Chapter XXVI

Foundations and Applications of Computer Based Material Flow Networks for Environmental Management

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INTRODUCTION

This chapter describes the foundations of Material Flow Networks for environmental management and gives an overview about their application fields. Material Flow Networks describe the flow of materials and energy within a defined system. The representation and evaluation of these material flows - especially when these flows have an impact on our environment and are caused by human business activities - has become one of the most important tasks of the so-called environmental management. The more familiar we become with the material and energy flows, the more we come to understand the relationship between human activities and our natural environment.

The kind of techniques and tools required for material and energy flow analysis focuses on understanding the underlying material and energy transformations and the environmental impact of the resulting material and energy flows. Given the above, a possible definition of material and energy flow analysis is the process of collecting material and energy flow data and of computing derived values from the collection of data. The resulting material and energy flow model is a representation of the underlying system. The model must allow the user to evaluate different aspects of a system (see also, Schmidt, 1997): In input/output balances of companies, plants or production processes within the system refers to a site-specific view and a certain period of time, whereas in a life cycle assessment (LCA) a product or service is the item of interest, which usually is far beyond the temporal and spatial dimension of a common input/output balance. In fact, the same system is modelled in both cases, but interpreted with regard to different perspectives and boundaries.

The outstanding feature of the Material Flow Network approach is that it combines these two aspects in a seamless way. The foundations of Material Flow Networks are explained in the first part of the chapter. As a result Material Flow Networks may be considered as frameworks for submodels, which describe material and energy transformations. In the second part of this chapter we provide two examples where we combine the Material Flow Network approach with methods from completely different fields of computer science (optimisation and discrete event simulation) to specify such transformations. This part can moreover be interpreted as an outlook on the future since it offers a method on how the Material Flow Network approach can be used as a basis for a component-oriented Industrial Environmental Information System.

FUNDAMENTALS OF MATERIAL FLOW NETWORKS

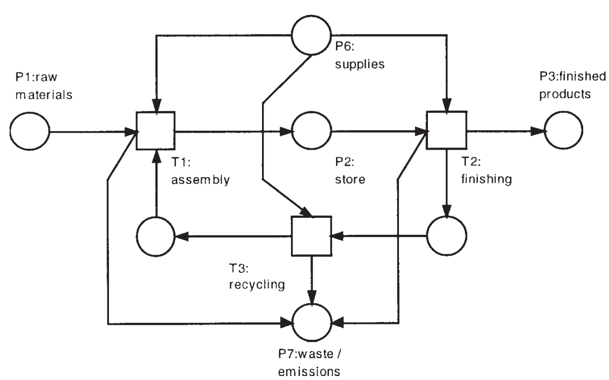
Material flow management is based on the idea of modelling networks of material and energy flows. The method used in the modelling process is called the Material Flow Network approach. Material Flow Networks have their origins in various disciplines. The most important are the Petri-Net theory, double-entry bookkeeping and cost accounting. The Petri-Net approach (Petri, 1962; Reisig, 1987) is used to describe the structure of a Material Flow Network. These consist of three elements: transitions, places and arrows. Mathematically speaking the structure of a Petri Net is a 3-tupel, $N=(T,S,F)$, $F\prod (S\infty T\approx T\infty S)$ with T being a set of transitions, S a set of places and F a set of arrows between transitions and places. Note, that there are neither direct connections between places nor direct connections between transitions.

In Material Flow Networks the transitions, represented in diagrams by squares, stand for the location of material and energy transformations. Transitions play a vital role in Material Flow Networks, because material and energy transformations are the source of material and energy flows.

Another defining characteristic of Material Flow Networks is the concept of places. Places separate different transitions. This allows a distinct analysis of every transition. Circles are used in diagrams to represent places.

Arrows show the paths of material and energy flows between transitions and places. The diagram in Figure 1 illustrates a Material Flow Network with several transitions and places connected by arrows.

Figure 1: Structure of a simple Material Flow Network



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