A reference architecture for the integration of EMIS and ERP-systems

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Abstract: The integration of EMIS and ERP-systems has been recognized as an important step towards a holistic and long-term oriented environmental management. A number of research projects attempted to model the environmental impact of products in ERP systems and to integrate environmental impacts into the operational decision-making and communication of companies with their customers. In this paper we elaborate further on a reference architecture that allows an increasing level of automation when calculating a company's environmental impact by concentrating on the own operations and assuming that the environmental impact data for input materials is provided by suppliers as a service.

1 Introduction

We have recently argued that the integration of environmental management information systems (EMIS) and enterprise resource planning (ERP) systems is an important prerequisite to account for environmental impact in corporate decision making on an operational but also strategic level [FMN09]. This integration was already proposed in the early 1990s and has since been explored in several research projects. The resulting concepts are often based on a full life cycle assessment (LCA), which accounts for all emissions along the cradle-to-grave path of products. However, the implementation of systems based on this research has not yet passed prototypical status.

ERP systems are able to not only account for the material but also for the substance flow necessary to determine the life cycle inventory. However using ERP systems (e.g. SAP Green 2.0) to account for substance flows in production processes involves significant manual effort to enter and manage the substance/material relation and the environmental impact of materials from external suppliers, even though data about the environmental impact is available in other systems such as LCA databases. But this data cannot be imported automatically because using life cycle inventory data requires making value choices, which have arisen because of the plurality of methods developed by the LCA community. Together with the absence of a common vocabulary this leads to what is called a semantic gap. We argue that this is the single most important reason that ERP/EMIS systems have not been developed beyond the prototypical stage. If ERP systems are to take account of environmental impact then new methods have to be developed to bridge this gap.

To determine the environmental impact of a company - and more important its products - we suggest to initially concentrate only on the part of the supply chain the company itself is responsible for. To separate concerns (and reduce complexity) we assume that suppliers in the pre-chains provide services offering information on the environmental impact of their products. Since these services are currently not available, one task is to get automatic (rough) estimates on the environmental impact of products from suppliers. We will address this question in our future work.

This paper is structured as follows: we start by summarizing results from related studies focusing on the integration of EMIS and ERP systems. We then present a reference architecture that could serve as an intermediate solution to allow a company to provide its customers with environmental impact data on its products.

2 Related Work

There are two streams of research related to this work. The first is concerned with recent projects dealing with EMIS/ERP-integration. Research methods employed in theses projects included prototyping, reference architectures, and field studies. The second stream stems from the life cycle assessment community.

2.1 Recent work on EMIS/ERP integration

Several authors (see for example [Rau97, KDF+00]) recognized the importance of EMIS/ERP-integration - especially the integration of material flow management with production planning and control [IR07] - early on. The integration of material flow management and PPC is accomplished using material flow networks [Möl94] of product structures (BOM), work plans and production orders. The most important problem areas are (i) the varying requirements concerning granularity and availability of data [MGPR04, MGGS06] as well as (ii) possible redundancies in the data management between PPC and material flow management systems.

Research projects include ECO-Integral [KDF+00], that developed a for the horizontal integration of EMIS and ERP systems, and a series of projects under the leadership of the Institut für Arbeitswissenschaften und Technologiemanagement (IAT) at the University of Stuttgart and the Fraunhofer Institut für Arbeitswirtschaft und Organisation [BEH00, BB04, LRW+03, LSL+04, LKH07]. In a project at the Technical University of Darmstadt [AABR07] a SAP system was extended to semi-automatically create a product-oriented LCA. A prototype developed on top of the SAP component EH&S supports all phases of the life cycle assessment according to ISO 14040.

Therefore, in principal ERP systems are able to portray the substance flow level and, thus, at least partially serve as a basis for life cycle inventory and finally for the life cycle impact assessment. The practical introduction of these solutions however involves a high degree of manual work when it comes to maintaining the material-substance-relation and deriving the impact assessment.

2.2 Life cycle impact assessment

Based on emissions and extractions of life cycle inventories, life cycle impact assessment (LCIA) aims to determine the environmental damage of products, processes, and companies. To do so, impact pathways link LCI-data with potential environmental outcomes or impacts. Following Jolliet et al. [JMWB+04] and other researchers in the field, there are two schools of methods (see fig. 1):

- By using quantitative models classical impact assessment methods (e.g. [GHH+02]) only link LCI data with impact categories at a midpoint level, e.g. global warming potential or acidification. Midpoint refers to the fact, that classical LCIAs stop before the end of the impact pathways down to subsequent damages to, e.g. humans.
- Damage oriented methods (e.g. [GS01]) model the cause-effect chain up to three endpoints: (i) human health expressed in DALY (Disablity Adjusted Life Years), (ii) ecosystem quality expressed as the percentage of species that have disappeared, and (iii) the remaining amount of natural resources and their future extractibility.

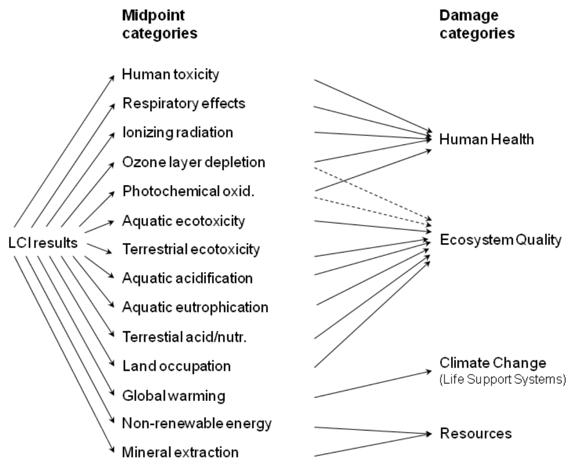

Figure 1: Linking LCI results via midpoint categories to damage categories (taken from [JMC+03])

Obviously, results from damage oriented methods can be more easily interpreted than midpoint categories but they also involve a higher degree of uncertainty, since the impact mechanisms are still under research. Hence, to reduce uncertainty in the environmental data passed between companies in a value chain, we propose to use impact categories at midpoint level.[1]

[1] It should be noted that significant work has gone into reconciling both approaches (e.g. IMPACT2002+).

3 Reference Architecture

In the following we assume that the customer of a company is enquiring about the environmental impact of a product bought from the company. The company provides a web service that describes the environmental impact in terms of impact categories at midpoint level as described in chapter 2.2. The information systems (IS) of the company (fig. 2, shaded area) is used in order to first of all determine the environmental impact the production processes controlled by the and to secondly compile these with the data from the pre-chain. The IS of the company contains the company's ERP, an integration platform and an EMIS. In order to determine the environmental impact of the pre-chain either suppliers provide a web service (see above) or the necessary data is estimated using LCA databases or environmental IO-tools.

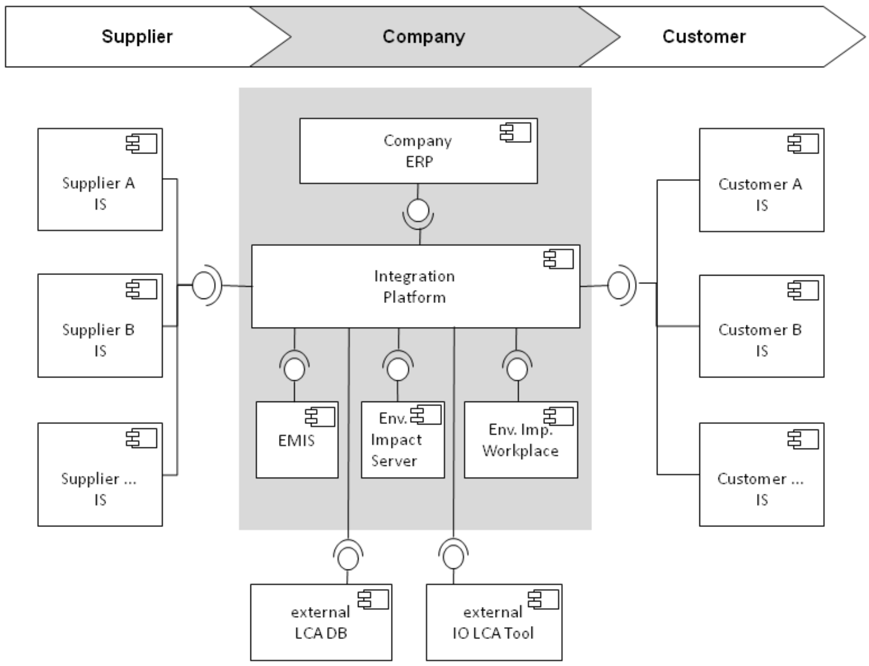

Figure 2: Systems involved in the process (highlighted areas refer to internal systems of the company)

To guarantee that the environmental impact data is reproducible, a so called Environmental Impact Server is used to store all environmental impacts that have been requested before. The company IS is completed by a user frontend we call Environmental Impact Workplace that supports the manual editing of missing environmental impact data. In addition, it enables a manual data checks. Fig. 2 shows the company internal and external systems and their interfaces to each other:

- Customer IS belongs to a customer that would like to have the environmental impact of products/services bought at the company documented. Depending on whether the customer inquires about the environmental impact of a product that has already been made or the anticipated environmental impact of a planned purchase, the interface expects either the delivery note item or an article number as an input parameter. The resulting vector encompasses the environmental impact categories at midpoint level.

- Supplier IS: Ideally the supplier would offer a web service similar to the one offered by the company (identical interface) that would allow to request information about the environmental impact. In this case the company can enquire about the environmental impact using the delivery note of the supplier. If such a service is not available the estimates must be made using LCA databases or IO-LCA tools or manually.

- Company ERP: This system knows the transaction data of the procurement, production and sales processes of the company. It provides a service that makes available for every product sold the concrete production processes and all of the products used in production. For the manufactured products the supplier and the external delivery note number from procurement are specified as input. The output includes supplies bills of material and work plans for the production processes. In practice it is often difficult to determine which procurement item material has been used in production. In such cases the company must make consistent assumptions about material usage.

- EMIS: The environmental management information system employed by the company knows the environmental impact of the production processes of the company. The EMIS provides a service that determines the environmental impact of the production processes involved in a particular production order. In addition, the environmental impact of the company that cannot be allocated to a particular production process has to be accounted for.

- LCA DB: These external databases should allow the environmental impact of a product to be determined using estimates based on its product classification. National and international LCA databases in use today (e.g. [FJA+05]) are not able to provide this information as they are designed to provide complete LCA studies, that cannot partially be used for automated processing. The construction of such a database remains a task for the LCA community.

- IP: The integration platform provides the web service which gives information about the product environmental impact and coordinates the process-oriented communication with internal and external systems.

- IO LCA tool: Using price and sector assignment of the product, as well as input-output data of the economy and the environmental interventions in particular economic sectors this system estimates the environmental impact of individual products (e.g. [SK05, WMBW06]).

- Environmental impact server: The task of the environmental impact server consists in documenting all environmental impacts and their corresponding calculation steps (intermediate results). It serves as a buffer for environmental impacts that have already been calculated. In addition it is able to provide details of all environmental impact information that has been communicated externally and so ensure that this information can be confirmed at a later date.

- Environmental impact workplace: This is a workflow management system that is able to rework in certain situations environmental impact statements that have been communicated externally. This would be then necessary if the environmental impact of the pre-chain cannot be determined using product LCA databases or IO LCA tools.

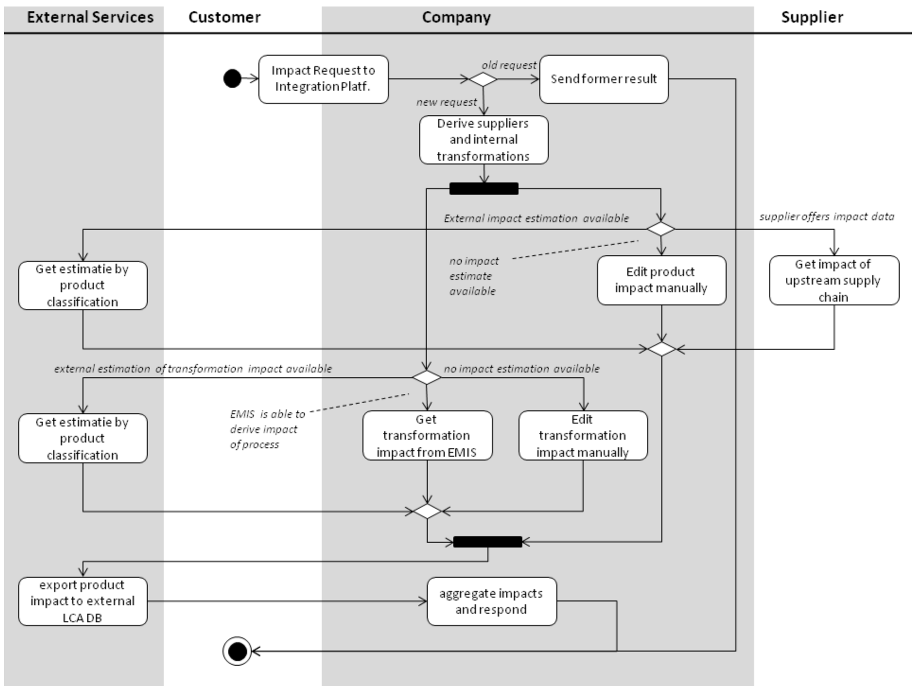

Figure 3: Activity diagram showing the process of determining the environmental impact

Based on these systems the following process (see fig. 3) can be implemented to determine environmental impact. A customer requests environmental impact information about a product he has purchased. The enquiry is sent to a service that the company's integration platform (IP) provides. The customer specifies the procurement order item associated with the product. The integration platform first sends an enquiry to the environmental impact server about whether an enquiry about this particular delivery note item has already been processed and if that is the case then receives the requested environmental impact information. In this case the IP delivers the result to the customer and the process is closed.

If however it is a new enquiry then the IP determines which concrete procurement and production processes were relevant to the production of the product. A corresponding request specifying the delivery note is sent to the company ERP. As response the IP receives a list of the procurement data (supplier, date, product, amount, price) and a list of the production documents (bill of material, work plans, specific work centers). Using the production documents the IP can now determine the part of environmental impact that the company has caused itself. This involves activating a service of the internal EMIS that calculates the environmental impact from the work plans and bills of material from the production documents. From the details about the procurement items the IP now determines the environmental impact of the pre-chain. This involves first checking whether the supplier of a particular procurement item has made the necessary data available through a service. If this is the case a request concerning the environmental impact is made. If the supplier does not offer such a service a request is sent to one or more external LCA databases. For those procurement items that also do not have results from an external LCA databases, an request is sent to an external IO-LCA tool. If this request is not met with a response then the item is entered for manual processing in the environmental impact workplace. As soon as all data are available the IP reports back to the customer the total environmental impact of the product based on all the relevant procurement items and production processes.

4 Conclusion and future work

In this paper we have presented a first draft of a reference architecture that enables product environmental impact information to be automatically calculated for customer use. The service-oriented architecture is characterised in that:

- interventions in existing operative applications (e.g. ERP systems) is held to a minimum
- calculations of environmental impact of the pre-chain involve only making enquiries to direct suppliers.
- existing external data on environmental impact of materials is used to as great an extent as possible in the calculation
- an initial entry of data on environmental impact at the level of individual company processes and materials is unnecessary. Instead this can be done gradually in response to customer enquiries.

As part of a project at the Leuphana University Lüneburg a prototype is being developed in order to evaluate the feasibility of this approach. We are currently developing the interfaces and processes using the SAP Exchange Infrastructure as the integration platform.

As a next step we will be investigating how the environmental impact information being made available can be used to enhance processes in the ERP systems the EMIS are embedded in: as a basis for operative decision-making and as a part of strategic planning and corporate risk management.

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