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## ABSTRACT

*This research focused on mid-term planning representing the tactical level of supply chain management among manufacturers. Mid-term planning is based on established frame contracts between suppliers and customers. Demand forecasts and early customer orders (from retailers or consumers) are the starting point for performing planning runs involving logistical functions such as procurement, production, storage, and distribution. The aim is to draw up consistent plans among supply chain partners.*

## INTRODUCTION

*Motivation for our Research Question*

The planning concepts that are being discussed in practice and science often face implementation obstacles. In the past, concepts focusing on centralized planning prevailed, as they were underpinned by reasoning theories, available software solutions, and consulting driven. The most prominent is the concept of the so called fourth-party logistics provider acting as a central supply chain manager of the entire network. However, this concept has never been realized among autonomous companies on the tactical planning level. A pilot project in the automotive industry (which was cancelled) had aimed at setting up centralized tactical planning comprising a three-tier network. Available software solutions do not take into account feedback mechanisms and operate under the assumption of isolated supply chains. Each OEM, for instance, maintains a separate system for supplier capacity checking. This leads to the so called multi-monitor syndrome at the supplier site. These solutions aim at providing OEMs with isolated optimization in their supply chain. Complex value networks, however, consist of many overlapping supply chains. The centralized approach is unlikely to be implemented, due to barriers such as computational complexity, resistance to disclose confidential information and to receive instructions from centralized decision making. There might be obstacles to successful business usage even in intra-enterprise planning via production plants utilizing advanced planning and scheduling systems. Nevertheless, there are some new initiatives in industry to optimize both intra- and inter-enterprise planning. They project for instance to establish multi-tier collaboration (supply chain monitoring). However, even logistics managers themselves are critical of the advantages that might be expected.

Companies are facing increased business pressure from intensifying competition and dynamic demand in the markets. This leads to growing expectations for solution capabilities of concepts like supply chain management and collaboration. Fortunately, there might be new or unexploited potentials. Advanced planning and scheduling systems offer functionality for collaborative planning which has rarely been used in practice. The software agent oriented technology is regarded to provide a revolutionary potential for solutions in the area of decentralized planning and control. Various research theories could help to take up challenges in logistics and supply chain management, e.g. theory of complexity, and theory of real options. There is a controversy going on between centralized control oriented researchers (e.g. operations research and logistics management institutes arguing with theory of constraints, hierarchical planning, or new roles of logistics service providers) and decentralized control oriented researchers (e.g. information technology, sociological, and natural science institutes making a case for agent-oriented technologies, theory of complexity, adaptive systems, or ubiquitous computing).

*Research Question and Objective*

Which degree of decentralization is appropriate for tactical planning and control in production and logistics networks? So the research objective is to determine appropriate coordination mechanisms based on theoretical solution development, survey and interview-based reasoning modeling, and to provide experimental evidence by performing planning games, and automated simulations.

## METHODOLOGY

*Theoretical Foundation based on Socio-Economical Theories*

The thesis outlines and verifies the potential of the theories for overcoming the challenges of tactical planning, e.g. theories of supply chains, of system dynamics, of strategic management, of coordination, of complex adaptive systems, as well as options-based supply contracts.

*Key Components of Description Models Involving Empirical Survey and Case Studies*

An empirical survey was conducted on the subject and it was complemented by expert interviews and a selection of business cases. The findings are consolidated into a five-level description model of cross-company network planning. On the first level, there is an analysis of normative views on concepts like trust, cost benefit sharing, and information transparency. A strategic level deals with the characteristics of frame contracts, and coordination agreements. The organizational level describes the status quo of relationship controlling, and customer dedicated teams and production lines. The process level covers both the status quo and the projected implementations of concepts such as demand and capacity management, multi-tier collaboration, allocation mechanisms, as well as other aspects like planning horizons. A level related to internal and common information systems deals with the status quo and the agenda of modules of advanced planning and scheduling systems, and web-based collaboration platforms. The model is completed by adding an analysis of the current implementation obstacles to tactical planning optimization such as the challenges related to interfaces, standards, critical network paths, and questions of responsibility.

*Approaches to Developing a Reasoning Model*

Drawing up a two-dimensional portfolio which shows the potentially evolutionary paths of tactical planning might help to analyze the main research question. The vertical dimension compares the degree of optimality with the degree of feasibility of solutions. The horizontal dimension contrasts central approaches (based on vertical/ hierarchical coordination) with decentral approaches (based on horizontal/ heterarchical coordination). The strategy prevailing in practice is based on planning with rule-based workflows such as the concept of manufacturing resource planning or multi-tier collaboration. This strategy is quite neutrally related to the horizontal dimension of centrality and located at the lower vertical end of feasibility. One potentially evolutionary path of tactical planning is opened up by mathematical optimization that uses goal functions as a coordination mechanism. This strategy is supported by operations research and advanced planning. It is located at the higher end of optimality and on the side of the central approach. Dynamic negotiations utilizing transfer payments as a coordination mechanism might provide an alternative opportunity for further development. This strategy is based on multi-agent systems, self control, and the theory of complexity. It is on the side of decentral approaches and is supposed to be a compromise between optimality and feasibility.

We set up a reasoning model involving the appropriate decentralization degree in tactical planning and production control as well as in the control of logistics networks. This model consists of three levels. The main dimension of the decentralization model relates to the degree of self-control. Both for intra- and inter-enterprise planning, the model distinguishes between the involvement of direct plants or partners, of an 'isolated' supply chain (referring to only one final product), or of the entire network (taking into account all interdependencies).

The normative level of the model analyses the question as to which degree decentralization is to be regarded as legitimate. In the interviews, logistics managers were asked to report on their (potential) readiness for cross-company information transparency related to e.g. components availability, genuine capacities as well as costs, and transfer payments. These levels of legitimatized transparency are connected and translated to the minimal degree of

decentralization (respective the maximum degree of centralization). This is the precondition for the next (strategic) level of the model. It raises the question which degree of decentralization is desirable. This question should be answered by the interviewees on the basis of the coordination mechanisms which they consider to be desirable. Therefore, further dimensions of the coordination mechanisms are the planning policy and automation. This policy deals with the trade-off between having the system under control versus utilizing dynamic solution generations. The relevant categories are mathematical optimization, rule-based heuristics, or dynamic negotiations with transfer prices. The automation of the solution process distinguishes between manual maintenance and communication, information technology supported processes, and entirely automated planning and control by multi-agent software systems.

The resulting degree of decentralization with its respective dimensions provides a solution to identifying the appropriate degree of decentralization on the tactical level of the model. Appropriate coordination mechanisms are designed on the basis of literature reviews, expert interviews, and own solution development.

### *Carrying out Experiments to Evaluate the Decentralized Planning Model*

Selected coordination mechanisms are integrated into a software tool for evaluation purposes. This ranges from scheduling lines without confirmation, over iterative exchanges of scheduling lines, transfer payments on bottlenecks, to negotiations and trading of real options. Various scenarios are available based on simulated volatile demand from retailers, the availability of raw materials and production capacities, and the different supply network configurations with alternative cost structures. When we organize planning games in computer-based classes, we arrange competitions for the students. In addition, we perform simulation runs in order to evaluate the findings. In both cases comprehensive sets of key performance indicators such as profit margins, costs, inventory levels, and multiple service levels are recorded and evaluated. The software component Supply Network Planning of the solution mySAP SCM® (formerly Advanced Planner and Optimizer®) is utilized to engineer a centralized supply network model. Simulation runs of this central supply chain manager serve as a benchmark for decentralized planning.

## RESULTS

The research results provide appropriate coordination mechanisms necessary for autonomous supply chain partners to make decisions in tactical planning and to draw up consistent plans. We want to highlight some aspects as follows: A bilateral, iterative negotiation mechanism is based on software agent technology using prices on bottleneck capacities which figure high on the list of priorities during the allocation process. This approach is extended by the concept of real options. These capacity options are subject to trade if they are highly recommended by partners or obsolete. This makes all participants of the network highly flexible in the way they respond to the dynamics of ultimate customer demands and to network capacity constraints. This holistic approach combines local hierarchical optimization of internal supply chains with collaborative planning within the network.

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