CHALMERS

General method for integration of industrial environmental information systems

Deliverable from the IMPRESS project

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Summary

A general method for integration of industrial environmental information systems has been developed. The purpose of the method is to make industrial environmental information systems more effective and efficient, i.e. decrease cost for developing, using and maintaining data, tools, and methods for industrial environmental management and to improve controllability of environmental performance. The method is aimed to both environmental coordinators and industrial environmental informaticians (or corresponding).

The method is based on experiences from the industrial case studies and on previous work with integration within the research group Industrial Environmental Informatics (IMI)[1] at Chalmers University of Technology and the Swedish competence Center for environmental assessment of Product and Material systems (CPM)[2], and has been developed and tested in case studies within three companies (ITT Flygt, SCA Hygiene Products and Akzo Nobel) and within IMI where an integrated concept tool Visualisation of Integrated Environmental Work Spaces (VIEWS) was implemented.

The method for integration of industrial environmental information systems consists of three main steps:

- *Analysis*:
  The purpose and scope of the integration is specified together with the stakeholders. Based on this, the current information system is investigated and described. Also, a draft vision of the integrated information system is developed to visualize the purpose and scope
- *Synthesis*:
  The result from the analysis is synthesized, and possible ways to integrate and rebuild the system is identified and described.
- *Implementation:*
  Based on the result from the synthesis, the implementation of the integration is prioritized and decided and the work is planned and performed. The implementation is also evaluated based in the purpose and scope.

In the case studies within companies, the steps analysis and synthesis have been performed.

- In the case study at *ITT Flygt* the purpose was to integrate the environmental work with the other work done in the product development, to make it more efficient and to be able to generate environmental decision support based on commonly shared and updated data. It was found in the synthesis that an implementation of such a system was feasible. It was also described how the use of environmental information in other functions in the company, such as the sales department and procurement, could be harmonized through a stepwise implementation.

[1] IMI - Industrial Environmental Informatics, Chalmers University of Technology, http://www.imi.chalmers.se, 2006-03-01
[2] CPM - Center for environmental assessment of Product and Material Systems, Chalmers University of Technology, http://www.cpm.chalmers.se, 2006-03-01

- At *SCA Hygiene Products* it was investigated how the work with life cycle assessment (LCA) could be harmonized with the generation of environmental product declarations (EPD). Further the intention was to adopt the technical specification ISO/TS 14048 LCA data documentation format[3] in the LCA work. The necessary actions to implement an integrated LCA and EPD system was described in the synthesis. It was also found that the users of the LCA and EPD results, e.g. the product developers, could generate much of the information themselves. The LCA specialist would then work as a support and possibly as data quality control. This would potentially make the LCA work quicker and make the interpretation of the results by the decision makers easier.

- The case study at *Akzo Nobel* concerned integration of the tasks to perform Eco-efficiency analysis and Risk assessment compliant with the future European chemicals legislation REACH. The synthesis resulted in three different solutions depending on method approach and choice of software solution. The decision regarding which alternative is more favorable is related to risks in terms of confidentiality, and costs in terms of education, software maintenance and development and data management.

The case study at IMI aimed applying the method including the practical implementation to create an integrated platform for different environmental information management applications into one common platform called VIEWS. The sub-views are applications for LCA, EMS, DfE, Chemical risk management, and Emission Trading Data management. The resulting VIEWS platform provides a showcase on how these tools can be practically integrated. Shared primary data entered in one view is immediately available in another. Most notably is an integration of the indicator management which is set on a global level and that primes all sub-views with relevant indicator subsets.

The method has been successfully used to identify ways to integrate information systems with different purpose and scope. The stakeholders in the case studies find the results from the synthesis useful as decision support for implementation. Although the implementation part still remains for the companies, an integrated perspective of their information systems is established, which provides an understanding of possibilities to reduce costs of data management and increase controllability of environmental work.

Further improvements of the method should involve more case study experiences from applying the method, specifically of the implementation step. In addition, the theoretical basis, involving integration dimensions and principles, should be further elaborated in research studies.

[3] ISO, 2002, “ISO/TS 14048 Environmental management — Life cycle assessment — Data documentation format”, ISO Technical specification 2002

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Introduction

Background

Industrial organisations apply many different methods and tools for environmental management, such as the environmental management system (EMS) ISO 14001, environmental performance indicators (EPIs) for communication, target setting and performance measurements, design for environment (DfE) methods and tools for integrating environmental considerations with product development, environmental risk assessment (ERA) to manage the risk of chemical substances, and life cycle assessment (LCA) to assess far-going both up-stream and down-stream consequences of the products. To motivate industry to reduce CO2-emissions, emission trading is currently to be introduced, and to enforce the chemical industry to take deeper responsibility of their products, the European REACH initiative is coming closer to realization.

Each of these methods and tools provide a specific piece of information to the management of the industry's environmental responsibility. But to utilize the full power of their capabilities, it is necessary to integrate them in an intelligent way. This is e.g. the aim of the European initiative Integrated Product Policy (IPP)[4]. The intention is to partly require, partly support an integrated approach and use of all the different environmental management methods and tools. [5]

The IMPRESS project

The general method for integration of industrial environmental information systems described in this report have been developed within the IMPRESS project, in sub-project 2.

Goals and objectives

The IMPRESS project (acronym for IMPlementation of integRated Environmental information SystemS) ran between 2004 – 2006, and aimed at showing how information, methods and tools that supports environmentally related decisions within the industry, can be integrated with each other and with the corporate business processes and also implemented into the organisations.

The companies participating in the project were Akzo Nobel, Bombardier Transportation, Duni, IKEA, ITT Flygt, SCA and Stora Enso. Research and development work was performed together with the research group Industrial Environmental Informatics (IMI) at Chalmers University of Technology. The project was funded by the Swedish competence Center for environmental assessment of Product and Material systems (CPM).

The overall task of IMPRESS was to implement method and tool integration with business processes in a number of industrial companies. The objectives were to:

- Decrease the cost for industrial environmental management.

[4] European Commission, "Green Paper on Integrated Product Policy", 2001
[5] Project plan for CPM-project "IMPlementation of integRated Environmental information SystemS" (IMPRESS), 2004-12-20, Industrial Environmental Informatics, Chalmers University of Technology

- Decrease the cost for developing, using and maintaining data, tools and methods for industrial environmental management.
- Facilitate acquisition of environmental information.
- Provide educational tools for industrial environmental management.

The project also aimed at investigating possibilities for exploitation and dissemination of previous and new CPM results to enhance the value and increase the usability of the results.

The specific methods and tools studied in this project are design for environment (DfE), environmental risk assessment (ERA), and life cycle assessment (LCA) from a product perspective, environmental management systems (EMS) and LCA from a process perspective, and CO_2-emission trading (ET) from a societal perspective. Six industrial application and implementation cases were included in the project:

- Emission trading
- Measurement and communication of environmental performance of products
- Environmental management at site and group level
- Risk management adapted to REACH
- Three tools for IPP
- Integration of experiences and new information

These six cases were studied in detail in close cooperation between IMI and the companies in different sub projects, including e.g. market analyses, specific method development, implementation etc. A general integration methodology was regarded in a separate sub-project. Similarly, technical maintenance for integration, commercialization work, and knowledge exchange was performed in three different sub-projects.

Sub project 2 General method development

The objective of subproject 2, General Method Development, was to develop a general method for integration of industrial environmental information systems. The results presented in this report involve a scientific foundation and practical guidelines for integration of environmental information management systems.

How to read the report

This report is intended to give an overview of the work that have been used as basis and the work that have been performed in the method development, and provide a description and guide to the method. Also, the report describes experiences from applying the method within case studies.

- Chapter *Integration method development* describes the purpose and the scope for the method as well as the integration dimensions that have been applied in the method. The chapter also provides an overview of the theoretical and empirical basis for the method, and a description of the practical work with the method development. The chapter is intended to give the background and the context for the method. Excerpts from the references used as theoretical and empirical basis for the method is available in *Appendix 2*.

- Chapter *Method for integration of industrial environmental information systems* provides a description of the method, and is also intended as a guide for applying the method.

- Chapter *Summary of results from case studies* provides an overview of the experiences from applying the method in each of the four case studies that have been performed. More details on each case study are available in *Appendix 1*, where reports from each case study are available.

- Chapter *Discussion and conclusions* describes the overall experiences and conclusions from developing and applying the method.

Integration method development

Purpose and scope of the method

The purpose of the general integration method is to make industrial environmental information systems more effective and efficient, i.e.:

- Decrease cost for developing, using and maintaining data, tools, and methods for industrial environmental management, e.g. a shared information base reduces risk of errors and is time efficient as changes/updates only is done once, one shared concept model with multi-disciplinary application reduces risk of misinterpretation and misuse of information
- Improve controllability of environmental performance, e.g. continuous data acquisition ensures that relevant information is available for decision, efficient information treatment and communication facilitates quicker feedback to the controller, a consistent aim and goal of activities/methods (harmonization of indicators) will increase the precision of the management

The scope of the method is limited to industrial environmental management responsibilities, as defined by the ISO 14000 standards. However it is *general* in the sense that it is independent of line of business, quality requirements, technology, methods, tools, concept and data models. *Integration* in this context refers to integration of environmental information management methods and tools, i.e. integration with each other and with corporate business processes. For example, from an environmental responsibility perspective, it could be relevant to incorporate activities like Product development, Sales and marketing, and Material management in the integration scope.

The intended users of the general integration method is the environmental coordinator (or corresponding) and the industrial environmental informatician (or corresponding). The environmental coordinator has a good overview of the environmental work, i.e. the needs, possibilities etc., and he or she can use the method to better understand and specify the purpose and scope of integration, cost and benefits, the competence requirements for integration. Also, he or she can use the method as support to coordinate the integration. The industrial environmental informatician has knowledge about information system development in the interdisciplinary context of industrial environmental management, and can use the method as support in the integration modelling.

Integration dimensions

The integration dimensions considered in this method are gaps and overlaps regarding primary data need, tasks, and communication in terms of controllability. Each dimension is briefly described below.

- **Gaps and overlaps in primary data need**
  The meaning of the term *primary data* in this context refers to the lowest level of aggregated data needed to produce an intended piece of information. Primary data is used as input for a task. A *gap* in primary data could be that the system lacks or cannot generate the information that is needed. It could also be that data that is not required or needed for a task is imported to or

created within the system, i.e. there is a gap between the data and its use. An *overlap* in the primary data means that the same primary data is required by two or more tasks.

- **Gaps and overlaps in tasks**
  Tasks are equivalent to work processes that are performed within the environmental information system. Examples of tasks are to measure, estimate or aggregate data, to make an analysis or take a decision. Each task involves processing a set of input data to generate a set of output data. A *gap* in work processes can be that a required task is missing to answer a specific question or to deliver information to a subsequent task. It could also imply that there is a task that is performed in the information system that are is required, i.e. there is a gap between the task and its purpose. *Overlaps* in work processes are when two or more tasks answer the same question or solve the same problem.

- **Gaps and overlaps in communication in terms of controllability**
  In this dimension it is analyzed whether there is an inconsistency regarding what is measured in the information system, in relation to what needs to be controlled. A *gap* in the control system implies that a goal or policy is not regarded in the operative work, i.e. there is a gap in the aggregation of information from measurements to compiled decision support. For example, it may be that no indicator is representing an important environmental statement in the policy. Another example is that there is manual data processing and transfer between two tools that is a potential source of errors due to insufficient or ambiguous description of how to conduct the processing. A *gap* could also mean that there is an indicator in the system that does not relate to any goal or policy. An *overlap* in the control system is when two communication chains delivers the very same or a similar indicator to a decision maker.

Theoretical and empirical basis for the method development

Industrial Environmental Informatics Framework

The integration method development takes a starting point in the Industrial Environmental Informatics Framework, i.e. the acquired knowledge and experience at IMI regarding industrial needs and industrial environmental information systems. Industrial environmental informatics is an interdisciplinary research area, based on scientific and technological perspectives and results:

- Classical physics; the information systems are established from identification of simple physical properties, interactions, processes, and laws.
- Cognitive sciences; the information is regarded from a human viewpoint and terms as e.g. meaning, semantics, context etc. are handled from the perspective of cognitive sciences.
- Computing sciences; for structuring and modelling of information systems and methods techniques from the area of computing science has been applied for e.g. data modelling, information systems design, etc.
- Quality management; information systems and information management methods are designed with long-term total quality maintenance in focus, ideas

of e.g. total quality management (TQM) are built in to industrial environmental management systems.

– Environmental management; the scope of industrial environmental informatics encompasses procedures, tools and methods supporting environmental management in the industrial society, e.g. resource and waste management, life cycle assessment, emission control, supply chain management, design for environment, etc. as well as corporate and authoritative policy setting, and modelling of environmental impact scenarios.

Integration principles

Previous knowledge and experiences in industrial environmental informatics at IMI and CPM present and give strong support for the use of concrete but general reference models as base for analyzing information systems.[6] [7] These reference models presents structured ways of looking at information, e.g. in perspective of basic data structure, aggregation of data, or communication in the control system.

Three basic reference models that have been developed at CPM and IMI constitute the foundation and describe the basic integration principles in this method development; the information model of SPINE, see figure 1, the navigation model, see figure 2, and PHASES, see figure 3.

SPINE

The high level information model of SPINE defines the scope and provides a structure for environmental information, see figure 1. It is used as a concept reference when analyzing information, to understand what type of data it is and how it relates to other data in the system. Any primary data used in applications analyzed within the scope of the integration method can be mapped onto this reference model.

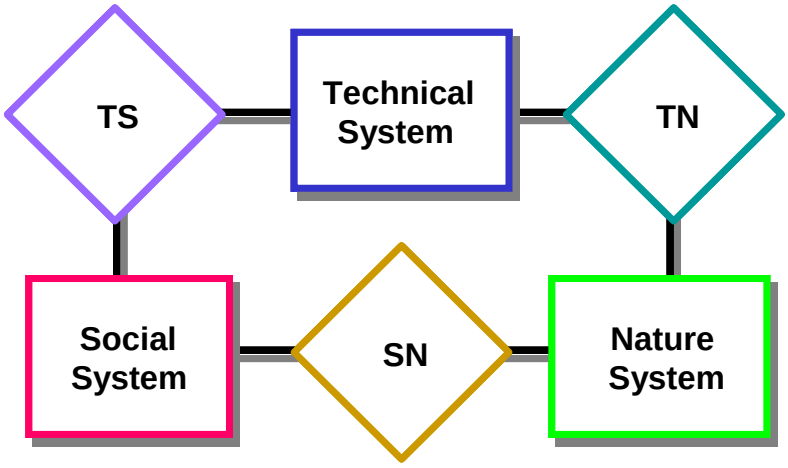

Figure 1 Three types of information are related and compose the scope of environmental information according to this information model. © Copyright Carlson R. IMI, Chalmers University of Technology, 1995

[6] Carlson R, Erixon M, Forsberg P, Pålsson A-C, "System for Integrated Business Environmental Information Management"**,** Advances in Environmental Research, 5/4, 2001, pp 369-375 (Also presented at ISESS 2000 'Integration in Environmental Information Systems', May 30-June 2 2000, Zell am See, Austria)

[7] Carlson R, Pålsson A-C, **"**Slutrapport projekt II:F:12 Integrerade Miljöinformationssystem", (Integrated Information Management Systems, report only available on Swedish), CPM rapport 2001:17

A more detailed information model, i.e. a data model, based on the high level information model SPINE is described in *Appendix 3*. This information model has been developed in the IMPRESS-project, and is based on several existing data models developed for different purposes within IMI and CPM. The model integrates data models for life cycle inventory[8] [9], life cycle impact assessment[10], environmental assessment of component structures[11], and environmental impact modelling[12].

The navigation model

The navigation model shown in figure 2 is also fundamental for the method. It describes the strategic role of environmental information systems, which is to provide decision support for efficient and effective control of the sustainability performance of a system, in line with continuous improvement and sustainable development. In practice, when using the integration method, this perspective supports e.g. the analysis of the overall aim of the information system.

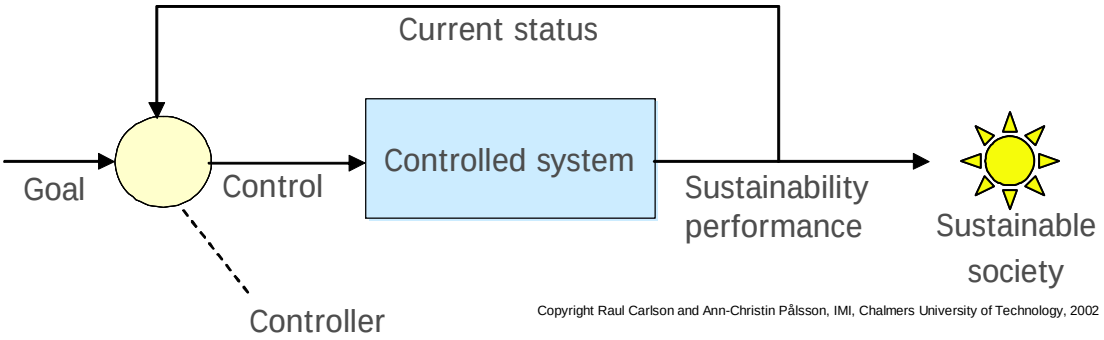

Figure 2 The navigation model describes how decision makers/controllers works to steer a system towards the sustainable society via environmental information.

A central concept in the work with environmental performance is the use of environmental indicators to get a measure the current status and to set goals. Indicators are quantifiable representations of environmental concern, e.g. the degree of recyclability of an electrical motor (weight %), the amount of emission of carbon dioxide from a manufacturing plant (ton CO2), increase of number of cancer cases among a human population (number of persons) etc.[13] The indicators provide key pieces of information to enable communication and understanding between users in an information system such as information suppliers and decision makers.

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[8] Carlson R, Löfgren G, Steen B, "SPINE, A Relation Database Structure for Life Cycle Assessment", Göteborg, IVL-REPORT, September 1995

[9] ISO/TS 14048

[10] Carlson R, Steen B, "A Data Model for LCA Impact Assessment", Presented at 8th Annual Meeting of SETAC-Europe 1998 14-18 April, Bordeaux

[11] Carlson R, Forsberg P "The RAVEL_Information Platform Data Model" 2000 RAVEL project doc nr CPM-000919 (report)
Dewulf W (Ed.), et al., "Integrating Eco-Efficiency in Rail Vehicle Design", Leuven University Press, Leuven, Belgium, 2001

[12] Tivander J, Carlson R, Erlandsson M, Erixon M, Geiron K, "Concept Model for the OMNIITOX Information System Including OMNIITOX Data Format Definition" OMNIITOX project report D20 and D26, 2004, EC contract G1RD-CT–2001–00501

[13] Carlson R, Erixon M, Erlandsson M, Flemström K, Häggström S, Tivander J, "Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems", Industrial Environmental Informatics at Chalmers University of Technology for the Swedish EPA (Environmental Protection Agency), 2005, chapter 2.1.1.3. Indicators (Currently in print 2005-12-22)

PHASES

PHASES (PHASEs in the design of a model of a System) is a procedural description that structures information about a model of a system, i.e. how primary data is defined and acquired, aggregated into system models and communicated [14]. PHASES is a general structure of the common steps involved when designing any model of a system. There are three specific implementations of PHASETS, PHASENS, and PHASESS, which describes how models of Technical systems, Nature systems and Social systems may be designed respectively (c.f. SPINE above). In the method development, this reference model is fundamental to describe the tasks in an information system, and how tasks and information are connected.

Following the direction information takes for reporting, PHASETS (i.e. the implementation of PHASES for models of technical systems) may be described sequentially as figure 3, from bottom up[15]:

0. *Defining an entity for a selected parameter*; The choice of entity to measure and the setting up of the measurement system defines the simplest concept; i.e. the meaning of a measured value.
1. *Sampling an individual value*; The sampling results in a value for the simplest concept, i.e. a measured value.
2. *Forming a frequency function from a set of sample values*; The frequency function aggregates sets of measured values into statistically expressed concepts.
3. *Synthesizing a model of a technical system*; The systems synthesis further aggregates the frequency functions from phase 2 into structured models of technical systems.
4. *Aggregating models of technical systems*; The models of technical systems synthesized in phase 3 may be aggregated into complex concepts describing e.g. averages or cradle to gate systems.
5. *Communicating information between different contexts*; between any two phases 0-4 the resulting data and information, is communicated from the generator to the consecutive phase.

[14] Carlson R, Pålsson A-C, "PHASES Information models for industrial environmental control", CPM-report 2000:4
[15] Carlson R, Pålsson A-C, "Industrial environmental information management for technical systems", Journal of Cleaner Production, 9 (2001) 429-435

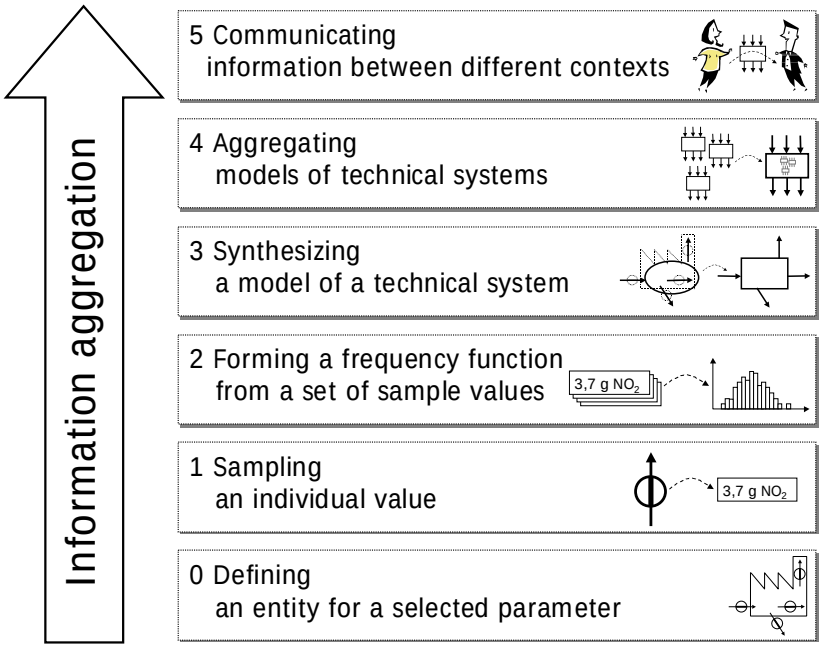

Figure 3 The information aggregation phases in the PHASETS model.

Previous work within IMI and CPM supporting integration dimensions and principles

The integration method and the integration dimensions and principles that are applied are based on ten years of experiences of integration of environmental information systems within CPM and IMI. In this chapter an overview of some relevant references to earlier work and publications are presented. In *Appendix 2* excerpts from these references are given, to provide further details for the specific issues that are described. The appendix can be used as a reference library when applying the method.

A study of other work in this field is found in the section *Related work*.

General information system requirements and design principles for integration

The project II:F:12 Integrated Environmental Information Systems (*Integrerade Miljöinformationssystem*, report only in Swedish)[16] aimed at compiling information from different main knowledge areas within IMI and CPM, that constitutes an industrial environmental information system, and to join this information system with other industrial information systems. The integration principles was (1) to adapt to a general but concrete model of the world, around which analysis of the real world was reflected and were hypothetic concept models was tested (2) to analyze, structure, and synthesize operative and pragmatic project results with the general but concrete model of the world as a base. A result from the project is a good, and partly connected, overview of methods and models to create an integrated industrial environmental information system. Further, different integration interfaces have been formalized, e.g. between LCA and LCC in Eco-efficiency, and LCI and LCIA in LCA.

[16] Carlson R, Pålsson A-C, **"**Slutrapport projekt II:F:12 Integrerade Miljöinformationssystem", (Integrated Information Management Systems, report only available in Swedish), CPM rapport 2001:17

A set of general requirements design principles when organizing environmental information systems supporting life cycle overviews of products is described in the report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* [17]. The principles that apply when building environmental information systems, also apply when integrating environmental information systems. The basic design principles concern functionality, pragmatics, and user friendliness. Since environmental issues are not a central concern in most businesses; this must be taken into account when designing environmental information systems. Therefore, when designing an environmental information system, one should strive to share costs by filling gaps, and designing for modularity and flexibility. This also implies that the design should be based on continuous feasible, well established and maintained improvements.

Gaps and overlaps in primary data need

An integrated information system design, named Integrated Business Environmental Information Management (IBEIM), is described in the article *"System for Integrated Business Environmental Information Management"* [18]. The system includes operational, procedural and organizational support for a business' entire environmental information management. IBEIM consists of a system architecture and an information and data content. IBEIM makes use of data that is already available in industrial management systems, such as procurement, logistics, and material management.

Much of the documented knowledge and experiences at IMI regarding gaps and overlaps in the primary data need have been compiled in the report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* For example, it describes how different environmental performance measurements and different users of environmental information can share the same data in order to achieve synergetic benefits and cost-efficient data management. The report also describes how to analyze data gaps in the integration work. Different aspects of data availability are defined and discussed.

The perspective of primary data gaps and overlaps is also a main integration aspect in the article *"Learning from management of LCA data"* [19], which compiles experience from different projects performed at IMI and CPM. It refers to that there is a direct relationship between environmental performance indicators (EPIs) and the required contents in the environmental database. The EPI methodology in DfE corresponds to the use of category indicators in LCA.

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[17] Carlson R, Erixon M, Erlandsson M, Flemström K, Häggström S, Tivander J, "Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems", Industrial Environmental Informatics at Chalmers University of Technology for the Swedish EPA (Environmental Protection Agency), (Currently in print 2005-12-22)

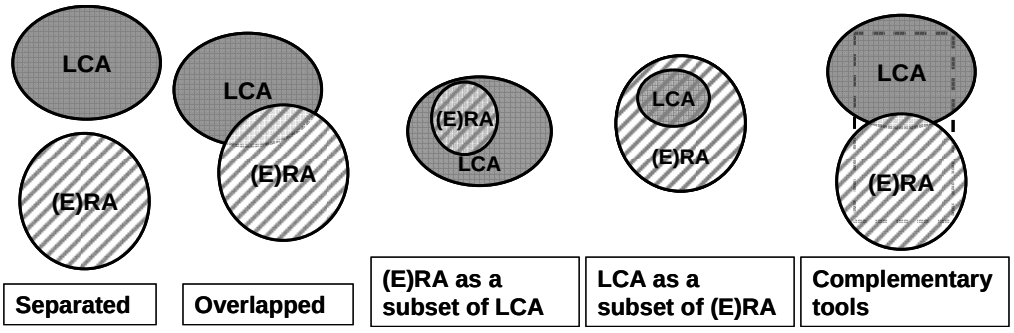
[18] Carlson R, Erixon M, Forsberg P, Pålsson A-C, "System for Integrated Business Environmental Information Management"**,** Advances in Environmental Research, 5/4, 2001, pp 369-375 (Also presented at ISESS 2000 'Integration in Environmental Information Systems', May 30-June 2 2000, Zell am See, Austria)

[19] Carlson R, "Learning from management of LCA data", Journal of Life Cycle Assessment, Japan, Vol. 1 No. 2 Jul, 2005, pp 102-111

Gaps and overlaps in tasks

To provide a structural support to identify users, information, tools, and method requirements for further analysis of an information system, the activities involved in the work with environmental responsibilities have been structured into five perspectives in the report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"*.

An in-depth comparison between the two tools LCA and Risk Assessment is described in the report *"Relationships between Life Cycle Assessment and Risk Assessment, Potentials and Obstacles"* [20]. The results show that there are similarities and differences e.g. in terms of data requirements, system boundaries of the analysis, methodology for impact assessment etc (see figure 4). The method for comparison applied in the study is useful when investigating how to combine or integrate methods, tools, or tasks.



© Flemström, Carlson, IMI, 2003, from NVV Report 5379 Relationships between LCA and RA

Figure 4 Alternative approaches of combining LCA and (E)RA in terms of simplified Venn diagrams.

The article *"A full Design for Environment (DfE) data model"* [21] presents results from the RAVEL project, in which a methodology was developed, together with web-based software tools with a knowledge base, to enable improved eco-efficiency of train vehicles for the entire rail industry, including suppliers and sub-suppliers, manufacturers, operators, and scrappers. The project is a good example of how a gap in the work process was identified for assessing environmental performance of products. The RAVEL data model and methodology was designed to fill this gap with clear interfaces to existing tasks, such as product development and procurement. Together these tasks form an integrated platform for DfE.

One main integration perspective in the article *"Learning from management of LCA data"* is that LCA data acquisition benefits from integration with the data acquisition in the environmental management system at production site. This is based on empirical studies in the project "CPM/SSVL - Methodology for handling

[20] Flemström K, Carlson R, Erixon M "Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles", Naturvårdsverket Rapport 5379, June 2004
[21] Carlson R, Forsberg P, Dewulf W, Ander Å, Spykman G, "A Full Design for Environment (DfE) Data Model", PDT Europe 2001, April 24th-26th, 2001, pp. 129-135

environmental data in the forest industry", where the PHASETS model was refined and tested for environmental data management within production sites[22].

Gaps and overlaps of communication in terms of controllability

The report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* structures methods and tools for environmental overview of product life cycles in three categories, to show how they communicate with each other and how the information flows. The report provides many examples of how tools can be used sequentially to provide relevant and understandable information needed for the decision makers. Further, the report argues for harmonization of indicators, to clarify the purpose of the work with environmental overview of product life cycles, to increase the controllability, i.e. understandability and communication, and to minimize data requirements.

A methodology for policy controlled environmental management work is described in the project report *"Policy Controlled Environmental Management Work"* [23]. The methodology aims at establishing controllability based on the policy, through a quantitative connection between indicators identified in the policy and the goals in the organization, see figure 5 below. The methodology can be applied to analyze how the environmental work relates to the strategic purpose and goal of the organization.

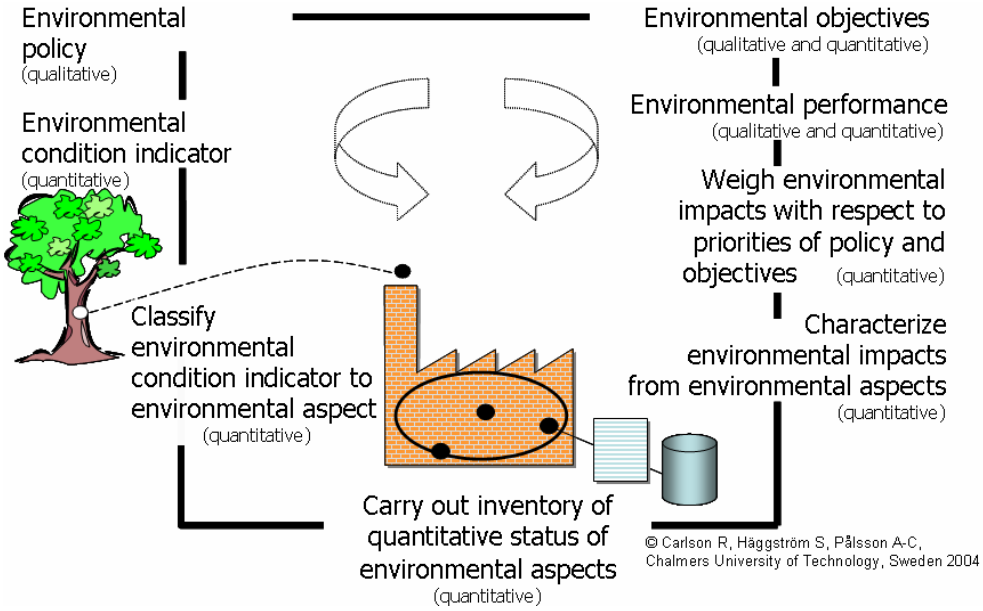


Figure 5 The methodology consists of eight steps and in each step a specific task in policy controlled environmental management work is performed. Each step can be performed independently of the other steps. The lines in the figure indicate how the different steps are related to each other and the arrows indicate that the different steps may be performed in any direction.

[22] Pålsson A-C, Svending O, Möller Å, Nilsson C, Olsson L, Loviken G, Enqvist A Karlsson G, Nilseng A: Proc. 7th International Conference on New Available Technologies, Stockholm, June 4-6 (2002), pp.177-181

[23] Carlson R, Häggström S, Pålsson A-C "Policy controlled environmental management work - Final report" CPM-report 2004:10

In the article *"System for Integrated Business Environmental Information Management"* an information system named Integrated Business Environmental Information Management (IBEIM) is described. It includes operational, procedural and organizational support for a business' entire environmental information management. The system architecture is designed from three thoroughly developed information models that support the integration of environmental information systems. The three models are: a reference model for information aggregation and communication, an information model for data structuring, and a modularization including module interface specifications. IBEIM shows e.g. how expensive technical obstacles that are common in the integration work can be solved with standardized formats and interfaces.

Related work on methodology for integration of environmental information systems

A brief literature study has been performed on related results and research on environmental information system integration. The results from the study are presented here.

The idea to integrate environmental information systems, in order to enhance the efficiency of information management, is commonly addressed in literature. However the bulk of the available texts on integration typically concern combinations of two or more specific applications to work within one software solution, e.g. CAD and EcoDesign[24] or LCA and business information management tools such as SAP[25].

The subject of integration methodology is rarely addressed. No material could be found that presented a general and practical method for integration of industrial environmental information systems, i.e. with a matching scope of the method presented in this report. A conceptual framework for integrating environmental performance evaluation with other corporate financial and operational performance is outlined by Sheu and Lo[26] pointing out the need for structuring the environmental information and connecting observable data with relevant indicators. Some generic environmental information system integration aspects focusing on geographical information systems (GIS) and decision support systems (DSS) are discussed by Denzer[27], who concludes that generic approaches to integrate interfaces between environmental information systems are yet to be developed. Some practical solutions exist however for generic interfaces and protocols for connecting environmental data sources, e.g. a system for querying heterogeneous environmental data sources developed in New Zealand[28], and the standardization efforts for managing

[24] Cappelli F, Delogu M, Pierini M, 2006, "Integration of LCA and EcoDesign guideline in a virtual CAD network", Proceedings of 13th CIRP Intl Conference on Life Cycle Engineering, Vol. 1

[25] Abele E, Feickert S, Kuhrke B, Clesle F-D, 2006, "Environmental Product Life Cycle Management – Customizing the Enterprise Specific Manaufacturing Processes", Proceedings of 13th CIRP Intl Conference on Life Cycle Engineering, Vol. 2

[26] Sheu H-J, Lo S-F, 2005, "A New Conceptual Framework Integrating Environment into Corporate Performance Evaluation", National Chiao-Tung University, Taiwan, Wiley InterScience Sustainable Development 13, 79–90

[27] Denzer R, 2005, "Generic integration of environmental decision support systems – state-of-the-art", Environmental Modelling & Software Vol. 20, Issue 10, pp 1217-1223

[28] Purvis M, Cranefield S, Ward R, Nowostawski M, Carter D, Bush G, 2003, "A multi-agent system for the integration of distributed environmental information", Environmental Modelling & Software 18 (2003), pp 565–572

environmental data on industrial processes including ISO/TS 14048[29] and the results from the CASCADE project[30].

Within generic information system development research the integration issue has been investigated for some time. Many efforts have been put on finding methods to harmonize heterogeneous data sources, e.g. regarding ontology integration[31] and distributed database collaboration[32]. The often cited text by Hasselbring[33] provides a structuring overview of general technical and organizational aspects of information system integration. Specifically three main dimensions are presented: autonomy, heterogeneity and distribution, where system integration involves striving to reduce all three dimensions.

Structure and content of the practical work with method development

To provide a framework for the integration method, it was divided into three steps: analysis, synthesis, and implementation. The method is developed and documented in an iterative process involving pre-studies, practical case studies, discussions with the reference group, and analysis, synthesis, and documentation by method developers. The method is described in detail in the chapter *Method for integration of industrial environmental information systems.*

Pre-studies

An overview of data input and output for all the IMPRESS tools were made in sub-project 2 and 3 early in the project. A result from this work is e.g. a table that exemplifies the concepts Policy and Indicator for the different environmental management and assessment tools, see *Appendix 4*. One conclusion from this work is that the concepts generally has the same meaning for all tools, e.g. in life cycle assessment (LCA), environmental management systems (EMS), or design for environment (DfE). However, a policy or an indicator developed for LCA may not be relevant, useful, or satisfactory described to be directly applicable in different context, for example in EMS. These conclusions were important input to the method development as the general integration method is about how concepts and information can be integrated.

Sub-projects versus case studies

The sub-projects in IMPRESS focus on implementation of tools and methods, and were formulated based on the interest of several companies. They involved general integration aspects for some specified environmental information management tool or method that can be beneficial for many companies to learn from, e.g. data acquisition,

[29] ISO, 2002, “ISO/TS 14048 Environmental management — Life cycle assessment — Data documentation format”, ISO Technical specification
[30] Philips C (ed), 2005, “CASCADE Final Report”,
[31] Wache T, et al., 2001, "Ontology-based Integration of Information - A Survey of Existing Approaches," Proceedings of IJCAI-01 Workshop: Ontologies and Information Sharing, Seattle, WA, 2001, Vol. pp. 108-117
[32] Fiedler G, Raak T, Thalheim B, 2005, “Database Collaboration Instead of Integration”, Kiel University, Conference on Conceptual Modelling (APCCM2005), University of Newcastle, Newcastle, Australia. Conferences in Research and Practice in Information Technology, Vol. 43
[33] Hasselbring W, 2000, “Information system integration”, Communications of the ACM, Vol. 43 No. 6

data exchange, or how to work with EPIs. The integration perspective for the subprojects is implementation and integration of a new method or tool within the business processes. The integration between methods and tools in the different sub-projects is based on the reference model compiled in sub-project 3.

To get practical experience with the actual information systems that are used within companies, four case studies were initiated in sub-project 2. Each of the case studies was formulated based on the integration need of one organization and they involved integration of very specific information systems (tools, methods, tasks, people etc.) at the case study companies.

Both sub-projects and case studies were important for the integration method development. The sub-projects contributed with experiences for the reference model development and tools in the integration work, such as data, data exchange formats etc. The case studies contributed with experiences from integrating concrete information systems, involving users, internally developed tools, specific work procedures, etc.

Case studies

All CPM companies were contacted to participate with case studies, and three relevant case studies were chosen at three different interested companies, ITT Flygt, SCA Hygiene Products, and Akzo Nobel. The case studies were chosen to represent different lines of businesses and different types of information systems. An additional case study was performed internally at IMI aimed at a practical implementation of an integrated platform for different environmental information management applications into one common platform called VIEWS.

Before the first case study was started, a general framework for the integration method had been developed, where the method were structured into the three steps; analysis, synthesis and implementation. The framework is based on earlier knowledge and experience in industrial environmental informatics. An initial draft of what the different parts involved was formed and a set of first questions was formulated for the analysis step. This framework was tested and continuously refined during the work with the case studies.

When the first case study started, the analysis and the synthesis step was tested and adapted to the practical work, e.g. the questions were re-formulated to be more relevant and easy to understand. The process of drawing pictures of the information system in focus for the integration was found to be a very efficient way to scope and find a common understanding of the work. The case study was carefully documented in parallel to the method development work.

The two other company case studies were initiated once the analysis in the first case study was finalized. In meetings with the companies the analyses work proceeded, involving drawing pictures together to define the scope and answering the questions to describe the components in the information systems. These analyses were less time consuming than in the first case, as the method had been refined. The work with the synthesis was also more refined in these case studies.

The case studies within companies were finalized and documented before January 2006. The VIEWS case study started in spring 2006 where a prototype implementation was finalized in June. The resulting implementation was presented to the CPM companies at the end of the IMPRESS project, which provided additional input to verify the usefulness of the results.

Reference group

A reference group was also formed, consisting of representatives from the industrial partners in CPM and personnel from IMI, as a forum to discuss the method development. The reference group involved people from CPM companies that were both involved and those not involved in the case studies and IMPRESS. In addition, two representatives from IMI were participating, the project leader of IMPRESS and a person with experience in method development. The aim of the reference group work was to get feed back on the integration method, the work procedure and the report. It was important to get a broad acceptance of the method, to develop a common language that all CPM-participants understand, and to increase the industrial relevance to ensure that the method was applicable also for other than the case study companies.

At the first meeting with the reference group the status of the integration method, method development, and case studies were presented and discussed. It was concluded that the method was scientifically founded, understandable and useful for the representatives in the group. The feedback from the reference group provided important issues to be considered or the further development and refinement of the method. Some issues needed further clarification, e.g. the concept indicator, specification of the competences required in the integration work etc.

At the second and final meeting with the reference group the methodological background, the integration method itself, application of the method in case studies and conclusions from the work were presented and discussed. A draft report from the work was discussed, and the group found that the description of the case studies made the method clearer and easier to understand, but that more direct references should be made to the case study text, to present good examples of how to perform the different methodological steps and how to document information that are acquired when applying the method.

Except for the feedback from the reference group, the status of the integration method, method development and case studies were presented and discussed with participants in the research project Industrial environmental informatics at IMI. An early outline of the method report (this report) was also presented and discussed. The participants from the research project especially wanted to see more clearly in the report how earlier work within IMI and CPM has been utilized in the method development. As a pragmatic solution it was decided that the theoretical background should be documented as references with text excerpts from relevant literature, to render concrete and clear connections to the extensive work performed in CPM and IMI regarding integration. In addition, the synthesis part was further elaborated.

Method for integration of industrial environmental information systems

In this chapter, the general integration method is presented. Based on the methodological background and the experiences in IMPRESS, this description provides a basic framework for practical integration work. The method includes the three main steps analysis, synthesis and implementation, see figure 6. In general, these steps are performed as an iterative process.

All stakeholders of the information systems should be regarded in the integration process, i.e. the commissioner, old and new system owner and manager, user, and receiver of information from user.

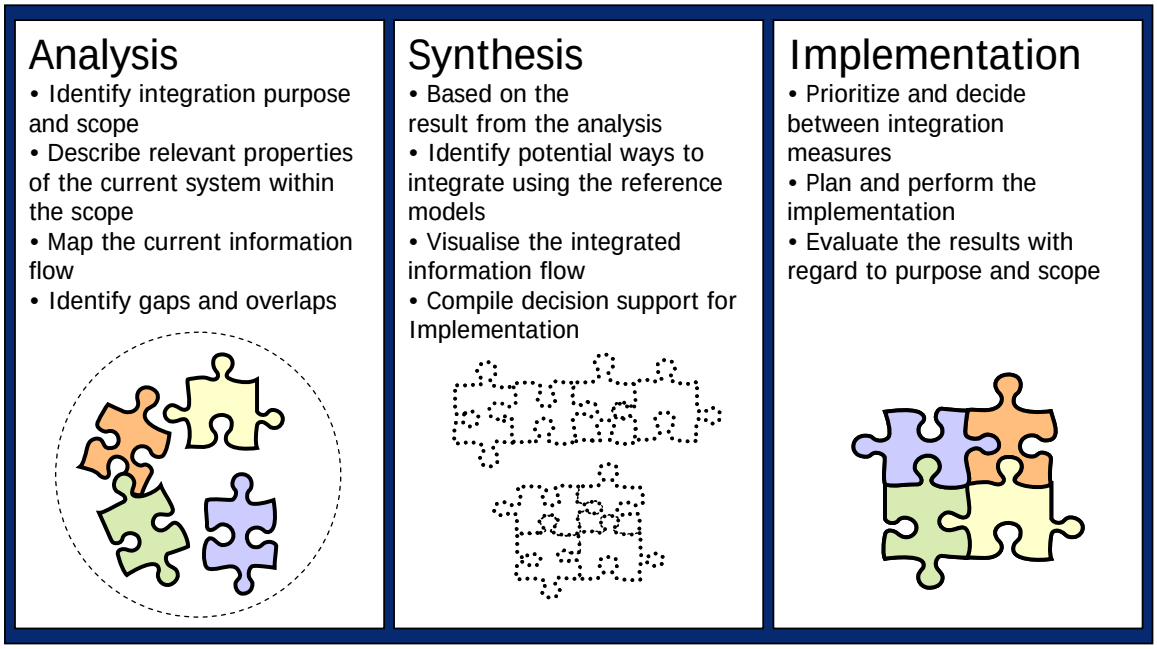


Figure 6 A short description of the three main steps involved in the method for integration of industrial environmental information systems

When working with the integration method, it is important to take into account how data is continuously acquired in the information system; both how data is acquired in current information system and how data will be acquired in the integrated system. The integration may for example require changes in the current data acquisition processes due to new or additional requirements, or establishment of new strategies and processes for data acquisition.

Analysis

In the analysis, the purpose and scope of the integration is specified. Together with the stakeholders it is decided what integration dimensions and principles shall be regarded in the integration. For example, one may specifically want to concentrate on gaps and overlaps in primary data need. The integration dimensions and principles applied in this method are described in the chapter *Integration method development*.

Based on the purpose and the scope for the integration, a description of the current information system as well as a draft vision of the integrated information system is discussed and developed together with the stakeholders.

The description of the current information system should provide a clear picture of the system and its parts, in terms of competence, tasks, software, methods and other tools, data and data acquisition, concepts, nomenclature, quality requirements, data formats, etc. The current system is described in a picture and in clarifying text. The system and its parts are compared to find similarities and differences. An example of a similarity is when two tasks both use information on process emissions. Examples of differences are when substance property information is stored in different data formats, or when different nomenclatures are used for naming materials depending on the user competence, etc. In the analysis similarities and differences are stated and relevant information to make further studies in the synthesis is acquired.

The draft vision of the integrated information system should provide a picture of how the stakeholders would like to see the integrated system to function. This helps to visualize the goal and scope of the integration. The vision is described in a picture and in clarifying text. This draft is further elaborated and altered in the synthesis and/or implementation phase, until a final vision described, in line with the goal and scope.

Performing the analysis

The analysis is performed through a survey in close collaboration with the stakeholders. The survey is based on the integration dimensions: Gaps and overlaps in primary data need, tasks, and communication in terms of controllability. A set of questions are formulated that, thoroughly answered, gives a good overview and detailed description of the system parts and guidelines for further integration work. The survey is performed by interviews and discussions in physical and telephone meetings, until a commonly accepted and understood description of the situation is finalized.

Formulation of questions for the survey

To ensure that relevant information is collected during the survey a set of questions is formulated. The questions are based on the integration dimensions, i.e. gaps and overlaps regarding primary data need, tasks, and communication in terms of controllability. The questions have been divided into four main categories (see figure 7):
(1) the purpose and goal of the integration,
(2) the scope of the integration,
(3) the indicator relevance and
(4) the quality management

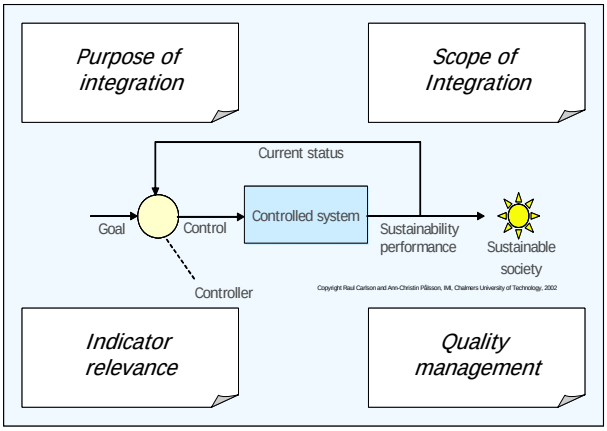


Figure 7 The four main categories of questions in the analysis. The questions are based on the integration dimensions and principles.

- **Purpose and goal of integration**
  It is important that the purpose of and expected benefits from the integration is explicitly formulated, to have a common understanding of the aim and goal of the integration work, and to have clear guidelines for the synthesis and implementation work. It is also crucial to define a way to measure the benefits of the integration, in order to argue for the investments. There may be tasks that are outside the scope that also can benefit from the integration. It is valuable to take note of this as additional support for investments and implementation.

- **Scope of integration**
  The integration scope includes the tasks and information needed to comply with the reasons for and expected benefits of the integration. It is crucial to thoroughly think through and explicitly define the boundaries for the integration scope. This is important in order to keep within budget and avoid the risk of uncontrolled expansion of the integration scope. It is also important not to set too narrow limits of the scope in order to avoid suboptimal solutions.

- **Indicator relevance**
  The analysis of the indicator relevance is important in order to check that the information in the system answer to the objectives of the organization. The indicators that are quantified in the information system are studied in terms of how they relate to policies, strategic statements, legislation, and other business objectives. T with support from the method for Policy controlled environmental management[34]. It is also noted how the indicators communicate to the decision makers in terms of understandability, acceptance, etc. For example, if a policy states that global warming is an important concern, emissions of greenhouse gases such as carbon dioxide should be measured and controlled within the system. “Emission of carbon dioxide equivalents” is one example of what can be an indicator in this case, but in order to communicate to e.g. a designer it might be appropriate to redefine the indicator to “Global warming potential”. If the indicator is normalized to an index, it can be easier

[34] Carlson R, Häggström S, Pålsson A-C “Policy controlled environmental management work - Final report” CPM-report 2004:10

to understand and work with it, for a person without expert knowledge on environmental processes.

- **Quality management**
  The quality management within the information system is analyzed in order to check that the quality of information is sufficient for its purpose. There might be a need to establish, document, or harmonize the information quality management. Quality management implies that the system is effective and efficient, where quality requirements and uncertainties are known, and agreed.

With regard to the integration dimensions, the primary data need and tasks are specifically investigated in the categories Scope of the integration and the Quality management. The picture representing the current system also illustrates these dimensions. The integration dimension Communication in terms of controllability is mainly investigated in the Indicator relevance category of questions. Purpose and goal is important to describe in order to make a first draft describing the vision of the integrated information system. This gives an indication of the scope and direction of the integration work, which is further elaborated in the synthesis.

For each category a set of questions have been developed, that can be used when performing the survey (see below). The questions are not to be regarded as the only relevant aspects to consider in the analysis, but rather as an indication of important issues to address, in accordance with the integration dimensions. Depending on the purpose and scope for the integration, specific issues may be needed to be investigated by posing more detailed questions.

Questions for the survey

(1) Purpose and goal of integration
   a. What is the reason for and expected benefits from integration?
   b. How is it measured?

(2) Scope of integration
   a. What tasks, tools (software, databases, etc.), and methods will be integrated?
   b. Who are the decision makers and other users in the information system?
   c. What information is generated by/ required from the tasks?
   d. What information is acquired/ required for the tasks?
   e. How often is the information generated/acquired?
   f. What method is used for external data acquisition?
   g. How is the information communicated between tasks/users?
   h. What concepts, data formats and nomenclatures do you use?

(3) Indicator relevance
   a. How does the tasks and information in the system relate to policy, legislation, and other objectives in terms of indicators?
   b. Are the indicators in the information system understood and accepted by the decision makers and other users?

(4) Quality management
   a. What information quality requirements do you use and how are they defined, documented, and maintained?

Using the reference models in the survey

When performing the survey, the reference models described in section *Integration principles* can be used as a basis for the understanding of the different elements of the information system. For example:

- The reference model SPINE can be used to distinguish and identify the type of data that is handled in the system, and can aid in the identification of gaps and overlaps in primary data need.
- The navigation model can be used to identify the purpose of the information system, and can aid in the identification of gaps and overlaps in communication in terms of controllability.
- The PHASES model can be used to identify different tasks performed in the information system, and can aid in the identification of gaps and overlaps in tasks.

Methods and tools described in the section *Previous work within IMI and CPM supporting integration dimensions and principles* can also be used as support when performing the analysis.

Documentation and illustration of results from the survey

During the analysis it is important to document the information collected from the stakeholders, since this information is the basis for the subsequent steps in the integration method, i.e. the synthesis and the implementation. It is therefore recommended to continuously document the answers that the stakeholders provide during the survey. Text descriptions of the elements and the overall information system should be supported with a picture that illustrates it. In these pictures, the core tasks, connected information pieces, tools and users are specified. A template for how to draw the different information system elements in the picture is provided in figure 8. Examples of text descriptions and pictures from the analysis in the case studies are found in *Appendix 1*.

Drawing pictures of the current information system and the draft vision of the integrated information system is a good way of describing the integration scope. The pictures provide visual maps of the flow and processing of information in the complete system and make it more concrete. They greatly facilitate a shared understanding between the different stakeholders and help to identify gaps and overlaps.

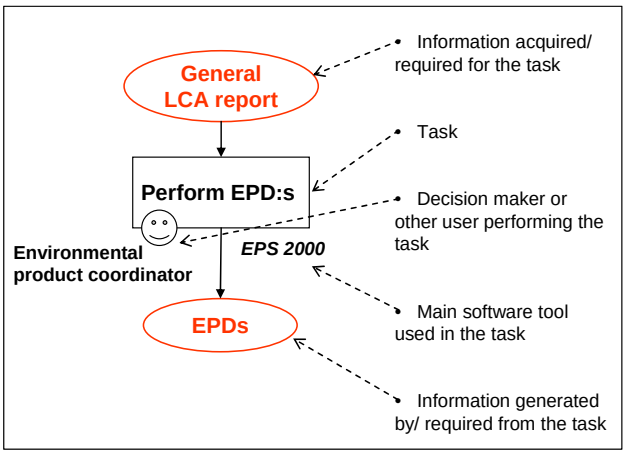


Figure 8 Explanation of the figures and text in the analysis and synthesis pictures.

Recommendations when performing the analysis

The answers to the questions in the analysis shall, together with the pictures drawn, provide sufficient input for the synthesis work. If the analysis is well performed, it may not be necessary to return to the analysis from the synthesis work, to e.g. reformulate the scope or to acquire a more detailed description of an information system element.

Since the information collected in the analysis is the basis for the subsequent steps in the integration, it is very important to carefully document the information that is acquired. Keep track of who have been involved in the analysis, all answers to questions and all documents that have been acquired, that describe different elements of the system.

The analysis is very much dependent on the cooperation of the stakeholders that are involved with the information systems that are to be integrated. When performing the interviews, the interviewees should be informed of the purpose of the interview and how the results will be used. There may, for example, be organizational issues that need to be regarded.

Synthesis

In the synthesis it is assessed and described how the information system can be re-built, from the elements described in the analysis, to an integrated information system, see figure 9. The final vision for the integrated information system is developed based on the purpose and scope defined in the analysis.

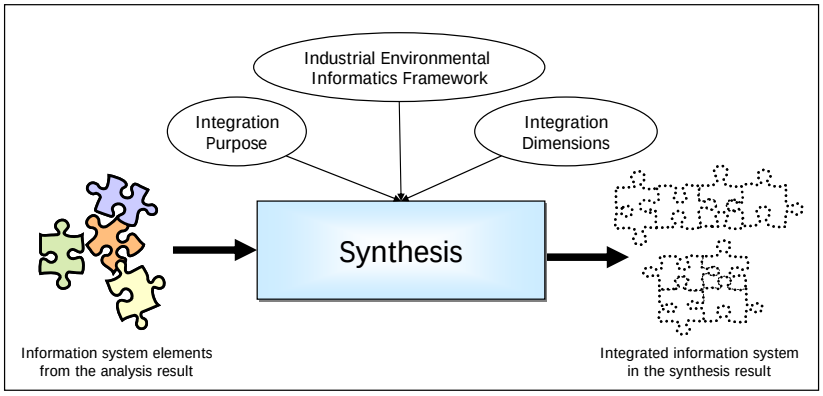


Figure 9 In the synthesis the information system is re-built, from the elements described in the analysis, to the integrated information system

The currently existing and new information system elements described in the analysis are considered equally important in the synthesis. The synthesis aims at fulfilling the purpose of the integration by considering the three integration dimensions; gaps and overlaps of primary data need, tasks, and communication in terms of controllability. The framework applied for this synthesis is defined as "Industrial environmental informatics", that is, experience and knowledge from interdisciplinary work as described in the chapter *Integration method development*, involving principles for integration and application of reference models.

The synthesis takes the starting point in the information gathered in the analysis phase about the integration purpose, scope, indicator relevance, and quality management. Thus, no new information about the system is added in the synthesis. However, at any point in the synthesis it may be found that it is needed to refine the analysis, e.g. due to that some vital information have not been collected.

The result of the synthesis is a decision support for the implementation phase.

Examples of results from the synthesis in the case studies are found in *Appendix 1*.

Performing the synthesis

There are three main steps in the synthesis:

- Study the information system elements described in the analysis, based on the integration dimensions, to find possible solutions to re-build the system. This involves e.g. a detailed study of the identified differences and similarities of the different parts of the current information system and how this can be handled in the in the integration.
- Describe
  - How the elements can be combined for integration in regard to the purpose and goal
  - What actions are needed for the integration
  - How the information processes are affected
- Summarize the suggested ways for integration and compile decision support for the implementation phase. Refer to the decisions regarding integration dimensions and principles made in the analysis.

In the process of finalizing the synthesis, an integrated perspective of the information system is developed, i.e. knowledge is gained on how the elements in the system are

related and depends on each other, and how each element contributes to the purpose of the system. Gaps and overlaps are identified, and possible solutions to overcome such problems to improve the efficiency and effectiveness of the system are described. Thus, one level of integration is gained already in the synthesis.

Documenting the synthesis

Since the result from the synthesis is intended to be used as decision support for the implementation, it is important to know who the stakeholders (receivers) of the result are, and to prepare the documentation of the result in line with their needs, competence and background.

As in the analysis, it is recommended to document the result by describing text and pictures.

Using the reference models in the synthesis

When performing the synthesis, the reference models described in section *Integration principles* can aid the practical work. For example:

- The reference model SPINE can be used as basis to describe the content and need for common concepts and data formats.
- The navigation model can be used to clarify the purpose of the integrated information system and the content and need for indicators.
- The PHASES model can be used as basis to describe the content of tasks in the integrated information system.

Also, methods and tools described in the section *Previous work within IMI and CPM supporting integration dimensions and principles* can be used as practical support when performing the synthesis.

Recommendations when performing the synthesis

When preparing the decision support for the implementation, it may be a good idea to distinguish between:

- existing parts of the system, that will remain unchanged in the integration
- existing parts of the system, that need to be further developed or changed in some way in the integration
- new parts of the system, that need to be developed in the integration

This will facilitate for the stakeholders to get an overview of the extent of development that is needed for the integration.

The purpose of the integration method is to reduce costs and increase controllability of environmental performance. To facilitate the decisions in the implementation the result from the synthesis should include some estimation of potential cost reductions and how controllability potentially can be increased. For example, an estimation of potential cost reductions can be made by comparing the costs for running the current information systems and implementing any new functionality or uses that have been identified in the scope, with the costs for running the integrated system which incorporates both current and new functionality and uses. Costs for running an information system include e.g. costs for data acquisition, processing etc and maintenance of the system. Potential increased controllability could be estimated by identifying data quality improvements or increased usability of the system, or by

measuring the response time to produce the required information to the decision makers.

Implementation

In the implementation the stakeholders prioritize between the different suggestions from the synthesis, and decide what integration solution to adopt. The concrete actions are planned and performed, and the results are finally evaluated in regards to the purpose and scope specification and the integration dimensions and principles.

Performing the implementation

In general, the implementation will involve the following steps:

- If there is a need, complement the decision support, e.g.
    - Make a feasibility study with regard to cost, competence, maintenance, continuous data acquisition etc. to describe drivers and barriers
    - Describe potential benefits outside the integration scope, to support motivation of integration (e.g. there may be other functions or tasks that may benefit from the integrated system, that are outside the scope that have been defined for the integrated system)
- Prioritize between different ways for integration together with stakeholders
- Stakeholders decide what will be implemented.
- Plan the implementation in terms of budget, actions, deliverables, etc.
- Perform the implementation e.g. in terms of technical development, education, data acquisition
- Evaluate the results with regard to the purpose and scope specification and the integration dimensions and principles

Recommendations when performing the implementation

The results from the previous steps are vital basis for planning the implementation. A good analysis and synthesis can identify the steps needed to avoid underestimation of resources and can reduce the risk of ending up with a costly system with insufficient data. As it is not realistic to expect every relevant issue to be identified in the analysis a resource buffer should be available in the implementation for unknown issues. Furthermore, a close collaboration between data managers, end users, and software developers is recommended to keep the implementation within the scope and focused on fulfilling the purpose.

Summary of results from case studies

The general integration method is mainly based on previous work with integration within IMI and CPM. The analysis and synthesis part have been further developed and tested in case studies within three companies (ITT Flygt, SCA Hygiene Products and Akzo Nobel) and within IMI where an integrated concept tool Visualisation of Integrated Environmental Work Spaces (VIEWS) was implemented.

Integrated information system for the environmental product management at ITT Flygt

Results from analysis and synthesis

In this case study only the analysis and synthesis steps have been applied.

Purpose, goal, and scope
The main purpose of integrating the environmental information systems in the case study at ITT Flygt is to efficiently share product and material data and to improve the management of environmental product performance, in terms of relevance, by introducing and harmonizing Environmental Performance Indicators, EPIs.

The tasks to perform life cycle assessment (LCA), environmental product declarations (EPD), and product design, were included in the original integration scope.

Much of the data required already exists in the current information system at ITT Flygt, i.e. material and material property data, and product content and structure data. However, the material properties need to be available in a database and explicitly connected to the product structure. Additional data that is required is EPI data and environmental properties of materials. These additional material properties can and should use the same nomenclature and data format as the available material properties. Data formats and methods for the development and management of EPIs are available, i.e. the RAVEL methodology[35], and the process to define relevant EPIs for ITT Flygt and acquire data is initialized in the IMPRESS project.

Work procedure
The contact person at ITT Flygt during this case study has been the environmental product coordinator. He has arranged meetings with several other users and stakeholders, such as product developers, material managers, and system administrators, which has been of great value for the result. ITT Flygt are currently working in several projects with integration of information systems, e.g. regarding design and material specification document references in the product development, production, and procurement work processes.

Further work
The environmental product coordinator intends to use the result from this case study as input to further discussions regarding implementation at the company of the proposed integration actions.

A stepwise plan was developed in the synthesis based on first implementing an integrated system within the original scope. As it was found that many other tasks in the company could also benefit from integration, additional required actions was described to also incorporate these tasks.

Implications on the method development
As this was the first case study in the method development it was more time consuming than the two others within companies. The method was further developed in parallel with the case study work: specifically the questionnaire used in analysis, the layout of the information flow pictures, and the understanding the role of reference models were refined.

A significant aspect of this study was that the scope was gradually extended as more relations to other tasks were incorporated. The breakdown of the required integration

[35] Dewulf W (Ed.), et al., “Integrating Eco-Efficiency in Rail Vehicle Design”, Leuven University Press, Leuven, Belgium, 2001

actions into smaller steps was found as a practical way that helped to clarify what to prioritize in the implementation. However, caution should be taken when incorporating more tasks in the integration scope. As a principle it is recommended to base the development of any environmental information system on continuous improvement and gradually establish working and well defined tasks.

Integrated information system for EPD management at SCA Hygiene Products

Results from analysis and synthesis

Purpose, goal, and scope

At SCA Hygiene Products it was investigated how the work with life cycle assessment (LCA) could be harmonized with the generation of environmental product declarations (EPD). This would enhance the information management and save time compared to performing EPD as a separate information process, next to the LCA work. Further the intention is to adopt the technical specification ISO/TS 14048 LCA data documentation format in the LCA work.

Work procedure

The contact persons at SCA Hygiene Products during this case study have been an LCA practitioner and an associate scientist LCA. As the scope was clearly defined by the limits of LCA and EPD work in the company and as these tasks are well known by the contact persons no other personnel have been consulted in the case study. A commonly accepted and understood description of the current system and draft vision was reached rather quickly.

The LCA tool LCA@CPM (developed within CPM and IMI) was tested by the LCA practitioner and it was concluded that the prototype can be used to simplify the EPD-work, with some adaptations of the interface and functionality of the tool. The necessary actions include data format mapping, acquisition and documentation of characterization data, and design, program, and test of new user interface.

Further work

The intention is to use the result from this case study as input to further internal discussions regarding introduction of an integrated information system that respond to future requirements, i.e. improvement of the LCA tool performance, adaptation to the upcoming EPD-activities at the company, and compliance with the international standard ISO/TS 14048 regarding LCA data documentation format.

It was also found that the users of the LCA and EPD results, e.g. the product developers, could generate much of these results themselves. The LCA practitioner would then work as a support and possibly as data quality control. This would potentially make the LCA work quicker and make the interpretation of the results by the decision makers easier.

Implications on the method development

The refined questionnaire from the ITT Flygt case study was followed in the analysis and it was found relevant, by both to the method developers and the contact persons at the company, to describe the main aspects of the information system. The scope of this study was clear and the included tasks well known. This gave time to analyze the system more in depth with more detailed questions on specific issues, which in turn

gave information to produce a more detailed synthesis result including good estimations of resources needed to implement the integrated system.

Integrated information flow for risk assessment and eco-efficiency at Akzo Nobel

Results from analysis and synthesis

Purpose, goal, and scope

The case study at Akzo Nobel concerned integration of the tasks to perform Eco-efficiency analysis and Environmental Risk Assessment (ERA) compliant with the future European chemicals legislation REACH[36].

Initially a number of other tasks were discussed to be included in the integration scope, including data management of toxicological substance properties, LCA, and EPD. Due to the limited time resources available, the scope was however narrowed down into Eco-efficiency and ERA.

Work procedure

The contact persons at Akzo Nobel during this case study have been environmental specialists. Relatively much time was spent on setting the goal and scope. Once it was commonly understood the important issues to address in the integration became clear. These issues were: how to include environmental risk assessment in general as an aspect of the Eco-efficiency method applied at Akzo Nobel, and how to introduce a task to perform simplified ERA with sufficient quality, e.g. that would still be compliant with the REACH requirements.

The synthesis resulted in three alternative ways to integrate risk assessment and eco-efficiency based on different methods for simplified ERA and different software solutions. The connection between ERA and Eco-efficiency would follow the same general structure in all three cases.

Further work

The intention at Akzo Nobel is to use the result from this case study as input to further internal discussions regarding introduction of an integrated information system that applies simple risk assessments according to the REACH requirements for more reliable eco-efficiency results. In addition, the simple risk assessments will become an efficient tool in the ordinary risk assessment procedure, to make a first scanning of which chemicals or products that requires a more comprehensive risk assessment.

The decision regarding which alternative is more favourable is related to risks in terms of confidentiality, and costs in terms of education, software maintenance and development and data management. Another decisive factor is whether the simplified

[36] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency and amending Directive 1999/45/EC and Regulation (EC) {on Persistent Organic Pollutants} Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Directive 67/548/EEC in order to adapt it to Regulation (EC) of the European Parliament and of the Council concerning the registration, evaluation, authorization and restriction of chemicals. Available at http://europa.eu.int/eur-lex/en/com/pdf/2003/com2003_0644en.html

ERA results that would be produced from the three alternatives are indeed relevant for Akzo Nobel. An ERA expert could be consulted to provide this information.

Implications on the method development
The method as such was not altered much during this case study. Most aspects of the method as specified at that time were reconfirmed. The study gave valuable experience on the process of understanding and describing the purpose and scope of the integration. A well understood purpose and scope is a prerequisite for relevant results from the following work.

Implementation of VIEWS (Visualization of Integrated Environmental Work Spaces)

Results from analysis and synthesis
Purpose, goal, and scope
The main purpose of the work with the VIEWS integrated platform was to demonstrate how tools and methods in IMPRESS can be integrated in practice. This would provide a hands-on possibility to look at the same primary data from different views in order to easier understand what is implied by integrating different tools and methods. The scope covers tools, databases and methods for Life cycle assessment (LCA), Environmental management systems (EMS), Design for Environment (DfE), Chemical Risk Management (CRM) and Emission Trading Scheme (ETS) that were worked with in IMPRESS. All of these tools were used within the other IMPRESS sub-projects.

Work procedure
The available tools developed at IMI within the scope were inventoried in terms of concept model, software platform, data format, data contents, etc. A picture of the current system was drawn and the possible interconnections were analysed. A vision was synthesized and a set of interfaces between the tools were specified to that would fulfil the purpose of the VIEWS platform. As the tools and methods within the scope were all well known to the VIEWS case study participants in terms of concept models, data availability, software implementation, etc, the analysis and synthesis steps of the work was completed relatively quickly compared to the previous case studies.

Results from implementation
The work tasks to implement the system included programming, data collection, writing of manuals, and testing. The tasks were distributed between the participants. As the work progressed several meetings and a continuous dialogue were held kept to synchronize the work and to refine the planned outcome. Many issues had to be solved and choices made on the way and as many new possibilities arose. A clear formulation of purpose and scope was found to be important in order to quickly arrive at decisions and solutions. The results was tested and further refined until an operational version was ready.

Referring to the integration purpose in this case study it was clear that the resulting VIEWS platform provided several ways to view the same primary data in different applications. Process data originating from data acquired for LCA can be viewed in the EMS tool and vice versa. A specific Process view has been included with a combined list of all process data sets in the system. The technical functionality

description part of the process data can be viewed as exposure scenario data in the CRM tool. Material properties used in the DfE tool that are based on LCA calculations are connected with the original LCA data. This makes a total of 5 different possibilities to view the same process data.

The VIEWS platform was demonstrated to representatives in six CPM companies in order to test that the results answered to the purpose of the case study. Included in the demonstration were also a briefing of background results such as reference models used and experiences from previous projects. In the discussions at the presentations the conceptual reference models and the VIEWS as a practical tool worked well as a support to define problem formulations specific to each company and ideas to proceed to find solutions. Specifically the practical demonstration of an integrated policy and indicator management was helpful to understand the benefits of integrated environmental information systems.

Implications on the method development

The work with VIEWS was the last of the four case studies and provided practical experience from the implementations step. It was concluded that the information gathered and compiled in the analysis and the synthesis steps provided a good decision support to start the implementation. A functional implementation of the VIEWS platform could be completed. Hence this case study can be seen as a verification of that the analysis and synthesis covers the needs to proceed with implementation.

However, as the implementation progressed, some issues was identified which was not found in the analysis including programming bugs and inconsistencies between the intended method implemented and the data format used in the original tools. When such issues are related to interfaces between tools, e.g. where data was to be shared in different tools, the implementation may take significantly longer than expected. A thorough analysis and synthesis should minimize the risk of encountering such problems but as it is not realistic to expect every relevant issue to be identified in the analysis a resource buffer should be available in the implementation for unknown issues.

Discussion and conclusions

A method for integration of environmental information systems has been developed and tested in three case studies. The method has been successfully used to identify ways to integrate information systems with different purpose and scope. The stakeholders in the case studies find the results from the synthesis useful as decision support for implementation. Although the implementation part still remains for the companies, an integrated perspective of their information systems is established. The integration perspective provides ways to reduce costs of data management and increase controllability of environmental work. Examples of reduced costs from integration in the case studies are synergies from co-ordination of data acquisition, increased usability of tools and information, mapping of data format, and adaptation of established tools, to include new application in terms of data and functionality. Increased controllability is reached through increased transparency, indicator relevance and harmonization.

The method provides a general approach to integrate environmental information systems, based on previous experiences and results within CPM and IMI, regarding different integration aspects. This report provides a summary of references to earlier scientific work, and the method framework is based on general integration principles identified in this work. The method framework, involving analysis, synthesis, and implementation, has been continuously refined in parallel to the practical work with the case studies. As a consequence the first case study at ITT Flygt was more time consuming than the others. Four to five person-weeks were spent by the method developers on the case study at ITT Flygt, while slightly more than two weeks were spent on each of the other two case studies. The companies have spent between two and five days on the analysis and synthesis.

Although the integration purpose and scope in the three case studies are quite different, the work process and the presentation of the results in the *analyses* are quite similar. However, the practical work in the *synthesis* differs, depending on which information system elements that are in focus for the integration. For example, in the SCA Hygiene Products study the main issue is to integrate the data formats, in the case study at Akzo Nobel the focus is method and tool compatibility, and for ITT Flygt the important aspects are harmonization of indicators and integration of data formats. Nevertheless, the same basic theoretical integration principles apply in all three cases. The presentation of the results from the syntheses also differs, depending on who the decision maker is and how it is used, e.g. if it will be part of a report to the group management, or part of a presentation to the board at the local production site.

One conclusion when applying this method is that a thorough purpose and scope description in the analysis makes the synthesis much easier and less time consuming. Another important aspect is to make sure to involve the right people from the beginning, i.e. central stakeholders such as the commissioner and people with a good overview and general knowledge of the system such as old and new system owner and manager, user, and receiver of information from user.

At the time of writing, implementation has only been performed within the VIEWS case study and not yet in any of the company case studies. The VIEWS case study showed that it is possible to achieve practical implementation of integrated

environmental information systems. The included tools and tasks in the resulting integrated system VIEWS were previously implemented as individual tools. In the integrated system data can be used in multiple applications, and this puts requirements on that the data is managed consistently to avoid misinterpretation and distortion of data as it is communicated between the applications. All the tools included in the implementation of VIEWS were originally developed based on open and documented concept models, databases, and software, which greatly facilitated an efficient synthesis and implementation of the integrated system. Deviations in the individual tools from their intended methods and ontologies were identified during the implementation which resulted in more a time consuming development. To conclude as prerequisites for integration it is essential that the method of each individual part of the system follows a well understood concept model with a well defined scope based on real world entities and relations.

Further improvements of the method should involve case study experiences of implementation, and experiences from more people using the method. In addition, the theoretical basis, involving integration dimensions and principles, should be further elaborated in research studies.

Appendix 1. Case study reports

Case study at ITT Flygt

Introduction to the case study report

This was the first case study of the three performed in the general integration method development work in sub-project 2 of IMPRESS. As the method was developed parallel to the case studies, there are some minor differences between the reports. For example, in this case study report an earlier version of the questions applied in the analysis is presented, in comparison to updated versions in the other two case study reports. The pictures are also a little different than the ones in the latter case study reports.

The contact person at ITT Flygt during this case study has been the environmental product coordinator. He has arranged meetings with several other users and stakeholders, such as product developers, material managers, and system administrators, which has been of great value for the result. ITT Flygt are currently working in several projects with integration of information systems, e.g. regarding design and material specification document references in the product development, production, and purchase processes. The environmental product coordinator intends to use the result from this case study as input to further discussions regarding integration of environmental information systems at the company.

Analysis

This section presents the results from the survey and analysis of the integration activities and current environmental information system for product management at ITT Flygt.

1. **Purpose of integration**
    a. **What is the reason for and expected benefits from integration?**

The environmental work in the product development at ITT Flygt today requires specific LCA-tools. These tools are used in parallel to other tools in the product development, such as PDM (Product Development Management) and CAD (Computer Aided Design) design tools. The intention is to integrate the environmental work with the other work done in the product development by using one database, to make it more efficient and to be able to automatically generate environmental decision support based on commonly shared and updated data. The benefits will be time savings when the product developers only have to use one database and not have to enter input data about the new product separately in the LCA-tool. The information will already be there as a result of e.g. the design process and earlier environmental studies.

Another reason for integration is to improve the environmental management by harmonizing and re-formulating the environmental indicators used in product development and in communication to customers and policy setters, so that the environmental performance can be communicated in a complete, clear, and uniform way to the different users. Today ELU (Environmental Load Unit)-values from the EPS (Environmental Priority Strategies)-system and impact categories and category indicators in the EPD (Environmental Product Declaration)-system are used in

parallel to product performance indicators developed at ITT Flygt. The company does not feel confident with how the indicators used today are representing the environmental product performance and want to add more relevant aspects to the assessment. The harmonization of indicators should also facilitate setting targets on environmental performance in the product development in the same way as it is done for technical performance. The benefits will be a more holistic, clear, and efficient environmental management with better control.

b. How is it measured?

The benefits of integration could be measured by presenting examples of the time spent on data generation for decision support today and after the integration. The improved environmental management can e.g. be observed by a quicker feedback in the product development, more precise information, and more confident decision makers giving a higher status for the environmental aspects.

The integration will also be beneficial for other users of the same/related information. For example, if a construction material is exchanged by the material group for any reason, the change will be automatically and directly visible for all users effected by this change, e.g. procurement, design, production etc. The time that is saved by this integration, i.e. separate communication to all relevant users of information, and the mistakes that are avoided (risk analysis) should be measured.

2. **Scope of integration**
    a. **What activities, tools (software, databases, etc.), and methods will be integrated?**
    b. **Who are the decision makers and other users in the information system?**
    c. **What information in terms of aggregated decision support is required?**
    d. **How often is the aggregated decision support generated?**
    e. **What information is needed to generate the aggregated decision support?**
    f. **What method is used for external data acquisition?**
    g. **How is the information communicated between activities/users?**
    h. **What concepts, data formats and nomenclatures do you use?**

The purpose of the environmental work in product development is to communicate environmental performance of products to customers, product developers, and the environmental coordinator of products, for them to make decisions based on the supplied information.

A consultant has performed a comprehensive and general life cycle assessment (LCA) for the company. The LCA is verified to confirm with EPD-regulations by Det Norske Veritas, an accredited certification company. This report is used as basis for environmental performance declarations (EPD:s) and a simplified LCA for calculating environmental performance of products in the product development process. The EPD:s have to be updated every three years. EPD:s for five products have been performed so far and the strategy is to make an EPD for each new product.

The LCA-consultant requires LCI-data from the ITT Flygt production, from suppliers upstream, about the use phase and the waste treatment. When data from suppliers are missing, general data from the LCI-database LCI@CPM or from the line of business is used, e.g. data from IISI for steel production etc. In the general LCA study the use phase data is based on European electricity mix according to the LCA database LCI@CPM. Further, the consultant has made assumptions about the waste treatment. Environmental impact assessment data from EPS is used. Guidelines from the EPD system is used to decide system boundaries, cut offs, and allocation principles.

The EPDs are all based on the general LCA with adjustments for each specific product. It is assumed that the production processes for the pumps are similar in terms of their environmental aspects, so the only differences between the EPDs depend on the various materials and their weights in the pumps. The EPD indicator result is calculated in Excel and the EPS 2000 tool, according to the EPD methodology as defined in EPS 2000.

The environmental product coordinator has designed a simplified LCA tool in Excel, to be used by the product developers. It is based on the general LCA, but additional information about e.g. the efficiency and product life time is included. The materials with ELU-values that are generated in the general LCA are included in the Excel based LCA tool. If the material doesn't have defined ELU values the ELU values for a similar material is used.

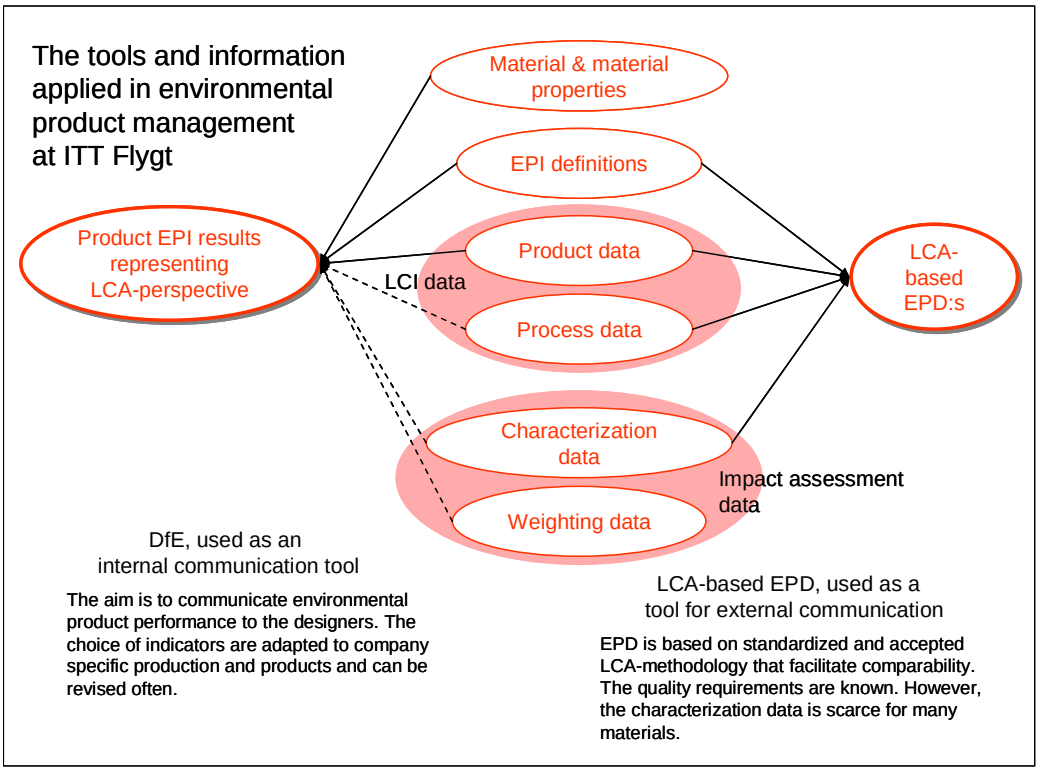


Figure 1 presents a schematic picture of the tools and information applied in the environmental product management at ITT Flygt.

The designers or project leaders in the product development enters product specific data based on the new design in the simplified LCA tool. An aggregated ELU-value for the product is calculated in the tool. The aim is to have a lower ELU-value for the

new product compared with the previous. About 5 simplified LCA:s are performed every year.

A gate model is applied in the product development process as a tool to decide if the product should be further developed or not. It involves e.g. checklists which states what should be regarded in each tollgate. No software or specific format is applied in the tollgate gate model process, meetings and available reports are used to communicate information and decisions. Tollgate 2 and 3 involves an environment, health, and safety assessment. The assessment includes the result from the simplified LCA, in terms of an aggregated ELU-value, and further, a human risk analysis for the use of the product, and a study of the waste situation. An approval by the environmental coordinator of products is required to continue the product development in that direction. The human risk analysis for the use of the product and study of the waste situation are not included in the integration scope.

The environmental policy is defined by the quality manager, in collaboration with the board of directors at the company. The environmental coordinator of products reports the results of environmental evaluation in the product development etc. directly to the director of research and development, who in turn report summarized ELU-results for groups of products to the board of directors.

A picture that describes the current environmental information system within the integration scope is shown in figure 2.

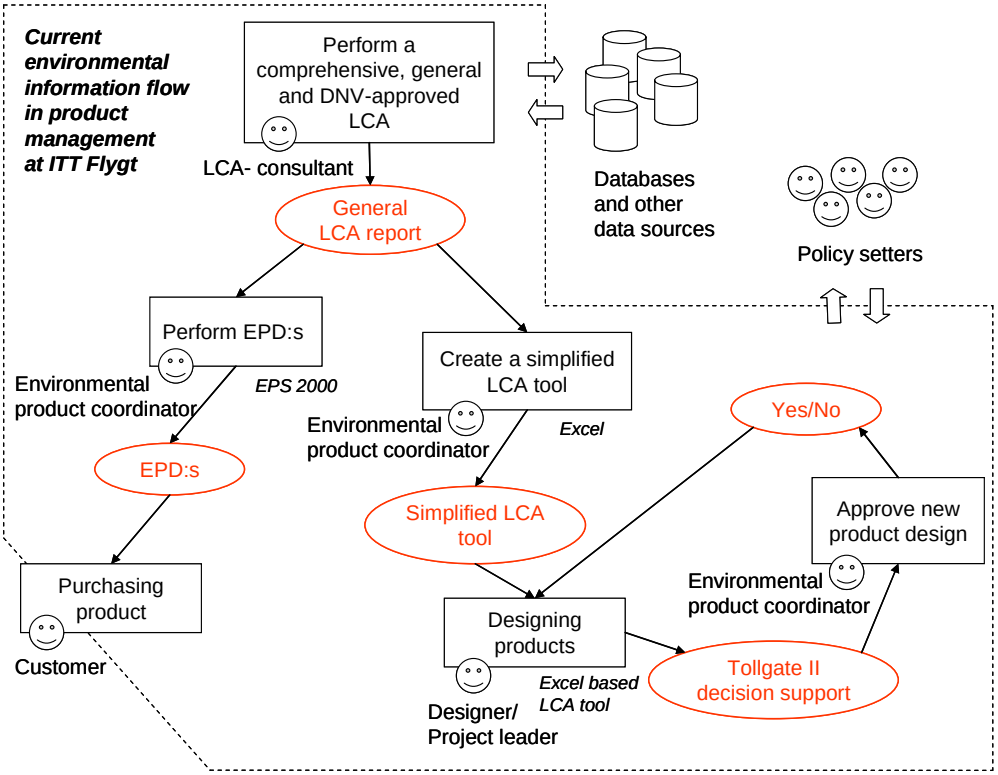


Figure 2 shows the current environmental information flow in product development at ITT Flygt.

Below is a short overview of the system in terms of lists of involved users, activities and software, databases, data sources, formats, nomenclatures, and concepts:

Users

- LCA consultants
- Environmental coordinator of products
- Customers
- Product developers/designers (project leaders)
- Board of directors (policy setters)
- Quality manager (policy setter)
- Director of research and development (policy setter)

Activities

- Perform a comprehensive, general and DNV-approved life cycle assessment
- Perform EPD:s
- Purchase a product
- Create a simplified LCA tool
- Product development
- Approve new product design

Software

- Software used to perform comprehensive and general life cycle assessment is unknown
- EPS 2000 Design System (Assess Ecostrategy Scandinavia AB)[37] and excel is applied when performing Environmental performance declarations (EPD:s) to calculate the impact values for the EPD environmental impact categories
- An excel based LCA tool (designed by ITT Flygt) is used to make simplified LCA:s in the product development
- Vista 32 is a tool for managing the main database at ITT Flygt (K012) that e.g. includes product information (This system is made by in house system developers)
- Crest is a tool to manage the internal material database (pdf-files)

FocalPoint is a new tool bought to be used for target setting of technical requirements in projects. Environmental aspects could be integrated. FLYPS is a tool that provides information on efficiency, internal costs (LCC) etc for pumps but also for complete systems. It is used by the sales personnel when they are communicating with the customer. Environmental performance could be presented here as well.

Databases, data sources, formats, and nomenclatures

- LCI@CPM and internal process inventory at Lindås (SPINE-format)
- IISI, Copper… (general material databases for a line of business)
- Environmental management system (inventory of processes at production site)
- Internal product database (K012) (include all articles and products, and material for articles that are not purchased)
- Internal material database (in pdf-format)
- EPS (EPS 2000)
- Swedish EPD System (report format, characterisation factors etc)

[37] Assess Ecostrategy Scandinavia AB; Mail address: Box 31024, 400 32 Göteborg, Sweden; Visiting address: Andra Långgatan 19 Göteborg; Electronic mail address: assess@assess.se; Web address: www.assess.se; Office phone: +4631422810; FAX number: +46317756858

- SDS from suppliers (some information in database at ecoonline.com and full SDS linked from ecoonline.com to supplier web site, in various formats)
- The black and grey list, based on the black and white Volvo/ABB lists (pdf-file)
- Human risk analysis and waste situation checklists

The product database dates back to 1967 and it is used for production, product development, and EPD generation. A material standard is available in pdf-files, except for the materials in electronic components. Component structures are presented in K012 so that under a specific pump, there are article numbers for each included component, except for electronic components, and at the bottom of the structure there is material from the standard, if the article is produced at ITT Flygt. The material standard is developed together with Swedish Standards Institute (SIS). It includes about 200 construction materials.

Concepts
In the LCA and EPD work ISO 14025 and 14 040-series of standards are applied. In product development, no specified standard of concepts and terminology is applied.

It is specifically important to adapt LCA and EPD concepts and terminology to product developers, policy setters, and customers.

3. **Indicator relevance**
    a. **How does the identified aggregated information support for decisions relate to the policy (indication principle) and objectives in terms of indicators?**

The environmental work in the product development is based on several policies at the company:

Product development
The environmental policy in product development at ITT Flygt implies that a new product shall always have lower environmental impact than the old product, based on a comparative LCA.

Company policy
The company policy states that ITT Flygt shall be and shall be regarded as the leading supplier of solutions and services for treatment of fluids – based on submersible products world wide – thus contributing to a better environment (”ITT Flygt ska vara och ska uppfattas som den ledande leverantören av lösningar och tjänster för vätskehantering – baserat på dränkbara produkter världen över – och bidrar genom det till en bättre miljö.”)

Environmental management system
Significant environmental aspects, based on the environmental review for ITT Flygt, are energy efficiency, choice of materials in the products, and human safety issues during the use phase of the life cycle.

Environmental product declaration
There are general and product specific requirements in the EPD-system.

- Requirements for Environmental Product Declarations[38]
- Product specific requirements (PSR)[39]
- ISO 14020 Environmental Labels and Declarations - General Principles[40]
- ISO 14025 Environmental Labels and Declarations - Environmental Labeling - Type III - Guiding Principles and Procedures[41]

European and Swedish legislation regarding forbidden and restricted materials
ITT Flygt has a material group that controls the material list, used in the product development. If a new material is introduced by the designers, procurement department or the suppliers, the material group will assess the properties and relevant legislation, e.g. by running the material in the Material Lookup tool to see how it is labelled and if it is banned anywhere in the world.

The significant environmental aspects that ITT Flygt has chosen to work with in product development are identified in the environmental review. They are: energy efficiency, choice of materials in the products, and human safety issues during the use phase of the life cycle. In the CPM-project IMPRESS, these aspects are formulated in to quantifiable environmental performance indicators (EPI).

The company has chosen to apply impact assessment methods from the EPS- and EPD-systems, table 1-5 in appendix A. However, the category indicators in these systems do not correspond to the significant aspects in a satisfying way, e.g. the aspect energy efficiency is not represented by a category indicator.

4. **Quality management**
    a. **What information quality requirements do you use and how are they defined and documented?**

The general LCA and the EPDs are reviewed based on the quality requirements in the EPD-system. The environmental quality requirements in the product development are set by the environmental product coordinator, who designs the simplified LCA tool and approves the new product design in respect to the environmental aspects.

Synthesis

The vision of an integrated information system
The vision of an integrated information system for the environmental product management at ITT Flygt is visualized in figure 3. It includes both core functionality and additional desired functionality within the integration scope. Except for the environmental product management, there are other disciplines involved in the integrated information system for product management, e.g. the product development, sales and marketing, material management, and corporate management.

[38] Requirements for Environmental Product Declarations (EPD) (MSR 1999:2), an application of ISO TR 14025, published 2000-03-27 by the Swedish Environmental Management Council
[39] PRODUCT-SPECIFIC REQUIREMENTS, Submersible pumps and mixers, PSR 2002:5, The Swedish Environmental Management Council, Version 1.0, 2002-10-04
[40] ISO 14020 Miljömärkning och miljödeklarationer -Allmänna principer (Environmental Labels and Declarations - General Principles)
[41] ISO/TR 14025 (Environmental Labels and Declarations - Environmental Labeling - Type III - Guiding Principles and Procedures

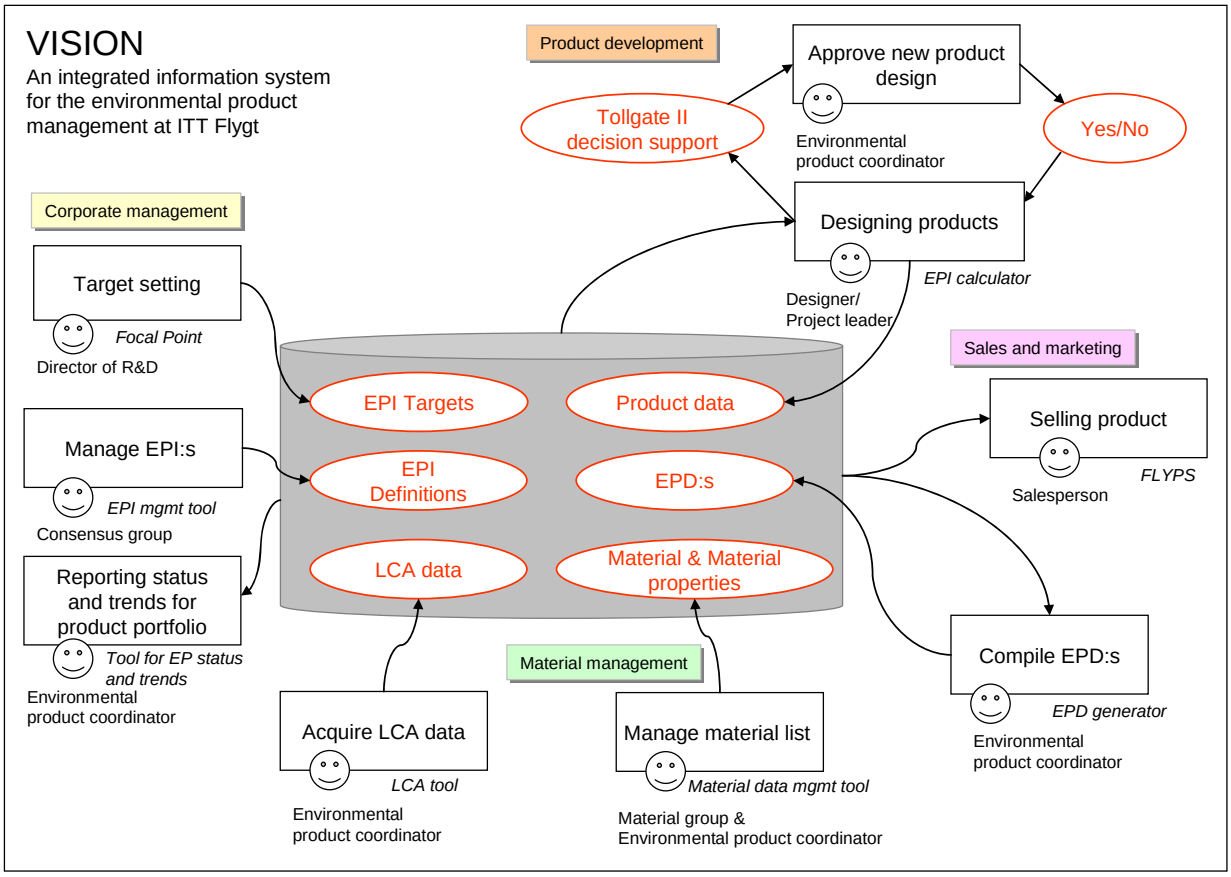


Figure 3 presents the vision of an integrated information system for the environmental product management at ITT Flygt.

The most important changes from the original information system are described below. They are based on the main reasons ITT Flygt had for starting the integration process and the integration methodology developed at Industrial Environmental Informatics at Chalmers.

One common database format

The databases and data sources that are used in the product management today is integrated in to one common database format, e.g. with shared nomenclatures for products, materials, chemicals, and EPI:s. This implies that the different user groups can focus on managing the information they are specialized on and still use the same language for the commonly shared information. The information only has to be entered once in the system and it is directly accessible to all other users. For example, product developers enters product information that are used by the environmental product coordinator when he performs the EPD:s, the material group and environmental product coordinator manages the material lists that are used by the designers in the product development, and the management decide on the product EPI:s that are used when performing EPD:s, designing products, and reporting environmental status and trends for the companies product portfolios.

Calculating environmental performance indicators

Environmental indicators are definitions of environmental impacts, e.g. global warming potential measured in CO2 equivalents, recyclability in percent of product

weight, energy efficiency in percent, etc. LCA is one methodology to calculate the impact on a set of indicators. LCA calculations require process data both upstream and downstream in the life cycle of the product, which is costly and difficult to acquire. Furthermore, the development of impact assessment models describing environmental effects is slow and they do not cover many materials or chemicals.

Due to this, LCA-practitioners are forced to use general process data and ready made impact assessment models, including defined indicators. The envisioned information system facilitates a more flexible way to work with EPI:s. By focusing on environmental indicators that are representative e.g. for a product or product group, other methods than LCA can be used to assess the environmental performance, e.g. target setting, health risk assessment, product development, etc. In this way, conscious choices of indicators can improve the relevance, controllability, and communication to different decision makers and users.

The current use of LCA tools such as EPS 2000 and the simplified Excel based LCA tool will be replaced by a generic EPI-calculator that calculates EPI values for any EPI-profile, e.g. in EPD:s, in company specific product design, in target setting etc. The generic EPI-calculator is applied in different user interfaces that are adapted to the user specific perspectives and concepts. For example, it is applied in a separate tool for product designers, in an EPD tool for the environmental product coordinator, and when reporting environmental status and trends for a product portfolio. In the same way it is possible to add EPI-profiles for future activities, e.g. risk assessment, eco-efficiency, emission trading etc.

Performing life cycle assessment
The introduced LCA tool enables that LCA:s can be done by staff at ITT Flygt. It performs the LCA calculations and supports the documentation requirements in the EPD-system. In addition, the documented LCA data will be stored in a database, easy available to reuse and update, as opposed to the general LCA that currently only is available in a report. Currently, only the quantitative inventory data is stored in a SPINE database. As previously mentioned, nomenclatures for e.g. material, products, and EPIs are shared with other users in the information system. This LCA tool can of course also be used by consultants, still allowing the LCA competence to be better kept within the company.

New functionality
There are additional functionalities within the integration scope, which are not implemented in the current system:

- *FocalPoint* is a target setting tool for the projects in product development. The new functionality allows requirements on environmental performance to be included and specified in terms of target values on EPI:s. The targets are communicated to product designers in the same way as other technical requirements on the product.
- *FLYPS* is a sale support tool, used by the salespersons when they are visiting a customer. It helps the customer to find the product that is most suitable for their specific requirements. The additional functionality involves the presentation of environmental performance of a product in terms of its EPD.
- *Reporting tool for status and trends of environmental product performance*

This is performed manually today. The additional functionality will support the compilation of EPI-reports to environmental and corporate management regarding status and trends for the company's product portfolios.

Suggested implementation measures and estimated costs

The design of the information system is modularized to enable step-wise implementation. One of the benefits with this principle is that the implementation is flexible. It is easy to budget the implementation, to measure the progress, and to choose the order of implementation, at least to a certain point. However, some of the functionality is fundamental for the integration purpose and need to be implemented first or in a specific order. However, other functionality does not have to be implemented to make the whole system work. A suggested order of implementation phases is described below.

The implementation measures are also specified to facilitate the assessment of the related costs by referring to relevant available resources and documented experiences.

Fundamental functionality

Phase 1: Common material, product and EPI database

This phase is implemented to facilitate the environmental product performance for the designers, so that they do not have to enter data for each new product. The functionality also implies shared nomenclatures for EPIs, materials, and products to support the material management, environmental management, and product development. The results from this tool can also be used to report comparative environmental performance of products to the environmental and corporate management. Other functions at the company that could benefit from this integrated database are standards management, production, and procurement, which all work with different aspects of materials and material properties.

Deliverables

- The ELU based indicator in the current system, i.e. total ELU per product, is translated into an EPI definition
- A common database for EPI definitions, material, and product data is created.
- An EPI calculator is developed and integrated in the product design process.
- The environmental and material group manages all material properties in the same data format.

Available resources and starting points

A method to create EPI:s including a documentation format is developed in the RAVEL[42] and REPID[43] projects. An example of an EPI definition, based on data from the REPID project, is developed in the IMPRESS project, see appendix B.

[42] Integrating Eco-Efficiency in Rail Vehicle Design, Edited by Wim Dewulf, Joost Duflou, Åsa Ander, Leuven University Press, 2001, Leuven

[43] Final report for the EU funded REPID project, Editor Mads Bergendorff, UIC, 2004, Copenhagen

ITT Flygt uses the Material Lookup Tool which is developed for the ITT group. This tool is a material database with a few material properties including labeling requirements and use restrictions in different countries. This database could be used as a starting point for the new material database at ITT Flygt. The product structures at ITT Flygt are available in the K012 database. The material and product structure data can be connected by an unambiguous nomenclature.

An example of a concept model and data format for a general component structure, based on results from the RAVEL project, can be found in appendix C. An example of a concept model and data format for material property management, based on SPINE[44] and results from the RAVEL and OMNIITOX[45] project, can be found in appendix D.

Currently, product and material information regarding electronic components is not managed at ITT Flygt, but there is some generic data available if this will be included in the environmental performance assessment of products, e.g. in the LCI data store[46].

The current development of a document management system for CAD/PDM should be considered when developing the common database for EPI definitions, material, and product data, as well as the work process of the standard group.

An example of an EPI calculator is the CPM Inventory Tool[47], which is a prototype tool for managing component structure data and calculating EPIs.

Support for data administration of the system can be found in literature, e.g. Establishment of CPMs LCA database[48]. It has to be considered that the management and maintenance of data is performed by several groups with different competence, i.e. the environmental coordinator updates and manages the EPIs and environmental properties of material, while the material group updates and manages the rest of the material properties etc. This put requirements on e.g. authorization issues.

It has been expressed by different users of the information systems at ITT Flygt that they wish to study how some other companies have solved these issues, e.g. Scania, Atlas Copco, ABB, Volvo, Siemens, Ericsson.

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[44] SPINE, A Relation Database Structure for Life Cycle Assessment, Carlson R, Löfgren G, Steen B, IVL-REPORT, September 1995, Göteborg

[45] OMNIITOX, EU-project within the Competitive and Sustainable Growth Programme 2001-2005, Official web site: www.omniitox.net, IMI web site: http://omniitox.imi.chalmers.se/

[46] LCI data store at http://databases.imi.chalmers.se/imiportal/, Centre for Environmental Assessment of Product and Material Systems, Industrial Environmental Informatics, Chalmers University of Technology

[47] CPM Inventory Tool at http://project.imi.chalmers.se/IMPRESS_SP7, Centre for Environmental Assessment of Product and Material Systems, Industrial Environmental Informatics, Chalmers University of Technology

[48] Project report, Establishment of CPMs LCA database, Raul Carlson, Ann-Christin Pålsson, CPM Report 1998:3, p4 in Appendix, Chalmers University of Technology, Göteborg

Phase 2: EPI management
In this phase an EPI management process is implemented so that ITT Flygt can define EPIs that better correspond to the environmental product performance in regards to their environmental policy. The management involves defining the EPIs in a consensus environment. The EPI calculator implemented in phase 1 can be used to calculate the new EPI values.

Deliverables
- New EPI-definitions that are representative for the environmental product performance at ITT-Flygt are defined in a consensus group at ITT Flygt.
- An EPI management process is developed.
- The material data required for the new EPIs is acquired.

Available resources and starting points
In the project IMPRESS several EPI-definitions with data relevant for ITT Flygt have been developed in collaboration with Chalmers and other companies.[49]

A data format and method for EPI management was developed and tested in RAVEL[50], REPID[51] and IMPRESS. The algorithms in the EPI definitions have to be implemented by a programmer.

Additional functionality

Phase 3: Harmonizing EPI profiles and calculate EPD:s
In this phase the functionality to calculate EPIs for EPDs is implemented. This implies a holistic and consistent management of EPI-profiles, for control and communication of environmental product performance to two (or more) different users.

Deliverables
- The category indicators used in EPD are defined as EPIs.
- A common database for EPI definitions, material, product, and LCA data is created.
- Develop an LCA data documentation tool.
- Enter LCA-data (LCI- and characterization data) in to the common database
- Develop a user interface for the environmental product coordinator to facilitate the calculations of EPI-profiles for EPDs.

Phase 4: Automatic generation of EPDs

[49] Final report from Sub-project 7 in IMPRESS (Preliminary name), Edited by Karolina Flemström, Centre for Environmental Assessment of Product and Material Systems, Industrial Environmental Informatics, Chalmers University of Technology, Göteborg
[50] Integrating Eco-Efficiency in Rail Vehicle Design, Edited by Wim Dewulf, Joost Duflou, Åsa Ander, Leuven University Press, 2001, Leuven
[51] Final report for the EU funded REPID project, Editor Mads Bergendorff, UIC, 2004, Copenhagen

In this phase an automatic generator of EPDs is implemented. The additional functionality to phase 3 is included documentation and design for a complete EPD-report.

Deliverables

– Develop a user interface for the environmental product coordinator to facilitate the generations of complete EPD:s, i.e. an extended version of the tool developed in phase 3.

Phase 5: Target setting in product development projects

In this phase target setting used in product development projects is developed to involve requirements on environmental performance in terms of target values on EPIs. The targets are communicated to product designers in the same way as other technical requirements on the product.

– Further develop the target setting tool FocalPoint to include requirements on environmental performance in terms of target values on EPIs.

Phase 6: Report status and trends of environmental product performance

The communication to the corporate management is supported by a tool that uses EPI-definitions and compiles EPI-reports regarding status and trends for the company's products and product portfolios.

Deliverables

– Develop a reporting tool, based on available EPI-definitions and EPI-calculator.

Phase 7: Perform LCA:s

In this phase a LCA calculation tool is developed, which enables that LCAs can be performed by staff at ITT Flygt. It is based on LCA data documentation tool introduced in phase 3 and supports the standardized LCA data format and methodology in the ISO 14040-series.

Deliverables

– Further develop the LCA data documentation tool to include calculation, i.e. normalization, characterization, and weighting

Phase 8: Communicate EPDs in a sale support tool

FLYPS is a sale support tool, used by the salespersons when they are visiting a customer. It helps the customer to find the product that is most suitable for their specific conditions. In this phase the additional functionality will be that the customer also can choose product from an environmental point of view, i.e. each product's EPD will be available for comparison in this tool.

Deliverables

– The additional functionality involves the presentation and comparison of environmental performance of products in terms of its EPD.

Also other environmental activities at the company can be integrated in a similar way as the above described, e.g. the environmental management system, and the human

risk analysis for the use of the product and study of the waste situation that are included in the tollgate decision support. However, these activities were not included in this integration scope.

Conclusions and recommendations for implementation

The main purpose of integrating the environmental information systems at ITT Flygt is to efficiently share product and material data and to improve the management of environmental product performance, in terms of relevance (introducing and harmonizing Environmental Performance Indicators, EPIs). Much of the data required already exists in the current information system at ITT Flygt, i.e. material and material property data, and product content and structure data. However, the material properties need to be available in a database and explicitly connected to the product structure. Additional data required is EPI data and environmental properties of materials. These additional material properties can and should use the same nomenclature and data format as the available material properties. Data formats and methods for the development and management of EPIs are available and the process to define relevant EPIs for ITT Flygt and acquire data is initialized in the IMPRESS project.

Many other core functions at the company can benefit from an integrated material and product database, e.g. procurement, standard management, and material management. The improved quality management is one advantage with data sharing, as updates will be available directly to all users in the system. Hence, errors due to delays and mistakes are minimized. In addition, the work with updates, corrections and additions will take less time as it only is done once. When someone wants to use the data, separate data search, and manual reformatting and exchange will not be necessary, which also is time saving.

The introduction of EPIs will lead to better precision in environmental product management at ITT Flygt, as the EPIs can be defined to reflect the environmental policy and goals and the most important environmental aspects for the products at the company. Today general and predefined LCA (Life Cycle Assessment) indicators are used, which do not consider the specific properties of the product or the circumstances in which it is produced and used. The results are therefore irrelevant for ITT Flygt and may be misinterpreted in the operational and strategic decision making. The introduction of EPIs will be a more flexible way to work uniformly with environmental management in many different areas, e.g. EMS (Environmental Management Systems), risk management, product development, green procurement, communication to corporate management and customers etc. The quantitative and uniform connection to the policy and goals will improve the follow-up and support decisions for future activities. Thus, this is a strategic choice and an advantage also in the long run. In addition, the EPIs can be defined to communicate better than today to the specific users, e.g. to designers, customers, and sales people, which will make the environmental work more easy to understand and comply with, i.e. more successful.

Environmental impact categories and category indicators

Table 1 Environmental impact categories and category indicators according to the EPD-system[52] and PSR/PCR (product specific requirements/product category rules)[53].

Environmental impact category	Category indicator	Indicator unit	Notes
Resource use	Use of non-renewable resources		
-"-	Use of renewable resources		
-"-	Use of electricity		Expressed as net consumption
Global warming	Emission of substances contributing to global warming	kg CO_2 equivalents (GWP) (100 years)	
Acidification	Emission of substances contributing to acidification	kmol H^+	
Ozone depletion	Emission of substance contributing to ozone depletion	kg CFC-11 equivalents (20 years)	
Photochemical oxidant formation (POCP)	Emission of substances contributing to photochemical oxidant formation (POCP)	kg ethene-equivalents	
Eutrophication	Emission of substances contributing to eutrophication	kg O_2	
Emission of toxic substances to air	SO_2 emission to air		

[52] Requirements for Environmental Product Declarations (EPD) (MSR 1999:2), an application of ISO TR 14025, published 2000-03-27 by the Swedish Environmental Management Council, p. 27
[53] PRODUCT-SPECIFIC REQUIREMENTS, Submersible pumps and mixers, PSR 2002:5, The Swedish Environmental Management Council, Version 1.0, 2002-10-04, p.8

-“-	NOx emission to air		
-“-	Cd emission to air		
-“-	Cr emission to air		
-“-	Hg emission to air		
-“-	Ni emission to air		
-“-	Pb emission to air		
-“-	Zn emission to air		
Emission of toxic substances to water	Cd emission to water		
-“-	Cr emission to water		
-“-	Hg emission to water		
-“-	Ni emission to water		
-“-	Pb emission to water		
-“-	Zn emission to water		
Waste	Hazardous waste		As defined by EU-directive
-“-	Regular waste		As a total sum
Usefulness	Total flow at specific head	kW (times efficiency in %)	Information about the work conducted by the product during the usage phase
Recycling	Recycling of materials		

Table 2 EPS impact categories and category indicators for human health effects.

Impact category name	Category indicator name	Indicator unit	Notes
Life expectancy	Years of lost life, (YOLL)	Person-year	Instead of excess mortality, which was used in earlier versions
Severe morbidity and suffering	Severe morbidity	Person-year	Including starvation
Morbidity	Morbidity	Person-year	Like a cold or flue
Severe nuisance	Severe nuisance	Person-year	Would normally cause a reaction to avoid the nuisance
Nuisance	Nuisance	Person-year	Irritating, but not causing any direct action

Table 3 EPS impact categories and category indicators for ecosystem production capacity.

Impact category name	Category indicator name	Indicator default unit	Notes
Crop production capacity	Crop production capacity (short name: crop)	kg	Weight at harvest
Wood production capacity	Wood production capacity (short-name: wood)	kg	Dry weight basis
Fish&meat pro-duction capacity	Fish&meat production capacity (short-name: fish&meat)	kg	Full weight of animals
Base cat-ion capacity	Base cat-ion capacity	H+ mole equivalents	Used only when models including the other indicators is not available
Production capacity for water	Production capacity for irrigation water (short name: irrigation water)	kg	Must be acceptable for irrigation, e.g. with respect to persistent toxic substances
Production capacity for water	Production capacity for drinking water (short name: drinking water)	kg	Fullfilling WHO criteria on drinking water (1997)

Table 4 EPS default impact categories and category indicators for abiotic stock resources.

Impact category name	Category indicator name	Indicator default unit	Notes
Depletion of element reserves	= "element name" reserves	kg of element	E.g. Cu reserves, kg Cu
Depletion of fossil reserves	Natural gas reserves	kg	The hydrocarbon part
Depletion of fossil reserves	Oil reserves	kg	
Depletion of fossil reserves	Coal reserves	kg	
Depletion of mineral reserves	= "mineral name" reserves	kg	

Table 5 EPS default impact categories and category indicators for bio-diversity.

Impact category name	Category indicator name	Indicator default unit	Notes
Extinction of species	Normalised extinction of species, short-name: NEX	Dimension-less	The normalization is made with respect to the species extinct during 1990

Example of a definition and data format for an Environmental Performance Indicator (EPI)

This appendix presents an example of a definition and data format for an Environmental Performance Indicator (EPI). The format is developed in the RAVEL[54] and REPID[55] projects and the definition is adapted to the IMPRESS[56] project context (not final version).

Name: Fraction recycled material

Definition/ description of function:
Monitor the weight fraction of recycled materials in the product.
The aim is to make suppliers use recycled material.
The term 'Recycled' in this indicator means that the material has been recycled through material recycling.
Material recycling means the reprocessing in a production process of the waste material for the original purpose or for other purposes but excluding energy recovery.
Post industrial scrap from one company's manufacturing unit is also considered recycled if used in another company's manufacturing of a product (see material property definition for more information).
If the user has entered a value for the actual recycled rate of a material in a specific component, this value will be used in the calculation otherwise a default value e.g. world (European) average value will be used.

Formula:
The first part of the formula describes the input of actual recycled material data or world average data for rates of recycled material.
If A is the set of all materials in the material list and $i \in A$
If a supplier gives the actual fraction of recycled material in a component this will be used, otherwise world average will be used. $AveRecycled_i$ is the world average rate of recycled material in material $i \in A$.

Calculation of rate of recycled material:
K is the set of all material occurrences found when traversing the inventory tree for the analysed component, $k \in K$
For every material occurrence k, the user should enter the choice of material ($Material_k$), the weight of the material ($Weight_k$) and the actual fraction of recycled material ($Recycled_k$), if available.
For k=1...K
    If $Recycled_k$ is empty, then
    $Recycled_k = AveRecycled_i$ where material i is equal to $Material_k$
end

[54] Integrating Eco-Efficiency in Rail Vehicle Design, Edited by Wim Dewulf, Joost Duflou, Åsa Ander, Leuven University Press, 2001, Leuven
[55] Final report for the EU funded REPID project, Editor Mads Bergendorff, UIC, 2004, Copenhagen
[56] Final report from Sub-project 7 in IMPRESS (Preliminary name), Edited by Karolina Flemström, Centre for Environmental Assessment of Product and Material Systems, Industrial Environmental Informatics, Chalmers University of Technology, Göteborg

You can get the total weight of recycled material of material *i* in product by multiplying [$Weight_k$] with [$Recycled_k$] and by traversing the inventory tree and summing the recycled weights for each material. Then;
The vector of weight for all materials = $Weight_k \ \forall k \in K$
The vector of recycled fraction for all materials = $Recycled_k \ \forall k \in K$
The total weight of all materials (in kg) $= \sum_{\forall k \in K} Totalweight_k$

Total amount of recycled materials (in kg) $= \sum_{\forall k \in K} TotalWeight_k * \mathrm{Re}cycled_k$

Fraction recycled material (in weight-%) $= \frac{\sum_{\forall k \in K} Totalweight_k * \mathrm{Re}clycled_k}{\sum_{\forall k \in K} Totalweight_k} * 100\%$

Unit:
[Weight-%], [kg]

Input:

User input:

- Actual rates of recycled material for each material occurrence[weight-%] (if available)

Material specific properties for this indicator:

- Average rates of recycled material [weight-%] See Material property specification for detailed definition.

Input for calculation:

- Weight for each material occurrence in the analysed component [kg]
- List of all materials used in the component
- Actual rates of recycled material for each material, if available otherwise average rates of recycled material.[weight-%]

Output:

- Fraction recycled material in the analysed component [weight-%]
- Amount of recycled material in the analysed component [kg]
- Total weight of analysed component [kg]

Comments:

The actual recycled rate numbers are only saved for the specific material in a specific component. If the user wants to use this value again, he has to insert it again. Otherwise the *World* average value will be used.

Case study at SCA Hygiene Products

Introduction to the case study report

This case study is one of three performed in the general integration method development work in sub-project 2 of IMPRESS. As the method was developed parallel to the case studies, there are some minor differences between the three case studies reports. For example, in this case study report a latter version of the questions applied in the analysis is presented, in comparison to the first version in the ITT Flygt case study report. The pictures are also a little different than the ones in the first case study report.

The contact person at SCA Hygiene Products during this case study has been an LCA practitioner and an associate scientist LCA. The intention is to use the result from this case study as input to further internal discussions regarding introduction of an integrated information system that has the performance requirements that is necessary in the future, i.e. adaptation to the upcoming EPD-activities at the company and the LCA data documentation format in ISO/TS 14048.

Analysis

This chapter presents the results from the survey and analysis of the integration activities and current environmental information system for product management at SCA Hygiene Products.

1. **Purpose of integration**
    a. **What is the reason for and expected benefits from integration?**

The current work with LCA at SCA Hygiene Products is in overall well established with routines for data acquisition, documentation, storage, and communication routines. However, they need to establish a solid information system for their work and develop their LCA work towards future plans of performing EPDs. Their current LCA tool lack in e.g. performance, technical support, and development why it is crucial for their practical work to find another LCA tool that correspond to their needs. The intention is also to adapt the LCA work to be compatible with the ISO/TS 14048 data documentation format and the current tool does not support that format.

The extensive LCA calculations currently take very long time. The calculations are significantly slower with increased geographical distance to the database server located in Göteborg. Work-around solutions have been tested for the performance problems by copying data from the central database to the local computer for manipulations in Excel but this has not been found as a long-term option.

SCA Hygiene Products have experience of e.g. the LCA prototype LCA@CPM developed at IMI[57], thus, it has been decided to evaluate the possibilities of introducing this prototype as a base for an EPD-adapted LCA tool. Solutions for conversion of data from the SPINE format, which is their current LCA data format, into an ISO/TS 14048 compatible format are available in LCA@CPM. In addition to a more effective, efficient and solid information system for LCA, the LCA tool also

[57] IMI Portal, Industrial Environmental Informatics, Chalmers University of Technology, http://databases.imi.chalmers.se/imiportal/ (2005-12-22)

needs to be independent of the person using it, i.e. the results should be reproducible by any co-worker with corresponding competence.

Other expected benefits of this integration work are better analysis possibilities, e.g. to get other alternatives of LCA result presentation, to be able to make data treatment in waste modelling less time consuming etc. In addition, if the tool is implemented as an in-house solution, the competence of the information system and tool will be kept inside the company.

Thus, improved functionality, secured technical support and development, and more time efficient work are the main reasons for integration.

b. How is it measured?

The integration investments can be argued for by making risk analysis of the situation with the current instabilities in the information system. In addition, it can be estimated how much time that would be spent on making (partly) manual EPDs, if a supporting tool is not available in the future. Other time savings, like improved performance and analysis when using the LCA tool, can be compared with the time it takes today to perform the task.

The EPDs requires an external review. One of the expected benefits with a new and integrated system for LCA and EPD are a more transparent system, which facilitate easy external reviews. In short, it is likely that SCA Hygiene Products will have to go through with such a review, when they perform their first EPD. Then it is possible to compare the performed review with a review based on the new, integrated and more transparent LCA/EPD information system, to see if it is more comprehensive and time efficient.

2. Scope of integration

a. What activities, tools (software, databases, etc.), and methods will be integrated?
b. Who are the decision makers and other users in the information system?
c. What information in terms of aggregated decision support is required?
d. How often is the aggregated decision support generated?
e. What information is needed to generate the aggregated decision support?
f. What method is used for external data acquisition?
g. How is the information communicated between activities/users?
h. What concepts, data formats and nomenclatures do you use?

At present LCA studies are performed at SCA Hygiene Products for various purposes, see figure 1 that shows an overview of the current environmental information flow within the integration scope. The integration scope includes the addition of Environmental Product Declarations (EPDs) to the current LCA related work.

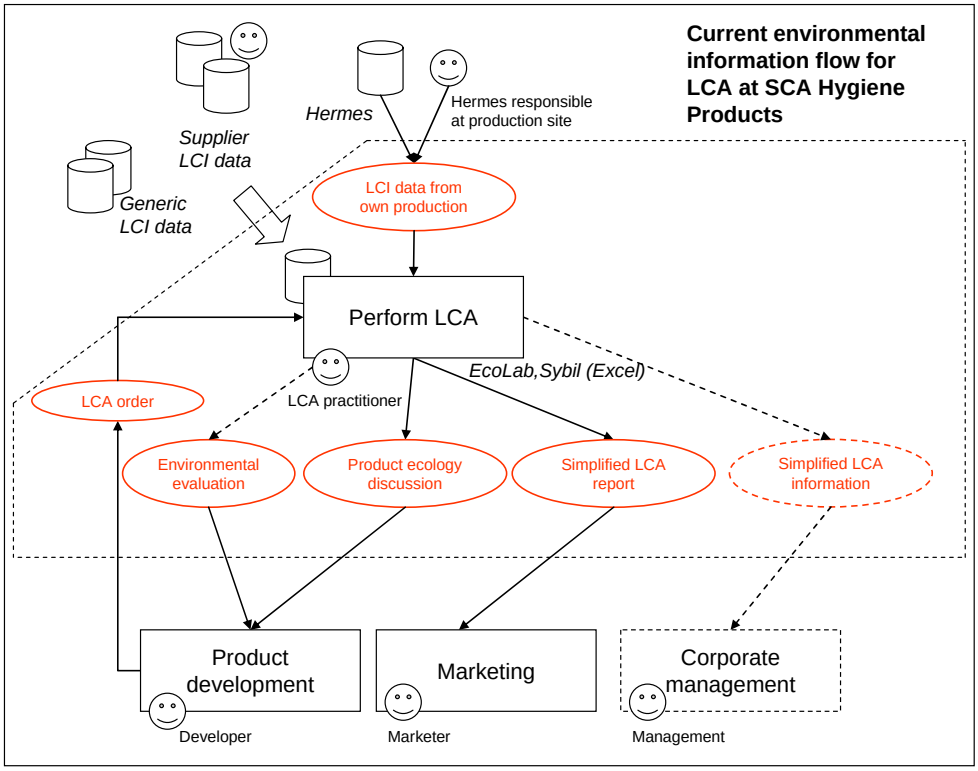

Figure 1 describes the current environmental information flow for LCA at SCA Hygiene Products.

As part of the formal product development process the environmental impact shall be assessed. The LCA practitioners receive orders for a specific LCA study for new products from the product development department. They also receive specifications of the material included in the products and packaging, information on what facility will produce the product, and data on estimated sales volumes on different markets. Process data needed for the studies is acquired from the internal data management system Hermes, with data on process emissions and raw material use from the company's production sites. Specific data questionnaires are used to collect process data from suppliers. It is often time consuming and costly to acquire this process data and when no site specific data can be acquired external databases are used, with generic process data. The LCA studies include a benchmarking to Best Available Technology (BAT) for tissue products. The BAT index data is acquired from the BAT reference document (Bref) for Integrated Pollution Prevention and Control (IPPC), compiled by the European Commission. Environmental impact model data is taken from the inherent database in the software EcoLab applied for LCA calculations. The waste model data is complied from various sources including elementary analyses performed at SCA research.

All LCI data is interpreted by the LCA practitioners and checked with the source, if any anomalies are found. The data is then manually documented in the SPINE formatted database in the LCA tool EcoLab. An additional Excel tool, Sybil, is used for calculating end of life scenarios in the LCA studies.

The results from the LCA studies are compiled into different reports, depending on the receiver. For new products comparable LCAs are reported to the product development as Environmental evaluation reports and Product ecology discussion reports. This is done 10-15 times per year. Simplified LCA reports are sent to the

marketing department about 2-3 times per year, to be used as environmental information to customers. General findings from the LCA work have also been communicated to the corporate management.

An overview of the system in terms of involved users and decision makers, concepts, data formats, nomenclatures, and software is listed below:

Users and decision makers
- LCA practitioner
- Hermes responsible
- Customer
- Product developer
- Market personnel
- Corporate management

Concepts, data formats and nomenclatures
- LCA methodology according to 14040 series
- SPINE concept model for life cycle inventory information
- EPD methodology Swedish programme, PCR and ISO 14025
- Nomenclatures: SCA Hygiene Products internal substance nomenclature for LCA based on EcoLab functionality, CPM 2004 (based on nomenclature rules in CPM 2000)

Data formats
- LCI data in SPINE format
- IA data in format inherent in EcoLab software
- Waste management data in Sybil Excel tool
- LCA reports word format
- EPD word format
- LCA order from PD department in an Excel template
- Product data in PDF
- Supplier data word template
- Generic process data in various data formats
- BAT for tissue data on Bref/IPPC document

Software
- EcoLab for LCA documentation, storage, and calculations
- Sybil (Excel) for waste management calculations
- Word
- Hermes for company process data

3. Indicator relevance

a. How does the tasks and information in the system relate to policy, legislation, and other objectives in terms of indicators?

There are six main indicators applied in LCA at SCA Hygiene Products:
- Global warming potential (GWP)
- Acidification potential (AP)
- Aquatic oxygen depletion potential (AODP)

- Photochemical ozone creation potential (POCP)
- Use of fossil resources
- Use of water

There are also some additional indicators regarding energy and land use that sometimes are measured:

- Energy use based on electricity
- Energy use in transportation
- Energy use based on bio-energy
- Energy use based on nuclear power (the nuclear waste is measured)
- Land use forestry (area to grow wood for pulp)

Further, there are some indicators measured that is based on the product and that does not cover the life cycle perspective:

- Weight of product
- Weight of product package
- Non-renewable material in product
- Landfill waste from product

The LCA indicators are chosen because they are relevant for the line of business and because they represent measurements that should be managed and coordinated from the central environmental organization. Examples of indicators that are not regarded as relevant is Ozone depletion potential (ODP) because it is not a major problem in the line of business, and Human toxicity, due to insufficient data quality. Other environmental indicators, like bad odor and noise, are managed on a local level, at the production sites. Thus, the LCA indicators are not directly extracted from the environmental policy.

The Swedish EPD programme includes predefined indicators that must be applied if the EPD should be certified. There are 5 emission indicators for tissue paper in the Swedish EPD programme:

- Global warming potential (GWP)
- Acidification potential (AP)
- Eutrophication (AODP)
- Photochemical oxidant formation (POCP)
- Ozone depletion potential (ODP)

Other indicators that shall be declared for the manufacturing and use phase are:

- Resource use
    - Use of non-renewable resources (with and without energy content)
    - Use of renewable resources (with and without energy content)
- Energy
    - Total energy
    - Electricity consumption (bought electricity)
    - Transport energy
- Other
    - Waste
    - Water
    - Material and chemical substances listed according to chapter 3:

- *For Tissue paper manufactured from recovered paper*: type of recovered paper, bleaching agents, group of functional chemicals in descending order according to table 1 & 2[58]
- *From Tissue paper manufactured from virgin fibers*: type of pulp bleaching agents, group of functional chemicals in descending order according to table 1 & 2[59]

Thus, there is a fairly good correlation between the current LCA indicators applied at the company and the EPD indicators required in the Swedish programme.

b. Are the indicators in the information system understood and accepted by the decision makers and other users?

This issue has been discussed internally at SCA Hygiene Products. It is a long term organizational learning process and the acceptance and understanding is gradually increasing.

The original indicators, named by the LCA practitioners, are in some cases translated depending on the receiver of the LCA result, e.g. "POCP" is translated to "Summer smog". Also the indicators are accompanied by explanations. In the simplified LCA only the differences of impacts from previous results are reported. The product developers have also been educated in basic interpretation of LCA results.

4. Quality management

a. What information quality requirements do you use and how are they defined and documented?

The quality requirements are not uniform for all data; there is a difference between SCAs own process data and data from suppliers. The data in Hermes, the SCA internal system containing data from the production plants, is reported in an EMS-report and are reviewed several times. The Hermes responsible person at the production plats makes some reviews e.g. on process metadata, the Hermes responsible person in the research management system (RMS) at the central organization makes other reviews, e.g. comparison of figures with earlier years, where deviations exceeding 5% must be explained, and EMS responsible personal makes final reviews before the aggregated information is distributed to an external reviewer.

Data from suppliers is reviewed by the LCA practitioners so that they seem reasonable, i.e. they make mass balances and compare the data with other suppliers, earlier years or generic data for the line of business. If the mass balance is not correct, generic data for the line of business is used instead. The data from the suppliers does not have to include comprehensive meta data on processes etc. as long as the mass balance is correct and the figures seem reasonable compared to other sources.

[58] Product-specific requirements (PSR) for preparing an environmental product declaration (EPD) for Tissue Paper manufactured from recovered paper, PSR 2004:8, The Swedish Environmental Management Council, Version 1.0, 2004-09-13

[59] Product-specific requirements (PSR) for preparing an environmental product declaration (EPD) for Tissue Paper manufactured from virgin fibers, PSR 2004:7, The Swedish Environmental Management Council, Version 1.0, 2004-09-13

Synthesis

Vision

In this vision the tool for performing LCAs is replaced by an in-house implementation of the LCA@CPM prototype. The prototype is based on the ISO/TS 14048 LCA data documentation format. The current SPINE formatted LCI database at SCA Hygiene Products can be automatically converted to the data format in LCA@CPM.

For the introduction of EPD work, additional data is required in the information system, denoted as additional environmental information, see figure 2. New LCI scenarios may have to be defined to match the system boundaries of an EPD. The process data needed is already available and the SPINE format facilitates such system model re-compilations. Further specific environmental impact model data that match the impact categories included in an EPD must be acquired and formalized as an impact assessment calculation model. A specific task to generate EPDs must be installed in the information system. This task would receive orders for from the marketing department who in turn handles calls for tenders from customers (public procurement) that require EPD information. The task would compile EPD reports based on the LCA data and the additional environmental information and report back to the marketing department. A specific EPD generation software tool would facilitate this work.

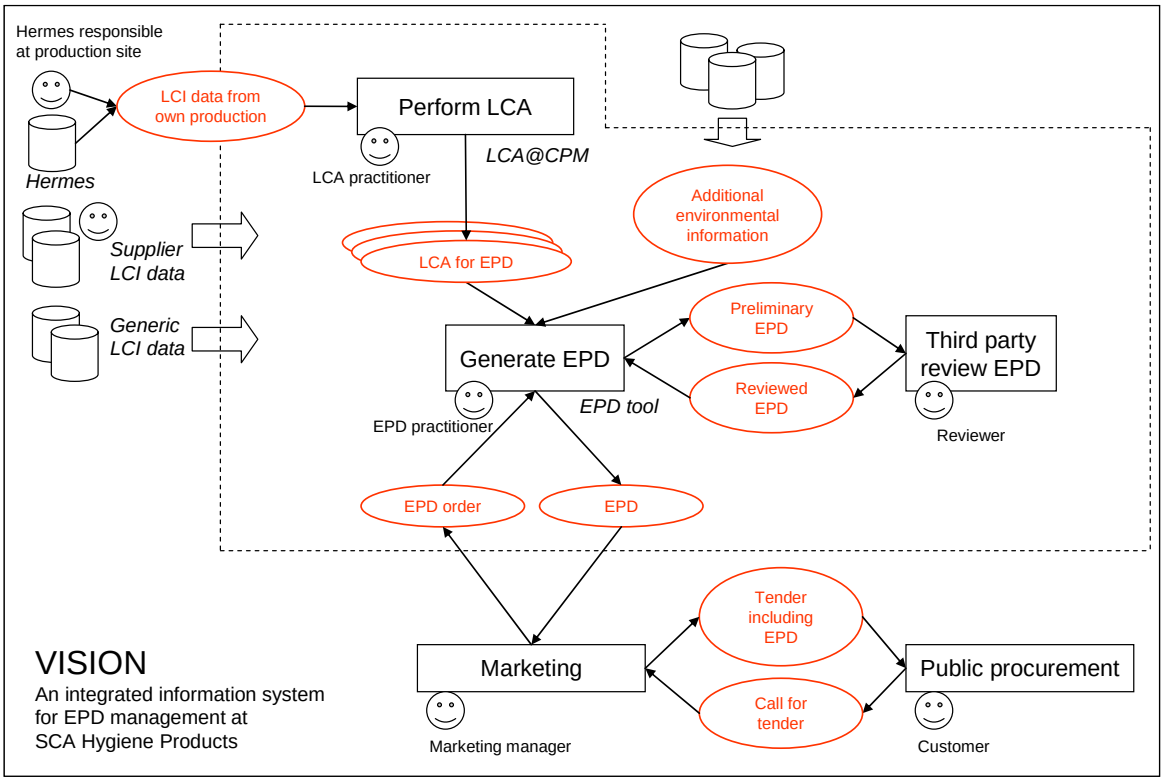

Figure 2 presents the vision of the integrated information system for EPD management at SCA Hygiene Products.

Practical work

The synthesis in this case study involves a draft mapping of the reporting requirements in the EPD system and the LCI data documentation format ISO/TS

14048, as well as a first investigation of the required changes in order to adapt the LCA tool LCA@CPM for the EPD reporting and review requirements.

As a part of this case study, personnel at SCA Hygiene Products have performed a simplified LCA in LCA@CPM, to test and evaluate the functionality of the tool. During the test IMI personnel have been involved to support the process and solve technical issues. The LCA@CPM is found by the LCA practitioner to be a feasible tool to perform LCA studies. It is generally intuitive and easy to work with, relatively fast to perform calculations. The possibility to import existing SPINE formatted data from EcoLab to ISO/TS 14048 formatted data in LCA@CPM is a great advantage which facilitates the change of tools. LCA@CPM is still a prototype and some additional functionalities are necessary to meet the requirements of the tasks to perform LCA and EPD. The main issues that need to be resolved are:

- Functionality to choose specific category indicators in the IA calculations.
- Functionality to define characterization factors or weighting factors.
- Support for parameterized processes

Within the IMPRESS project the LCA@CPM is further improved. A further evaluation of the tool is planned when the above issues have been implemented.

Mapping of ISO/TS 14048 and EPD reporting requirements
An initial mapping of the requirements in the PSR for Tissue paper manufactured from recovered paper[60] and Tissue paper manufactured from virgin fibers[61] with the LCI data documentation format ISO/TS 14048 has been performed. The outcome is that the format ISO/TS 14048 can be used for storage and communication of EPD studies. There are some issues that need to be further elaborated before it can be implemented:

- The parameters to be declared in the EPD (chapter10)
  The parameters that need to be declared according to the EPD could be specified by “Inputs and outputs properties” in the ISO/TS 14048 format. This information can then be used in a characterization method, to generate the required indicators, e.g. Non-renewable recourses without energy content, Total energy, and Waste. However, the ISO/TS 14048 format requires that “Inputs and outputs properties” are stated as numerical values, and a solution for this must be further specified.
- Other environmental information (chapter12) (Additional environmental information in figure 2)
  In the two PSRs available, it is not stated what kind of information that is/can be included here. Thus, it must be further investigated where in the format this information should be included.
- Reporting format (enclosure 2), including introductory part and description of the company/organization and product/service
  This information is slightly out of the LCI-scope, involving other activities at the company/organization. However, the description of the

[60] Product-specific requirements (PSR) for preparing an environmental product declaration (EPD) for Tissue Paper manufactured from recovered paper, PSR 2004:8, The Swedish Environmental Management Council, Version 1.0, 2004-09-13
[61] Product-specific requirements (PSR) for preparing an environmental product declaration (EPD) for Tissue Paper manufactured from virgin fibers, PSR 2004:7, The Swedish Environmental Management Council, Version 1.0, 2004-09-13

company/organization and product/service could be documented in "Technical content and functionality", possibly with pre-defined headings. Some of the information in the introductory part can be included in "Administrative information".

- Reporting format including recycling declaration
  This chapter is missing (!) in both PSRs, why it is not possible to determine if and where this information fits.

Adaptation of LCA@CPM to EPD reporting and review requirements

LCA@CPM is an LCA tool developed at IMI[62]. It is based on the LCA standards, i.e. ISO 14040 series, including the LCI data documentation format ISO/TS 14048. However, all details in the data documentation format is not fully implemented, e.g. the fields for "Inputs and outputs properties". In LCA@CPM the IMI2003[63] data format is used, which includes an LCI data format according to ISO/TS 14048 and an LCIA data format based on ISO 14042. The ISO/TS 14048 format is also used to structure data of the goal and scope, interpretation, and critical review of LCA studies, in addition to the LCI documentation[64].

- Characterization method
  The characterization factors for emissions, i.e. for Global warming, Acidification etc, can be implemented in the tool. An interpretation of the receiving environment specification for the substance flows, i.e. whether it is emitted to air, water etc, has to be made. The characterization for resource use, energy, and other (waste, water and materials/chemicals substances) also has to be interpreted and implemented.
- New interface for EPD specific data input
  In order to make the documentation work efficient, the tool needs some additional and adapted interfaces for EPD purposes, e.g. pre-defined/standardized headlines to comply with the reporting format, fields to document inputs and outputs properties etc.
- Implementation of data categories
  Since the EPD has clear requirements regarding which data categories[65] (specification of required inputs and outputs) to declare, the functionality of data categories in LCA@CPM should be further implemented. This will simplify the LCI work as these data categories can be reused when performing other EPDs based on the same PCR.
- Reporting functionality
  The report functionality can be adapted to comply with the reporting format for the EPD, involving logotype headings, the right order of information and correct names and numbering of headlines etc. The report functionality can go all the way, to generate a final Pdf- or Word document, or it can generate a draft text document that can be further elaborated in e.g. Word.

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[62] Industrial Environmental Informatics, Chalmers University of Technology, www.imi.calmers.se (2005-12-22)

[63] Markus Erlandsson, Raul Carlson, Johan Tivander "Documentation of the model IMI2003 Management rev1", IMI internal report, 2005

[64] Karolina Flemström, Sandra Häggström, Ann-Christin Pålsson, "Manual for LCA@CPM", IMI, available at http://databases.imi.chalmers.se/imiportal/, 2006-03-01

[65] ISO 14041 Environmental management – Life Cycle Assessment – Goal and Scope Definition – Inventory Analysis

- The third party review can also be supported by the tool. The reviewer could have access to read all the underlying documentation in the tool and document the review process and results of the review directly in the tool.

Conclusions and recommendations for implementation

The LCA@CPM tool has been tested by the LCA practitioner to evaluate its potential as a tool for performing LCA and EPD at SCA Hygiene Products. In general, it has been found to be a feasible option to replace EcoLab. It is however necessary to implement some further functionalities to fully meet the requirements of performing LCA. This includes functionality to choose specific category indicators in the IA calculations, functionality to define characterization factors or weighting factors, and support for parameterized processes. With some adaptations of the interface and functionality, LCA@CPM can be used to simplify the EPD-work.

An estimation of resources needed to implement the integrated information system involves:

- finalization of the mapping of the formats (1-2 person-weeks)
- acquisition, interpretation, and documentation of characterization data (1-2 person-weeks)
- design, program, and test of new interface and functionality (4-6 person-weeks)

Additional resources will be required to develop the prototype LCA@CPM so that it has the standard of a commercial product, and e.g. to perform the in-house installation of the tool.

This integration will affect the way that LCAs are performed, compared to the current situation. The test shows a first indication of how the information process can be changed. The LCA practitioner sees this as a possibility that the persons that need the results, e.g. the product developers, can perform the LCA calculations themselves. The LCA specialist will work as a support and possibly as data quality control. This would potentially make the LCA work quicker make the interpretation of the results by the decision makers easier.

The integration with future EPD work will enhance the information management and save time compared to performing EPD as a separate and perhaps partly manual information process, next to the LCA work.

The overall international and internal strategy, to increase the LCI data availability, is supported by the implementation of the ISO/TS 14048 LCA data documentation format.

Case study at Akzo Nobel

Introduction to the case study report

This case study is one of three performed in the general integration method development work in sub-project 2 of IMPRESS. As the method was developed parallel to the case studies, there are some minor differences between the three case studies reports. For example, in this case study report a latter version of the questions applied in the analysis is presented, in comparison to the first version in the ITT Flygt case study report. The pictures are also a little different than the ones in the first case study report.

The contact persons at Akzo Nobel during this case study have been environmental specialists. The intention is to use the result from this case study as input to further internal discussions regarding introduction of an integrated information system that applies simple risk assessments according to the REACH requirements[66] for more reliable eco-efficiency results. In addition, the simple risk assessments will become an efficient tool in the ordinary risk assessment procedure, to make a first scanning of which chemicals or products that requires a more comprehensive risk assessment.

Analysis

This section presents the results from the survey and analysis of the integration activities and current environmental information system for environmental risk assessment (ERA) and eco-efficiency.

1. **Purpose of integration**
    a. **What is the reason for and expected benefits from integration?**

The purpose of the integration is to improve the decision support generated by the eco-efficiency task by including ERA, adapted to future REACH requirements. Currently, the eco-efficiency tool includes a toxicity potential, which is only based on risk-phrases for all substances that occur in the life cycle. In addition, the tool considers risk phrases for all substances in the life cycle, including those which occur in a closed system and is not emitted to the environment. The practice of performing simplified toxicity potential assessments based on risk phrases is not seen as a feasible long term solution as it is not consistent to the other ERA activities carried out.

The intention is also to gain time-savings when the work with ERA in eco-efficiency and REACH management are integrated.

Thus, the eco-efficiency tool will be much more useful if it includes standardized ERA. The eco-efficiency results will be much more trustworthy, i.e. can be used in a

[66] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency and amending Directive 1999/45/EC and Regulation (EC) {on Persistent Organic Pollutants} Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Directive 67/548/EEC in order to adapt it to Regulation (EC) of the European Parliament and of the Council concerning the registration, evaluation, authorization and restriction of chemicals. Available at http://europa.eu.int/eur-lex/en/com/pdf/2003/com2003_0644en.html

broader application, and the same ERAs can also be used for other purposes, e.g. product portfolio assessments and as REACH registration information.

Additional foreseen long term benefits are:

- reduce the risk of making wrong decisions by including the impact of REACH legislation in eco-efficiency studies
- the possibility to use conducted, simplified or extensive ERA studies in eco-efficiency
- integrated data acquisition for LCA and ERA
- increased awareness of environmental performance in decision making by combining solid (toxicity) environmental assessment results with economical data, in terms of eco-efficiency
- better understanding of how ERA, eco-efficiency, and REACH requirements are related

b. How is it measured?

Time and resource savings are expected when ERAs can be used for eco-efficiency analysis as well as product portfolio decisions.

It is difficult to measure the benefits of a more trustworthy tool and result. The company has to define the quality requirements of the tool and result before it is possible to measure improvements.

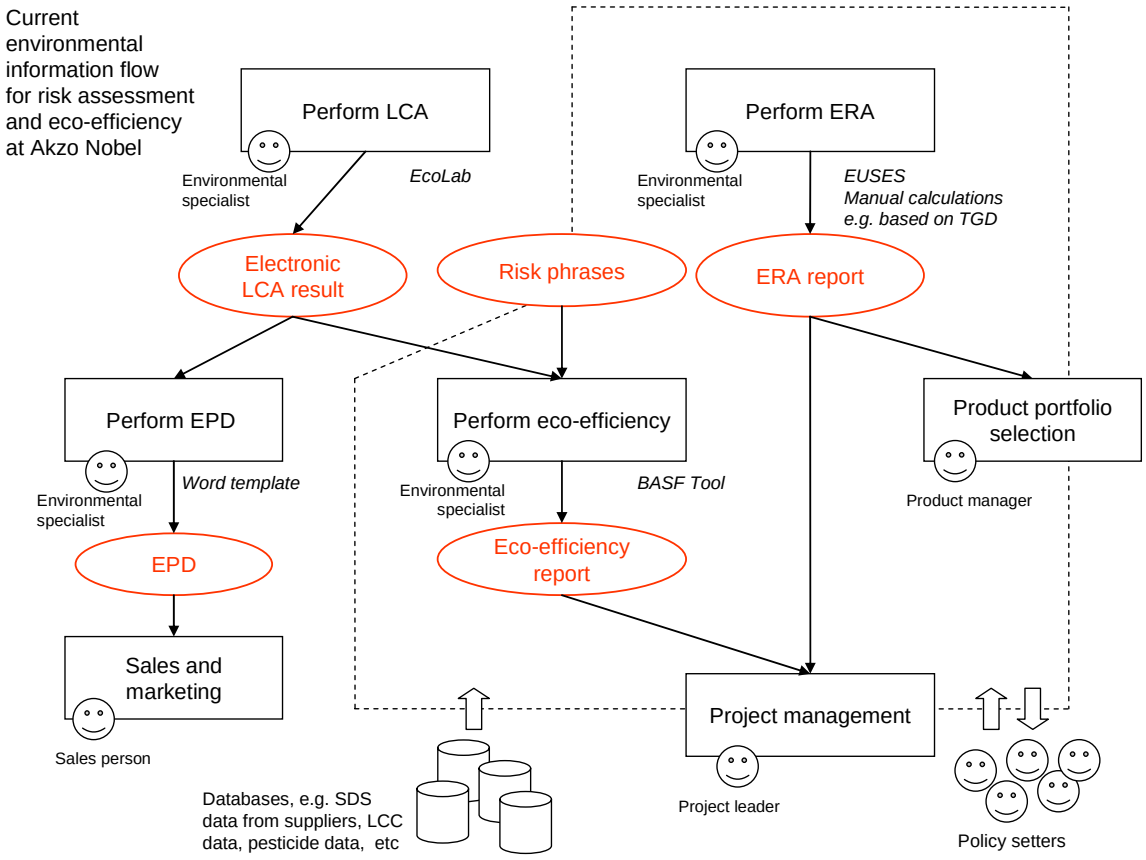


Figure 1 presents the environmental information system for risk assessment, LCA, and eco-efficiency at Akzo Nobel.

2. **Scope of integration**
    a. **What activities, tools (software, databases, etc.), and methods will be integrated?**
    b. **Who are the decision makers and other users in the information system?**
    c. **What information in terms of aggregated decision support is required?**
    d. **How often is the aggregated decision support generated?**
    e. **What information is needed to generate the aggregated decision support?**
    f. **What method is used for external data acquisition?**
    g. **How is the information communicated between activities/users?**
    h. **What concepts, data formats and nomenclatures do you use?**

The scope of the integration at Akzo Nobel includes the tasks of performing ERA and eco-efficiency studies of products. The eco-efficiency studies are carried out on a project basis for various reasons, e.g. comparing new products with old, decide where to build a production plant etc. ERA studies are carried out by risk assessors and used by the product management in the product portfolio selection process as well as in the eco-efficiency studies.

Eco-efficiency Analysis
The current eco-efficiency studies are done according to the BASF method[67]. An Excel spreadsheet tool is used to perform the calculations. The required data include Life Cycle Assessment (LCA) results, Life Cycle Cost (LCC) results, and risk phrases for substances in the products. The risk phrases are used in a simplified toxicity potential assessment in the eco-efficiency tool. This part of the study takes between one to three days. Many methods are used to acquire the data, including personal communication, supplier queries, searching in internal product databases, etc. The resulting eco-efficiency reports are sent to project management as printable documents. Currently seven pilot eco-efficiency studies have been made and if these studies are perceived to provide useful information for decision making it is foreseen by the environmental specialists that the demand for eco-efficiency assessments will increase to between 5-20 studies per year.

Environmental Risk Assessment
Data collection and ERA calculations are done according to the Technical Guidance Document on Risk Assessment[68] (TGD). If applicable, the EUSES model[69] and software is used to facilitate the calculations. Alternatively customized spreadsheet calculations are done. A tiered approach is used with increasing data demand. Substance property data is required including laboratory test data on toxicity, chemical and physical properties. Data is needed on production volume, downstream product propagation including usage and emissions to the environment; nature

[67] Eco-efficiency Analysis by BASF: The Method, Saling P, *et al.*, Int J of LCA 7(4) 203-218 (2002), BASF AG Ludwigshafen
[68] Technical Guidance Document on Risk Assessment, Edition 2 (TGD), European Chemicals Bureau, IHCP JRC, European Commission
[69] European Union System for the Evaluation of Substances 2.0 (EUSES 2.0). EC (2004). Prepared for the European Chemicals Bureau by the National Institute of Public Health and the Environment (RIVM), Bilthoven, The Netherlands. Available via the European Chemicals Bureau, http://ecb.jrc.it

property data is needed to assess the exposure of the substance to species in the environment. The ERA results are reported as printable documents to the project management and to the product portfolio selection task. Each ERA study takes between four to six weeks to perform. Collection of background information for ERA studies are ongoing and conducting ERAs for product portfolio decisions will be started in due course.

It is noted that data collected for the ERA studies may also partly be used in the LCA studies; however this overlap in data need is not included in the integration scope.

Short overview of the system in terms of lists of involved data sources, concepts, data formats, and software:

Data sources

- LCA results – communicated electronically from LCA task performed at Akzo Nobel
- LCC results – communicated electronically from LCC task performed at Akzo Nobel
- Risk phrases – included in SDS from suppliers, or from company internal test data.
- Downstream use scenarios – internal database of customers and personal communication
- Substance properties – IUCLID, internal data source including result from laboratory tests, …

Concepts and formats

The eco-efficiency terminology is not based on any consensus based concept model. "Standard" ERA terminology is applied as stated in the TGD.

Software

- Modified BASF tool (spreadsheet software), economical indicator is based on LCC study.
- EUSES 2.0.1 for ERA calculations
- Customized Excel spreadsheets for higher tier ERA calculations.

3. Indicator relevance

a. How does the tasks and information in the system relate to policy, legislation, and other objectives in terms of indicators?

The use of eco-efficiency is based on company policy statements regarding a need to relate environmental costs to product value. The specific impact assessment method, including indicators, used in the BASF tool is currently used as it is. Future analysis of the method may be performed but is not planned for the moment.

ERA is performed in order to meet EU and Swedish legislation for products.

b. Are the indicators in the information system understood and accepted by the decision makers and other users?

LCA indicators are considered too comprehensive to be used by decision makers and a need to include other environmentally relevant information for chemicals (beside the LCA results) was also perceived, why eco-efficiency indicators are interesting. The

connection to economical values is also essential for decision making. The current indicator for toxicity in the eco-efficiency tool is however not satisfactory as it does not include of the risk, i.e. the predicted exposure in relation to the predicted effect of a substance.

4. **Quality management**
    a. **What information quality requirements do you use and how are they defined and documented?**

The ERAs are performed according to the Technical Guidance Document (TGD)[70] and the LCAs are performed according to the ISO 14040 series. No quality requirements are however explicitly stated for the eco efficiency studies. The quality of eco efficiency results are discussed on a case to case basis, similarly to the interpretation of LCA according to ISO 14040-series. It is also common to study how external consultants perform their eco-efficiency analyses.

Synthesis

Vision of integrated environmental information system
In the envisioned information system the toxicity potential assessments in the eco-efficiency tool has been replaced by ERAs, see figure 2. The same ERA results can also be used in the product portfolio selection task. A tiered approach is applied for the ERA studies, where even the simplest ERA complies with REACH requirements. This tiered approach makes it possible to perform screening ERAs on all products including those already in production.

The work with LCA is included in the picture of the vision to show how it relates to the eco-efficiency work. However this is outside the current integration scope.

[70] Technical Guidance Document on Risk Assessment, Edition 2 (TGD), European Chemicals Bureau, IHCP JRC, European Commission

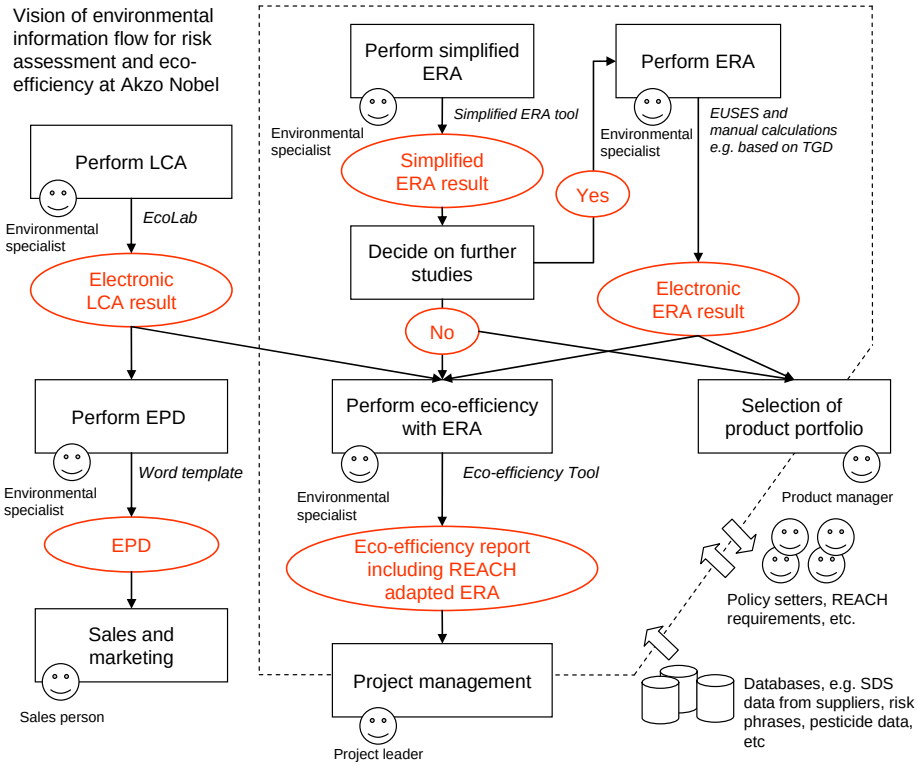


Figure 2 The vision of an integrated environmental information system at Akzo Nobel.

Addition of simplified ERA task

A first brief study of the software EUSES and ECETOC has been made, to find out how transparent and easy to use they are and if they comply with the REACH requirements and TGD on RA.

EUSES 2.0.3

The tool EUSES 2.0.3 is provided by the European Chemicals Bureau (ECB)[71] and is an implementation of the EUSES 2.0 model. The model is based on the TGD and hence it follows the REACH requirements for risk assessment as far as they are presently defined.

A wizard is available in the user interface that guides the user through the input data requirements. It is possible to insert a lot of parameters, but in order to get a result it is sufficient to insert:

- Substance name
- Molecular weight
- Vapor pressure
- Water solubility
- Log K_{ow}
- Characterization of biodegradability (pre-defined nomenclature with five choices)
- Production data (including import export volume of chemical in EU, etc)
- Use category (pre-defined nomenclature)

[71] European Chemicals Bureau, http://ecb.jrc.it (2006-01-03)

- Toxicity test data for aquatic organisms (at least one of e.g. LC50, EC50, NOEC)

One of the results is environmental Risk Characterization Ratios (RCR) i.e. PEC/PNEC for various compartments and organisms. If a toxicity test data for mammals, including humans, is inserted in addition to toxicity test data for aquatic organisms, the results also include Risk Characterization for humans in terms of Margins of Safety (MOS) values.

There is an extensive documentation of the EUSES model available in separate report[72], however it is difficult to understand how the input data relates to the output when working with it in practice. Education is necessary in order to use the tool correctly.

It is possible to save data about one substance in a separate "study", but this data is not saved in a common database, available for other studies. Only one substance can be assessed at a time. The data in a study can be communicated to other users in a custom communication format EUSES Exchange Format (EXF). EXF files for some substances are downloadable from the ECB website.

ECETOC

The ECETOC Targeted Risk Assessment Web Tool is provided by the European Centre for Ecotoxicology and Toxicity of Chemicals (ECETOC)[73]. It is stated by ECETOC that the tool is a demonstration of the practicability and functionality of the ECETOC Tiered Risk Assessment approach, Tier 0 to Tier 1 for environment and health, resulting in a Chemical Safety Report and that the tool is still under development. The tier 0 assessment is based on a sensitivity analysis of the EUSES model, with assumptions of a worst case scenario. Persistence, bioaccumulation and toxicity are dealt with at Tier 0 and Tier 1 according to the principles of the EC TGD and EUSES 1.0. Further discussions are on-going to incorporate the latest scientific developments. The tool is very easy to follow through to acquire calculation results. In tier 0 the following data is required for environmental assessment:

- Substance name
- Annual Tonnage (metric tonnes / year)
- Main Use Category (pre-defined nomenclature)
- Vapour Pressure (hPa)
- Dustiness (pre-defined nomenclature, not mandatory)
- Log Kow (pre-defined nomenclature, including unknown)
- Molecular Weight
- Number of emission days per year
- Biodegradation (pre-defined nomenclature with two choices Readily biodegradable or not)

[72] EUSES 2.0 background report, European Chemicals Bureau, 2005, available at http://ecb.jrc.it (2006-01-03)
[73] European Centre for Ecotoxicology and Toxicity of Chemicals http://www.ecetoc.org/ (2006-01-03)

- Substance classification from pre-defined nomenclature, EU classification in terms of risk phrases or PNEC values, to state hazard potential (optional, if no information is entered, a worst case scenario is assumed)

The result is of the environmental assessment is presented as the PEC/PNEC ratio with an interpretation comment, e.g. “Further risk assessment required. PEC / PNEC > 10“. For health assessment the corresponding classification data is needed. The result is presented as a comment, e.g. “No Immediate Concern”. If further risk assessment is required in the result of a tier 1 study, the method recommends the user to apply EUSES methodology to make extended assessments. However, there is no support for data communication between the ECETOC TRA Web Tool and the EUSES 2.0.3 tool.

The algorithms are to a large extent transparently presented in the tool in terms of simple lookup tables, and the basic principles are described in a report[74]. However, further information about the calculation method is needed in order to make it comprehensive. Not all parameters are unambiguously defined e.g. for Annual tonnage it is not clear whether this implies emissions or production, by whom and when, etc.

The data entered is automatically stored in separate studies which are available in a common database for any user. All data for a substance must be entered manually and only one substance can be assessed at a time.

Comprehensive ERA task
The comprehensive ERAs are performed as in the existing information system at Akzo Nobel, with support from EUSES or manually. If a simplified ERA has been made in EUSES, the input data can be reused. If the ECETOC TRA Web Tool will be used for simplified studies, a mapping between the input parameters is required to establish consistency between the simple and comprehensive ERA tasks.

Adaptation of BASF eco-efficiency tool
The risk characterization result (PEC/PNEC) from any of the ERA tasks can, without further calculations, replace the toxicity potential result in the spread sheet of the eco-efficiency tool BASF. However, in order to include the new indicator in the overall eco-efficiency result, a weighting factor must be defined for the indicator. In addition, it would be preferable to indicate if the risk characterization result has a value higher than 1, as it implies implementation of risk management measures. A reference to the underlying ERA study should also be documented, to enhance the transparency.

The tier 0 algorithm in the ECETOC TRA Web Tool could be implemented directly in the Excel BASF tool, as a simple ERA module. In this way a simple ERA is included in the Eco-Efficiency task, and the company will have full control of the confidentiality of the data. This would also enable the user to run batch calculations of several substances automatically. It is not investigated in this case study whether the tier 1 algorithm could also be implemented in the same way.

[74] ECETOC, Pragmatic Approach to Risk Assessment, 2003, available at https://www.ecetoc-tra.org/index.asp, 2006-01-03

Conclusions and recommendations for implementation

Based on the scope of this case study, three alternative ways to integrate risk assessment and eco-efficiency are suggested. The BASF tool is used for eco-efficiency and EUSES is used for comprehensive ERA studies in all three alternatives. In order to introduce ERA in the eco-efficiency task, the BASF tool needs some further development, see Adaptation of BASF eco-efficiency tool above. All alternatives provide ERA that is based on the TGD, i.e. REACH requirements as far as defined at this date.

The difference between the alternatives concerns the simple ERA, where application of ECETOC TRA Web Tool, EUSES 2.0.3 tool, and an implementation of the ECETOC TRA method in the BASF excel tool are compared. The ECETOC TRA method is consistent with the EUSES method, as it is based on a sensitivity analysis of the more comprehensive model.

Alternative 1: ECETOC TRA Web Tool, EUSES 2.0.3 tool, and BASF tool
The ECETOC TRA Web Tool is used to perform simple ERA. If further assessment is required the EUSES 2.0.3 tool is used. The risk characterization results from the ERA studies are manually inserted in the BASF eco-efficiency tool.

+ The ECETOC TRA Web Tool for the simplified ERA task is easy to use
+ No software development costs to introduce the simplified ERA task
+ The expert tool EUSES 2.0.3 is only needed for comprehensive ERA

- Three different tools is required to perform ERA and eco-efficiency
- Data transfer between simplified and comprehensive ERA is manual
- Potentially confidential data is stored externally
- Simplified ERA batch calculations of many substances is not possible
- The ECETOC method and tool is still under development

Alternative 2: EUSES 2.0.3 tool and BASF tool
Both the simplified and the comprehensive ERA are performed in the EUSES 2.0.3 tool. The risk characterization results from the ERA studies are manually inserted in the BASF eco-efficiency tool.

+ Only one tool is needed for all ERA studies
+ No software development costs to introduce the simplified ERA task
+ Data transfer between simplified and comprehensive ERA not needed
+ Potentially confidential data is stored internally

- Education is required to use EUSES
- Toxicity test data is always required which may be difficult to find compared to risk phrases
- Simplified ERA batch calculations of many substances is not possible

Alternative 3: BASF tool including implementation of ECETOC method and EUSES 2.0.3 tool
The algorithm for the ECETOC method is implemented in the BASF excel tool. Comprehensive ERA is done with EUSES 2.0.3.

+ Only one easy to use tool required for both simplified ERA and eco-efficiency + The expert tool EUSES 2.0.3 is only needed for comprehensive ERA + Simplified ERA batch calculations of many substances is possible + Potentially confidential data is stored internally + It is possible to automatically connect to in-house substance databases + The company has control of the tool development, further adaptations are possible	- Additional development and maintenance costs to include the ECETOC method in the BASF eco-efficiency tool - Data transfer between simplified and comprehensive ERA is manual (however it is also possible to automate this)

The decision regarding which alternative is more favorable is related to risks in terms of confidentiality, and costs in terms of education, software maintenance and development and data management. Another decisive factor is whether the simplified ERA results in ECETOC and EUSES, as discussed in this case study, are indeed relevant for Akzo Nobel. An ERA expert could be consulted to provide this information.

Case study of VIEWS

This case study was initiated as a contribution to the overall objective of the IMPRESS project to concretely implement integrated environmental information systems. The general idea of the case study was to produce an integrated information system of the tools used within the industrial sub-projects in IMPRESS. A conceptual idea of the integrated platform was discussed and given the name VIEWS, an acronym for Visualization of Integrated Environmental Work Spaces. The VIEWS case study was performed by researchers at IMI.

Analysis

Purpose of integration

The reasons and expected benefits from the integration were found to be:

- A possibility to look at the same data from different views (Life cycle assessment (LCA), Environmental management systems (EMS), Design for Environment (DfE), Chemical Risk Management (CRM) and Emission Trading Scheme (ETS))
- To provide a visual platform in order to easier understand what is implied by integrating different tools and methods.

The benefit of the result can be measured by:

- The amount of new possibilities to look at data from different views.
- The number of IMPRESS project participants that state that the VIEWS platform increase their understanding of how integration can be implemented in reality.

Scope of integration

The scope of VIEWS was to cover and integrate the different tasks, methods and tools that were dealt with in the industrial sub-projects of the IMPRESS project. This included the tasks Life cycle assessment (LCA), Environmental management systems (EMS), Design for Environment (DfE), Chemical Risk Management (CRM) and Emission Trading Scheme (ETS). A set of corresponding software tools developed by IMI and CPM were selected:

- The LCA tool WWLCAW
- The DfE tool CPM Inventory tool + EPI reporting tool
- The EMS tool EMS@CPM
- The ETS tool IMPRESS Emission Trading data tool
- Support for assembled risk documents needed for the REACH legislation

The IMI material database (material nomenclature and substance properties) was used for the DfE data supply. The life cycle inventory (LCI) data base LCI@CPM was used for the LCA data supply. Some additional data needed to be acquired to provide good example data fulfilling the purpose of VIEWS, e.g. product specific data from the companies. The CPM data quality criteria were to be used for new data acquisition. The limitations in resources lead to the decision to only include the impact assessment method EPS 2000, and hence only LCI data matching the scope of the EPS method was acquired.

A specific aim was to integrate the use of indicators in all the included tools and methods.

Synthesis

Vision

During the synthesis the possibilities of combining the different tools was discussed. Pictures were drawn of the vision of the VIEWS system with the final version shown in figure 1.

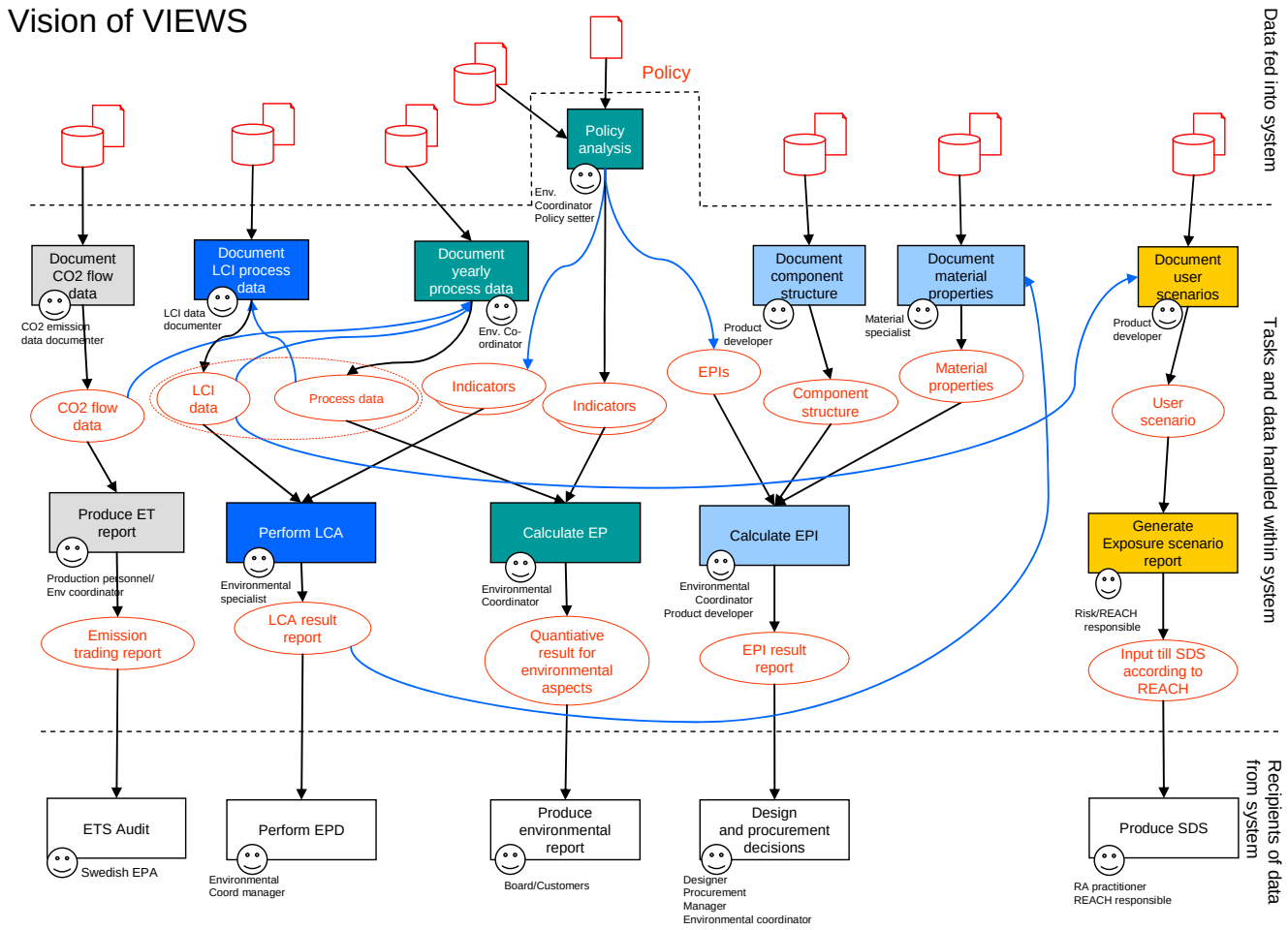


Figure 1 The vision of the integrated information system VIEWS.

The picture of the vision was compiled based on tasks and information within individual tools. The colours of the tasks indicate the tools in which they were originally implemented: gray for emission trading data, blue for LCA, green for EMS, light blue for DfE, and yellow for CRM. The blue arrows in the picture represent interfaces between tools that ware not previously developed, including a combined and consistent policy analysis not only for EMS but also for indicators used in LCA and DfE, and communication of LCA result data as basis for material property data. Many other possible connections were discussed. In addition, the existing implementations into software and data format played a large part in the discussions of feasibility to produce an operational system within budget. What is shown in the picture is what was used as basis in the implementation step.

Implementation

Based on the analysis and synthesis results it was decided to implement the VIEWS platform with the functionality as shown in the vision picture. Much of the functionality of the VIEWS platform was already available in the individual tools. However adjustments were needed to harmonize common functionality. The result is a modularized system of individually functional parts. The main features that were further developed are described below.

A common web based portal

A common entry to all tools was created as a web-portal, as shown in the screenshot in figure 2.

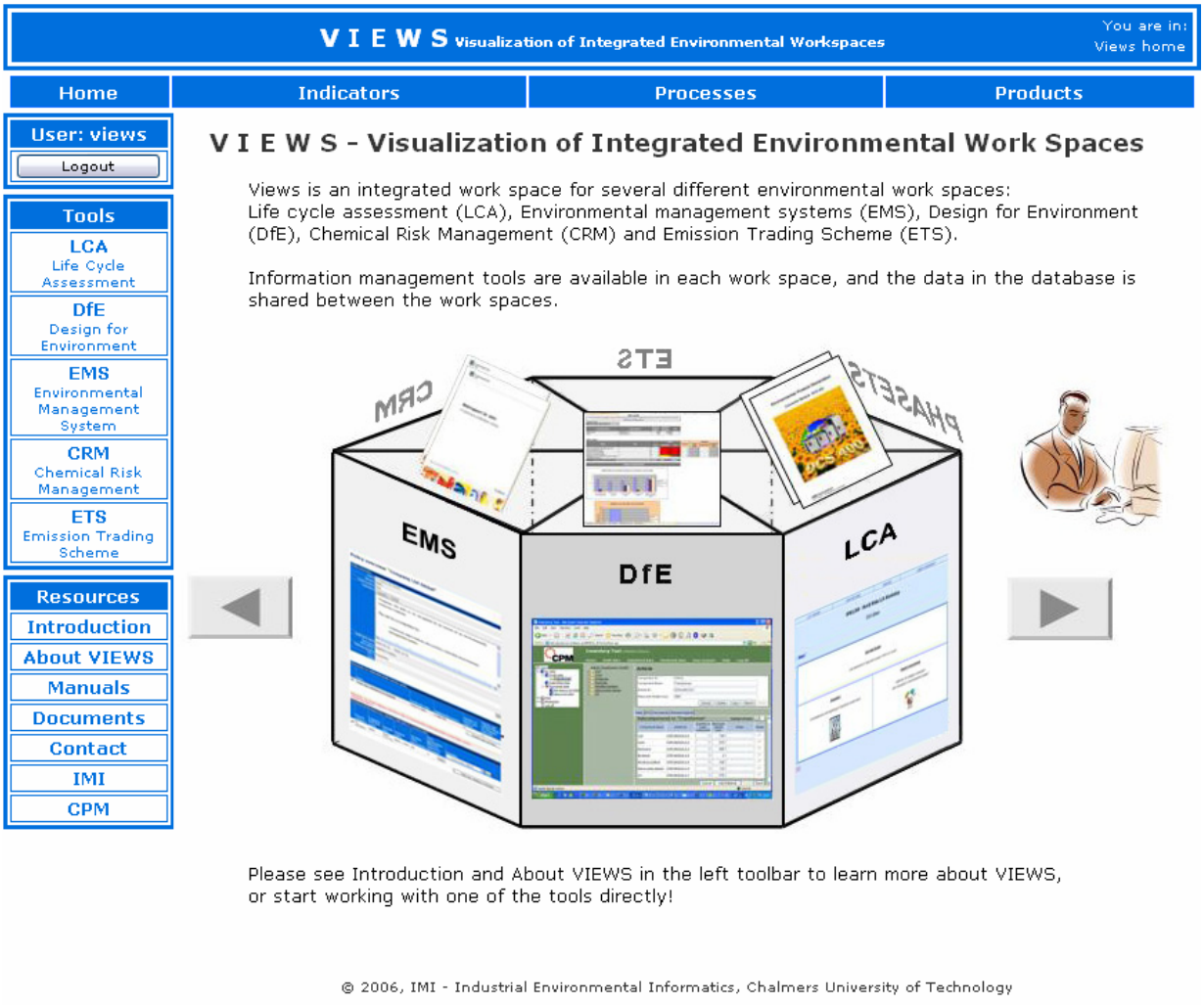


Figure 2 Screenshot of the VIEWS start page.

A conceptual visualization of VIEWS was created as a three dimensional figure as can be seen on the start page of VIEWS web platform. The bottom of the shape represents the primary data shared by the work spaces. The sides of the shape are the different work spaces, i.e. different ways of viewing and aggregating the data, and the top represents the reports that can be communicated from the system. Figure 3 below shows both sides of the shape.

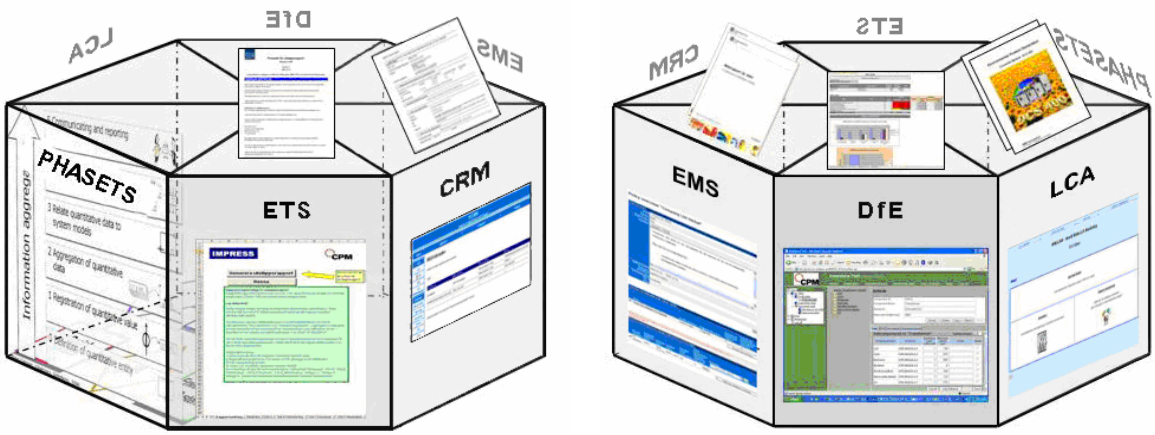


Figure 3 Conceptual illustration of VIEWS in IMPRESS with five applications and two reference models; PHASETS and SPINE. SPINE can be seen at the bottom of the left figure.

A common product management view was also developed to give the user an overview of al information that is available for each product; life cycle inventories, component structure etc. Likewise, a common process management view was made to give an overview of all available process information; inventories for EMS and LCA are listed.

Common indicator management for the different work spaces
Indicators are used in LCA, ETS, EMS, DfE, and environmental impact modelling. A common indicator management view for the indicators was created based on the prototype implementation of software for the Policy controlled environmental management. The set of relevant indicators are connected to an environmental policy which is shown in the indicator management view. This policy is common for all tools so that all tools work with common priorities towards the same goal. An integrated selection of indicators for all tools is thus made. However the VIEWS system was designed to allow for overruling the common selection within each individual tool.

Integration interface between DfE and LCA
The interface between DfE and LCA was constructed as material properties in terms of life cycle indexes in the material property database. The life cycle indexes were created by calculation of LCA results, cradle to gate, with the EPS 2000 impact assessment method and the results are stored as material properties in the IMI material database. The material property life cycle index thus requires that an LCA data set exists for that material. Both characterization and weighting is included in the life cycle index. The life cycle index is recalculated if any changes are made to the LCA data set so that the value is always updated (compare with ETS data to the EMS work space below).

Integration interface between EMS, LCA and ETS
The gate to gate life cycle inventory (LCI) data set and the documentation of the inputs and outputs for the environmental management system (EMS) have been merged in VIEWS. This means that the same data set can be used for both purposes. When the data set is shown in the LCA work space, the functional unit is e.g. 1 kg of product, and when the data set is shown in the EMS work space, the functional unit is scaled to the yearly production. The data requested by the emission trading scheme (ETS) is regarded as a subset to EMS, but with additional documentation

requirements. The inputs and outputs documented in an ETS data set can thus be imported to a data set in the EMS work space and be continuously updated (compare with LCA data to the DfE work space above).

Integration interface between LCA and CRM
Data for the exposure scenarios for chemical substances created in the CRM tool can be imported from an LCA study. The name and class of the process where the substance is used and information about operational conditions description of the operational conditions matches the content in the ISO/TS 14048 fields "Name", "Class" and "Technical content and functionality" which can be imported to the exposure scenario documentation. In the CRM tool there is also a direct link to substance data from OMNIITOX IS.

Additional development
The design for environment (DfE) tool in IMPRESS, the CPM Inventory Tool, was further developed in VIEWS in order to show a realistic work procedure. The user interface of CPM Inventory Tool is in the VIEWS version divided into two parts:

- *Environmental coordinator's interface* with the possibility to define indicators, setting target values and document specific values on the material properties
- *Designer's interface* where designers and suppliers can document component structures and material content of products and components

Substantial improvements were done to the LCIA calculation and reporting functionality. Any bugs encountered in the existing tools was followed up and eventually fixed. This included miscalculations done by the LCA tool. The security handling was also harmonized between the tools to reduce the number of required user logins to make it easier to navigate between the work spaces.

Data collection
A data collection was performed to supply VIEWS with data relevant for all companies participating in IMPRESS in order to show and exemplify how VIEWS could be used:

- Environmental policy to be valid for the entire VIEWS
- Definition of relevant products, one product from each of the companies participating in IMPRESS
    - Product data – materials, component structure etc.
    - Production data – inputs and outputs from production site
- LCA data sets for the selected products and the included materials
    - Cradle to gate data sets
    - Gate to gate data sets
- The environmental aspects covered by the impact assessment method EPS 2000 (i.e. the data categories[75] for the inventories)
- Definition of relevant EPIs and material properties needed for the EPI calculations.
    - Target values on EPIs for different products
- Safety data sheets for the selected products
- Emission trading data for the relevant sites

[75] International Organization of Standardization; *"ISO 14041: Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis"*; 1998

User manuals
The individual tools already had user manuals with varying quality. A new manual was written for the overall VIEWS web-platform and the individual manuals were revised and edited into a consistent format. Additional help texts were written for the new integration interfaces.

Use case testing
A test of the platform was done in order to discover potential flaws and receive recommendations for improvements. A temporary employee at IMI conducted the test and it was intentional that the person was not familiar with CPM results. The results from the tests led primarily to improvements of user manuals and navigation help as it sometimes was difficult to understand which the current view was, especially when working with data communication between the views.

Demonstration of VIEWS
At the end of the IMPRESS project the resulting VIEWS platform was demonstrated to the CPM companies. IMI personnel made individual presentations to ABB, IKEA of Sweden, Stora Enso, Schenker, and Bombardier Transportation. VIEWS was also a central part of the presentation and discussions at the IMPRESS kick-out where ITT Flygt, SCA, and Swedwood participated. The intentions with the presentation were to reach out with research results and receive feedback from the companies. It was emphasized in the presentations that VIEWS is a demonstration tool, not intended for direct use in industry. Included in the demonstration were also a short presentations of background results such as reference models used and experiences from previous projects.

Conclusion

Fulfilment of purpose
This case study resulted in a successful implementation of integration of tools used within IMPRESS, as intended. The VIEWS platform provides a hands-on tool to look at the same data from different views (Life cycle assessment (LCA), Environmental management systems (EMS), Design for Environment (DfE), Chemical Risk Management (CRM) and Emission Trading Scheme (ETS)). VIEWS is a tool primarily for demonstration and educational purposes to show possibilities to integrate different tools. It should be noted that the VIEWS platform is not intended as a tool that can be directly used by a company for their operational work.

The benefit of the result can be measured by:

- The amount of new possibilities to look at data from different views.
- The number of IMPRESS project participants that state that the VIEWS platform increase their understanding of how integration can be implemented in practice.

With regard to new possibilities to look at data from different views an example is LCA data. Process data originating from data acquired for LCA can be viewed in the EMS tool and vice versa. A specific Process view has been included with a combined list of all processes in the system. The technical functionality description part of the process data can be viewed as exposure scenario data in the CRM tool. Material properties used in the DfE tool that are based on LCA calculations are connected with the original LCA data. This makes a total of five different possibilities to view the same LCA data in the same information system.

Based on the reactions from company representatives to whom the VIEWS platform was demonstrated we conclude that the integration purpose to provide a visual platform in order to easier understand what is implied by integrating different tools and methods has been partly fulfilled. VIEWS in itself may not be sufficient to describe the integration benefits or process but should be accompanied with a clear presentation of the underlying reference models and methods. In this way VIEWS can be seen as a practical support to understand fundamental principles of integration of industrial environmental information systems. In the discussions at the presentations at the CPM companies VIEWS worked well as support to visualize, understand, and define problem formulations specific to each company and to find ideas to proceed to find solutions. Specifically the practical demonstration of an integrated policy and indicator management was helpful to understand the benefits of integrated environmental information systems.

Lessons learnt
This case study involved the coordination of the information management of tools that have been developed individually. In this process it became evident that it is crucial to have a clear understanding of the original meaning of the information pieces used in each tool. All the tools included in the implementation of VIEWS were originally developed based on documented and open concept models, database formats, and software. This greatly facilitated an efficient synthesis and implementation of the integrated system. A close dialogue between data collectors and software developers also helped to keep the development on within the intended scope.

However, in the integration it was found that the technical implementation of data formats and software for some of the included tools did not fully follow or match the method they were intended to support. For example unique identifiers of data were used to control semantics of data, i.e. convey information and meaning to the user, even though the identifiers was only intended as pure technical handles for a computer to keep track and enable quick access of data in a database. In practice such mix-up of specific technical solution with end user information may result in misinterpretations. When integrating data in different applications it implies that data must either be reformatted or that another concept model must be applied to describe the database which results in a more time consuming development. Another example causing problems were when additional data tables not following the original data format or concept model had been created. This may result in double storage of primary data and hence there is a risk unexpected behaviour of the tool to the user if the data is not kept consistent between the different storage locations at all times. When this was the case in the integration of VIEWS the individual tools were redesigned including reprogramming and reformatting of data to be consistent with the original methods and their ontologies before the actual connectivity between tools was developed. A source to inconsistencies between software data format and method are typically caused when the system developers are on a too tight time-schedule or have not fully understood the method they are implementing. It should be noted that the software tools included in the integration were all prototypes to demonstrate research results with limited technical support and hence not intended for direct use in industrial applications.

To conclude as prerequisites for integration it is ideal that the method of the original each individual part of the system follows a well understood concept model with a well defined scope, based on real world entities and relations.

Appendix 2. References to CPM and IMI-literature supporting integration dimensions and principles

The integration method is based on ten years of experiences of integration of environmental information systems within CPM and IMI. This appendix contains excerpts from a selection of relevant references to earlier publications are provided and commented. In this way a transparent summary of scientific references is presented. The references to other chapters in the excerpts points to the respective report the excerpts are taken from. A study of other work in this field is found in the chapter *Related work* in this report.

General information system requirements and design principles for integration

The project II:F:12 Integrated Environmental Information Systems (*Integrerade Miljöinformationssystem*, report only in Swedish)[76] aimed at compiling information from different main knowledge areas within IMI and CPM, that constitutes an industrial environmental information system, and to join this information system with other industrial information systems. The integration principles was (1) to adapt to a general but concrete model of the world, around which analysis of the real world was reflected and were hypothetic concept models was tested (2) to analyze, structure, and synthesize operative and pragmatic project results with the general but concrete model of the world as a base. A result from the project is a good, and partly connected, overview of methods and models to create an integrated industrial environmental information system. Further, different integration interfaces have been formalized, e.g. between LCA and LCC in Eco-efficiency, and LCI and LCIA in LCA.

In the report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* [77] a set of general requirements design principles are described when organizing environmental information systems supporting life cycle overviews of products. The principles that apply when building environmental information systems, also apply when integrating environmental information systems.

> *"When implemented, the information system described here should meet three basic requirements, derived from the purpose of the information system:*
>
> *1. Functionality: Supply each user anywhere throughout the life cycle with a sufficiently correct product life cycle overview. Since this is the intended purpose of the information system, this requirement must be met.*
>
> *2. Pragmatics: Take into regard that all information cannot be acquired; limitations and simplifications must be part of the design. This fact is derived from chapter 4, subsection 4.4 and the facts*

[76] Carlson R, Pålsson A-C, Slutrapport projekt II:F:12 Integrerade Miljöinformationssystem, CPM rapport 2001:17 (only in Swedish)

[77] Carlson R, Erixon M, Erlandsson M, Flemström K, Häggström S, Tivander J, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems, Industrial Environmental Informatics at Chalmers University of Technology for the Swedish EPA (Environmental Protection Agency), (Currently in print 2005-12-22)

presented there concerning data availability. If the ambition is too high the goal will not be reached, mostly due to lack of data.
3. User friendly: Be appropriately simple to use for each involved user. Any technology, tool or information intended for public or routine use must be simple and clear, since specific education cannot be given and high attention cannot be guaranteed.

These three requirements must be met while taking into regard that environmental aspects are not central in most businesses, environmental science is a developing field, and environmental decisions need sufficiently good information now. Therefore, the following design principles, formulated by the authors, should help to take these limitations into account while building up the information system for environmental overview of product life cycles:

- *Be economic and focus on needs: By focusing on user needs, the information system will be relevant, easy to use and economically efficient.*
- *Accept ambition based on that environmental issues are secondary: Environmental issues are at its best side dishes to the main courses of e.g. business and consumer decisions. Therefore environmental information systems cannot be designed on the basis of major attention from the end user.*
- *Share costs by filling gaps, modularize design and flexibility: Current environmental information systems have gaps that are costly to fill. A flexible information system may be achieved by regarding data sources, expertise and tools as flexible modules.*
- *Be pragmatic, enter at a low initial threshold, establish compatibility and be built on principles of continuous improvement: Many valuable components are already at place, with both weaknesses and limitations. User needs will be quickly met by utilizing these as starting points of a strategic path paired with a commitment for continuous improvement.*
- *Set individual life cycle overviews and establish knowledge maintenance: Strategic knowledge foundations and competence sources for the information system must be established and maintained."*

(5.1.1 Organising an information system, Introduction, Basic requirements and design principles, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems).

Gaps and overlaps in primary data need

In the article *"System for Integrated Business Environmental Information Management"* [78] an information system named Integrated Business Environmental Information Management (IBEIM) is described. It includes operational, procedural and organizational support for a business' entire environmental information management. IBEIM consists of a system architecture and an information and data content. IBEIM makes use of data that is already in industrial management systems, such as procurement, logistics, and material management.

> *"The scope for IBEIM is the same as the scope for the industrial environmental responsibilities and activities described in the ISO 14000 standards. One boundary for the scope is drawn at defining environmentally relevant physical entities and indicators, as described in ISO 14031 (1999). The reporting to an end-user of the system draws another boundary, for example internally for aggregated environmental performance reports or statements for the director, or externally for simplified environmental product declarations, for example according to ISO 14020 series (1998), presented to customers."*
>
> *IBEIM is prepared for full supply-chain information management, meaning it is open for communication in each customer-supplier interface. Many different reports can be generated as information for customers, and the customer may be free to either import the report into their own IBEIM, or to acquire them as separate pieces of information. In addition IBEIM generates supplier-questionnaires on demand and may even allow suppliers to enter information directly into the IBEIM information platform. In a fully integrated IBEIM the customer and supplier may share access to parts of each other's systems (see also figure 2).*
>
> *Any industry already has much of the information needed in IBEIM structured in other information management systems, such as economic, logistic, product data management, etc. systems. IBEIM does not require parallel storage of and structuring of this information, but instead connects to and reformats the information in other systems, on demand."* (Scope of system, System for Integrated Business Environmental Information Management)

The report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* compiles much of the documented knowledge and experiences at IMI regarding gaps and overlaps in the primary data need. For example, it describes how different environmental performance measurements and different users of environmental information can share the same data in order to achieve synergetic benefits and cost-efficient data management.

> *"The main purpose of this report is to show how the same primary environmental data can be shared by different applications and be used for*

[78] Carlson R, Erixon M, Forsberg P, Pålsson A-C, System for Integrated Business Environmental Information Management**,** Advances in Environmental Research, 5/4, 2001, pp 369-375 (Also presented at ISESS 2000 'Integration in Environmental Information Systems', May 30-June 2 2000, Zell am See, Austria)

different purposes, in different applications, and in different methods and tools. Sharing of data will reduce costs for redundant data acquisition and maintenance and for quality review. It will also reduce costs for updating of databases. In addition, reducing redundancy may contribute to quality improvements, such as reduced ambiguity, improved consistency and easier updates.

In section 2.3 the different environmental product perspectives were introduced: Purchasing products, Designing products, Analyzing content of product, Considering risks of product, and Societal consequence of product. As presented in chapter 3 there are many different methods and tools needed to enable these over-view perspectives, ranging from laboratory test data to willingness to pay to avoid environmental damages and many different types of engineering data and data about the behavior and the sensitivity of nature. In addition, depending on the different user categories presented in section 2.2 and table 1 (Authors note: the four user categories are 1.The environmental expert working with science and expertise; 2.The generalist expert setting rules, policy, legislation etc; 3.The purchasing/technical expert taking professional decisions; 4.The layman concerning technicalities of the decisions, doing everyday actions)*, different users need different information about the same perspective, i.e. a consumer may be satisfied with knowing that a washing powder is eco-labelled, while a professional purchaser may have to know the detailed formula of the same product, to meet water emission regulations, as well as some key life cycle data to meet her company's environmental policy.*

To share the same primary data between different methods and tools, data acquired for different purposes will need to be understood from the viewpoint of other purposes. For example, primary data collected for environmental management systems may be used for LCA, primary data collected for LCA may be used for design for environment, and primary data collected for emission trading may be used for environmental labelling, etc.

Section 4.3 presents a common data structure that serves all methods and tools described in chapter 3 (the presentation continues in appendix 2). Such a common data structure may serve as a bridge between different primary data sources and applications, with the purpose of enhancing data flow and integration between different methods and tools, and between primary data sources and users. A common interpretation of primary data is a prerequisite for efficient data communication in an information system (see section 1.2.2). The data structure presented in section 4.3 is in major parts tested for industrial environmental management systems - EMS (see Appendix 1, Example 2), life cycle assessment - LCA, both complete and simplified (see Appendix 1, Examples 3 and 6), environmental product declarations - EPD, design for environment - DfE (see Appendix 1, Example 1), green procurement - GP (see Appendix 1, Example 1), and for modelling environmental characterization of toxic substances (see Appendix 1, Example 5).

The tests has been performed by developing tools and databases for e.g. full LCA according to ISO 14040 and to use the same database structure and database contents for e.g. EMS, DfE or EDP. Often the same data fields and the same data can be used, but sometimes additional fields and data contents are needed for new applications. However, since the additions are very small in comparisons to what can be reused it may be argued that the

> *structure has proven effective and successful for these different applications."* (4.2.3 Sharing environmental information, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems)

The report also describes how to analyze data gaps in the integration work. Different aspects of data availability are defined and discussed.

> *"Whether data is available or not is not possible to answer in general, since availability as a concept involves many aspects, and data availability varies much depending on type of data in focus and especially for what purpose the data is intended. Some data are abundant, but for specific purposes it may be very hard to find the right data.*
>
> *For example, LCA-data for many types of plastics are available at the web site of APME (Association of Plastics Manufacturers in Europe), e.g. Polyvinyl chloride, Polymethyl methacrylate, Nylon, etc. A common guideline for LCA-practitioners is to turn to this organization when data on plastic production is required for the study. Nevertheless, it is a fact that the total supply of plastics in the society today is not represented at this LCA data source, hence today LCA practitioners need data for plastics that is not available here. Further, the LCA-data for e.g. Polycarbonate derives from 1992-1996 and over ten years old when this report is written. Also, the APME LCA data are European averages and does not apply for LCA studies for specific suppliers of plastic components. In some senses LCA data for plastics are available, but in other senses there are no plastics data available. Hence, there are many aspects to consider concerning environmental data availability, and here we list six aspects:*
>
> - *Existence, i.e. whether anyone have ever structured this precise type of data, be it toxicological data in terms of risk phrases, LCI-data on cement production, or cause-effect modelling of CO2-emissions, into e.g. a database, a report or a call-service.*
> - *Coverage, i.e. to what extent the data covers the exact needs, e.g. if risk phrases for all of the chemicals in my scope is covered, or only maybe 30%. It could also be that the coverage depends on the selection principles applied when data have been acquired. The reason for acquiring LCI-data for cement production could be to make a future scenario for a new production site in North America. This data may not be relevant to use in an LCI-study focusing on the average production of cement in Sweden.*
> - *Understandable, i.e. whether the data is documented so that it can be interpreted by a user. For example, a product developer that need toxicological data in terms of risk phrases for his design for environment-tool may have difficulties to understand the toxicology terminology. Further, it is crucial that the data is available in a language that user can appreciate.*
> - *Maintenance, i.e. whether there is anyone to contact in order to get more information about the data. Maybe it is possible to increase the coverage, or to get a better understanding of the data, by posing questions to an administration, a person that has documented the data, or someone that just knows more about this specific kind of data.*

- *Accessibility, i.e. whether the data is actually accessible from the perspective of the data user in terms of cost, secrecy issues, etc. If the requested data is documented in a company's internal report involving commercial strategies, product recipes, etc., it might be difficult to get the information. Someone have to go through the document, take decisions on what to publish and how to separate the secret information from the open information. This is time consuming and may not be done, especially if it does not gain the data supplier in some way.*
- *Formatting, (see section 4.3.3) i.e. whether the data is separated in specified data fields in the documentation, or whether it is available only in free text in literature or structured in databases. If the information only is available in free text, someone has to read the text, interpret the text, and extract exactly the information needed. Thus, if there is a great amount of data needed, this will be a very time consuming and expensive task. It may also be difficult to find a person that can interpret the information correctly, see Understandable.*

Experience shows that it is difficult to judge actual availability without testing the data sources in real cases. One way of doing this is to look from the viewpoint of a specific indicator (see section 4.3.3.3) and to start a data acquisition task in a limited and well-defined project-form, by performing a data inventory, where one part should be to test the availability of the suggested data sources. This was tested in the EU-project OMNIITOX between 2002 and 2003. By testing the availability of the data in the suggested data sources, an early indication regarding the outcome of the data acquisition, and in fact the project as a whole, was presented. In projects that involve data acquisition, the success depends on a good understanding of real data availability and on methods for data acquisition.

A realistic balance between ambition and realism is a success factor, since many of the pretended available data sources fail to exist in one or more of the availability aspects listed above. In the following we will anyway try to present general availability of the data types described in the previous sections, mainly concerning Existence, since each new application may set requirements that make any specific data source useless." (4.4.1 The concept 'availability', Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems)

The perspective of primary data gaps and overlaps is also a main integration aspect in the article *"Learning from management of LCA data"* [79], which refers to that there is a direct relationship between environmental performance indicators (EPIs) and required contents in the environmental database. The EPI methodology in design for environment corresponds to the use of category indicators in LCA.

[79] Carlson R, Learning from management of LCA data, Journal of Life Cycle Assessment, Japan, Vol. 1 No. 2 Jul, 2005, pp 102-111

"The first information system based on the data format for impact assessment[80] was tested within CPM, for electronics manufacturing[81] and later also for DfE applications in the European project RAVEL (Rail VEhicLe eco-efficient design)[82]. An extension of the SPINE format and an application of the CPM data quality management were integrated with a DfE system and an eco-procurement system for the European railway sector. One result is that the host of the Swedish national LCA database today also holds a database of environmental properties of materials for measuring environmental performance of rail vehicles. A valuable learning from the RAVEL project is the understanding of a direct relationship between environmental indicators and choice of contents of an environmental database; data should not be collected before it is known how it measures environmental performance, and environmental indicators should not be defined unless one is clear about data availability. Environmental performance indicators and database contents are two sides of the same thing, the environmental information system." (DfE information management in rail industry, Learning from management of LCA data)

Task gaps and overlaps

In the report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* the activities involved in the work with environmental responsibilities are structured into five perspectives. The perspectives provide a structural support to identify information, tools, and method requirements for further analysis of an information system, which also is further presented in the report.

- *"Purchasing products; to assess a product from the perspective of becoming an owner of e.g. a product or facility.*
- *Designing products; to assess a product from the perspective of being able to improve its design.*
- *Analyzing content of product; to asses the material contents of a product for the purpose of overviewing the environmental consequences from choices of materials.*
- *Considering risks of product; to assess a product from the perspective of its potential risks or its ability to cause harm over its life cycle.*
- *Societal consequence of product; to assess a product based on environmental consequences from large-scale production of the product."* (2.3 Reasons for product life cycle overview, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems)

[80] Carlson R, Steen B, "A Data Model for LCA Impact Assessment", Presented at 8th Annual Meeting of SETAC-Europe 1998 14-18 April, Bordeaux
[81] Erixon M, "Information system supporting a web based screening life cycle assessment tool", CPM Report 2001:14, CPM, Chalmers University of Technology (2001)
[82] Dewulf W (Ed.), et al., "Integrating Eco-Efficiency in Rail Vehicle Design", Leuven University Press, Leuven, Belgium (2001)

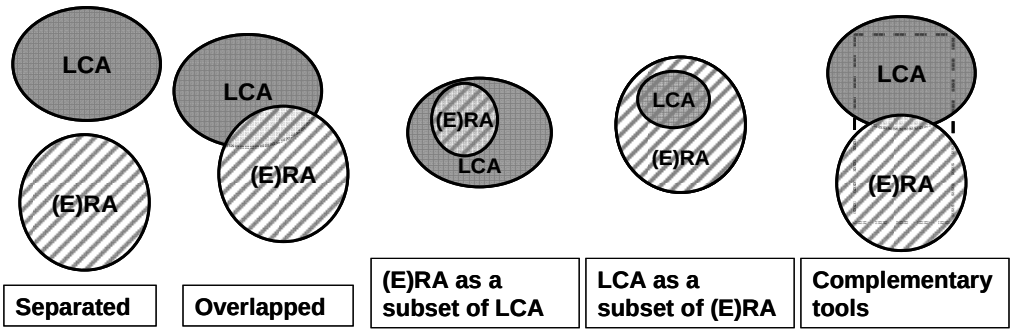
In the report *"Relationships between Life Cycle Assessment and Risk Assessment, Potentials and Obstacles"* [83] an in-depth comparison between the two tools in the report title are made. The results show that there are similarities and differences e.g. in terms of data requirements, system boundaries of the analysis, methodology for impact assessment etc. The method for comparison applied in the study is useful when investigating how to combine or integrate methods, tools, or tasks.

> *"Both life cycle assessment and risk assessment provide ways for structuring, evaluating and presenting environmental information relevant for different types of environmental decision making. However, in spite of the fact that the methods address neighboring problem domains and provide complementary information, the two methodologies are not yet easy to combine. Different methodological approaches, different scientific viewpoints, and different disciplinary traditions need to be bridged. To be effective and efficient tools the approaches of LCA and RA needs to be harmonized in some way. The issues dealt with both tools are very complex and it is not uncomplicated to explicitly explain all the aspect of the information provided by the tools. The study resulting in this report indicates that the knowledge about integration of the tools regarding technical feasibility, potential advantages and obstacles are not yet sufficiently examined, and that e.g. the different attempts to integrate LCA and RA that has actually been made have resulted in contradictory results. Both purpose and perspective of the two methods are often different and the connections between them are not fully investigated in literature to date.*
>
> *Both RA and LCA are system analytical methods that can be adjusted to answer a specific question or to provide a solution to a problem in a specific situation. It is important to understand that the two methods are intended to apply to two different problem focuses. RA deals with risks associated with the production, use, and disposal of a particular chemical substance and can also deal with human or environmental impacts from a specified industry and the emissions emitted from the industry. LCA deals with an aggregated potential environmental impact of technical systems e.g. a production site seen from the product or process point of view and therefore analyses a different system than RA. The functional unit is the base, the reference for the LCA study, and all emissions etc are related to the chosen functional unit. The functional unit is also used as reference for comparison.*[84]
> […]
>
> *The simplified Venn diagrams A- E presented in section 3.3 shows the different alternative approaches for a combination of LCA and RA. Alternatives for how to integrate or combine the two tools in terms of differences, advantages and obstacles may be discussed in terms of these diagrams.*
>
> *The separated approach, represented by A in figure A2.1, is the most frequently occurring relationship. The tools are used to solve different problems and the results from them can also be in conflict with each other. But*

[83] Flemström K, Carlson R, Erixon M "Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles", Naturvårdsverket Rapport 5379, June 2004

[84] Molander, S, Lidholm, P, Schowanek, D, Recasens, M, Fullana, P, Moller Christensen, F, Guinée, J, Hauschild, M, Jolliet, O, Carlson, R, Pennington, D, Bachmann, T M, OMNIITOX operational lifecycle impact assessment models and information tools for practitioners, 2003

this is not considered a serious contradiction, as long as the results from two tools are not compared. An analysis of the two methods LCA and RA shows that there is also a distinct overlap between them, and that they could be regarded as overlapping, as illustrated in B. When performing a LCA study of a product taking toxicity impact into consideration there is an overlap concerning risk assessment related data etc." (8 Discussion and Conclusions, Relationships between Life Cycle Assessment and Risk Assessment, Potentials and Obstacles)



© Flemström, Carlson, IMI, 2003, from NVV Report 5379 Relationships between LCA and RA

Figure A2.1 Alternative approaches of combining LCA and (E)RA in terms of simplified Venn diagrams.

The article *"A full Design for Environment (DfE) data model"* [85] presents results from the RAVEL project, in which a methodology was developed, together with web-based software tools with a knowledge base, to enable improved eco-efficiency of train vehicles for the entire rail industry, including suppliers and sub-suppliers, manufacturers, operators, and scrappers. The project is a good example of how a gap in the work process was identified for assessing environmental performance of products. The RAVEL data model and methodology was designed to fill this gap with clear interfaces to existing tasks, such as product development and procurement. Together these tasks form an integrated platform for DfE.

"Project management and the real design of the vehicle is not made with tools provided by the RAVEL workbench, since those tools already exists within the organizations where the RAVEL workbench will be used, and are better developed by other competencies. Instead the workbench and its information platform is designed to match with its neighboring information systems by e.g. having space for addresses and identifiers to projects and project members, and design drawings. The workbench could however offer support for administrating DfE responsibilities.

The RAVEL workbench is also designed to handle information from outside of its scope, by importing necessary information from other tools, e.g. material and component structures from CAD and PDM systems, and life cycle data from LCA or LCC tools. The general strategy and principle to enable such import is the data model and the structure of the RAVEL information platform. By having a clear and concise structure within the boundaries of the RAVEL information system, it is possible to unambiguously

[85] Carlson R, Forsberg P, Dewulf W, Ander Å, Spykman G, *"A Full Design for Environment (DfE) Data Model"*, PDT Europe 2001, April 24th-26th, 2001, pp. 129-135

> *define the mapping from any other well-structured information system. In figure 2 the 'strippers' should be understood as different software modules importing parts of the information from other files or databases through such well-defined mapping schemes that are defined specifically for each different external data source.*
>
> *The principle for the scope of the RAVEL workbench can be summarized as that it consists of information management tools for the intersection of all information necessary to perform a comprehensive DfE of a rail vehicle. However, it does not include any of the tools that are necessary to produce intermediate results e.g. LCA, LCC, DfD (Design for Disassembly). If suitable tools of such kinds do not exist elsewhere, the RAVEL information platform allows for them to be added, and is designed to store the required information."* (2.2. The Scope of the RAVEL Information System - the RAVEL workbench, A full Design for Environment (DfE) data model)

One main integration perspective in the article *"Learning from management of LCA data"* is that LCA data acquisition would benefit from integration with the data acquisition in the environmental management system at production site. This is based on empirical studies in the project "CPM/SSVL - Methodology for handling environmental data in the forest industry".

> *"Approaches for industrial environmental information management were tested thoroughly in the Swedish paper and pulp industry between 1999 and 2002. The PHASES method[86] was refined and tested for environmental information management and LCA data acquisition at industrial production plants, with the intention to decrease costs, increase quality and coordinate environmental information management. The project developed a practical methodology that fulfilled these intentions. The results were published as a methodology report[87], a manual[88], a technical licentiate degree[89] and articles presented to the international pulp and paper sector[90]. Learnings were that it is practically possible and economically beneficial to produce well documented LCI data already at the production site. The information becomes quality assured and the routines become independent of the persons who work."* (Information management system in paper and pulp industry, Learning from management of LCA data)

[86] Carlson R, Pålsson A-C, "Industrial environmental information management for technical systems", Journal of Cleaner Production, 9, (2001) pp 429-435
[87] Pålsson A-C, Enqvist A, Karlsson G, Loviken G, Möller Å, Nilseng A B, Nilsson C, Olsson L, Svending O, "Methodology for handling forest industry environmental data – Method report", CPM-report 2005:1, CPM, Chalmers University of Technology (2005)
[88] Pålsson A-C, Enqvist A, Karlsson G, Loviken G, Möller Å, Nilseng A B, Nilsson C, Olsson L, Svending O, "Methodology for handling forest industry environmental data – Manual", CPM-report 2005:2, CPM, Chalmers University of Technology (2005)
[89] Svending O, "Internal allocations in the Swedish pulp and paper industry", CPM report 2002:3, CPM, Chalmers University of Technology (2002)
[90] Pålsson A-C, Svending O, Möller Å, Nilsson C, Olsson L, Loviken G, Enqvist A Karlsson G, Nilseng A, Proc. 7th International Conference on New Available Technologies, Stockholm, June 4-6 (2002), pp.177-181

Gaps and overlaps of communication in terms of controllability

The report written for Swedish EPA *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* structures methods and tools for environmental overview of product life cycles in three categories, to show how they communicate with each other and how the information flows. The report provides many examples of how tools can be used sequentially to provide relevant and understandable information needed for the decision makers.

> *"Chapter 3 present methods and tools that are intended to provide an environmental overview of product life cycles, or that supports such overview indirectly by e.g. providing data. The methods and tools are selected on the basis of which information that users in sections 2.3.1 to 2.3.5 express needs for.*

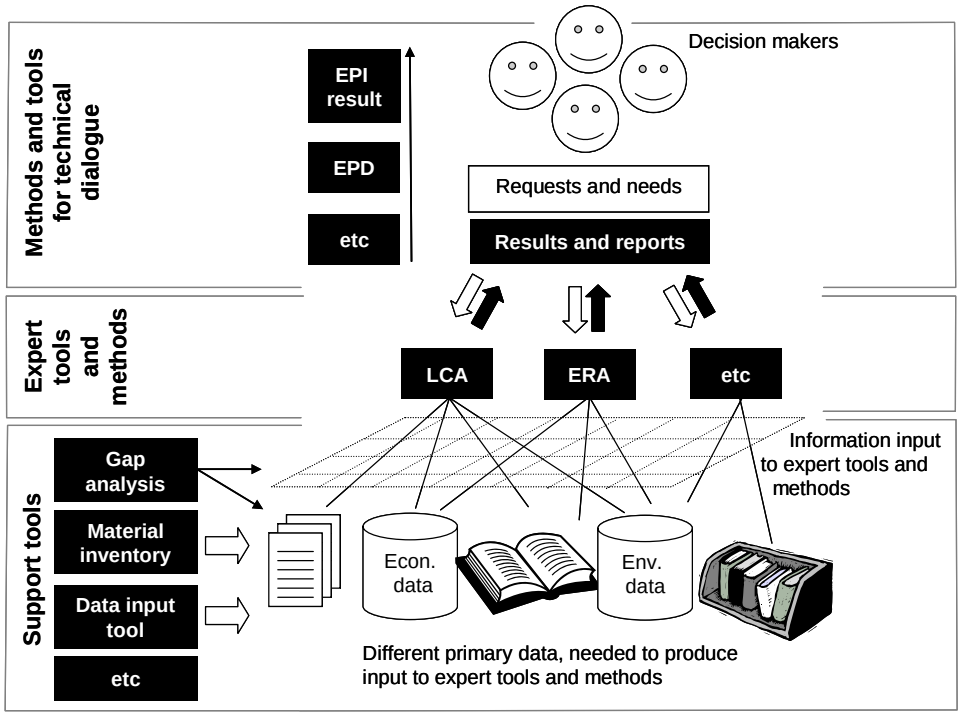


Figure A2.2 The tools are grouped after their intended use; support tools, expert tools and communication tools. The expert tools and methods handle the requests and needs of the decision makers. The support tools give information input to the expert tools. The methods and tools for technical dialogue are used to make the results from the expert tools understandable to the decision makers.

The methods and tools are assessed with special regards to describe their data input needs, as well as to suggest tools to be used together or in sequence. The data input needs are specifically analyzed for the purpose of finding their common primary data needs, i.e. which same data that many different methods and tools need, and to identify the availability of this data.

The methods and tools are divided in categories after their intended use; communication tools, expert tools and support tools. Communication tools are intended to simplify environmental information in different ways, so that it is understand-able for the decision maker. Examples are environmental performance indicators (EPIs), different standardized data sheets and

> *environmental declarations. Expert tools are intended to answer complex questions about environmental performance, such as decision support tools for procurers or designers, or analysis tools for environmental experts. Support tools provide expert tools with information input but can also be used independently. Examples are databases, restriction lists and data input tools. Figure A2.2 describes the relation ship between the different tools.*
>
> *The three types of methods and tools are relevant for SMEs, large corporations, for nations or for international co-operations. SMEs should seek to use methods and tools that are easy to use, interpret and communicate and they should seek to share costs for expert tools and support tools with e.g. other SMEs or larger corporations. Publicly funded initiatives and large corporations should seek structured ways to share data and information by e.g. striving to harmonize environmental performance indicators.*
>
> *The authors note that there are a large number of methods and tools available, and that it is not likely that ordinary users will themselves find the most appropriate tool without substantial support from expertise. Unfortunately most tools also face substantial data availability gaps. It may be suggested that the situation should be substantially weeded out by further relevance and data availability studies and assessments.*" (3 Methods and tools, 3.1 Introduction, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems)

Further, the report argues for harmonization of indicators, to clarify the purpose of the work with environmental overview of product life cycles, to increase the controllability, i.e. understandability and communication, and to minimize data requirements.

> "*In section 1.2.1 it was described how environmental information about a product life cycle describes how resource use, waste generation and emissions from the processes of the product life cycle and from the product itself impacts the environment. The precision of this description may range from being unspecific and qualitative to expressing quantitative values on well-defined environmental impact indicators. Examples of such indicators are presented in Appendix 3, section 3.1.5. To be able to calculate quantitative values on impact indicators the underlying information must be appropriate and suitable. There are little chances that available data will by coincidence suit the needs of relevant indicators. Appropriate and suitable data must be worked for, strategically. Primary data may be acquired and data may become available to users if appropriate indicators are communicated and harmonized. Such efforts may be supported with the setting of individual life cycles as described in section 5.1.6, and must be done in concert at different strategic levels:*
>
> - *At societal scale, the national environmental quality targets may serve as suggestions for choosing indicators, but they are not indicators in themselves.*
> - *At global scale the choices of indicators may concern globally accepted environmental problems, such as the ones addressed by the GRI .*

- *Commonly accepted indicators for products and industry sectors are handled in e.g. the different industrial sector forums and in the different systems for types I, II and III eco-labels and environmental product declarations, described in chapter 3.*
- *Effective environmental performance indicators for product life cycle need to be chosen so that they are meaningful at different stages throughout the life cycle.* "(5.3.2 Harmonization of indicators, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems)

In the project report *"Policy Controlled Environmental Management Work"* [91] a methodology for policy controlled environmental management work is described. The methodology aims at establishing controllability based on the policy, through a quantitative connection between indicators identified in the policy and the goals in the organization, see figure A2.3 below. The methodology can be applied to analyze how the environmental work relates to the strategic purpose and goal of the organization.

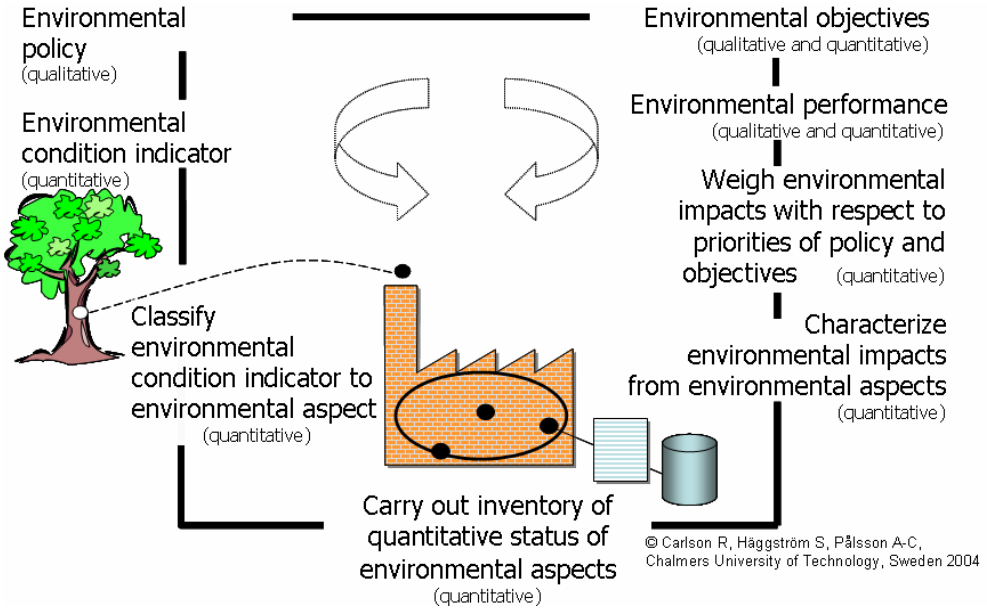


Figure A2.3 The methodology consists of eight steps and in each step a specific task in policy controlled environmental management work is performed. Each step can be performed independently of the other steps. The lines in the figure indicate how the different steps are related to each other and the arrows indicate that the different steps may be performed in any direction.

> *"A methodology for policy controlled environmental management work has been developed to enable a higher controllability of the environmental performance of an organization. The difficulties in improving the environmental performance of a company do seldom lie in the environmental management system but in making inconvenient decisions. The environmental consequences are seldom given the same priority as the other business consequences. However, by establishing a clear connection between*

[91] Carlson R, Häggström S, Pålsson A-C "Policy controlled environmental management work - Final report" CPM-report 2004:10

environmental policy and environmental priorities, objectives and decisions, the basis for them will be more transparent and easy to communicate both internally and externally.

The developed methodology will also enable a company with several production units to make the different environmental management systems uniform by using the company policy as the common basis."

In the article "*System for Integrated Business Environmental Information Management*" an information system named Integrated Business Environmental Information Management (IBEIM) is described. It includes operational, procedural and organizational support for a business' entire environmental information management. The system architecture is designed from three thoroughly developed information models that support the integration of environmental information systems. The three models are: a reference model for information aggregation and communication, an information model for data structuring, and a modularization including module interface specifications. IBEIM shows e.g. how expensive technical obstacles that are common in the integration work can be solved with standardized formats and interfaces.

"IBEIM is a structured information system, i.e. a system architecture with an information and data content.
The IBEIM architecture is built from three elements (see also figure 1):

- *A basic information platform, the data structure, implemented as a relational database for storage, and a standardized format (STEP) for data communication within the system and between separated sub-systems (ISO/IEC 9075:1992)(ANSI X3.135-1992)(ISO 10303-11:1995)(ISO 10303-21:1995). Using STEP as the communication format will ensure external compatibility with other software and internal transparency between system modules.*
- *PHASETS (PHASEs in the design of a model of a Technical System), which is a reference model including 6 phases for communication and aggregation of industrial environmental data and information (Carlson, Pålsson, 2000). Each phase in the model describes functions and management tasks, without specifying how these tasks should be performed. The reference model serves as a template for the architecture of the IBEIM system, and as a task and a reporting sequence for the different types of information handled within the system.*
- *A modularization based on the information platform i.e. the data structure of the database,the distinguished phases of the reference model PHASETS, and on organisational tasks that the users perform i.e. the organisational structure. The modularization is documented as an application programmers interface (API) specifying the interfaces and the communication and collaboration between software modules of the system. Formulation of an API makes it possible to add/change modules according to present needs in the form of for example plug-ins. The API documentation will be maintained in a public forum and will be publicly available for different software developers to apply and conform to. Current IBEIM systems being built, does not make use*

of the IBEIM API.” (Components of system, System for Integrated Business Environmental Information Management)

“The successful design of IBEIM is due largely to the PHASETS reference model, in that it supplied a thorough model for information management at different organisational levels and with different information aggregation. PHASETS serves as a design guideline through the development of an information system reaching from the level of physical flows at manufacturing plants, up to strategic organisational levels, such as the executive management board and the marketing departments. It also serves as a high-level software modularization schema, including high-level communication interfaces and task descriptions. Another valuable component for the design of IBEIM is the underlying model describing the format for the environmental information. This model originates from the work made in the Swedish industry, with the SPINE model and format (Carlson et al, 1995)(Carlson, Pålsson, 1998), and on the work made within ISO, with standardising a format for LCA data documentation, the upcoming ISO 14048 (ISO/CD 14048). This work has revealed the important aspects of information describing the environmental performance of technical systems, i.e. production processes, service activities, transports etc. It has also resulted in a substantially improved understanding of the different and special data quality aspects of such information, and has identified methods for administrating and maintaining the quality of such information systems (Carlson, Pålsson, 1998). These accomplishments have guided both the development of the PHASETS model, as well as the general design of the IBEIM system. The importance of well described data formats and well-designed transformations between systems cannot be underestimated, and it sets the foundation for the quality of the entire information system.” (Conclusions, System for Integrated Business Environmental Information Management)

List of references

Carlson R, Pålsson A-C, “Slutrapport projekt II:F:12 Integrerade Miljöinformationssystem”, CPM rapport 2001:17 (only in Swedish)

Carlson R, Erixon M, Erlandsson M, Flemström K, Häggström S, Tivander J, “Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems”, Industrial Environmental Informatics at Chalmers University of Technology for Naturvårdsverket (Swedish Environmental Protection Agency), (Currently in print 2005-12-22)

Carlson R, Erixon M, Forsberg P, Pålsson A-C, “System for Integrated Business Environmental Information Management”**,** Advances in Environmental Research, 5/4, 2001, pp 369-375 (Also presented at ISESS 2000 'Integration in Environmental Information Systems', May 30-June 2 2000, Zell am See, Austria)

Carlson R, “Learning from management of LCA data”, Journal of Life Cycle Assessment, Japan, Vol. 1 No. 2 Jul, 2005, pp 102-111

Carlson R, Steen B, “A Data Model for LCA Impact Assessment”, Presented at 8th Annual Meeting of SETAC-Europe 1998 14-18 April, Bordeaux

Erixon M, “Information system supporting a web based screening life cycle assessment tool” CPM Report 2001:14, CPM, Chalmers University of Technology (2001)

Dewulf W (Ed.), et al., “Integrating Eco-Efficiency in Rail Vehicle Design”, Leuven University Press, Leuven, Belgium (2001)

Flemström K, Carlson R, Erixon M, “Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles”, Naturvårdsverket (Swedish EPA) Rapport 5379, June 2004

Molander S, Lidholm P, Schowanek D, Recasens M, Fullana P, Moller Christensen F, Guinée J, Hauschild M, Jolliet O, Carlson R, Pennington D, Bachmann T M, “OMNIITOX operational lifecycle impact assessment models and information tools for practitioners”, 2003

Carlson R, Forsberg P, Dewulf W, Ander Å, Spykman G, “A Full Design for Environment (DfE) Data Model”, PDT Europe 2001, April 24th-26th, 2001, pp. 129-135

Carlson R, Pålsson A-C, “Industrial environmental information management for technical systems”, Journal of Cleaner Production, 9, (2001) pp 429-435

Pålsson A-C, Enqvist A, Karlsson G, Loviken G, Möller Å, Nilseng AB, Nilsson C, Olsson L, Svending O, “Methodology for handling forest industry environmental data – Method report”, CPM-report 2005:1, CPM, Chalmers University of Technology (2005)

Pålsson A-C, Enqvist A, Karlsson G, Loviken G, Möller Å, Nilseng AB, Nilsson C, Olsson L, Svending O, “Methodology for handling forest industry environmental data – Manual”, CPM-report 2005:2, CPM, Chalmers University of Technology (2005)

Svending O, “Internal allocations in the Swedish pulp and paper industry”, CPM report 2002:3, CPM, Chalmers University of Technology (2002)

Pålsson A-C, Svending O, Möller Å, Nilsson C, Olsson L, Loviken G, Enqvist A Karlsson G, Nilseng A, Proc. 7th International Conference on New Available Technologies, Stockholm, June 4-6 (2002), pp.177-181

Carlson R, Häggström S, Pålsson A-C, “Policy controlled environmental management work - Final report” CPM-report 2004:10

Appendix 3. Integrated data model

An integrated data model has been developed in the IMPRESS-project, which is based on several existing data models developed for different purposes within IMI and CPM, e.g. LCA, DfE, and environmental impact modelling. The integrated IMPRESS data model is used as a reference model, to describe how different types of environmental information, i.e. from the nature, social and technical system, can be formatted and related in a meaningful way. It provides structure for the information that shall be integrated, e.g. in terms of identifying what kind of information is needed by different users, finding similarities between information used in different applications, defining relevant level of detail of information, finding support for nomenclatures etc. It can also be used directly to build a database.

The reference model is extensive and described in full in the sub-project report "IMPRESS integrated data format with mappings to user applications"[92]. It is based on existing data models for life cycle inventory[93] [94], life cycle impact assessment[95], environmental assessment of component structures[96], and environmental impact modelling[97]. These original models have been partly integrated by IMI in a working draft reference model, IMI 2003[98] also including concepts from the ISO/TS 14048 LCA data documentation format.

The IMPRESS reference data model is developed based on essential concepts and relations in a user domain. Thus, an interpretation of the data is built in to the database and gives the data meaning. Such a database preserves the value of the information, also if software, technical platforms and interfaces are changing.

Example extracted from IMPRESS reference data model

To illustrate how the reference data model can be used in the integration work, an example with integration of substance and material property data is presented. Environmental impact model specialists and DfE specialists both manage substance property information. The DfE specialist deals with properties relevant for the design and component structure of an article, while the environmental specialist deals with toxicological, fate, and exposure properties required to assess how substances interact with the environment. Although these properties are used in different contexts and for

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[92] Tivander J et al, "IMPRESS integrated data format", Final report from sub-project 3 in the IMPRESS project, Industrial Environmental Informatics, CPM Report 2006:15, Chalmers University of Technology, Göteborg

[93] Carlson R, Löfgren G, Steen B, "SPINE, A Relation Database Structure for Life Cycle Assessment", Göteborg, IVL-REPORT, September 1995

[94] ISO/TS 14048

[95] Carlson R, Steen B, "A Data Model for LCA Impact Assessment", Presented at 8th Annual Meeting of SETAC-Europe 1998 14-18 April, Bordeaux

[96] Carlson R, Forsberg P "The RAVEL_Information Platform Data Model" 2000 RAVEL project doc nr CPM-000919 (report)
Dewulf W (Ed.), et al., "Integrating Eco-Efficiency in Rail Vehicle Design", Leuven University Press, Leuven, Belgium, 2001

[97] Tivander J, Carlson R, Erlandsson M, Erixon M, Geiron K; "Concept Model for the OMNIITOX Information System Including OMNIITOX Data Format Definition" OMNIITOX project report D20 and D26, 2004, EC contract G1RD-CT–2001–00501

[98] The work draft reference model is applied in the IMI Portal, involving tools for LCA and EMS, see http://databases.imi.chalmers.se/imiportal/ (2005-11-23)

different purposes, they share the same conceptual structure, see figure A3.1. A common database format could therefore correspond to both user requirements.

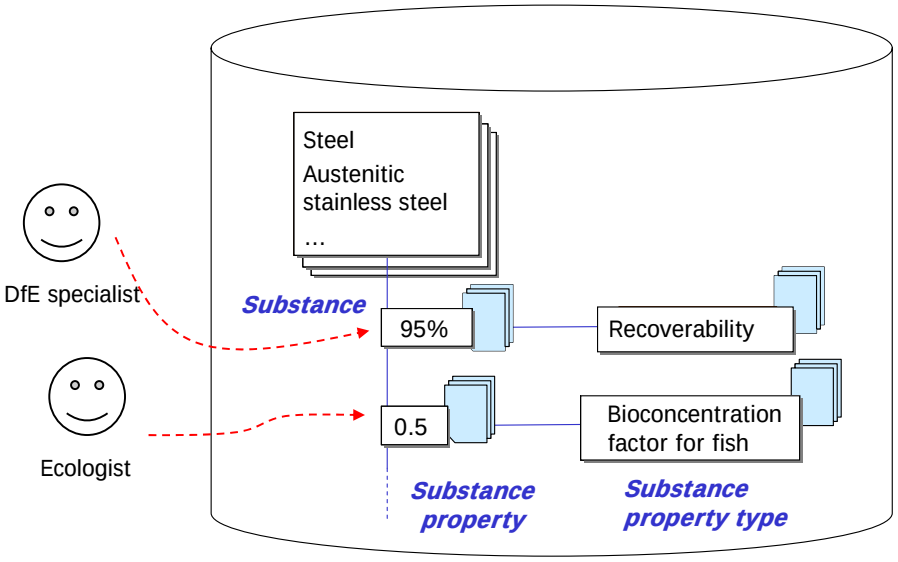

Figure A3.1 Different users can share the same data model regarding substance properties.

To exemplify how the reference data model is designed, the tables that corresponds to the concepts Substance, Substance property type, and Substance property are shown in figure A3.2. The concept Substance property parameter type in the data model enables substance properties to have several parameters, e.g. the substance property Boiling point is dependent on the parameter Atmospheric pressure, the substance property Bioconcentration factor for fish is dependent on type of fish, duration of the test, etc.

The similarities between the two perspectives in this example may be rather obvious, but the principle is applicable also for more complex relations, e.g. the conceptual structure for substance properties can also be applied for nature properties such as Average precipitation, Surface area of water, Sun hours per year. Other examples of more complex relations are when integrating data models for EMS, LCA, and DfE. More examples of relations between the reference data model and user perspectives is found in the report *"Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems"* [99] written for the Swedish EPA.

[99] Carlson R, Erixon M, Erlandsson M, Flemström K, Häggström S, Tivander J, Establishing common primary data for environmental overview of product life cycles; Users, perspectives, methods, data, and information systems, Industrial Environmental Informatics at Chalmers University of Technology for the Swedish EPA (Environmental Protection Agency), (Currently in print 2005-12-22)

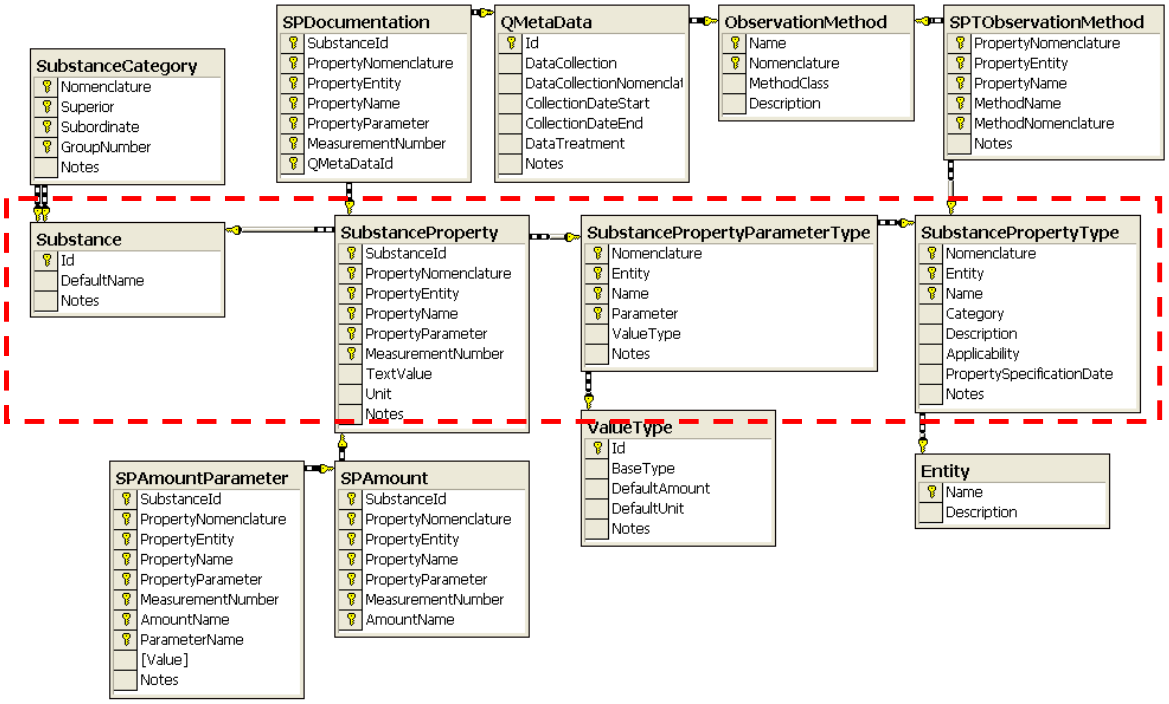

Figure A3.2 An extraction of the IMPRESS reference data model for structured storage of substance property data.

Appendix 4. Examples of policies and indicators in different environmental management and assessment tools

Design for Environment	
Policy:	"Environmental policy" (RAVEL methodology)
Indicator:	"Environmental Performance Indicators" (RAVEL methodology)
Example of policy and indicators:	
Policy:	The policy is to have material content of the product in focus. Recyclability and renewability of materials are prioritized. *(From the IMPRESS project)*
Indicator:	• Fraction renewable material in Weight-%, kg • Fraction recycled material in Weight-%, kg • Can be material recycled in Weight-%, kg • Can be incinerated with energy recovery in Weight-%, kg • Materials inventory degree and product weight in Weight-%
Environmental Management System	
Policy:	"Environmental policy" (ISO 14001, EMAS)
Indicator:	"Environmental Condition Indicator" (ISO 14031)
Example of policy and indicators:	
Policy:	The policy is to comply with compulsory requirements from government and requirements in the Nordic eco-label "Svanen" regarding paper production. Further, there is a focus on local emissions and a set of indicators that can be agreed on in a consensus process. *(From the IMPRESS project)*
Indicator:	• Emission of phosphorus (P-total) in kg/tonne of paper • Emission of nitrogen (N-total) in kg/tonne of paper • Emission of substance with chemical oxygen demand (COD-total) in kg/tonne of paper
Life Cycle Assessment	
Policy:	"Impact indicator principle" (IA 98), "Goal and Scope Definition" (ISO 14041)
Indicator:	"Life cycle impact category indicator" (ISO14042) "Category indicator" (IA 98) "Environmental indicator" (WWLCAW)
Example of policy and indicators:	
Policy:	Eco-Indicator '99: If we damage our environment too much it will no longer be able to support mankind. We have chosen the following definition of the term environment: A set of biological, physical and chemical parameters influenced by man that are conditions to the functioning of man and nature. These conditions include Human Health, Ecosystem Quality and sufficient supply of Resources. In the Eco-indicator '99 we only look at environmental problems as they occur in Europe.

	From this definition it follows that there are basically three damage categories: • "Human Health" contains the idea that all human beings, in present and future, should be free from environmentally transmitted illnesses, disabilities or premature deaths • "Ecosystem Quality" contains the idea that non-human species should not suffer from disruptive changes of their populations and geographical distribution, • "Resources" contains the idea that the nature's supply of non-living goods, which are essential to the human society, should be available also for future generations. Please note that it is also possible to select other damage categories, such as material welfare, happiness, equality, safety etc. We have chosen not to include these aspects, partially because it is too complex to define or model such damage categories and partially because in general products can have both an intended positive effect as well as a negative (environmental) effect. *(From: The Eco-indicator '99, A damage oriented method for LCA, Methodology Report, Mark Goedkoop and Renilde Spriensma, Pré Consultants, 17 April 2000)*
Indicator:	• DALY (Disability Adjusted Life Years) in person-years • Potentially Disappeared Fraction (PDF) in % • Resource damage in MJ/kg
Emission trading	
Policy:	"Emission trading scheme" (Directive 2003/87/EC)
Indicator:	CO2 emissions
Example of policy and indicators:	
Policy:	**"**This Directive establishes a scheme for greenhouse gas emission allowance trading within the Community (hereinafter referred to as the 'Community scheme') in order to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner." *(From: Directive 2003/87/EC)*
Indicator:	• Emissions of CO2 in tonne per year
Risk phrases	
Policy:	"Regulations" (Sweden)
Indicator:	"Risk", "Toxic effect"
Example of policy and indicators:	
Policy:	Allergenic substances: According to the Swedish Chemicals Inspectorate, allergenic substances are dangerous to health and have to be classified. Regulations state that allergenic substances involve substances that can be allergenic if inhaled and/or in contact with skin. *(From: Swedish Chemicals Inspectorate: http://www.kemi.se/templates/Page____372.aspx)*
Indicator:	• R42 Allergenic at inhalation as in 'yes', 'no', or 'ambiguous' • R43 Allergenic in contact with skin • R42/43 Allergenic at inhalation and in contact with skin