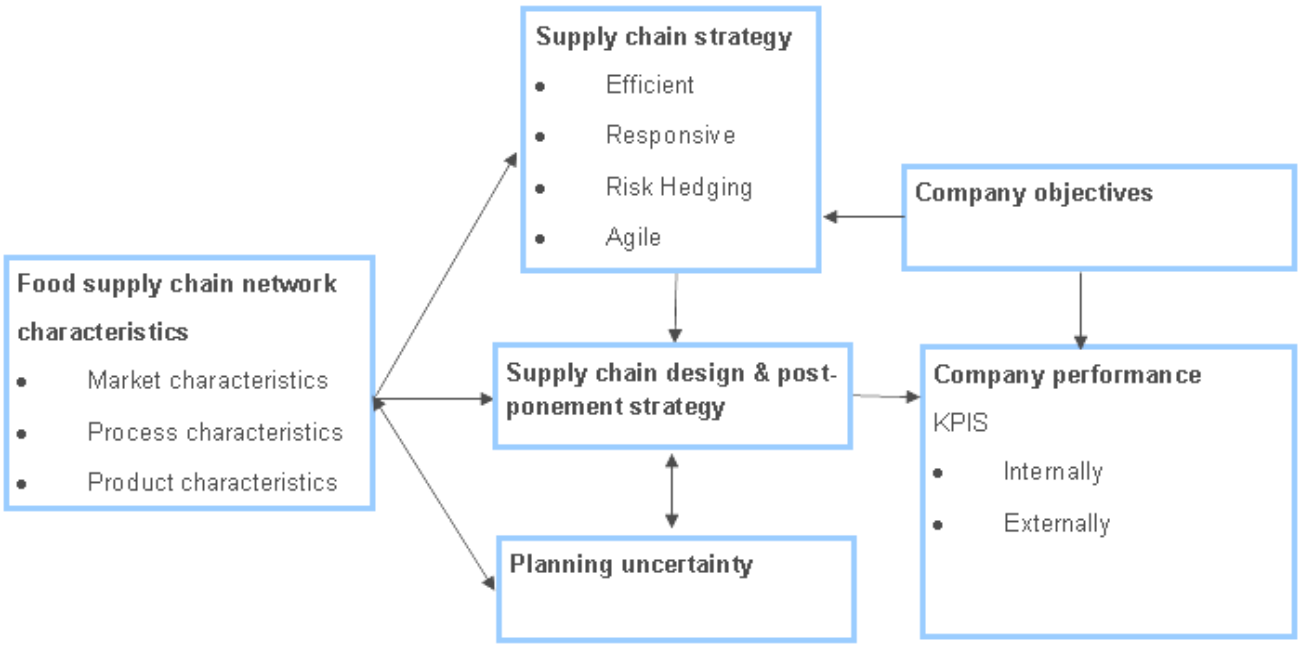
Bachelor thesis

Operations research and logistics

The relationship between planning uncertainty and postponement in the meat sector



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Summary

This thesis aims to describe and clarify the relationship between uncertainty and postponement in the meat chain. The objective of this thesis is formulated as:

'Analyze whether postponement in meat chains could be an effective strategy to reduce planning uncertainty and improve supply chain performance'

The following research questions were defined:

1. Which postponement strategies exist and are relevant for the meat supply chain?
2. Which factors influence the choice of a postponement strategy?
3. What is the influence of postponement strategies on planning uncertainty and how do they impact the key performance indicators?

To answer these research questions a literature review on postponement strategies uncertainty and Key Performance Indicators (KPIs) is performed. Based upon this literature review proposed relationships are presented in a conceptual model. Based upon this information a questionnaire is prepared and expert interviews in the meat and cheese chain were held to test the conceptual model.

Answer research question 1

In literature four important postponement strategies were identified by Pagh and Cooper (1998) and chosen to use in this research. These strategies were:

- Full speculation strategy
- Logistics postponement strategy
- Manufacturing postponement strategy
- Full postponement strategy

These strategies all have differrent advantages and disadvantages and there are product characteristics, market and demand and manufacturing and logistics characteristics that have to be taken into account when choosing a certain postponement strategy.

Answer research question 2

Different factors influence the choice of a postponement strategy. Specific Food supply chain network (FSCN) characteristics were found to have a big influence. Furthermore these characteristics often influence the degree of demand and supply

uncertainty in the supply chain. The degree of planning uncertainty also interrelates to the postponement strategy applied.

Relationships between supply chain strategies (Lee, 2002) and postponement strategies (Pagh and Cooper, 1998 were defined (figure 14). In the expert interviews held these hypotheses were not always found to be correct.

There are thus different factors that influence the choice of a postponement strategy: the supply chain strategy, FSCN characteristics and the degree of uncertainty.

Answer research question 3

The expert interviews clarified that use of postponement has different effects on the KPIs. Postponement can be a good way to reduce uncertainties but there is a possibility the application of postponement also has negative effects, for example on costs: economies of scale can reduce, productivity may decrease and supply chain redesign costs may be needed. So far, advantages seem to outweigh potential disadvantages in meat and cheese chains: more flexibility is created to respond to volatile demand, more products can be made customer- specific and there can be better dealt with planning uncertainties. Further research in more sectors is required to prove this. However, some disadvantages may also exist: production will typically be order-specific and will take place in smaller batches, which can reduce efficiency.

The interrelationships between FSCN characteristics, supply chain strategies, postponement strategies, planning uncertainty, company objectives and company performance is presented in the following model.

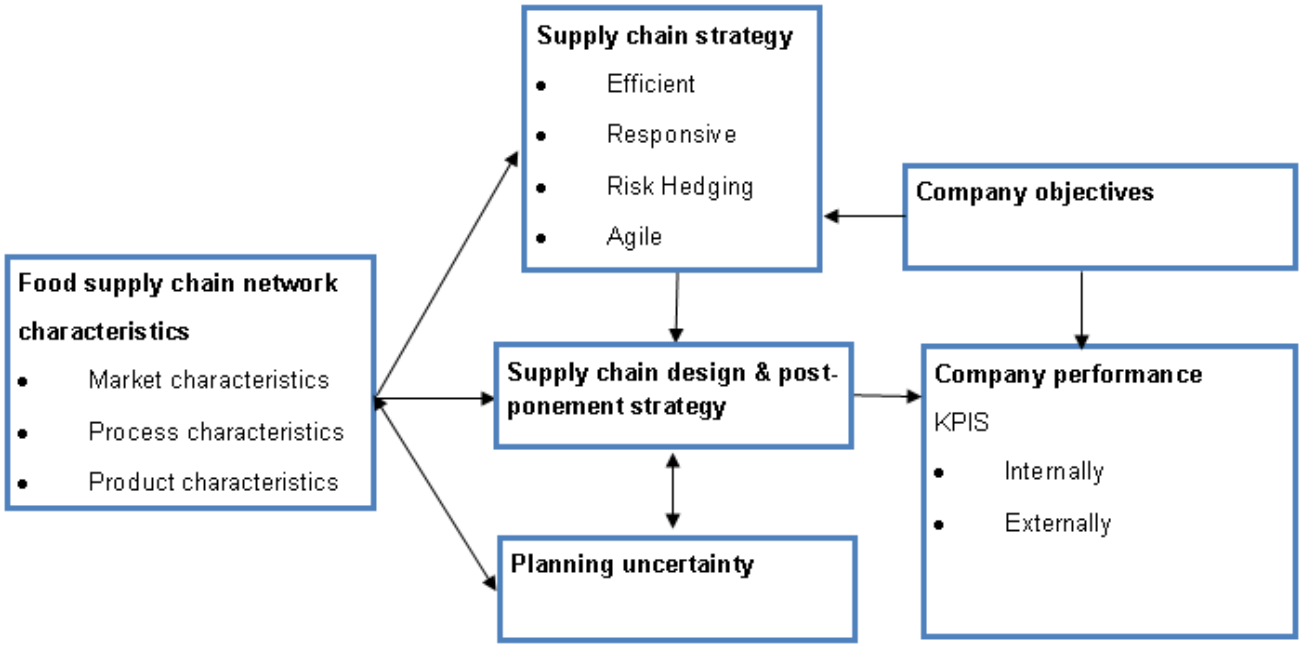


Figure 0-1 Conceptual model

There is suggested to do further research in more supply chains on the potential advantages and disadvantages of postponement in food supply chains. Furthermore more quantified research has to be done to examine the exact effects of postponement on the different KPIs.

Table of contents

1. Introduction

1.1 Introduction and problem description

Food supply chains have very specific supply chain characteristics, such as variable supply of raw materials and a high risk of obsolescence of products (van Donk, 2001). These characteristics are also present in the pork sector, which has a complicated and fragmentized supply and demand market. In this sector there are big differences in the characteristics of the pigs that are delivered from farmers to the processor and there is a great variety of end products (Rijpkema, 2009). Furthermore customer demand fluctuates and is not known in advance. For this reasons the pork sector has to deal with uncertainty in both supply and demand and thus faces high planning uncertainty. This uncertainty leads to inefficiency in matching raw materials and end products which results in high total chain costs.

A PhD student of Wageningen University performed a research on the redesign of a meat supply chain, carried out for VION Netherlands, an international meat processor. He proposed a redesign of the supply chain, where the use and position of product differentiation points (PDP's) is changed. *Product differentiation points* are the points at which products are processed from a generic, multi-purpose form into a less generic form (van der Vorst, 2001). Changing the position of PDPs in the supply chain upstream can lead to higher planning uncertainty. To reduce this uncertainty the use of pig batch quality information turned out to be very promising and a better match between raw materials and specific orders (Rijpkema, 2009).

In literature postponement is mentioned as a good method to reduce uncertainty. The use of *postponement* to reduce planning uncertainty was, however, not considered within the research of Rijpkema. Postponement is an organizational concept whereby some of the activities in the supply chain are not performed until customer orders are received (van Hoek, 2001). Use of postponement in meat supply chains will be analyzed within this research because postponement might improve planning performance and reduce uncertainty.

To assess whether postponement is an effective concept for supply chain performance improvement insight in the current logistics concept is required. *Supply chain performance* can be measured using key performance indicators (KPI's).

KPIs represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of an organization (Parmenter, 2010).

1.2 Objective

The goal of this thesis is:

'Analyze whether postponement in meat chains could be an effective strategy to reduce planning uncertainty and improve supply chain performance'

1.3 Research question

To reach this goal the following research question is defined:

'Does postponement have the potential to reduce planning uncertainty and improve performance of meat processing companies?'

The following sub questions have been derived:

1. Which postponement strategies exist and are relevant for the meat supply chain?
2. Which factors influence the choice of a postponement strategy?
3. What is the influence of postponement strategies on planning uncertainty and how do they impact the key performance indicators?

1.4 Research strategy

To answer the research questions existing literature about postponement, product differentiation points, uncertainty and performance will be reviewed. A conceptual model will be made and tested by the use of expert interviews.

Research question	*Methodology*	*Expected outcome*
1. Postponement strategies	Literature review	An overview of the existing postponement strategies
2. Choice of a postponement strategy	Literature review Expert interviews	An overview of the factors that influence the choice of a postponement strategy
3. Influence of postponement on uncertainty and KPIs	Literature review Expert interviews	A clarified relationship between uncertainty, postponement and performance. Conceptual model.

1.5 Thesis structure

In chapter 1 the introduction, objective, research question and research methodology of the thesis will be presented. In chapter 2 a literature review on supply chain management, supply chain performance, uncertainty and postponement is performed. Chapter 3 will combine and relate all the concepts. A conceptual model is developed and will be tested by the use of expert interviews in chapter 4. In chapter 5 conclusions, discussions and recommendations for further research are presented.

2. Literature

This chapter will give a literature review. Paragraph 2.1 introduces supply chain management. In paragraph 2.2 uncertainty and supply chain strategies are presented. A review of the concept postponement is in paragraph 2.3.

2.1 Supply chain management

This section will, based on a literature review, introduce supply chain management. First definitions of this concept are given (2.1.1). Food processing industries have some very specific characteristics that influence supply chain management (2.1.2). The measurement of supply chain performance is explained (2.1.3). Then product differentiation points (2.1.4), customer order decoupling points (2.1.5) and the position of this point are reviewed (2.1.6). Also the material and information decoupling point, two different decoupling points, are defined (2.1.7).

2.1.1 Definition supply chain management

Supply chain management has developed into an important business concept. Because of high competition in global markets and the introduction of products with shorter life cycles, high efficiency is needed and businesses are forced to invest in and focus on supply chains (Simchi-Levi et al., 2000). A supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer (Christopher, 1992). This supply chain has to be managed effectively. Fawcett et al. (2007) defines supply chain management as the design and management of seamless, value-added processes across organizational boundaries through the integration of people and technological resources to meet the real needs of the end customer. The essence of supply chain management is to align goals, share resources and collaborate across company boundaries where planning and control are of great importance.

2.1.2 Food Supply Chain Network characteristics

This research focuses on postponement opportunities in food industries. These industries have some very specific characteristics that will be mentioned as Food Supply Chain Network Characteristics (FSCN) within this research. van Donk (2001) categorized some of these characteristics. These characteristics are valid for companies that produce consumer products. Most food products can be typified by a limited number of these characteristics.

- Plant characteristics
    - Expensive and single-purpose capacity coupled with small product variety and high volumes
    - Long set-up times between different product types

- Product characteristics
    - Variable supply, quality and price of raw material due to unstable yield of farmers
    - Perishable raw material, semi-manufactured products and end products
- Production process characteristics
    - Processes have a variable yield and processing time
    - At least one of the processes deals with homogeneous products
    - The processing stages are not labor intensive
    - Production rate is mainly determined by capacity
    - Divergent product structure, especially in the packaging stage
    - Extensive, labor-intensive packaging phase at factories that produce consumer goods
    - Uncertainty in pricing, quality and supply of raw materials leads to different recipes for a product

These characteristics affect logistics planning and supply chain management within these industries and have to be taken into account for planning and scheduling purposes.

2.1.3 Supply chain performance

Supply chain management has been very important in realizing a greater productivity and profitability in companies. To make supply chain performance measurable key performance indicators (KPIs) can be identified. KPIs represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of an organization (Parmenter, 2010).

Based on company objectives, KPIs can be defined. Within this thesis company objectives are defined as goals that an organization sets for itself, for example, profitability or sales growth. These goals are the foundation upon which the strategic and operational policies adopted by the organization are based (Business dictionary). Companies also have logistical objectives. The goals of logistics are to shorten troughput times, realize higher flexibility, improve dependable delivery and reduce integral costs. These objectives are mutually dependent (Visser and van Goor, 2008) and influence the logistical KPIs.

Besides logistical KPIs there are five basic performance objectives that apply to all types of operations (Slack et al.,2007):

- *Quality*: consistent conformance to customers' expectations.
- *Speed*: the elapsed time between customers requesting products or services and receiving them.
- *Dependability*: delivering, or making available, products or services when they were promised to the customer.
- *Flexibility*: the degree to which an operation's process can change what it does, how it is doing it, or when it is doing it.
- *Costs:* costs will be the major operations objective. Low costs is a universally attractive objective.

The performance objectives have both internal and external effects. This is clarified in figure 1. Internally, all objectives affect productivity and thus costs and revenue. So, an important way to improve the cost performance objective is to improve the other performance objectives. Externally low costs allow companies to ask lower prices or realize higher margins. The other performance objectives have influence on customer satisfaction.

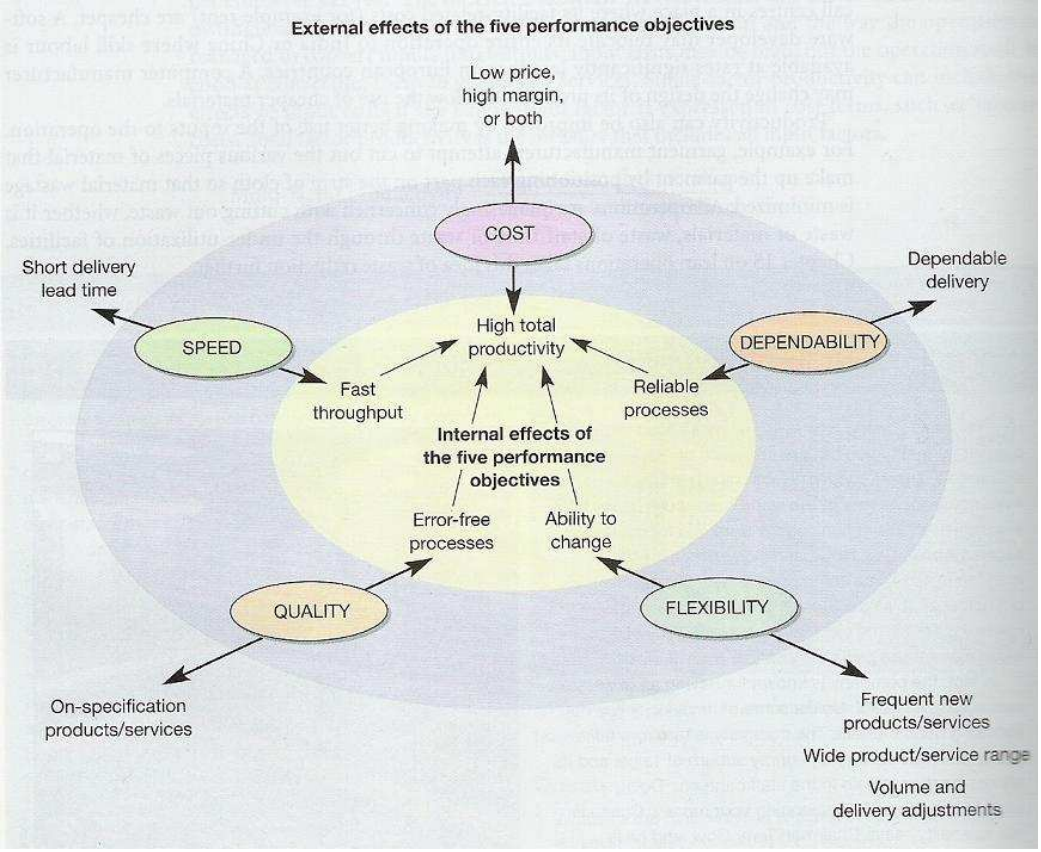


Figure 1 Performance objectives and their internal/external effects (Slack et al., 2007)

2.1.4 Product differentiation point

In making decisions for supply chain design, the use of product differentiation points and customer order decoupling points is important. A product differentiation point (PDP) is a point at which a process is performed that transforms a product from a generic in a less generic form (van der Vorst, 2001). A product differentiation point is an important decision moment in supply chains, which determines the form of a product and therefore the final customer or market where the product arrives. In most supply chains multiple product differentiation points are available because there is often no unique point that separates the raw material from its final form.

For example in the fashion industry, the final product has to be weaved, dyed and packaged: all these points in the supply chains can be seen as product differentiation points because it makes a product distinguishable.

2.1.5 Customer order decoupling point

An important aspect in the supply chain design is the position of the customer order decoupling point (CODP). A CODP is a special variant of a PDP. Hoekstra en Romme (1992) define the customer order decoupling point as the point that separates the part of the organisation oriented towards activities for customer orders from the part of the organisation based on forecasting and planning. Olhager (2003) calls this CODP the order penetration point and defines it as: “the point in the manufacturing value chain for a product where the product is linked to a specific customer order”. In short the CODP is the link between forecast-driven activities and customer-order-driven activities (figure 2).

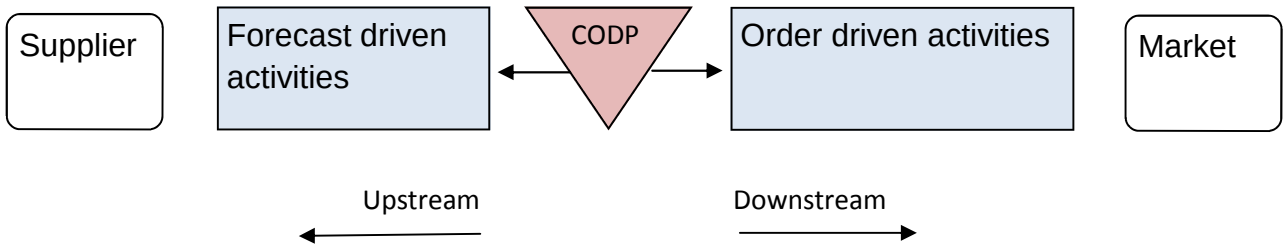


Figure 2 Customer order decoupling point

2.1.6 The position of the customer order decoupling point

A company can perform more forecast-driven or more order-driven activities. Therefore the CODP can be shifted upstream or downstream. Shifting the CODP downstream increases manufacturing efficiency. Shifting this point upstream leads to increased knowledge of the content of customer orders at the time of production. This trade-off is clarified in figure 3.

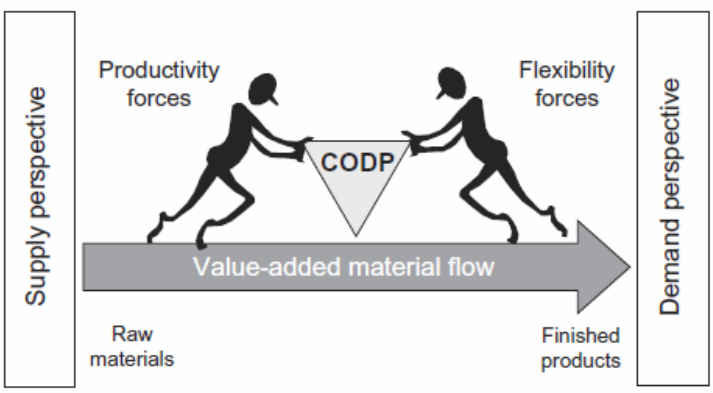


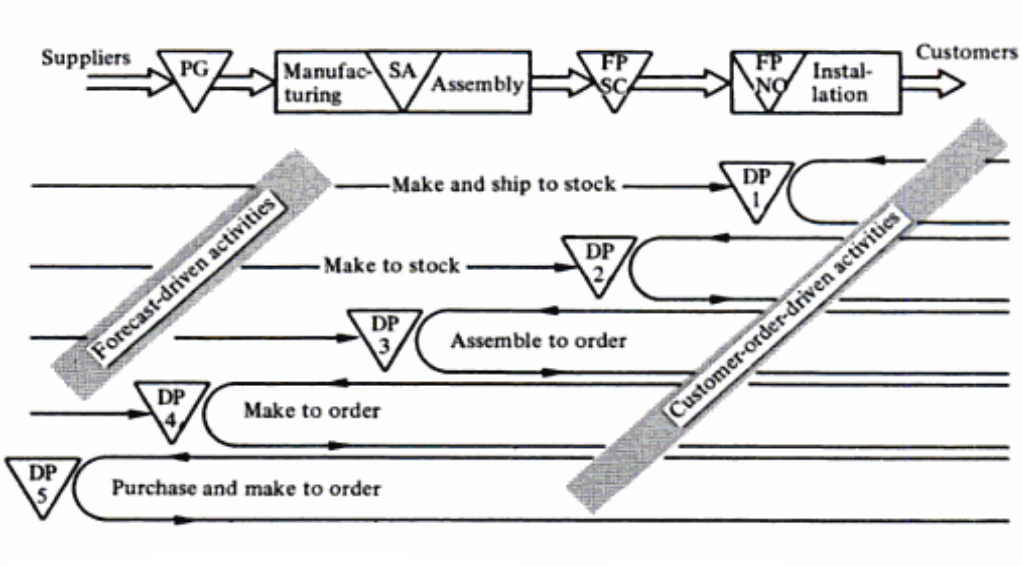
Figure 3 Trade-off between productivity and flexibility (Rudberg and Wikner, 2004)

The CODP can have different positions in the supply chain and that positions relate to different manufacturing situations (Olhager, 2003).

Hoekstra and Romme distinguish five different positions of the decoupling point:

- *Make and ship to stock*: the final products are distributed to different stock points. From there they are delivered to customers.
- *Make to stock*: after production products are held in a central stock, from where they are delivered to customers. The production depends on the demand forecast.
- *Assemble to order*: only elements or subsystems are held in a stock. When an order is received the final product is assembled to this specific order.
- *Make to order*: there are only raw materials kept in stock. Each order is a specific project.
- *Purchase and make to order*: there are no stocks. When an order is received the process starts and raw materials and elements are purchased for specific orders.

The possible positions of the CODP and the related manufacturing situations are clarified in figure 4.



Five DP positions represent five logistic structures: PG, purchased goods; SA, sub-assemblies; FP, finished products; SC, supply centre; NO, national organization. Inverted open triangles indicate possible stock points

Figure 4 The different positions of a customer order decoupling point (Hoekstra and Romme, 1992)

The most suitable position of the CODP depends on several supply chain characteristics. Olhager (2003) grouped these characteristics in market-related factors, product-related factors and production related factors (table 1).

These factors all affect the position of the CODP and are to some extent interrelated. The specific food supply chain network characteristics also have influence on the position of the decoupling point.

Table 1 Factors influencing the customer order decoupling point based on Olhager, 2003 and Van Donk, 2001

Market related factors	**Product related factors**	**Production related factors**
Delivery lead time requirements	Modular product design	Production lead time and costs of steps in the (primary) process
Delivery reliability requirements	Customization opportunities	Costs of stock-holding and value added between stock points
Product demand volatility	Material profile	Number of planning points

Product volume	Product structure	Flexibility
Product range and product customisation requirements	Risk of obsolescence	Position of the bottleneck
Customer order size and frequency		Sequence dependent set-up times
Seasonal demand		Controllability of manufacturing and procurement

The factors in table 1 have different effects on the position of the CODP and the manufacturing approach. For example a high delivery lead time required and low product demand volatility mean a product can be produced forecast driven, while products with a high risk of obsolescence and wide customisation opportunities ask for an order based approach. More elaborate information on these characteristics is given by van Donk (2001) and Olhager (2003).

2.1.7 Material and information decoupling point

Mason-Jones and Towill (1999) and Christopher and Towill (2000) distinguish two different decoupling points. Sales information is important and should be transferred upstream the supply chain. Therefore the first point is the *information decoupling point (IDP)*, the furthest point to which information on real final demand penetrates. This point should lie as far possible upstream in the supply chain because then the companies in the supply chain and the marketplace will be linked. In this way it is possible to make maximum use of order information (Mason-Jones and Towill, 1999). The second point is the *material decoupling point (MDP)*, the point where strategic inventory is held. The ideal position of these points according to Mason-Jones and Towill are presented in figure 5.

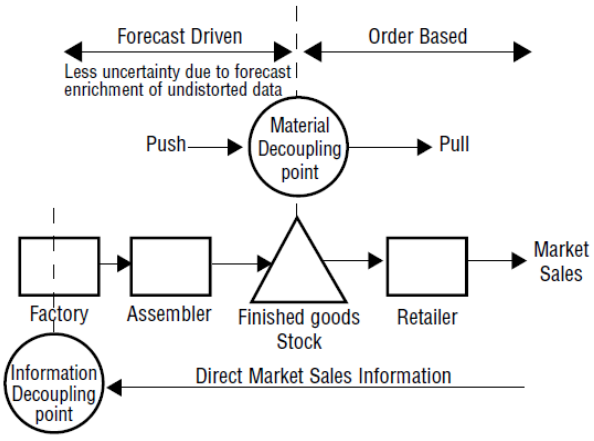


Figure 5 Comparison of MDP and IDP (Mason-Jones and Towill, 1999)

These authors state each supply chain both has an information and a material decoupling point. When these points are positioned at the same place in the supply chain, the value of undistorted order information will be wasted. Therefore, the position of the IDP has to be before the MDP. In this way order information can already be used at the factory. This is shown in figure 5.

2.2 Uncertainty and supply chain strategies

This section will introduce uncertainty and different supply chain strategies. Uncertainty and different types of uncertainty are reviewed (2.2.1) and types of products (2.2.2) and types of supply chains (2.2.3) are presented. Finally, supply chain strategies are explained (2.2.4).

2.2.1 Uncertainty

In the position of the CODP, MDP and IDP the degree of uncertainty in a supply chain is important because uncertainties in supply and demand are recognized to have a major impact on the manufacturing process (Van der Vorst, 2000). Uncertainty means 'be doubtful about something' (Van Dale). If outcomes will occur with a probability that can not be estimated, the decision maker faces uncertainty. This is different from risk, where outcomes will occur with a certain probability.

The environment of many companies can be characterized as dynamic or unpredictable. This results in a lot of uncertainty in supply chains, leading to strategies that are aimed to cope with this uncertainty, for instance by building larger stocks or expanding capacity. These strategies increase operational costs without adding extra value, thus leading to a lower profitability. Therefore it is important to reduce uncertainty.

In supply chain management a match has to be made between demanded end products and supplied raw materials. Therefore two different types of uncertainty can be distinguished: demand and supply uncertainty.

- *Demand uncertainty* is linked to the degree of predictability of demand. The predictability depends on customer and retailer demand. These demands can have different patterns. Demand uncertainty leads to higher inventories, longer lead times and hence lower responsiveness which will bring extra costs (Van der Vorst, 2000). To reduce demand uncertainty sharing of information and synchronized planning are crucial (Lee, 2002).

- *Supply uncertainty* does also exist. There is a risk suppliers do not produce fast enough and there is also a risk of suppliers overproducing. When this happens matching of raw materials and end products becomes very difficult. Especially in agri-food chains there is supply uncertainty in quantity, quality and price (van Donk, 2001). To reduce these risks free exchange of information is extremely important as well (Lee, 2002).

Van der Vorst (2000) distinguishes four types of uncertainty. Besides the two aforementioned types of uncertainty, process and planning and control uncertainty are distinguished.

- *Process uncertainty* is uncertainty related to the production system, for example, the availability of adequate capacity to produce a particular product or the availability of raw materials from stock with sufficient quality. Furthermore output yields fluctuate.
- *Planning and control uncertainty* is uncertainty related to the planning and communication structure, for example, uncertainty as to whether inventory levels are accurate or whether consumer wishes are communicated correctly and on time.

2.2.2 Types of products

There are different decoupling points, manufacturing positions and also different types of products and supply chains. The type of product and the type of supply chain should match. Fisher (1997) distinguishes two types of products and states the first step in defining the right supply chain strategy for your product is to consider the nature of demand for the products that are supplied. The distinction between the two types depends mainly on the degree of demand uncertainty.

- *Functional products* are products that satisfy basic needs and do not change much over time. They are characterized by stable and predictable demand and have long life cycles. Functional products have few variants which are sold in high volumes through many market channels (Chopra and Meindl, 2008). The supply chains of these products should focus on efficiency. An example of a functional product is tinned soup.
- *Innovative products* are successfully innovated products. Demand is unpredictable and life cycles are short. There are many variants of these products. These supply chains should focus on responsiveness. An example of an innovative product is trendy clothing.

The characteristics of the two types of products are typified in figure 6.

Functional	Innovative
Low demand uncertainties	High demand uncertainties
More predictable demand	Difficult to forecast
Stable demand	Variable demand
Long product life	Short selling season
Low inventory cost	high inventory cost
Low profit margins	High profit margins
Low product variety	High product variety
Higher volume per SKU	Low volumes per SKU
Low stockout cost	High stockout cost
Low obsolescence	High obsolescence

Figure 6 Demand characteristics of functional and innovative products (Lee, 2002)

In analyzing these characteristics it is important to realize this classification uses two extremes. Products are often mainly functional or mainly innovative and combinations of characteristics do also exist.

2.2.3 Types of supply chains

The two product types described above require a different supply chain approach to address their specific characteristics (Mason-Jones et al., 2000). A distinction between different supply chain types can be made. Fisher (1997) distinguishes between physical efficient supply chains and market responsive supply chains.

- *Efficient supply chains* focus on minimizing physical costs while supplying the predictable demand of customers. The goals are: maintain a high utilization rate , minimize inventories and shorten lead times as long as it does not increase costs. Suppliers are selected primarily for cost and quality. The overall goal is maximize performance while minimizing costs.

- *Responsive supply chains* respond quickly to unpredictable demand in order to minimize stock outs, forced markdowns and obsolete inventory. These supply chains focus on deploying excess buffer capacity, deploying significant buffer stocks of components or finished products and reducing lead-times as much as possible. Suppliers are selected for speed, flexibility and quality. A responsive supply chain uses modular design in order to delay product differentiation as long as possible.

Combining the type of demand, product type and supply chain leads to the following distinction:

Table 2 Demand, product type and supply chain strategy, based on Fisher (1997)

Demand	Product Type	Supply chain
Predictable	Functional	Efficient
Unpredictable	Innovative	Responsive

Naylor et al (1999) distinguish two different supply chain paradigms, lean thinking and agile manufacturing:

- *Leanness* means developing a value stream to eliminate all waste, including time, and to ensure a level schedule. When there is a focus on leanness, the goal is to minimize physical costs related to production, transportation and inventory storage. Lean is about doing more with less and reduce wasteful activities (van der Vorst et al., 2001). The origins of lean manufacturing can be traced to the Toyota Production System (van der Vorst et al.,2001). Functional products, as described above, are suited to a lean environment.

- *Agility* means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place. When there is a focus on agility, the goal is to minimize market mediation costs. Market mediation costs arise when the products reaching the marketplace do not match with consumer demand. The key characteristic of an agile organization is flexibility (van der Vorst et al., 2001). Innovative products, as described above require an agile environment.

A supply chain does not necessarily have to be lean or agile. Some supply chains have both characteristics of a lean and an agile supply chain. Therefore an intermediate form has to exist. A combination of both types is defined as a 'leagile' supply chain (van der Vorst, 2001).

- *Leagility* is defined as 'the combination of the lean and agile paradigm within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream, yet providing level scheduling upstream from the decoupling point' (van der Vorst, 2001). The decoupling point is the point in the manufacturing value chain for a product where the product is linked to a specific customer order (Olhager, 2003). The leagile supply chain is clarified in figure 7.

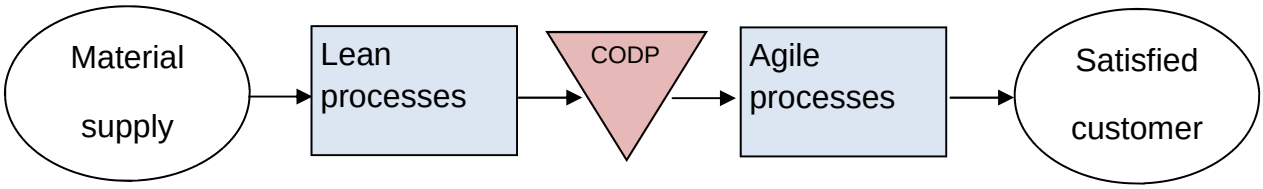


Figure 7 Leagility (Mason-Jones et al., 2000)

2.2.4 Supply chain strategies

After the characteristics of products and supply chains are determined a strategy can be chosen. Lee (2002) distinguished four types of supply chain strategies based on the degree of supply and demand uncertainty that is present. This is clarified in figure 8.

Figure 8 Matched strategies (Lee, 2002)

- *Efficient supply chains*: this strategy is aimed at creating the highest cost efficiencies in the supply chain. In this strategy it is important to eliminate non-value-added activities, realize economies of scale, deploy optimization techniques and establish information linkages. This strategy matches with functional products (Fisher, 1997).
- *Risk-hedging supply chains*: this strategy is aimed at pooling and sharing resources so that the risk is also shared. A single entity in a supply chain can be vulnerable to supply disruptions but if there are more or alternative supply sources available the risk of disruption will be reduced.
- *Responsive supply chains*: this strategy is aimed at being responsive and flexible to the changing and diverse need of the customers. To realize high responsiveness companies use make-to-order and mass customization processes. “Mass customization relates to the ability to provide customized

products or services through flexible processes in high volumes and at reasonably low costs" (Da Silveira et al., 2001). Order accuracy is of big importance. This strategy matches with innovative products (Fisher, 1997).

- *Agile supply chains*: this strategy is aimed at being responsive and flexible to the changing and diverse need of the customers, while the risks of supply shortages or disruptions are hedged by pooling inventory or other capacity resources. These supply chains have strategies that combine hedged and responsive supply chains.

Lee also gives examples of products that match with these uncertainties and supply chain strategies. These examples are presented in figure 9. Lee puts food products at the left side of this table. In section 2.1.2 characteristics of food products by van Donk (2001) were presented. These characteristics also influence the degree of demand and supply uncertainty. Because of these characteristics this classification is not always valid. This will be further explained in paragraph 3.2.

		Demand Uncertainty	
		Low (Functional Products)	High (Innovative Products)
Supply Uncertainty	Low (Stable Process)	Grocery, basic apparel, food, oil and gas	Fashion apparel, computers, pop music
	High (Evolving Process)	Hydro-electric power, some food produce	Telecom, high-end computers, semiconductor

Figure 9 Matched products and uncertainty (Lee, 2002)

2.3 Postponement

In this section the concept postponement will be introduced. Postponement is an important organizational concept that can be used to reduce uncertainties and risk. "The more uncertainty related to a process, the more waste there will be in the process'' (Persson, 1995). By applying postponement the non value-adding activities in the supply chain, for example high inventories and inefficient processes, will be reduced.

First definitions of postponement will be given (2.3.1). Three main types of postponement are presented (2.3.2), strategies are explained (2.3.3) and determinants for choosing the right postponement strategy are presented (2.3.4).

2.3.1 Definition postponement

In literature several definitions of postponement are used. Two definitions are presented here. Van Hoek (2001) defines postponement as an organizational concept whereby some of the activities in the supply chain are not performed until

customer orders are received. Companies finalize their output according to customer preferences. Postponement can occur along the entire supply chain. Hopp (2008) sees the basic idea of postponement as holding partially completed goods in a generic state and customize them only when demand becomes known. So, postponement affects the position of the MDP and IDP.

2.3.2 Types of postponement

There are three main types of postponement: time, form and place postponement.

- *Time postponement* refers to the delaying of the forward movement of goods until customer orders have been received (Van Hoek, 1997). “The goal of time postponement is to ship exact product quantities from a central location to satisfy specific customer requirements” (Yeh and Yang, 2002). When applying time postponement the biggest advantage is transportation between warehouses and factories can be avoided by transporting finished goods to the customer directly. This will increase efficiency and shorten lead times.

- *Form postponement* involves delaying the completion of the final product configuration until after the customer requirements are known. Form postponement is characterized by standardizing the upstream stages as much as possible so that the product remains generic longer (Graman and Bukovinsky, 2005) Differentiation of the product can occur at different process stages (manufacturing, assembly, packaging, labeling). So an example of form postponement is a company that does not package products before orders are received. A big advantage of form postponement is the reduction of big inventories of finished goods (Graman and Bukovinsky, 2005). Inventory costs will be reduced. Furthermore the inventory is generic. This implies greater flexibility and variety of end products, which will lead to improved customer satisfaction. Forecasts will become more accurate because forecasting is easier at the generic level than at the finished item level (Christopher and Towill,2000).

- *Place postponement* refers to the centralization of inventories in a limited number of centralized inventory-keeping points in the chain and postponement of the downstream shipment until orders are received (Van Hoek, 1999). An example of place postponement in combination with form postponement is applied by the company HP, where the final printers are assembled at their distribution point (Enarsson, 2006).

These three types of postponement also have some drawbacks. Implementation of postponement leads to reducing economies of scale because production will typically be in smaller batches and furthermore leads to increasing cycle time because there will be more points where inventory is held (Yang and Burns, 2003). Production costs using postponement are typically higher than without postponement because of production in smaller batches (Chopra and Meindl, 2010). Furthermore, implementation of

postponement requires a redesign of the supply chain, which involves high costs as well (Cheng et al., 2010).

2.3.3 Postponement strategies

Based upon the three main types of postponement, there are different postponement strategies. Pagh and Cooper (1998) identify four postponement strategies by combining logistics and manufacturing postponement. They identify logistics and manufacturing postponement as follows:

- *Logistics postponement*: the notion is to maintain a full-line of anticipatory inventory at one or a few strategic locations, and to eliminate or reduce inventory further down the chain. This means postponing the inventory location downstream in the supply chain to the latest possible point. An example of logistics postponement is Ford's European Distribution Centre for spare parts, which is supplying dealers and garages with spare parts all over Europe within 24 to 48 hours (Mikkola and Skjøtt-Larsen, 2004). Logistics postponement can be seen as a combination of time and place postponement.

- *Manufacturing postponement*: the notion is to retain the product in a neutral and noncommitted status as long as possible. This means postponing differentiation of form and identity to the latest possible point. Products are finalized in response to customer orders and then shipped to that same customer (Nair, 2005). An example of a company which successfully made use of manufacturing postponement is Dell. Dell holds inventory of component parts in a few centralized locations and when the customer order arrives the product is assembled exactly to the customer's requirements (Kong and Allan, 2007).

Combining logistics and manufacturing postponement leads to four postponement strategies (figure 10):

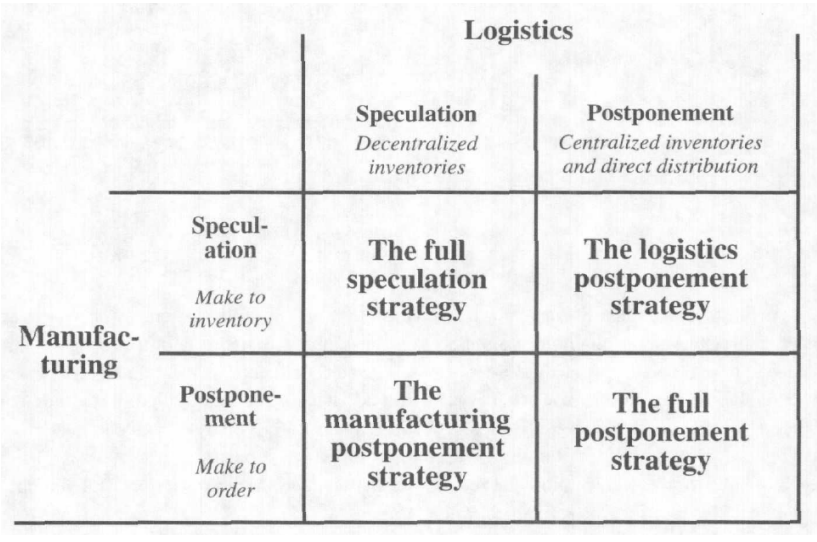


Figure 10 Four supply chain strategies, combining logistics and manufacturing postponement (Pagh and Cooper, 1998).

- *Full speculation strategy:* Full speculation of all manufacturing and logistics operations is practiced. This is done by inventory forecasts. All products are finalized before the customer order is received. The product is stocked close to the customer. So, all manufacturing operations are performed prior to the differentiation of the product by location, this is a make-to-stock process. The full speculation strategy can be applied when there are high economies of scale and there exists little uncertainty.

    - Advantages: full manufacturing and logistics economies of scale, low distribution costs, high customer service

    - Disadvantages: high inventory costs, obsolescence may occur.

- *Manufacturing postponement strategy:* In this strategy the products are not finalized until a customer order has been received. The final manufacturing operations are performed downstream in the supply chain. Inventories are held close to the customers. An example of this strategy is holding paint in a neutral color and customize the final color based on customer orders. This postponement strategy relates to the manufacturing situation assemble-to-order.

    - Advantages: reduced variety of differentiated products while providing a full assortment, reduced total value of inventory, low distribution costs.

    - Disadvantages: increased costs and complexity of customer order processing, reduced manufacturing economies of scale.

- *Logistics postponement strategy:* Manufacturing is based on speculation and logistics is based on postponement. All manufacturing operations are performed prior to logistics operations. Logistics operations are initiated by customer orders. The fully finalized products are directly distributed to the final retailers/customers.

    - Advantages: preserved manufacturing economies of scale, increased on-time deliveries of complete customer orders, reduced inventory costs, constant transportation costs, faster introduction of new products in the assortment.

    - Disadvantages: reduced or eliminated anticipatory nature of logistics, increased shipment costs.

- *Full postponement strategy:* Both manufacturing and logistics are customer order initiated. This strategy can be applied when there exists high demand and supply uncertainty.

- Advantages: reduced inventory and inventory costs
- Disadvantages: high distribution costs, low customer service

An other author, Yang et al. (2004), makes another classification and relates postponement to uncertainty. Yang states “The logic behind postponement is that the delay of activities leads to the availability of more information and thus the risk and uncertainty of those activities can be reduced or even eliminated”. Besides Yang links postponement to modularity. “Modularity means building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole.” Therefore, Yang distinguishes four other postponement strategies.

2.3.4 The choice of a postponement strategy

There are certain determinants that should be taken into account when choosing a postponement strategy. Of course the company strategy and the most important KPIs must be analyzed. Furthermore the type of product, type of supply chain, industry characteristics and degree of uncertainty influences postponement.

According to Pagh and Cooper (1998) there are three main categories:

- Product characteristics
  - Life cycle: products have a life cycle (introduction, growth, maturity, decline). In the first stages the focus is on customer service and a speculation strategy is preferred. In later stages postponement would be a good strategy.
  - Monetary density: products with high monetary density (ratio dollar-value/ weight or volume) benefit more from applying postponement.
  - Value profile: the value profile refers to when and how much the value of a product increases during the chain processes. If much value is added in the last stages it could be beneficial to postpone these processes.
  - Product design: for a highly customized product postponement can be beneficial.
- Market and demand characteristics
  - Relative delivery time: the average delivery time in proportion to average manufacturing and delivery lead-time.
  - Relative delivery frequency: the average delivery frequency in proportion to the average manufacturing and delivery cycle-time.

- Demand uncertainty : if the demand uncertainty is high, the risk of speculation is high as well.

- Manufacturing and logistics system

  - Economies of scale: if the economies of scale are very high, postponement may be less beneficial.

  - Special knowledge: if a large degree of special knowledge is required in the manufacturing process, some speculation may be beneficial.

By analyzing all these decision determinants, a profile analysis can be made. In figure 11 the supply chain implications of each decision determinant and strategy are shown.

Some important P/S-decision determinants			Generic P/S-strategies			
			The full speculation strategy	The manufacturing postponement strategy	The logistics postponement strategy	The full postponement strategy
Product	Life cycle	Stage	Introduction	Growth	Maturation	Mat./Decline
		Volume	Low/Med.	Med./High	Med./High	Low/Med.
		Cost/service strategy	Service	←	→	Cost
	Product characteristics	Product type	Standard	←	→	Customized
		Product range	Narrow	←	→	Wide
	Value	Value profile	Initial stages	←	→	Final stages
		Monetary density	Low	Low	High	High
Market and demand		Relative delivery time	Short	←	→	Long
		Delivery frequency	High	←	→	Med./Low
		Uncertainty of demand	Low	←	→	High
Manufacturing & logistics		Economics of scale	Large	Small	Large	Small
		Special capabilities	Yes	No	Yes	No

Figure 11 Decision determinants in postponement/ speculation (P/S) strategies (Pagh and Cooper, 1998)

By analyzing postponement it is shown that postponement can be used through the whole supply chain. Postponement has many advantages. If a company wants to postpone it is important to analyze the product, supply chain, industry characteristics and degree of uncertainty first. Then a choice for a certain strategy can be made.

2.4 Conclusion chapter 2

In this chapter an overview of existing literature is presented. An overview of supply chain management and related concepts is described in section 2.1. Literature regarding uncertainty and supply chain strategies is presented in section 2.2. In section 2.3 the concept postponement is introduced and different strategies are described.

3. Conceptual model

This chapter will relate the important concepts of chapter two: postponement, key performance indicators, supply chain strategies, planning uncertainty, food supply chain networks and company objectives by presenting and explaining a conceptual model.

3.1 Introduction

Based on the literature review in chapter 2 important concepts in supply chain management are linked to each other and a conceptual model is developed (figure 12). In his model relationships between these concepts are proposed. These propositions will be tested in the next chapter.

In this model the following relationships are proposed:

- Food supply chain network characteristics have influence on the supply chain strategy and supply chain design and postponement strategy a company applies. Furthermore these characteristics influence the degree of planning uncertainty in a company.
- The supply chain strategy influences supply chain design and postponement strategy applied by a company.
- Company objectives influence the choice of a supply chain strategy and the company performance.
- Supply chain design and postponement strategy applied by a company influence the degree of planning uncertainty and influence company performance.
- The degree of planning uncertainty has an influence on company performance.

First the influence of food supply chain network characteristics will be explained (3.2). Then the relationship between supply chain strategies and postponement will be presented and hypotheses are formulated (3.3). Finally, the influence of supply chain design/ postponement strategies on the key performance indicators will be clarified (3.4).

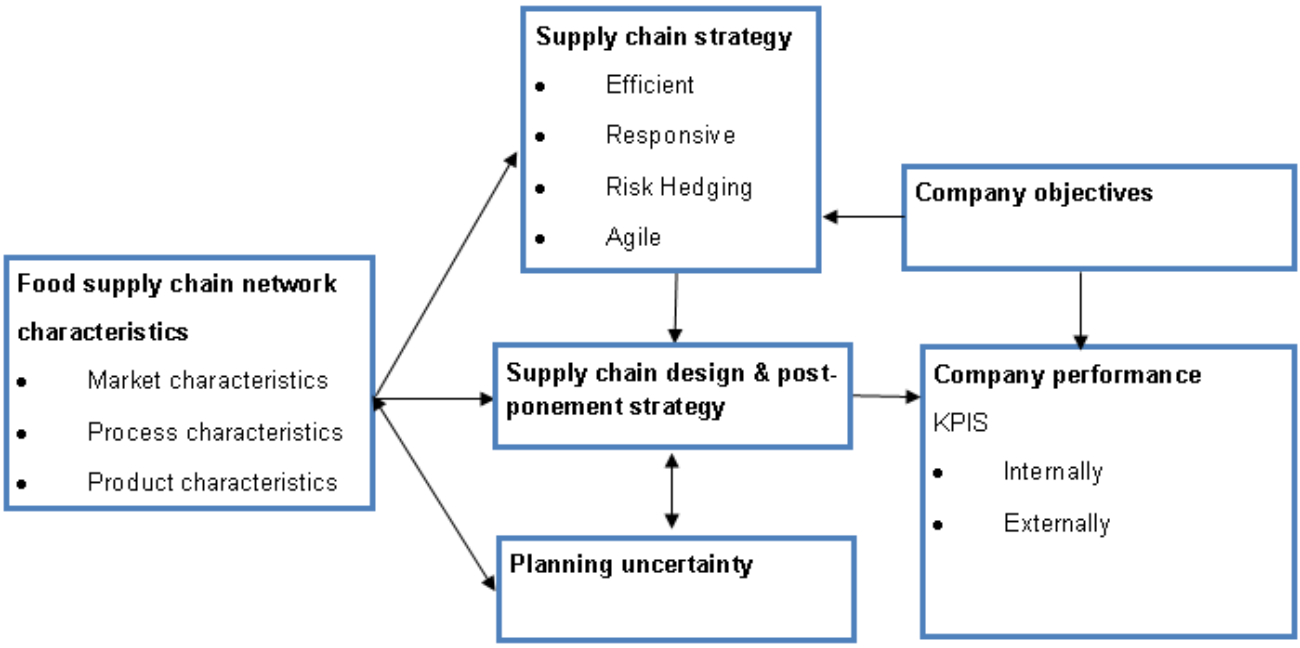


Figure 12 Conceptual model

3.2 The influence of Food Supply Chain Network Characteristics

This thesis focuses on food supply chain networks. Food supply chain networks have some very specific characteristics. (FSCN characteristics) that are discussed in section 2.1.2 and have influence on the supply chain strategy (3.2.1) and supply chain design and postponement (3.2.2) that are pursued by a company. There also is a relationship between FSCN characteristics and uncertainty but since uncertainties can be seen as FSCN characteristics and FSCN characteristics in combination with planning uncertainty influence supply chain design, this will be discussed in the next paragraph (3.3).

3.2.1 Supply chain strategies

Within this model we focus on the four supply chain strategies determined by Lee (2002). FSCN characteristics influence the choice of one of these strategies. In pratice, the classification is not that strict, mixed strategies do often exist. Lee put this four strategies in a matrix (figure 8) and states food products can be classified as products with low demand uncertainty.(figure 13).

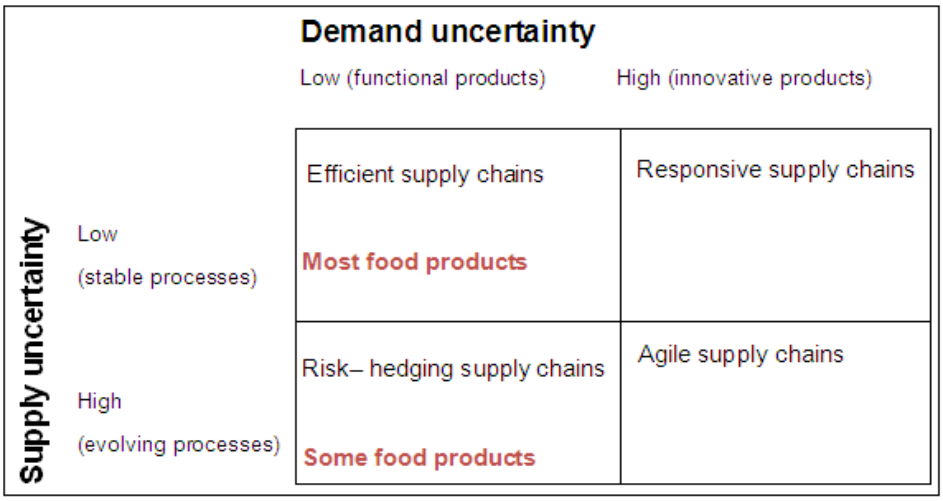


Figure 13 Supply chain strategies and food products (based on Lee, 2002)

According to this author food products will require an efficient or risk-hedging supply chain. This classification in questionable. In this section food products will be linked to these strategies and also the effects of the other strategies will be analyzed, based on literature review.

- *Efficient supply chain:* this supply chain strategy seems to be the best strategy for most food products because in literature these products are often related to low demand and supply uncertainty. Economies of scale are of big importance in choosing this strategy. Producing should be as efficient as possible (Lee, 2002). Long set-up times can be avoided because of production in big batches. This production method guarantees fast throughput times, which reduces the risk of obsolescence. A major problem in choosing this strategy is the fact demand for food products is not always predictable. (van der Vorst et al., 2001). Furthermore, applying this strategy flexibility will be low. Other FSCN network characteristics can also be problematic, such as producing a great variety of end products. This characteristic conflicts with the characteristics mentioned by van Donk (2001) but is sometimes present in food products, for example in meat products (van der Vorst, 2001).

- *Risk-hedging supply chain:* in food chains supply uncertainty can be high. In this case a risk-hedging strategy can be a good strategy to pursue. When a shared stock can function as safety buffer; economies of scale can be preserved. Because of delivery from central inventory delivery times can be very short and because of high stock delivery reliability will be high. Problems are related to the great amount of stock: high inventory costs, high risk of obsolescence and the great variety of end products that have to be kept in stock. Risk can also be hedged by having alternative suppliers or using supply contracts.

As mentioned above, in practice demand is not always predictable in food industries (van der Vorst, 2001) and therefore the classification is not valid for every food product. There are also food industries that require a responsive or agile strategy. This implies more products have to be made to order. Due to the FSCN characteristics there also exist disadvantages in applying these strategies.

- *Responsive supply chain:* this strategy is a good strategy when supply uncertainty is low, demand uncertainty is high and a company aims to be very flexible. Often companies have to be flexible, because retailers demand responsive deliveries. Products can be made according to customer order but due to the characteristics of food products some problems arise. Raw materials often differ in quality and supply is therefore not always predictable. Furthermore products are perishable, which makes it difficult to have a stock of raw material. Due to being flexible, economies of scale can reduce because of production in smaller batch sizes. Longer set-up times can be necessary. This implies throughput time and delivery time will increase. The biggest advantage in using this strategy is no big stocks of end products are needed. This reduces inventory and makes a company able to respond to the changing demands of customers and retailers.

- *Agile supply chain:* this strategy is a combination of risk-hedging and responsive supply chains. So, a company aims to be flexible while hedging for risks. These goals can sometimes conflict, mainly when supply uncertainty is high. If a food processor hedges for risks, for example by the use of contracts, and demand turns out lower than expected, problems arise because of the perishability of food products. When a stock of endproducts is used, it is more hard to respond to changing demand.

In analyzing this strategies it becomes clear FSCN characteristics are of great importance in choosing a strategy. Each food products has different FSCN characteristics and requires a different strategy. One company can use different strategies for different products or use mixed variants.

Besides the supply chain characteristics there are also company characteristics that influence the supply chain strategy. Here the company objectives related to supply chain management are of importance. A company makes logistical objectives, for example improve customer service while keeping integral costs stable or decrease integral costs while maintaining the customer service level (Visser and van Goor, 2008) and these objectives influence the choice for one of the four strategies of Lee.

3.2.2. Supply chain design and postponement

An important concept in supply chain management is the position of the CODP. Postponement is previously described as shifting the CODP or MDP downstream the supply chain to reduce uncertainty. This means more products will be made according to customer order and there will be less production based on forecasts.

The CODP separates order-driven activities from forecast-driven activities. In section 2.1.5 factors influencing the customer order decoupling point were presented. When the determinants of the decoupling point according to van Donk (2001) are combined with the FSCN characteristics determined by the same author we get the following table.

Table 3 Characteristics of food supply chains and the influence on food supply chains (based on van Donk, 2000)

Characteristic	Presence/value in food	Effect on CODP
Market characteristic		
Delivery reliability	High	Downstream
Delivery time	Short	Downstream
Predictability demand	(Rather) Unpredictable	Upstream through information sharing
Specificity of demand	Great variety end products	Upstream possibilities
Process characteristic		
Lead times and costs	Relevant set-up times	Downstream
Controllability	(Sometimes) Low	Downstream
Value added and costs of stock-holding	Unclear	-
Product characteristic		
Risk of obsolescence	High	Upstream

From this table it is shown that the FSCN characteristics have very different effects on the position of the CODP. This makes the position of the decoupling point in such chains very complex. Problems in applying postponement in food industries are the risk of obsolescence, the sometimes great variety of end products and uncertainty in supply and demand. The relation between FSCN characteristics and uncertainty will be discussed in the next section (3.2.3). However, postponement can also bring advantages to food supply chain networks: uncertainty can be reduced, inventory costs can decrease, delivery times can decrease and a company can become more flexible. The relationship between the four supply chain strategies of Lee and postponement will be clarified in the next section.

3.3 Supply chain design and postponement strategies

In the conceptual model supply chain design is a central element that is influenced by FSCN characteristics and supply chain strategies (3.3.1) and has a relationship with planning uncertainty. (3.3.2).

3.3.1 The relationship with supply chain strategies

In literature there are many supply chain strategies that exist and can be used. Within this research the focus will be on the supply chain strategies defined by Lee (2002). These strategies are discussed in section 2.2.4. The choice for one of these supply chain strategies depends on the company objectives, the FSCN characteristics. The relationships between FSCN characteristics and supply chain strategies are discussed in the previous section. In this section hypotheses about the relationship with postponement strategies are formulated. Within this thesis the postponement strategies of Pagh and Cooper (1998) are used.

- *Efficient supply chain:* this strategy matches with functional products. It is not always profitable to apply postponement because economies of scale can become lower, but there is a chance these disadvantages are outweighed by advantages. If postponement would be applied, probably the best option is logistics postponement because in this strategy economies of scale in manufacturing processes can be maintained. Using this strategy implies you do not need to stock end-products at every location. Instead products can be distributed from a centralized warehouse: this reduces inventory costs and new products can be introduced faster. FSCN characteristics also play an important role in the effectiveness of logistics postponement. Having less inventory points can be an advantage because food products are often perishable.

- *Responsive supply chains* match with innovative products which often have a modular product design. Often it can be profitable to apply manufacturing postponement because then products are finalized according to customer orders and thus the manufacturing process becomes very flexible while inventory costs will be reduced. Logistics postponement will probably not be a good option because when there is a big inventory of finished goods you are able to deliver products fast but will be less able to respond to changing customer and market demands and there will be less custimization options.

- *Risk hedging supply chains* match with functional products. In this strategy keeping central stocks is necessary (Seuring, 2003). To create this central stocks logistics postponement can be applied and the central stock can function as a safety buffer. This enables a company to deliver finished goods to customers or retailers very fast. A problem is the fact that food products are often perishable and keeping a large stock is therefore not always desirable.

- *Agile supply chains:* are a combination of responsive and risk-hedging supply chains. Therefore manufacturing and logistics postponement can be applied and most likely it is best to apply a full postponement strategy. A disadvantage is that lead times will increase.

Based on the above mentioned information hypotheses about the relationship between supply chain strategies and postponement strategies are made. These are clarified in figure 14.

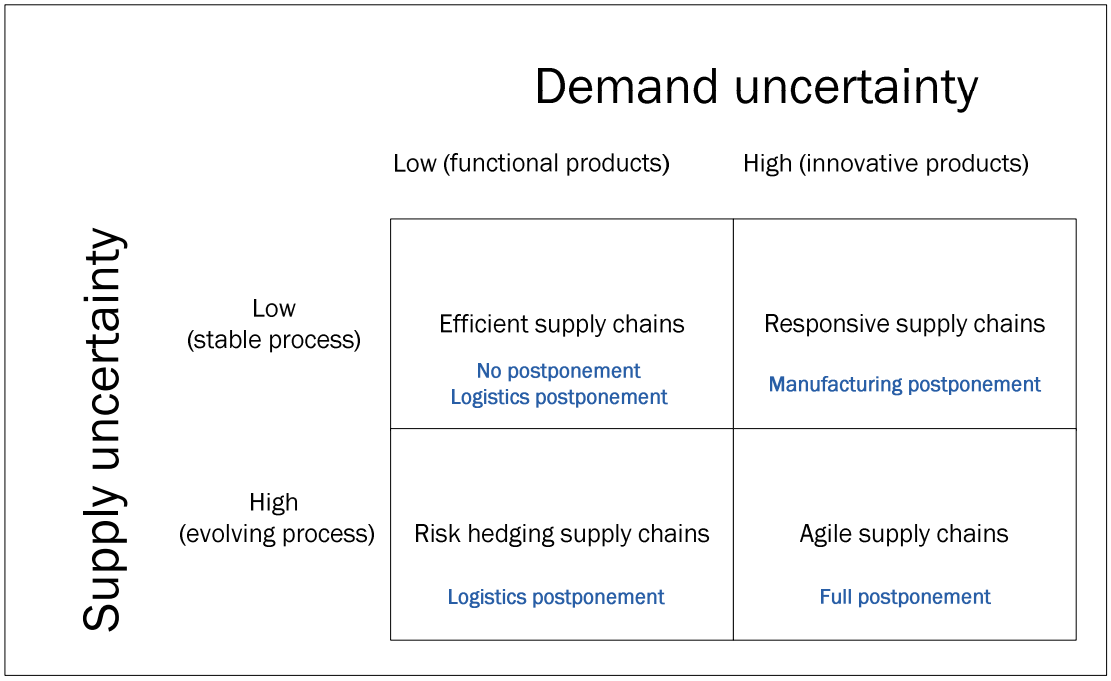


Figure 14 Relationship supply chain strategies, uncertainty and postponement (Based upon Lee, 2002 and Pagh and Cooper, 1998).

These hypotheses will be tested using a case and expert interviews (chapter 4).

3.3.2 The relationship with planning uncertainty

Within this research the supply chain strategies of Lee (2002) were used. This author relates this strategies to the degree of supply and demand uncertainty. This can be seen in the figure above. The combination of the degree of these two uncertainties relates to the degree of planning uncertainty. For example, when supply uncertainty and demand uncertainty are high it becomes more difficult to determine the level of stock to keep and to match raw materials and end products. To decrease the degree of uncertainty postponement strategies can be used (figure 14).

3.4 Company performance

In this section the effects of a supply chain design and postponement strategy on company performance are explained. Company performance can be measured by using KPIs, which are critical factors for the success of an organization. In this model the performance objectives defined by Slack (2007) are used as KPIs. These were described in section 2.1.3 and presented in figure 1. The change of the supply design by implementing postponement can have big influence on these KPIs. The implementation of the full speculation theory is not explained, because when this strategy is used no postponement is applied.

3.4.1 External KPIs

There are both internal and external KPIs. The following factors are used as external KPIs.

- *Delivery time:* the speed of production processes will go down when manufacturing postponement or full postponement is applied because of production of more customized products in smaller batches. The number of inventory points in the supply chain increases. These factors will in most cases increase delivery time. On the contrary, when logistics postponement is applied, manufacturing processes are still based on customer orders, so production can still take place in big batches. Besides the inventory with end products is located close to customers. This enables short delivery times.

- *On- specification products/services:* this KPI is expected to increase when manufacturing postponement or full postponement is applied. The product will be finalized based on customer orders, so there will be more specification options. When logistics postponement is applied it will be harder to customize products according to customer order, because it will be too complex to hold a full-line of inventory of different end products.

- *Wide product/service range:* when manufacturing postponement or full postponement is applied it is likely that it becomes more easy to offer a wide product range. Products can be finalized and differentiated downstream the supply chain, according to customer orders. When logistics postponement is applied it probably becomes more hard to offer a wide product range, because finalized products are held in a centralized stock. It is not wise to build up too big inventories because this will bring high costs and risk of obsolescence.

- *Volume and delivery adjustments:* when manufacturing postponement is applied it can become easier to adapt to volume and delivery adjustments due to smaller batch sizes, made according to customer order. When logistics postponement is used it becomes harder to make volume and delivery adjustments, because production took place according to forecasts. But, on the contrary, when there is a big inventory of finished goods, adjustments can

be made using this inventory. If full postponement is applied manufacturing and logistics operations are performed according to customer order. This makes a company very flexible and therefore it is expected it becomes more easy to make volume and delivery adjustments.

- *Dependable delivery:* the different postponement strategies have different effects on the dependability. To analyze the exact effects of postponement more research has to be done.

- *Costs:* when a postponement strategy is introduced there is a chance the supply chain needs to be redesigned. This can involve high costs. With manufacturing postponement production will be in smaller batches so economies of scale reduce but due to customization opportunities margins can be higher. When logistics postponement is used inventory costs will be reduced but shipment costs will increase when finalized products are held at one or a few locations. If full postponement is applied inventory costs will also reduce. On the contrary there is a possibility distribution costs go up.

The above described influence of postponement strategies on the external KPIs is clarified in table 4.

Table 4 The proposed influence of postponement strategies on external KPIs

KPI	External KPI	Influence of manufacturing postponement	Influence of logistics postponement	Influence of full postponement
Speed	Delivery time	Decrease	Increase	Decrease
Quality	On- specification products/ services	Increase	Decrease	Increase
Flexibility	Wide product/ service range Volume and delivery adjustments	Increase Increase	Decrease Different effects	Increase Increase
Dependability	Dependable delivery	-	-	-
Costs	Low price High margin	Different effects		

3.4.2 Internal KPIs

Besides external KPIs internal KPIs exist. The introduction of a postponement strategy also has a big impact on the internal company processes.

- *Throughput time:* when manufacturing postponement or full postponement is introduced, the throughput time will increase because the complexity of order processing probably increases and there will be more inventory points in the supply chain. When logistics postponement is applied the throughput time can be reduced because fully finalized products are made and production can be in big batches.
- *Error- free processes:* with manufacturing postponement or full postponement errors can occur more often because complexity of production and packaging processes can increase: the number of product types increases. When logistics postponement is applied manufacturing will occur in big batches so the chance of errors may be production is smaller. It is however not certain if these effects will occur.
- *Ability to change:* introducing any form of postponement will make a company more flexible, in manufacturing, logistics or both processes, so the ability to change will increase.
- *Reliable processes:* The reliability of production processes will probably not change much due to logistics, manufacturing or full postponement.
- *High productivity:* if manufacturing or full postponement is applied there will be more product forms and thus different processes needed after the MDP. This implies in most cases there will be produced less products per hour. If logistics postponement is used productivity will not change much because manufacturing economies of scale can still exist.

The influence of postponement on the internal KPIs is clarified in table 5.

Table 5 The influence of postponement strategies on internal KPIs

KPI	Internal KPI	Influence of manufacturing postponement	Influence of logistics postponement	Influence of full postponement
Speed	Throughput time	Slower	Faster	Slower
Quality	Error- free processes	-	-	-
Flexibility	Ability to change	Increase	Increase	Increase
Dependability	Reliable processes	No effect	No effect	No effect
Costs	High total productivity	Decrease	-	Decrease

3.5 Conclusion chapter 3

In chapter three some important concepts related to postponement, based on the literature review (chapter 2), were linked to each other. It is shown FSCN characteristics play an important role in designing a supply chain. Furthermore the different postponement strategies are shown to have very different and often opposite effects on important internal and external KPIs.

4. Testing the conceptual model

4.1 Introduction

The hypotheses based on the conceptual model are tested in the meat sector, using a case from VION. VION is an international food company and one of the largest players in the meat processing industry. VION processes livestock to fresh meat and semi-manufactured products. VION Food Group has more than 35,000 staff members worldwide and realizes an annual turnover of approximately €9,6 billion. VION fresh meat is the largest division of VION. This division has five pig slaughterhouses and three pig meat processing locations (Rijpkema, 2009). VION has difficulties in managing their uncertain supply and demand, which leads to inefficient use of raw materials, relatively long troughput times, variation in product quality and high logistical chain costs.

In chapter three a conceptual model is described and relationships between uncertainty, supply chain strategies and postponement strategies were proposed. This model will now be tested. First the research methodology will be explained (4.2). The relationships will first be tested in the pork supply chain (4.3). This chain will be analyzed based on information from Rijpkema (2009) and an expert interview held with an expert in supply chain planning in the meat sector. The model will also be tested in another food chain, the cheese production chain. Testing will be done interviewing an expert in this chain (4.4).

4.2 Research methodology

To test the conceptual model and proposed relationship an analysis of the pork supply chain will be made. The presented information will be largely based on Rijpkema (2009). Based on this information and the proposed relationships in the conceptual model a questionnaire is prepared and used to interview an expert in the meat production chain, a quality manager at VION Netherlands. This questionnaire will also be used to interview an expert in the cheese production chain. With this information there will be tried to fill in the conceptual model.

4.3 The pork supply chain

The pork supply chain starts with the breeding of pigs and ends with delivering the final pork products to the consumer or retailer. In this section the focus will be on the activities of the meat processor.

Specific supply and demand characteristics of the pork industry will be described. (4.3.1 and 4.3.2) The above described process will be clarified by reviewing the different processing steps (4.3.3). Furthermore differentiation points in this chain (4.3.4) and postponement opportunities (4.3.5) will be described. Finally the model will be applied to this case (4.3.6) and the expert interview will be used to complete and test the model (4.3.7).

4.3.1 Supply characteristics

Farmers deliver pigs to the meat processor. The pork industry is characterized by a variety of farming systems, which results in heterogeneity in quality features of finished pigs. This affects multiple quality features like weight, lean meat ratio, sex and fat layer thickness. This heterogeneity exists both between pig batches coming from different farmers and within pig batches itself. Due to these characteristics the supply uncertainty in this chain is very high. This uncertainty asks for a good planning system, to allocate the pigs to the different slaughterhouses.

4.3.2 Demand characteristics

Meat processing companies serve many consumer markets due to the globalization of the meat industry. The demand of these markets differs for specific quality features, meat cuts, logistic services and volatility of demand. The demand is characterized as uncertain.

In order to efficiently match the uncertain quality of supplied livestock with demand for specific end products or markets, effective logistics control mechanisms are required. The use of quality information is a key feature in these logistical control mechanisms.

4.3.3 Process description

In the pork chain we distinguish six processing steps and seven product differentiation points (figure 15):

- *Livestock supply and receiving*

  This process involves supplying the slaughterhouses with livestock. When pigs arrive at the slaughterhouse they have to be temporarily stabled. An operational buffer is created for the slaughtering line and the pigs are allowed to rest after transport, this reduces stress levels. (A survey of pork quality in relation to pre-slaughter conditions, slaughterhouse facilities and quality insurance, Lammens, 2007).

- *Slaughtering and evisceration*

  Before the pigs are slaughtered they are stunned. Next they are killed and put on a hook. The intestines are removed and the pig is cut into two parts. If the pig is approved for further processing the carcass characteristics will be measured.

- *Carcass cooling*

  The process of cooling carcasses in the cooling room until they have a core temperature at which they can be processed. Furthermore this cooling room can be used as an operational buffer for the cutting and/or processing lines.

- *Carcass cutting*

  The process of cutting carcasses into technical carcass parts (shoulder, ham and middle) or exporting carcasses to external processors as complete carcasses.

- *Meat processing and packaging*

  The process which transforms technical parts to final, packed end products.

- *Distribution*

  The distribution of the end products to the customer or temporary storage.

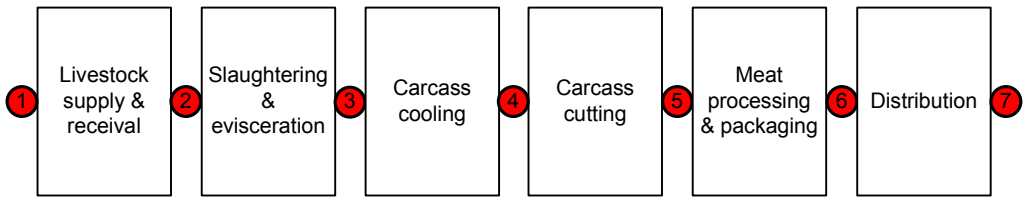


Figure 15 Processing steps

4.3.4 Differentiation points

We distinguish seven product differentiation points in the above described chain:

1. At this differentiation point the processor chooses how much livestock to buy, at which location the livestock is processed and how/when the livestock will be transported.
2. The processor chooses which livestock will be slaughtered and when this will happen.
3. The processor decides where and when to cool the carcasses.
4. The processor chooses which carcasses will be pulled from the cooling and how these carcasses are matched with the cutting lines.
5. At this point the processor decides which technical parts will be used for which end products.
6. The processor will match packed end products with customers or inventory.
7. At the last differentiation point the processor decides which customer orders to accept.

4.3.5 Postponement in the pork chain

To reduce uncertainty in the supply chain postponement may be used. Postponement implies some activities will be delayed until more information about customer orders is available. In the previous section the differentiation points were described. The processor has CODPs at more than one place.

- DP 4, CODP after cooling: complete carcasses are selected to be exported to external customers.
- DP5, CODP after carcass cutting: the hams are graded, sorted and selected for customer orders. This happens after the carcasses have been cut in different technical parts.
- DP6, CODP after meat processing: minced meat is largely created from side-products that originate in processing of other fresh meats. These side-products are then mixed and minced to fit the quality specifications ordered by the customer.
- DP7, CODP after processing and packaging. Some products are not produced to order, but are produced based on order forecasts. They are therefore sold from stock and can be distributed to the end customer directly after selling them.

The material decoupling point (MDP) is at DP3, the point where strategic inventory is held. At this point, before cooling, the product is still generic. The goal of applying postponement is to keep the product generic as long as possible.

4.3.6 Pork chain model

Based on the information on pork supply chains, we can already partly fill in the conceptual model for these chains (figure 17).

Some very specific food supply chain network characteristics are present in the pork chain: an unpredictable demand, great variety of end products and high risk of obsolescence. These characteristics have a big influence on the supply chain design.

The pork chain faces high supply and demand uncertainty. In principle, high uncertainty matches with innovative products. Pork meat cannot be described as an innovative product. Due to the specific characteristics described above, some food products are characterized as functional products with volatile and unpredictable demand (van der Vorst, 2001). To fill in the rest of the model, an expert interview is held.

4.3.7 Results expert interview pork chain

To determine the most important KPIs for the pork chain, to analyze which supply chain strategy would fit best and to explore postponement opportunities, an expert interview with a quality manager at VION Food Group is held. The full interview (in Dutch) is added as appendix 1.

Key performance indicators

Based on this interview the most important performance indicators for VION internally and externally can be determined. Internally, the most important is to carry out orders according to customer orders. This is for example measured by complaints analysis. Besides costs/ productivity (for example the number of pigs slaughtered per day or productivity in the cutting room) are important. Externally reliability, quality, yield raw materials and flexibility are of big importance.

Reliability is the most important KPI because that is the foundation of the organization and influences all other KPIs. This KPI actually is an internal KPI, because it is about the reliability of processes. Quality is also important, if you do not deliver high quality products, the rest is not important. The yield on raw materials is of importance because of the low margins in the meat sector. Flexibility is absolutely necessary because pork meat is perishable; there are few opportunities for buffer storage of products.

FSCN characteristics

The FSCN characteristics that are important for VION are:

- Variable supply and quality of raw materials: this is extremely important in meat chains, where homogenization of products is not always possible. The pork chain is very dependent on the supply side of the chain, because farmers are not obliged to deliver pigs to VION. This means supply of pigs fluctuates and the company has to deal with this characteristic.
- Perishable raw materials, semi-manufactured products and end products: this characteristics is also very important, there are strict regulations regarding freshness of products. On the other hand hygiene has improved in the last years and also cooling and packaging techniques have improved. This results in longer shelf lives.
- Processes have variable yield and processing time: This is the case in the pork industry. For example, it makes a difference if you only have to debone a carcass or if you make a fully processed product, such as non-fat pork meat. At VION different processing locations try to specialize: one slaughterhouse only slaughters and cuts pigs, the other slaughterhouse processes the parts further. This has consequences for yields and processing times.

- Divergent product structures and end products: There are a lot of end products at VION. Therefore VION tries, as described above, to specialize, so there is no slaughterhouse that makes end products for consumers or retail.

Uncertainty

There is high supply uncertainty because of the open trade relations with suppliers. Therefore, there are high fluctuations in supply of pigs. Managing happens by relations management and the tool farming net. This tool gives farmers valuable information about the livestock delivered to VION: this is an advantage for the farmers. In this way VION wants to establish a stable relationship with its suppliers.

VION wants to deliver as many markets as possible. This ensures flexibility and makes sure VION has a lot of options and can deliver many customers, because retailers sometimes offer big discounts and campaigns: this results in fluctuations in demand. So, when you have to deliver big volumes to big retailers this implies you are not able to deliver meat to all of your customers. Thus, there are customers to whom you deliver stable volumes and customers where you need a lot of flexibility: VION needs a good mix of different customers.

VION partly works on basis of contracts, which makes the predictability of demand higher.

Concluding it can be said VION faces strong supply uncertainty, but also demand uncertainty. This makes matching pork meat to orders difficult.

Customer order decoupling point

The CODP in the pork supply chain lies at the cutting room or at the deboning phase (decoupling point 5, figure 16). At this point most products are made customer-specific. For new concepts as biologic meat or good farming welfare, the CODP lies earlier in the supply chain: you have to select animals at arrival at the slaughterhouse and process them separately. These concepts make logistical processes more complex but on the other hand, when you do not produce these special products, you lose customers and markets and these products have the highest margins.

Postponement

VION already applies postponement: almost all products are made-to-order because keeping high inventories is not desirable. Especially manufacturing postponement is applied: for example packaging processes, VION tries to use uniform package material, but not all retailers accept this.

Because of the specialization of locations the CODP already lies upstream the supply chain: already early in the production process products are divided among different production locations to be processed further, therefore they are already made order-specific.

A mixed form of postponement is partially applied: there is a big distribution centre from where many orders are delivered to retailers. Labeling processes are postponed: products are labeled at this distribution centre.

The use of postponement has different, sometimes opposite effects on the identified KPIs, for example flexibility can go up, but productivity can go down. Overall, at VION a full product assortment and flexibility are of big importance, therefore postponement has many advantages.

4.3.8 Filling in the conceptual model

By the use of the information from the interview we can fill in the conceptual model (figure 16). The most important FSCN characteristics are defined. Based on Lee (2002), VION can best use an agile supply chain: it looks like they face high supply and demand uncertainty. This indicates full postponement would be the most suitable strategy for VION (section 3.3).

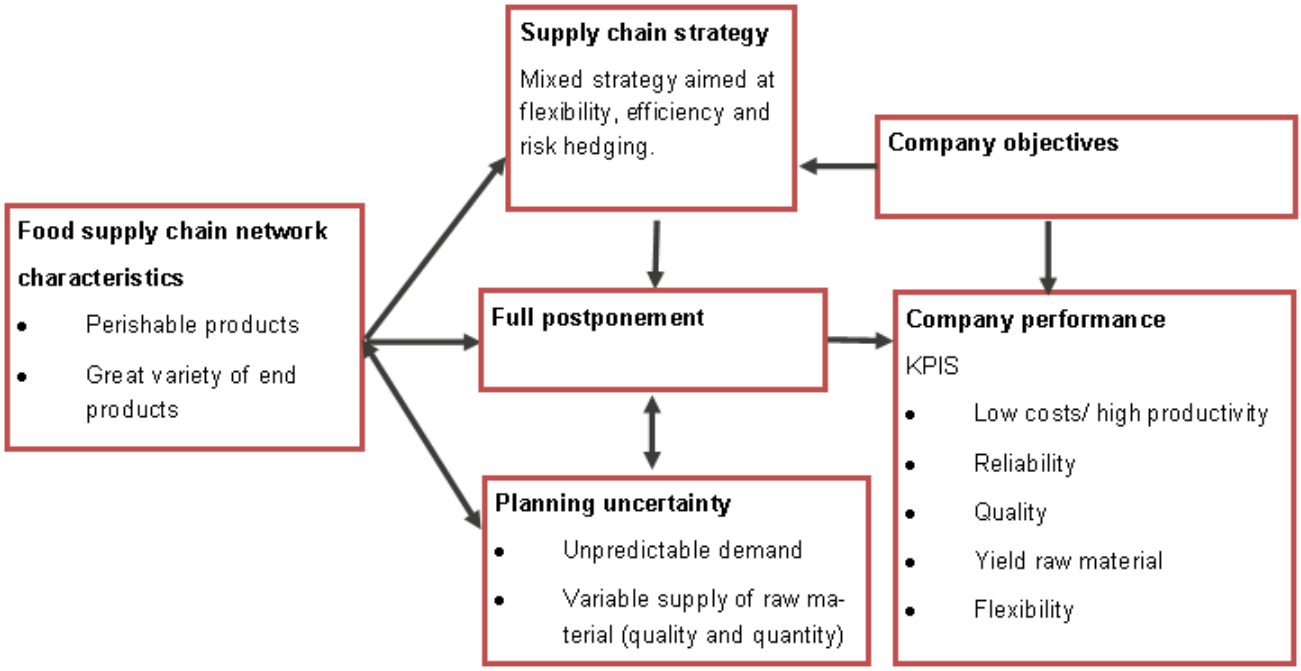


Figure 16 Conceptual model VION

On the contrary, Lee stated food products require an efficient or risk-hedging supply chain strategy. For VION this is less applicable because of high supply uncertainty. Based on the information from the case and interview we can see VION pursues a mixed supply chain strategy: flexibility is of big importance and they try to adapt quickly to changing demand. Besides they try to hedge risks by having many customers and markets and by the use of contracts. Furthermore, at the meat sector it is extremely important to produce against low costs: margins in this sector are low.

At this moment VION partially applies both logistics postponement and manufacturing postponement, but there are opportunities to postpone even further.

An option can be to move the CODP to the cooling phase and process carcasses according to slaughter sequence. This can enlarge productivity but there can also be problems regarding the variable quality of the carcasses (Rijpkema, 2010, unpublished material). To investigate these opportunities further research is needed.

Based on literature about 'standard' supply chains related to uncertainty (Lee, 2002), full postponement would be the best strategy for VION to pursue, because of the high supply and demand uncertainty combined with the agile supply chain strategy, but due to specific (FSCN) characteristics and KPIs this strategy probably is not the best strategy for VION to apply: the meat chain is characterized by extremely low margins (functional products). Therefore efficiency, productivity and reliability are of big importance in this sector. These KPIs will probably go down because more production has to take place in smaller batches when applying full postponement: this makes manufacturing, packaging and logistics processes more complex. Postponement also brings advantages: flexibility and quality can increase: production can take place according to customer orders. Furthermore the yield on raw materials is likely to increase because if the CODP is moved upstream the supply chain there will be for example more room for special concepts, where margins are higher.

Combining the expectations, based on literature, the case and the results and analysis of the interview leads to the following table:

Table 6 Meat chain: comparison literature and case

	Literature	**Case + interview**
Type of product	Functional product	Functional product with volatile demand and supply
Supply chain strategy	Efficient/ risk hedging strategy	Mixed strategy
Uncertainty - **Demand** - **Supply**	 Low Low	 High High
Postponement	No postponement/ logistics postponement	Full postponement
KPIs	Efficiency	- Efficiency, productivity and margins

		- Reliability - Flexibility

4.3.9 The gap between case and literature

Analyzing this table we can conclude there is a gap between literature and our findings. These gaps are mainly caused by the specific characteristics of meat supply chains (FSCN characteristics).

Based on literature (Fisher, 1997), meat products have to be functional products: they have to satisfy basic needs and have long life cycles, product margins are low. When we combine this information with the uncertainties and supply chain strategies from Lee (2002), we could say food products need an efficient supply chain.

In the meat chain indeed an important focus is on efficiency, margins are low and costs and productivity are thus important in designing the supply chain. But there are some characteristics of functional products that are different from characteristics of meat products: demand of meat products can be very volatile, supply is not guaranteed and volumes and quality fluctuate, there are many end products and meat products are perishable. These characteristics make a fully efficient strategy not applicable to VION: they have other importance goals, like flexibility.

In realizing this flexibility, postponement can be a good option. Postponement can reduce uncertainty in the meat chain while efficiency still needs to be a focus.

Based on the information from the interview we state VION uses an agile strategy and uses both (partially) manufacturing and logistics postponement but full postponement is probably not the best strategy for VION to use because by using this strategy margins and productivity can go down.

Therefore, postponement can bring many advantages in the meat supply chain but an intermediate postponement strategy has to be searched for. To examine the exact results of applying different postponement strategies and the effects on the different KPIs, further research has to be done.

4.4 Expert interview cheese production chain

To be able to compare the analysis of the meat chain, another expert interview is held. We analyzed another food supply chain: the cheese production chain. Recently there were some interesting developments in this chain: the logistical stream of cheese to Albert Heijn, the supermarket chain with a very large market share in the Netherlands, is now arranged by one specialized service provider and there is one shared warehouse. Albert Heijn introduced Vendor-managed-inventory (VMI): this means cheese suppliers themselves are responsible for their bulk stocks.

To analyze the supply chain characteristics of the cheese production chain and to see if there are options for postponement an expert interview with a supply chain planner was held. The full interview (in Dutch) is given in appendix 2.

4.4.1 Results expert interview

To analyze the cheese production chain, first the most important elements and processes of the chain are identified:

Collection of milk – allocation of milk – milk arrives at factory – production – storage – if necessary, transport – refinement storage – if necessary, decoration or wax lamination – packaging – transportation – distribution centre – retail – customers.

Key performance indicators

In the cheese production chain one of the most important KPIs is related to stocks. These stocks may not be too high. Also the age of the cheese and the quality are of big importance. Furthermore costs are essential and there are KPIs based on sales, turnovers and margins.

There are differences in KPIs for standard cheeses and special cheese types. For standard cheeses yield on raw material and high productivity are of big importance. When you look at special cheese types, flexibility and quality are of more importance.

FSCN characteristics

The FSCN characteristics that are important in this chain are:

- Perishable raw materials, semi-manufactured products and end products: this is of big importance in cheese, especially in packaged end products and / or at the stores.
- Divergent product structures and end products: this is extremely important; there are many different cheese types and end products.
- Variable supply and quality of raw materials: the milk supply can sometimes fluctuate and therefore this factor can be of importance. Differences in quality do not have big influence.
- Long-set up times between different product types: Cheeses have different shapes: they are not all even big and heavy. This means there are set-up times and in between machines have to be cleaned. Overall this does not have a very big influence.

Uncertainty

Uncertainty always has influence but compared to other industries the cheese market is quite stable: everyone keeps eating cheese, although volumes can vary sometimes, for example per season. The supply side, the milk delivered by farmers,

is also quite predictable. Sometimes there can be problems: for example is there is too much milk and there are no orders. Then stock has to be built and questions rise: which cheese can you make best and at which location?

To reduce uncertainty in the supply chain, there are meetings where sales and operations gear their activities.

CODP

In principle milk is divided among butter, powder, cheese and fresh based on market demands. Cheese has different types, for example 30+ cheese, but that type has again 25 end products. Therefore, in advance there is not decided for which end product the milk is used. So, if you have a four-week old cheese, there is the possibility to sell it if there are orders, if not, it can continue to ripe.

Both MTO and MTS are used: when MTO is used the base cheese will be intended for a certain customer and when the order arrives the cheese can be cut and/ or packaged. When MTS is used these processes take place based on forecasts.

Postponement

Probably in the cheese production chain there will be more development towards MTS than MTO, so the opposite of postponement happens. This happens because retailers order very late and the trend is cheese processing companies have to predict the amount of cheese customers want to have.

Manufacturing postponement is already applied at this moment: there is a base cheese and this product can be made specific when orders arrive by for example cutting or packaging.Logistics postponement is also applied: end products are kept in a central stock.

The application of postponement ensures more flexibility, this is the main advantage. Furthermore production can be cheaper and quality can sometimes be better.

A potential disadvantage is you do not want to make and package a separate cheese for each order, this implies high set-up costs, and so you try to cluster products. But, in general postponement is very meaningful.

4.4.2 Filling in the conceptual model

Based on the information from the expert interview we can also try to use the conceptual model for analyzing the cheese chain. We made two models, because the models are very different for standard cheeses and special cheeses.

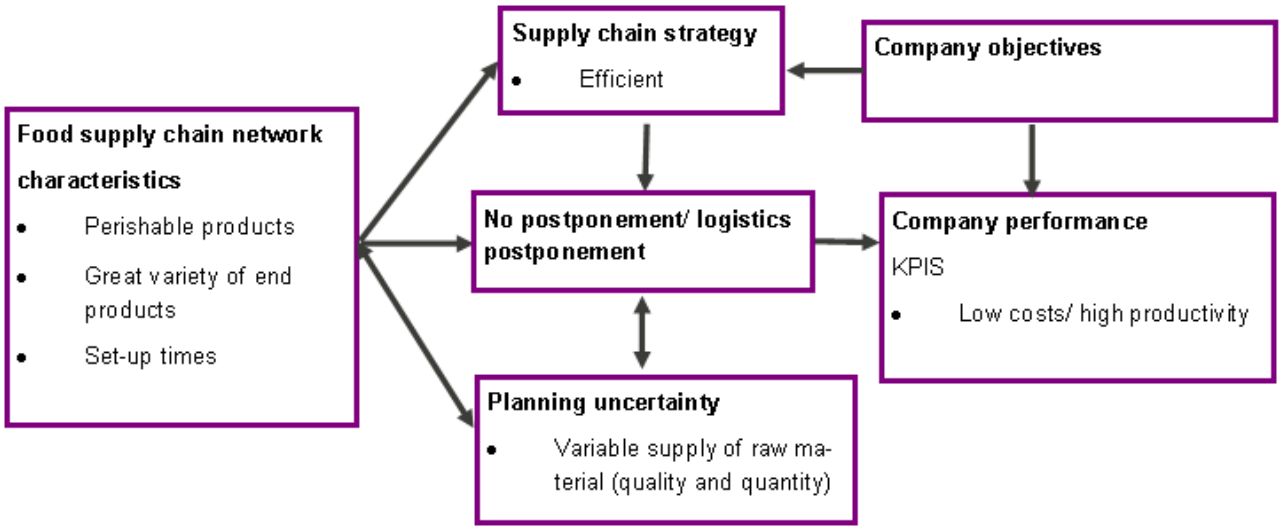


Figure 17 Conceptual model standard cheeses

For standard cheeses, the most important KPIs are costs-related. Based on the information from the interview, we can therefore say an efficient supply chain is needed for these types of products. According to the proposed relationships in section 3.3.1 it is best to apply no postponement (full speculation) or logistics postponement. When logistics postponement is applied, manufacturing economies of scale will be maintained. These relationships are presented in figure 17.

In the case of this cheese production chain manufacturing postponement is also applied. This can be a good strategy because not only standard cheeses, but also special cheeses are produced and the number of product types and end products is very high. The model for the special cheeses is shown in figure 18.

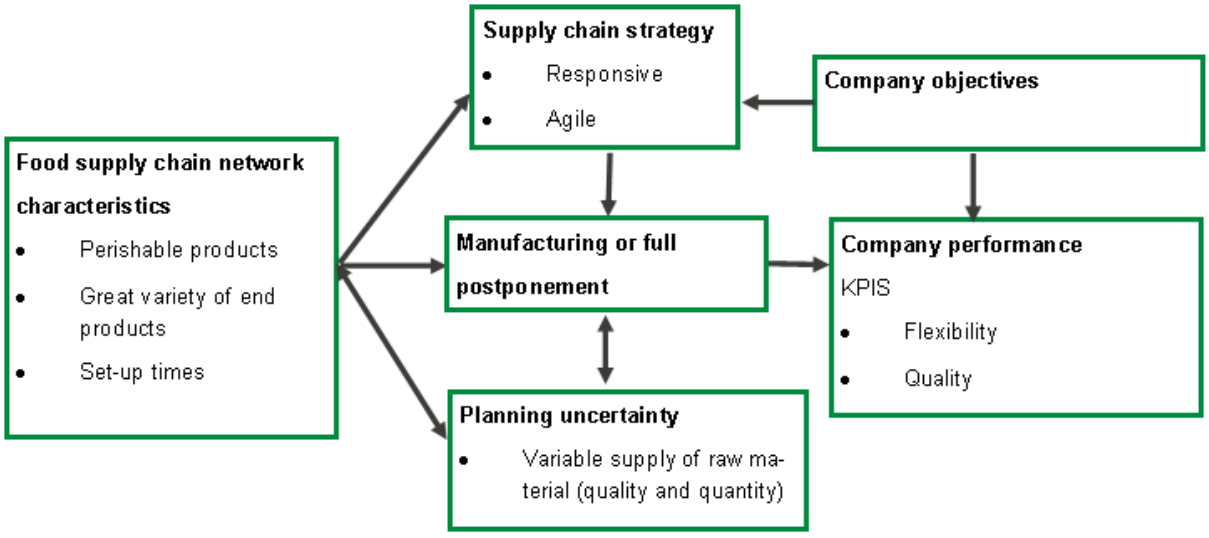


Figure 18 Conceptual model special cheeses

In the production of special cheeses different KPIs can be classified as very important: flexibility and quality. These KPIs in combination with the FSCN characteristics make a responsive or agile supply chain strategy the best strategy, which can be combined best with manufacturing or full postponement. As described above, manufacturing postponement is already applied in this chain: products are finished according to customer orders. Therefore they are quite generic.

4.4.3 The gap between interview and literature

The comparison between information based on literature and information based on the interview is presented in table 7. Just as in the meat chain, on the basis of the literature review (chapter 2), an efficient supply chain can be expected because cheese is a functional product (Fisher, 1997). Manufacturing postponement is not expected based on the literature review about 'standard' supply chains but in this specific supply chain this turns out to be a good strategy because of the FSCN characteristics and the combination of standard and special cheeses.

Van Hoek (1999) found that application of postponement in food supply chains focuses mainly on packaging and distribution, rather than on product customization. This is not valid in cheese production chains, where cheeses are finalized based on customer orders: this strategy works quite good. This strategy probably works well because of the specific characteristics of cheese: if there are no orders cheeses can ripe further. Furthermore there are many end products: cheese types can still be transformed to 25 end products. Therefore flexibility is of great importance.

The application of manufacturing postponement has a positive influence on this flexibility, just as on the quality of the cheeses.

The effects on productivity are likely to not be that positive, but on the contrary, basic cheeses can still be made according to forecasts so economies of scale can be maintained.

The trend in this industry is to produce more to stock and cheese producers will be responsible for the stocks at the big retailers. In this case it can be the case postponement has other effects in this case. To examine these effects more research has to be performed.

Table 7 Standard and special cheeses: comparison literature and interview

	Literature	Interview	
		Standard cheese	**Special cheese**
Type of product	Functional product	Functional product	Functional product
Supply chain strategy	Efficient/ risk hedging strategy	Efficient strategy	Intermediate form, efficient but mainly responsive
Uncertainty			
- **Demand**	Low	Low	Relatively low
- **Supply**	Low	Relatively low	Relatively low
Postponement	No postponement	Logistics postponement	Manufacturing postponement
KPIs	Efficiency	- Low costs/ high productivity - Yield raw materials	- Flexibility - Quality

4.5 Conclusion chapter 4

In this chapter the propositions of the conceptual model were tested. It became clear FSCN characteristics indeed play an important role in designing the supply chain. However, the relationships between supply chain strategies, postponement strategies and uncertainty (figure 14) are not always valid. This is mainly caused by this specific FSCN characteristics. Furthermore, often mixed supply chain and postponement strategies exist, which is not accounted for in the model. The differences between literature and our findings in different supply chains were clearly presented in tables 6 and 7.

5. Discussion and conclusions

In this last chapter the research questions will be answered (5.1) and discussed (5.2). Finally recommendations for further research are given (5.3).

5.1 Conclusion

In this thesis a literature review is done and based upon literature, a conceptual model is proposed to define the relationship between FSCN characteristics, supply chain strategies, postponement, company objectives and KPIs. This model is tested in two different food supply chains. This is done to answer the following research questions:

1. Which postponement strategies exist and are relevant for the meat supply chain?
2. Which factors influence the choice of a postponement strategy?
3. What is the influence of postponement strategies on planning uncertainty and how do they impact the key performance indicators?

This research questions will now be answered.

Research question 1

In literature four important postponement strategies were identified by Pagh and Cooper (1998) and chosen to use in this research. This strategies were:

- Full speculation strategy
- Logistics postponement strategy
- Manufacturing postponement strategy
- Full postponement strategy

These strategies all have differrent advantages and disadvantages and there are product characteristics, market and demand and manufacturing and logistics characteristics that have to be taken into account when choosing a certain postponement strategy.

Research question 2

We can state FSCN characteristics play an important role in determining supply chain design and postponement strategies. The decision to apply a specific postponement strategy is dependent on for example the perishability of products, the number of end products offered, and the variable supply and the sometimes uncertain demand. High supply and demand uncertainty can result in planning

uncertainty. If there is high planning uncertainty, postponement can be a good option to reduce this uncertainty. If there is almost no uncertainty, postponement may be less profitable.

In this thesis the different supply chain strategies of Lee (2002) were used to analyze their influence on supply chain design and postponement strategies. Lee stated a certain supply chain strategy should be chosen on basis of the degree of demand and supply uncertainty.

However, this research shows this classification is not always valid. This is because some food products have some very specific characteristics (for example unpredictable supply and a great variety of end products) which make an efficient supply chain not always appropriate. For example cheese can be described as a product with relatively low supply and demand uncertainty but still a purely efficient strategy is not the best strategy to apply. The differences between the classification of Lee and these findings can probably be described by the very specific FSCN characteristics.

A relationship between the supply chain strategies of Lee and the postponement strategies of Pagh and Cooper (1998) is defined (figure 14). In the expert interviews held these hypotheses were not always correct. In the meat chain a mixed supply chain strategy combined with full postponement is used. The model does not include mixed strategies.
In the standard cheese production an efficient supply chain is used in combination with logistics postponement. This seems to be in line with the relationships defined in figure 14.
In the special cheese production the supply chain strategy was hard to define, it looks like a mixed form is used as well. Therefore this relationship cannot be tested using this conceptual model.

There are thus different factors that influence the choice of a postponement strategy: the supply chain strategy, FSCN characteristics and the degree of uncertainty.

Research question 3

In the expert interviews was clarified the use of postponement indeed has different effects on the KPIs. Postponement can be a good way to reduce uncertainties but there is a possibility postponement also has negative effects, for example on costs: economies of scale can reduce, productivity may decrease and supply chain redesign costs may be needed. So far, advantages seem to outweigh potential disadvantages in meat and cheese chains: more flexibility is created to respond to volatile demand, more products can be made customer- specific and there can be better dealt with planning uncertainties. However, further research in more sectors is required to prove this.

5.2 Discussion points and recommendations for further research

- In this thesis a literature review is performed but almost all literature is based on ‘standard’ supply chains and the characteristics of FSCN are not taken into account yet. This complicates this research and makes it interesting.

- In the conceptual model the supply chain strategies defined by Lee (2002) and the postponement strategies defined by Pagh and Cooper (1998) were used. In practice, many mixed strategies exist: the current model does not account for this and may therefore be less applicable to these cases.

- Within this thesis relationships between uncertainty, FSCN characteristics and postponement strategies were proposed. Sometimes these relationships conflict with the presented literature. For example with the relationships defined by Pagh and Cooper (1998) in figure 11. More research needs to be done to examine the ‘gaps’ in the current literature.

- Expert interviews were held to test the conceptual model. However, only two expert interviews were held due to time restrictions. To gain a complete insight in a sector, more interviews need to be held and more information needs to be gathered. Furthermore, more interviews need to be held in different food sectors. The conceptual model is now only tested in the meat and cheese sector.

- The conceptual model is now only tested using interviews. To analyze the effects of postponement in food supply chains more research methods need to be used and quantified results are needed.

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Appendices

The full interviews are excluded due to conficential reasons.