Kaipia, R., Kallionpää, S. (2007), Exploiting VMI to increase flexibility in packaging material supply, International Journal of Production Economics, in review.

Exploiting VMI to increase flexibility in packaging material supply

Riikka Kaipia, Santtu Kallionpää
Department of Industrial Engineering and Management
Helsinki University of Technology

Abstract

This paper discusses how flexibility can be increased in packaging material supply. Case study results indicate that by improving supply chain planning with superior information sharing practices, an increase in flexibility can be achieved even in a nonflexible production environment. Decision making in production planning was improved because of shortened planning horizons and greater accuracy of data. The results revealed that too precise a response to a demand signal impedes VMI supplier's benefits. The value of flexibility was measured as the relationship between costs and reduced lead-time. This paper provides empirical evidence how a VMI supplier can better match its operations with demand.

Keywords: *flexibility, supply chain, VMI, information sharing, supply chain planning, case study.*

Introduction

Collaboration based on communicating demand and inventory visibility is essential to improve the supply chain performance (Lee et al. 2000, Chen et al., 2000a and Chen et al., 2000b). An increasingly popular way to start building a more effective supply chain is through collaboration in replenishment and inventory management (Buzzell and Ortmeyer 1995, Clark and Hammond 1997, Waller et al. 1999). Vendor Managed Inventory (VMI) has become popular, following the success of industrial examples from top retailers in the grocery sector. VMI has also been implemented in the supplier-manufacturer relationships.

Two factors are adding challenges for the VMI-supplier within the context of the information that the supplier receives. Demand fluctuations tend to amplify towards the upstream part of a supply chain, a phenomenon referred to as the bullwhip effect by Lee et al. (1997). The demand that the suppliers face has been modified and batched in the supply chain planning and decision-making phases, for example in production planning. The second reason is that plans and forecasts are communicated more frequently and accurately to suppliers, because of improved information sharing in the supply chain. This practice may provide suppliers with varying and inaccurate data, as plans are updated frequently. This causes pressure on suppliers to increase flexibility, and better match their operations with demand.

Despite the more efficient information-reach, the manufacturing environment has undergone little change (Das and Abdel-Melnyk 2003). Many suppliers are struggling in a situation where production economics require large production batches to fulfill production capacity efficiently, while trying to respond to downstream demand. Traditionally, raw material and packaging material inventory-buffers are used to level the impact of suppliers' long lead-times (Baganha and Cohen 1998). These inventories are often over-sized buffers against demand uncertainty. For example, for packaging materials, the economics-of-scale at the supplier is the primary reason for buffering.

The justification of buffering for packaging materials is no more valid for two reasons. It is not uncommon that these inventories become obsolete, because changes in packages take place more frequently. This means that at packaging material supplier the available production capacity has been misused. The second reason comes from the greater fluctuation in demand and increased competition. As changes in the industry sector take place more frequently, slow packaging supply, and lengthy throughput have become the main obstacles for renewing products.

In this case study-based research, we examine means to increase flexibility in a grocery supply chain, and specifically in packaging material supply. The manufacturer in our case is a confectionary producer that faces uncertainty from customers and from suppliers. These issues have been addressed by improving demand forecasting and by stocking packaging materials. Recently, incremental visibility has been offered to the suppliers to better anticipate demand. Exploiting this visibility is, however, challenging.

The purpose of this paper is to discuss how supply chain flexibility is affected by improved access to downstream information as realised in a VMI model. Through two empirical case studies, we examine factors that affect the exploitation of shared information in packaging material during production planning. By targeting on planning processes, we study mix flexibility, volume flexibility and new product flexibility, which represent different types of output flexibility (Sawhney, 2006).

The paper commences with a literature review of the VMI operations model, particularly from the viewpoint of benefits gained from information sharing, and, second, supply chain flexibility. The paper then progresses to discuss the methodology adopted in this research. Next, background information on the product manufacturer and the suppliers is given. Then, case results are presented. Finally, conclusions are presented and the study's contributions to theory are discussed.

Literature review

Vendor-managed inventory

VMI is a business model where supplier is authorized to make replenishments to customer inventory based on shared information. VMI eliminates one step in the information chain, and therefore reduces information distortion. Sharing inventory information enables the supplier to synchronise its own operations according to the customer demand, not customer orders, and ensuring a superior service level (Holmström, 1998, Daugherty et al. 1999, Kaipia et al. 2002). One advantage of VMI is reduction of bullwhip (Disney and Towill, 2003).

There are few examples of efficient utilisation of demand information in VMI relationships. Yu et al (2001) found that in a VMI relationship both the manufacturer and the retailer benefited in the form of lower inventory levels; the manufacturer benefits more than the retailer does. In relationships without replenishment collaboration only the manufacturer benefited. Ellinger et al. (1999) showed in a study of automatic replenishment programs, that to achieve logistical benefit requires a high level of involvement by the supplier. The main obstacle was *how* enterprises and their employees use available information to improve efficiency in warehousing, inventory management, purchasing, and production.

Empirical research results are scarce that describe how benefits from supply chain collaboration can be realised in production. According to Vergin & Barr (1999) only two out of ten manufacturers have been able to benefit from VMI in production. A recent study (Småros et al. 2003) used simulation to show that production loading and scheduling becomes increasingly level when there are more customers engaged in a VMI relationship. Waller, Johnson and Davis (1999) demonstrated how VMI can improve the customer service offered by a supplier without increasing production and inventory buffers. Their simulation shows how the improvement is possible when operations are controlled using the less variable demand of the retailer as compared to the more variable – often heavily batched demand - from a distribution centre. Furthermore, an empirical study (Kauremaa 2006) on VMI implementation could not show benefits for supplier companies in production planning, although other benefits from the relationship existed.

The research results on the lack of benefits from VMI is somewhat surprising, because multiple model-based studies have shown that information sharing along supply chains is beneficial for the overall supply chain performance (see for example Lee and Whang 2000, Gavirneni et al., 1999, Cachon and Fisher 2000). Studies that focus on suppliers, for example Gavirneni (2006), shows supply chain cost savings of between 1 per cent and 16.3 per cent when suppliers' know daily inventory levels of their customers. Not surprisingly some researchers emphasize connecting information sharing to practical and operational goals in order to make supply chain decisions more efficient (Li et al. 2005).

Supply chain flexibility

Supply chain flexibility can be considered at the levels of strategic, tactical, or operational flexibility (Stadtler 2005). In this literature survey, we concentrate on tactical and operational flexibility, which coincides with the levels we are considering using our VMI cases. Flexibility has been defined as the ability to react or transform with minimum penalties in time, cost and performance (Upton 1994). Flexibility is regarded as 'the ability to adapt to change or uncertainties' (for example in Vickery et al. 1999).

Manufacturing flexibility can be defined as the capacity of an organisation to adapt successfully to changing conditions, coming from inside the system as well as from the environment (Das and Abdel-Melnyk 2003). The definition includes the specific feature of manufacturing flexibility, which is the single-company perspective. The definition stems from internal and external reasons to create flexibility (Upton, 1994). Three different characteristics of flexibility that managers should consider are:

- *Dimensions of flexibility*: what exactly is the flexibility required for?
- *Time horizon*: what is the time horizon over which changes should occur?
- *Elements of flexibility* are range, mobility or uniformity. Range element means the ability to produce different sizes, volumes or variations of products. Mobility element is the cost or time that it takes to change between these range elements. The element of uniformity is the ability to produce similar results

within a range measured with some performance measure such as quality or yield.

Bertrand (2003) argues that flexibility stems from three sources. First, the variety of manufacturing technologies defines how large variety of different products can be made. Second, the amount of capacity available for production may limit the volume of products delivered to the market. Third, there is the inflexibility in the timing of production batches and infrequency of production that are often restricted by change-over or set-up costs. Inflexibility in timing and frequency of production leads to high inventories, and work-in-process, and, to long lead times of introducing new product variants. The third source is the most interesting source in light of the case studies in this paper.

Supply chain flexibility extends the concept of flexibility of manufacturing systems to the whole supply chain. Aprile et al. (2005) state that supply chain flexibility can be defined as process flexibility of each supply chain firm and logistics flexibility in the connections between these firms. Supply chain flexibility not only encompasses the manufacturing flexibility, but also the flexibility of different supply chain processes and functions (Vickery et al. 1999). Thus, when considering supply chain flexibility the manufacturing flexibility dimensions that take place at the plant level are of interest for each of the plants involved in a supply chain.

In a recent article (Sawhney 2006) discusses the competing uses of flexibility. It is argued that it is 1) a coping mechanism against uncertainty in the organisations internal or external environment, and 2) it provides a competitive advantage for companies. This dual role of flexibility is treated across the supply chain, from customers (output flexibility) to processes (process flexibility), and suppliers (input flexibility). Different types of flexibility are classified as depicted in Table 1.

Table 1. Types of supply chain flexibility.

Classification	Type of flexibility	Author(s)	Ability needed
Input flexibility	Supplier flexibility	Sawhney 2006	The responsiveness enjoyed by the firm to the desired changes in its raw material supply involving mix, volume, delivery time and new product/modifications
Process flexibility	Labor flexibility	Upton 1994, Sawhney 2006	The ability of the workers to handle a range of tasks
	Changeover flexibility	Pagell and Krause 2004	The ability of a manufacturing system to handle additions or subtractions to the product mix
	Modification or design change flexibility	Pagell and Krause 2004, Upton 1994	The ability of a manufacturing system to implement minor changes in current products
	Product flexibility	Vickery et al. 1999, Upton 1994	To produce customised products
	Equipment or machine flexibility	Upton 1994, Sawhney 2006	The ability of equipment to handle a wide range of operations
	Material-handling flexibility	Sawhney 2006	To accommodate changes and efficiently link different machine centers in the production system
	Input quality flexibility	Sawhney 2006	The ability of the production system to accommodate a range of input variations and conform a range of tolerances
	Expansion flexibility	Upton 1994, Sawhney 2006	To increase the capacity of the production system within the company's minimum planning period
Output flexibility	Distribution or access flexibility	Vickery et al. 1999	To spread products to the market
	Responsiveness to the market	Vickery et al. 1999	To meet or exceed customer requirements
	Volume flexibility	Pagell and Krause 2004, Vickery et al. 1999, Upton 1994	To increase and decrease production in response to customer demand within the minimum planning period
	Mix flexibility	Sawhney 2006, Uoton 1994, Pagell and Krause 2004	To produce a wide range of product lines within the minimum planning period
	New product flexibility	Vickery et al. 1999, Sawhney 2006	To introduce many new products and product varieties within the minimum planning period
	Delivery flexibility	Pagell and Krause 2004	To shorten or lengthen delivery time

Internal flexibility dimensions describe the types of flexibility inside one plant, such as machine, labor, materials handling, operation and routing flexibility. These are not the primary focus of this paper, neither are flexibility types that focus on distribution or deliveries. Relevant flexibility dimensions at the supply chain level are, according to Bertrand (2003), volume, mix and new product flexibility. Vickery et al (1999) identifies two additional flexibility types of customer focused supply chains. Access flexibility means the ability to spread products to the market. The other type of flexibility is responsiveness to the target market.

Based on the classification in Table 1, Sawhney (2006) presents a framework on exchange of flexibilities along the supply chain, between the above mentioned input stage, process stage and output stage. The framework expands the single-company perspective by considering the feedback loops in the supply chain. Sawhney (ibid) suggests that flexibility can flow both upstream and downstream, and supply chain partners are transferring flexibility, and uncertainty, to their suppliers and customers as companies are optimising their own profits.

Notable in the classification in Table 1 time-related flexibility types, for example those concerning timing or time horizons in planning, are not visible. An example of a timing flexibility study is a modelling exercise where it is shown how the type of demand process to which the supply chain is responding influences the value of quantity and timing flexibility. Timing flexibility is of most value in the standard demand case. The value of quantity flexibility was at its greatest when demand was volatile. When demand was evolving, the value of quantity flexibility depended on supply lead time: The value was high when lead times are short, and low in the case of long lead times (Milner, Kouvelis 2005).

One additional study is treated here because it investigates the impact of different demand types on flexibility. Aprile et al. (2005) address supply chain flexibility by focusing on process and logistics flexibility. They study different supply chain configurations under demand variability and production capacity uncertainty in a model-based study. They show an interesting finding: the higher the demand uncertainty, the more beneficial is flexibility at the supplier level. This means that process flexibility at the supplier stage allows higher demand uncertainty to be faced without sacrificing supply chain efficiency.

Gaps in the literature

Two significant knowledge gaps are identified in the literature. Flexibility literature has traditionally considered manufacturing flexibility and, consequently, knowledge on supply chain flexibility is not yet as extensive. Few empirical studies focus on this issue. We studied two modeling-based researches: specifically, Aprile et al. (2005) treats flexibility in a supply chain and Sawhney's (2006) research is based on observations from a field study. However, studies on the impact of efficient demand communication on supply chain flexibility are rare. When considering VMI-literature, it is noticeable that solutions for suppliers on *how* to benefit from the incremental VMI visibility are not offered.

In the flexibility literature, time related issues are not totally ignored but studied to a lesser extent. Upton (1994) states that the time horizon under which adaptations to changes should occur should be considered. Bertrand (2003) discusses the effects of transfer delays, set-up times and batch sizes on throughput time and concludes that these reasons may seriously decrease the benefits of other flexibility types. In Sawhneys (2006) paper, planning period lengths are treated as one attribute in defining volume flexibility, mix flexibility, new product/modification flexibility, and expansion flexibility. However, supply chains have to react to significant changes within an appropriate time frame to ensure their competitiveness. The question of *how* information sharing frequency, planning cycles and planning horizon affect flexibility is not treated.

Methodology

Research question and research methods

Our research concerns the increased requirement for flexibility in the supply chain. The research question is: *How can VMI information sharing practice be exploited to promote more flexible upstream operations?* The objective of this research is to empirically examine different solutions to increase flexibility and explain with situational factors the applicability of each solution for companies.

The research was carried out as an empirical two-case study, where we seek ways to increase flexibility and to improve production decision making in packaging material supply. We address different solutions in our cases to increase flexibility, and measure the costs and benefits of each solution. First, the analysis focuses on what flexibility is required for; as was suggested in Upton's (1994) paper. Then we study which types of flexibility can be affected by the VMI information sharing practice.

The cases are based on two separate studies conducted during the years 2005 and 2006. The end-product manufacturer wanted to investigate possibilities to shorten packaging material lead-time. Project teams in both cases consisted of 5 to 6 people from the end-product manufacturer, and 2 from a 1st tier supplier, and two researchers. Researchers were responsible for the current-state analyses: specifically, data collection, interviews and data analyses, and analyses of case results. In pilot projects the responsibility of implementation was given to the participating companies.

Both studies followed the same pattern. First, a current state analysis was carried out in the form of numerical analyses and interviews. Second, developmental action plans and targets were chosen. Third, pilot projects were implemented and the profitability of the proposed actions was analyzed.

The paper examines a supply chain consisting of an end-product manufacturer, and two packaging material suppliers, referred to as Alpha and Beta. Both suppliers operate in a vendor-managed inventory (VMI) mode. Also, second tier suppliers' and distributors' operations are examined. The benefits of each change are measured using the impact on lead time, changes on planning horizon and accuracy of used information.

Collecting and analyzing data

In the first study with supplier Alpha, data concerning demand, confectionary production, finished goods inventories, packaging material inventories, and packaging material production were collected from the time-period of the first nine months of the year 2004. Data was collected from three supply chain phases, customers, the manufacturer, the packaging material supplier, and the data concerned both forecasts, and actual goods flow. To understand the operative and planning processes, altogether eleven (11) key persons were interviewed in the two companies, representing production, production planning, forecasting, purchasing and order handling. The purpose of the interviews was to map the current practices regarding the goods flow, data flow, and planning processes along the supply chain.

Numerical analyses on four supply chain phases were carried out. In initial state, a large group of products were analysed. Approximately 50 products were reviewed to create understanding on the dimensions between supply chain phases. Detailed analyses were carried in one product group, consisting of 5 products. The analysed chain consisted of three manufacturing phases (confectionary production, packaging production, and raw material production), packaging material inventory, finished goods inventory, and distributor operations. Demand forecast accuracy was investigated, in addition to production planning accuracy and planning nervousness. Packaging material inventory levels were analyzed. The data for the analyses was accessed from the OEM data systems and from the supplier production planning systems. The studied supply chain is illustrated in Figure 1.

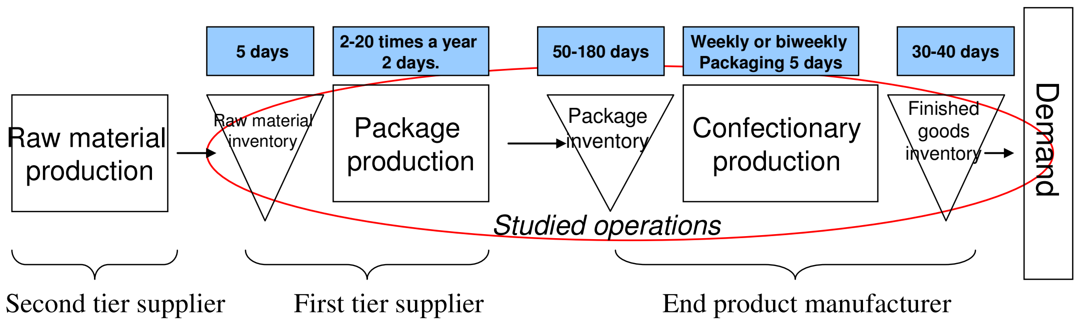

Figure 1. Studied supply chain in Case 1.

In the study with supplier 2, Beta, the workflows, and demand-supply processes between the manufacturer and the packaging supplier were analyzed. In addition, the operations, production cycles and information delays concerning a second-tier supplier, a cardboard manufacturer were studied. Altogether, 12 people were interviewed in three companies. The studied supply chain is illustrated in Figure 2.

Numerical analyses were carried out concerning demand forecasts, production plans and inventory levels. The end product forecasts were investigated in comparison to realized demand. End product demand, forecast data and stock levels were analyzed statistically and in a simulation model concerning 13 products. The production plans were compared with realized production. Based on the results, a pilot project with a four-step action plan was established: namely, the package production batch size was redefined, information sharing between three supply chain levels were synchronized, the possibility for raw materials cardboard warehousing was examined, and the warehousing system between the manufacturer and the packaging supplier was improved.

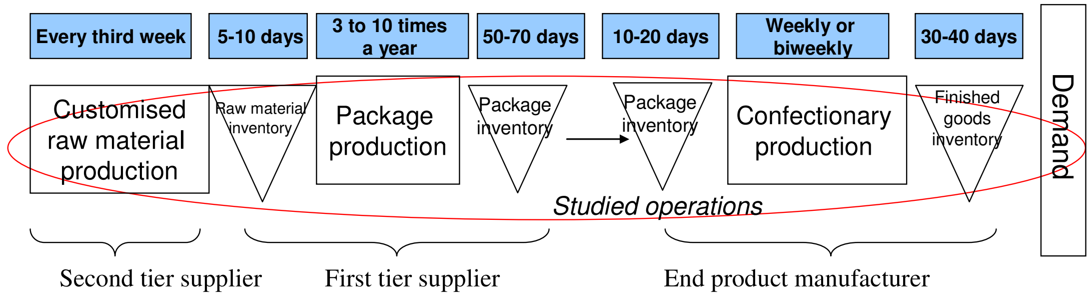

Figure 2. Studied supply chain in Case 2.

Case setting

End-product manufacturer

The manufacturer is a Scandinavian chocolate and sugar confectionary producer. The company produces to stock in a batch production mode in five plants. Their principal customers are distributors and wholesalers in Scandinavia, who deliver the goods to retail stores and other customers. The manufacturer also produces special export products for tax-free sales and other export customers. Finished goods inventory is used to level the gap between batch production and consumption.

The initiative to study packaging material supply came from the confectionary manufacturer. Packaging materials supply is challenging for many reasons. Packaging is an essential part of the product in the confectionary business, and the case company's strategy is to offer its products in attractive packages with high-quality printing. Changes in packages are common due to marketing requirements, offering the products to new geographical markets, or legal changes, and seasonal products are offered in special packages. The packaging industry is capacity-intensive with a strict requirement for capacity usage rate. The difficulties in managing packaging materials lead to obsolescence problems; on average 2 per cent of the value of package materials become obsolete in the case company.

The manufacturer has developed a monthly collaborative forecasting process, which produces a demand forecast for 52 weeks. Production planning is supported by enterprise resource planning (ERP) systems, but the final decisions and schedules are carried out manually. The production planner takes into account demand forecasts, inventory levels, production optimality in the form of production order and batch size, use of personnel, and production breaks. The confectionary manufacturer offers production plans weekly, and packaging material-inventory status daily to its suppliers through a supplier-portal.

The initial motivation for this company to study packaging material supply was the long lead-times of packages, which was a problem especially in new product introductions. The company wanted to study possibilities to improve the match between packaging supply and demand. The need concerns mostly special situations, where demand is difficult to predict.

The suppliers

The differences in supplier operations are presented in Table 2. Both supplier companies receive similar information from the manufacturer. Beta is dependent on the cardboard producer's production schedules and order timetables, which makes the planning horizon longer. Therefore Beta has to make decisions on the basis of more inaccurate information than Alpha.

Table 2. Situational factors of the two suppliers in cases.

	Alpha	**Beta**
Dependency on 2nd tier suppliers	Low, upkeeps raw material inventories and cardboard supply is flexible.	High, dependent on cardboard manufacturing schedules, delivery time varies between 2-6 weeks.
Planning horizon for package material production	2 to 4 weeks, shorter if needed.	8-12 weeks.
Access to demand info (to manufacturers production plan)	Each week freshest plans available, planning focus on 2-8 weeks plans	Each week freshest plans available, planning focus on 10-24 weeks plan
Implemented changes	Production close to need Smaller production batches.	Smaller production batches Synchronized planning Cardboard inventory for metal coated products Simplified inventory

Supplier 1, Alpha

Alpha is a corrugated cardboard manufacturer, whose production is divided into two phases: processing the corrugated cardboard, and refining; which is divided into cutting and printing. Production throughput time is 1 to 2 days. The supplier operates on customer orders, and delivers directly from production to customers. The supplier produces even 10000 product variants, each tailored to the customer. The supplier has several VMI-customers, whose deliveries represent less than 10 per cent of production volume. Alpha upkeeps raw material inventories for most of its raw materials. Alpha provides 250 different packaging materials for the confectionary producer.

Production planning at Alpha takes place in two phases: first, the deliveries are scheduled according to customer needs and production requirements. Planned delivery times are communicated to customers according to this plan. Typical delivery time for the customers varies between 2 to 3 weeks. The detailed scheduling of production may happen very close to execution, even only a few hours before production. The main factors that direct the production planning are capacity usage, optimality in production, and customer needs.

Two factors affect the flexibility in Alpha's production. First, Alpha is not dependent on raw material suppliers, because it stocks the primary raw materials. Second, the production-planning horizon is short. The planning schedule allows the supplier to accept express orders under certain conditions. These are delivered within a few days.

Alpha's goal in this study was to improve the quality of shared information and to test the ability to synchronize production with demand.

Supplier 2, Beta

Beta produces customized carton packs for grocery, beverage and tobacco products. The main processing phases are printing, folding and cutting. For the case manufacturer the supplier produces packages to be stocked in its own inventory, from where deliveries are scheduled according to customer needs. Production set-up times are long, forcing the packaging material supplier to produce in large batches. Additionally, the supplier is dependent on the availability of product-specific cardboard sheets or rolls from 2nd tier suppliers. These suppliers obey a strict three-weeks´ production schedule with a dynamic closing date (depending on the total quantity of incoming orders) for each production batch.

In the studied supply chain, the whole process from the order of product-specific cardboard until finished goods inventory, takes 130-170 days. Moreover, there are long planning horizons in the process. The packaging material Order Planner schedules the next production batch 8 to 12 weeks in advance. The demand forecast, which this decision is based on, extends to weeks 24-26. The planner suffers from data inaccuracies and uncertainty in planning.

The Order Planner at the packaging material supplier is in a challenging decision-making situation each time a production batch is scheduled, and faces uncertainty from both upstream and downstream. Average lead-time for *ordinary* cardboard varies from 3 to 5 weeks. In the metal-coated cardboard product, the lead-time is approximately two weeks longer due to the metal coating process.

The analyses and simulation results revealed that the production forecasts did not reflect the same inaccuracies as the demand forecasts. Furthermore, it was seen that the uncertainty in production forecast was not causing the supplier and manufacturer to maintain high packaging material stock levels. Both package material and finished goods inventory levels were pushed up by the production process requirements**.** Current finished goods stock levels are oversized to satisfy the fluctuations in demand.

The motivation for Beta to join in this study was improving planning and shortening the planning period in production planning without risking capacity usage rate. The second reason was to utilize visibility to increase freedom in decision making. Currently Beta is dependent on downstream and upstream players' timetables.

Case results

Cases were established as pilot projects upon completion of the structural and numerical analyses of the supply chain.

Case 1, Supplier Alpha

Synchronizing supplier's production with end product production

The current state analyses revealed that Alpha's production batch sizes are 3 to 10 times larger than end-product batches. Analysis also showed that package material inventories were large and the level could be lowered without risking service levels. For these reasons the pilot project at Alpha targeted on synchronized operations between these two production processes. This change became possible due to improved visibility to downstream plans implemented in VMI.

The goal of this pilot project was synchronizing Alpha's production, according to the downstream production plan. The supplier decreased batch sizes and scheduled production close to end-product production. The change resulted in radically reduced inventories. However, demand features affected the result. Products with variable, but low, demand did not reach set target levels. The inventory levels for products with constant demand dropped almost to one-third of the previous figure.

This case showed that flexibility can be increased in upstream operations through the efficient use of visibility to downstream plans. Two flexibility types, timing flexibility and volume flexibility were affected. Even through the product group was highly challenging for the packaging material supplier, it was possible to plan and execute the production batches very close to need. However, the operations model proved to be too tight for two reasons. First, high capacity usage is extremely important for corrugated cardboard producers, and, second, maintaining high quality is difficult in small production batches.

In the second phase of the pilot project, the supplier decided to shift the production focus somewhat and produce more infrequently in larger batches and to leave a safety time between delivery and need. Combined production batches for a product group could be formed, which reduced the number of changes and production costs as well. The supplier could take advantage of shared information to form efficient production batches. Also the product quality improved. Planning was simplified, as the impacts of forecast changes in supplier production planning can be eliminated with the use of a safety-time between planning and execution.

The case illustrated that the full benefit of shared information can be realized only if the supplier has the freedom to schedule deliveries. In other words, the supplier should have timing flexibility to exploit the shared information. It was noted that if the VMI-supplier wants to deliver very close to need, it is not possible to efficiently use visibility in production planning and execution. In this case the suppliers' ability to provide volume flexibility was limited due to high set-up costs and quality issues.

Case 2, Supplier Beta

In case two, several improvements were suggested and studied in pilot projects. First, the possibilities to reduce production batch sizes were investigated, and second, information-sharing practices were studied. The third pilot project targeted on adding a new raw material buffer inventory in order to shorten planning horizon. The last change simplified warehousing practices.

Decreasing production batch size

Under study was the impact of reducing supplier's batch size to correspond to two months demand. Prior to the pilot project, the batch size was set equal to three months demand of the end-product manufacturer.

This change affects the production planning. Before the pilot project, the package manufacturer's production planner had to deal with demand forecasts of 16 weeks. If the production batch size was reduced, the Production Planner needs to deal with 12 weeks demand forecast, which is 5-15 % more accurate.

In this pilot, the supply chain becomes more reactive. With the lower packaging stock levels, for example, changes to the packages can be made with shorter lead-times and the probability of obsolescence costs will be lower.

Decreasing the package production batch, increases the package manufacturer's cost per package by approximately 9 per cent principally due to batch-specific set-up costs. The impact on throughput time is a reduction by 30 days. In this case, the obsolescence costs of the investigated packages over one year were higher than the extra cost of a smaller production batch would have been.

Synchronized information sharing practices in the supply chain

The next pilot project targeted improved decision-making, by synchronizing information sharing and operations between the studied three phases in the supply chain. The change stabilised information sharing practices, and sought for the optimal moment to place an order for raw materials from 2nd tier suppliers. This order is essential, because it defines both quantity and timing of the next production batch.

To identify the latest possible moment for placing the order on the cardboard manufacturer's next production batch, the communication between the parties had to be improved. The new process is presented in Figure 3. The end-product manufacturer updates its production plan in a weekly process and it is available for the suppliers every Thursday. In the pilot project, the cardboard manufacturer was requested to deliver information on the free capacity of its next production batch on the same day. The order is based on the freshest available information, or the decision is delayed until next week.

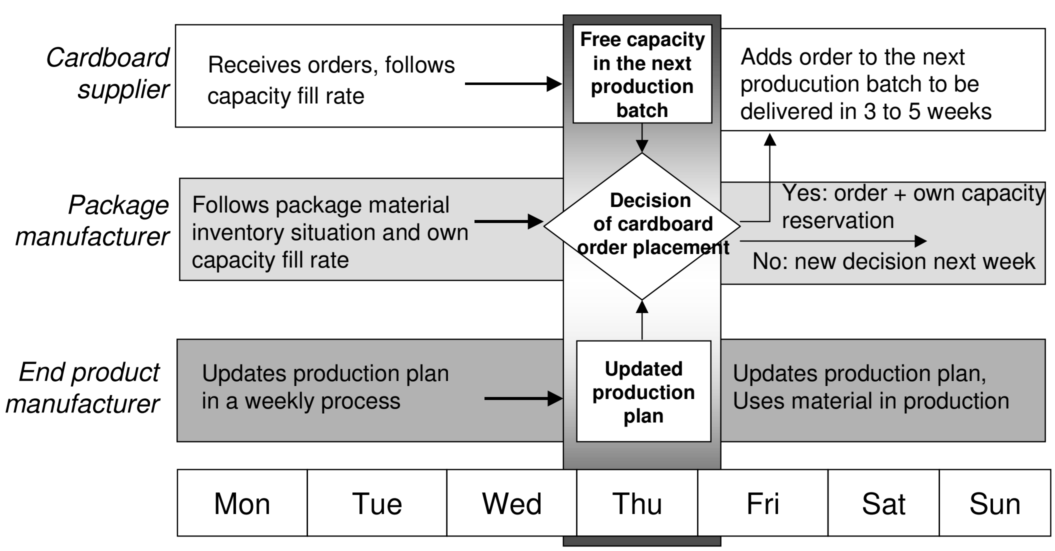

Figure 3. Cardboard order decision based on the most precise information available.

This weekly decision concerns the exact size and timing of the production batch. These are locked-in at the moment the cardboard order is placed. There is however another decision to be made, the exact amount of each package variation in the production batch. As the numerical analysis had revealed, the aggregated forecast was more precise than the product variation level forecasts. This is why the decision concerning the exact amounts of the package variations should be delayed until the latest possible moment. Just before the package production the supplier can base the decision on more accurate data. This adds mix flexibility by allowing more accurate response to demand.

This synchronized decision making utilizes freshest information both from downstream and upstream, and shortens total throughput times in package material supply from 11-12 weeks to 8-9 weeks with no additional costs.

Cardboard buffer for special packages

The demand of the end-products using the metal coated packages is most difficult to forecast. Also, the throughput time of the metal coated packages has been the longest, because of the multi-phased manufacturing process, long capacity reservation times and cardboard lead time. Therefore managing these products has been challenging.

In the new model, cardboard is kept in stock for metal coated packages. The metal coating can be done only when the production day of the packages is known, because the package quality suffers from long stocking times. Therefore a tentative capacity reservation is completed for the subcontractor a few weeks before, and the final order is placed only when the production batch size and timing have been decided (based on an end product production plan). The metal coating process takes two weeks, and afterwards, or even during this process, a decision of different variables in package production can be made.

Presently, the production decision of metal-coated packages can be made approximately two weeks before the need. The cost of this set-up is the cost of the new buffer. Total throughput time can be shortened to 8 weeks. This is a considerable improvement, since these packages have been very difficult to manage due to a lengthy material lead-time.

Simplified stocking of packaging materials

In the current-state analysis, it was found out that customized packaging materials were stocked at the supplier, and deliveries were decided in a weekly planning round according to downstream need. In this situation, the packaging material stocking was distributed as follows: inventory for two weeks demand was kept in the manufacturer's facilities and the remainder of the packaging materials (corresponding approximately to10 weeks´ demand) was warehoused at the packaging manufacturer. The pilot project's objective was to combine these two separate inventories to achieve operational benefits and to reduce inventory levels.

Through this pilot, all existing package materials can be seen in the end-product manufacturer's ERP system, which increases flexibility in production planning. Due to this improved visibility the production planner has more freedom to respond to demand changes and to manage the finished goods inventory more accurately.

Results indicate that the throughput time of the packages can be shortened and duplicate work could be eliminated by combining the two warehouses. The weekly planning process of the package material supplier was no longer needed. This also meant that the end-product manufacturer was able to make changes in its production plans flexibly, because the total inventory can be monitored in its production planning system. This pilot study did not increase the costs of the supply chain parties.

Summary of the case results

The results are presented in Table 3. The value of flexibility is described as reduced throughput time and the cost of incremental flexibility is estimated. In case two were found ways to increase flexibility without adding costs to the system.

Table 3. Achieved flexibility and costs from cases.

		Achieved increase in flexibility		***Costs of the increase in flexibility***		
	Case	*Description*	*Throughput time reduction*	*Description*	*Costs*	*Estimated annual costs*
Synchronized production	1	Reduced inventory level	30-40 days	Production batch costs rise due to set up costs	N/A	N/A
Smaller production batches	2	Shorter throughput time, reduced inventory level	30 days	Production batch costs rise due to set up costs	Appr. 9 % cost rise per package	3000-4000 e
Synchronized planning process	2	Eliminating delays, more accurate decision making	0-20 days	Creating routines in decision making and information sharing	No additional costs	0 e
Raw material buffering	2	Shorter throughput time	20-30 days	Inventory risk from the new buffer	Costs of the new buffer	500-1000 e
Simplified warehousing practice	2	Simplified operations, reduced inventory level	15-25 days	Risk of warehouse overloading	No additional costs	0 e
Total Case 1 *Total Case 2*			30-40 days 65-105			N/A 3500-5000 e

Improved planning and decision making increases flexibility, more specifically timing flexibility and mix flexibility. Volume flexibility can be increased only to a limited manner, because it suffered most from the inflexible production and long planning horizons. New product flexibility can be best affected by smaller production batches at the supplier, but this change proved to be expensive. Responsiveness to the target market was improved by several ways in Case 2. However, the total throughput time remains relative long.

Conclusions

The principal similarity of the two suppliers was the requirement for high capacity usage rate and high set-up costs, which favor large production batches. In addition to quality problems, this is the main explanatory factor for not implementing smaller and more frequent production batches. However, smaller batches would bring benefits in the supply chain in the form of lower inventories and shorter total throughput time.

Furthermore, the decision-making frequency concerning each product would be increased, which allows matching supply better according to demand. These benefits increase the overall attractiveness of these changes. The dimension of flexibility that this change affects most is the lead-time of introducing new products or product variants. However, with current inflexible packaging material machinery, production batch reduction can be used only in a limited manner to increase supply chain flexibility.
Conclusion 1: Process flexibility can be affected only to a limited extent through more efficient information sharing, particularly when capacity usage rate is kept high. Packaging material production processes and machinery should be developed to allow efficient production in small batches.

In case 1 it was remarked that the products with variable and low demand were more difficult to manage: they caused the most problems in the supply chain. These products suffered most from the current inflexible planning practices. In Case 2 a new upstream buffer stock for a product with variable demand brought valuable benefits.
Conclusion 2: Upstream buffers can be used to increase flexibility when dependency on suppliers is high and when demand is variable.

In both cases the suppliers are serving a batch-type production process. To benefit from the shared information, it was essential that the suppliers received production plans from downstream.
Conclusion 3: In a VMI relationship with variable demand, inventory level information is not adequate, additional information on forecasts or production plans need to be shared.

Suppliers' production planning faced many constraints, especially in Case 2. In Case 1 it was studied that matching package material production close to need, limited the production planning freedom at the supplier.
Conclusion 4: To benefit from shared information requires timing flexibility in decision making.

The confectionary manufacturer shares information to its suppliers on inventory levels and production plans. On the basis of this information the suppliers are expected to keep the service-level high. Many physical constraints are limiting the suppliers' ability to benefit from the frequent information sharing practice. The most successful pilot projects were those that targeted on improving planning and shortening planning horizon.
Conclusion 5: Flexibility can be increased by developing planning processes. Decision-making can be improved by synchronising information sharing and decision making practices to benefit from the freshest and most accurate plans possible.

The value of flexibility was measured by comparing costs to the achieved reduction in lead-times. In the cases under study, the manufacturer did not accept any additional costs from increased flexibility, which means that it chooses to create supply flexibility from the packaging material inventory. In a constant demand case, and for products in maturity phase, this is an appropriate solution. However, this does not add flexibility for new product development or modification, nor does it add responsiveness to the market.

Conclusion 6: Without agreement on the sharing of costs, no increase in flexibility can be achieved, when the division of benefits and costs from development activities is not even.

Discussion

It can be stated that the VMI information sharing mechanism is transferring uncertainty towards the supplier, as was suggested by Sawhney (2006). To be able to benefit from VMI, the suppliers ought to develop such flexibilities that can exploit the visibility. It was noticed that to benefit from shared information the supplier needs to have freedom in decision-making. In this paper the constraints that prohibited the supplier from benefiting from visibility were connected to production capacity usage and planning horizon.

This study contributes to the flexibility literature by addressing planning processes. In an environment with nonflexible production it was indicated that flexibility can be increased by targeting planning and information sharing practices. Suppliers with long planning horizon are less able to benefit from visibility. Shorter planning horizon allowed the decision-maker to use more accurate information.

In efforts to gain greater supply chain integration, companies from different industries with different clock-speeds share information and seek ways to synchronise operations. Frequent downstream information sharing as such do not solve the problems connected with capacity usage, production planning or raw-material lead times. Through the cases was pointed out difficulties in targeting process flexibility.

In further studies, supply chain planning processes could be investigated from the point of view of uncertainty. The many roles of planning and decision-making could be studied, for example planning as a source of uncertainty, a receiver or shaper of uncertainty, and a provider of flexibility. Additionally, in this study the impacts of different demand patterns and demand predictability were only considered briefly. How to target flexible supply chain solutions or flexible capacity towards those products and those life-cycle phases of a product that require flexibility most would be an interesting research issue.

References

Aprile, D., Garavelli C., Giannoccaro, I., 2005. Operations planning and flexibility in a supply chain. Production Planning and Control, 16 (1), 21-31.

Baganha, M.P., Cohen, M.A., 1998. The stabilizing effect of inventory in supply chains. Operations Research, 46 (3), 72-83.

Bertrand, J.W.M., 2003. Supply chain design: Flexibility considerations, In: de Kok, A.G., Graves, S.C., (Eds.). Handbooks in Operations Research and Management Science, Vol. 11. 2003, Elsevier.

Buzzell, R., Ortmeyer, G., 1995. Channel partnerships streamline distribution. Sloan Management Review, 36 (3), 85-96.

Cachon G.P., and Fisher, M., 2000. Supply chain inventory management and the value of shared information. Management Science, 46 (8), 1032-1048.

Chen, F., Drezner, Z., Ryan, J.K., Simchi-Levi, D., 2000a. Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead-times and information. Management Science, 46 (3), 436-443.

Chen, F., Ryan, J.K. and Simchi-Levi, D., 2000b. The impact of exponential smoothing forecasts on the bullwhip effect. Naval Research Logistics, 47 (4), 269-286.

Clark, T.H., Hammond, J.H., 1997. Re-engineering reordering processes to improve total supply chain performance. Production and Operations Management, 6 (3), 248-265.

Das, S.K., Abdel-Malek, L., 2003. Modeling the flexibility of order quantities and lead-times in supply chains. International Journal of Production Economics, 85 (2), 171-181.

Daugherty, P.J., Meyers, M.B. and Autry C.W. "Automatic replenishment programs: an empirical examination" Journal of Business Logistics, Vol. 20, No. 2, pp. 63-82.

Disney S.M., Towill, D.R. 2003. The effect of vendor managed inventory (VMI) dynamics on the bullwhip effect in supply chains. International Journal of Production Economics, 85 (2), 199-215.

Ellinger, A; Taylor, J and Daugherty, P., 1999. Automatic replenishment programs and level of involvement: Performance implications. International Journal of Logistics Management; 10 (1), 25-36.

Gavirneni, S., Kapuscinski, R., Tayur S., 1999. Value of information in capacitated supply chains. Management Science, 45 (1), 16-24.

Gavirneni S., 2006. Price fluctuations, information sharing, and supply chain performance, European Journal of Operational Research, 174 (3), 1651-1663.

Holmström J., 1998. Implementing vendor-managed inventory the efficient way. Production and Inventory Management Journal, 39 (3), 1-5.

Kaipia, R., Holmström J., Tanskanen K., 2002. VMI: What are you losing if you let your customer place orders?, Production Planning and Control, 13 (1) 17-25.

Kauremaa, J., 2006. VMI-operating model: a comparative study, Licentiate's Thesis, Helsinki University of Technology (in Finnish).

Lee, H.L., Padmanabhan, V., Whang, S., 1997. The bullwhip effect in supply chains. Sloan Management Review, 38 (3), 93-102.

Lee, H.L., So, K.C., Tang, C.S., 2000. The value of information sharing in a two-level supply chain. Management Science, 46 (5), 626-643.

Lee, H. L., Whang, S., 2000. Information sharing in a supply chain. International Journal of Technology Management, 20 (3/4), 373-387.

Milner, J. and Kouvelis, P., 2005. Order quantity and timing flexibility in supply chains: The role of demand characteristics. Management Science, 51 (6), 970-985.

Sawhney, R., 2006. Interplay between uncertainty and flexibility across the value chain: Towards a transformation model of manufacturing flexibility. Journal of Operations Management, 24 (5), 476-493.

Småros, J., Lehtonen, J., Appelqvist, P., Holmström, J., 2003. The impact of increasing demand visibility on production and inventory control efficiency. International Journal of Physical Distribution & Logistics Management, 33 (4), 336-354.

Stadtler, H., 2005. Supply chain management and advanced planning – basics, overview and challenges. European Journal of Operational Research, 163 (3), 575-588.

Upton D.M., 1977. Process range in manufacturing: an empirical study on flexibility. Management Science, 43 (8), 1079-1092.

Vergin, R.C., Barr, K., 1999. Building competitiveness in grocery supply through continuous replenishment planning: insights from the filed. Industrial Marketing Management, 28 (2) 145-153.

Vickery, S., Calantone R., Droge C., 1999. Supply chain flexility: an empirical study. The Journal of Supply Chain Management, 35 (3), 19-24.

Waller, M., Johnson, M. E., Davis, T., 1999. Vendor-managed inventory in the retail supply chain", Journal of Business Logistics, 20 (1), 183-203 .

Yu, Z., Yan, H., Cheng, T. C. E., 2002. Modelling the benefits of information sharing-based partnerships in a two-level supply chain. Journal of the Operational Research Society, 53 (4), 436-446.