CHAPTER 8

USING SOFTWARE SYSTEMS TO SUPPORT ENVIRONMENTAL ACCOUNTING INSTRUMENTS

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Abstract. In the past 25 years various information instruments for environmental management have been developed. Some of them focus on the production process and hence can be called "process oriented". The most important process-oriented instruments are corporate input-output balance, Environmental Performance Indicators and methods of flow cost accounting. They are described and compared in this paper. Benefits for the use of the different instruments are shown. For a continuous use of Environmental Accounting Instruments in day-to-day environmental management, these instruments need to be supported with modern information technologies. This paper shows IT strategies on how to integrate Environmental Accounting functionalities into a Business Information System, which are discussed and partly supported by results from two surveys. The benefit of a structured approach to develop and integrate Environmental Accounting functionalities into a Business Information System is shown. A process model for the IT implementation of Environmental Accounting instruments taking into account the integration into existing business software is presented based on the prototype model. The nine phases of the model are described and discussed. A case study at the glass manufacturing company SCHOTT Glas shows how Environmental Performance Indicator Systems can be implemented in SAP R/3 and in ERP Systems in general. The findings presented here are results from the research project INTUS[1].

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1 CONTROLLING FUNCTIONS OF ENVIRONMENTAL MANAGEMENT

1.1 Objectives of Environmental Management in Companies of the manufacturing sector

According to the position of the European Commission (2002 p. 23), environmental management holds a key role within the concept of corporate social responsibility (CSR) in the manufacturing sector. Environmental improvement measures have to be identified, analysed, managed and controlled with respect to financial and environmental effects. New targets have to be set on a regular bases within a management cycle in order to achieve continuous improvements. Within such a management cycle, information from different company units has to be gathered and consolidated. These are a typical controlling tasks but they all focus on environmental data, so they are usually carried out by the environmental management unit. The environmental manager edits environmental information and makes it available to a variety of company officers including himself as a basis for decision-making.

New interfaces for environmental information flows emerge, which require a systematisation and integration into the organisational structure of the company (Müller-Christ, 2001). Hence, the controlling function of environmental management comprises the following functions (Wöhe, 2002):

- Information supply and choosing the right instruments for it (see below)
- Coordination of environmental issues within corporate planning
- Managing and controlling environmental issues within the realisation of corporate measures and with respect to the environmental dimensions of corporate strategy

A prerequisite to ensure these functions is the availability of relevant information on the environmental performance and environmental aspects of the enterprise in an efficient information system. Nowadays, such an information system can be implemented by means of software. This facilitates the consolidation and aggregation of environmental information such as indicators on resource and energy consumption, waste disposed of or wastewater and air pollution emitted.

1.1.1 Instruments of Environmental Accounting

For the controlling function of environmental management various instruments of environmental accounting have been developed in the last 25 years[2]. They can be categorised according their purpose and focus on:

- Product-oriented instruments (e.g. life cycle assessment instruments)
- Process-oriented instruments (e.g. Environmental Performance Indicators)

The product-oriented instruments focus on the environmental aspects of the products and provide information for environmental product design. Within these instruments life cycle assessment according to ISO 14040 ff is one of the most important ones. Product-oriented instruments may serve various purposes such as design of environment (DFE) (ISO/TR 14062), environmental labelling (ISO 14024) and laws and regulations. The provision of instruments and information for DFE can be seen as part of the controlling function of environmental management.

The process-oriented instruments focus on the environmental aspects of the production process in industry.[3] The most important process-oriented instruments are corporate input-output balance, Environmental Performance Indicators and methods of flow cost accounting (Strobel, 2001). They are all designed to support environmental management by supplying information on the environmental performance with the focus on material and energy flows.

Due to their different focus and purpose, the process-oriented instruments and the product-oriented instruments have to provide very different kinds of information. The distinction between product-oriented and process-oriented instruments is simple but within each category there is an overlap between the functionality of the instruments, and there are different software solutions available to support the collection and calculation of the information needed. In the following the focus is set on process-oriented instruments in order to discuss function overlaps and to introduce modern solutions for software support.

1.1.2 Environmental Performance Indicators

The most popular of the process-oriented instruments are Environmental Performance Indicators (EPI).[4] Their implementation and use is described in various guidelines (BMU, UBA, 1997, LFU, 1999, WBCSD, 2000) and even within the ISO 14000 series (ISO 14031). EPIs are absolute or relative measurements with environmental focus. They can be used to describe amount, mass, concentration, costs or other environmentally relevant figures within the company. With EPI, actual performance can be compared with targets to make sure that targets and objectives are reached (e.g. Kottmann et al., 1999). This management cycle is described as a plan-do-check-and-act process within ISO 14031. EPIs are further used for environmental communications in especially in environmental or CSR reports. The importance of external reporting is stressed by the European Commission which asks all European stock listed companies to give details of their social and environmental performance in their annual report. (European Commission, 2001).

1.1.3 Input-Output Balance

The corporate input-output balance (also called input-output account by Schaltegger and Burritt, 2000) is one of the first instruments developed for environmental management. The first projects were reported in the middle of the 1980s (e.g.

Projektgruppe Stoff- und Energiebilanzen, 1984). A corporate input-output balance lists all materials and energies used as inputs and on the other hand all products, waste and emissions for a certain period of time, usually for one year. The name balance is derived from the balance sheet in financial accounting. In Europe, especially in Germany, Austria and the Scandinavian countries, EMAS (Parliament and Council of the European Union, 2001) was a main driver in spreading the instrument, as EMAS companies have to give a quantitative overview of their relevant environmental aspects. In Denmark and in the Netherlands, mandatory reporting laws demand the publication of input-output balances from the most relevant polluting industries in their country (Danish Environmental Protection Agency, 2003).

Hence, input-output balances mainly serve especially three purposes. They provide a systematic background to identify the relevant environmental aspects, they provide information for environmental communication and they are a starting point to identify environmental protection potentials.

1.1.4 Flow Cost Accounting

According to a study carried out by Loew et al. (2001), flow cost accounting, mainly developed by Strobel (2001) and in a modified version by Fischer (2001), is one of the most developed approaches of Environmental Cost Accounting[5]. This and other related material flow-oriented cost accounting approaches were developed in the late 1990s when it was recognised that the calculation of environmental protection costs does not in itself provide sufficient information to identify measures to improve eco-efficiency. At this time it became clear that for this purpose the focus had to be directed to materials and energy flows.

The basic idea of flow cost accounting is to gain transparency in material flows in order to assign to these all the costs that they cause, from procurement up to disposal or sale by the company. By doing so, one main weak point of conventional cost accounting is tackled: The lack of transparency of the material flows in the cost centres. The improved cost information provided by flow cost accounting helps companies to identify inefficient material use in their production process. The implementation of flow cost accounting can also have a significant effect on the mutual understanding between the controlling department and the environmental manager. The focus of the controlling department is widened to material flows, whereas the environmental manager receives financial information on the hazardous and in other sense environmentally relevant materials, waste and emissions.

As Flow Cost Accounting is further developed it turns out that this approach is more and more becoming a conventional improvement of the cost accounting system with rather an economic then an environmental focus. As this partly is valid for EPIs too, it can still be seen as an Environmental Accounting Instrument.

1.1.5 Comparison of Instruments

The above instruments of environmental accounting show some overlap in their functionality. They can all be used as a tool to identify environmental efficiency potentials. This overlap was the starting point for an in-depth comparison of these instruments in the research project INTUS based on empiric evidence from four case studies with industrial companies.

The result of the comparison is shown in Table 1. It turns out that input-output balances are only one of the three instruments which supports environmental management to identify the relevant environmental aspects of the production site. Only a complete overview of all inputs and outputs enables environmental management to identify all environmental aspects with certainty. This does not mean that the quantities for all in and outputs have to be determined. Here a focus on relevant material and energy flows is sufficient. As a consequence of this finding, companies which alter their products and/or their production process have to work out an input-output balance on a regular basis, e.g. every two or three years. As the input-output balance does not sufficiently support all tasks of environmental management it needs to be combined with further information instruments which provide more detailed information for shorter time periods.

Out of the three discussed instruments Environmental Performance Indicators support the largest number of environmental management tasks. They can be used in an analysis to identify cost saving and non-cost saving environmental protection measures. When provided regularly, they can promote continuous improvements, continuous measures, compliance and information for mandatory reports to environmental authorities. Additionally, EPI can be integrated in the regular Management Performance Indicator System of the enterprise, which is a standard instrument to control corporate activities. For many companies, Environmental Performance Indicators provided regularly and an input-output balance every two or three years seems to be a good combination for ambitious environmental management.

Now and again flow cost accounting is discussed as a powerful instrument to both improve corporate cost accounting and to exploit existing eco-efficiency potentials. A closer look at pilot projects showed that flow cost accounting is usually combined with performance indicators, as for some purposes cost information is more convenient to interpret physical information. But when flow cost accounting is introduced, the set of Environmental Performance Indicators is smaller then without flow cost accounting. So due to the trade offs, flow cost accounting is not a simple additional tool, but it entails a different design of the EPI set. Still flow cost accounting is the less common instrument in practice which seems to be due to the following reasons: The use of flow cost accounting for a single analysis does not need too much effort but already gives helpful information on available cost saving environmental protection potentials. On the other hand, the implementation of flow cost accounting in the existing cost accounting system demands a lot of effort and know-how and usually cannot be done without external consulting. As it turned out in various pilot projects, the implementation of flow cost accounting is only to be recommended under the following circumstances (Loew, 2003):

- High material costs and high value added within material losses
- High complexity of material flows
- Fully developed cost accounting system
- Sufficient database in material-management

If all these characteristics apply, flow cost accounting should be an interesting option to improve the existing cost accounting system. For all other companies – and this seems to be the majority – the combination of the instruments Environmental Performance Indicators and input-output balance is recommended.

Table 1. *Benefits of the instruments for environmental management (Loew, 2003)*

Benefits for environmental management (*further benefits in italics*)	Input-Output *Balance*	Environmental *Performance* Indicators	Flow Cost *Accounting*
Identification of relevant environmental aspects	l	m	m
Exploitation of cost saving environmental protection potentials (single measures)	l	l	l
Exploitation environmental protection potentials which are not cost saving (single measures)	l	l	m
Support of continuous environmental protection measures / promotion of continuous improvements	m	l	m
Illustration of trends in corporate environmental performance	w	l	w
Compliance	m	l	w
Information for environmental / sustainability reporting	l	l	m
Information for mandatory reports to environmental authorities	m	l	m
Improvement of the corporate cost accounting system	m	m	l
Identification of cost saving potentials (*without environmental benefits*)	m	m	l

key:

l = relevant support by the instrument,

w = partly relevant support by the instrument

1.2 Advantages of IT support for Environmental Management

A major problem in industrial practise is that Environmental Accounting Instruments such as Environmental Performance Indicators are usually generated and interpreted by experts in the environmental management system. Often this expert information is not integrated into a broader scope of business functions. Therefore, many decision making-processes in the general management system cannot be supported. To alleviate this situation it seems to be crucial to focus on the following issues:

- Environmental information often has expert character. Hence, it is necessary to set up Environmental Accounting Instruments to structure this information. They can make the underlying facts understandable for managers without expert knowledge in this field.
- Environmental information is often generated separate from other business information. Thus, it is necessary to integrate Environmental Accounting Instruments into the existing IT infrastructure to reach all relevant persons in the company.

Environmental information can be processed in separate Environmental Management Information Systems (EMIS) or in the existing IT infrastructure (see Page and Rautenstrauch, 2001). In general, Environmental Accounting Instruments integrated into a company's information technology (e.g. in the form of an IT-integrated EPI system) can lead to the following benefits for corporate controlling:

1. Increased information quality within the enterprise
The quality of information regarding environmental and controlling concerns can be increased. An IT-integrated Environmental Accounting Instrument such as Environmental Performance Indicators (EPI) does not necessarily mean that new data are generated, unless new data are collected or gathered automatically. However, existing data can be put into a new perspective and thus create new information in a more efficient way. New references can evolve, such as resource consumption compared with costs or production output. This leads to new information resulting in a better knowledge of what occurs within the enterprise. Additionally, information can then be provided continuously, and be supplied much quicker in a timely manner with easy-to-handle methods. If related directly to cost centres, environmental information can serve as controlling figures.

2. Improved measures for strategy implementation measures
With an IT integrated Environmental Accounting Instrument, new measures become available for the operative controlling of an enterprise. New strategic goals can be derived that can be monitored quantitatively with the higher information density achieved. Information distributed in different parts of the company can be efficiently consolidated in a way to support a management cycle for "green" measures to put into place. On the one hand, the instrument can be used to manage and control goals, and on the other hand, it can be used to derive new goals.

3. Higher Transparency within the Enterprise
An effective access to a highly detailed Environmental Accounting Instruments facilitates a more timely reaction to new challenges at the plant or company level. However, such an increased transparency over cost centres or business divisions can lead to new conflicts of goals. Managers responsible for adverse environmental effects can be forced to explain themselves, which in turn can lead to a rejection of the instrument.

To conclude, an IT-integrated environmental accounting system can provide a systematic basis for an effective diffusion of environmental information into all areas of decision-making in a company. IT makes the continuous supply of user-related information supply.

1.3 Requirements for IT support of Environmental accounting

Workshops and interviews with practitioners of the four pilot companies in the research project INTUS stipulated the following requirements towards an IT-integrated environmental accounting system in order to support planning, management and control of environmental impacts within a producing company (criteria derived from Müller-Christ, 2001 p. 355 and adapted in interviews):

1. Completeness
The completeness of environmental information has to be assured through incorporating different business information such as for instance production amounts, cost information to build indicators with a high significance.

2. Reduction of Complexity
The complexity of the information has to be reduced by supplying information aggregated over business divisions or cost centres and with an appropriate time reference, and by joining indicators into subject groups.

3. User Specific Views on Information
Role concepts have to be defined to allow the user specific views on environmental information. The goal is to allow customized views for the individual users. Since such information can be sensitive and confidential, misuse has to be prevented.

4. Systematics and Plausibility
The collection of data has to be organized in a systematic way and should be plausible and easy to understand for the personnel involved. It should be coordinated by a central officer. The definition of separate business processes for collecting data can lead to systematic data administration and high data quality ensuring a high acceptance of the Environmental Accounting Instruments. This is the more important, the

more environmental aspects become part of a business unit's set of goals, and even wages are connected to the environmental performance of the business unit .

Allocation to Place of Origin
Environmental impacts should be allocated to the place where they originated, if possible on a high level of detail. This can point to measures on how to reduce the environmental impact. If possible, cost centres should be used as such a place of origin. Through this, the environmental and cost responsibility are connected leading to a clear connection with a responsible officer alias the cost centre manager.

1.4 IT Strategies to Integrate Environmental Accounting Functionalities into a Business Information System

Environmental information can be integrated into the information technology infrastructure of a company by adapting or enhancing the existing information system without re-engineering[6]. Rikhardsson identified four general approaches to this strategy (Rikhardsson, 1998, pp. 112-119):

1. In the *office application approach*, standardized office application software for desktop PCs are used, such as text processing, spreadsheet or database applications. This setup is very easy to handle, easy to adapt, and only requires limited training, since the software used is often used for other business purposes already. However, it often creates information islands that are isolated from each other and access is dependent on the staff using it, since the application will often be adapted in a way that is difficult to comprehend by others.
2. Using a *company-wide software system without modifications* of the program code has become more attractive during the last couple years, since the ability of such applications, especially ERP Systems [7] such as SAP R/3®, Oracle®, Baan®, Navision Financials® increased rapidly. ERP Systems and their data are a valuable information source for environmental information and supply functionalities to process it.
3. Using *Environmental Management Information System modules* in ERP Systems: This approach has been given a lot of attention in the past when it comes to the implementation of new functionalities to collect, store, evaluate and display environmental information. It was assumed that such modules would be further developed in a fast pace to administer more and more environmental information (Rautenstrauch, 1999 p. 57, Rikhardsson, 1998 p. 155).

4. In the *Data Warehousing approach*, data is collected from existing information systems in a company and consolidated in a central database (i.e the data warehouse or business warehouse) to facilitate evaluations. This approach has become more and more standard practise for traditional business data and can be used for environmental data as well.

After technological advances in the past years, the situation at present looks as follows:

The office application approach (approach 1) is still widely used in environmental management in manufacturing companies as a survey conducted in the research project INTUS[8] showed . Another survey conducted by IAT University of Stuttgart showed that the hopes of further development of Environmental Management Information System modules (approach 3) have not been fulfilled: Questionnaires were sent to 151 ERP software companies from Germany, Switzerland and Austria in 2001 (Rey et al., 2002). The goal of the survey was to assess to what extent ERP systems can support different tasks of environmental management. Nine per cent of the questionnaires were returned. One of the questions inquired about the controlling features of the systems. There were questions as to whether the integration of environmental goals in the corporate goal system, the aggregation of environmental data for input-output balances can be performed, whether the environmental performance of a company can be evaluated, whether measured data can be compared with target data, and whether eco-indicators can be defined.[9] Answers showed that most ERP systems (71%) do not have any functionality to incorporate environmental accounting features into their system. Other functionalities were prevalent but with a percentage result of less than 30 per cent (see Figure 1).

Data Warehouse functionalities (approach 4) have been integrated into conventional ERP Systems in the last couple years. So-called Management Information Systems were the starting point of that development. They were the precursors to the now prevalent Data Warehouse or Business Warehouse modules that are often part of the ERP System as a separate module or as an integrated part of the ERP System. They provide functionalities to extract data from the operative ERP environment, import data from other data sources, consolidate the data to form a common data base, calculate indicators, which can be stored over long periods of time for time series evaluation, and graphical evaluation of the data. Some work has already been conducted on using data warehouses for environmental accounting (Pfennig and Scheide, 2002).

Approach 2 to use a company-wide software system without modifications has been further developed in the research project INTUS. ERP systems can mainly support environmental accounting in two ways: by supplying the required data for environmental information, and by supplying functionalities to integrate Environmental Accounting Instruments into business processes with regard to analysis and evaluation of production impacts. Within the research project INTUS, concepts were developed and implemented with pilot companies for these two aspects:

- Extension of material master data with a numerical "eco-key" to evaluate material input bookings with regard to environmental aspects and to display them in a corporate input-output balance.
- Extension and adaptation of existing business intelligence functionalities to collect, store and evaluate environmental data in order to calculate and display Environmental Performance Indicators.

The second concept will be presented in the case study in section 3 of this article.

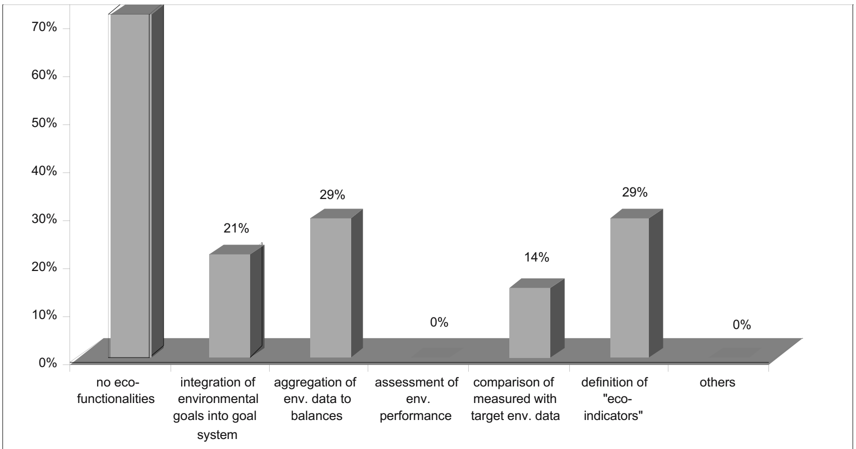


Figure 1. Results of a survey among ERP vendors in Germany, Austria, and Switzerland with respect to a question for environmental accounting functionalities (see footnote 9)

2 A STRUCTURED APPROACH TO DEVELOP AND INTEGRATE ENVIRONMENTAL ACCOUNTING FUNCTIONALITIES INTO A BUSINESS INFORMATION SYSTEM

When conducting a project to implement an Environmental Accounting Instrument into the information technology infrastructure of a company, organisational as well as IT aspects have to be considered. Work with the four pilot companies within the research project INTUS showed that a structured approach to conduct such a project facilitates the project progress and its success.

In the literature, different phase concepts dealing with software development are well established. The basis of all these models consists of the following steps: requirements definition, development of a preliminary concept, verification, modification and refinement of the preliminary concept, implementation, testing, final installation operation and maintenance (Krcmar, 2002 p. 123).

In practice, process models are defined based on such phase concepts, consisting of different steps that are well separated. Examples for such process models are the prototype model, waterfall model, or the V-model (Balzert, 2000 or Sommerville, 2000). Process models to implement Environmental Information Systems in the literature have a rather general character and are focused on software modules already existing on the market (Rikhardsson, 1998 pp. 121-123 or Tschandl et al., 2003). Methods presented here focus on the development and implementation of IT-based Environmental Accounting Instruments in already existing business software such as an Enterprise Resource Planning System (ERP System).

Experiences within software development in general have shown the following key problems within software development (Balzert, 1998 p. 114).

- Client and user are often not capable to define their requirements completely. This makes an intensive interaction between users and developers necessary.
- Some development tasks can be solved with several different development methods. After an experimental development of different solutions, a discussion with all relevant people has to be conducted in order to find the best solution.
- Within decision-making about a certain project in a company, it is sometimes necessary to convince the client about the feasibility of an idea.

These problems can, at least partially, be solved with the so-called prototype model. Balzert defines a software prototype as follows: „A software prototype shows a choice of features of a target product in a practical application. It is not only a simulation of the target product“ (Balzert, 1998 p. 114). A prototype can be used to clarify relevant requirements or development problems. It can serve as a discussion basis and can be used experimentally to collect practical experiences (Balzert, 1998 p. 119). Software prototypes can be used to validate requirements, i.e. to find faults, inconsistencies and open questions in the proposed requirements (Sommerville, 2001

p. 181). Developing software with the prototype model necessitates an intensive cooperation of the prospective users and the direct contact of all persons involved in the development process. As a result, risks within development can be reduced, the creativity for solution alternatives can be stimulated, and client and end users can be involved well in the development process (Balzert, 1998 p. 119).

Prototypes are of special interest for the information technology-based implementation of Environmental Accounting Instruments. The experience from work with manufacturing companies in the research project INTUS showed that such an implementation has the following characteristics:

- The involvement of company staff with different backgrounds (e.g. environmental officer, environmental manager, controlling department, IT department, management) leads to a high potential for multi-disciplinary miscommunication. A prototype can serve as the basis for communication and support the process of requirements definition.
- Information might have to be used that was formerly used by single users and tailored only to their needs[10]. This information can often not be accessed by others and is prevalent in so-called information islands. A prototype can serve as a means for integrating all these information.
- Environmental accounting instruments are still not much known to many manufacturing companies. Their adaptation to the company's needs is still characterised by many misunderstandings about their capabilities and their characteristics. Thus, the information needs for the different users and required functionalities can often not be clearly determined. A prototype can visualise planned functionalities and make them tangible for users. It can lead to learning effects and serve as a driving force in the development process.
- In order to implement such instruments into the IT infrastructure, the benefit of such an implementation has to be shown clearly to all people involved. This can be a time-consuming and complicated task. The prototype model incorporates intensive user involvement, which can help to convince members of the project team and prospective users of the project benefit and motivate them.

The prototype model is a good basis to take all this into account. Balzert and Sommerville offer a detailed description of this model[11]. It was adapted within the research project INTUS and further developed to a process model for the IT implementation of Environmental Accounting Instruments taking into account the integration into existing business software. This modified prototype model consists of the nine phases shown in figure 2.

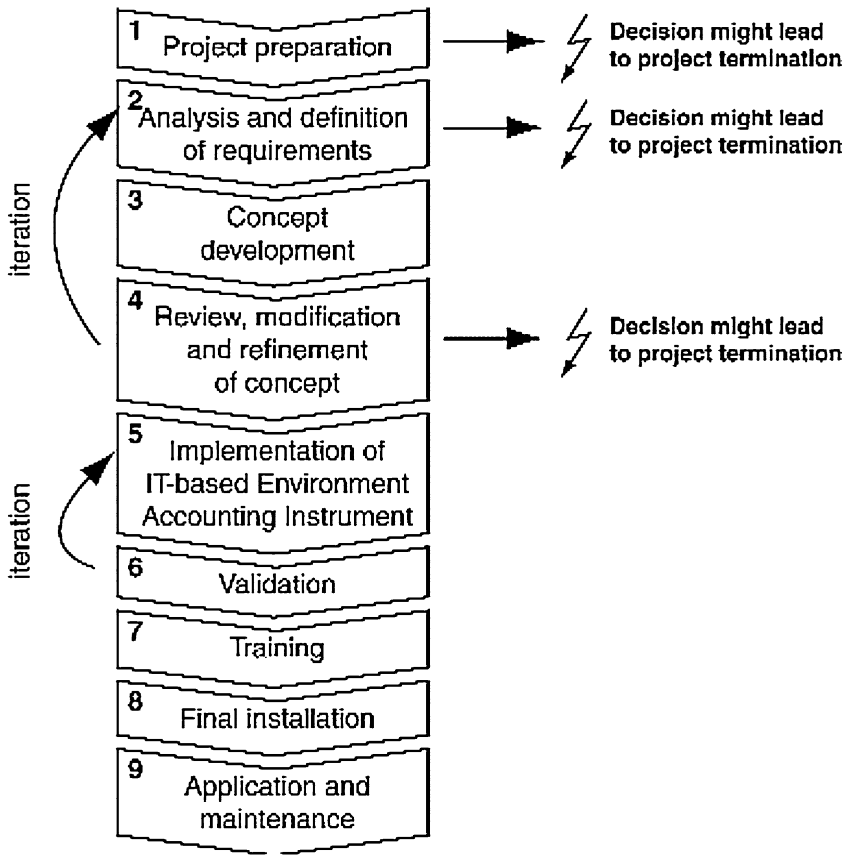


Figure 2. *The Structured Approach to Develop and Integrate Environmental Accounting Functionalities into a Business Information System*

1. Project Preparation

A rough pre-analysis has to be conducted to specify the needs for Environmental Accounting Instruments. A pre-choice of the instruments to be applied has to be made and put into the context of the company. The project has then to be defined and the project team has to be assembled. Choosing the right people as team members is crucial for the project success. Important aspects are whether a prospective team member can either bring in concrete experience and knowledge to work on specific tasks in the project (a so-called know-how promoter) or if he or she has certain sources of power within the enterprise to help overcome barriers within the course of the project (a so-called power promoter). The project coordinator is regarded as the process promoter and must have the ability to mediate between the various team members and to override administrative barriers. Hauschildt offers a description of different promoters in innovation projects (Hauschildt, 1997).

2. Analysis and Definition of Requirements

In the second phase of the process model, organisational, technical and information technology prerequisites have to be examined. This is followed by the development of solution alternatives and a study of their feasibility. After choosing one of these alternatives in a management decision, a product specification is drawn up. These steps will be described in more detail below:

The requirements for environmental information and functionalities should be analysed involving prospective users from all business divisions of the enterprise. Interviews should be conducted to collect these requirements. Collected requirements have to be structured and prioritised. Such an analysis is an iterative process and can be supported by standardised methods such as the VORD-Method (Viewpoint-Oriented Requirements Definition (Sommerville, 2001 p. 127)).

When analysing requirements, three dimensions should be regarded (Sternemann, 1999).

- Information demand: which information does the user need (e.g. performance indicators, material properties, environmental costs, documents, …)
- Business process: which business processes or activities are to be supported with information (e.g. investment decisions, process optimisation, product design, legal requirements, …)
- Scope: which scope is effected by decisions? (e.g. product, production, personnel, organisation, …)

At the same time, existing environmental data should be analysed. This analysis is the basis for a uniform data structure to be developed at a later stage. Data can be available in different structures and formats depending on the standard software used in the company. In addition, data relevant for environmental accounting can also be found in software run as stand-alone systems not connected to any other system.

Solution alternatives have to be defined specifying the use of instruments, their detail with respect to time and space within the enterprise. It should be evaluated how functionalities of existing IT systems can be used to support these alternatives. A brief feasibility study should then be performed for these alternatives including a cost benefit analysis. This can be followed by a management decision on whether to continue with the project and on which alternative to select.

The chosen alternative can then be described in more detail in a requirement concept containing a product specification. The most important part of this specification is the abstract description of the required product functionalities. A formal description language such as UML or ARIS can be used[12].

3. Concept Development

The product specification is the input for the development of a detailed concept for the implementation of the Environmental Accounting instrument in software. It contains the software architecture consisting of technical definition of functionalities within system components, technical requirements, data structures, required programme algorithms, interface specifications and the description of different user groups, their required reports as well as functionalities for data import and export. The use of a formal description language is pivotal to reach the best understanding between personnel from the environmental accounting team and software development staff.

The result of this phase is a concept for an IT-based Environmental Accounting Instrument put together in a so-called functional specifications concept. Some (but not all) aspects of this concept should then be implemented in a software prototype. The prototype should be able to visualise some evaluation capabilities as planned in the concept and should be designed in a way that it can be continuously expanded towards the final IT-based Environmental Accounting Instrument.

Experience from the research project INTUS shows that the concept development as well as the next phase should be performed in a small team, whereas feedback from prospective users should be gathered at a later stage.

4. Review, Modification and Refinement of Concept

The fourth phase of the process model contains a review and an intensive testing of the prototype by the project team using example cases and exemplary data from the real company environment. Prospective users will be included into testing at a later point to make it more efficient. Testing consists of validation (which ensures that the software meets the requirement of the users) and verification (which ensures that the software conforms to specified functional and non-functional requirements) (Sommerville, 2000 pp. 419-420). The required changes have to be incorporated into the definition of requirements (phase 2) and subsequently into the concept development phase in an iterative process. At the end of this phase stands a decision on whether to continue the project and proceed to the fifth phase.

5. Implementation of IT-based Environmental Accounting Instrument

In this phase, the product architecture as described in the functional specifications concept will be implemented into programming code. This leads to a pilot system that has to be integrated into the existing IT infrastructure. Case studies performed with the four companies participating in the research project INTUS showed that today's ERP systems provide functionalities that can be used with relatively low effort to implement IT-based Environmental Accounting Instruments.

Parallel to this process, the required data to be used by the IT-based Environmental Accounting Instrument should be structured according to the rules defined in the concept developed in phase 3. It is necessary to obey this structure to facilitate the development of interfaces.

Through an organisational integration it should be assured that the implementation will be actively used later on. The use of the instrument should be integrated in the management system and business procedures of the enterprise.

6. Verification und Validation of IT-based Environmental Accounting Instrument
After the implementation, the pilot system will be verified and validated by the project team and the prospective users. Modifications will be carried out in an iteration of the implementation phase.

7. User Training
The training of users is an important phase, since it assures the acceptance of an IT-based Environmental Accounting Instrument. Training can be carried out by the project team. Either all users are trained directly by them or via intermediates using the train-the-trainer concept.

8. Installation of IT-based Environmental Accounting Instrument
After positively completing all tests and verifications, the IT-based Environmental Accounting Instrument can be installed.

9. Operation and Maintenance of IT-based Environmental Accounting Instrument
The operation and maintenance of IT products is often underestimated when planning the project. Efforts and costs can arise to adapt the product over the years due to a changed cost centre structure, new Environmental Performance Indicators, new production facilities or business units, technical updates of the software etc. As with IT personnel, a responsible person should be defined to carry out these adaptations, the operation and maintenance of the IT-based Environmental Accounting Instrument.

Experience from case studies within the research project INTUS led to the deduction of this nine phase model. It is well suited for integrating Environmental Accounting Instruments, Environmental Performance Indicators and input-output balances into existing ERP systems. A more detailed description of the nine phases will be published in another article. A case study will be described in the next section of this article.

3 CASE STUDY SCHOTT GLAS

SCHOTT is a technology company producing speciality glass for household appliances, display solutions, pharmaceutical systems, opto-electrics, and advanced optical materials and components. It has about 20,000 employees worldwide.

3.1 Initial Situation of Data Management at SCHOTT GLAS

At the beginning of the project, environmental information at SCHOTT was spread over different information systems. It represented specialized knowledge hard to trace back to its sources. This posed an obstacle to meet requirements of ISO 14000 or the EU Eco-Management and Audit Scheme (EMAS) within Schott's Environmental Management Scheme. In an implementation project of the research project INTUS, it was shown how that problem can be solved by integrating an Environmental Performance Indicator System into the existing ERP system. Schott's decision in favour of environmental performance indicators was based on two considerations. On the one hand, flow cost accounting did not seem to bring additional benefits in terms of better understanding of the costs of the material flows, as within each of Schott's production sectors the complexity of material flows is not so high. There is enough knowledge on the material cost of material losses and awareness on the value added which is wasted with additional losses (see above in the section Comparison of Instruments. So Flow Cost Accounting would not bring more benefits than the implementation of a comprehensive Environmental Performance Indicator system. On the other hand, Schott already had a variety of environmental information in different fields – water and energy consumption, waste disposal, amount of recycled material, emissions, information on occupational safety including associated costs. Originally, respective data was collected, stored and maintained in different divisions of the company in isolated Microsoft Excel databases, in computers for emission measurements required by environmental regulations, and in the existing ERP system, SAP R/3. Thus, collecting and processing data from heterogeneous sources to make internal and external reports took considerable time and effort. This stipulated the decision to store this data centrally in SAP R/3 so that Environmental Performance Indicators could be calculated as a basis for reports to be created directly in the system.

The company defined the following issues as relevant for an Environmental Performance Indicator System:

- waste balances,
- industrial health and safety reports,
- environmental protection costs, as legally required by the German Federal Statistical Agency,

• cost centre-based resource consumption for individual company divisions,

The existing data on these topics was analysed and restructured by topic according to a hierarchy. An Environmental Performance Indicator system was defined based on a general proposal for the chemical industry. EPIs cover absolute quantities and costs of materials, substances, and energies – for example, the amount of a particular production waste in kilograms. Relative EPIs set individual consumption values in relation to specific production output of different business units. The time resolution for the performance indicators ranges from a business year to one month. The EPIs were assigned to cost centres. The existing cost centre key could be used with minimal adjustment.

3.2 Implementation of EPIs in SAP R/3

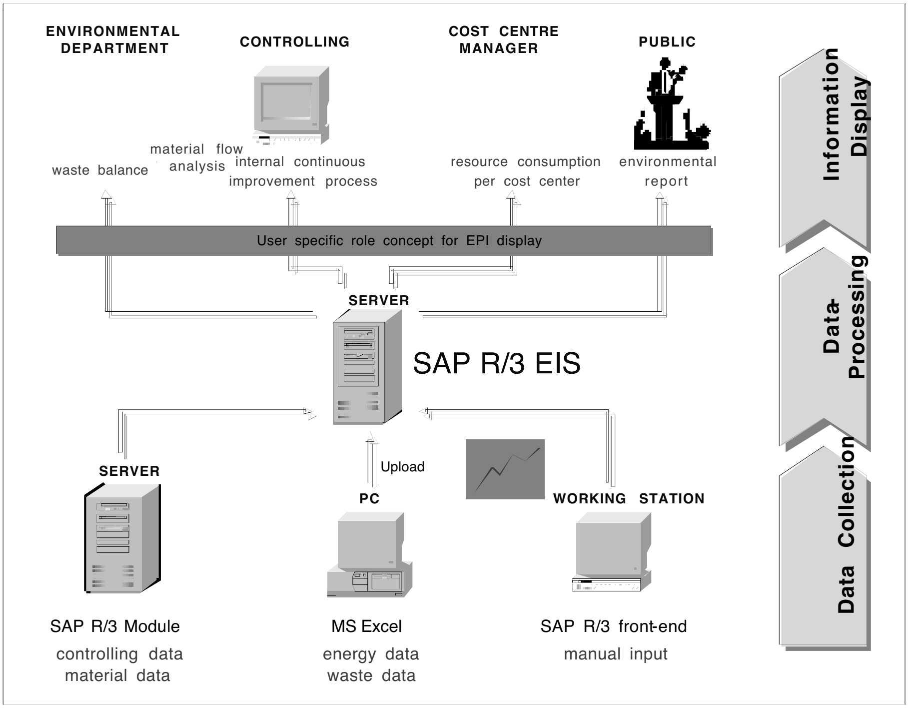
The EPI system was implemented in SAP R/3, which Schott had just migrated to. This migration was a good opportunity for the implementation of the EPI system, since there was still a high openness to change within the company. The EPI system was implemented in the Executive Information System (EIS) of SAP R/3. The EIS allows the easy definition of data structures and has reporting options available. The necessary data structure was created in a simple data table using so-called *aspects*. The data fields for the Environmental Performance Indicators were defined using a number key based on units (for example, kilograms, tons, kilowatt hours) and an additional field for costs. An additional field gives users the option to decide whether the performance indicator contains a planned or an actual value. Individual indicators can be assigned to a cost centre as well as a particular time period (for example, month or business year).

Data entry is performed monthly: SAP internal data is imported into the EIS, specialist information is uploaded from external data sources such as spreadsheet applications, and data can also be entered manually at the SAP front end. The Environmental Performance Indicators are calculated in EIS based on this data, and the details for each cost centre are displayed, as well as aggregated figures for different organisation levels.

EPI reports are used by company managers, division heads, and employees responsible for site controlling or environmental protection and industrial health and safety. A role concept allows the display of information tailored to the needs of the user. Three roles were defined: the display of a group of EPIs for all cost centres (e.g. for the occupational safety department), the display of all EPIs for one cost centre (for the cost centre manager), or the display of all EPIs for all cost centres (for the controlling department and plant management).

At the beginning of each month, the EPIs from the previous month are available. Users can view the indicators at their work place in SAP R/3, generate reports, and carry out evaluations. For the individual cost centre, the performance indicators are shown graphically or in multi-level lists and can be used as control quantities in decision processes.

Figure 3. *Integration of Environmental Performance Indicators at SCHOTT GLAS*



3.3 Flexible Concept of EPI Implementation in ERP systems

The implementation has shown that SAP R/3 can, with little tailoring, support planning and decision processes in the areas of industrial ecology and industrial health and safety. The programming required for the implementation of the EPI system was minimal, since existing import, calculation, and display functionalities of SAP R/3 could be used. However, the structuring of the imported data and associated discussions with staff in different areas involved significant effort – about as much as the implementation process.

The concept developed at Schott is flexible, adaptable, and transferable to other companies. In principle, an Environmental Performance Indicator system can be implemented using other SAP software, such as SAP Business Information Warehouse (SAP BW). Hence, environmental information can be integrated in SAP R/3 without the acquisition of new software. Functionalities similar to those used in this project can be found in many other ERP Systems on the market. Thus, the IT-based implementation of an EPI System is generally feasible in manufacturing companies using ERP systems.

The EPI system is currently being used at Schott. Existing work processes were adapted and new work processes are being created that enable better integration of environmental issues in standard business processes.

3.4 Benefits of Integration in this Case Study for SCHOTT GLAS

The case study SCHOTT GLAS showed that the integration of an Environmental Performance Indicator system can be realised within the existing information technology infrastructure using existing functionalities of the ERP system SAP R/3. Developing a uniform data structure for environmental data was a key issue and required approximately as much effort as the adaptation of the software. This has to be done once – the continuous effort to collect information is subsequently reduced. Expert systems in different enterprise divisions accepted by their users (mainly based on Microsoft Office applications) remained in use. However, data needed from these systems were integrated into the SAP R/3 system and evaluated in Environmental Performance Indicators. These are now available throughout the company and the generation of specific EPI-based reports contribute to a better diffusion of environmental information into the decision making at SCHOTT GLAS by supplying information tailored to the needs of the respective cost centre. Such a project cannot only be conducted using SAP software – many other ERP systems provide functionalities similar to those used in this case study.

Experience from the project with SCHOTT GLAS also showed that EPI were not only developed following set objectives in environmental management – existing EPIs can also lead to new objectives by combining information previously not linked, for example the relation of investments in occupational safety and work accidents, or the relation of energy consumption to CO_2 emissions.

It could also be shown that by integrating EPI into an ERP system, benefits additional to these mentioned in table 1 (section 1) can be realised. First, the use of the ERP system (well known to most employees as compared to new software) and the utilisation of a personalised user concept improves user acceptance. Standard interface functionalities already available within the ERP system can be used to gather data which minimises programming effort. Data availability, level of detail and the methodological approach of the Environmental Accounting Instrument to be used determine the need to integrate data from subsystems. If environmental questions such as the *polluter pays principle* are to be integrated into a company's organisation, the cost centre structure in the ERP system can be used if available with enough detail. Using existing data in the ERP system about material flows, costs, or occupational health leads to a common decision base for environmental and traditional business management. Using an ERP system for the IT support of Environmental

Accounting Instruments as opposed to developing a new software tool also means that the costs for maintenance and software support are lower throughout the lifespan of the software, especially since programming and maintenance know-how as well as reviews and audits already exist in the enterprise.

4 CONCLUSION

Out of the three discussed instruments, Environmental Performance Indicators support the largest number of environmental management tasks. When provided regularly, they can promote continuous improvements, continuous measures, compliance and information for mandatory reports to environmental authorities. For many companies, Environmental Performance Indicators provided regularly and the set up of an input-output balance every two or three years seems to be a good combination for ambitious environmental management. For some companies, flow cost accounting can be an interesting option to improve the existing cost accounting system.

In general, Environmental Accounting Instruments integrated into a company's information technology can lead to advantages such as increased information quality and higher transparency within the enterprise. Different requirements have to be fulfilled to support instruments with information technology. The existing business information system such as an ERP system can often be used to integrate Environmental Accounting Instruments. Using a company-wide software system without modifications is one approach that can be used with most ERP systems nowadays. This was shown in the case study presented in this paper. A structured approach as shown with the nine-phase process model for the IT implementation of Environmental Accounting Instruments can facilitate such a project. Such a structured approach is crucial for project success and to ensure the use of the instrument in the day-to-day routine in the company.

NOTES

1 The distinction between environmental management and environmental controlling is to our understanding mainly popular in Germany. This is reflected by publications called Öko-Controlling (Hallay and Pfriem, 1992) or Environmental Controlling (BMU and UBA, 2001). A comparison of environmental management and environmental controlling has been carried out by Loew et al. (2002).

2 A good overview is given for instance by Schaltegger and Burritt (2000), BMU, UBA (2001) Bennett and James (2000). Also see Bennett et al. (2003).

3 In a wider sense, considering other sectors, production-oriented instruments consider the in- and outputs of any kind of organisation.

4 First empirical evidence for the broad use of EPI is given by Loew and Hjalmarsdottir (1996). The popularity of EPIs is also reflected by their use in environmental/sustainability reports, and EMAS statements.

5 For a summary of the results see Loew (2003).

6 This is only one of four different strategies to set up an Environmental Management Information System as described by Rikhardsson (1998). Other strategies include the design of a new Environmen-

tal Management Information System (EMIS), the re-engineering of an existing corporate information system, or the implementation of a standard system package.

7 An ERP (Enterprise Resource Planning) system can be considered as a company's backbone information system containing data on materials, production planning, purchasing and sales, cost accounting, etc.

8 See Beucker et al. (2002) for a survey among 1,300 EMAS-registered manufacturing companies in Germany. 11 per cent of the questionnaires were returned, main industry branches were chemical, paper, electric/electronic, manufacturing and food industries.

9 The question was: Does your system support one or more of the following functionalities: the integration of environmental goals in the corporate goal system, the aggregation of environmental data for product, process, plant or corporate balances, the assessment of environmental performance of a company with regard to types of impact, equivalence factors, etc., the comparison of measured data target data, and the definition of eco-indicators (e.g. energy consumption per planning period).

10 Microsoft Office Tools are widely used within Environmental Accounting, see survey in Beucker et al. (2002).

11 See Balzert (1998), p.114f and Sommerville (2001) p. 181f.

12 UML: Unified Modelling Language, a standard maintained by OMG (Object Management Group). See http://www.omg.org/uml/ or (Fowler, 2003), for ARIS see (Scheer, 1998).

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