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COORDINATING MATERIAL AND INFORMATION FLOWS WITH SUPPLY CHAIN PLANNING

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ABSTRACT

Purpose of this paper

This paper studies how companies can select a supply chain planning mechanism to improve the balance between material flow and information flow.

Design/methodology/approach

The methodology of the paper is an inductive case study approach. Coordination theory is used as a background for the paper. Based on a literature survey, determinants of the selection of a supply chain planning approach are defined. Cases of supply chain planning are used to validate the framework presented.

Findings

Specific supply chain characteristics need to be balanced by selecting a coordination mechanism that uses information optimally to support the material flow. Flexible material flow needs frequent updates of the plan based on accurate information. If frequent information sharing and planning practices are used to support inflexible material flow, the result may be volatility in plans, and planning resources are wasted. If a flexible material flow is supported by inadequate information, waste may be produced in the material flow, in the form of excess inventories or capacity.

Research limitations/implications

The paper presents a framework for finding the balance between information flows and material flows and for applying a coordination mechanism. The validity of the framework is tested with two earlier case studies. More case studies are needed to ensure the generalizability of the results.

Practical implications

Companies can use the framework to analyse the management of their material flow and their use of information. In future research the framework could be developed to give more support for situations with different levels and sources of uncertainty.

What is original/value of paper?

The paper provides a new perspective on the discussion how information should be used to improve supply chain performance.

Keywords: supply chain planning, framework, coordination theory, information quality, supply chain flexibility

1. INTRODUCTION

The design of information flow in supply chains has traditionally followed the physical flow along the chain (Lewis and Talalayevski, 2004). Sub-optimal supply chain performance, in many cases, has been the result of poor information sharing. Adopting advanced information systems, which enable efficient information sharing between the members of supply chains and over supply chain phases, may however change the situation. Instead of suffering from *scarcity of data*, the challenge for companies is to achieve good quality information (Wagner, 2002) and to decide which data can be utilized in decision making to improve supply chain performance and which data can be ignored.

The purpose of this paper is to develop a framework that can be used by companies to support the selection of a planning mechanism that will allow them to coordinate their physical flow and information flow. The scope of this study is long-term supply chains and manufacturing companies, because they occupy a central position in the supply chain and, especially when they are brand owners, have an interest in the improvement of supply chain performance.

The background of this paper is taken from coordination theory, which offers a framework for identifying and classifying different types of dependencies and for proposing mechanisms that can be used to manage these dependencies (Malone and Crowston, 1994, Lewis and Talalayevski, 2004). The purpose of coordination is to achieve collectively goals that individual actors cannot reach. The need for coordination is evident in supply chains, as companies forming a supply chain are dependent on the performance of other organisations. Supply chain coordination is achieved when a decision maker, acting rationally, makes decisions that are efficient for the supply chain as a whole (Gupta and Weerawat, 2006). The focus of this study is on operational supply chain linkages and it addresses the connection between information sharing and physical flow coordination. This topic has been studied before, for example by Sahin and Robinson (2002; 2005), who state that incomplete understanding on the interaction between information sharing and physical flow hinder attempts to achieve higher levels of supply chain integration. In many cases information sharing alone does not improve supply chain performance. They argued that physical flow coordination among the trading partners was also required.

The study deals with a specific supply chain coordination mechanism, supply chain planning. Supply chain planning means the activities that focus on evaluating demand for material and capacity, together with the processes of formulating plans and schedules to meet demand and company goals (Gupta and Maranas, 2003). This mechanism includes the essential features to improve the balance between demand and supply, as has been described by other authors (e.g. Lambert, 2004, and Vitasek et al., 2003).

This paper starts with a review of previous studies on the selection of a supply chain planning solution. After that it discusses the information sharing literature, especially from the viewpoint of information quality. The next section presents the methodology used and describes the phases of the research. Then the framework is presented. The paper continues with the application of the framework to analyse findings from two previous studies. The final section presents conclusions.

2. A REVIEW OF THE LITERATURE ON SELECTING A SUPPLY CHAIN PLANNING SOLUTION

This section reviews studies that deal with the question of how supply chain planning solutions should be selected. It starts with the product-process matrix (Hayes and Wheelwright, 1984). Although this framework does not address planning directly, it provides a background for the evolution of supply chain strategies and their selection. This section continues with Fisher's (1997) framework on selecting the appropriate supply chain strategy, and draws on two studies where the framework has been applied. Lastly, papers where a specific supply chain planning approach is chosen or evaluated are described. A summary of the studies is given in Table 1.

Product and process coordination was examined in the product-process matrix developed by Hayes and Wheelwright (1984, pp. 197-227). This matrix treats the relationship between product volume and mix and the characteristics of the production process. The production process is described along a continuum of processes that ranges from a job shop to a continuous flow process. The product-process matrix proposes the optimum match between process character and product volume. A variant of the product-process matrix was developed by Schmenner and Swink, (1998) and their formulation described the axes as 'demand variability' and 'speed of flow'. The matrix identified operations that are least productive, specifically, producing commodity products with steady demand in a job shop production environment and using high-speed continuous flow for products with high demand variability.

Fisher (1997) proposed that alternative product demand characteristics require different supply chains. There are two basic types of supply chains: effective, which aims at cost-effectiveness and lean operations, and responsive, which aims at adapting the supply chain according to customer demand. According to this framework products can be considered to be functional, requiring efficient supply chains, or innovative, which are best managed in a market-responsive supply chain. The model was further developed by Li and O'Brian (2001), Collin (2003) and de Treville et al. (2004). All these studies concluded with suggestions to add more supply chain types to the framework. Lee (2002) argued that the primary criterion for supply chain strategy choice is aligning demand uncertainties with supply uncertainties.

Two studies have examined the problem of how to study different product characteristics and how to choose the appropriate supply chain strategy for each. Childerhouse et al. (2002) investigated the design of focused demand chains of an electric lighting manufacturer. Five product characteristics were chosen to form uniform product groups, namely: annual demand volume, responsiveness of order cycle, life cycle, demand variability, and product variety (referred to as DWV^3). The products were grouped according to these parameters, and a focused demand chain strategy was developed for each cluster.

Table 1. Studies on selecting a supply chain planning solution.

Author(s)	***Focus of the study***	***Determinants***	***Finding / Result***
Hayes and Wheelwright 1984	Coordination and finding a match between product and process	Product volume and mix	A product-process matrix
Schmenner and Swink 1998	Selecting the type of production process	Speed of flow (thoughput time) and demand variability	A variation of the product-process matrix
Fisher 1997	Selecting the right type of supply chain for a product.	Product features, supply chain features	Effective supply chain should be chosen for functional products and market-responsive supply chain for innovative products
Li and O'Brian 2001	Selecting the supply chain with a mathematical model	Product types, 3 supply chain strategies	Presents quantitative evidence for Fisher's (1997) ideas, except when production capacity is low.
Lee 2002	Selecting supply chain strategies	Demand and supply uncertainties	Efficient, responsive, risk-hedging, and agile supply chains in different levels of demand and supply uncertainty can bring competitive advantage.
De Treville et al. 2004	Comparing three levels of demand information transfer with lead time reduction	Demand information transfer, lead time reduction	Improvement in lead times should be prioritised over demand information transfer.
Hvolby and Trienekens, 2002	Planning solutions for small and medium-sized companies	Supplier lead times, customization stage	The use of electronic markets, VMI, supplier hubs, classical purchasing and advanced planning systems
Childerhouse 2002	Focused supply chain strategies for a case company	Demand volume, responsiveness of order cycle, life cycle length, demand variability, product variety (DWV^3)	Chosen determinants brought a desired strategy selection outcome and increased the competitiveness of the company.
Wong 2006	Supply chain strategy for innovative and seasonal products	Forecast uncertainty, contribution margin, demand variability	Three strategies that differ in the level of responsiveness.
Kajiwara and Miyabayashi, 2006	Finding a balance between the capabilities	Planning capability, production capability	High production capability should be supported with high planning capability, and low production capability with lower level of planning capability
Singh et al. 2007	The fit of supply chain technology (SCT) to a supply chain	Nature of use, nature of process, nature of SCT	Conceptual architecture on aligning organisational processes and SCT
Hvolby et al. 2007	The choice of planning approach according to supplier types.	Customization and the level of integration.	A framework linking supplier typologies with supply chain planning solutions.
Johnsson et al. 2007	To apply advanced planning systems (APS) for supply chain planning	Planning situation, model design, the use of APS	Effects of APS on tactical and strategic levels

A similar study was reported by Wong et al. (2006). They studied innovative toy products with volatile and seasonal demand. The determinants that were used to define appropriate levels of responsiveness were forecast uncertainty, contribution margin and demand variability. The researchers found that most products required market responsive operations, as they had high forecast uncertainty, demand variability was at a medium or high level, and the contribution margin was also at a high or medium level.

Planning solutions were considered in the framework presented by Kajiwara and Miyabayashi (2006), who proposed that planning capability and production capability need to be synchronised (Figure 1). They suggested that both planning and production capabilities should support each other. If planning reacts more quickly than the production capability, the company is in a mismatch situation; resulting in frequent plan changes, which wastes planning resources. In the lower left quadrant (see Figure 1) resources are wasted, because unnecessary physical capabilities are maintained in the supply chain. These may be in the form of flexible production capacity that cannot be utilised due to inadequate information.

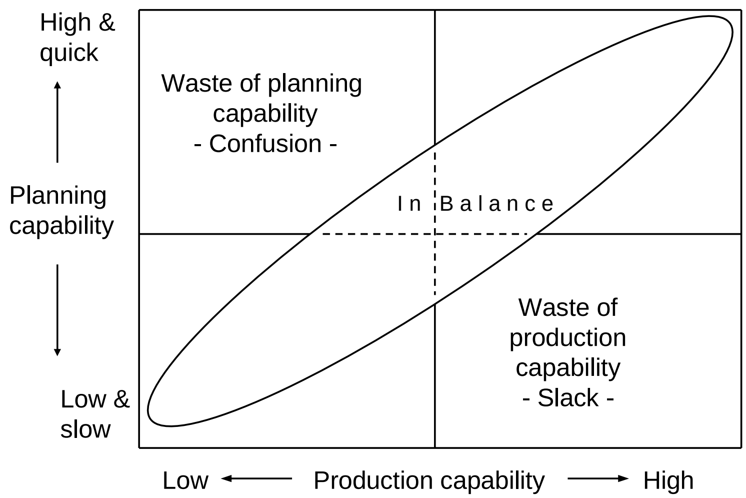

Figure 1: Balance between production capability and planning capability (adapted from Kajiwara and Miyabayashi, 2006).

One study proposed a method to choose planning solutions for small- and medium-sized companies (Hvolby and Trienekens, 2002). These companies face more challenges in their planning and control systems because of fluctuations in the markets. They make their choice according to supplier lead-times and customization stage. The writers found that vendor managed inventory, VMI, is one way to simplify the supply chain planning process, as stock management is handled by suppliers. At their best, advanced planning systems (APS) offer a way to include suppliers and customers in the planning procedure and to improve the performance of the whole supply chain. In a more recent study Hvolby et al. (2007) link planning solutions to buyer-supplier typologies.

The choice of implementing the right technology in the supply chain is a topic of two recent articles. Singh et al. (2007) propose that technology decisions should be aligned with the nature of processes, the use of technology and nature of supply chain technology. Jonsson et al. (2007) study in a comparative case study how the use of advanced planning systems impact planning effects.

In summary from the previous studies it can be seen that the determinants that affect the choice of a planning approach are related to market and product characteristics. Demand and product variability, and customisation appear to be crucial determinants for the selection of a supply chain strategy and supply chain-planning solutions. Interestingly, no studies have addressed aspects related to information sharing as a determinant of planning approach. Clearly, it has been assumed that all relevant information was available, and in the correct and usable form.

3. THE EFFECTS OF INFORMATION QUALITY ON THE BENEFITS OF INFORMATION SHARING

Previous studies have largely dealt with the benefits of information sharing for supply chain performance. A large number of papers have presented analytical studies about the benefits of information sharing (Cachon and Fisher, 2000; Gavirneni, et al., 1999; Zhao et al., 2002; Cavirneni, 2006; Lee et al., 2000; Yu et al., 2001; Cheng and Wu, 2005). All these studies found information sharing beneficial, but they describe somewhat different levels of benefit from information sharing, depending on the assumptions and features of the model used. Typically only the benefits are considered, not the associated costs. Also, in the more empirically oriented papers, information sharing is found to be beneficial. Examples are the case study by Byrne and Heavey (2006) and the paper by Småros et al. (2003), which studied the impact of sharing point-of-sale data. One previous study compared the efficiency of different means to improve supply chain performance and concluded that lead time reduction improves supply chain performance more than information sharing (De Treville et al., 2004). Barrat and Oke (2007) took a different approach. They differentiated between the terms 'visibility' and 'information sharing' and emphasized that visibility should improve decision making.

The key to enhanced supply chain operations does not lie solely in efficient information transfer and sharing, but also in information availability and timeliness (Kehoe and Boughton, 2001, English, 2001). The quality of shared information has a clear impact on the planning outcome (Petersen, 1999, p. 69-88) and is critical to the effectiveness of decision making (Petersen et al., 2005). Furthermore, Simchi-Levi et al. (2003, p. 11) saw supply chain management as being concerned with utilising the data and the sophisticated analyses of this data. The primary issue is *what* data should be transferred and *what* part of the data can be ignored. There are, however, few research results that relate to how the quality of shared information affects the performance of supply chains.

Information quality is defined as the degree to which the information meets the needs of the organisation. Information quality includes such aspects as accuracy, timeliness, adequacy, completeness, credibility, ease of access, and compatibility across users (Monczka et al., 1998). Petersen (1999) used five characteristics of information quality: information currency, accuracy, completeness, consistency and ease of access. English (2001) described information quality according to the needs of the decision maker, and argued that the right data in a complete form and in the right context is needed. The data need to be accurate and objective, and the decision maker should have a single version of the information. The data should be in such a form that it can be used efficiently and effectively, and at the right time and place for the right purpose.

Some writers have pointed out a new challenge which arises from frequent and wide information sharing practices: companies may face difficulties surviving the *overabundance* of data (Malhotra, 2000). A few studies have examined how offering information from various sources and in a frequent manner may harm decision making. One example is the study by Disney et al. (2004), who based their work on the earlier study by Hong-Minh et al. (2000), and studied decision making in the Beer Game. They noticed that the decision maker could not improve decisions when he/she had a wide range of data; it confused the player and ended up in worse decisions and higher inventories in the chain. It was concluded that, particularly when human intervention is needed, decision making becomes more complex in a transparent environment. Another example is the study by Steckel et al. (2004), who noticed that sharing end-customer sales data was harming the supply chain performance in an experimental simulation, when demand was assumed to be changing continuously.

To sum up, a considerable body of literature has addressed the benefits of information sharing with varying results. In some studies the benefits may be low or information sharing may even harm supply chain decision making. Therefore it can be concluded that the level of information sharing, which may also be described as the volume of information shared, should be adjusted according to the decision making situation.

4. METHODOLOGY

This paper aims to build theory based on the inductive case study approach. The phenomenon under study is managing the relationship between information flow and material flow, and the objective is to explain and improve understanding of the phenomenon. The process leading to this paper was a long-term iterative process. Figure 2 illustrates how the study was performed.

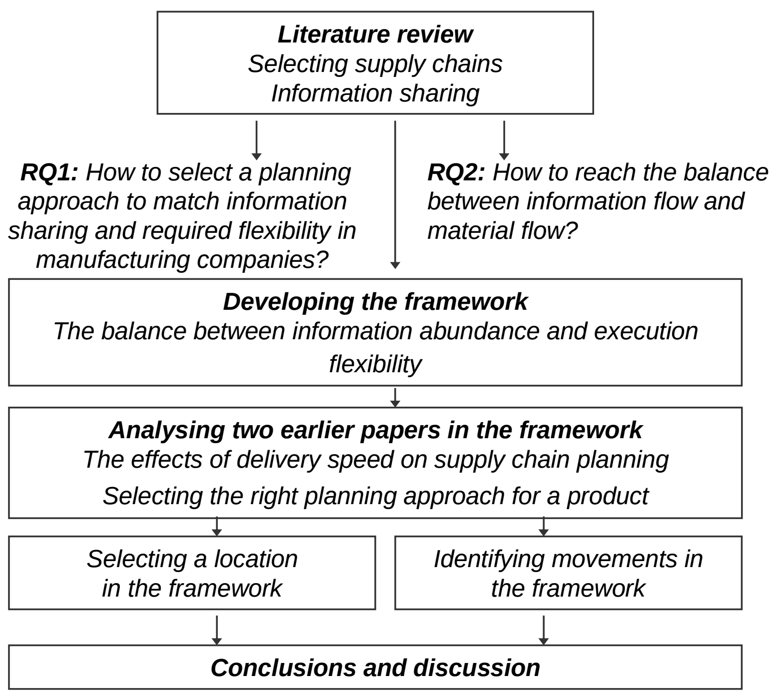

Figure 2. Overview of the study.

The framework developed in this paper is founded on a literature survey on two topics. The first topic is how a supply chain planning approach should be selected. This part presents previous studies on selecting supply chains and the factors affecting the choice. This literature review adds understanding of the determinants that should be used in planning approach selection. The second part of literature concerns information sharing in supply chains. The information sharing literature is examined from the viewpoint of information quality, which means how well the available information meets the needs of a supply chain decision maker, i.e. how well information supports supply chain planning.

The findings from the literature lead to two research questions. Research question 1 (RQ1) is: How should a planning approach be selected to match information sharing and required flexibility in manufacturing companies? Research question 2 (RQ2) is: How to achieve a balance between information flow and material flow?

To test the framework, two earlier published studies on selecting approaches to supply chain planning are used. The results from these studies are examined through the framework, based on the required flexibility in each case, and the available information. Then, a separate section analyses which movements need to made in the framework to reach a balance. The two earlier studies are described below and the used methods are collected in Table 2.

Table 2. Research methods in the two studies.

Study	***Research method***	***Sample/ Unit of analyses***	***Data collection***	***Data***	***Analyses***
Study 1 Planning in manufactur-ing companies	Multiple case study	Planning process in six manufacturing companies	Structured Interviews, 1 to 4 in each company	Planning and information sharing and collaborative practices, plan quality	Within-case analyses and cross-case analyses on explanatory factors for planning approach.
Study 2 Selecting planning approach	Selection model and a case	Product features and planning approach features	Benchmark study and literature survey, case product features	Product types with different demand and supply features. Data requirements for each planning approach.	Testing the framework in one case, Testing the suitability of the selection criteria.

Study 1: The effects of delivery speed on supply chain planning

This study was a multiple case study on the state of supply chain planning in six manufacturing companies. The aim was to investigate the use of different planning approaches in varying environments. The study aimed to discover how manufacturing companies define their future volumes and which factors define the chosen planning approach. Furthermore, the state of planning integration with suppliers and customers was studied, together with the question of how planning results support company goals. For this purpose the companies were selected among Finnish manufacturing companies that acted as brand owners in their supply chains, because such companies should have an interest in planning future volumes, and ensuring availability to customers. The case companies were chosen from different industry sectors: two companies produce consumer groceries, two durable goods for consumers and two offered long-lasting products for company customers.

The study followed the case study principles described by Eisenhardt (1989). When studying planning approaches in different environments, a broad range of data on the phenomenon is required to cover the subject and to understand the situational factors. In this kind of situation, a case-study research is the most productive way to collect and understand contextual data. The number of cases was limited to six to allow deeper analyses of each case.

The main data-collection method involved structured interviews. In each company 1 to 4 persons were interviewed. The respondents filled a questionnaire before the interview, and afterwards they were asked to check and correct interview memos. Case analyses focused on finding factors inside cases for the planning approach adopted, and, in the cross-case analyses, on identifying similarities and differences in planning approaches and finding explanatory factors for these.

The main findings were that sources of flexibility had a connection with the planning approach and that delivery speed affected planning. Those companies that had to deliver at a high speed to customers had adopted proactive planning modes and were closely integrated with the upstream members of the supply chain.

Study 2: Selecting the right planning approach for a product

The study concentrated on supply chain planning principles for highly innovative consumer products. The project focused on creating solutions to problems relating to demand planning for new products with short life cycles. The solutions aimed to utilise true demand information from the sales channel and points of sale to steer planning and support life-cycle planning. The case company needed to differentiate planning to support different supply chains in the new business unit. The new unit had a wide range of diverse products and many alternative ways of sourcing them. The diversification of planning approaches became urgent, as the current approaches worked well for stable product portfolios and supply networks, but could not produce satisfactory planning results for innovative products with the available personnel.

The data collection in this study targeted identification of alternative planning approaches, and it was conducted in the form of a benchmark study. Reports on planning practices in companies that offered innovative products with short life cycles were reviewed in several industry sectors. Further analysis focused on three innovative planning approaches for dealing with a diverse and changing product portfolio. Literature sources were also used to identify planning approaches.

The result of the study was a framework for selecting a supply chain planning approach for product types. The goal was to establish a formal approach to selecting the supply chain planning method. The used procedure aimed at efficient planning resource usage and improved planning results by matching product features to the information and resource requirements of each planning approach. The procedure was tested for a group of products in the case company.

5. FRAMEWORK DEVELOPMENT

In this section an information flow – material flow framework is presented (*Figure 3*). In addition to coordination theory and the identified need to coordinate information sharing and physical flow (Sahin and Robinson, 2002), this framework builds on Fisher’s (1997) approach to the selection of a suitable supply chain according to product features, Kajiwara and Miyabayashi’s (2006) ideas on aligning planning capabilities and production capabilities, and Lee’s (2002) principles for supply and demand uncertainties.

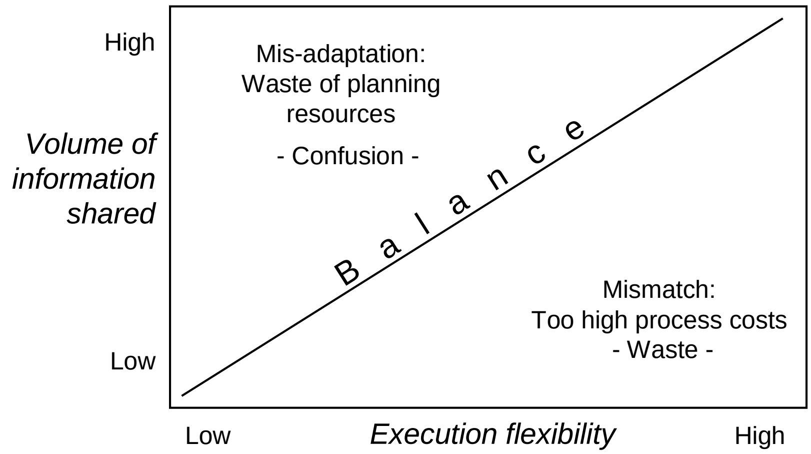

Figure 3: Volume of information shared – execution flexibility framework.

Information flow is described on the y-axis as *volume of information shared*, which describes the existence, extent, and availability of data and also includes three features of information flow: speed, frequency, and abundance of information. This follows the suggestions and definitions derived from the literature, especially by Samaddar et al. (2006), Petersen et al. (1999), and English (2001). Volume of information shared is selected because advances in information technology have made it possible to communicate demand between supply chain partners and also over supply chain echelons. In some cases a company may suffer from *overabundance* of information, in the upper part of the diagram, or from *scarcity of data*, in the lower part of the diagram. Traditionally companies have suffered from inadequate or asymmetric information and had to base their decisions on local and often sparse information, which lead to many supply chain inefficiencies (Patnayakuni et al., 2006). It has become imperative for firms to receive and share information to align supply and demand and to cope with changes in the environment. The term ‘volume of information shared’ is related to the term ‘information quality’, when it is understood broadly, in a meaning how well information supports the needs of a decision maker. However, information quality is realised only when information is used.

On the x-axis material flow is described as *execution flexibility*, which is the ability of the physical flow to adapt to changes. Flexibility means the ability to produce different sizes, volumes, or variations of products with minimum penalties in costs, quality or time (Upton 1994). It incorporates the aspects of volume, mix, timing, and new product flexibility, as well as responsiveness to the market, which have been identified to be the most important aspects of supply chain flexibility (Vickery et al., 1999). The rationale for selecting flexibility to describe material flow is that flexibility has become one of the most important performance characteristics of operational systems, in addition to costs, quality and reliability (Bertrand, 2003). The reason for this is the growing demand uncertainty at the product variant level, as the competitive situation is requiring companies to compete on product innovation and differentiation. This increases the requirement for flexibility of manufacturing systems, as well as whole supply chains. This phenomenon has been widely studied in the literature on agile manufacturing, for example Aitken et al. (2002).

The basic principle in the framework is that each location inside the matrix represents different coordination mechanisms with different levels of available information and different levels of execution flexibility. The locations are different supply chain planning approaches, and therefore the first research question (RQ1) is dealt with here. The model suggests that the balance between execution flexibility and volume of information shared is along the diagonal line. Frequently shared and high volume information should be made available if execution flexibility is high. In other words, flexible operations should be supported by such planning as will capture demand quickly and make frequent re-planning rounds. If execution flexibility is low, it needs to be supported by more stable planning. In the upper left quadrant of the matrix volatile planning with frequent capturing of demand information is used despite relatively low-level of execution flexibility, and is marked as a mismatch-location. This approach wastes information sharing and planning resources, because the production processes cannot respond to information and frequent re-planning. The other mismatch location is in the lower right quadrant, where planning is not capable of supporting the potential flexibility in material flow execution.

In the next section, the framework will be used to analyse the two studies previously described.

5.1. Selecting between order-based and forecast-based planning

Different supply chain planning approaches are located into the information flow – material flow framework. In a recent study (Kaipia, 2008) it was indicated that the planning approach is closely connected to the source of flexibility. Order-based planning was argued to be an appropriate coordination mechanism when the customer accepts a long delivery time. In this context, delivery time means the time from the customer placing the order to the customer receiving the delivery. Forecast-focused planning, which was also known as 'proactive planning', was used when delivery time is short. These approaches require different levels of information sharing and supplier and customer integration.

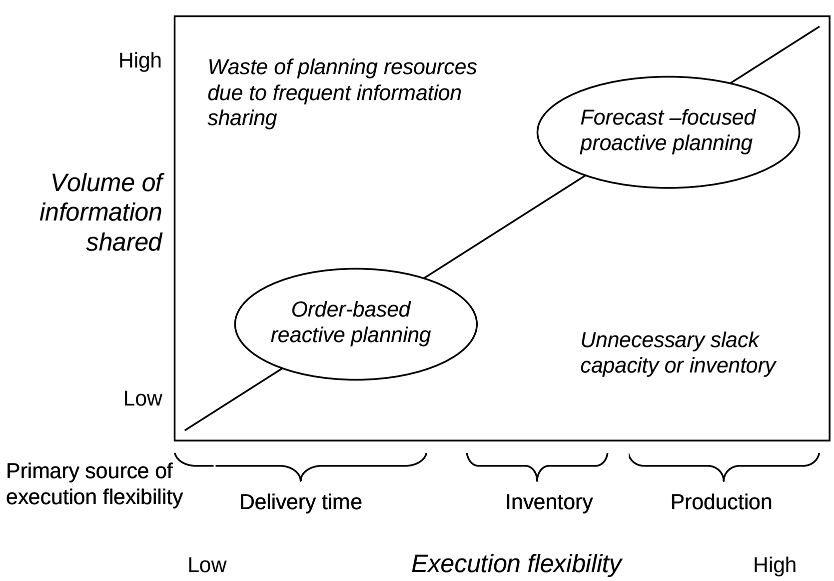

Figure 4: Selecting between order-based and forecast-focused planning.

The connection between sources of flexibility and planning is depicted in Figure 4. Flexibility in this context means the ability to react to short term changes in demand (Upton, 1994). There are three basic sources of flexibility: delivery time, inventory and production (Newman et al., 1993). Order-based planning can be used when delivery time is used as the source of flexibility, and when other means of achieving flexibility are too expensive. When inventory is the main source of flexibility, both order-based and forecast-based planning may be used. In these cases, the required delivery time and product features define the planning approach. Products with short life cycles need forecasting, because inventory risk grows. In some cases order-based and forecast-focused approaches can be combined. Forecast focused planning fits the situation where production is the main source of flexibility. This approach requires utilizing multiple information sources and many types of information from the distribution channel.

5.2. Differentiating planning

In this section the question of how to differentiate supply chain planning for products with different demand features and different life-cycle phases will be discussed. The goal is to improve the use of planning resources by automating planning wherever possible and by using scarce and expensive managerial or expert resources where most needed. Differentiated planning is needed for large product portfolios with different types of products. One example of differentiated planning for innovative products is presented in Figure 5 (based on a study by Kaipia and Holmström, 2007).

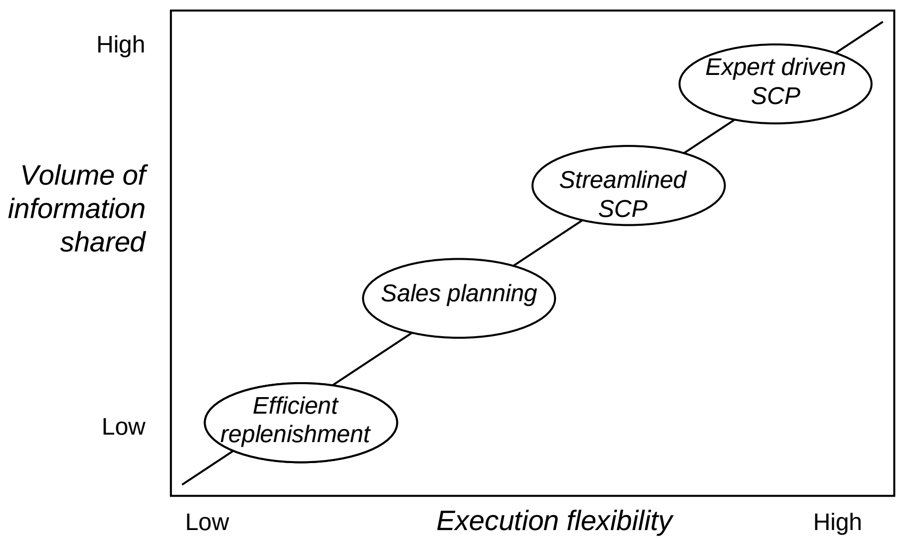

Figure 5: Differentiating supply chain planning (SCP) for innovative products.

According to coordination theory, information processing capability needs to be adjusted to the amount of information and to the uncertainty in the environment (Danese et al., 2004; Galbraith 1977: 35-57). The different planning approaches are positioned in Figure 5 according to this principle. This illustrates that the higher the execution flexibility and volume of information, the less automated planning approaches apply.

For example, in Figure 5, a planning approach called ‘efficient replenishment’, or vendor-managed inventory, VMI, is located close to the lower-left corner. This type of planning supports relatively stable and continuous demand. The next approach, ‘sales planning’ requires forming a collaborative sales plan that is matched with supply capabilities; and therefore availability can be guaranteed for the quantities in the confirmed plan. This approach requires the organization to create the sales plan. In ‘streamlined supply chain planning', purchases and assembly are based on downstream visibility rather than forward plans. This approach requires efficient sharing of downstream demand information, and can be used to support stable sales and continuous demand. Inventory buffers are needed to balance minor changes in demand and supply. In 'expert-driven planning' a specialist group generates a volume estimate for variable or unpredictable demand, when historical sales data or other available data proves inadequate support for planning. Expert-driven planning requires a large planning effort.

The planning approach for a product is determined by sequentially considering how the product fulfils the requirements for each planning approach. There are two basic criteria for selecting the mechanism: the first is the availability of planning resources and information needed and the second is how easily the planning can be automated and whether it is possible to set rules and procedures for performing the planning task. Efficient replenishment is considered first as it requires the least planning effort, whilst expert-driven demand-supply planning is considered last, as it requires the most planning resources. In an ideal situation, these approaches are located along the diagonal in the matrix, as is shown in Figure 5. This suggests that information sharing practices and planning in each approach would optimally support the execution for each product group.

5.3. Reaching a balance between information flow and physical flow

In this section, the changes that are needed to improve the match between information flow and material flow are discussed. Thus, answers to research question 2 are sought here. Figure 6 illustrates the changes required in different situations to balance the information and materials flow. Movements up and down in the framework take place by changing information sharing and planning processes, and left and right by changing physical processes.

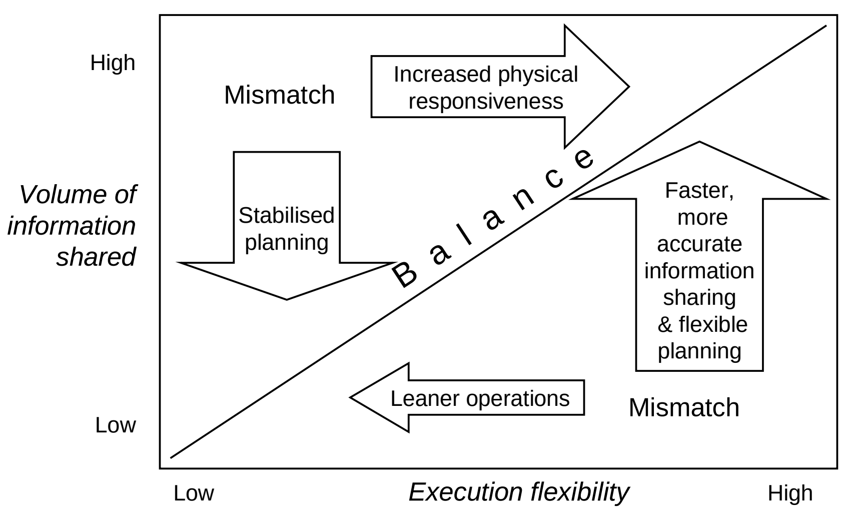

Figure 6: Movements in the volume of information sharing - execution flexibility framework.

In the upper left quadrant, the company's planning system reacts fast to signals from the environment, for example demand changes, which leads to a situation that can be called "planning nervousness" (the term used by Stadtler, 2005). In this location, companies should adopt simplified and more stable planning practices to avoid wasting planning resources. This may mean, for example, reducing the number of planning updates, raising planning levels higher up the product hierarchy, or choosing planning horizons that are adequate for each type of plan update. One possibility is to reduce the frequency with which the figures are altered, for example replacing weekly planning with exception-based planning. It is possible that companies end up in this location due to frequent and abundant information sharing practices. A common solution is to select the most beneficial and useful information and ignore the rest (Simchi-Levi et al., 2003). This, however, requires skilled analysis of the information sources to identify the most useful part of the available information for each supply chain decision. Using too many information sources may confuse the decision maker. This situation has been discussed in the literature, for example by Disney et al. (2004), Hong-Minh et al. (2000) and Steckel et al. (2004).

The other option in the upper left quadrant is to increase execution flexibility. This may be achieved by investing in flexible production capacity, for example by utilizing subcontractors and contract manufacturers, as many electronic product manufacturers have done. In many cases of process-type production, this movement is not possible, or it is a far too costly solution.

The second mismatch location is in the lower-right quadrant. Here the companies are maintaining production capacity or inventories that are not required or utilized to satisfy customers, and these can be considered as *slack resources*. These companies can either make changes in physical operations, or adopt more volatile and demand-responsive planning. Changes in physical operations should be considered if savings can be achieved by reducing inventories or changing to a cheaper and less flexible production system. The latter alternative means capturing demand information closer to the end-customer and creating processes to align to those signals. These issues are widely discussed in literature in the context of the value of information sharing (for example in Cachon and Fisher, 2002; Yu et al., 2001; Zhao et al., 2002).

6. DISCUSSION

The framework provides a new viewpoint on the literature that addresses the issues of information sharing and its impacts on supply chain performance. Many writers suggest that information sharing improves performance, but the costs or resources associated with information sharing are not considered (i.e. Kulp, 2002, Li et al. 2002, Yu et al. 2001). Another frequently repeated view is that information should be ubiquitous; supply chain parties should have full visibility and all information should be made available (Simchi-Levi and Simchi-Levi, 2002). This study challenges these statements and suggests that the level of information sharing should be selected to match the flexibility needed.

In information-sharing literature, information is assumed to be of high quality (for example, Lee et al., 2000; Gavirneni et al., 1999). In reality, there may be problems with information availability and accuracy, and this will have an effect on supply chain performance (Petersen, 1999). This paper suggests that the effect of poor information quality and limited access to information can be reduced by targeting information sharing and planning resources and planning efforts towards those situations and products that require them most.

In organizational research (for example Galbraith, 1977) it is stated that effective organizations fit their information-processing capacities to the level of information they have. The framework presented here supports this basic principle. It suggests that ways should be found to utilize the scarce and expensive planning resources efficiently. In addition it helps to identify whether there is a need to increase or decrease the amount and frequency of information sharing or planning resources. It also helps to identify when changes in physical operations should be considered.

The best way to choose a suitable supply chain strategy according to demand and product features has been investigated in several studies. These studies, for example Fisher (1997), Lee (2002), Li and O'Brian (2001) and Wong et al. (2006), have classified product and demand features and selected different types of supply and demand chains to match these features. This paper adds a new dimension to this stream of literature, by suggesting the need to consider supply chain *planning* solutions to support different supply chain features.

This study has several limitations. The framework was tested with two cases, which were not originally designed for this purpose. A further limitation is connected to the measures of material flow and information flow, it is not defined how exactly the variables are measured.

7. CONCLUSIONS

This paper presents a framework for the selection of a supply chain planning approach according to supply chain flexibility. The framework addresses the question of how companies should design information gathering and information flow to meet their information needs, and how to benefit most from shared information in decision-making. Incorporating an adequate level of information sharing into the coordination mechanism is the central idea in this research. Investment in information technology makes real-time information available and feasible. The profitability of the investment should be ensured by selecting a level of information sharing that improves decision-making and supply chain performance. Supply chains are formed of companies from different types of industries with different clock-speeds (Fine, 1998). When such companies share information, the frequency of information sharing and the ability to react to that information may not match. For example, capacity-intensive industries are not capable of responding to the requirements of consumer product producers.

Companies with large product portfolios should differentiate their planning modes in order to improve the use of planning resources. A high level of execution flexibility is required for products with volatile demand or in some special situations, such as the introduction of new products. According to the volume of information – execution flexibility framework, each level of execution flexibility should be supported by an appropriate level of information sharing, and planning frequency. The planning level should be adjusted according to the product needs.

Two main reasons for imbalance between the volume of information shared and execution flexibility were identified. Frequent plan updates according to demand changes caused planning nervousness. Other factors contributing to the phenomenon are varying planning processes, delays in information flow, multiple decision-making phases, unsynchronized planning calendars, and long planning horizons. These cause bullwhip-effect and large volume changes at the supplier. Planning nervousness can be reduced by stabilizing planning and synchronizing information sharing with upstream and downstream players to ensure that decisions are based on the freshest available data. It was also found that rapidly responding supply chains require more integrated planning and frequent information sharing.

In further research the framework presented in this paper needs to be further elaborated. Especially the measurement of variables along the axis was not touched in this research. Exactly what are the features of information flow and material flow, and how they can be measured deserves more attention. Additional case studies would be valuable to ensure generalizability of the framework.

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