特集「LCA データベース&ソフトウェア」

総説

Learning from management of LCA data

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Synopsis: The Swedish national LCA database was built to support industrial LCA needs. All experiences during the build-up and all data were documented so that the acquired knowledge should be useful in the future. This article describes many learnings and positive side-effects from ten years of establishing that database. The national co-operative form is presented, as well as the layout of the project. The data format and data quality approaches are described in terms of relevant choices and learnings. Learnings acquired in the project were put into use early, and integration of LCI data acquisition with industrial environmental information systems were tested in industries as early as 1997, and full-scale tests were proven successful in 2001. Integration with DfE methodologies has also been tested at industrial scales, as well as semi-automated environmental reporting.

In 2005 the database is still running and is actively maintained and is further developed. Companies start to want to update the database, and all key learnings from the ten years are available and can be utilised as competence for new projects, strategies and visions for more and better LCA data.

Key Words: environmental information management, environmental management system, design for environment, LCA database, data format

Introduction

Starting the Swedish national LCA database

Plans for the Swedish national LCA database were sketched in the early 1990s ¹⁾, from lessons learned from data acquisition in different LCA studies in industry ²⁾ and for the Swedish government, such as the Swedish packaging LCA performed in 1991 ³⁾. These were similar to those that later led to e.g. the SPOLD data format ⁴⁾ and formulations from LCANET in 1997 ⁵⁾.

Included with the Swedish plans were lists of criteria, such as that:

- The data should be documented in English.
- The database should suit different types of LCA.
- The data should contain meta-data.
- It should be possible to connect the database to different (software) applications.
- Data quality should be assessed before data were entered into the database.
- The database should be continuously updated.

In 1994 there were few experiences from building general, sector independent, transparent and quality assessed LCA databases. Learnings had to be acquired from own experiences.

The co-operative national effort

The starting point was the forming of the Swedish national competence centre CPM ⁶⁾. CPM started in early 1996, as a joint research forum between Chalmers University of Technology ⁷⁾, 10-15 Swedish industries and government (through the agency NUTEK ⁸⁾, later VINNOVA ⁹⁾). A main purpose of CPM was to establish and maintain a Swedish national LCA database, and to conduct research in LCA and product related environmental assessments. CPM started as a ten year governmental investment, financed with equal parts from government, industry and Chalmers.

The CPM project for establishing the database started in April 1996, and according to the plan the objective was to increase availability, usefulness and quality of LCA data by installing and managing a physical database for LCA data,

by developing and managing the database's conceptual data model (see section 'The LCI data format' below), and to work towards a standardised LCA data communication format. The project should also acquire and enter data into the physical database. The database should also have a data quality management system.

During the project runtime two small reports were produced, to answers 12 common questions or misunderstandings during the project work¹⁰⁾, and to clarify the strategy of the project¹¹⁾. The final result of the project was reported two years later in the project report¹²⁾. It was written as guidance for others who need to establish a similar database.

Learnings from the project are that the strength from having ten years of combined governmental back-up, industrial commitment and funding for academic research provided the necessary courage for CPM to formulate serious questions and set relevant goals for the work; the LCA database should comply with industry standards so that LCA would comply as an industrial methodology and tool. In the following a number of detailed spin-offs and learnings will be presented.

Data

The LCI data format

The data format for the database was developed in a joint Nordic project, with companies and research institutes from Norway, Sweden and Finland into a commonly agreed upon data format. The format was described in a public report¹³⁾, and the format was given the name Sustainable Product Information Network for the Environment (SPINE)¹⁴⁾. During the development it was anticipated that SPINE should apply to any type of LCA, and also for environmental accounting, environmental management systems (EMS), design for environment (DfE), and for simultaneous environmental reporting. It was also designed flexibly to be compatible with other LCA data formats.

The impact assessment data format

In 1998 the ISO standard for life cycle impact assessment, ISO 14042¹⁵⁾, was in its finalisation phase, and the LCI part of the SPINE data format was well tested in industry and by software developers. A compatible data format for impact assessment data, according to ISO14042 was therefore developed¹⁶⁾. It was tested, and was made public in the year 2000 as a transparent and reviewable impact

assessment database combined with the Swedish LCI database, into web-based LCA tool¹⁷⁾. The database contains the most well known and commonly applied LCA impact assessment methods at that time, complete and well-documented; Eco Indicators 99¹⁸⁾, EDIP^{19, 20)}, and EPS 2000^{21, 22)}. The learnings from documenting these three impact assessment methods in the format were published as documentation guidelines for impact assessment data²³⁾.

The data quality criteria

When establishing the national LCA database a separate sub-project was dedicated to define the quality criteria for the database. The sub-project was industrially driven and based on relevance and consensus. The result was the CPM LCI data quality criteria²⁴⁾ which were in fact documentation criteria (English version of criteria in terms of ISO 14041 was published in 1999²⁵⁾). These criteria were expressed as a list of mandatory data fields of the SPINE format; each mandatory data field should be filled in to allow for publication in the CPM database. As a result, since 1997 each data is manually reviewed for clarification and consistency, and to facilitate compliance with these criteria, manuals for data documentation²⁶⁾ and for data review²⁷⁾ were produced, and courses were held for industry, institutes and academia.

In parallel to developing the documentation criteria, CPM also performed theoretical data quality studies, with the aim to find a quantitative approach to complement the documentation criteria. These studies resulted in a licentiate thesis in 2001²⁸⁾, but the findings have not been possible to operatively integrate with the database.

The CPM data documentation quality criteria are valuable since they are easy to understand and flexible to any industry or any application. They also provide the natural interpretation of the data format, and database users highly appreciate to get documented data. The weaknesses are that users find it tedious and time consuming to document the data, and that the quantitative data are not reviewed. To review that quantitative LCA figures are correct would require competence from many or all industry sectors. This has instead been approached by developing methodologies for environmental information quality management in production plants.

Information and database management

Data quality is the result of quality processes

The data quality criteria developed by CPM requires documentation of data, and in the project an obvious fact was learned; If data is not documented when presumptions, assumptions, errors, limitations and other important facts about data are known, then these facts will never be known again and will never be documented later on. The implication is that data need to be documented already when it is produced, e.g. as a sampling value at the measurement site or when calculated by an emission-model. Such LCI data documentation was not generated anywhere in 1996 and the methodology had to be developed.

A general methodology for how documentation could be merged with the handling of environmental information within industries were described already in 1998²⁹⁾, and refinements were made due to practical tests in industry³⁰⁾. The aim was to reduce costs by integrating environmental information management systems with other business functions, while improving precision and documentation quality of the data. The theoretical framework named PHASES (PHASEs in the design of a System) supports this^{31, 32)}. PHASES conceptualises the different steps needed to produce environmental data, from defining and setting up a measurement system to the final reporting of an LCI data set or a complete LCA. Among other applications, PHASES was adapted in the European thematic network CASCADE (Co-operation and Standard for Life Cycle Assessment Data in Europe)³³⁾ as a data collection process that results in high quality LCA data^{34, 35)}. One extra benefit from having a quality management view on LCA data handling is that it provides better understanding about the quality of industrial environmental data management in general; there is a dependency between LCA data quality and the quality of EMS.

Environmental data management in industry

From learning that LCA data quality results from information management within the EMS, a number of master thesis studies were performed to investigate this relationship^{36, 37)}. At the SETAC meeting in Leipzig in 1999 a general principle of industrial environmental information quality management system was presented³⁸⁾. Between 2001 and 2004 a number of CPM companies ran a project aimed at practically improving environmental data handling within industrial EMS^{39, 40, 41)}. It was based on a direct coupling

between a company's environmental policy and its environmental information system, and quality implications from this. One finding was that there are data gaps in current EMS. This conclusion was further underlined by a data requirements gap analysis of the ISO 14001 standards that was performed in 2004⁴²⁾. The gap analysis shows that the standards include expectations on data quality but supply insufficient support for how to meet these expectations. From working with LCA data quality management as part of the industrial EMS it was learned that there are gaps between company's policy levels and the operational levels. Hence, the building up of the Swedish national LCA database developed far from scientific data and statistics, into the core of industrial EMS.

Applications of methodology in different industrial sectors

Tests and feasibility studies

The SPINE data format was designed to be independent of industrial sectors, and this claim is tested and proved within different industries that run SPINE databases as corporate LCA network databases or as standalone software applications. Except for practical and commercially based SPINE installations, feasibility assessments of the format have been made in the building sector⁴³⁾, the waste management sector⁴⁴⁾, the electronics sector⁴⁵⁾ and the aluminium sector⁴⁶⁾. All tests have given positive results, but it may be that the broad practical success is one reason why it was not fully appreciated in different LCA communities outside of Sweden; the practical quality tests used up the resources that could have been available for scientific dissemination and practical marketing.

Information management system in paper and pulp industry

Approaches for industrial environmental information management were tested thoroughly in the Swedish paper and pulp industry between 1999 and 2002. The PHASES method³²⁾ 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 report⁴⁷⁾, a manual⁴⁸⁾, a technical licentiate degree⁴⁹⁾ and articles presented to the international pulp and paper sector⁵⁰⁾. 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. It was also learned that such benefits are not sufficient for introducing systematic environmental information management; most companies chose not to implement the system after the project was over. The reasons need to be further assessed and understood.

DfE information management in rail industry

The first system based on the data format for impact assessment (see section 'Data' above) was tested within CPM, for electronics manufacturing⁵¹⁾ and later also for DfE applications in the European project RAVEL (Rail Vehicle eco-efficient design)⁵²⁾. 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.

Sector independency

Semi-automated reviewable reporting

The Swedish Environmental Product Declarations (EPD)⁵³⁾ system was developed in parallel with the Swedish LCA database. It was intended that the database should support the EPD system. The first contribution from the LCA database was to share its review principles; the EPD system was to apply the same documentation criteria as the database⁵⁴⁾. Many Swedish LCAs for EPD purposes have utilised data from the Swedish LCA database, and the database has developed to more efficiently support the EPD system. A methodology to generate fully transparent and reviewable complete LCA studies⁵⁵⁾ is described, and parts of it will be implemented as prototype tool in a CPM proj-

ect named IMPRESS⁵⁶⁾.

It is expected that integration of web-based LCA tools for reviewable LCA studies with the Swedish national LCA database will reduce costs for performing reviewable LCAs.

Approaches to simplify data acquisition

In parallel with integrating the LCA database with different software applications and LCA data acquisition routines with operative EMS, approaches to simplify continuous LCA data acquisition have also been made. Three examples are:

- It was assessed whether the environmental reporting that Swedish companies are obliged to submit to the government includes the information that is needed to perform an LCA⁵⁷⁾. It was found that since they lack data on production volumes they were not fit. (Assessments of usability of a combination of publicly available economic and environmental reporting have not yet been made.)
- Principles and tools were developed to support and encourage LCA data providers to establish mutual LCA data trading⁵⁸⁾. Courses were provided by CPM, and software, common nomenclatures and a common data exchange format were made available at no charge. In spite of this, the idea was not implemented. This was largely due to competition between initiators, and today a new technical platform has been developed to facilitate for different ideas and business principles⁵⁹⁾.
- A guideline for LCI data acquisition strategies for companies or LCA projects were produced⁶⁰⁾. The guidelines are based on limited practical tests in the electronics sector.

Learnings from simplifying LCA data acquisition into general strategies and business networks may form basis for next generation of LCA data support systems. Currently there is no approach that both meet LCA data documentation requirements and that are propelled by an economically sustainable business model. The LCA data acquisition problem is not solved by a database.

Harmonisation and standardisation

When the Swedish national LCA database-work started in the mid 1990s it was understood that life cycle assessment was in its infancy. Much was to come, such as the integration with EMS and international exchange of envi-

ronmental product data. Therefore, already from the beginning it was understood as necessary to work towards international harmonisation of life cycle data formats, and that these needed to be flexible beyond LCA. The development of the common Nordic format SPINE¹³⁾ was a first step in this direction. The next step was taken in 1997 to propose initiation of an ISO standardisation of a LCA data documentation format. In parallel to this CPM also participated to develop and improve the SPOLD format^{4, 61)}, and in Sweden harmonisation efforts aimed to facilitate data exchange between software and LCA users in consultant agencies, industrial companies and research institutes⁶²⁾. When ISO released the technical specification ISO/TS 14048 Data documentation format in 2002⁶³⁾ CPM published examples⁶⁴⁾, a computer implementable version of the format⁶⁵⁾, a mapping-table between SPINE and ISO/TS 14048⁶⁶⁾, a guide for documenting LCA data using the ISO specification⁶⁷⁾, a report that describe how to apply the CPM documentation criteria on the ISO format⁶⁸⁾, and a quick guide for LCA practitioners to switch from SPINE to ISO/TS 14048⁶⁹⁾.

Learnings are that harmonisation investments are worthwhile. The Swedish contributions to documentation requirements on LCA data are globally accepted, though not always applied. Another learning is that harmonisation takes time; over ten years of Swedish development is relatively quick when compared internationally, much due to the steady financing of CPM and the close relationship with industry work. Harmonisation efforts may sometimes be regarded as threats, unless care is taken to help others to catch up and prosper from the mutual benefits.

The Swedish LCA database today

In March 2005 the Swedish LCA database holds 536 LCI data sets, covering energy and transport sectors and many industrially consumed raw material and products. Data sets are sold for a price in the range of USD 150 per data set. The data can be viewed and purchased in the format of either SPINE or ISO/TS 14048. These and other facts about the database were presented at The Sixth International Conference on EcoBalance, Oct. 25th - 27th, 2004, Tsukuba, Japan⁷⁰⁾. Over time, the different learnings described in this article have been disseminated to industrial companies in CPM since the mid 1990s.

Two distinct learnings about LCA databases in general have been noted during the way:

- How to efficiently set up a practically useful LCA database⁷¹⁾.
- How to continually improve an LCA database according to practical experiences⁷²⁾.

Further key learning is that well-structured documented data is valuable and can be reused; the industrial LCA practitioners that have worked with the SPINE format and who applied the CPM documentation criteria find it easy to understand the contents of their own LCA databases long after they entered them into the database. Involving new colleagues is easy, whether it concerns the in-house LCA database or the national database. Much LCA costs have been saved due to that. But many LCA practitioners still perform data collection without documenting sufficiently. Long-term economic benefits are difficult to communicate. Over the years, the Swedish national database administration matured into a research unit within the university, with the name of Industrial environmental informatics, IMI⁷³⁾. The research is based on questions and findings when establishing the national LCA database and addresses issues such as environmental indicators and performance measurements, setting up databases, defining data quality systems and data acquisition. Much of the research is performed through software prototypes and different industrial environmental databases.

Conclusions

All conclusions from establishing the Swedish national LCA database in joint CPM co-operation cannot be condensed in one article. But some essential conclusions will be noted here.

Many of the original criteria for the national database proved true, such as that:

- The data should be documented in English. It facilitated that the database can be appreciated also in 2005 when all Swedish companies that entered CPM in 1996 are now parts of global corporations.
- The database should hold data for different types of LCA and the database should contain meta-data and be transparent. It ensured that users in 2005 can review data entered in 1996.
- It should be possible to connect the database to different (software) applications. A fact that has been proven by integration into DfE-tools, web-based LCA

tools and impact assessment databases etc.

- The data quality must be assessed before data are entered into the database. This has facilitated data management and has held maintenance costs at a minimum, since each data set need to be assessed only once.
- The database was expected to become systematically updated. But this has not been done, though voices today claim that it should.

There also are learnings that are results from choices of technologies and strategies, rather than from original criteria. Examples of such learning are

- The LCA database should comply with industrial technology and quality standards, which has facilitated integration with industrial data systems and EMS.
- Ten years of governmental back-up, industrial commitment and academic funding provided the courage to form serious questions that established new knowledge about data for product life cycles.
- The quality management view of LCA data learned more than that had been questioned before, i.e. that it had direct implications to quality management of EMS in general.
- There were great benefits from having compatible data formats for LCI and impact assessment data. Integration of LCA tools for transparent LCA studies is an example of that, and costs for developing different LCA tools can be decreased.
- The CPM data documentation criteria are easy to understand and flexible to any industry or any application. The weakness is that users find it tedious and time consuming to document the data.
- Harmonisation efforts are well worth the investments and need to take time, but the broad practical success may be the reason why the Swedish approach have not been fully appreciated in different LCA communities; practical tests used resources that could have been used for dissemination and marketing of results.

From the close relationship with industry, the development of LCA applications could be foreseen early, in terms of reuse of LCA data, integration into industrial environmental management and design for environment and green procurement. CPM development has made some early findings:

- It is practically possible and economically beneficial to

produce well documented LCI data already at the production site. However, these benefits are not sufficient for introducing such routines (see section 'Information management system in paper and pulp industry').

- Environmental performance indicators and database strategy are two sides of the same thing; there is a direct relationship between environmental indicators and choice of contents in an environmental database for environmental performance measurements (see section 'DfE information management in rail industry').
- Documented and well-structured data can be reused, and LCA costs can therefore be saved. However, many LCA practitioners still do bad documentation since such long-term benefits seem meaningless to inexperienced practitioners (see section 'The Swedish LCA database today').

CPM learnings has been disseminated in e.g. Swedish EPA reports⁷⁴⁾ and other articles and reports, and as results out from e.g. the project DANTES⁷⁵⁾. CPM's international lead concerning LCA data handling has also been confirmed by three international assessments of CPM⁷⁶⁾.

A general learning is that when producing a new type of database one should expect to have to solve interesting problems, and this work might lead farther than was intended by the actual task. From the viewpoint of the new research field of industrial environmental informatics, the intensive work at the cross section between industry and academy during the establishment of the Swedish national LCA database was an ideal spot for evolution of new ideas. Development, rejection and redevelopment of tools, methodologies and a new scientific approach have been quick.

Future development

The Swedish national LCA database is a fundament on which new work can be built. Practical issues to deal with already are the updating, or the second version of the database. Since one of the key learnings is that there is a direct relationship between environmental performance indicators (EPIs)⁷⁷⁾ and the database content, future databases should be established on well defined EPIs, and much effort should be spent on identifying the intended user groups and their actual needs. This will save cost and ensure relevance.

Data acquisition of different kinds, such as laboratory tests and measurement in natural environments should be performed to improve characterisation modelling, and demographic studies should be performed to improve weighting and prioritisation modelling. LCI data is not valuable on its own.

Harmonisation efforts are regarded as threats and care must be taken to assist and disseminate results. This will be achieved by stronger participation in different international networks, e.g. UNEP/SETAC LC Initiative⁷⁸⁾ etc.

But the LCA database management shall also still function as a living learning forum, for integration of industrial environmental information systems⁷⁹⁾, and for further studies that relate environmental information and data quality issues with aspects of the inter disciplinary fields of cognitive science⁸⁰⁾.

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