Coordination of Supply Chain
– Lessons from Finnish Manufacturers
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ABSTRACT
In this paper we study the systems currently used in manufacturing companies for coordinating the supply chain through production and sales functions. Instead of relying solely local objectives and resource utilization targets, proper chain-wide coordination aims at global service objectives, information sharing and consistent prioritizing of orders. The requirements of, and methods for, different coordination mechanisms are discussed in terms of classifications of manufacturing processes and customer service approaches. The complexity of the coordination task depends on the criteria of order priorities as well as on the stage first quoting the priority, whether on shop floor or at sales office. Promising areas for priority-based mechanisms are identified with suggestions for matching information systems and organization support. Preliminary results of in-depth interviews in three manufacturing companies are discussed.

Keywords: manufacturing, coordination mechanisms, process requirements

1 INTRODUCTION
The management of supply chain pursues global objectives of fast order turnaround, high utilization of resources and flexible customer service throughout different stages such as order processing, production and shipment. At each stage, the members of supply chain deal with daily operating decisions, which have to be coordinated to achieve the global objectives. In this paper, these local decisions are portrayed as priority scheduling rules for which new coordination mechanisms need to be developed. Coordination problems occur, while parties of supply chain reach to fulfill simultaneously customer promises and company-specific goals. Causes of the problems are, for example, misinterpretation of demand and capacity information, strive of firms to divergent goals and inability to respond quickly to modifications in any information, which specifies supply chain activities. While the organizational behavior of companies should be changed at first, the consideration of supply chain-wide objectives calls also for tools that enable functional supply chain coordination to be implemented.

In the academia, supply chain coordination often refers to the centralization of decision-making. It has been argued that centralized control of supply chains would maximize its total expected profit. This means, however, that a single decision-maker should have all available information, for example, on the needs of customers, production capacity and delivery options. In the ever more global business environment this is not a realistic assumption. Since the members of supply chain have their own incentives as well as different information accessible. Hence, in this paper supply chain coordination refers to actions to link different activities to-
gether in a smooth converted way to enable harmonious function of activities for effective results. Coordination differs from synchronization and integration activities. It does not imply that different activities have to recur at exactly same time periods as presumed in synchronization. Nor are separate functions to be incorporated into a unified whole, which is the purpose of integration activities. Consequently, a coordinated supply chain may equally have a centralized or decentralized decision-making structure.

Coordination mechanisms as such seek to give supply chain players the scope to operate without strong and close ties to other companies. As Lambert et al. (1998) suggest integration and management of all business process links throughout the entire supply chain is not appropriate, because the need and possibilities of process integration as well as the obtainable level of integration varies from link to link. Thomas and Griffin (1996) argue that the models of supply chain coordination at an operational level in a dynamic environment are yet to be addressed adequately. Some work on the coordination of decisions, for example, within decentralized multi-echelon supply chains has, however, been completed (e.g. Lee and Whang 1999).

Acknowledging the definitions above, for example, how can sales coordinate the supply chain by enforcing consistent due-dates and order priorities throughout manufacturing and shipping companies? Since the members of supply chain do not discuss priorities in advance in a convergent way, but use those to achieve local objectives. We propose that priority coordination can provide supply chains with tools that enable them to master and control the flow of information and goods with an appropriate intensity. Yet, relationships between firms have been studied extensively in marketing, and scheduling is a classic problem in operations research the complexity of supply chain coordination with scheduling priorities is still not completely explored (e.g. Baker 1974, Pinedo 1995, Vepsalainen and Morton 1987, 1988). It already has been shown that scheduling procedures can be profitably applied to supply chain context (Kjenstad 1999). Research on supply chain scheduling, nevertheless, seems to overlook the applicability of extensive systems. Besides the efficient employment of mathematical programming techniques decision-making processes should also be considered. As one can intuitively expect practitioners are more willing to accept and apply simple priorities, which are proved to be of real value to the organization, than start using complex decision-making routines (Boyd 2000). We believe that what supply chains need is a set of consistent priority indices, showing the value of each order and unit of capacity, which can be used in comparing the criticality of orders at any stage and any point of time. In addition, for ensuring coordinated and flexible operational decisions the priority rules should facilitate reliable communication on the urgency of orders and the availability of capacity within the supply chain.

The objective of this preliminary study is to clarify the current situation of manufacturing companies regarding the systems used to coordinate activities among different stages of supply chain. Firstly, we classify different types of coordination mechanisms and define the methods of coordination. Secondly, we specify the requirements of the mechanisms based on evaluation of manufacturing processes and customer service capabilities. Thirdly, we determine promising areas for application of priority-based mechanisms. Through in-depth interviews we have also collect empirical data on the operating modes of three manufacturing companies. Based on the data we describe some preliminary observations regarding the efficiency of inter- and intra-company communication, the forms of scheduling decisions and the methods of coordination.
This paper is organized as follows. In Section 2, the process requirements and coordination mechanisms are specified based on manufacturing and customer service capabilities. Empirical observations from three manufacturing companies are explained in Section 3, followed by discussion and concluding remarks.

2 COORDINATION FRAMEWORK

In this section, we introduce classifications used in evaluating the requirements of manufacturing and customer service on coordination. The classification, visualizing production capabilities, is the product-facility matrix (Kela 1993; adopted from Hayes and Wheelwright 1979). As shown in Figure I, different product mixes and facility patterns form combinations on the diagonal, which represent efficient trade-offs between transaction and production costs. These manufacturing processes can be managed with conventional production planning and control mechanisms. Design/construction capability, referring mostly to projects, has primarily time-based systems, whereas bulk process capability is linked to rate-based systems as defined by Vollman et al. (1997). Discrete manufacturing capability is a typical assignment problem with shorter production runs, whereas mass manufacturing has longer production runs.

![Figure I. Manufacturing service matrix based on type of product mix and facility pattern (Hayes and Wheelwright 1979; Kela 1993).](image)

According to Hayes and Wheelwright (1979) cost-efficient production facilities locate on the diagonal of the product-facility matrix. However, it has been shown that other efficient positions exist. For example, flexible manufacturing systems exhibit economies of integration by providing the ability to produce a variety of customized products and high volume of low-cost products (Noori 1990). Similar observations have been done on the concept of mass customization (Pine 1993) and relationships with customers, purchasing high volumes (Figure I). While these situations become more common, the need for coordination emerges especially for managing heterogeneous customer types within production systems. In this paper we focus on analyzing the interfaces between production and customer service functions since the shipment of orders is often done according to routines, and does not require specific coordination.
Besides identifying manufacturing capabilities, the evaluation of process requirements on coordination calls for an analysis of service and ordering types. These capabilities can be analyzed with the service-channel matrix developed by Tinnilä (1997). In the matrix, service refers to the output of service process, and is evaluated in terms of information complexity, frequency and timeliness of transactions and type of resources used. Services develop from a contingent relationship to mass transaction through standard contract and customized delivery. Type of channel varies depending on organizations and systems from indirect to direct order. Service capabilities formed in the matrix are:

1. Agent-based process
2. Multi-echelon process
3. Routine order through the net

In the agent-based process, an external intermediary typically handles sales and ordering process. Multi-echelon process refers to an arrangement, where sales activities abroad are managed and performed by subsidiaries. Routine order process through the net equals to an automated process, which emphasizes the role of decentralized control. In general, the need of decentralized control increases, when the system moves downwards on the diagonal. We assume that as decentralized control strengthens the need of priority-based coordination increases. Priorities facilitate the decentralized control of supply chain, and improve service concurrently as company transfers off the diagonal in the service-channel matrix.

By combining main elements of the product-facility and the service-channel matrices a framework, which illustrates the process requirements of different coordination mechanisms, is developed (Figure II). Coordination with knowledge-based mechanisms refers to systems, where employees have skills and expertise required for making routine as well as specific decisions about delivery promises. This system is preferred, for example, if numerous sales agents sell products manufactured by facility, which has discrete manufacturing capability.

![Figure II. Process requirements derived from production and service capabilities.](image-url)
Coordination with centralized mechanisms means that decision rights regarding order acceptance and production schedules are given to selected employees. Operational decisions can still be done by anyone if detailed instructions, guidelines or protocols are given. Authorized person (‘gatekeeper’), nevertheless, controls decisions on capacity allocation and prioritizing of orders. This system is sensitive to unexpected disturbances, but risk is taken since poor decisions, for example, on production schedules can be costly.

The core of priority-based mechanisms are priority rules, which aggregate essential information from the entire chain into indices based on which prioritizing of orders is possible in a consistent and robust way. The priorities are suitable, for example, for firm that has discrete manufacturing capability and ordering process, which is performed directly via the Internet. Similarly the priority-based coordination works in situations, where standard community products are sold through numerous agents. The need of this type of coordination mechanism, in general, arises because:

- Shorter lead-time requests uncover operational problems.
- Emphasized customer-orientation requires decisions, e.g., on delivery times to be done close to customer, which stresses the importance of communicating production-related data quickly and reliably to the customer interface.
- Requirements of different supply chain stages are difficult to consider and control.
- Improved information sharing and new technologies facilitate the development of new operating models, which often leads to heterogeneous production and service processes.
- Changes in industry structures create businesses, which locate off the efficient diagonal of the product-process matrix.

The methods of coordination can be classified to three groups with different structural forms. Coordination through control is the most conventional way of operation. Another method of coordination is meetings, which can have different roles depending on who participates and how often. Third form of coordination relies on controlling the decision-making environment. For example, formal scheduling system limits the options of both production and sales people regarding lead-time quoting and order sequencing.

Besides the structure of coordination there are factors, determining how organizational support and information sharing match. Type of information systems used and the degree of IS integration within supply chain influences on the coordination method because sophisticated systems often require more information. Type of information sharing either via systems or verbally has an impact on the level of coordination, because the basic data set without more profound knowledge on it can lead to different conclusions. Type of incentives and rewards within supply chain effect coordination since, for example, priorities base on joint incentives. Other factors, contributing to the success of coordination are the type of contracts, use of penalties, collaboration benefits and performance measures.

The complexity of the coordination task depends on the criteria of order priorities as well as on the stage first quoting the priority. This can be illustrated with a classification, which is formed by the priority driver and the locus of prioritization (Figure III). Different information sets are available to different actors. Capacity constraints are the driver of prioritization on shop-floor, whereas sales personnel use individual customer orders as the basic data set and
scheduling unit. If production people on shop-floor strive towards considering customer and individual order data in their decisions, they face increasing communication problems. Similarly, if sales people in contact with customers try to consider the load of production, the availability of right data becomes problematic. Preliminary results on decision-making rules used within supply chains show that most coordination mechanisms are focused on one driver such as customer type or class. So, the main problem of coordination mechanisms is the lack of well-organized systems, which stresses the importance of developing new priority coordination methods. Those are needed especially for managing increasing amount of data on the level of individual orders.

![Diagram of Priority Quotation and Driver](image)

Figure III. Classification of coordination systems based on priority quotation and driver.

3 EMPIRICAL STUDY

In general, within stochastic environment the more complex supply chain is the more coordination is needed. The need and actual level of coordination, however, depend on several variables such as production planning and control philosophies, number of stages, type of interfaces between stages, speed of change and expectations of customers. The availability of right information and tools has perhaps the largest impact on actual coordination. In section 3.2, we describe some preliminary observations on the current situation of Finnish manufacturers regarding decision-making and production scheduling procedures.

3.1. DATA COLLECTION

The main purpose of this empirical study is to explore and analyze how Finnish manufacturers coordinate their supply chains especially in export operations. In this primary stage of empirical research, three metal product manufacturers were selected as case companies to illustrate different coordination needs and systems. The average number of employees is 270, and the average value of export totals up to FIM 650 million. Altogether 20 managers, who work either for manufacturing, sales or logistics departments, were interviewed to collect the data. In-depth interviews, of which each took 2.5 hours, were based on a 12-page survey instrument. The survey consists of three parts (Figure IV). Part one discusses organization and culture
within manufacturing unit. Besides supply chain structure it seeks to identify what logistics strategies and management styles are employed. Second part of the survey follows logically the functions of a manufacturer. It covers customer order processing, manufacturing flow management, scheduling of orders and dispatch planning. In part three, customer service and type of supply chain relationships are discussed.

3.2. OBSERVATIONS

Prior to EDI connections and EPR solutions, cost of information sharing was relatively high. Because of improved technology the transmission of information and data is no longer a significant problem. Manufacturers have capabilities to share order and schedule information with their supply chain partners, for example, through integrated IT systems. Besides inter-firm communication also intra-firm data sharing has become faster and easier. Production planning departments do not need to request additional information on individual customer orders from sales continuously. Neither are employees responsible for dispatch planning forced to do ‘management by walking’ on the shop-floor in order to decide the composition and timing of shipments. Another result of improved technology is that supply chain members have new ways of communication. Faster and more efficient information sharing has thereafter clarified the roles and responsibilities among sales and production units. Nevertheless, some overlapping activities and inconsistent incentives still exist.

Improvements and technical innovations in technologies and tools used in production planning and sales management enable firms to develop new concepts for capacity management and process control. However, the agility and reliability of order processing and delivery performance is not high enough to enable meeting of customer requirements. Manufacturers manage all orders through the same order-delivery process due to which, for example, customization of lead-times depending on customer importance is not performed in an organized manner.
There are numerous studies on scheduling problems within manufacturing environment (e.g. Morton and Pentico 1993, Pinedo and Chao 1999). Many of those deal with capacity utilization and delivery accuracy problems, which ought to be solved optimally. Often the number of parameters to be considered, however, is so high that in order to formulate a linear programming problem some objectives have to be limited out. On the other hand, stochastic scheduling environment with continuously changing order and capacity information does not facilitate LP formulation. So, firms often find that all available information, including profit and delay penalties, cannot be considered in scheduling decisions. Therefore, the main purpose of scheduling is to sequence orders for production-site activities based on capacity and due date information.

The capabilities of manufacturing facilities develop from production technology and product innovations, is an often-stated argument. Excellent customer service, which may require a detailed analysis of customer needs and product profitability, is not seen vital to manufacturing performance. According to some evidence customer priority decisions are often made informally, although casually managed production system can have devastating ramifications to the overall performance (Malhotra et al. 1994). Production is planned and controlled based on production constraints and sales forecasts, and explicit priority indices are not used to coordinate orders throughout supply chain. This implies that within production environments, where priority-based coordination suits, tighter systems should be developed. Coordination systems should consider production (capacity, set-up times, disturbances), product (profitability) and customer (service requirements, profit, strategic importance) data.

Customer requirements vary. Key customer at times needs urgent delivery and next time standard lead-time is acceptable. Another customer may order special products irregularly, and standard products on a regular basis. Today manufacturers have developed divergent service processes (Jahnukainen and Vepsäläinen 1998) to be able to meet customer requirements better. Flexible order-delivery processes, if existent, enable firms to offer services implemented on the basis of customer requirements not production constraints.

4 CONCLUSIONS AND FUTURE RESEARCH

In this paper we have presented some preliminary results of the study on how manufacturing companies coordinate their supply chain activities. On the basis of manufacturing processes and customer service approaches we have specified different coordination mechanisms and their requirements. Difficulties, arising in the actual coordination process were illustrated through analyzing the impact of priority driver and the stage first quoting the priority. Based on the analysis we identified promising areas for applying priority-based mechanisms. Based on empirical data we described the efficiency of inter- and intra-company communication, forms of scheduling decisions, and current methods of coordination.

In future it will be tested how different process requirements such as manufacturing and service influence on coordination systems. Similarly, we study what are the requirements and possibilities of priority-based coordination and what prioritization methods can be used in practice. Issues, applying to existing mechanisms and systems, are examined on the basis of empirical data collected through in-depth interviews from about 20 Finnish manufacturing companies. Experimental methods such as simulation are possibly used to test new coordination mechanisms.
REFERENCES


