# An Evaluative Framework for Conceptual and Analytical Approaches Used in Environmental Management*

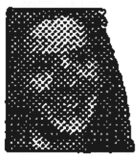
Henrikke Baumann
*Chalmers University of Technology, Sweden*

Sarah J. Cowell
*University of Surrey, UK*

**In the last 30 years, a number of new approaches for use in environmental management have been developed for use by decision-makers. This paper presents a framework for comparing these approaches based on various methodological features. These include: nature of the approach, type of decision-maker, overall purpose and object analysed, perspective, investigated dimensions, character of the approach, basis for comparison, system boundaries, type of data, and evaluation of results. Use of the framework is illustrated for four approaches: industrial ecology; design for environment; environmental impact assessment; and environmental accounting. The approaches can be used consecutively, or be complementary, competing, encompassing or overlapping in their applications. The research suggests that there is considerable scope for exploring these relationships between and within approaches. Rather than developing new tools for environmental management, it may now be appropriate to focus on practical integration of existing approaches for different applications.**

- Environmental management
- Evaluative framework
- Concepts
- Tools
- Integration

Kikki Baumann works on research issues related to the application of LCA, collaborating with colleagues in the Business School of Göteborg University and at Technical Environmental Planning, Chalmers University of Technology.



Technical Environmental Planning, Chalmers University of Technology, Göteborg, Sweden
henrikke@vsect.chalmers.se
http://www.tep.chalmers.se

Sarah Cowell, Lecturer at the Centre for Environmental Strategy, University of Surrey, works on development of environmental life-cycle approaches and their integration into decision-making. She chairs the SETAC Working Group on LCA and Decision-Making, and has published and taught students on this subject over a number of years.

Centre for Environmental Strategy, University of Surrey, Guildford, Surrey GU2 5XH, UK
s.cowell@surrey.ac.uk
http://www.surrey.ac.uk.CES

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In the last 30 years, a number of new approaches for environmental management have been developed for use by decision-makers. These vary from concepts such as sustainable development and industrial ecology to specific environmental management tools such as substance flow analysis (SFA) and environmental accounting systems. A number of these approaches are listed in Table 1; they are not described in detail in this paper but further information can be found in SETAC-Europe Working Group (1997).

There has been relatively little consideration of how the different approaches complement or duplicate each other, and their appropriateness and usefulness for different decision-making contexts, perhaps because the focus has been on developing the approaches themselves. This is certainly true in the case of life-cycle assessment (LCA), an environmental management tool for evaluating the environmental impacts of products and services from cradle to grave in their life-cycles. This led the Society for Environmental Toxicology and Chemistry (SETAC) to set up a Working Group in 1993 to consider 'LCA and Conceptually Related Programmes' as one of a number of working groups aiming to take forward the methodological development of LCA. The purpose of the group was to investigate the relationship of LCA with conceptually related environmental management approaches in order to enhance overall decision-making processes and reduce unnecessary duplication of effort. The group recently finished a report on its findings (SETAC-Europe Working Group 1997). It presents a framework for describing relationships between LCA and other environmental management approaches, and applies this framework to a number of different approaches. Others have also proposed similar frameworks, for instance van Berkel *et al.* (1997) who based their framework on a categorisation of applications for industrial ecology tools.

In this paper, we develop the framework as a basis for comparing all environmental management approaches (section 1), and illustrate its use for four approaches: industrial ecology, design for environment (DfE), environmental impact assessment (EIA) and environmental accounting (section 2). The framework is based on various methodological

*Table 1:* EXAMPLES OF ENVIRONMENTAL MANAGEMENT APPROACHES
*Source:* Adapted from SETAC-Europe Working Group 1997

- **Cleaner production**
- **Integrated substance chain management (ISCM)**
- **Cleaner technology**
- **Life-cycle assessment (LCA)**
- **Design for environment (DfE)**
- **Life-cycle thinking**
- **Energy and material analysis**
- **Product line analysis (PLA)**
- **Environmental auditing**
- **Risk assessment**
- **Environmental impact assessment (EIA)**
- **Substance flow analysis (SFA)**
- **Industrial ecology**
- **Total quality environmental management (TQEM)**

features of the approaches. Using such a framework gives us a better understanding of the structure and, therefore, appropriate use of different environmental management approaches. This should lead to improved and more efficient decision-making as different environmental management approaches are adapted and combined in response to the needs of decision-makers and relevant stakeholders. Section 3 provides some examples of how the framework can be used in this way.

## 1. The framework

Each approach can be understood as a means of collecting, structuring and conveying information about the world. Since the approaches do this in a variety of ways, they can be used to inform us in different ways. This is perhaps a trivial description, but it allows us to point out two important elements of the decision-making process: the approaches themselves and the situations in which the approaches are used. Hence the framework described below is structured for comparison of the approaches with regard to:

- **Contextual aspects** such as the types of decision-maker using the approaches and the objects analysed
- **Methodological aspects** such as which issues are considered, structural elements, and the types of data required

In addition, we distinguish a third group of *generic aspects*, concerned with the overall nature of the different approaches. Within these three groups, the approaches can be compared and discussed for a number of specific aspects as listed in Table 2. Each of the approaches has its own terminology, and sometimes they use the same term with very different meanings (for example, the term 'life-cycle' in LCA and in life-cycle costing) or different terms that have the same meaning. In order to compare them, we have tried to establish a common terminology, and it is this that is presented in Table 2.

In the remainder of this section, we discuss each of these aspects and show how they can be used to describe the different approaches.

### Generic aspects

Generic aspects are concerned with the overall nature of the different approaches. Here, we identify one aspect: the nature of the approach.

#### Nature of approach

We have found that the approaches used for environmental management can be divided into concepts and tools. A *concept* in this case is an idea about how to achieve sustainability. Different concepts often originate from specific professional disciplines; for example, DfE is a typical designer's approach and cleaner technology is an engineering approach. Compared with concepts, tools represent a more specific type of assessment. A *tool* is defined here as an approach that typically consists of a systematic step-by-step procedure and a mathematical model. For example, in LCA the procedure consists of goal definition and scoping, inventory analysis, impact assessment and improvement assessment (terminology according to Consoli *et al.* 1993), and the mathematical model is the flow model used to calculate material flows and emissions from cradle to grave in the life-cycle. The relationship between concepts and tools is that tools are often used to support a concept in order to measure progress towards sustainability. For example, LCA can be used in the

| Aspects | Categories |
|---|---|
| **Generic aspects** | |
| *Nature of approach* | *Type:*<br>▸ Concept<br>▸ Tool |
| **Contextual aspects** | |
| *Type of decision-maker* | *Decision-makers:*<br>▸ Governments/authorities<br>▸ Industrial companies/business enterprises<br>▸ Non-governmental organisations (NGOS)<br>▸ Individuals (for example, as consumers) |
| *Overall purpose* | *Uses:*<br>▸ Decision support: operative or strategic<br>▸ Communication |
| *Object analysed* | *Focus:*<br>▸ Ecosphere<br>▸ Technosphere |
| *Perspective* | *Nature of perspective:*<br>▸ Prospective<br>▸ Retrospective |
| **Methodological aspects** | |
| *Investigated dimensions* | *Main dimensions:*<br>▸ Environmental<br>▸ Economic<br>▸ Social |
| *Character of the approach* | *Emphasis on procedure:*<br>▸ Problem identification<br>▸ Problem formulation<br>▸ Modelling<br>▸ Interpretation<br>▸ Implementation<br>▸ Feedback and learning<br>*Emphasis on modelling:*<br>▸ Flexibility in model(s) used<br>▸ Defined model(s) used<br>▸ Additional models used for interpretation |
| *Basis for comparison* | *What is kept constant in a comparison:*<br>▸ Measured environmental parameter or indicator<br>▸ Facility<br>▸ Quantity of product or service<br>▸ 'Total production unit'<br>▸ External standard or other level of acceptability<br>▸ Lifetime |
| *System boundaries* | *Spatial modelling:*<br>▸ One geographical area (single site)<br>▸ Many geographical areas (many sites)<br>▸ No defined geographical areas (no defined sites)<br>*Time modelling:*<br>▸ Snapshot view somewhere in time (past, present or future)<br>▸ Snapshot views at intervals over a period of time<br>▸ Whole lifetime included (use of discounting rate) |
| *Type of data (input and output data)* | *Subject of data:*<br>▸ Physical systems<br>▸ Social and economic systems<br>*Nature of data:*<br>▸ Quantitative<br>▸ Qualitative |
| *Evaluation of results/Interpretation* | *Presentation of results:*<br>▸ Single parameter<br>▸ Few parameters<br>▸ Many parameters<br>*Purpose of additional models for evaluation:*<br>▸ To aggregate data<br>▸ To identify critical data |

*Table 2:* ASPECTS OF ENVIRONMENTAL MANAGEMENT APPROACHES

context of cleaner technology to determine whether new technologies do, in fact, deliver overall environmental benefits to society (see e.g. Clift and Longley 1996).

## Contextual aspects

The contextual aspects of an approach describe the situation in which the approach is used: in other words the decision-making context. Typical descriptors concern the type of decision-maker, the purpose of using the approach, the object of the decision and the relevant time perspective.

### Type of decision-maker

Several types of decision-maker can be identified that use environmental management approaches. Four main categories are: *governments/authorities*, *companies*, NGOs and *individuals*. They will be involved in decision-making to varying extents, and will also involve other actors varying from analysts to data suppliers, the public and university researchers. Hence the approaches can be described by their main users, in other words the categories of decision-maker typically using the approaches and/or their results.

### Overall purpose

Environmental management approaches can be used for different purposes. It is not unusual to distinguish two main purposes: decision support and communication (Jansson 1992). Regarding decision support, decisions can be described as operative or strategic. *Operative decisions* are concerned with routine operating procedures. In contrast, *strategic decisions* involve development of new and most probably creative answers to unique situations (March and Simon 1958). In practice, it is usually difficult to distinguish clearly between operative and strategic decisions since routine and innovative elements are present in all decision situations to varying degrees (Hirschhorn and Gilmore 1992; Nonaka and Takeuchi 1995). Nevertheless, we use these terms here as general descriptors. The use of an approach for *communication* purposes can be exemplified by an NGO's awareness-raising campaigns or an environmental department's work to persuade other actors within a company. Using an environmental management approach for decision support usually implies that the decision-maker is informing him/herself about the problem at hand and the consequences of alternative solutions. This can lead to surprises and learning for the decision-maker. In contrast, using an approach for communication implies that the information is directed at others than oneself.

### Object analysed

The object analysed identifies the focus of the decision. For example, in SFA this would be the substance used in an economy, and in EIA it would be the siting of a facility. At a general level, it is possible to categorise approaches as either having an *ecosphere* or a *technosphere* focus. The first category implies a focus on use of land and the latter a focus on use of technological systems. Examples of decisions using approaches focused on the ecosphere include siting of construction projects and resource exploitation activities. Examples of decisions using approaches focused on the technosphere include choice of process technology and materials in products, or improvements in technical systems or performance rating of organisations/businesses.

### Perspective

A third contextual aspect concerns the perspective of the approach. Two categories can be distinguished: *prospective* and *retrospective* perspectives. Prospective approaches look forward in time. They are about choices between alternatives that are compared with regard to their predicted consequences. Prospective approaches are used to inform decision-making and are usually undertaken as specific, self-contained projects. An example is economic investment calculations. Retrospective approaches look back in time. They are about what has been accomplished, and can be used to identify evolving trends by monitoring and keeping track of past actions. Retrospective approaches are therefore often used at regular intervals, and can be useful for problem identification and stimulating the generation of ideas for alternative actions. They are the equivalent of accounting in economics.

## Methodological aspects

Through 'teasing apart' the methodology of an approach and looking at its constituent parts, we have been able to identify a number of general methodological aspects shared by the different approaches. Using these aspects, we can describe and compare the structure of the various concepts and tools in a common language. However, since tools are more structured than concepts and, because most concepts do not identify a specific methodology, the majority of these aspects are only valid for the tools and so are described below in relation to tools rather than concepts.

### Investigated dimensions

At a very general level, the types of effect studied using tools can be classified in either *environmental*, *economic* or *social* categories. Some tools focus on environmental effects such as quantities of natural resources used, wastes produced or on concentrations of substances and exposure of target organisms. Other tools may also include social and economic effects. For example, LCA is used to investigate environmental effects while EIA may be used to look into all three dimensions. Looking in more detail, one finds that classification of the effects considered by different tools into these categories is sometimes unclear. Indeed, some effects can fall into more than one category, and are also cause for debate in the circles of methodology developers. Should human health impacts arising from environmental change be classified in the social or environmental category? Is depletion of the stock of resources an economic or an environmental issue? Despite these complications, it is useful to classify tools in these categories because it helps us to draw links between different tools and determine their complementarity in terms of data requirements.

### Character of the approach

Tools often consist of both a *procedure* and a mathematical *model* of some kind. A procedure describes the best way of progressing towards a decision while a mathematical model aims to find (or at least progress towards finding) the best decision. Some tools emphasise procedure while others focus on the construction of a defined type of mathematical model. An emphasis on procedure does not imply an absence of modelling but usually indicates that there is a certain freedom of choice concerning which models can be used in the tool.

The procedure describes the stages included in the process of 'using' the tool. Typical stages are problem identification, problem formulation, modelling, interpretation, implementation, feedback and learning. The extent to which each of these steps is included in the methodology varies between tools. Some tools are more prescriptive concerning use of the tool in decision-making processes, and have more elaborate procedural descriptions. For example, there are legal requirements concerning the different stages of EIA in many countries.

The mathematical model is usually in the form of a computational algorithm: for example, a flow model with certain characteristics or a rigorous economic model. Sometimes additional models are used for interpretation of the results as well as the core model (for example, the impact assessment models used in LCA).

### Basis for comparison

Studies that inform decision-making concerning alternative actions must have a basis of comparison. In other words, something must be kept constant in all compared alternatives. This basis for comparison differs from tool to tool and is strongly related to the object analysed using the tool. In our overview of environmental management approaches, we have identified six types of basis for comparison:

- A measured environmental parameter or indicator (as in environmental accounting)
- A facility (as in using EIA for siting decisions)
- A quantity of product or service (as in LCA and product line analysis [PLA])
- A 'total production unit' (as in SFA and technology assessment)
- An external standard or other level of acceptability (as in risk assessment)
- A lifetime (as in investment calculus)

### System boundaries

If the basis for comparison is at the centre of the mathematical model used in a tool, then the system boundaries define the 'realm' of the model. This usually implies defining boundaries in space and time. *Spatial modelling* can be carried out in a number of ways. Some tools investigate only a single site, some aggregate information from many sites, and others use non-site-specific modelling (thus avoiding the problems of adding information from various geographical locations). *Time modelling* is not so straightforward. Assumptions about time are not always explicit in the tools, and the time dimension can therefore be somewhat invisible. However, its influence on the model can be shown by considering the validity of a model over time. For example, SFA gives a 'snapshot' presentation of current use of a substance in an economy that is unlikely to be relevant in ten years' time. However, snapshots taken at intervals can show trends evolving over time (as in environmental accounting). Another way of handling time is to include all effects occurring during, for example, the lifetime of a project and add them together using a discounting rate.

### Type of data (input and output data)

Tools require input data and produce output data. The data used in different tools can be categorised according to whether they are concerned with *physical* systems or *economic and social* systems. Examples in the first category are data on flows of energy and matter in technological systems and data on changes in ecosystems. Examples in the latter category are financial data and data on values held by humans. Another way of categorising data involves distinguishing between *quantitative* and *qualitative* data.

### Evaluation of results / interpretation

Output data are subject to evaluation of the results. The tools can deliver their output data in a *more* or *less aggregated format*. For example, results can be presented as single parameter, a few parameters or as many parameters. To facilitate evaluation, *additional models* for analysing the results may be used. These can reduce the number of parameters in order to simplify decision-making (for example, Global Warming Potentials [GWPs] provide a way of aggregating data on air emissions with a specific environmental impact), or show that certain data are particularly critical to the final results (for example, sensitivity analysis). When using additional models, the former output data become intermediate output data, and conclusions can be drawn at different levels of data aggregation.

## 2. Examples of approaches

### Industrial ecology

Industrial ecology is defined as the network of industrial processes as they interact with each other, not only in the economic sense but also in the sense of direct use of each other's material and energy wastes (Ausubel 1992). It is concerned with the evolution of technology and economic systems such that human activities mimic mature biological systems as regards being self-contained in their material and resource use (Allenby 1994). It can thus be regarded as a *concept* whose main purpose is defined as *communication*. However, examples of a more specific application of the concept in *strategic decision-making* exist, in the form of 'Industrial Ecology Parks' or 'Eco-Industrial Parks'. A number of these parks have been set up through the initiative of *companies* with the aim of maximising recycling and re-use of resources within a *specific geographical area* (see e.g. Côté *et al.* 1994; Ehrenfeld and Gertler 1997). However, as well as companies, the involvement of decision-makers in *government* is also necessary to create a regulatory environment that encourages industrial symbiosis. This may include measures such as high waste disposal costs, and taxes on pollution and virgin materials (Ehrenfeld and Gertler 1997).

The focus of industrial ecology initiatives has tended to be the *ecosphere*: in other words, the siting of industrial activities so that they can make use of each other's waste-streams. Indeed, the idea of 'evolution' of industrial processes to complement each other has not received much attention, and could make a stimulating contribution to operationalisation of this approach. This is an example of using industrial ecology with a *prospective perspective* but it may also have a *retrospective perspective*; for example, it provides a basis for evaluating existing industrial systems.

Many of the methodological aspects of the framework are not applicable to industrial ecology because it does not have a *defined procedure* or *model*, although natural ecosystems with their network of interacting processes are used as the 'role model'. The most relevant methodological aspects concern the investigated dimensions and type of data. Industrial ecology focuses on *environmental* effects, and considers *physical systems* in putting forward its ideas about pathways to sustainability.

### Design for environment (DfE)

DfE has been developed to integrate environmental considerations systematically into the design of products, processes and services. A number of methodologies have been suggested, varying from informal interpretation of a variable number of DfE strategies, to use of qualitative matrices, to detailed LCA studies of alternatives (Hodgson *et al.* 1997). As a result, DfE can be regarded as a *concept* or *tool* depending on the methodology used in a study.

Since DfE has strong roots in the design world, it has mainly been used in *operative* and *strategic* decision-making by *companies*. However, there has also been interest among *NGOs* in using the ideas of DfE to stimulate new approaches to design of products. For example, at a conference on 'Towards Sustainable Product Design', Greenpeace's Climate Campaigner gave a presentation on design of a new type of fuel-efficient car: the SmILE (Small, Intelligent, Light and Efficient) car (Hubmann 1997). Nevertheless, the focus of DfE remains on design of products (i.e. the *technosphere* in our framework) and comparison of *prospective* alternatives rather than taking a retrospective perspective, using a *quantity of product or service* as a basis for comparison.

Regarding its methodological aspects, DfE focuses on informing the *environmental dimension* of the design process. However, the need to balance environmental with economic and social considerations in decision-making is acknowledged to a greater extent in DfE than in many other environmental management approaches. Thus the outer boundaries of the design space (i.e. the conceptual area within which alternative design options are created and analysed) are consciously set by economic and social factors (to a greater or lesser extent) throughout the decision-making process.

To the extent that DfE can be regarded as a tool, the emphasis has been on *procedure* rather than modelling, in acknowledgement of the existence of LCA as an appropriate modelling approach for use in DfE studies. Guidelines about procedure are comprehensive, extending from problem identification through modelling to implementation. However, the need for simplification and *flexibility in modelling* using LCA methodology is also recognised in DfE, given typical decision-making contexts characterised by limited resources and tight deadlines. Thus aspects such as the *system boundaries*, *nature of data* and *presentation of results* are left to the discretion of users of the tool.

## Environmental impact assessment (EIA)

> EIA can be described as a process for identifying the likely consequences for the biogeophysical environment and for man's health and welfare of implementing particular activities and for conveying this information, at a stage when it materially affects their decision, to those responsible for sanctioning the proposals' (Munn 1979).

EIA is typically used for assessment of proposed projects such as construction of roads and bridges, siting of industries and landfills, and changes in waste-water systems (Wathern 1988; Gilpin 1995). The formal approach is one in which EIA procedures are defined by statute with additional detailed guidance on use of the procedures (Gilpin 1995). Although EIA is generally concerned with authorisation of individual projects, the concept has more recently expanded into assessment of policies, plans and programmes. It may then be called SEA (strategic environmental assessment). New terms such as LEIA (life-cycle environmental impact) have also been used for approaches based on EIA (Gilpin 1995).

The detailed descriptions of EIA procedure in statutes indicate that EIA can be regarded as a *tool*, and the uniqueness and scale of each project indicate that EIAs *support decisions* that are *strategic* in character. Since EIAs are always used for assessing proposed projects, this implies that they are used in a *prospective* way. The object analysed in all these applications is the *ecosphere*, since the focus is on identifying the environmental effects associated with use of land rather than on improving a technological system. The number of actors involved in the decision process is large, and their roles are usually defined in EIA legislation. The final decision-maker is usually a *regional* or *national authority*. However, it bases its decision on an EIA document produced by the *applicant*, i.e. the organisation responsible for carrying out the EIA in accordance with the regulations. As part of the process, the *public* is consulted and encouraged to participate actively in the decision-making process through, for example, meetings and responding to questionnaires. Also, the applicant must be in consultation with the *local land-use planning authority*.

EIA procedures do not give specific lists of issues to study but relevant issues are defined in the scoping phase of each study. These always include *environmental effects* and, in some countries, *social effects* are also investigated in the EIA procedure (Pellizoni 1992). All descriptions of EIA focus on procedure, and there is international agreement about the general procedure (Wathern 1988; Wood 1995). It encompasses more or less the whole of the decision-making process from definition of the proposal itself and considerations about whether or not an EIA is necessary, through to implementation and auditing after completion of the project. Regarding use of models for predicting emissions or their effects, EIA allows for *flexibility in models used*. It can therefore be said that the *emphasis is on procedure* rather than on modelling.

The basis for comparison in an EIA is the *facility*, usually comparing a proposed site or sites before and after construction. The emphasis on procedure means that explicit criteria for definition of system boundaries are difficult to find in EIA methodology. Since it is up to the participants in the EIA process to identify which impacts to consider, it is difficult to define system boundaries in general terms. In principle, it can be said that system boundaries are defined by the spatial and temporal distribution of 'significant direct and indirect impacts' caused by the planned project (Wood 1995), which leaves scope for very wide system boundaries. In practice, judging from the use of maps and the contents of many checklists used (Wathern 1988; Gilpin 1995; Wood 1995; RRV 1996), spatial modelling focuses on the *geographical area* around the planned facility. In temporal modelling, impacts from construction and operation of the facility are included, giving *'snapshot views'* of the present and future state of the geographical area. Most data collected in an EIA describe the *physical system* (such as emissions and geography of the site), but some refer to the *social system* (for example, the number of inhabitants affected in the vicinity of the site). They tend to be a mixture of *quantitative* and *qualitative data*.

The outcome of an EIA is usually a formal document. Results are presented in a number of ways, depending on the procedure and models used in the EIA process. Different types of environmental impact are usually described separately. In addition, methods exist to reduce all information to a single 'score' (see e.g. Leopold *et al*. 1971; Dee *et al*. 1973; Sondheim 1978; Wathern 1988). Their main purpose is to *aggregate data* in a way that incorporates the values of involved persons. Results can therefore be presented both in the form of a *single* and/or *many parameters*.

## Environmental accounting

Environmental accounting is a sub-area of accounting and refers to both national income accounting and corporate accounting. Environmental and traditional accounting are to a large extent based on the same principles. A difference is that environmental accounting relates to activities only with environmental connotations (ACCA/EPA 1995). Here, our concern is corporate environmental accounting, which is a very flexible *tool* with a host of applications. This tool can be sorted into two main types of application: financial and managerial accounting, which differ in overall purpose. The main purpose of financial accounting is *communication* with the external stakeholders of a company. The target audiences includes *investors*, *lenders* and *customers*. Traditional financial accounting enables companies to prepare financial reports following generally accepted accounting principles of accounting. The environmental version of financial accounting implies, for example, the preparation of environmental reports. On the other hand, managerial accounting is used as *decision support* internally in the *company*. Ideally, managerial accounting lays the foundation for all other accounting systems and for communication with external stakeholders (ACCA/EPA 1995; Schaltegger *et al*. 1996). The basic purpose of environmental managerial accounting is to account for the financial impacts of environmentally related activities such as environmental protection activities and investment. It primarily involves tracking and tracing of environmental costs (e.g. site-specific clean-up costs) but also allocation of costs to products and activities, investment appraisal and life-cycle costing (Schaltegger *et al.* 1996). Serving all levels of management in a wide range of situations, it is used for both *strategic* and *operative* decisions.

As corporate environmental accounting is used for controlling and improving a company's cost structure and environmental performance (ACCA/EPA 1995), it implies that the object analysed is part of the *technosphere*. Depending of the application, environmental accounting can represent either a *retrospective* or a *prospective* perspective. For instance, tracking of environmental costs is based on a retrospective perspective, while investment appraisal of an environmental project is made with a prospective perspective.

Practices and systems for environmental accounting vary according to the needs of different companies. Traditionally, accounting refers to a company's cash flow. In contrast, environmental accounting uses physical as well as monetary units. In its monetary form, it is used for investigating the *economic* dimension of a company's environmental operations. Accounting in physical units is used for describing the environmental dimension of the company's operations, and involves the tracking of a company's emissions and resource use. Regarding the monetary side of environmental accounting, it is worth noting that the term 'environmental cost' can refer to a company's private costs as well as those incurred to society and the environment (i.e. external costs). Furthermore, whether an environmental cost should be counted as an asset or an expense is a controversial issue for accountants (Schaltegger *et al.* 1996). Terms such as 'full', 'total', and 'life-cycle' are used to indicate a form of accounting that goes beyond traditional private cost accounting. In practice, there is yet little evidence of companies computing external figures, and whenever environmental accounting is used, the main emphasis is on private costs (KPMG 1996; Owen *et al.* 1997). However, the number of companies introducing environmental monetary accounting is expected to increase with increased environmental compliance costs (Schaltegger *et al.* 1996) and, in the United States, new regulations requiring the proper allocation of environmental compliance costs (Hamner and Stinson 1995). In all cases, however, data are mainly *quantitative* and concern the *economic* system (i.e. environmentally related costs in the economic system) and/or the physical system (for example, energy and raw material usage, and related emissions). Whenever external costs are included, the scope of data is expanded to also encompass *quantitative* and *qualitative* data about *social* systems.

Environmental accounting focuses on modelling, although procedural descriptions exist for traditional financial accounting. Depending on the application, different *defined types of model* are used, which describe the cash flow and/or physical flows of the company in various ways. For financial accounting, which is very regulated, the model is largely defined by generally accepted accounting principles. The regulations require the information to be faithfully represented, neutral (without bias), and complete. This is to ensure that financial reports give a true and fair view of the financial position of a company. To date, no standards regulate environmentally related financial information, although regulatory bodies are under increasing pressure to introduce such standards (Schaltegger *et al.* 1996). In comparison, since traditional and environmental managerial accounting is used in internal information systems, it faces no regulations. Managerial accounting can be divided into accounting of products, sites, divisions and the whole company (ACCA/EPA 1995; Schaltegger *et al.* 1996) which result in spatial modelling encompassing *one* or *many geographical sites*. Also the temporal modelling depends on the application. In the monitoring of environmental costs, the temporal modelling is based on *time series*. On the other hand, in the investment appraisal of a project, a *discounting rate* is used. The application also determines the basis for comparison which can be anything from a single, measured site-specific parameter to a company's total environmental spending. Examples of comparisons include comparison between different operations, development over time, with different budget levels and against external benchmarkers. The many types of possible comparison complicate generalisation. However, each comparison is often made on the basis of a single or a few parameters, which implies that many of the resulting initial parameters are *aggregated*. Cost parameters in particular lend themselves well to aggregation. Results typically consist of a set of measured cost and/or environmental parameters for the site, the division, etc. Parameters can be combined using additional models to provide key ratios such as eco-efficiency indicators to evaluate trends over time and to identify critical activities in the company.

## 3. Application of the framework

By considering the different aspects of environmental management approaches, we have been able to clarify how each approach can—or could—support decision-making in environmental management. Having identified aspects that are shared or different between approaches, it becomes easier to explore how approaches can be used to improve decision support in environmental management. Based on our research, we suggest that it is possible to define five basic relationships between approaches. They are illustrated in Figure 1, and are:

- **Consecutive.** The results of using one approach become the input data for another approach. An example is use of environmental accounting data in LCA.
- **Complementary.** Two approaches use the same basis for comparison but give different results because they investigate different dimensions. Here, making links between approaches that focus independently on the environmental and economic dimensions of environmental management may be particularly useful given the popularity of concepts such as the Best Practicable Environmental Option (BPEO) and Best Available Technology Not Entailing Excessive Cost (BATNEEC).
- **Competing/incompatible.** Two approaches use the same basis for comparison and investigate the same dimension(s) but give different results because they make different assumptions about the scope of the analysis, i.e. the system boundaries. In this case, it can be useful to clarify the assumptions underlying choice of the different system boundaries to facilitate constructive discussion about the most appropriate choice in a particular environmental management context. For example, EIA and LCA use different system boundaries (generally defined by geographical location in EIA and defined in relation to a product or service in LCA). However, it may be possible for the two tools to complement rather than compete with each other in certain environmental management contexts (Cowell *et al.* 1997).
- **Encompassing.** One or more approaches form an integral part of another approach. Often environmental management approaches encompass one or more tools. Thus EIA can be viewed as a tool within the industrial ecology concept because it focuses on processes and flows of materials within a defined geographical area, and industrial ecology is concerned with networks of industrial processes and their physical relationships.
- **Overlapping.** Both approaches give the same result because their methodological aspects are identical. An example is LEIA, which appears to be equivalent to LCA in terms of its results (Gilpin 1995).

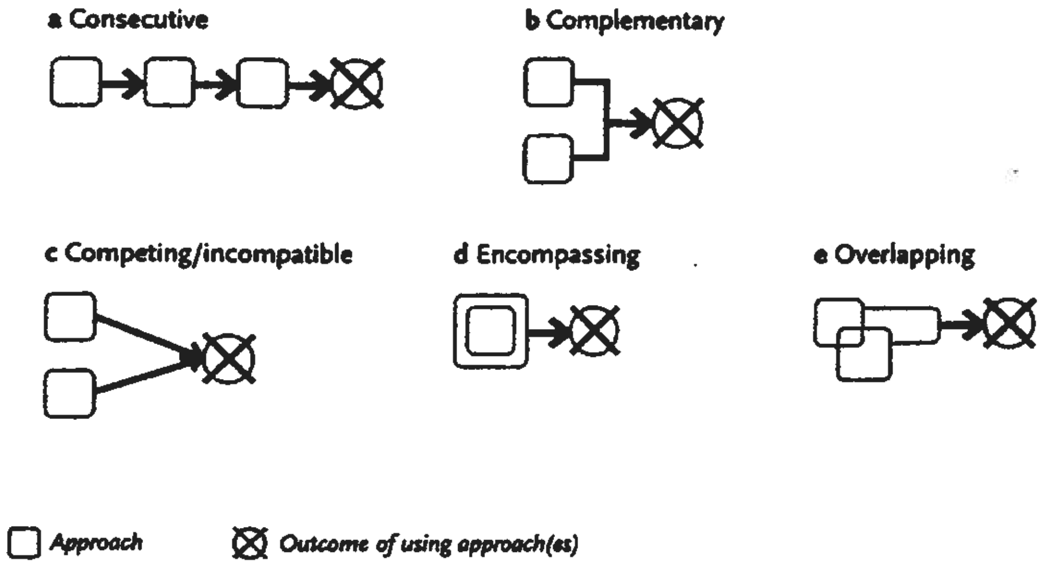


*Figure 1:* RELATIONSHIP BETWEEN APPROACHES

## Conclusions

The increasing number of environmental management approaches 'on the market' has led to some concern that there may be duplication of effort in developing and attempting to operationalise these approaches. This duplication may not be obvious initially because the approaches use different terminology. This is often because concepts and tools originate in different professions. Therefore, in this paper we have developed a common framework and terminology for describing the approaches. Use of the framework suggests that approaches can be used consecutively, or be complementary, competing, encompassing or overlapping in their applications. Our research suggests that there is considerable scope for exploring these relationships between and within concepts and tools, and we have given a few examples in the previous section. Rather than developing new tools for environmental management, it may now be appropriate to focus on practical integration of existing approaches for different applications.

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