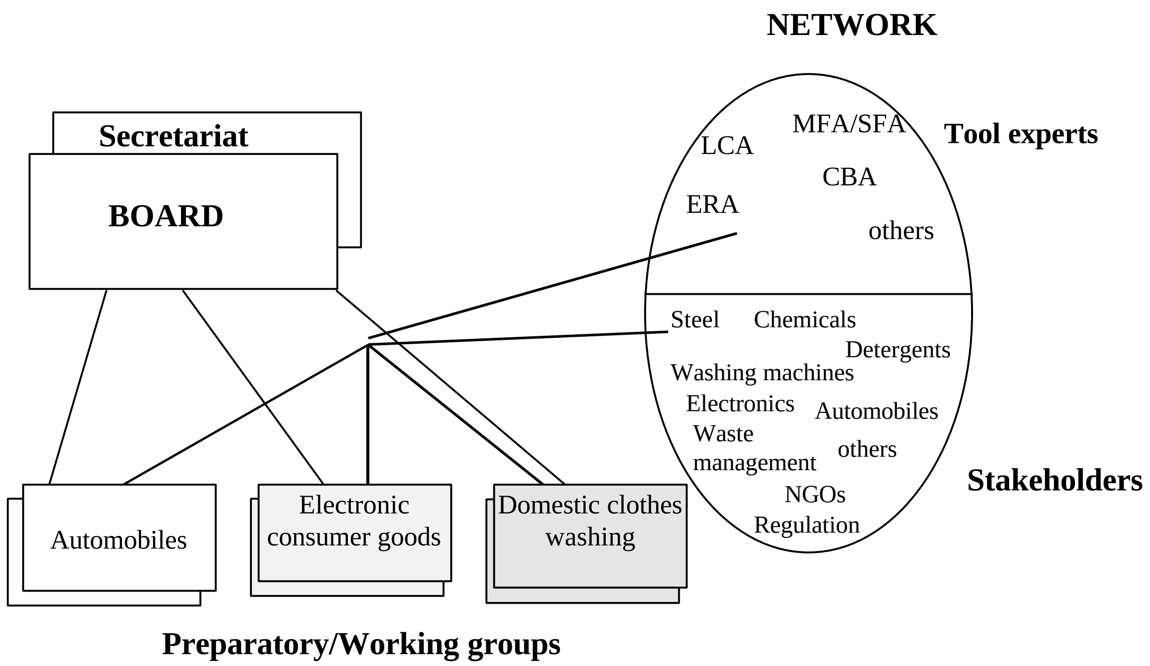


Figure 5: The organisation of CHAINET

4.1 The role of the Board and the Partners

The Concerted Action is managed by a *Board* consisting of partners from eight scientific European institutes and consultancies (listed in Appendix 1), chaired by Prof. dr. Helias A. Udo de Haes (CML, Leiden University). The Board is responsible for the reports, meetings and workshops. The Chairperson is responsible for this Document and the draft of the Guidebook. The prime responsibilities and supporting roles of the Partner Institutes are outlined in Table 4.

4.2 The role of the Secretariat

The Secretariat is housed in CML. It is responsible for the co-ordination of activities and publishes the progress and the results of the project in a newsletter and a WWW homepage. Four newsletters will be made available to all interested parties. The homepage will be updated once every two months.

Partner/ board member	Defin. Doc.	Washing of clothes	Auto-mobiles	Elec-tronics	Web site	News-letter	Guide-book	Inaug. meeting	Concl. meeting	Netw. Organ.
1. CML (secr. + chair)	X			X	X	X	X	x	x	X
2. CES Surrey		X					x	X		
3. TU Dresden			X							
4. Lyngby University		(x)	x							
5. ESU Zürich		x								
6. Keele University				x						
7. Wuppertal Institute										x
8. IPTS	x						x		X	

X = prime responsibility, x = supporting responsibility

Table 4: Overview of the partners and their specific tasks

4.3 The role of the Preparatory Groups

The *Preparatory Groups*, one for each of the three cases, will be responsible for the preparation of case reports and will set out detailed programmes for invited workshops and, later, for the open workshops. The Preparatory Groups are responsible for the organisation and documentation of the workshops. The Preparatory Groups consist of at least two key stakeholders and two tool experts from the Board. One of the Board members has the overall responsibility for the case report and the two workshops. The members of each Preparatory Group (listed in Appendix 1) are identified by the Board.

4.4 The role of the Working Groups

Working groups will be formed for each of the three cases, see Figure 6. The Working Groups will be consulted on draft case reports and on the documentation to be provided to the workshops. All members of the Working Groups will be invited to participate in the invited workshop, however, the number of participants are limited. The Working Group members will also participate in the open workshops, which will be open to others as well as CHAINET members.

4.5 The role of the Network

The *Network* consists of two major groups (see Figure 5): stakeholders and tool experts. The Network is to be built, first, by linking existing networks representing stakeholders or tool experts. The tool experts are mainly represented by professional analysts working with environmental assessment tools. Examples of such networks are: LCANET, ConAccount, SETAC, and so on. The stakeholders are represented by examples of “stakeholder” networks such as O2, TANNET and ETCA.

Network building requires approaching members of existing networks and other key persons, and inviting them to take part in the Network meetings and workshops and in the Preparatory Groups. This is the responsibility of the Secretariat.

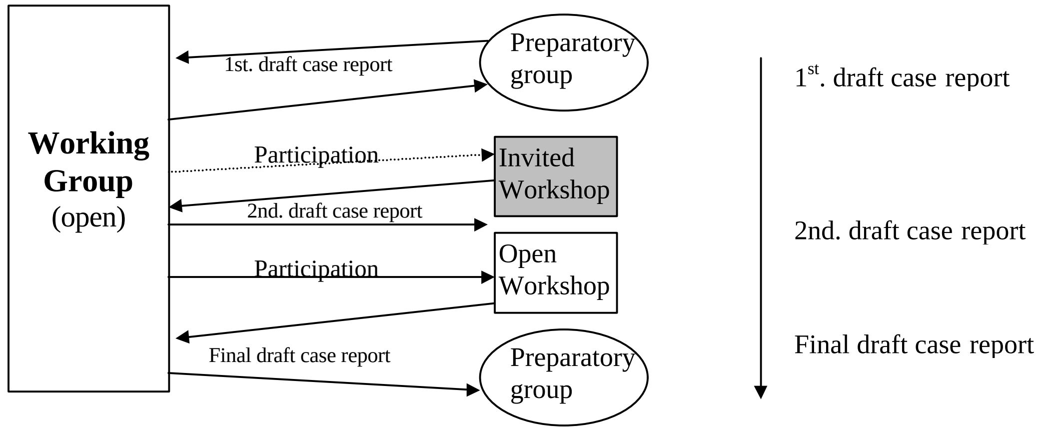


Figure 6: The role of the Working Groups.

4.6 Work Programme

The Concerted Action will have a duration of two years. The work programme is divided into three phases, conducted over six months, twelve months and six months respectively. Box 3 provides a detailed timetable.

The ***first phase*** consists of the building of the Network, the completion of the Definition Document and an inaugural meeting. The first Network meeting discusses the draft Definition Document. The main subjects of presentation and discussion are the different tools for analysis and their possible roles in environmentally related decision-making. The draft Definition Document is finalised following further comment.

In the ***second phase***, the analysis focuses on the three cases - the supply, use and waste management chain for automobiles, for electronic consumer goods and for domestic washing clothes. For these cases different chain management tools are specified, already performed studies and research topics are identified, success factors are specified and guidelines for their application are investigated. The three Preparatory Groups set out detailed programmes for both their invited as well as their open workshops. A first draft case report is drawn up, with the assistance of key stakeholders and the tool users and analysts from both within and outside the Board.

There is one invited workshop of two and a half days duration for each case. Each workshop will comprise around 20-25 participants. Their composition requires a broad coverage of both the tools and the applications. The scope and the specific content of each draft case report will be discussed. The results of the workshops are discussed at the second Board meeting. The common elements are to be harmonised. The draft case reports are revised. The set up of the open workshops will be discussed. About 30-50 participants will attend each of the open workshops. These workshops will discuss the second draft case reports and will discuss the possibility for a more permanent forum. Subsequently the Preparatory Groups will meet to finalise the case reports. These will be sent to all Network members.

Phase 1, December 1997 - June 1998:
- Board meeting (18 February 1998)
- Network meeting (26 May 1998)
- Formation of Preparatory Groups and Working Groups
- Definition Document (July 1998)

Phase 2, July 1998 - June 1999:
- Preparatory Group meetings (begin September 1998)
- Invited workshops (29-30 October, 1998) in Noordwijkerhout, The Netherlands
- Board meeting (30 October, 1998) in Noordwijkerhout, The Netherlands
- Open workshop (25-26 March, 1999) in Seville, Spain
- Case reports (June 1999)

Phase 3, July 1999 - December 1999:
- Board meeting (10 September, 1999) in Leiden, The Netherlands
- Network meeting (6-10 October, 1999) in Dresden, Germany
- Guidebook (December 1999)

Box 3: Time table of CHAINET activities.

In the ***third phase***, the experiences derived from the three cases are brought together to generate the Guidebook. The possibilities are further investigated for establishing a permanent network. The Secretariat produces a draft outline of the Guidebook. This is discussed at the third Board meeting, along with the main options identified for making a permanent network. A first draft of the Guidebook is produced for discussion at the Network meeting as well as the final proposals for making CHAINET permanent. Afterwards these issues are finalised.

The final products of the project will be the Guidebook along with the three case reports, the Network newsletters, a possible proposal for the permanent organisation of the Network, and the web site with these and other relevant documents.

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Appendix 1: CHAINET BOARD

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Members of preparatory group of Automobiles:
Bernd Bilitewski (Chair-person), TU Dresden
Finn Bro-Rasmussen, DTU
Michael Kundt, Wuppertal Institute
Invited Ford Werker,Volvo, Bosch, EDF

Members of preparatory group of Consumer electronics:
Gjalt Huppes/Rene Kleijn, CML (Chair-person)
Paul Ekins/Stephan Speck, Keel University
Ab Stevels & Hans van der Wel, Philips
Invited Sony, Nortel

Members of preparatory group of Washing clothes:
Roland Clift (Chair-person), CES
Rolf Frischknecht, ESU Services
Henry King, Unilever
Paul Smith, Environmental Health Officer
Erica Ison, Centre for Greening the NHS
Marjolijn Knot, TU Delft
Washing machine manufacturer (TBA)

Appendix 2: Explanation of tools

The following tools are shortly described:
A2.1 Check-lists
A2.2 Cost-Benefit Analysis
A2.3 Cumulative Energy Requirement Analysis
A2.4 Environmental Impact Assessment
A2.5 Environmental Risk Assessment
A2.6 Input-Output Analysis
A2.7 Life Cycle Assessment
A2.8 Material Flow Accounting/Substance Flow Analysis
A2.9 Material Intensity Analysis
A2.10 Multi-Criteria Analysis

A2.1 Check-lists (CL)

Check-lists are qualitative tools that may give guidance to design, environmental management, setting eco-labelling criteria, etc.. The check-lists used for a particular purpose, such as check-lists for design, may be general or customised for a specific sector or company. Check-lists consider various different aspects such as recyclability, minimising harmful substances, and so on. They may be differentiated by underlying bases and principles, such as:

- social perception of environmental risks,
- compliance with environmental legislation,
- common sense/expert judgement on environmental aspects,
- environmental analysis.

However, check-lists may often consider several principles at the same time. These principles can be used to characterise and compare check-lists, and to draw conclusions with respect to their applicability to specific decision situations.

Relevant litterature
Examples of check-lists for design are given in:
Behrendt et al., 1997. Life Cycle Design - A manual for small and medium sized enterprises

Brezet H. and Hemel, C, 1997. Ecodesign: a promising approach to sustainable production and consumption. UNEP-Industry and Environment, ISBN 92-807-1631.

A2.2 Cost-Benefit Analysis (CBA)

Cost-benefit analysis is an economic tool for supporting decisions on larger investments from a social, as opposed to a firm's, point of view. Its domain of application includes regulatory and technology choices. It has been developed as a tool to remediate a number of shortcomings of a purely market oriented analysis of costs and benefits. In a world with perfect markets, costs and benefits would indicate to any decision maker everything relevant for economic welfare. Markets are not perfect. Cost-benefit analysis repairs some of the deficiencies caused by these market imperfections. Three types of correction take place:

- for transfer payments, that is taxes and subsidies, which shift purchasing power but do not indicate welfare changes for the community as a whole
- for price distortions, as created by monopolistic and oligopolistic markets
- for external effects and collective goods, which are not, or not adequately, expressed in market prices.

It is the latter type of effects which is of interest for environmental analysis. Most environmental problems can be seen as ***external effects*** of economic activities, like the costs of emissions which are not paid for to those damaged, or as ***collective goods*** which are not priced and hence overused, like fish from the oceans, wood from forests, and the beauty of a landscape.

In cost-benefit analysis, a first step is to specify the effects as related to the decision at hand. In the cost-benefit literature this step has not been worked out in much detail. Models may be restricted to more or less direct effects, may include indirect effects and may even take into account secondary effects involving macro-economic mechanisms.

Next to market related costs and benefits, a number of other effects are specified, including all relevant environmental effects.The main focus in the current development of cost-benefit analysis is on how to evaluate these unpriced effects. The dominant approach is based in Paretian welfare theory, where the individuals confronted with these external effects judge their importance. As in market choices, their preferences can be expressed in money terms. The overall evaluation then is in one single category: money, providing a comparable yardstick for the decision maker.

Cost-benefit analysis, contrary to the other tools for environmental decision support, can take the time horizon of effects into account. By discounting future costs and benefits, the more future effects are the less important they become. Often, in cost-benefit analysis an equilibrium situation is specified, as mostly is the case in, e.g., LCA, and discounting then is not possible.

Cost-benefit analysis and LCA can be integrated, applying the analysis to a (broadly defined) unit of function and setting up the LCA characterisation and evaluation in line with the Paretian approach: specifying damage functions and valuating the damages from the point of view of those concerned. Recent examples of integrating LCA and cost-benefit analysis are in assessing different options for energy production and for waste management.

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E.J. Mishan, 1971. Cost-Benefit Analysis, an informal introduction. Unwin Brothers Limited454 pp, 1971. ISBN 0-04-338080 8.

A.2.3 Cumulative Energy Requirements Analysis (CERA)

CERA is used to quantify the primary energy requirement for products and services in a life-cycle perspective. It had been developed to consider the upstream energy flows when optimizing production processes. The cumulative energy requirement indicates a basic environmental pressure associated with the use of energy. Similar to material intensity the energy intensity can not be used to quantify specific environmental pressures (e.g. ozone depletion) rather than a generic pressure.

The primary energy requirements are measured in Joules and aggregated into one number. Interpreting lower values as being associated with less environmental burden is only justified if the relative share of the energy carriers will not be changed towards more hazardous ones.

CERA can be used to

- quantify the energy intensity of products, services and national economies;
- analyse options for energy savings in industry;
- provide energy input coefficients for base materials to support engineering and design of products.

Relevant literature:

Verein Deutscher Ingenieure (VDI) (Hrsg.) (1997): Kumulierter Energieaufwand - Begriffe, Definitionen, Berechnungsmethoden. Richtlinie VDI 4600, Beuth Verlag, Berlin

A2.4 Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) is the process of identifying and evaluating the consequences of one economic activity on the environment and, when appropriate, mitigating those consequences. EIA is used as an aid to public decision making on larger projects, such as the construction of a highway, powerplant or industrial production sites. Precise elements of this process and specific technical guidelines and legal requirements that pertain to it vary from nation to nation and, within one nation, vary with time. However, despite the diversity of techniques, the differences in emphasis, and the varied objectives that characterise impact assessment as practised in different nations, four important aspects of environmental impact assessment are increasingly approaching consensus:

1. Consideration of impacts on both the physical and the social environment.
2. As a tool of decision making, the value of environmental impact assessment is more likely to be realised in the timely communication of information between individuals conducting the assessment and individuals planning a proposed project than in the writing of a massive technical document. Although written assessments, often called Environmental Impact Statements (EISs) or Environmental Impact Reports (EIRs), are required by legislative or executive mandates, the general understanding is that such documents tend to serve more as records of decision making than as active tools in decision making.

3. Many environmental components, processes, and attributes are amenable to currently available methods of quantification, but includes other which are not (e.g. sociological, political and psyhcological factors). By their nature these may never become quantifiable, regardless of the continuing development of new analytical paradigms. EIA should consider both quantifiable and non-quantifiable attributes.
4. Mitigation of significant impacts, which includes the minimisation of undesirable impacts and the enhancement of desirable impacts, must be assessed for all possible impacts.

Relevant literature

Colombo, A.G. (ed.), 1992. Environmental Impact Assessment. Dordrecht, NL, Kluwer Academic Publishers.

Erickson, P.A., 1994. A practical guide to environmental impact assessment. Academic Press, Inc. ISBN 0-12-241555-8

A2.5 Environmental Risk Assessment (ERA)

Risk and risk assessment processes are both connected to the comprehensive evaluation of the potential, or rather the probability that damage or adverse effects will occur.
A full risk assessment for chemicals which are considered hazardous, is normally preceded by and based on a **Risk Characterisation** involving the integration of three steps:

- A **hazard identification**, by which a relationship is studied between different levels of exposure and the *incidence and severity of (an) effect(s)*, normally including toxicological as well as ecotoxicological effects evaluation
- An **effects assessment**, which is dominated by the determination of the *PNEI, or PNEC for the effect(s)* defined via Hazard identification, *i.e. Predicted-No-Effect-Level/ of Concentrations*, and
- An **exposure assessment** in which *PEC, i.e. Predicted Exposure Concentration* (or *Total Daily Intake*) are determined by measurement and/or assessed, including description of nature and size of exposed targets, as well as magnitude and duration of exposure.

In regulatory risk evaluation, distinction is normally made between Environmental (including Ecological) Risk Assessment (ERA) and Human Health Risk Assessment (HRA). Both of these are mostly carried out stepwise following tiered process schemes and according to guidelines developed under international expert guidance, *cf.* OECD and EU Test and Risk assessment guidelines. The ERA comprises the risk assessments of substances on non-human species in complex systems. A highly significant **PEC/PNEC-ratio** is often taken to define a chemical's risk to the environment.

The most obvious difference between ERA and HRA is that ERA deals with millions of species rather than only one (man). Apart from this, differences in toxicological endpoints, spatial and temporal scales, complexity of exposure and several other parameters can be identified, explaining that variability in exposure and effects assessments is crucial for the ERA, necessitating an extreme use of simplifications of reality, *i.e.* via models. Considering these factors, the simplifications of ERA are far-reaching and only very few PEC's and PNEC's are actually determined.

Relevant literature

Overviews:
EEA, European Environment Agency, 1998. Environmental Risk Assessment, Approaches, Experiences and Information Sources. Written by Robyn Fairman, Carl D. Mead & W. Peter Williams, MARC, King's college London for the EEA, Copenhagen.

Van Leeuwen, CJ. & Hermens, J.L.M., 1993, Performing ecological risk Assessments. Lewis Publishers, MI, USA.

Instructive proceedings:
M.I. Richardson (editor), 1986, Toxic Hazard Assessment of Chemicals. Comprised mostly by papers presented at meetings of the (British) Royal Society of Chemistry. Published by the Royal Society of Chemistry, Burlington House, London.

M.I. Richardson (editor), 1988, Risk Assessment of Chemicals in the Environment. Proceedings from the Third European Conference on Chemistry and the Environment held in Guildford on 11-14 July 1998. Published by the (British) Royal Society of Chemistry, Burlington House, London.

Technical Guideline documents:
CEC/ECB, Commission of the European Communities/European Chemical Bureau, 1996. Technical Guidance Documents in support of the commission Directive 93/67/EEC on Risk Assessment for New Notified Substances and the Commission Regulation (EC) 1488/94 on Risk Assessment for Existing Substances. Published by the CEC, European Chemicals Bureau, Ispra, Italy.

OECD, 1995. Report of the EOCD Workshop on Environmental Hazard/risk Assessment, No. 94. Organisation for Economic Co-operation and Development, Paris.

For further references, including industrial viewpoints, see:
ECETOC/IRPTC, 1996. Inventory of Critical Reviews on Chemicals. Published by ECETOC, European Centre for Ecotoxicology and Toxicology of Chemicals, Brussels, and IRPTC, International Register on Potentially Toxic Chemicals, Geneva.

A2.6 Input-Output Analysis (IOA)

As part of the establishment of national accounts, input-output analysis was devised in the 1930s, and first implemented in the 1940s for the USA. Its founder was Wassilyu Leontief (1936), and his approach to national accounts was a disaggregated one, focusing on how industries trade with each other, and how such inter-industry trading influenced the overall demand for labour and capital within an economy.

The basic distinction that is made in input-output analysis is between the demand for goods and services sold to 'Final Demand' (households, governments, exports, investment), and the 'Total

Demand' in the various sectors, resulting from the direct impact of final demand, and the indirect impacts resulting from inter-industry trading (intermediate demand).[2]

Total demand = intermediate demand + final demand

One of the main uses of input-output analysis is to display all flows of goods and services within an economy, simultaneously illustrating the connection between producers and consumers and the interdependence of industries. An advantage of input-output tables is that economic components, such as income, output and expenditure, are presented in a consistent framework reconciling the discrepancies between the estimates of these components.

Using linear algebra, input-output analysis allows all economic activity to be directly related to final demand. Of course, the final demand for the various producing sectors sums to Gross Domestic Product (GDP), one of the fundamental measures in national accounting. Input-output tables can be, and are being, used for various economic analyses within and outside Government. The use of input-output tables is particularly important for analysing structural adjustment in industry. For a full description of input-output analysis, see Miller and Blair (1985), and its application to environmental issues, Proops et al. (1993).

Relevant literature

Leontief, W. (1936) Quantitative input-output relations in the economic systems of the United States. *Review of Economics and Statistics*, Vol 18, pp.105-125.

Miller, R.E. and P.D. Blair (1985) Input-Output Analysis: Foundations and Extensions. Prentice-Hall, Englewood Cliffs, New Jersey.

Proops, J., Faber, M. and Wagenhals, G. (1993) Reducing CO2 Emissions: A Comparative Input-Output Study for Germany and the UK, Springer-Verlag, Heidelberg.

A2.7 Life Cycle Assessment (LCA)

Basically, LCA aims at specifying the environmental consequences of products or services from-cradle-to-grave. LCA is one of the tools that has received much attention from both the scientific world and the policy makers. Much effort has been put and is being put into the development of the LCA methodology and the establishment of LCA software and databases. Although the methodology is by no means finalised and a number of important issues still must be resolved, LCA is currently being standardised within the ISO framework (ISO series 14040).

The main characteristics of LCA can be formulated as follows:

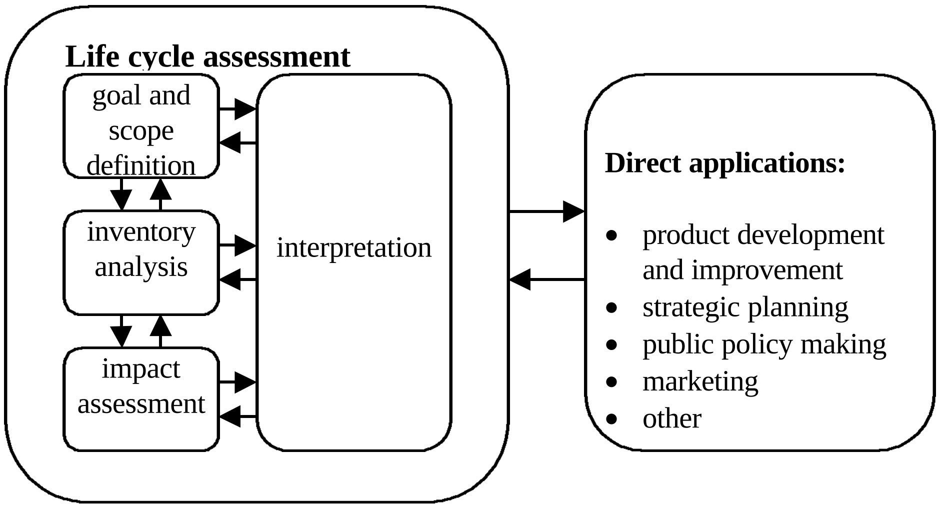
- LCA is a study of different options to supply a given *function*. Thus, it links changes in products (goods and services) in the economy to impacts on the environment.
- LCA follows a *cradle-to-grave approach*: all processes connected with the function, from the extraction of resources until the final disposal of waste, are being considered. This

[2] For instance, almost no iron and steel products are sold directly to domestic consumers (final demand), but a great deal is sold embodied in manufactured goods, such as cars and washing machines.

cradle-to-grave approach may induce companies to look beyond their gates, or governments to detect unexpected side-effects of their policies;
- LCA is *comprehensive* with respect to the environmental interventions and environmental issues considered. In principle, all environmental issues or problems connected with the function are specified as resulting from extractions, emissions and other physical interventions.
- LCA may provide *quantitative* or *qualitative* results. With quantitative results it is easier to identify problematical parts of the life-cycle and to specify what can be gained by alternative ways to fulfill the function.

The technical framework for the LCA methodology as it is defined in ISO 14040 consists of four phases:
1. Goal and scope definition
2. Inventory analysis
3. Impact assessment
4. Interpretation

These phases are not followed just one after the other. It is an iterative process, which can be followed in different rounds achieving increasing level of detail (from screening LCA to full LCA), or which may lead to changes in the first phase because of the results of the last phase.



Phases of an LCA

Relevant literature

Heijungs, R., J.B. Guinée, G. Huppes, R.M. Lnakreijer, H.A. Udo de Haes, A. Wegener Sleeswijk, A.M.M. Ansems, P.G. Eggels, R. van Duin & H.P. de Goede: Environmental Life Cycle Assessment of Products, Guide - October 1992. Centre of Environmental Science, Leiden University, 1992.

SETAC: Guidelines for Life-Cycle Assessment: a 'Code of Practice'. SETAC publications, Brussels, 1993.

Udo de Haes (ed.): Towards a Methodology for Life Cycle Impact Assessment. SETAC publication, Brussels, September 1996.

Udo de Haes, H.A. and Wrisberg, N., 1997. LCANET. European Network for Strategic Life-Cycle Assessmnet Research and Development. LCA Documents, Vol.1. Eco-Informa Press.

UNEP Industry and Environment: Life cycle assessment: what is it and how to do it. United Nations Publication Sales no. 9C-III-D.2, Paris, 1996.

A2.8 Material Flow Accounting/Substance Flow Analysis (MFA/SFA)

Material Flow Accounting (MFA) refers to accounts in physical units (usually in terms of tonnes) comprising the extraction of production, transformation, consumption, recycling and disposal of materials (e.g. substances, raw materials, base materials, products, manufactures, wastes, emissions to air, water or soil) in a specific region. According to different subjects and various methods, MFA covers approaches such as Substance Flow Analysis (SFA), product flow accounts, material balancing, and overall material flow accounts.

Two basic types of accounting may be distinguished according to the objects of primary interest:

- Type 1 starts with specific problems that are related to selected substances or materials. The flow of eco-toxic substances such as heavy metals is studied because they are associated with environmental problems, for instance by accumulation. The flow of nutrients like nitrogen is accounted because it may be critical to eutrophication. The flow of carbon is studied because it is e.g. associated with global warming. The flows of chlorinated substances are quantified because they are rendered to be critical for various pollution problems. Selected flows of materials may also be of interest. Energy carriers, moved masses, plastics, wooden products, biomass and aluminium may be associated with certain environmental pressures and/or may be studied in order to optimise their economic use or improve recycling and cascading strategies. Studies relating specified emissions to the production of base materials or to various sectors of industry lead to the next type of accounting.
- Type 2 starts with the question whether the volume and structure of the throughput of selected sectors or regions is sustainable. For instance, industrial sectors, chemicals production, or construction are studied with respect to their throughput of substances or materials. Cities, regions or national economies are studied with regard to selected materials flows, the total throughput and/or global material input. One major aim of those is the derivation of indicators for environmental pressure. This does not only refer to total mass throughput but - for instance - also to the relation of renewable to non-renewable inputs on order to indicate structural properties.

Relevant literature

Bringezu, S., Fischer-Kowalski, M., Kleijn, R. and Palm, V., 1997. Regional and national Material Flow Accounting: From paradigm to practice of sustainability. Proceedings of the ConAccount workshop 21-23 January, 1997, Leiden, The Netherlands.

A.2.9 Material Intensity Analysis (MAIA)

According the concept of MIPS (Material Input per Service unit) MAIA is used to quantify the life-cycle-wide requirement of primary materials for products and services. Analogously to the quantification of the cumulative energy requirements MAIA provides information on basic environmental pressures associated with the magnitude of resource extraction and the subsequent material flows which end up as waste or emission.

The input of primary raw materials (including energy carriers) is measured in physical units (kg) and aggregated to five main categories:
- abiotic raw materials (non-regrowing inputs)
- biotic raw materials (regrowing inputs)
- soil removal
- water
- air (inputs for physico-chemical conversion, usually for combustion, therefore in most cases also strongly correlated with carbon dioxide emissions)

MAIA has been developed since 1992. It has been conceived as a screening step for LCA. It has been used to
- operationalize the concept of dematerialization and to contribute to the implementation of eco-efficiency (factor 4 to 10)
- quantify the material intensity of products and services
- elucidate options for material and energy savings in industry in order to increase resource productivity
- provide material input coefficients for a variety of base materials to support sustainable product design
- quantify the Total Material Requirements of regional and national economies (TMR).

Relevant literature:

Schmidt-Bleek, F. et al. (1998): Einführung in die Materialintensitäts-Analyse nach dem MIPS-Konzept. Wuppertal Texte, Birkhäuser Verlag, Berlin, Basel, Boston

Bringezu, S., Stiller, H., Schmidt-Bleek, F. (1996): Material Intensity Analysis - A Screening Step of LCA. Proceedings of the Second International Conference on EcoBalance, Nov. 18-20, 1996, Tsukuba, Japan, p.147-152

Liedtke, C., Orbach, T., Rohn, H. (1997): Towards a Sustainble Company: Resource Management at the „Kambium Furniture Workshop Inc.“. In: Bringezu, S., Fischer-Kowalski, M., Kleijn, R., Palm, V.: Analysis for Action. Support for Policy towards Sustainability by Material Flow Accounting. Proceedings of the ConAccount Conference, 11-12 September 1997, Wuppertal, Wuppertal Special 6, pp. 163-174

MIPS-online: http:/www.wupperinst.org

A.2.10 Multi-Criteria Analysis (MCA)

(After Paruccini et al., 1997)
Orthodox decision theory focuses on finding the best solution to any decision problem. In doing so, the theory employs analytical tools and specific theoretical language rooted in the paradigm of substantive rationality using constrained optimisation. The optimising approach is based on the assumption that different objectives can be expressed with respect to a common denominator by means of trade-offs (complete commensurability) so that the loss in one objective can be evaluated against the gain in another. Thus the orthodox approach is firmly based on a single-criterion approach. However, most decision makers would agree that the norm is decision making in situations where a single criterion in not sufficient – *i.e.* multiple criteria are needed. During the last two decades, further support has emerged for the view that a decision is a multidimensional concept (Bana e coste, 1990; Nijkamp et al., 1990; Paruccini, 1994).

From the point of view of the decision maker,, it is also clear that, the moment a decision has been made the multi-dimensional problem, with a large number of possible solutions, has in fact been reduced to one solution. The role for decision support systems is in facilitating the process of the necessary reductions. Thus the most important distinction between the different types of Decision Support Systems is whether they can handle single or multiple criteria: clearly multi-criteria systems offer several advantages for policy decisions, where conflicting interests have to be considered.

A large number of multi-criteria evaluation methods have been developed and applied for different policy purposes in different contexts. As a tool for conflict management, multi-criteria evaluation has demonstrated its usefulness particularly with regard to environmental management problems. In general, a multi-criteria model presents the following aspects:

- There is no solution optimising all the criteria at the same time and therefore the decision maker has to find compromise solutions.
- The relations of preference and indifference are not enough in this approach, because when an action is better than another one for some criteria, it is usually worse for others, so that many pairs of actions remain incomparable with respect to a dominance relation.

Thus the concept of ‘decision process’ has an essential importance. The final outcome is more like a ‘creation’ than a discovery. With a multiple criteria decision aid the principal aim is not to discover a solution, but to construct or create something which is viewed as useful to an actor taking part in a decision process (Roy, 1995).

Relevant literature

Bana e Costa C. A. (ed.), 1990. Readings in Multiple Criteria Decision Aid. Springer-verlag, Berlin.

Nijkamp, P. Rietveld P. and Voogt H., 1990. Multicriteria Evaluation in Physical Planning, North-Holland, Amsterdam.

Paruccini, M., 1994. Applying Multicriteria Aid for Decision to Environmental Management, Kluwer, Dordrecht.

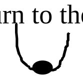
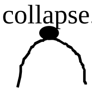
Paruccini, M., Haastrup, P. and Bain D., 1997. Decision support systems in the service of policy makers. The IPTS report ,14, May 1997, 28-35.

Appendix 3: Environmental strategy levels for companies

Environmental strategy	Characteristics
Compliant	Compliance with all environmental health, and safety regulations. This is the minimum levels of environmental strategy an organisation can adopt.
Informed	Compliance tracks key activities beyond compliance and participates in external activities such as trade associations. Time and and resources are spend on collecting information.
Market driven	An organisation responds not only to regulatory requirements, but also is reactive to its customers environmental expectations by providing leading product/service and operational performance.
Competitive	An organisation is not only in compliance, but understands its environmental market opportunities and proactively uses that knowledge to create markets where it has sole or leadership positions, resulting in revenue generation.
Sustainable	An organisation proactively integrates economic growth; environmental, health, safety and social well being into its operations for competitive advantage, revenue generation and long-term viability.

Environmental strategy levels for companies. Modified from Fava et al., 1998.

Appendix 4: Cultural Theory

Political cultures	Nature view	Management principle
The Fatalist: Groups with marginal influence (poor consumers, business in extremely hard competition)	**Nature capricious**: The world operates without rhyme or reason. 	No management or learning. Just coping as best they can with erratic and unpredictable events.
The Hierachist: Hierarchist corporations, conservative and old socialist politicians, regulators, political and expert establishment	**Nature tolerant:** The world is one of forgiving of most events, but is vulnerable to the occasional knocking of the ball over the rim. 	Develop expertise to determine just where this dividing line is, and then ensure that everyone stays on the right side of it: statutory regulation
The Individualist: Individualised corporations, liberal politicians, “normal’consumers, business oriented eco-establishment.	**Nature benign:** The world is in global equilibrium. Such a world is wonderfully forgiving. No matter what knocks the ball it will always return to the bottom of the basin. 	Laissez-faire attitude.
The Egalitarian: Egalitarian corporations, environmentalists/grassroots, green politicians, green consumers	**Nature ephemeral**: The world is a terrifyingly unforgiving place, and the least jolt may cause its catastrophic collapse. 	The precautionary principle.

Different political cultures have distinct perceptions of nature and its management (after Schwarz and Thompson, 1990).