Evaluation of interdependent plans

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Abstract

Objective of this paper is to present a procedure to evaluate a company's planning scenarios. At first, we will provide a procedure to improve the transparency of an enterprise-planning scenario. The procedure describes the material flow of a company and the information flow between different planning units. Both flows will be combined to estimate the strength of interdependency between planning units. For different scenarios, we will then derive an adequate coordination mechanism. Finally, we will provide a simulation model, which supports an enterprise to quantify the impact on the goal attainment of different coordination mechanisms, to find an adequate level of coordination.

Keywords

Enterprise Resource Planning, Coordination, Planning, Interdependence.

INTRODUCTION

The main challenge of most industrial enterprises is to cope with fast changing customer requirements, short delivery times and competition due to market prices. To be able to run an enterprise within this environment, companies have to align relevant business processes to the customer requirements and monitor them very closely (Kidd 1994). Order processing includes sales process, requirements calculation, purchasing of raw material, manufacturing, invoice as well as shipment of finished goods. These processes form a very complex network, because many different persons or decision makers handle different tasks, and they all interact (Brown 2001). These interactions i.e. interdependencies emerge from simultaneous use of resources through different tasks (Crowston 2002). To guarantee an efficient process sequence, enterprises have to coordinate all processes and tasks. In this paper we will only deal with planning activities as tasks and resources with finite availability. Planning tasks are most important, because decisions for future activities will be determined by the planning decisions.

Coordination means communication or exchange of information between different planning activities (Becker *et al.* 2001). Considering different detail levels of planning tasks, we can distinguish two kinds of coordination: vertical (in general Top-Down-) coordination is applied, if rough information is used as key data for a

H. S. Jagdev et al. (eds.), *Collaborative Systems for Production Management*

more detailed plan e.g. customer order planning communicates promised date to requirements planning. Schneeweiss (2000) discussed different kinds of vertical coordination aspects. He used top - and base levels to describe a general hierarchical system including antagonistic behaviour. Planners will exchange information horizontally, if several work centres or different plants use the same resources. Coordination can also involve an integrated decision-making taking into account that all partners are affected by the decision (Malone & Crowston 1994).

The environment of a company is very dynamic: on one side, there are external changes of customer requirements or changes of suppliers. On the other side, there are many internal events e.g. break down of a work centre or shortage of material, which drive the degree of dynamics. In many plants, the impact of internal drivers as well as external drivers is very strong (English and Taylor 1993; Grfrerer and Zäpfel 1995). The dynamics within production environment leads to a divergence of plan and reality. To avoid divergence, the planner can rearrange the plan whenever it diverges from reality. After that, he has to communicate relevant changes to other planners according to dependencies. But if a planer rearranges a plan too often, planning nervousness will occur and concerned persons will not take a new plan seriously anymore. Neither persons who have to execute a plan nor different planers who have to take changes into account will then use the new plan (Yellig & Mackulak 1997).

Furthermore, if the information to generate a plan is not realistic, the attainment of customer oriented objectives like due date reliability or service and delivery reliability are jeopardised. Supplementary, internal objectives like high work centre utilisation or small inventory are not attainable (Figure 1).

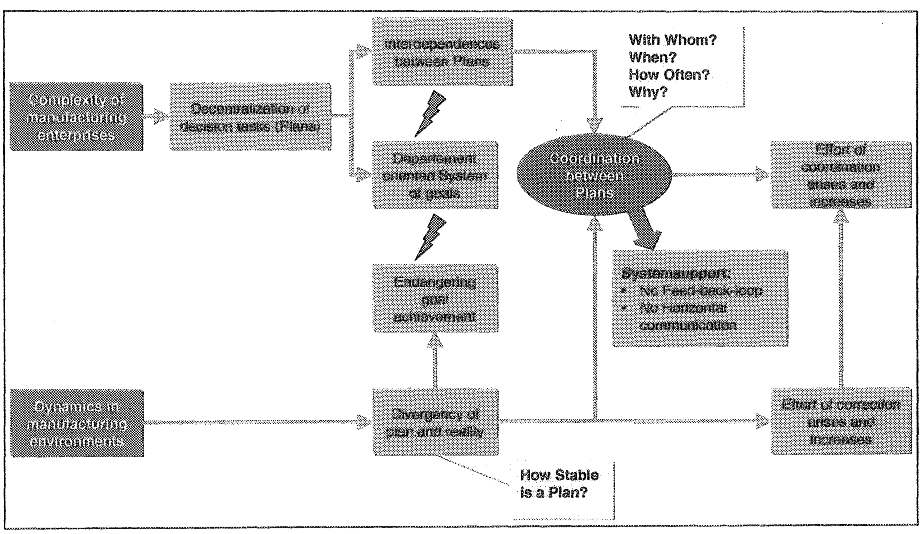

Figure 1 - Challenges for industrial enterprises

Complexity of order processing and dynamic of production environment requires an efficient coordination of planers in a company. About 75 % of industrial enterprises use ERP-/MRP-Systems to support order processing and to coordinate corresponding actors (PAC 2000; Techconsult 2002). Normally, these systems use algorithms for a Top-Down coordination, but mechanisms for a horizontal exchange of info rmation are not provided. Especially companies with different plants in a supplier-customer-relation have to exchange information in a structured manner. Additionally, only a few ERP-/MRP-Systems provide functions for Bottom-Up communication to produce a closed control loop. Hence, new systems which can evaluate the coordination concept for the complete system need to be developed and conceptualised (Treutlein *et al.* 2000).

The basic challenge of many enterprises is to identify those planers, who should exchange information or better be coordinated by another partner. To enable such coordination, a well-defined method and mechanism to determine the intensity of coordination and to exchange corresponding information is missing. A company has to find an optimum between benefit and cost of coordination. On one side, coordination means effort. Expenses emerge from collecting relevant information, calculating a plan and communicating to other planers about results. On the other side, autonomy costs are emerging, because of inadequate information as basis for planning decisions and use of inefficient information management methods (Frese 2000). We will consider autonomy costs as opposite of the attainment of company goals. High autonomy costs therefore denote only little attainment of company objectives and vice versa. The challenge, which has to be solved, is to find an adequate relation between coordination costs and autonomy costs and an efficient way to estimate these costs. Total cost is the sum of coordination and autonomy cost, which will be used as a comparison for efficiency of coordination measures.

OBJECTIVES

Objective of this paper is to present a procedure for the evaluation of company planning scenarios. At first, a company will be enabled to describe the whole logistical planning scenario, from sales planning to shop floor control and shipment, to gain a high level of transparency. After that, the company can evaluate planning scenarios to derive some measures to improve coordination efficiency (Figure 2). In evaluating the interdependence of plans, we can use a graph for benchmarking purpose, to see what is the status of the organization in sharing information, and what further improvements are feasible.

To describe and to evaluate planning scenarios, we have to develop different models, considering task-resource-interactions (N.N. 2002). An efficient approach will be realized by describing the models with parameters. Additionally, they must be hierarchical to consider different levels of planning tasks in a company. At first, we will present a generalized model of planning activities, which describes our understanding of planning.

The origin of interdependencies is the flow of material through capacities and planning activities determine this flow. Planning activities correspond to different levels, so a hierarchical model of the production structure will be provided. This model will describe the flow of material as well as the concerning strength of interdependencies. To fulfil a plan information is required and information is generated as a guideline for other planning units. Therefore, we will provide an information model. This model will be hierarchical, too and can be used to derive the flow of information and the strength of interdependency between different planning units. Ideally, there can be various planning units interacting with each other where everyone's decision affects not only their own performance. We will describe a model, which evaluates the performance of the complete system.

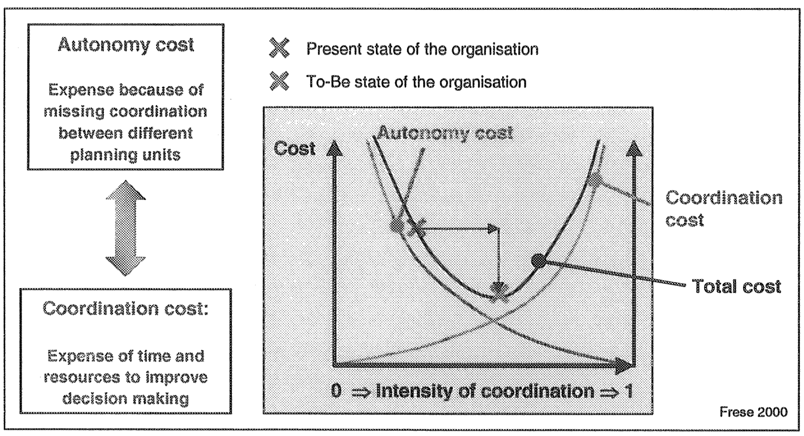

Figure 2 - Context of autonomy cost and coordination cost (Frese 2000.

The applicability of the procedure and the models will be limited to enterprises with different sites which are legally dependent. Suppliers and customers will not be taken into consideration; external suppliers are considered to be capacities. The flow of material is supposed to be directed (no job shop) and the depth of production is low. Additionally, it is assumed, that production as well as planning scenarios can be described using three different hierarchical levels.

GENERALIZED MODEL OF PLANNING TASKS

Planning is defined as structured thinking and calculating to prepare decisions for future activities (out of alternatives) to attain given objectives. The result of a planning activity is a plan in form of information for future activities. The content of a plan are orders to be executed by the group of resources planned. An order is a verbal or written request of an authorised planning unit to another planning unit to execute a precise task. Planning units then have to refine or to execute orders. Furthermore, we assume, that orders are always related to capacities. Therefore, a planning activity includes the dimensions quantity, time and capacity. These dimensions can either be variable or constant.

Quantity: In general, quantities refer to material lot size and will be taken into consideration by orders. There are different degrees of precision for quantities being referred: a quantity might be an item, a module, a product or a product group. We will also distinguish different kinds of orders e.g. customer-, stock-, and manufacturing-or assembly-order.

Time: To plan future activities a planning unit has to calculate finish time, start time and / or duration of tasks. Hereby, the specificity of these aspects depends on the planning task. Furthermore, planning horizon, planning-period and –raster and planning-advance-time correspond to time and future aspects of a plan. These parameters vary with the level of planning, e.g. the complete plant may be scheduled for the complete months, and individual shops would schedule themselves on a weekly basis. In general, a company distinguishes between three different levels of planning: long-term, mid-term and short-term.

Capacity: Performing a task, always means to allocate a quantity (order) to a capacity. The capacity can be a work centre, a supplier, a warehouse or a transport unit. Personnel will not be taken into account, because of its flexibility. The precision of the capacity within a certain planning task varies for example from a single capacity through a capacity group (department) to a whole plant. Most companies distinguish these three levels of aggregation.

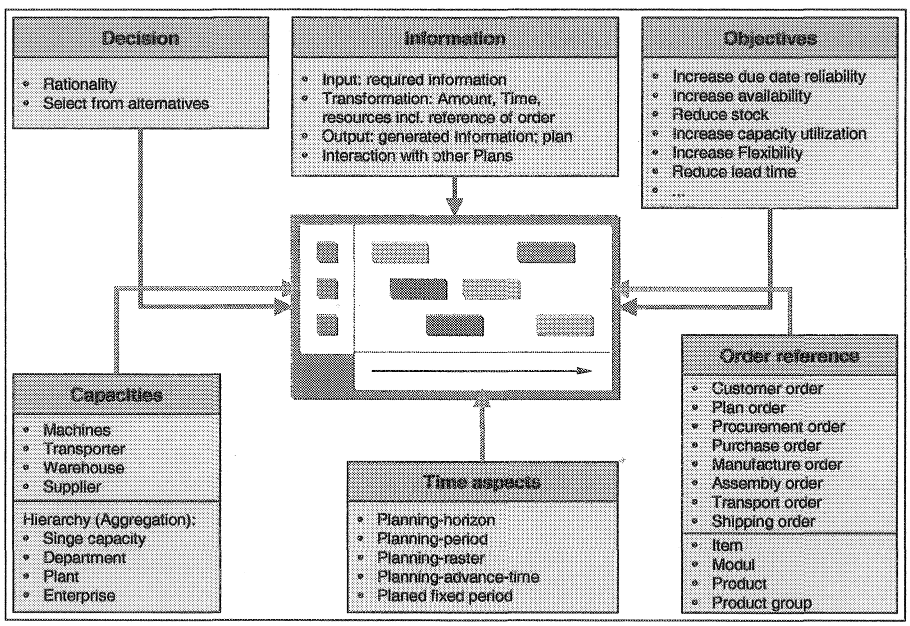

Figure 3 - Generalized model of a planning task

There are different possibilities to change a plan according to the planning dimensions. The degree of freedom to change a plan can vary from very stringent to very flexible limits. A quantitative change could be a change of lot size, an order split or an order join. Changes of time aspects could be a point of time, a duration or a customer priority. Capacity oriented changes correspond to variation of order sequence or allocation of order to another capacity.

A planning unit requires information to execute a planning task. On one side, the planner needs master data like e.g. material-, supplier-or customer-data. On the other side, the planner gets orders from other units, which contain relevant information about quantity and time aspects. Result of the planning task is a plan, which contains new and / or detailed information aspects about quantity, time and capacity of orders. Normally, input information and output information always differ within a planning task. The relevant planning tasks of a company can be identified and assigned to one of the levels (long-term, mid-term, short-term).

Another aspect to evaluate planning scenarios is the robustness of a plan. Robustness is defined as insensitivity of a plan in the light of unpredictable changes. A plan is robust, if the achievement of objectives is not affected by changes. To measure robustness, we will use the idea of a "planning-horizon-limit". We define planning-horizon-limit as the duration from the generation of a plan to the point of time, when divergence of plan and reality becomes unacceptable. In reality, a planner knows this duration according to his activities. ERP-/MRP-Systems support a top-down approach, to coordinate different planning activities of an enterprise, so this concept is more useable for horizontal coordination.

PROCEDURE

To evaluate the planning scenarios of a company, we have to provide different models. At first, the material flow will be described at the reasonably lowest level, using parameters. Based on this lowest level, the material flow related interdependency parameters will be aggregated for the different other planning levels e.g. departments or plants. Results of this study will be used on one side as filter for an efficient and reduced information flow analysis. On the other side, the results will partly achieve the interdependence strength of a planning scenario.

Second step in this procedure is to describe the flow of information between planning units. We will provide some relevant parameters, which drive the interdependence between different units. These parameters will be used to estimate the strength of interdependence between different planning units as well as of the complete planning scenario.

In a third step, we will analyse different coordination mechanisms to reduce the interdependency. Using this analysis, a company will be able to determine planning activities which have large impact on other activities and activities which will be influenced.

Model of production structure

The production structure represents the flow of material and corresponding resources. In this paper, resources are considered to have a finite capacity. The model has to fulfil the following requirements:

- Depict and describe the flow of material,
- Estimate the interdependencies within the flow and
- Represent production in a hierarchical way.

To describe the complete and relevant flow of material, corresponding capacities have to be detected. We will consider relevant suppliers, work centres, warehouses and transporters as capacity. A capacity is relevant, if it is either mentioned in a routing or if it provides production data. Suppliers and warehouses are relevant if corresponding purchase orders or stock orders exist. The flow of material, including alternative ways of production, can be described by using routings. All different flows of material determine possible interdependencies. To represent the flow, we can use square matrices (number of capacities X number of capacities). Relevant cells will be identified and marked according to the sequence of activities.

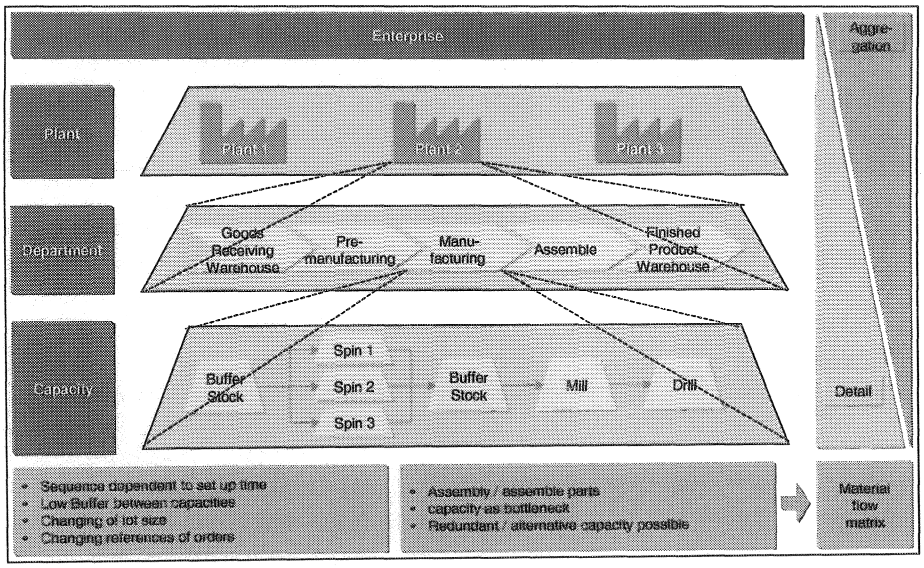

Figure 4 - Model of production structure to determine flow of material

Furthermore, we have to identify the drivers of interdependency within the flow of material, to estimate the corresponding strength (Schotten 1998). To record the drivers with reasonable effort, parameters will be used for description. Interdependencies within the flow of material will occur, if output of a capacity has impact on output of another capacity. In a first approximation, we just consider the direct impact between capacities. Bottom of Figure 4 shows revealed parameters. To estimate the strength of interdependency, the parameters have to be quantified. The values should vary between 0 and 1. The sum over all values represents the strength of interdependency. A value benefit analysis can be used to weight different parameters. The results will be transferred to the material flow matrix, where only marked cells have to be taken into account.

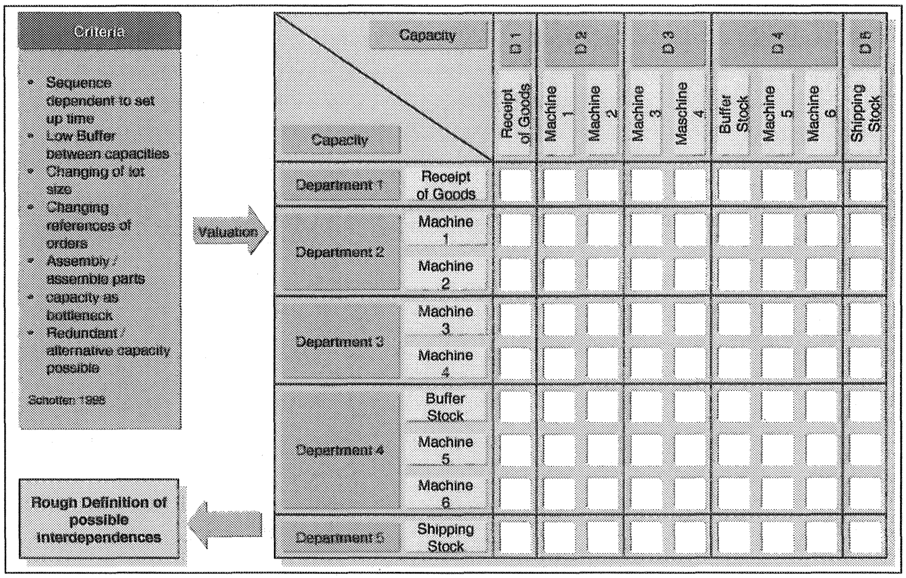

Figure 5 - Model of material flow

Benefit of this kind of representation is the estimation of interdependency strength and further refinement and filtering of activities which need to be coordinated. Furthermore, parts of the material flow can be detected, which are decoupled. This means, that interdependencies in this part can be neglected. We can define a threshold to determine a value, where different planning units – all referring to one decoupled part of the material flow – do not have to be coordinated (Figure 5).

We can also use the material flow matrix to estimate the strength of interdependencies for different aggregations of capacities (capacity group / department or plant). The different capacities in the matrix have to be assorted department wise and plant wise. The assorting process includes both, rows and columns simultaneously. The matrix then also includes groups of rows and columns. The "new" cells are containing the estimated values for interdependency strength (Figure 5). For a first approximation, a "modified sum" of these values estimates the interdependency strength between two departments or plants. The "modified sum" includes rules, which take different kind of flows (split, join, parallel etc.) into account. These values should be normalized to the highest value.

Comparable to the deepest level of aggregation, threshold values can be defined, where different planning units do not have to be coordinated. For the following procedure, the material flow matrix will be used on the one hand as a filter to reduce the effort of evaluating the information flow and on the other hand as aspects of the evaluation.

Model of information

The information model represents the flow of information and corresponding planning activities. Relevant information in this paper are variable data. Master data are considered to be available for everyone, at any time, so it does not play the role of a bottleneck resource. For the evaluation of interdependency in a planning scenario, the information model has to fulfil the following requirements:

- Guarantee an efficient way to record information,
- Describe the flow of information,
- Determine the drivers of interdependency and
- Estimate the interdependencies within the flow.

To guarantee an efficient way of recording relevant information, information according to the planning levels and to the dimensions quantity, capacity and time have to be classified. As follows, we provide a model to describe the information flow, including aspects of changes (*Figure 6*).

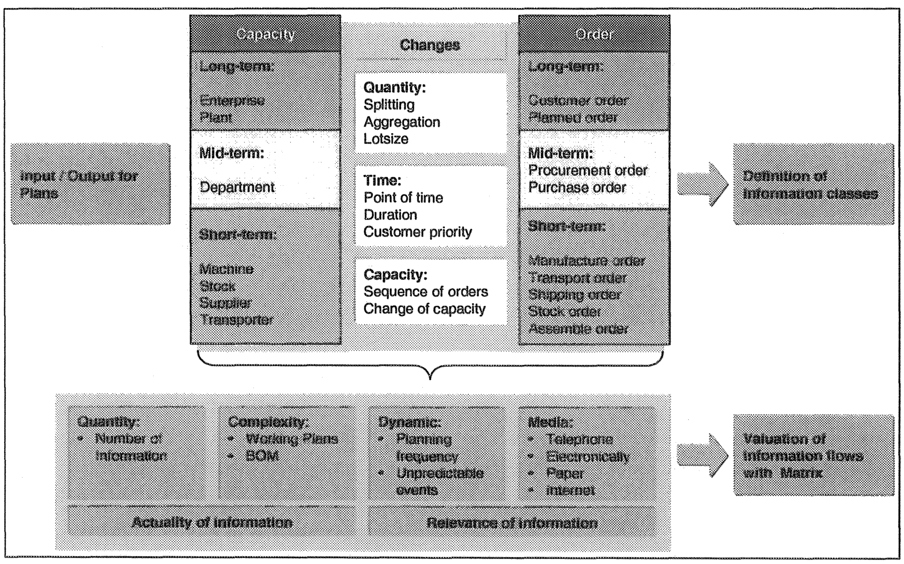

Figure 6 - Model of information classes

Different kinds of orders, used in a company, describe quantity aspects of information such as customer-, plan-, procurement-, manufacturing-, assembling-, purchase-, shipping-, transport-and stock-orders. These orders are related to a certain level of product (item, module, product or product group). The hierarchy of the orders, combined with BOM and routing reveal interaction between different planning units. A planner has different opportunities to change quantitative aspects of a plan. He also can change the lot size of an order, he can split an order or he can join different orders. These changes influence the information output of the planning unit.

Aspects of capacity refer to a single capacity, a capacity group (department), a plant or the entire enterprise. A single capacity is considered to be work centres, suppliers, transporters or warehouses. We assume, that the capacity is finite and orders are competing for availability. Personnel as the most flexible resource will not be taken into account. A planner can have different degrees of freedom to change capacity aspects. He may allocate orders to different capacities or change the order sequence of one capacities queue. These changes also have an impact on input information of other planning units.

Duration and point of time are further aspects to describe information. Both aspects vary with the degree of precision for different planning tasks. We will distinguish hour, day, week, month and year. A planner can change the order duration or the order point of time, which may affect input information of other planning units.

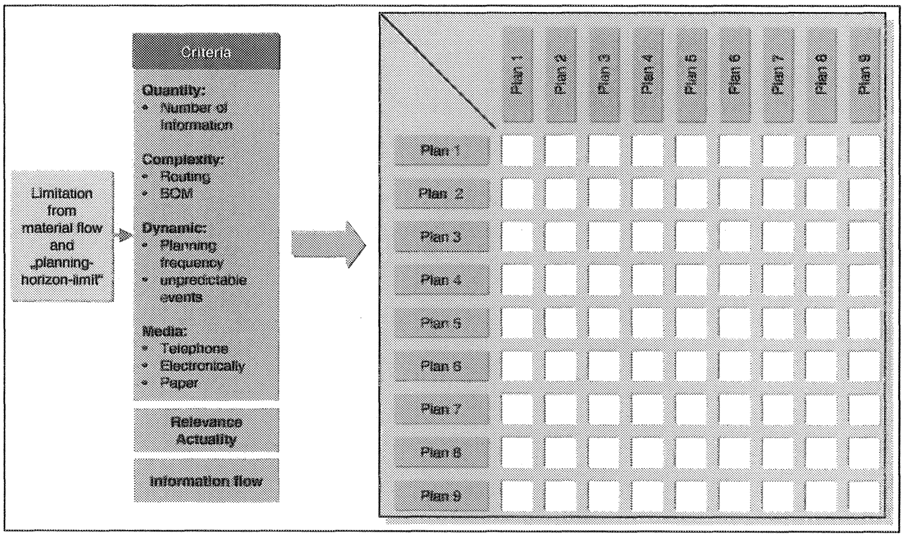

Figure 7 - Model of information flow

To provide the information flow, for every planning task, input - as well as output - information has to be recorded. We will record information according to the information classes. To derive the flow of information, we assume that if one planning unit generates information and another planning unit requires this information as input, an information flow exists. The flow of information for every planning unit can be determined by comparing all required and generated information (Österle 1995). To represent the information flow, we use square matrices, comparable to the material flow. The size of the matrices is equal to the number of planning tasks (Figure 7). The complete matrix describes the actual information flow of a company. General requirements for the information exchange can be derived.

After describing the information flow, the interdependencies between planning units have to be evaluated. We will provide two aspects for a reduction of the information flow matrix to increase the efficiency of evaluation. First aspect comes from material flow matrix. If all capacities related to two planning units are decoupled according to the material flow, the information flow between these planning activities does not have to be taken into account. This will lead to a first reduction of the information flow complexity. The second aspect to reduce the complexity is the planning-horizon-limit (Figure 8). If the planning-horizon-limit of a predecessor planning unit is shorter than the combined order lead time of both planning unit, a close coordination between these planning units would lead to a planning nervousness. To avoid planning nervousness, corresponding planning units should be decoupled. Comparably, the planning-horizon-limit of a successor planning unit should be longer than the complete order lead time of both planning units (Kath 1994).

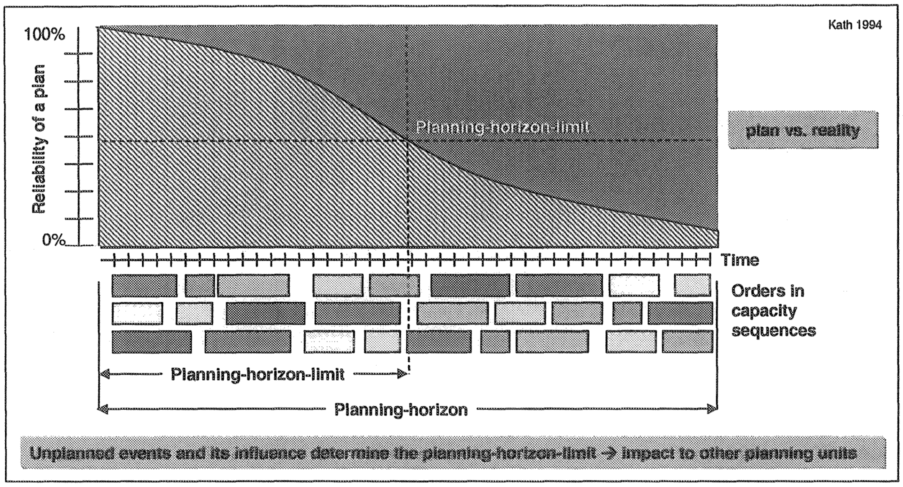

Figure 8 - Concept of planning-horizon-limit

If both rules are fulfilled, planning units should not coordinate too close. In turn, the corresponding flow of information does not have to be taken into consideration. Additional information or a higher exchange rate does not lead to an organisational improvement.

Model of coordination

To derive the drivers of interdependency, we have to identify criteria to evaluate information classes. Information classes can be described using corresponding quantity parameters. These parameters are e.g. number of orders or –positions per day or number of capacities. Additionally, complexity, changes, actuality and relevance of information have been taken into account. To determine relevance of information, rules for every planning unit have to be defined, which classify information classes to be relevant or not. Actuality of information corresponding to unpredictable events jeopardizes the planning process (English & Taylor 1993). Furthermore, the corresponding material flow interdependency factor influences the strength of interdependency between two planning units as a constant factor for a given order input.

To reduce interdependency between different planning units, different kinds of coordination exist. Many authors are dealing with coordination theory (N.N. 2002) and some developed reference models for special situations. Schneeweiss (2000) for example developed a reference model to describe hierarchical connected planning units. In his model behavioural aspects of different planners are taken into consideration. In this paper we will discuss different kinds of coordination mechanism, presuming no antagonistic conflicts.

We will distinguish three different types of coordination mechanism (Figure 9). For the easiest case, a prerequisite mechanism should be used. Here, plans and rules will be handed from one planning unit to the other. The next more detailed kind of coordination mechanism is a mutual adjustment, where one planning unit hands on orders with certain quantity and time limits to another planning unit. This planning unit will then promise a "realistic" schedule and quantity within the limit for the order. A feedback coordination mechanism means negotiations between two planning units.

Based on these three basic types, we will find rules to determine, which coordination mechanism fits which situation to improve the ratio of communication effort to goal achievement. We will derive these rules, using the analysis of material and information flow. The effort of communication which determine coordination cost are depending on the intensity of coordination. Coordination intensity varies with:

- Relevance of information,
- Additional information,
- Frequency of information exchange,
- Medium to exchange information

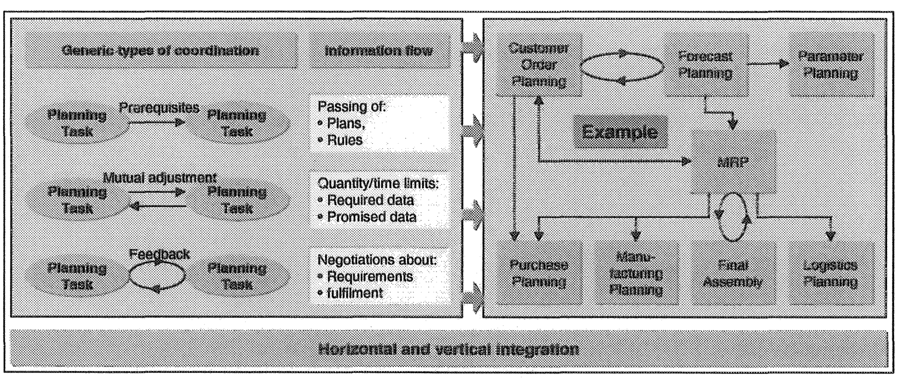

Figure 9 - Generic types of coordination.

Evaluation of planning scenarios

To evaluate a planning scenario, we have to compare the actual state of organisation to different other states. Basis for the evaluation is the information flow matrix. We assume, that we do not introduce additional information flow and the distribution of unpredictable events is considered to be constant in a company. We will provide a model to describe autonomy cost and coordination cost. A simulation model will be used to compare different states of the planning scenario.

Coordination cost as well as autonomy cost depend on the intensity of coordination (Figure 2). We will use a linear model to determine coordination cost in a first approach. The kind of coordination between two planning units can be varied as well as the intensity parameters for every information exchange between two planning units. Furthermore, the intensity can be either increased or decreased. The higher the frequency of information exchange and the more additional information is used for the planning task, the more coordination cost emerges. The medium to exchange information increases coordination cost, if the exchange is executed manually and it will decrease, if an electronic medium is used. To support the process of coordination, a workflow management system could be used. On one hand, it reduces the effort of communication. Information can be transmitted without delay to a corresponding person (Müller & Stolp 1999). On the other hand, cost of autonomy are not affected. The coordination cost for every information flow will be filled in the information flow matrix.

We assume, that an improvement of the information basis according to a planning task will lead to a decreasing of autonomy cost. Drivers for autonomy cost are actuality and relevance of information, because only actual and relevant information will guarantee a sufficient goal attainment for the entire company. Varying very many parameters and calculating corresponding results with reasonable effort, means to use a simulation tool. Furthermore, the goal attainment for every planning scenario will result from the flow of material. This means, the material flow has to be considered with a dynamic simulation tool, too.

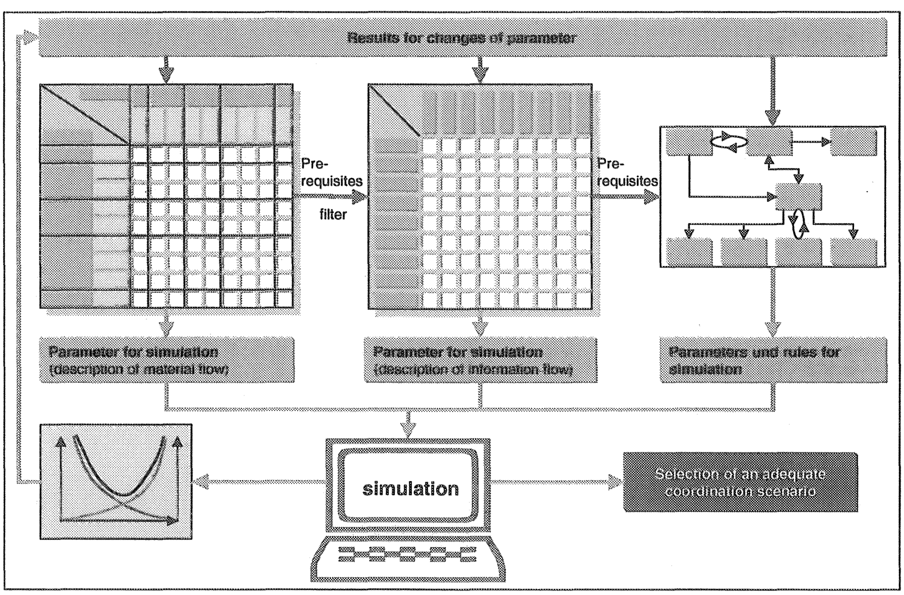

Figure 10 - Simulation of different coordination scenarios

An adequate simulation tool is able to record and represent all different calculations. The generalized planning models, the production structure model, the information model and the coordination model including the rules will be basis for the simulation tool (Figure 10). We can compare different results of a simulation by calculating the sum over all coordination cost and the sum over all autonomy cost. A company is then able to select the best simulation result and therefore the best coordination parameters. Since the models being defined and simulated are depicting the system at a macro level in terms of planning processes and information flow, the results obtained are an approximation for the system but give very useful insight for incorporating coordination. For getting further insights into the behaviour of the system, a very detailed model needs to be set up and simulated.

CONCLUSIONS

We provided a procedure to improve the transparency of a company's planning scenario and to evaluate the interdependencies between different planning units. Therefore, we presented three different models. The generalized model of planning tasks describes the relevant dimensions of planning activities. The planning-horizon-limit was introduced to indicate coordination respectively decoupling requirements of several planning units. The model is basis for a simulation model. A production structure model is used to determine interdependencies within the material flow. The results of the material flow analysis will be used to reduce the complexity information flow interdependencies. The third information model will be used to analyse the flow of information between different planning units. Information classes were introduced to reduce the effort of recording required and generated information of planning units. These models are input for a simulation model, which can be used to compare different planning scenarios. Results of a simulation form a good approximation for initial quantification of coordination effects and also the procedure is very efficient. The planning scenarios differ according to coordination intensity between planning units. Therefore, a company will be able to choose reasonable coordination intensity.

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