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OPPORTUNITIES AND REALITIES OF SUPPLY CHAIN INTEGRATION: THE CASE OF FOOD MANUFACTURERS

Dirk Pieter van Donk[1,*], Renzo Akkerman[2] and Taco van der Vaart[1]

[1] Faculty of Economics and Business, University of Groningen, P.O. Box 800, 9700 AV, Groningen, The Netherlands. (d.p.van.donk@rug.nl, j.t.van.der.vaart@rug.nl)
[2] Department of Manufacturing Engineering and Management, Technical University of Denmark, Produktionstorvet 425, 2800 Kgs. Lyngby (Copenhagen), Denmark. (rak@ipl.dtu.dk)
* *Corresponding author*

ABSTRACT

Purpose
The purpose of the paper is to investigate the limitations and barriers for supply chain integration that food manufacturers experience and to highlight their planning and scheduling problems. Possible ways to cope with these are offered.
Methodology
The paper is theoretical/conceptual in nature: the findings are illustrated in an explorative case study.
Findings
It is often suggested that food supply chains are typical for what can be achieved in supply chain management. This paper challenges this belief by investigating the possibilities and limitations for supply chain integration for food manufacturers. We argue that a combination of typical food characteristics and the use of shared resources limit the possibility for integration, while uncertainties and complex business conditions increase the need for integration. In a case study, the paper explores alternatives to cope with that situation.
Limitations/implications
The paper is based on previous empirical work, which is applied and further developed in a case-study setting of a consumer product food manufacturer. We argue that the case has several generic characteristics, but further research is needed to test the main ideas in a wider context.
Practical implications
Production managers and planners in food manufacturing are often aware of the described situation, but general managers, marketing managers, and supply chain managers can learn that there are limits to aligning operations to customers. The paper offers a number of solutions that might assist production managers in better understanding their situation and thinking about improvements.
Originality/Value of the paper
The paper introduces buyer focus, shared resources and the limitations of supply chain integration into the field of food supply chains.

Keywords: supply chain management, supply chain integration, buyer focus, shared resources, food industry

INTRODUCTION

Supply chain integration is often described as the seamless flow of products and information from supplier on to customer. Food supply chains are among the often-quoted examples of reaching this ideal state. For instance, Hill and Scudder (2002) suggest that food supply chains are in the front line with respect to supply chain practices, coordination of the chain, and the use of concepts like EDI, VMI, QR and CPFR. Often referred showcases are in the grocery chain and many articles refer to Wall-Mart and Kmart (Schwartz, 2004) as being benchmarks for supply chain integration. There are also numerous papers suggesting the introduction of quick response (Whiteoak, 1999), CPFR (Fliedner, 2003), Category management (Hutchins, 1997), and other tools and concepts to improve the flow of goods and information in the food supply chain. It is evident that the supply performance of food manufacturers has increased over the last years, largely driven by the restructuring of the food sector (e.g. Duffy et al., 2003; Hendrickson et al., 2001). The initiatives of powerful retailers have resulted in reduction in inventories in their distribution centres while maintaining the same level of customer service. Exchange of information, use of category management, and cross-docking operations are among the most applied practices (Van der Vorst and Beulens, 2001). However, it seems that the reality for food manufacturers is less fortunate than the rhetoric of many papers and popular books suggest. For example, Morgan et al. (2007) state that practice of supplier involvement in category management is low "despite the widespread prescription" (p. 513). They also state that the literature offers few empirical studies on that subject. All in all it seems that the position of food manufacturers is relatively ignored in the literature.

In this paper the aim is to explore the specific problems of food manufacturers seeking supply chain integration. It is our contention that the characteristics of many food manufacturing companies limit the possibilities of, whereas the supply requirements from retailers increase the need for integration. This might be not too new for many practitioners, but, so far, has not been dealt with sufficiently in research. This paper aims at analysing the specific characteristics of and demands placed upon food manufacturers in the context of supply chain integration. In other words, we focus our analysis on the operational problems stemming from supply chain requirements. As a consequence , we will not provide an extensive review of the supply chain management literature. Further, we limit ourselves to food manufacturers that produce for consumer markets, although part of our analysis might be relevant for other food producers. Supply chain integration is defined as the mutual coordination within or across organisational boundaries (Stevens 1989). The main points of our study will be illustrated in a case study.

The paper is organized as follows. The next section will develop the theoretical background of the paper by linking previous work on supply chain integration to the specific characteristics of the food industry. The third section of the paper will elaborate upon the supply chain strategies as mentioned above. Then, we will introduce the case and subsequently, analyse demand, production and planning aspects of this case. The fifth section will pay attention to (re-)design alternatives. In the last section we will formulate our conclusions.

SUPPLY CHAIN INTEGRATION AND FOOD CHARACTERISTICS

In this section we outline the theoretical background of the research. We explore supply chain integration, food manufacturing, and in the third subsection, their relationship.

Supply chain integration

Over the last decade, different instruments and approaches to enhance supply chain integration have been investigated, mainly looking at the impact of supply chain integration on performance. So far, the influence of information systems (e.g., Vickery et al., 2003), the influence of operational practices (e.g., Frohlich and Westbrook, 2000), and the effect of simplifying the materials flow (e.g., Childerhouse and Towill, 2002) have been investigated. Others stress the development and implementation of specific tools, such as Vendor Managed Inventory (VMI), Collaborative Planning, Forecasting and Replenishment CPFR, radio frequency identification (RFID) or bar-coding in a supply chain context. The above and similar studies add to our knowledge and understanding of what can be achieved and how performance can be improved. Most of the published studies fail to address the business conditions or context of a supply chain (Ho et al., 2002). Ramdas and Spekman (2000) are among the few that investigated the influence of factors such as availability of substitutes, changes in market conditions, changes in technology, market maturity, and product life cycle in order to distinguish between functional and innovative products. As such, they add to the work of Fisher (1997) who argues that innovative products can be associated with high levels of uncertainty and need responsive supply chains, while functional products need efficient supply chains.

So far, specifically the influence of uncertainty in demand on supply chain management and integration has been explored. To Lee (2002), uncertainty is one of the drivers for supply chain integration. Empirical evidence also indicates that the level of uncertainty influences the level of integration (Davis, 1993; Childerhouse and Towill, 2002). Recently, Van Donk and Van der Vaart (2004) measure operational characteristics that influence supply chain integration, labelled as business conditions: the decoupling point (MTO/MTS), time window for delivery, volume-variety characteristics, process type (batch size, set-ups, and routings), and order-winners. In line with Davis (1993), these factors are important indicators for the amount of uncertainty manufacturers are facing in their production planning and delivery schedules. Van Donk and Van der Vaart (2004) distinguish between simple (high volume, low product variety, large batches, make-to-stock, and costs as a major order-winner) and complex (low volume, high product variety, small batches, make-to-order, and flexibility among the main order-winners) business conditions. Complex conditions correspond with a high level of uncertainty within the supply chain. They state and empirically show that only complex business conditions require a high level of supply chain integration. However, they also show that shared resources (capacity used to serve different customers) limit the possibilities to perform integration while buyer focus (singling out capacity for the purpose of serving one customer) is an enabler for supply chain management integration. A combination of uncertainty and shared resources is seen as one of the most difficult ones and it seems that many food manufacturers are exactly in that position. Figure 1 summarises the above relationships (Van Donk & Van der Vaart, 2004). In our view, integration relates to the amount and the level of activities such as vendor-managed inventories, packaging customisation, joint planning and forecasting, dedicated planners, use of inter-organisational planning systems, and use of Point of Sale (POS) data. A high level of integration corresponds with more intense and more activities.

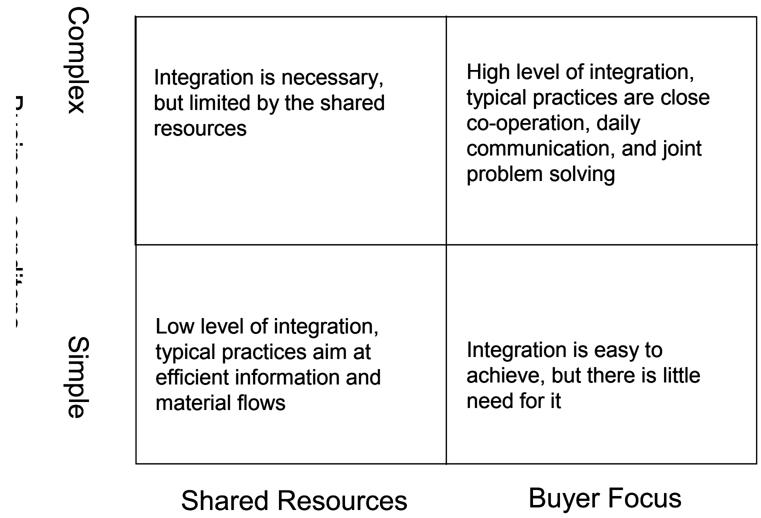

Figure 1. Context and supply chain integration (Van Donk and Van de Vaart, 2004).

Food manufacturing

Food manufacturing is generally considered as a part of the (semi-) process industry. Process industries in general and food manufacturers in particular have been considered as being large-scale, capital-intensive, mass producers of bulk products in large batches for low costs. This uniform picture of process industries has been challenged by empirical work by Dennis and Meredith (2000), who clearly showed the diversity in production systems in process industries. For many food manufacturers the scenery has changed due to trends in markets and changes in consumer's preferences. As a result, food manufacturers and specifically those that manufacture consumer products have adapted their product portfolio and production strategy in order to survive. The market for food products is more and more consumer-driven (Kinsey, 2003), and can be characterised by an increase in packaging sizes, products, recipes and product introductions (Meulenberg et al., 1998); higher logistical performance due to restructuring in the supply chain of retailers (e.g. Wall-Mart); and low margins in retailing and thus downwards pressure on prices for the manufacturers (Dobson et al., 2001). As a result, food manufacturers face a dilemma, as on the one hand they have to produce in response to the market, but, on the other hand, they have to produce at the lowest cost. In other words, flexibility and dependability are needed and on the other hand high utilisation. To complicate supply chain management initiatives further, we need to incorporate a number of food specific production characteristics. From previous studies (Van Donk, 2000) we compile the following enumeration:

(1) *Plant characteristics*: expensive capacity, flow shop oriented design, long (sequence dependent) set-ups;

(2) *Product characteristics*: variable supply, quality, and price of raw material due to unstable yield; raw material, semi-manufactured products, and end products are perishable;

(3) *Production process characteristics*: variable yield and processing time; homogeneous products; not labour intensive except for the packaging phase; production rate determined by capacity; divergent product structure especially in the packaging stage.

For many food manufacturers, the above characteristics are not all present and not all characteristics present will be evenly important for managing the process. Moreover, only a few of them will be really influential in implementing supply chain management initiatives.

Supply chain integration in the food industry

If we combine the two above subsections, some interesting first observations can be made. With regard to the type of resources, we can conclude that both types co-exist for many food manufacturers. Shared resources can be recognised in the expensive capacity and high set-ups, but packaging lines are often more dedicated to a limited number of products and buyers. Total output is usually determined by the (limited) capacity of the processing stage. Decoupling of the two stages is normal, but rather limited due to limited storage space and limited shelf life of unpacked products. The flexibility of the packaging stage is normally larger: fluctuations in mix (different packages) can easily be dealt with and fluctuations in volume can be achieved by adapting the amount of labour.

With respect to the business conditions one might be inclined to see food manufacturing as a typical case of functional products and simple business conditions as high volume, low variety, make-to-stock, short time for delivery, and costs as a major order-winner. However, the market requirements ask for smaller batches, more product differentiation and product innovations. The make-to-stock policy is not viable in a number of situations as retailers demand products with the most recent best-before date. Due to the nature of raw materials, processing times and yields in the processing stage can be unpredictable. Also the attuning of the two main stages (processing and packaging only separated by a limited storage capacity) results in delays and waiting times (Akkerman et al., 2007). This last type of uncertainty is, together with the earlier mentioned business conditions typical for the type of uncertainty that has to be dealt with in production planning and control (Davis, 1993).

What are the consequences for supply chain management in the food industry given these observations? Taking Figure 1 as a point of reference, it seems that many food producers are still in the lower-left quadrant (simple business conditions and shared resources) where initiatives to increase efficient flow of information and material between food manufacturers and retailers are appropriate. However, the combination of increased performance requirements, higher variety and specific characteristics of the food industry presses at least part of the industry into more complex business conditions. The conclusion is that supply chain integration is increasingly needed, but hard to reach due to the shared resources and other specific food characteristics.

OPTIONS FOR SUPPLY CHAIN INTEGRATION IN THE FOOD INDUSTRY

The above section made clear that two types of uncertainty are important for managing the supply chain in the food industry: uncertainty in demand and uncertainty in manufacturing due to typical food characteristics. Moreover, the tuning of the processing stage and the packaging stage adds to the complexity of supply chain management for food manufacturers. Each of the two stages has different characteristics. The processing stage is often flexible with respect to the type of product (e.g. the recipe processed in a tank), given the availability of raw materials but inflexible with respect to volume as capacity is limited (e.g. size of a tank). The packaging stage often is inflexible with respect to type of product as lines are dedicated for one (or a few) type(s) of packaging (e.g. only litres or half-litres), but volume flexibility is often considerable because labour is relatively flexible (e.g. adding an extra shift). In summary, the challenge for many food manufacturers is to deal with the external and internal uncertainty while attuning the two stages in their process.

Based upon the previous sections and earlier attempts in the literature, we distinguish four different strategies to achieve the performance required:

- buyer-focused operations,
- virtual buyer focused operations,
- aggregated hierarchical planning,
- integrated planning and scheduling decisions.

The first approach is to single out part of the (shared) resources with the purpose of satisfying demand for one single buyer. More specific, buyer-focused operations aim at reacting to the changes in mix, volume and timing of demand of a specific buyer. In a number of situations the packaging stage might be buyer-focused already if either the volume of one buyer is large enough to justify such or if the type of packaging is buyer specific. However, as indicated previously, the main problem might be the coordination of the processing stage and the intermediate storage. Singling out part of the capacity can only be achieved in case of different lines or capacities. In some cases the processing stage is one source of capacity e.g. a kettle or integrated process. Then, of course, capacity cannot be singled out for one buyer. In other cases, we might have a number of interchangeable kettles. Then we can single out one kettle to serve the needs of one single buyer. The advantage will be that flexibility in mix and delivery can be totally attuned with the buyer to achieve a high level of supply chain integration, although capacity utilisation is likely to decrease.

The second option is to single out part of the capacity for specific buyers virtually. This might be an option if physically singling out resources is not possible either because of technological or financial reasons. Depending on the situation, capacity is allocated to a certain buyer for a fixed number of days each week or a number of hours each day. There is an analogy in the real-life example of the allocation of capacity of an operating theatre in hospitals. Each specialist medicine is given certain time that can be freely used. In food manufacturing, such allocated capacity can be used to produce the different products of the buyer. On the one hand, supply chain integration will be limited, but the flexibility to change priorities and react to uncertainties will be larger within a more or less fixed volume. It seems that one of the prerequisites is that volume uncertainty is not too large and that the packaging stage can react without taking into account other products (limited or no shared resources). This option is comparable with the approach outlined in Lowson et al (1999) for quick response supply chain relationships in the textile industry, where manufacturing capacity is booked and flexibility maintained in order to adjust to unpredictable market demand.

The third way to manage this type of situation is to organise the planning decisions in a hierarchy. This approach goes back to among others Hax and Meal (1975) and the basic idea is to attune decisions at an aggregate level. Within the boundaries of the aggregate plan decisions at lower levels of aggregation can be decoupled, including processing and packaging stage. Van Dam et al. (1998) design such an approach in a case study of a tobacco company. Basically, the demand of each group of products or customers is balanced against the available capacity over a longer period of time e.g. a week or month. Within the planning horizon, each group receives a part of the available capacity that can be filled without any further attuning with other decisions. Here, the division of capacity at an aggregate level is crucial for the success of the approach. Stability of aggregate demand is a prerequisite.. If uncertainty is mainly related to the demand within product families (the mix within product families), this might be the ideal way of dealing with uncertainty.

The last possibility stems from the more classical production and operations management approach. The basic idea is that by using all available information regarding orders to be produced, processing times and sophisticated algorithms and software, the problem of attuning the two stages can be reduced to a scheduling problem of finding the optimal order of producing the required product quantities in time. This usually involves mathematical programming techniques ranging from basic linear programming (LP) models to more advanced models based on mixed integer linear programming (MILP). It might be clear that considerable effort is needed to implement this option, as all basic data with regard to processing need to be known, and food-specific characteristics need to be considered in the algorithms. Product shelf life is one of the most important factors in this industry, and has recently been studied in this context by Lütke Entrup et al. (2005). Another prerequisite is that within the scheduling/planning horizon, the number of changes should be minimal. Rescheduling an integrated schedule/plan will cause a lot of organisational disturbance and confusion (e.g. Van Wezel et al., 2006). Rescheduling might also take too much time. It seems therefore that this option is specifically relevant for situations with relatively low levels of uncertainty within the planning horizon, little production disturbances and relatively low complexity of the process.

We realize that each of the above strategies might be appropriate under the circumstances sketched, but each strategy is probably only applicable if the business context (or both types of uncertainty) is more or less homogeneous for all main buyers, or if the production for each buyer can be dealt with independent from the production for the other buyers. If this is not the case (due to e.g. the shared resources), it is not directly clear if and how different strategies can be mixed or applied next to each other for different buyers.

INTRODUCTION TO THE CASE STUDY

The food manufacturer in this case study is part of a multinational company that operates a large number of plants across the world and serves both consumer and industrial markets. The specific plant under study is large in this type of industry and mainly produces consumer products for both export and domestic markets. The majority of products is produced as own brand, some of them premium brands, but the plant also produces private label products for large retail chains, as well as a limited number of brand-products for other food companies. The variety in products is extensive: both in recipe and in package sizes and labelling. All production is make-to-order for three buyers that are the commercial business units (BUs) of the parent multinational. These BUs stock and distribute the products to a large number of customers around the world. End products have a shelf life between nine months up to two years. Still, products cannot be stored that long, as buyers will not accept relatively short remaining shelf lives.

Data collection

In the collection of data, a variety of data-gathering techniques was used: mapping of the processes, interviews with employees, reading reports and manuals (for formal procedures), and analysing data with respect to production and demand from the plant's ERP system. A substantial part of the material was collected by a student as part of his thesis project, complemented with data collection during a project by one of the authors

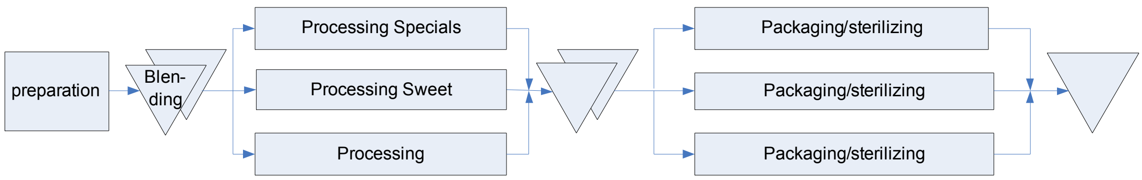

Figure 2. Flow of goods.

and plant visits by the others. The main focus of this project was to investigate the operation of the plant, but we also took interviews with representatives of the business units. While the use of different methods and sources of data already guarantees the quality and reliability of the findings, we also presented the main results and findings at several occasions to the management of the plant to ensure validity of the data and further triangulate the findings. .All in all, we gathered data on the capabilities and limitations of the production system, demand characteristics (mix, volume, uncertainty), the characteristics of the business units, and the planning procedures and practices.

Production and process characteristics

The production process is typical for food manufacturers. There are two main stages: processing and packaging. The operations in the processing stage can be subdivided into three main categories. The first stage involves preparation activities like, the receiving of raw (natural) materials and the pre-processing of raw materials to achieve homogeneous materials. The second stage is blending batches of different types of raw materials in tanks and adding additives to have the basic recipes. In the third processing stage products are separated in three different product streams, based on the product type (normal, sweetened, and special products). Each op these categories has its own process routings, mainly concerning heat treatment for condensing or pasteurising the (fluid) product. After processing the products are temporarily stored in a large number of intermediate storage tanks.

The packaging stage consists of three departments that package a specific range of packaging sizes and types (cartons, glass bottles, cans). The operations performed consist mostly of sterilizing, packaging (sometimes in reversed order), labelling, case-packaging and palletising. It is important to note that all product types can be used by all packaging departments. The flow of products is summarised in Figure 2, and is mainly characterised by product types in the first stage and by packaging types in the second stage. This characterisation also causes the intermediate storage tanks to be quite important in the control of the production system.

As indicated above, the plant has three buyers: the commercial BUs of the parent company that are responsible for the contacts with the customers and for inventory control. Each of the BUs has distinct characteristics and different types of customers in diverse markets:

- BU Export delivers products to a number of European, Asian and African Markets. Here a number of well-established brands are delivered to partly independently operating foreign buyers, which distribute and sell the products in their countries. In general, demand is unpredictable. The timing of the deliveries is partly dependent on shipping dates.
- BU Home Market sells and distributes the own well-established brand to all retail chains and some other distributors as well as some retail brands for large retailers. Achieving an almost 100% customer service is one of the main objectives, as well as good cooperation with major buyers to support

promotional activities. In general, the demand of the consumers is relatively predictable and stable.

- BU Supply maintains and supports buyers that outsource their production to the focal plant. Supply started as a way to utilise excess capacity, but is now a significant part of the total business. Here, less influence and insight exists with respect to demand and demand patterns, but fluctuations in capacity usage are more or less restricted by agreements with respect to total capacity and number of batches. The forecast accuracy differs between the buyers.

As is the case for most food manufacturers, this plant has experienced a steady increase in the number of SKUs over the years. The number of recipes increased due to the increased pressure for healthy and low-fat food and variety in taste and ingredients, while also the number of packaging sizes and types increased due to demographic reasons (e.g. on average smaller sizes of households), increase in brands and demand for easy-to-use products. The increase in both recipes and packaging types, while total demand is staying the same, naturally reduces batch sizes in both stages of production. Batch sizes are further decreased as a result of stock reductions in the supply chain. To some extent, this is problematic, as the plant was originally developed (as many food manufacturing plants are) to produce large batches.

More and more it is felt that whereas packaging can cope with fluctuations and due dates, the processing department has problems in producing the required amounts. In fact, processing has become the bottleneck of the whole process, whereas it previously could supply the packaging departments without problems. The increase in recipes and the reduced batch sizes cause more set-ups and cleaning time than before. All things considered, it is clear that the plant under consideration is finding itself precisely in the situation sketched earlier. Each of the various factors from the theoretical introduction will be further analysed in the next section.

ANALYSIS OF THE CASE STUDY

Figure 1 is the starting point for our analysis: assessing the fit between business conditions and the type of resources. More specifically, the aim of this section is to analyse and confront demand (demand uncertainty) and production process characteristics. The third part of our analysis relates to the role of planning in handling demand and its uncertainties. In other words, we explore the fit (or lack of it) between demand and production characteristics and planning.

Demand

Our analysis shows that the batch sizes are decreasing both at the recipe and the packaging level. This can be illustrated by the total number of SKUs produced (about 590 each month for all packaging departments), which is increasing with a yearly rate of about 3. It can also be illustrated by the difference between expected and actual number of SKUs produced for one particular packaging department: 154 expected and174 produced.. The increase in the number of recipes produced each month is 10%, partly due to the introduction of new recipes.

The demand pattern and uncertainty in demand are rather different between the three BUs:

- BU Export keeps a close contact with their customers and forecasts monthly demand over a horizon of three months, based on forecasts of the customers and a number of important factors. However, the average forecasts suffer from a very low accuracy (about 44% lies outside the preset accuracies). For

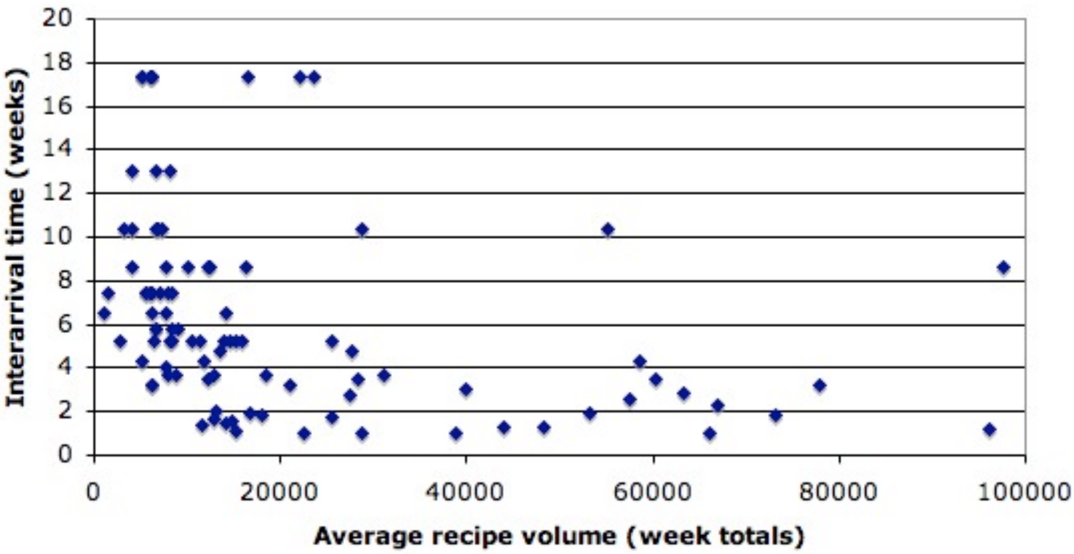

Figure 3. Demand pattern on the recipe level.

some products the actual demand differs 100% from the forecasts. The knowledge of upstream inventories is weak and delivery lead times of these export products are one month.

- BU Home Market operates in a rather stable market and sells a large variety of different packaging sizes and types. The BU keeps stocks of all products, both own brand and retail brands. Demand is forecasted on a weekly base (with a horizon of 13 weeks) and production orders are based upon demand and stock positions. The main deviations here are caused by promotional activities, which are generally known beforehand.
- BU Supply receives estimated demand for a year of most customers. At the operational level an 8-week rolling forecast is provided. The reliability of the rolling forecast differs among customers: some provide more or less lumpy, hardly forecasted demand, while others have the ability to make reliable forecasts. In general minimum batch sizes are agreed upon.

For the processing department, production is based on type of recipe, and orders for different SKUs can often be combined into one processing order if it involves the same recipe. Still, on the recipe level, a lot of variety exists in the demand patterns; some recipes are produced every week in about the same volume, but a lot of recipes have a more irregular pattern (in volume and order size). This is illustrated in Figure 3, where for all recipes, the average weekly recipe volume is plotted against the average time between two orders for that specific recipe. It should be noted that to ensure confidentiality, the volumes have been multiplied by a constant. Obviously, this does not affect the structure of the graphic. The figure clearly shows the large differences between recipes, both in volume and regularity.

Production

Just looking at the performed operations, production seems relatively simple as it basically concerns mixing, processing, packaging and preservation. However, the amount of lines and products adds to complexity. The large number of routings possible and the connections and relations between packaging lines and processing stages further increases the complexity. Packaging lines within one department use common equipment (shared resources); lines in different departments package the same recipe and might get the intermediate product from the same storage tank.

In production, we also see a number of typical food characteristics. Limited shelf life of some (and certainly the main) raw material induces the need for cleaning after a certain time period but also between different recipes. Contamination of different products is usually seen as a large problem both from a quality and hygienic perspective. As production speeds differ and because the processing is batch oriented, the processing and packaging stage are separated by a number of tanks. The three processes in the processing stage and the tanks are all more or less general purpose: serving a broad range of products/recipes. Although there are quite some intermediate storage tanks, the increase in the number of recipes, combined with the decrease in batch sizes, results in extremely high utilisation rates of the tanks, although the average tank content drops. The packaging departments have lines that are more labour intensive and dedicated to one type of packaging (e.g. glass bottle of 0.5 litre). Some packaging lines are even producing for just one end user or one BU. Here, cleaning is also an issue. Most packaging lines operate at high speed, but seem to be vulnerable to breakdowns. The due date performance is, as a result, rather fluctuating. The result is that the intermediate storage is longer occupied and the processing stage and specifically the special products lines that have limited capacity cannot produce at full speed.

Planning

Planning needs to balance demand and capacity at various levels over time and at the same time assure supply of raw material. Specifically with respect to the main raw material, coordination takes place at various levels and plans are adapted at various moments in time to assure optimal supply. Due to the possibility to balance the supply of this factory with others, supply of raw materials is generally not a problem. As the company as a whole has a policy of being market-oriented and market-driven, the starting point for planning are the packaging departments. In general, their plans form the basis for the plans of the processing department, including planning of the required raw material. Here, a capacity check is made at various levels (monthly, weekly and daily plan). In general, inventories of finished products are hardly considered in the planning process, as stocks are kept by the customers (for BUs Export and Supply) or by the buyers (in case of BU Home Market). Furthermore, it is felt that coordination at a monthly level is insufficient and that too many adaptations have to be made to the more detailed plans. Finally, due to the vulnerability to breakdowns in the packaging departments, a lot of rescheduling is done on the operational level (also affecting the processing stage through the strong interrelationship).

Conclusion

All in all, the conclusion is that the business conditions are complex due to the unpredictability of demand, the process interactions between departments and the uncertainty in production. In complex business conditions, one would like to have a high level of integration in the chain, but due to the shared resources and some of the specific food characteristics, this seems hard to achieve. It is also clear that there is hardly any difference between the different buyers with respect to integration, although they have quite different characteristics (summarised in Table 1). The next section explores to what extent the four basic strategies are applicable.

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Table 1. Main characteristics in the case study.

Scope	**Characteristics:**					
	Products	**Customers**	**Demand**	**Forecast**	**Production**	**Planning**
General	Increase in number of SKUs and recipes		Decreasing order sizes		Process inter-actions, packaging breakdowns, shared resources	On various levels, market-driven, lot of rescheduling
BU Home	Large variety of premium and retail brands	Retail chains and distributors	Relatively stable, some deviation by promotional activities	13 weeks, updated every week, high quality		
BU Export	Well-established premium brands	Foreign distributors	unpredictable	12 weeks, updated every 4 weeks, low quality		
BU Supply	Processing and packaging capacity	Food companies	Contract agreements	1 year, updated every 8 weeks, quality varies between buyers		

REDESIGNING THE CASE

It might be obvious that choosing one of the suggested strategies is the preferred course of action for changing the current situation. Before investigating that choice, it should be stressed that from a SCM point of view, it is not that bad to start planning with actual demand and due date setting, and with the planning of the packaging departments. Due to the flow of goods between the processing and packaging departments, complex interrelationships come into being. The shared resources in the processing stage limit total output both in the long and short run, and output is also partly determined by the type and size of packaging orders and the disturbances in packaging. It seems logical to pay attention to the operational constraints (Bertrand et al., 1990) on the orders accepted and planned for packaging. Bertrand et al. mention batching constraints (e.g. to avoid set-ups), sequence constraints (e.g. to combine work orders), workload constraints (to realize a certain level of utilisation), and capacity constraints (possible adjustments in the short and long run). A second concern is that the three BU's and their customers differ in type and the ability to forecast demand and thus pose different requirements on the production system.

If we consider the analysis of the case and the above conclusions, it seems that each of the proposed alternative strategies is hard to implement as an overall solution (see Table 2).

Each of the alternatives, however, can be used at a lower level of analysis. Our concern is thus to split the overall complexity into relatively manageable parts. For that purpose a number of observations can be made: (*i*) the BUs differ in level of uncertainty, (*ii*) some packaging lines are almost dedicated to buyers (or buyer-focused), and (*iii*) for a selection of products, volumes are large and stable –in Figure 3, these are the products/recipes in the lower-right corner.

The relationship with BU Home Market has relatively little uncertainty, a number of specific recipes and packaging types, and there is a low level of integration with the buyer. In principle according to Figure 1, this might be fine. Part of the buyer-focused strategy can be used here. The exchange of more information, better and joint decision making e.g. with regard to inventory and batch sizes could yield some extra flexibility to cope with the uncertainty of the other business units. For a number of products it is beneficial to increase batch sizes if all costs are considered (labour, waste, etc.). Currently, such trade-offs along the supply chain are hardly made. For some of the high-volume recipes it could be beneficial to single out part of the capacity in the processing stage to integrate it with the packaging lines that are already buyer-focused. Here, Figure 3 could be used as a guideline in the selection of recipes, also taking into account their regularity. This separation of capacity can be achieved virtually by reserving capacity each week or on certain days. Actual processing and packaging

Table 2. Applicability of integration strategies in the case

Supply chain integration strategy	Limitation / barrier
Buyer-focused operations	Volume uncertainties Capacity used for several buyers
Virtual buyer-focused operations	Volume uncertainties
Aggregated hierarchical planning	Processing and packaging not fully decoupled Different demand characteristics for buyers
Integrated planning and scheduling	Uncertainties in the market Production induces frequent rescheduling High complexity of the plant

might be postponed until relatively late in the planning process to produce those packaging sizes that are most needed for replenishing (change of capacity constraint). The positive effect can be increased delivery performance if for these products a limited number of fixed tanks is used such that disturbance here do not influence other parts of the process. An integrated scheduling and planning approach could manage this part of the supply chain (last strategy).

The workload and capacity constraints also need to be changed in order to maintain supply chain control. As a result of the market-orientation, batches tend to become smaller (recipes move left in Figure 3). Given the considerable amount of cleaning time, the influence of batch sizes on capacity utilisation is rather large. So far, too much emphasis has been put on overall volume of products, while from a capacity point of view, the number of cleaning and set-up times can be directly incorporated. Specifically for BU Supply this will result in proper agreements with customers to really sell capacity. That implies that within a given volume the number of different recipes (and thus the amount of cleaning time) will be restricted. Here in fact the operational constraints in processing and packaging can result in the adoption of the third strategy of aggregate hierarchical planning at a high level that is detailed in a later stage within the agreed constraints.

For the BU Export it seems that the current efforts paid to forecast demand is a waste of time. The uncertainty in demand is not really a problem as the lead-time is about one month. The preferred course of action is to invest in developing the tools to schedule the orders that come in. Good planning and scheduling to be able to process the orders, fast delivery of supplies and coordination with transport are the main instruments to increase performance.

CONCLUSIONS AND DISCUSSION

This paper aims at developing a better understanding of the specific problems of food manufacturers that aim at supply chain integration. While it seems that integration is specifically high in food supply chains, we show that the specific nature of food manufacturing companies and specifically the shared resources that are operated in such companies can be barriers for integration. Specific factors are the increase in product variety, smaller batch sizes and uncertainties in demand, combined with limited shelf life of products and processing uncertainties. We discuss four basic strategies to deal with these circumstances: singling out buyer-focused resources, virtual buyer focus, hierarchical planning, and integrated planning and scheduling.

A case study is used to illustrate the concepts and relationships developed. The case clearly shows the problems that have to be dealt with by food manufacturers. The four strategies developed are applicable to improve supply integration and performance, if different types of demand are dealt with separately, linked to specific characteristics and to the structure of the process. Dealing with the shared resources is possible, but they will remain a major factor in supply chain improvements. We realize that the empirical part of this paper concerns only a single case study, but based on existing research on the characteristics of food manufacturing, we feel that this case study represents a typical food manufacturer.

For the longer run it seems that constantly monitoring the product portfolio both in terms of SKUs and recipes and their profitability is needed. A second point related to that is the possibility to change the point at which products become specific. Most products consist basically and for the larger part of the same raw materials and only their relative percentages and some ingredients differ, the specific recipes are mixed before the processing stage. Considerable amounts of cleaning time could be saved if mixing could be postponed until just before packaging. It seems that technological progress will allow for that soon. It should be noticed, however, that while such solutions are promising, they do not solve the fundamental problem of shared resources.

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