

Integration of Environmental Management into Production Organization and Information Systems

Ralf Pillep, Richard Schieferdecker

Research Institute for Operations Management at Aachen University of Technology (FIR)

Pontdriesch 14/16, D-52062 Aachen, Germany

{pi|sd}@fir.rwth-aachen.de

Key words: environmental management, Enterprise Resource Planning

Abstract: The issue of environmental management will be successfully pursued within production companies only if three conditions are met: complete integration into relevant business processes, minimized additional organizational effort and benefits in terms of costs. Additional efforts must be kept as small as possible in organizational and financial regard. Decisive factors are the integration into existing IT systems, e.g. Enterprise Resource Planning (ERP) systems, and better support for the employees. A reference model has been developed by FIR (Research Institute for Operations Management). This model is based on the conventional MRP II concept. The environment-oriented reference model does not depend on specific developments and boundary conditions. It can be used for the organizational design of environment-related order processing in the enterprise and as a basis for the expansion of existing operational information systems.

1. STARTING SITUATION

For many production companies, environmental management is a task which is required by legal obligations. For this reason, it is important to fulfill these tasks efficiently. Beyond the legal requirements to be met, the aspect of costs caused by environmental control plays a crucial role. In this regard, the operative support by an operational IT systems has an important impact. The concept of an integrated environmental management within the steps of order processing appears to have the largest potential.

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: [10.1007/978-0-387-35503-0_29](https://doi.org/10.1007/978-0-387-35503-0_29)

Many IT systems for operational environmental management, e.g. administration, hazardous waste handling instructions, are designed as stand-alone solutions. Enterprises, therefore, often use many different systems to handle the environmental tasks. The existing ERP systems do not adequately take environment-related aspects within their planning logic into consideration.

For these reasons, the research project OPUS "Organizational Models and Information Systems for Production Integrated Environmental Protection OPUS"⁴, promoted by the German Federal Ministry of Education and Research, pursues an integrated approach. OPUS is a comprehensive and continuous concept for environment-oriented order processing (Fig. 1) (Bullinger 1997, Aghte 1998).

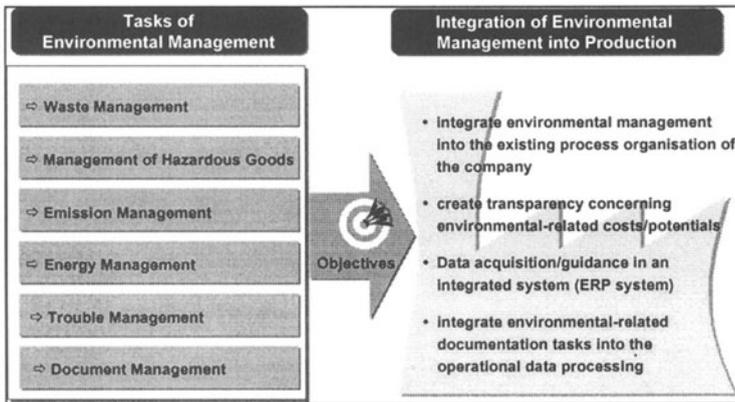


Figure 1. Requirements of environmental management in production companies

The next section will describe the basics for the integration of the environmental management into order processing. This will be followed by an explanation of the practical implementation of the designed concept.

⁴ OPUS is a network project at the Institute for Ergonomics und Technology Management (IAT), University of Stuttgart, Research Institute for Operations Management at Aachen University of Technology, Fraunhofer-Institute IPT Productionstechnology, Aachen, Chair of Business Administration, Production Management and Industrial Organization, University of Bremen and Chair for Production Engineering Laboratory for Machine Tools and Production Engineering (WZL), Aachen University of Technology (BMBF, promoting identifier 01 RK 9602).

2. ENVIRONMENTAL ERP-REFERENCE MODEL

The basic strategy of the designed methodology requires additional planning subjects within the ERP planning concept. Wastes, emissions and energies have to be considered in the planning processes.

The integration of environment-related aspects into production planning and control is based on an extension of the organizational view. Having defined the necessary environmental tasks, they have to be integrated into the business processes. The information view can be derived from the business processes with the necessary functions and additional data.

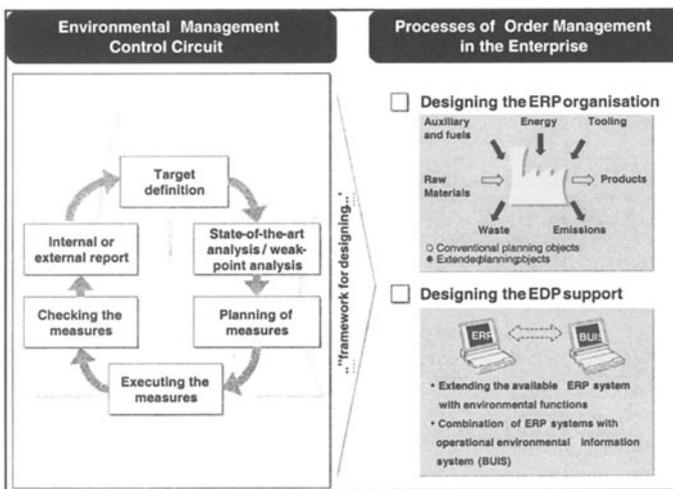


Figure 2. Implementation Procedure

For efficient support of production integrated environmental control, it is important that all environment-related information is integrated into the databases used for production planning (Fig. 2).

1.1 Environment-oriented Task Model

The task view of the model represents necessary tasks of production planning and control in an aggregated manner. Within the framework of their environment-oriented expansion, the existing partial tasks are in part carried out in an extended context and/or with additional planning and control objects. The goal of the extension of the ERP is to take into regard the environment-oriented aspects within the planning process.

For the concept of an environment-oriented ERP, the task complexes of material flow management, energy/emission management and environmental controlling are considered. All material flows in production should be

planned and controlled comprehensively by the material flow management. This is the basis for product and material recycling which is required by law (Rautenstrauch 1997). Restrictions due to environmental legislation and regulations affect the manufacturing process. Referring to energy management, the environment-oriented ERP tasks include the planning of the shared use of central energy sources, the planning of the emission amounts as well as of the residual heat use. Within the framework of environmental controlling, the environment-related ERP must assure availability of data for the operational material and energy management on different planning stages. By an extension of the production program as well as the procurement and disposal program, a continuous supply of operational environmental controlling data will be established.

In the following, the designed environment oriented task complexes of the ERP will be described in more detail (Fig. 3).

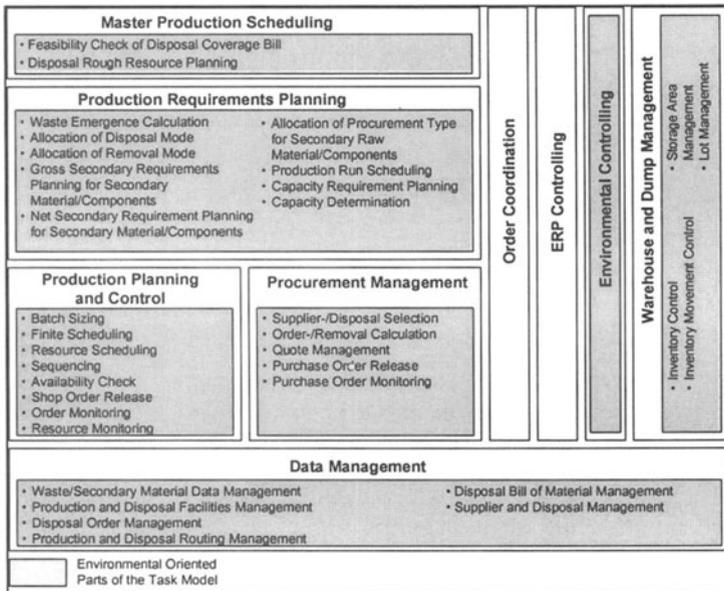


Figure 3. Task Model

The long-term, forecasting based planning of demands and supplies regarding material and capacities also includes secondary, i. e. recycled, materials. Additionally, these planning steps have to be performed for disposal (recycling and removal of material) activities.

Rough capacity planning for product recycling estimates the required recycling capacities for returned products after use. *Rough disposal resource planning* determines the amounts of material which are planned for internal

recycling or external disposal. The demand for secondary raw materials existing in production as well as the capacity situation of the recycling resources are balanced with this material supply.

The shared usage of central energy sources includes an *extended rough resource planning* supplemented by energy and emission aspects (inter-company, if necessary) and determines rough quantity-related profiles concerning the emissions resulting from production.

Environment-related production requirements planning plans material and capacities with a middle to short term horizon based on actual customer orders. The objective is to determine and balance the supplies and demands of new and secondary (recycled) materials as well as production and recycling capacities. Having calculated material requirements for production, the mode of procurement (use of secondary components and/or raw materials in production) as well as the amount of resulting waste has to be determined.

As a next step, the rough scheduling of the disposal tasks has to be executed with regard to deadlines and on a quantity basis. To fulfill the secondary raw material and/or component requirements, the enterprise internal disposal is synchronized with production. The capacity material requirement planning regards energy and emission aspects as extended additional conditions.

The objective of environment related extended production planning and control is the finite scheduling and control of all production, recycling and removal processes carried out enterprise-wide. This synchronized planning results in a far higher complexity because of the high number of orders interdependent from each other. The subject of environment oriented procurement management is the purchase of secondary raw materials and/or components as well as the external removal of waste. The external removal is regarded similarly to a purchase of a disposal service.

Within the framework of inventory and storage management, transactions to and from storages and dumps have to be registered, considering reservations, required safety and/or acceptable maximum stocks. For secondary raw materials and components, and waste, a stock location and storage area administration is necessary. Restrictions with regard to possible incompatibility or legal requirements must be considered.

The objective of environment-oriented data management is to register, process and provide environmentally relevant information. This includes controlling data as well as disposal and energy/emission specific data. New or partially extended data records, e.g. disposal routings and bill of materials, material compatibility informations, must be handled by an environment-oriented ERP system.

The main task of environmental controlling is to collect, provide and evaluate data for the material and energy accounting in the company. With the balance results, the planning processes can be revised when appropriate.

2.2 Environment-Oriented Expansion of Process Model

Process models describe the chronological and logical connections of tasks (Much 1995). The existing Aachen process model was extended in order to include all necessary activities for environmental management. These environment related extensions will be explained using the example of *production requirements planning* and *external disposal management*.

Input for production requirements planning is formed by the production program. The environment-related expansions concern the material and capacity planning as well as the gathering of data for environmental controlling. An explosion of bills determines the rough requirements on the level of secondary raw materials and components. After the inventory balance the corresponding net secondary requirement is determined (this is not related exclusively to secondary (recycling) material but sums up the demand for units, parts and raw materials). After determining the mode of procurement the net secondary requirements can be obtained by purchasing of secondary raw materials and/or components or by in-house recycling.

The amount of waste resulting from actual production are determined from the procurement program proposal, to which a mode of disposal (circulation process/ recycling, internal removal or external disposal) is assigned. It is checked, whether the amounts of waste identified for the circulation process and the old product components can cover the net secondary requirements of secondary raw materials and/or components. In the case of over coverage, the method of procurement is determined again with the aim to decrease the percentage of secondary material. In the case of under coverage a higher external purchase is necessary, and the mode of procurement must be redetermined. If the requirement is covered, a disposal program proposition is released. The *production run scheduling* as well as the *capacity requirement planning and determination* assure the balancing of manufacturing and disposal capacities with regard to deadlines and capacities. If there are resulting capacity restrictions for disposal, it may be necessary to carry out the mode of disposal determination as well as the subsequent steps again.

The *disposal planning and control* corresponds to the purchase of an external service. Therefore, its execution is largely similar to the procurement management. However, there are a number of major differences, e.g. the flow of materials is going in the opposite direction as purchasing (which leads to another logic of determination of demands) and

the keeping of deadlines is not as important. There are other decision parameters and limiting conditions for the execution of the process steps, e.g. the conformity with environmental legal regulations. Information for waste balance sheets is made directly available via the disposal tasks from environmental controlling. Consequently, the reception of the disposal planning and control as a new, additional component into the total process model seems reasonable (Fig. 4).

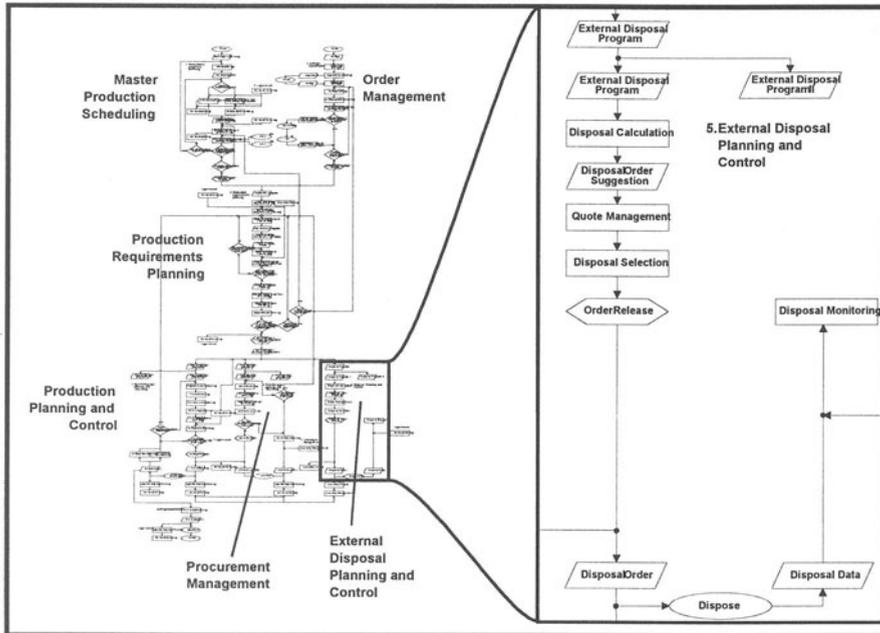


Figure 4. Process Model (Example)

These two examples should demonstrate the extension of individual process steps.

2.3 The extension of the function and data model

The function and data model views were developed in order to describe and systematize the required additional ERP system functionalities and data. The designed environment-related system functions must support the organizational tasks of material flow management, environmental controlling as well as energy and emission management. The required software functions are derived from the designed environment-relevant components of the process model. The design of these extensions results

from a description of the ERP functions required by every extended or additional step of the process model as well as their input and output data.

This procedure will be demonstrated using an example from *production requirement planning*. The *calculation of disposal lot sizes* is a completely new process step which is necessary to determine disposal lots and/or demand for energy and emissions from the production program. This information is required for an environment optimized scheduling and capacity planning of the production and disposal facilities. Forecasting calculations are largely done in a deterministic way, i.e. on the basis of ERP data in routings and bills of material. If accumulating these data requires too much effort, data from past planning periods should be used.

The ERP data model is extended by modification of existing or addition of new data structures. The goal is to support the environment-related expansion of existing standard ERP systems conceptually and with minimal effort.

The procedure of the data extension is explained using the example of the *resources master data*. The already existing machine related data are completed by environment relevant data (e.g. run time specific energy consumption or waste per set-up operation). These data can be used in the environment related ERP both for the preparation of extended routings or calculations and operations.

3. IMPLEMENTATION OF THE CONCEPT

The implementation approaches developed in OPUS are applied in the company for the purpose of waste management and the environment-oriented balancing. A further essential aspect of the project is the organization of the industry-wide cooperation of lubricant management with a subcontractor.

3.1 Procedure

The first step of the investigation was the analysis of the environment-relevant organizational processes and all relevant material flows. Based on the example of a flexible manufacturing center in the section of mechanical manufacturing — consisting of three CNC processing machines, tool and palette transportation control as well as a control computer — material flows and organizational processes were analyzed (Fig. 5). The materials were classified with regard to their environmental relevancy. It is important for planning whether the materials can be assigned to an order or appear periodically. The quantitative recording of the material flows permits an allocation for purchasing and disposal costs. The documentation of the

organizational processes combined with the material flow links these to order processing.

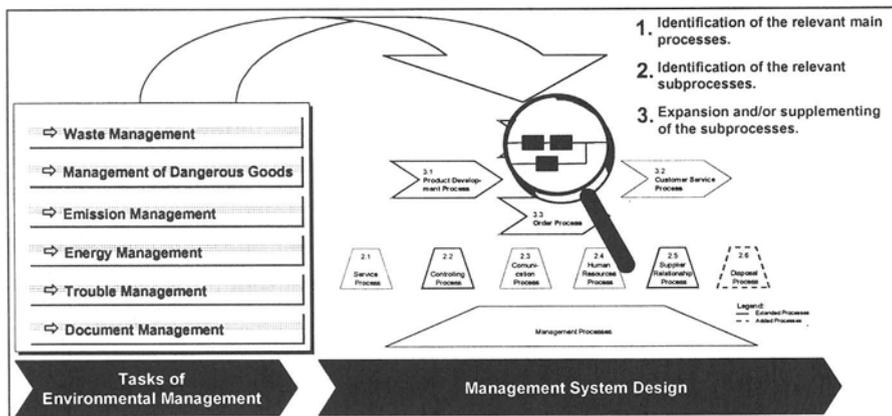


Figure 5. Implementation of organizational expansions

A complete documentation of all relevant material flows and organizational processes is generated by transferring analysis results and conception from the analyzed processing station to all production and assembly processes.

3.2 Extension of the operational information system

Nearly all production relevant data is handled by the implemented ERP system. However, the ERP system must be extended in some areas in order to make the operational waste management and the environment-relevant material balancing as simple as possible. These expansions mainly deal with the tasks of *material flow management* and *environmental controlling*.

For the time being, the implemented prototype is supposed to handle tasks related to lubricant management and wastes. Therefore, the ERP system is linked to a Lubricant Management System.

All environment-oriented activities in the ERP system are based on the extension of the master data management.

The management of environment-relevant materials requires additional environment-relevant features besides the usually existing material master data, e. g.

- hazardous material,
- hazardous goods,
- a safety data sheet has to be available,
- the waste identifier,
- the water hazard classification,

- the maximum inventory quantity (safety-related) or
- necessary features for the inventory of hazardous substances.

For waste, comparable master data, extended by information about authorized waste disposal companies and the necessary documentation must be maintained.

Master data for waste disposal companies are usually the same as for suppliers. Important information are which waste disposal company is authorized to dispose of which waste, and the disposal authorization period.

If a safety data sheet is required but not available, orders for environment-relevant material are not allowed. The maximum inventory quantity must be checked for dangerous materials at incoming goods transactions (safety-relevant).

When outgoing transactions of environment-relevant material occur the responsible cost center is charged. The following data will be transferred to the Lubricant Management System (LMS):

- material
- quantity
- cost center

Further data handling (e. g. register usage data) of the lubricants is managed by the LMS. If waste master data are transferred as well, used lubricants as well as any other waste can be registered.

All registered waste data are consolidated for each responsible cost center and transferred back to the ERP system. Each responsible cost center is charged with the most recently determined waste disposal cost. The accurate disposal costs can be determined only after the disposal.

If the inventory control for wastes results exceeds the maximum stock, disposal order suggestions are generated, from which disposal orders can be generated by the waste representative. The relevant data for disposal order as well as the data origin is shown in Fig 6.

After the waste disposal company has picked up the waste, an outgoing transaction in the ERP system results. A disposal monitoring systems checks whether the date and the documentation obligations are met. Different types of evaluation reports can be generated from the existing environment-relevant data in the ERP system. All disposal orders are consolidated into a waste balance as required by the environmental protection authority. A complete material balance can be generated by adding the standard as well as the environment-related orders. German enterprises using or manufacturing hazardous materials are required to manage an inventory of hazardous substances. Based on the environment-relevant material information (master data) in connection with the responsible cost center transactions this inventory can be generated. Both for the cost centres as well

as for individual waste categories cost analyses based on the disposal costs can be determined.

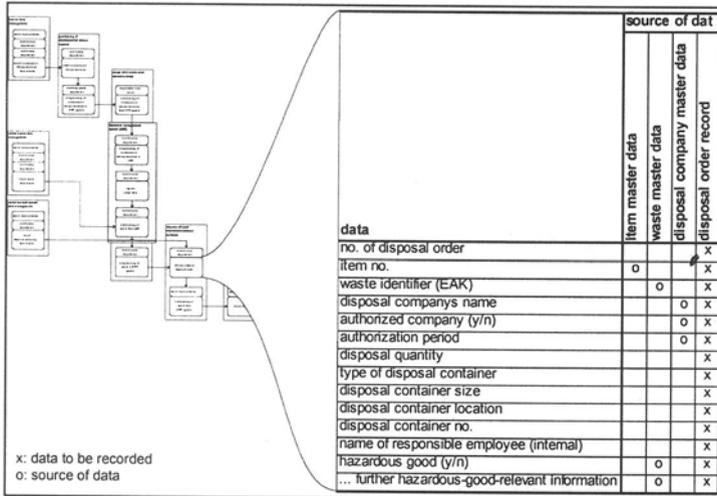


Figure 6. Data model for lubricant management process (example)

4. OUTLOOK

Experiences from the practical implementation have shown that through the basic concept of an integrated environmental management in production organization and information systems ecological and economical potentials can be accessed. Though, the initial effort can not be regarded as negligible and the organizational embedding in the form of an continuous improvement cycle is necessary. The developed approach of an integrated support through an "environmentally oriented" ERP system has proven to be feasible, due to similar logical processes in production and disposal planning and control. Therefore, the developed concept does represent a contribution for a sustainable production company.

5. REFERENCES

- Bullinger, H.-J. (Hrsg.): Anforderungen und Methoden für eine umweltorientierte Auftragsabwicklung. Projektbericht, Universität-Stuttgart, Germany 1997
- Agthe, I., Pillep, R., Schieferdecker, R.: Standard-PPS — umweltorientiert erweitert. In: PPS-Management, 3(1998)2, Berlin, Germany
- Rautenstrauch, C.: Fachkonzept für ein integriertes Produktions-, Recyclingplanungs- und steuerungs (PRPS)-System. Berlin, Germany 1997
- Much, D., Nicolai, H.: PPS-Lexikon. Berlin, Germany 1995