IMPACTS OF SUPPLY CHAIN DESIGN PARAMETERS ON RETAILER IN-STORE LOGISTICS PERFORMANCE

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF SOCIAL SCIENCES

OF

IZMIR UNIVERSITY OF ECONOMICS

BY

CANSU KANDEMIR

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

IN

THE GRADUATE SCHOOL OF SOCIAL SCIENCES

JULY 2012

Approval of the Graduate School of Social Sciences

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ABSTRACT

IMPACTS OF SUPPLY CHAIN DESIGN PARAMETERS ON RETAILER IN-STORE LOGISTICS PERFORMANCE

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July 2012, 84 pages

Due to the complex structure of today's supply chain and recent competition in the retailing industry, retailers are striving to improve their operations. Under the conditions imposed by the new business environment, the final few meters of the supply chain turns out to be very crucial because of directly affecting significant performance parameters, such as customer service levels, store revenues, stock out costs, and inventory costs. Therefore, companies continuously seek for ways to run their stores, hence, in-store logistics more efficiently. Traditional approaches concentrate mainly on the internal management of the dynamics of in-store logistics. In this study, we look at the problem with a broader perspective. We question the interaction between supply chain structural parameters and in-store logistics. In doing so, we aim to identify the effects of supply chain parameters such as demand rate, inventory management policies, stock replenishment intervals and distribution center capacity as well as in-store logistics operational parameters such as shelf filling regimes, shelf capacity, inventory control policies on in-store logistics and supply chain performance. We start with the identifying supply chain structure and defining the environmental parameters; whereafter we employ simulation as an analytical tool for our research. We use ARENA Simulation Software version 13.9.

Keywords: Supply chain management, in-store logistics, discrete-event system simulation

ÖZET

TEDARİK ZİNCİRİ TASARIM PARAMETRELERİNİN PERAKENDE MAĞAZA LOJİSTİĞİ ÜZERİNE ETKİLERİ

Cansu Kandemir

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Temmuz 2012, 84 sayfa

Günümüzün karmaşık tedarik zinciri yapısı ve perakende sektöründeki rekabet nedeniyle perakendeciler faaliyetlerini geliştirmek için yoğun çaba harcamaktadırlar. Yeni iş ortamının dayattığı koşullar altında, müşteri hizmet düzeyleri, mağaza gelirleri, stok maliyetleri ve stok dışı olma durumu gibi performans parametrelerini doğrudan etkilemesi nedeni ile, tedarik zincirinin son birkaç metresi gitgide daha önemli hale gelmektedir. Bu nedenle şirketler mağazalarını, dolayısı ile mağaza lojistiğini daha verimli hale getirmek için çeşitli yollar aramaktadırlar. Geleneksel yaklaşımlar mağaza lojistiğinin içsel yönetim dinamikleri üzerine yoğunlaşmaktadır. Bu çalışmada, probleme daha geniş bir perspektif ile bakılmaktadır. Tedarik zinciri yapısal parametreleri ve mağaza lojistiği arasındaki etkileşimi sorgulanmaktadır. Bunu yaparken, talepler, envanter yönetimi politikaları, stok yenileme aralıkları ve dağıtım merkezi kapasitesi gibi tedarik zinciri yapısal parametrelerinin yanısıra, raf doldurma rejimleri, raf kapasitesi, stok kontrolü politikaları, gibi mağaza içi lojistiği operasyonel parametrelerinin de tedarik zinciri bütününün performansına etkilerini tespit etmeyi amaçlıyoruz. Çalışmaya, tedarik zinciri yapısı ve parametrelerini tanımlayarak başlıyoruz. Daha sonra analitik araç olarak benzetim yöntemini kullanılmaktadır. Çalışmada Arena Benzetim Paketi Yazılımı versiyon 13.9 kullanılmıştır.

Anahtar kelimeler: Tedarik zinciri yönetimi, mağaza lojistiği, ayrık olaylı benzetim

To my parents

Acknowledgement

First and foremost, I would like to thank to my advisor, Asst. Prof. Dr. Muhittin Hakan Demir for his continuous guidance and support throughout my thesis. This thesis would not have been possible without his effort, suggestions and motivation.

I would like to show my gratefulness to Asst. Prof. Dr. Ahmet Camcı, Prof. Dr. Okan Tuna, Asst. Prof. Dr. Özgür Özpeynirci and Asst. Prof. Dr. Yiğit Kazançoğlu for their guidance, insightful comments and participation in my thesis committee.

I owe my special thanks to my colleagues, especially, to Tunca Tabaklar for his support, patience and aid during my thesis studies.

Finally, it would be impossible to underestimate the understanding, encouragement and continuous moral support that my mother Nuray Kandemir and father Erdem Kandemir has offered.

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CHAPTER I

INTRODUCTION

The new business environment is characterized by severe competition, imposed by globalization. With increased globalization and offshore sourcing, supply chain management is becoming a more important and complex issue for many businesses. Today, suppliers, producers and retailers are geographically dispersed to the whole world. The varieties of the products are huge with different stock keeping units. Furthermore, customers expect shorter lead times, high product availability at low costs. Under the conditions imposed by the new business environment, the final few meters of the supply chain turns out to be very most crucial because of directly affecting significant performance parameters, such as customer service levels, store revenues, stock out costs, and inventory costs.

Retail stores are highly dynamic; there are many parameters involved and a high level of uncertainty that cause difficulties in the management process. To make the situation even more complicated, too many decision makers and stakeholders such as customers, suppliers, store workers, even drivers have an effect on the management. Traditionally, an operational point of view is followed in management of the stores. By this we mean that the main concentration is on store operations.

Areas of concentration include shelf replenishment, inventory control, cashiers' operations, unloading of the products… Although this approach does not leave strategic aspects of management totally out of scope, strategic decisions or variables are not explicitly considered in store management. That is, the strategic decisions are taken once, most probably with an upper management perspective, and the (future) implementation phase is taken for granted. The possible effect of jointly considering strategic and store-operational decisions is usually overlooked. This leaves out the chance of improving the whole supply chain performance via the signals obtained from the store itself. For instance, replenishment policies or supplier selection whether international or local may drastically affect the store performance, mainly due to lead time variations of distant suppliers. It is not possible to detect and resolve the problems without observing the effect in the store, isolating and identifying the underlying reasons. In such case of the previous example, changing supplier selection policy may improve overall supply chain performance. Another example may be related with the distribution center on central warehouse. The distribution center is in the midway between the suppliers and stores. A capacity problem in the distribution center may affect both upstream and downstream performances, since with a capacity problem in the distribution center the suppliers will have to buildup inventories or fall to respond to distribution center's demand while the store will face frequent stock-outs. This then suggests that an improvement in distribution center capacity would affect the customer satisfaction positively.

With these ideas in mind, this thesis aims to provide a viewpoint that pictures the supply chain as a whole, with the store in the focus. To make the point more clear, we will try to identify key parameters of the store, through a supply chain perspective, that affect the performances of the store along with its impacts on the whole supply chain, through its capability to serve customers. We will do this mainly by a determination of the parameters of the store through which we can identify pointers to improve the whole supply chain performance. Although typical in-store analysis focuses on customers and transactions, our viewpoint puts particular emphasis on in-store logistics operations since we believe that the logistics component, has the capability to reflect a broad range of decisions and processes, from strategic to operational. In-store logistics involves the set of operations of store management to manage the inventory at the point of sale and the flow of goods from the store's loading dock to the stock room or to the store warehouse shelf. With this perspective, in-store logistics includes the most crucial stages before, as well as the actual sale of goods to consumers.

The approach that is employed in this thesis, therefore, calls for a two-way analysis. That is, looking from the store upstream to the distribution centers, suppliers, the associated logistics network etc., and looking from suppliers, distribution centers, strategic management decisons downstream to the store. One concrete example, for instance, would be to look at whether and how supplier batch sizes may affect lost sales in store. We may as well question the possible improvement on distribution center performance metrics by a reconsideration of the shelf filling regime in the backstore.

A summary of the approach in this thesis would be to say that, we question the interaction between in-store logistics parameters such as inventory management policies, stock filling regimes, shelf capacities, as well as supply chain parameters such as supplier locations, distribution center capacities on supply chain and in-store logistics performances. We start with the identifying supply chain structure and defining the environmental parameters; whereafter we employ simulation as an analytical tool for our research. We use ARENA Simulation Software version 13.9.

We can identify two main reasons concerning the importance of the in-store logistics activities. These are on shelf availability of the products that has a direct effect on the purchasing transactions and inventory carrying and handling whose costs are at store level and are relatively intense. According to Kotzab and Teller (2005), the main aim of in-store logistics is to offer the quantities of items as requested by end-users at lowest cost possible which means the efficient management of in-store logistics.

Looking from the store management side there are some controllable and uncontrollable parameters involved. Inventory management policies of the suppliers, number of distribution centers, demand patterns etc. are the parameters that are usually out of control of store managers. Conversely, number and capacities of shelves, store inventory control policies, number of store workers and equipments or layout of the store are the variables that management of the store is more likely to be able to modify. In this thesis, we look at both type of parameters and their effects in two sides, namely supply chain and store.

There are several performance metrics that are commonly used for evaluating store performances. Some are related with customers such as number of customers who wait for shelf replenishment, lost sales. Some have direct effect on customer service, however are more on the backstore side such as average inventory and inventory turnover rate of distribution center and backstore, inventory in waiting area of the backstore, number of incoming products batch that waiting in the backstore for the replenihsment to backstore. The ones that related with distribution center may be average inventory of distribution center and inventory turnover rate of distribution center.

Primarily, we aim to identify the effects of in-store logistics parameters on these performance metrics. Then our objective is to construct an ordering of impact list of parameters with respect to in-store logistics performance metrics. That is, we aim to identify a “critical” set of parameters for in-store logistics.

CHAPTER II

LITERATURE REVIEW

In this chapter, we present a review of the literature relevant to the problem we analyze in this thesis. Review of the literature involves two main topics: In-store logistics and use of simulation as a methodology for solving in-store logistics problems. Therefore, we design the literature review as follows:

We first argue that any analysis would start with the definition of performance metrics. Since our perception of the in-store logistics problem relies more on the supply chain view, we briefly discuss the literature on supply chain performance measures.

Next, having analyzed performance metrics, we investigate studies that involve evaluating supply chains using analytical tools. In this field, we particularly concentrate on studies that utilize simulation as a tool.

Finally, we consider the line of research that is in the focus of this thesis; we consider the literature related to in-store logistics. In doing so, we analyze the studies based on the methodology used, main results and impacts of these results.

2.1 Supply Chain Performance Measures

The review of literature in supply chain performance measures demonstrates that almost all researchers agree on a set of common criteria; and the conclusion that a group of performance criteria are needed to evaluate supply chain performance.

Stainer (1997) claims that a performance measure, or a set of performance measures, is needed to determine the efficiency and effectiveness of an existing system, or to compare competing alternative systems. An accurate overview of supply chain performance indices can be found in Beamon (1998, 1999).

Thor (1994) points out the importance of the conformity of performance measures with the used methodology. There should be a multi measures based approach for obtaining successful results on supply chain management while using modeling and simulation. This must be a set of four to six performance measures, usually including productivity, quality, and customer satisfaction, which together furnish an all-inclusive view of results.

Swaminathan et al. (1998) and Beamon (1998) advocate that supply chain performance measures can be divided in two categories: quantitative and qualitative. Similarly, Swaminathan et al. (1998) add that one of the objectives must be to simultaneously observe global and local performance of the supply chain. Chan and Chan (2005) present a comparative analysis of qualitive and quantitative performance measures. For qualitative performance measures, it is not easy to come up with a commonly accepted definition and measurement. Quantitative performance measures are those that are described numerically. Quantitative supply chain performance measures may be categorized on cost or profit, measures of customer responsiveness, and productivity. Since quantitative measures can be described and handled more easily, as many qualitative measures should be translated into quantitative measures as possible. Main categories of quantitative performance measures for measuring supply chain performance can be found in Table 1 and 2.

Table 1. List of qualitative performance measures for supply chain

Qualitative performance measures for supply chain	
Customer satisfaction	The degree to which customers are satisfied with the product and/or service received, and can be applied to internal customers or external customers. Customer satisfaction comprises of three elements, namely, pretransaction satisfaction, transaction satisfaction, and posttransaction satisfaction.
Flexibility	The degree to which the supply chain can respond to random fluctuation in the demand pattern.
Information and material flow integration	The extent to which all functions within the supply chain can pass information and transport materials smoothly.
Effective risk management	All of the relationships within the supply chain contain inherent risk. Effective risk management describes the degree to which the effect of these risks is minimized.
Supplier performance	A measurement to describe how good a supplier can deliver raw materials to production facilities on time and in good conditions.

Table 2. List of quantitative performance measures for supply chain

Quantitative performance measures for supply chain		
Measures based on cost	Cost minimization	The most widely used objective. Cost is typically minimized for an entire supply chain. One example is to minimize transportation cost.
	Sales maximization	Maximize the amount of sales dollars or units sold.
	Profit maximization	Maximize revenues less costs.
	Inventory investment minimization	Minimize the amount of inventory costs, i.e., the reduction of the inventory level is required.
	Return on investment maximization	Maximize the ratio of net profit to capital that was employed to produce that profit.
Measures based on customer responsiveness	Fill rate maximization	Maximize the fraction of customer orders filled on time.
	Product lateness minimization	Minimize the amount of time between the promised product delivery date and the actual product delivery date.
	Customer response time minimization	Minimize the amount of time required from the time an order is placed until the time the order is received by the customer, i.e., order lead time.
	Lead time minimization	Minimize the time that required from the time an order has begun its production until the time the order is ready for shipment
	Function duplication minimization	Minimize the number of business functions that are provided by more than one business entity.
Measures based on productivity	Capacity utilization maximization:	Maximize the capacity utilization.
	Resources utilization maximization	Maximize the resources utilization

We can observe that a significant number of studies fit into the performance criteria classification presented by Chan and Chan (2005). Li and O'Brien (1999) provide analytical models of supply chains. They use four performance criteria; profit, lead-time, delivery promptness, and inventory cost, when proposing a hierarchical approach to supply chain modeling. Fleisch and Tellkamp (2002) study how process quality, theft and unsalable affect inventory inaccuracy, the out-of-stock level, and the cost related to inventory inaccuracy. Persson and Olhager (2002) use cost and inventory as resource measures, quality, lead-time, and lead-time variability as output measures, and lead-time and lead-time variability as flexibility measure. Thus, lead-time and lead-time variability will serve double purposes, in reflecting both output and flexibility. When simulating supply chains, Lau et al. (2008) use five criteria to measure the supply chain performance. Three of these are cost related and two are service level related, respectively. The five criteria are setup cost, transportation cost, and inventory carrying cost, percentage of the retailers' orders satisfied through the available inventory of the supplier and percentage of customer demand satisfied through the available inventory of the retailers.

From the literature review we can understand that different supply chains are characterized by different critical performance parameters need to be identified, based on the structure of the supply chain. In any case, a variety of parameters regarding different aspects of the supply chain, need to be investigated.

2.2 Evaluating Supply Chains using Analytical Tools

Many studies involve evidence, justification and importance of using simulation as a methodology in supply chains. For instance, Ingalls (1998) has discussed advantages and disadvantages of using simulation for supply chains as the analysis methodology. He propose that there are some problems that very difficult for optimization even when variance does not exist, however, in operational planning where a short time horizon with limited scope exists, instead of simulation, mathematical programming tools may be used. Beamon (1998) claims that the objective of the simulation model is to evaluate the effects of various supply chain strategies on demand. Moreover, Lee at all (2002) state that simulation can work for global optimization in supply chains and also able to find local optimum values within each component.

Manzini et al. (2005) emphasize the importance of simulation in supporting decisions concerning the design and management of supply chains in their great complexity and in a stochastic competitive and extended context. Jain and Leong (2005) supported this idea by underlining the potential of simulation for continued applications to support the supply chain for operational planning including responding to unplanned events.

We can also see studies that emphasize the design of the details of methodology to be used in supply chain simulation. Hicks (1999) propose a four step methodology of simulation and optimization for using in supply chain planning. Those steps consists of network optimization, network simulation, policy optimization and design for robustness. The final step is to make sure that supply chain structure and policies operate well under a wide variety of situations. Banks et al. (2002) discuss the use of simulation in process control, decision support, proactive planning and how simulation can be used through the supply chain life cycle. Moreover, they provide evidence on ways of using simulation in supply chain management. Vieira and Cesar (2005) present the development of conceptual models that can be used in the creation of certain types of supply chain simulation projects.

In the literature, various studies are done that focus on implementations regarding supply chain management using modeling and simulation. Persson and Olhager (2002) evaluate different supply chain structures for real case in the mobile communication industry with respect to lead times, quality and cost and the interaction between those parameters. Chan and Chan (2005) built five different supply chain models and grouped them into three different categories: inter organizational supply chain; network supply chain and regional clustering supply chain. Four parameters were used to evaluate the performance of the supply chain models, namely, inventory level, average order lead time, transportation cost, and resources utilization. Reiner and Trcka (2004) develop a simulation environment for supply chain in food industry to measure and analyze the performance effects (e.g., work in process, lead time) of the supply chain configuration alternatives depicted. They also point out that an analysis of a supply chain must be very product- specific. Umeda and Zhang (2006) made a simulation model that include supply-chain management operations, such as demands predictions, manufacturing planning, material purchasing, manufacturing and transportation ordering, and products shipping. These models also involve activities in manufacturing and transportation operations, further demonstrates simulations of the typical forms of supply chain systems like centre-controlled ordering system, vendor reorder-point system, and pull-operational system, then these simulation results are compared with supply chain performance.

Performance indices that tracked using supply chain simulation can be measured under different parameters such as inventory control policies, replenishment modes, lead times, demand variability. Ganeshan et al. (2001) simulate the impact of the forecast error, the mode of communication between echelons, the planning frequency and management techniques on the performance of an expanded and comprehensive retail supply chain. Vieira (2004) simulate a traditional supply chain to measure average inventory level and service level, both for each stage at and for the whole supply chain. Fleisch and Tellkamp (2005) examine the relationship between inventory inaccuracy and performance in a retail supply chain by simulating a three echelon supply chain with one product in which end-customer demand is exchanged between the echelons. Lau et al. (2008) investigate the interaction between inventory policy used by the retailers and the costs of the supplier, retailers, and the service levels of the supplier and the retailers.

There are many recent studies that involve analysis of supply chains under inventory inaccuracy by simulating the whole supply chain. Lee et al. (2004) provide a quantitative analysis to demonstrate the potential benefits of RFID (radio frequency identification) in inventory reduction and service level improvement. Lin et al. (2008) discuss the push and pull shelf replenishment policies for retail supply chains. Their results indicate that a RFID triggered pull replenishment policy can reduce lost sales and increase supply chain performance. Another study that analyzes impacts of RFID technologies on supply chain performances is conducted by Sarac et al. (2008).

They simulate a three level supply chain in which thefts, misplacements and unavailable items decrease supply chain performance. By using different RFID technologies, they measure the changes in the supply chain performance.

A literature survey chart for supply chain simulation can be found in Terzi and Cavalieri (2004). The authors also claim that among the techniques supporting a multi-decisional context such as a supply chain, simulation can certainly play an important role, especially for providing what-if analysis and evaluating quantitatively benefits and issues deriving from operating in a co-operative environment rather than playing a pure transaction role with the upstream or downstream tiers.

To our best knowledge, the most comprehensive supply chain simulation study done by Longo and Mirabelli (2007). They argue that the modeling and simulation based approach for studying supply chain has to be flexible and parametric for evaluating different scenarios; time efficient even in correspondence of high number of supply chain stages and high numbers of items; and repetitive in its architecture for easily changing the number of supply chain stages. They create a decision making tool capable of analyzing different supply chain scenarios by using an approach based on multiple performance measures based on fill rate, on hand inventory and inventory costs and user-defined set of input parameters.

2.3 In-store Logistics

After reviewing literature that related with supply chain performance metrics and supply chain simulation, we now focus on the studies related with in-store logistics. We perceive the contents of in-store logistics as the set of operations to manage the inventory at the point of sale and the flow of goods from the store's loading dock to the store shelf. Mckinnon et al. (2007) points out that in terms of cost and service quality, effective management of the last meters to the shelf is critical.

There is limited literature that uses the term in-store logistics for a single well defined problem. What we consider for in-store logistics in this thesis is a collection of subproblems in retail such as product handling, shelf stacking, order picking, shelf space allocation, product assortment, inventory management. According to The Logistics Glossary (2008), in-store logistics involves services that precede the actual sale of goods to consumers. Kotzab and Teller (2005) define in-store logistics as the logistics activities that occur within a retail store and the main aim is to offer the quantities of items as requested by end-users at lowest cost possible which means managing efficiently in-store logistics activities.

The importance of a store from a supply chain perspective arises from two reasons: costs for inventory carrying, inventory handling and human resources are high at that level of supply chain and availability of products in the shelves is an important key performance indicator for the purchasing transaction (Liebmann and Zentes, 2001). However, Kotzab and Teller (2005) points out the deficiency of the academic and practical discussion of operational issues within retail store, such as in-store logistics. Raman et al. (2001) reinforce that argument by recognizing "execution" as the missing link in retail operations. By execution they mean holding accurate inventory records and systematically placed stock keeping units that increase their performance and ability to satisfy customer.

The literature contains studies that pose conceptual models to identify and discuss in-store logistics related issues. For instance, Kotzab and Teller (2005) propose a generic model of in-store logistics which consider specific (diary) product flow processes that can be applied in any store format. Then they validate the model with interviews with store managers representing different store types of a leading retail chain within the Austrian grocery industry. Their model and the related information can be found in Figure 1. The steps in the model posed by authors refer to a generality of in-store situations. In that sense, the model is directly related with our study. Therefore, we utilized steps in the model while developing a particular module of our simulation model, namely the "store" part.

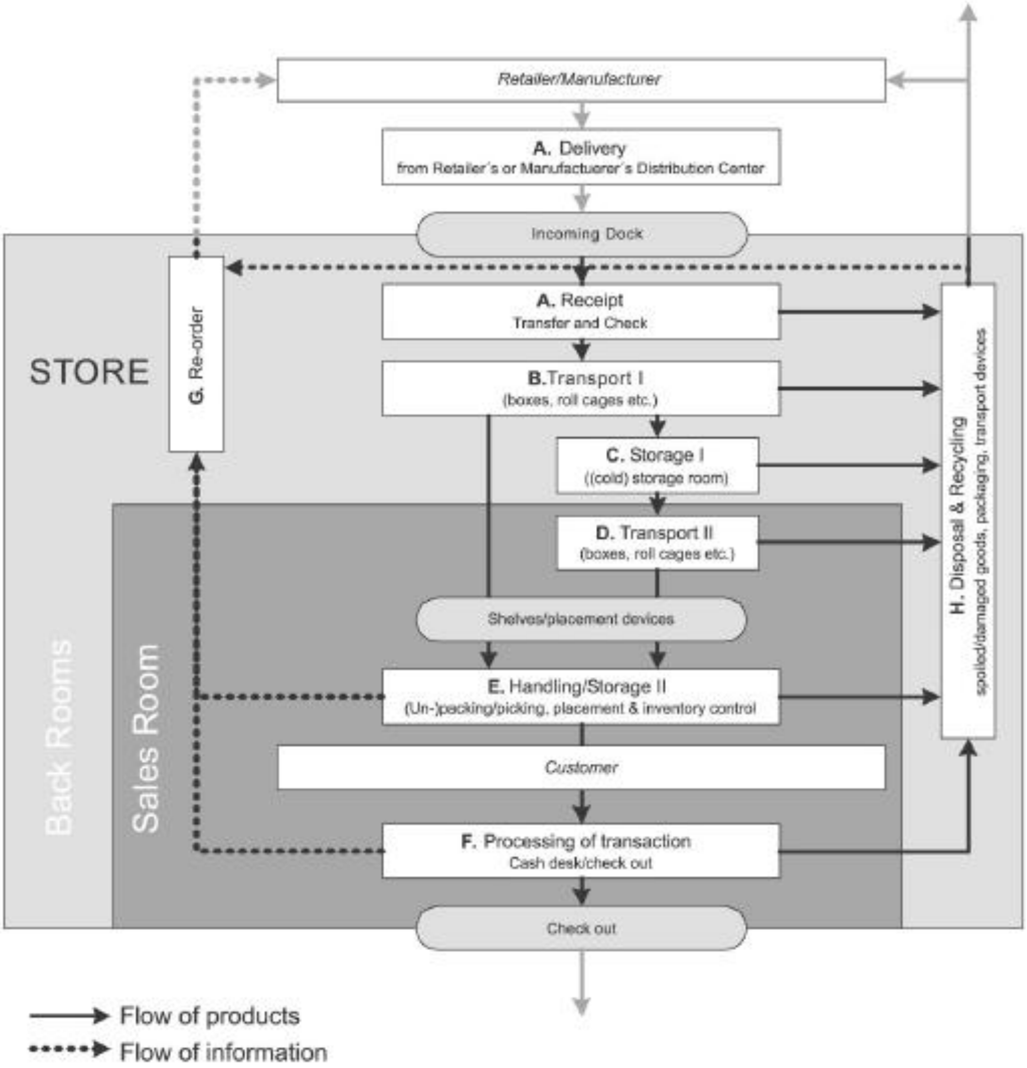

Figure 1. In store logistics operations and their information (Kotzab and Teller, 2005)

On-shelf availability relates to one of the sub-problems in in-store logistics. Researchers have shown high interest in studies on on-shelf availability. Fisher (2004) state that the question "Did you find what you were looking for?" is the primary question that used in customer satisfactory surveys. He grouped out of stock (OSS) causes in three categories: assortment planning, statistical stock outs, and store level execution. Assortment planning means the product is not in retailer's assortment list. Statistical stock outs cause from forecast errors. Store level execution means items are in store but not on the shelves. According to Retail Out of Stocks

(OOS) report issued by Association of Grocery Manufacturers of America (2002), between 65 % and 75% of OOS are caused in the store, while 25% to 35% are due to upstream causes at the distribution center or headquarter level. If the causes are sliced by retail processes, almost half of the assigned OOS cause is related to ordering problems often because they have inaccurate or unreliable forecasts. A detailed chart for the OOS causes can be found in Figure 2 and worldwide averages of OOS causes by process and responsible entity are shown in Table 3. In this thesis, we try to make an assessment of these cause-effect relationships regarding effects of decisions' different parts of the supply chain on in-store performance under various settings.

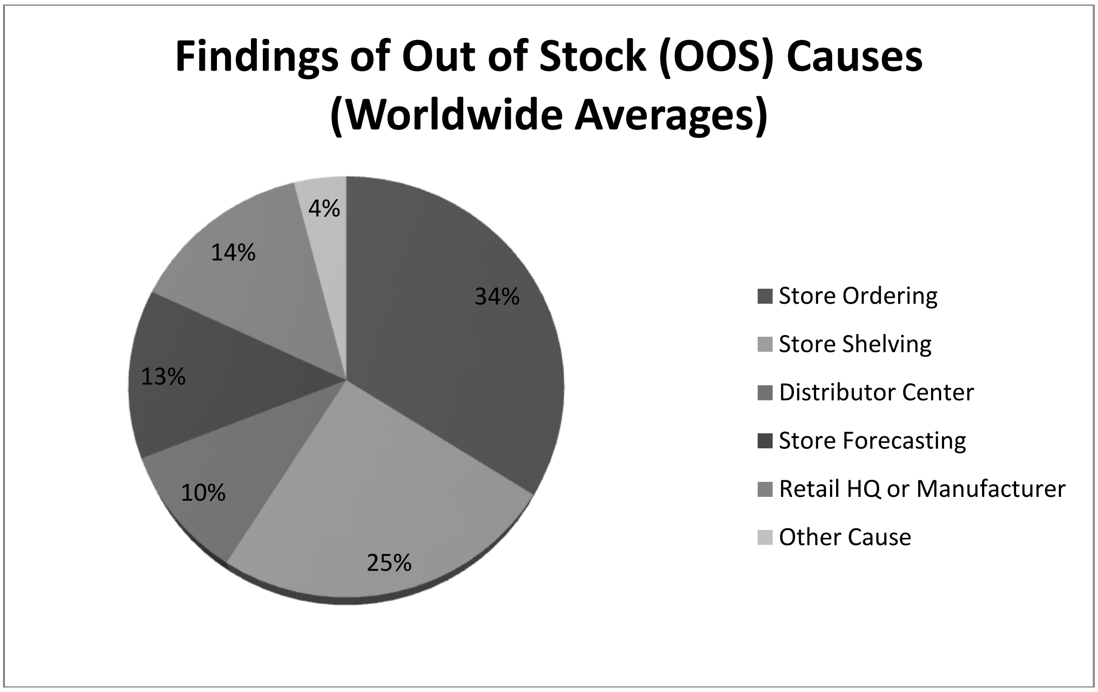

Figure 2. Worldwide averages for causes of OOS
Source: *Retail Out-of-Stocks: A Worldwide Examination of Extent, Causes and Consumer Responses (2002)*

Table 3. Worldwide averages for OOS Causes by Process and Responsible Entity
Source: *Retail Out-of-Stocks: A Worldwide Examination of Extent, Causes and Consumer Responses (2002)*

Out of Stock Causes by Process and Responsible Entity (Worlwide Averages)				
	Ordering	Replenishment	Planning	Total
In-Store	47%	25%	-	72%
Supply Chain	-	10%	18%	28%
Total	47%	35%	18%	100%

Mckinnon et al. (2007) study on the on-shelf availability (OSA) of three categories of product: dairy products, frozen foods and health and beauty items. They conduct interviews with consumers at shop checkouts and managers of the shops. According to their study, inbound logistics, inaccurate inventory data, organization of the backroom, nature of the packaging can be included as the main reasons for out of stock situations. In addition to those causes, Green (2004) observes that there are also other processes and decisions on the upstream of the supply chain, for example, long order lead times, planning and forecasting errors of manufacturers, results OOS in store.

One other significant activity of in-store logistics is handling. Zelst et al. (2006) points out that in retail stores, handling operations cover the largest share of operational costs and time. They first define the handling activities in warehouses, then stacking activities in stores. A chart for the share of the operational logistical costs in a retail supply chain can be found in Figure 3. Warehouse handling activities are modeled in detail (Rouwenhost et al. 2000). Moreover, Gagliardi et al. (2007) studied on order picking and shelf allocation strategies to reduce operation cost while defining each strategy in detail. However, literature on store handling is not very rich.

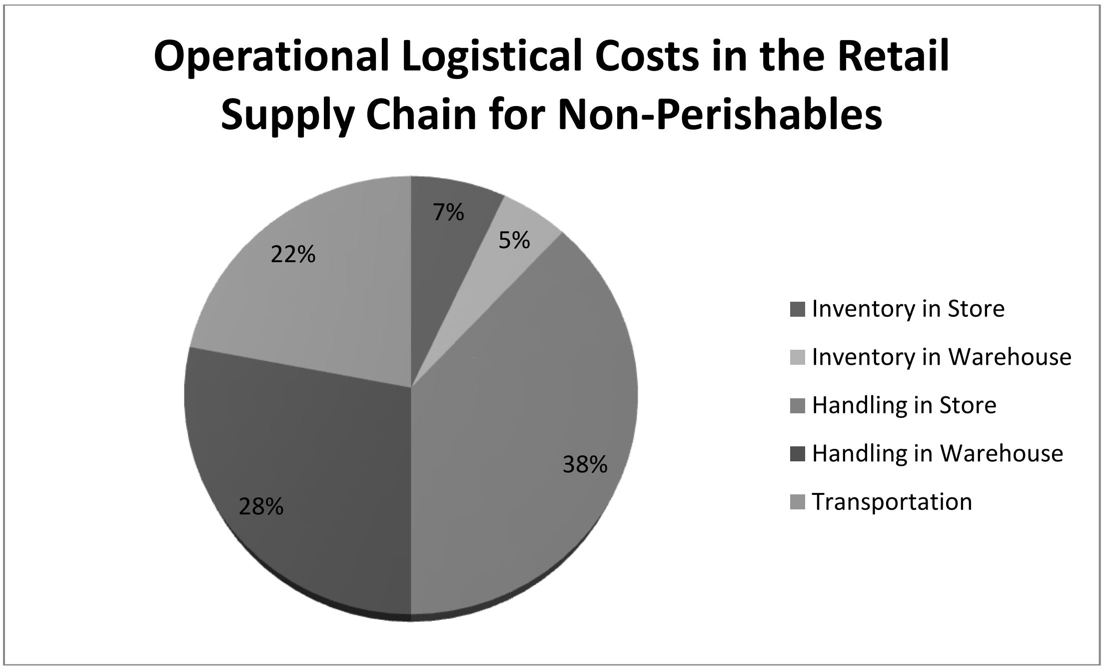

Figure 3. The share of the operational logistical costs in a retail supply chain

Shelf stacking can be seen as the reverse of order picking in a warehouse and it starts with grabbing a casepack from store incoming door and ends with the disposal of the empty casepack. It can be viewed as similar to zone picking in a warehouse. Gagliardi et al. (2007) suppose that in zone stacking the incoming goods are already sorted at the supplier according to the aisles of the store. As Zelst et al. (2006) states, there are three different ways to fill a shelf:

1. Unit filling regime: putting the individual customer units on the shelf.

2. Tray filling regime: putting casepack directly on the shelf.

3. Loose filling regime: dumping items without arranging.

The store can be viewed as a warehouse itself. The in-store logistics approach strengthens this view. Curşeu et al (2006) divided the shelf-stacking activity into seven sub-activity to better analyze the total shelf stacking time per customer unit. Those activities are grabbing and opening a case pack, searching for assigned location, walking to assigned location, preparing the shelf for stacking new items, filling new items on the shelf, filling old items back on the shelf, disposing the waste. They identify the drivers such as packages and product category for shelf stacking (Table 4). A detailed study on evaluation methods concerning packaging concepts from a logistical point of view can be found in Saghir and Jönson (2001). Moreover Waller et al. (2010) work on the casepack quantity effects on sales. According to their findings bigger casepacks has a positive effect on store fill rate while having a negative effect on backroom logistics. A related figure is can be found below (Figure 4). We point out to the importance of such activities and processes on the store performance. These reflect operational aspect of in-store logistics along with the design of these activities. Therefore, we include them in the highest level of detail, as possible, in our simulation model.

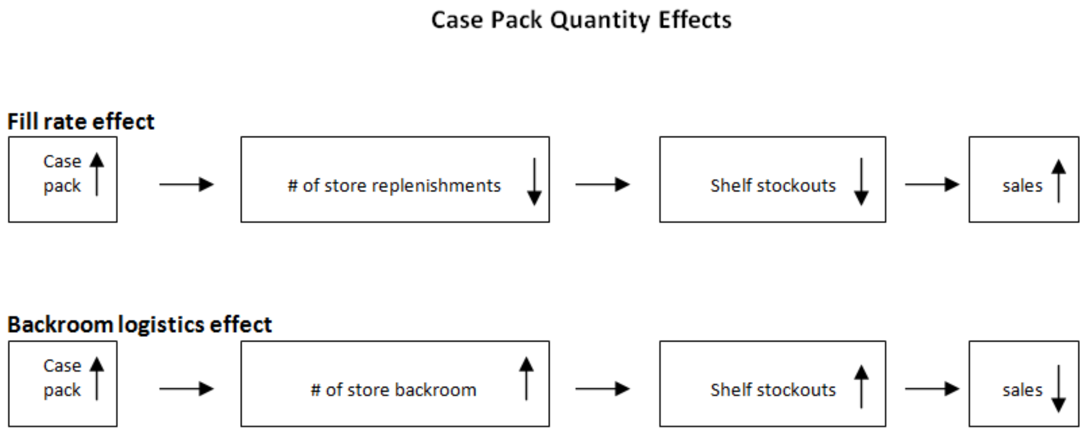

Figure 4. Case pack quantity effects (Waller et al., 2010)

Table 4. Potential drivers of time variation, for each sub-activity (Curşeu et al, 2006)

Sub-activity	Order Line Information		Product Information
	Number of Case Pack	Number of Customer Units	Product Category
1 Grabbing/ Openning	X	X	X
2 Searching	-	-	-
3 Walking	X	-	X
4 Preparing	-	-	X
5 Filling New Inventory	X	X	X
6 Filling Old Inventory	-	-	-
7 Disposing Waste	X	-	-

Analytic methods concentrate on optimization of shelf space allocation, product assortment and inventory replenishment. In general those models has focus only one or two area. Rajaram (2001) worked on assortment planning, Yang and Chen (1999) studied shelf space allocation and management, Hwang et al. (2005) developped a model for shelf space allocation and inventory control, Urban (1998) investigate product assortment and shelf space allocation problems. However, Hariga et al. (2007) claims that in order to obtain an optimal solution those problems must be solved jointly which result in huge number of variables and difficulties in finding exact solution.

As the literature review suggests, there are not many studies looking at other parts in supply chain while working on in-store logistics problems. Also, we can observe that the in-store problem is viewed mostly in the domain of retail management. Analytical methods are not used or have been of limited use due to problem complexity. As Kotzab and Teller (2005) states as a future work, simulation of in-store logistics would be very useful in identifying the relationships between different parameters such as storage space, delivery times, share of damage goods on availability of products.

In coming chapters, we discuss our perception of the supply chain. We employ simulation for the supply chain structure under consideration. We define our parameters in order to measure the supply chain and store performance metrics that we decided to use.

CHAPTER III

THE SUPPLY CHAIN STRUCTURE AND PROBLEM DEFINITION

In this chapter, we demonstrate our perception of the supply chain, its players and interactions between these players. The setting we consider in this thesis involves members of the supply chain, with special emphasis on the store and directly related components. Some of the directly related components are direct suppliers, customers, warehouses. For a more comprehensive definition of the thesis scope, we need to describe the supply chain structure that we base our analysis on.

According to Beamon (1998) a supply chain may be defined as an integrated process where a number of business entities such as suppliers, manufacturers, distributors and retailers work together in an effort to acquire raw materials, convert these raw materials into specified final products and deliver these final products to retailers, who then satisfy the demand of the end customers of the supply chain. The supply chain involves a forward flow of materials and a backward flow of information. As Agarwal and Shankar (2002) make a conceptual definition of supply chain as it is an inter-linked set of relationships connecting customer to supplier, generally through a number of intermediate stages such as manufacturing, warehousing and distribution. Physically, a typical supply chain consists of suppliers, manufacturing centers, warehouses, distribution centers and retailer outlets, as well as raw materials, work in process inventory, and finished products that flows between facilities (Figure 5) (Simchi-Levi et al., 2008).

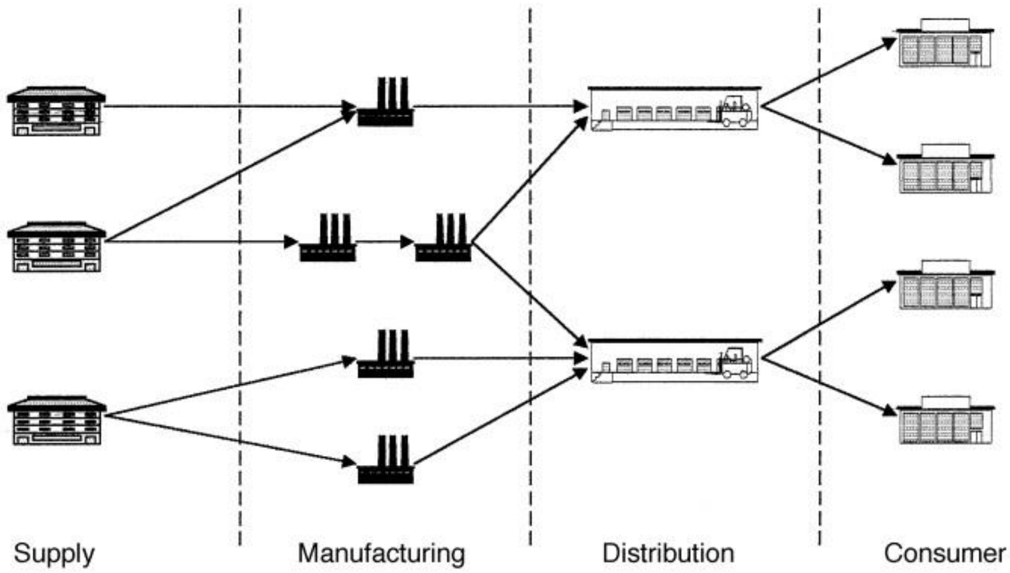

Figure 5. Overview of a typical supply chain (Beamon, 1999)

While defining the structure of the supply chain, it is first necessary to identify the members. Cooper at al. (1997) argue that how much a supply chain needs to be management is related with complexity of the product availability, number of the suppliers and raw materials. Dimensions to consider include the length of the supply chain and the number of suppliers and customers at each level. As Lambert et al. (1998) state the members include all organizations or companies with whom the focal company interacts directly or indirectly through its suppliers or customers, from point of origin to point of consumption. However, to make a very complex network more manageable, it seems appropriate to distinguish between primary and supporting members. Primary members are all autonomous companies or strategic business units who actually perform operational and or managerial activities in the business processes designed to produce a specific output for a particular customer or market. Supporting members are companies that simply provide resources, knowledge, utilities or assets for the primary members of the supply chain. As far as the scope of this thesis is concerned, we identify the retail store as the focal member of the supply chain. We take the primary members to be customers, store itself, store warehouse/backstore, distribution centers and immediate suppliers of the store.

The analysis to be presented in this thesis will try to reveal the relationships between components and parameters of supply chain. For instance, we aim to demonstrate the effect of replenishment policy changes of a particular supplier on in-store inventory levels, on customer service levels. We also suggest the outcomes to be utilized for policy making in supply chain management. Simchi-Levi et al. (2008) define supply chain management as “Set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements”. Lambert et al. (1998) claim that there are three structural dimensions in the supply chain network that used for describing, analyzing and managing the supply chain. These are horizontal structure, vertical structure and horizontal position of the focal company in the supply chain. Horizontal structure is the number of tiers across the supply chain. Vertical structure refers to the number of suppliers or customers within each tier. The third one, company’s horizontal position within the supply chain, as an example the company may be near the initial source of supply or be near to the customer or be somewhere between these points. The approach we take in this thesis refers to the horizontal position in supply chain. Simchi-Levi et al. (2008) highlight that, when analyzing supply chains, it is sometimes necessary to account for the suppliers' suppliers and customers' customers because they may have an effect on supply chain performance measures.

Some of the key issues in supply chain management are distribution network configuration, inventory control, production sourcing, supply contracts, distribution strategies, and information technology and decision support systems (Simchi-Levi et al., 2008). These issues span a large spectrum from strategic through the tactical to operational level. Strategic level deals with that have long lasting effect on the firm. The tactical level includes decisions that may be updated quarterly or once in a year. The operational level refers to day to day decisions. In this thesis we mainly focus on tactical and operational level decisions.

Main components of the supply chain model that we analyze comprise of suppliers/producers, distribution centers, stores and customers. The number of the suppliers/customers in a tier, distribution strategies, inventory control policies, inventory holding capacities, number of workers in a company varies according to scenarios. Our main focus is the stores and their performances. We believe that tactical and operational level decisions of the supply chain members may have a significant impact on the store performances measures.

Next, we detail the problem setting that is analyzed in this thesis. In doing so, we align the system under consideration in the context of a supply chain. We also identify processes and parameters of supply chain management that fall into the scope of our thesis.

The supply chain under consideration is in the retail industry. We assume that the endpoint of the supply chain are individual customers who themselves are also end users of the product(s) offered by the supply chain. The products are sold in retail stores. We concentrate specifically on one typical retail store within the supply chain. In the downstream, there are the customers. Customers visit the store to satisfy their demand for a particular class of products. In the upstream of the supply chain, there may be suppliers and distribution centers/warehouses. We leave the second tier and further suppliers out of scope and assume that there is a single level of immediate suppliers and level of immediate distribution centers/warehouses. We do not overlook the possible effect of further-tier suppliers on supply chain and store performance, however we believe that it is reasonable to assume that the components of the supply chain that are taken in-scope are sufficient to explain the majority of the interactions.

We assume that each type of product is supplied to the store exclusively by a single supplier based on a particular replenishment policy. In the retail practice, the replenishment policy is usually a central corporate decision, based on the demand structure for the particular product. Some of the products are shipped directly to the store whereas others are transported through distribution centers. Distribution centers act as consolidation and dispatching centers, which also ship to stores based on a replenishment policy or a shipping schedule. In the case of a warehouse/distribution center, the shipping schedule is also based on the appropriateness of freight consolidation and vehicle utilizations. The capacities of the warehouses are also important parameters of the system under consideration, since capacity restrictions may limit some inventory or dispatching policies from practice.

It is not likely that all the parameters under consideration regarding the supply chain can be identified as point values. The inherent uncertainty due to the nature of the supply chain affects all parameters. Therefore we need also to consider the randomness of parameters.

The focal point of the system is the store itself. We also detail the process in the storage area of the store. This area is called the back-store. The main processes under consideration are the main flow of goods from suppliers to customers and the replenishment flows. The latter flow refers to the replenishment of store shelves in order to meet immediate or anticipated customer demand. The replenishment process is typically executed in a mixture of pull and push operations. When the inventory level on shelves decrease below a threshold level, this triggers a pull signal where after material is taken from back-store to refill the shelf inventories. However, the supplier, distribution center, back-store operation usually follows a push process. The replenishments are made with predetermined inventory policies based on anticipated demand.

With these supply chain components under consideration, we particularly concentrate on inventory management, material handling, and order fulfillment. Inventory management is analyzed in two main levels: The first one is related with the more strategic supplier to store replenishments. The second one is much more operational and dynamic which is the in-store inventory management. Material handling considering throughout the suppliers, distribution centers and stores. The focus is on the methods, equipments and related controls used in warehouses and stores shelf display and shelf replenishment policies. Order fulfillment occurs at the store where it is the point of sales.

In the next step, we will define the system under consideration. We will give some additional information with back and forth discussion for the supply chain structure that we assume.

In order to demonstrate the concepts and the ideas presented in this thesis, we make use of a hypothetical supply chain environment. We disregard several details of the supply chain and concentrate on certain components, flows, and the interactions between components. In this setting, assume a supply chain that consists of three main product categories. Each category is assumed to represent a product family. Product families have their specific characteristics of demand volumes, sizes, replenishment policies. We further assume that, associated with each product category, we have a cluster of suppliers who produce and replenish the products; either to distribution centers or directly to the store itself. In the downstream part of the suppliers, we have the distribution centers. Each distribution center has its own assigned product types, associated capacity and inventory policies.

The focal player of this supply chain is the store itself. The store is the point of the supply chain that interacts with the customer. It receives goods from the suppliers and distribution centers in order to meet customer demand.

Under this supply chain structure, we are particularly interested in supply chain and store parameters, their interactions and effects on the supply chain and retailer store performance measurements.

Thor (1994), points out the importance of a multi measures based approach for obtaining successful results on supply chain management while using modeling and simulation. This must be a set of four to six performance measures, usually including productivity, quality, and customer satisfaction, which together furnish an all-inclusive view of results. As Stainer (1997) suggests, a performance measure, or a set of performance measures, must be used to determine the efficiency and effectiveness of an existing system, or to compare competing alternative systems. We take Beamon's (1998,1999) supply chain performance indices as a base while selecting our performance measurement criteria.

Swaminathan et al. (1998) and Beamon (1998) advocate that supply chain performance measures can be divided in two categories: quantitative and qualitative. Chan and Chan (2005) present a comparative analysis of qualitive and quantitative performance measures. Qualitative performance measures are not easy to describe. Quantitative performance measures are those that described numerically. Quantitative supply chain performance measures may be categorized on cost or profit, measures of customer responsiveness, and productivity. Since quantitative measures are something that can be described and handled easy, as many qualitative measures should be translated into quantitative measures as possible.

We mainly choose customer satisfaction from the qualitative performance measures. Customer satisfaction is the degree to which customers are satisfied with the product or service received, and can be applied to internal customers or external customers. It comprises of three elements, namely, pretransaction satisfaction, transaction satisfaction, and posttransaction satisfaction. We are interested in transaction satisfaction. We measure customer satisfaction as the number of successful sales that have been done in mainstore. In other words, it can be defined as the demand fill rate.

Out of quantitative performance measures, average inventory level, stock-out rate and inventory turnover rate of distribution center, backstore and mainstore are taken into consideration. Average shelf replenishment time of mainstore is another important performance measure that we believe has an effect on customer satisfaction. We also measure, resource utilization of store, both in backstore and mainstore.

The environment we define can be used to represent a variety of retail constructs such as supermarkets, construction markets or electronics retailer stores. For the sake of ease of output analysis, we concentrate on three different product families sold in the store under consideration. We analyze the store in two components: backstore and mainstore. Those three types of products are displayed for sale on the mainstore's shelves. Each customer may have a demand for a collection of the three product families. Purchase of a customer takes place if there is sufficient amount in the shelves of the mainstore. If the shelves are out of stock for a demanded product, the customer may choose to leave the store without making the purchase, or ask the personnel for the product. In the latter case, the replenishment workers fill in the shelves provided that the backstore contains the required amount of products. However, the customer may not have the patience to wait for the whole shelf replenishment time, whereby he/she may still leave the store without purchasing the specific product. Backstore is physically connected to mainstore and used as a warehouse. So, we are particularly interested in inventory holding and shelf replenishment in both mainstore and backstore. During the time between customers leave at 10 pm and the next day when the store will open again at 10 am, the shelves are refilled from the backstore by the store workers with the related equipments. The aim is to begin the day with the full shelves prior to the arrival of customers. However, as we mentioned before, this is not always the case. Some customers ask for the products to a store worker when the shelf is empty or there is not enough amounts of products on the shelf. The shelves are replenished between the business hours with the request of customers. This type of operation involves complications due to high level of interaction and flows between mainstore and the backstore. However, we believe that this improves inventory management, shelf space utilization and customer satisfaction. Our experimental study will test the efficiency and effectiveness of such policy.

There are also losses that occur in the mainstore because of thefts, distortions and damages which lead to stock-outs and low customer satisfaction. We include these since those situations frequently faced in the supermarkets, construction markets or electronics retailer stores etc… In our case; mainstore layout, shelf replenishment policy, number of equipments, workforce and mainstore capacity are the parameters that we will be interested in.

The backstore is a critical location in the supply chain. It is central to the suppliers, distribution center and mainstore. It has an interaction with both upstream and downstream of the supply chain. Any inefficiency in backstore may directly affect the supply chain and store performance. Backstore is feeding the mainstore while receiving the products from the distribution center and suppliers. As an example a delay in the unloading operation of incoming products may cause a delay in the main store shelf replenishment process that results in low level of customer satisfaction.

The incoming products from the distribution center and suppliers are firstly filled to the backstore shelves. Backstore has a predefined capacity. Product families have different inventory control/replenishment policies. The policy for a product family is decided upon based on the demand structure, demand variability, distance to supplier, criticality of the product, other product characteristics such as perishability etc. In the case that the received products cannot be filled into the shelves because of insufficient space, the products are moved to the waiting area where they are held until there is available space in the backstore shelves. Products in the waiting area cannot be used for replenishing the store shelves and they require extra handling for being placed from receiving area to waiting area as well as from waiting area to backstore shelves. Shelves are filling by the store workers and related equipment. Products require various levels of workforce and equipment usage for handling due to different weights and volumes. Backstore capacity, number of equipments, workforce, and shelf replenishment policies are the defining parameters of the backstore. We will observe the interactions of those parameters and the effects on performance measures.

The components in the upstream of the supply chain, namely suppliers and distribution centers are taken into consideration with lower level of details, since the focal component of the supply chain is the store itself. We model suppliers and distribution centers in that level of details to properly demonstrate their main processes as well as their interactions with the backstore and mainstore. Distribution centers ship the products to store based on the particular replenishment policy for the product. It is also works as a consolidation and dispatching center. Especially the suppliers that have a long distance to store use the distribution centers as the transshipment point. The shipments can be made only under the case of availability of a required level of inventory. Capacities of the distribution centers are important parameters for the system, since capacity restrictions may limit some inventory or dispatching policies from practice. Since distribution centers typically work under periodic replenishment policies, products are received with respect to time intervals implied by these policies. In the case of inadequate space, products accepted partially. We assume that, the products are available for sale in competitor stores. Therefore, in the case of out-of-space situation, remaining products are directed to some other retailer.

The suppliers decided on the production lot sizes, based on the demand and replenishment policy for the particular product. For instance, if an EOQ type of replenishment is used, the supplier is most likely to go towards a periodic, fixed-lot-size, no inventory production plan. On the other hand, if periodic review type of replenishment is used, the supplier employs a make-to-stock production policy in order to cope with varying replenishment sizes.

Supply chain and store performance measures are affected by internal and external parameters. We take internal parameters are the ones that are closely/directly related with the store such as mainstore and backstore capacities, inventory control policies, shelf replenishment policies, workforce levels, number of equipments in the backstore and the mainstore, variety of product families, loading, unloading and replenishment time of a product family. Variety of product families is also an external parameter. The rest are number of suppliers, distribution centers and their distance to the store which affect the transfer time of the products. Inventory control and replenishment policy of the suppliers and distribution centers are the important ones of the external parameters. By the help of the simulation model that we develop, we investigate interactions of these parameters and their effect on the performance measures such as average inventory level, number of stock outs, inventory turnover rate of distribution centers and store, average shelf replenishment time and resource (workers, equipments) utilizations and customer satisfaction level.

CHAPTER IV

THE SIMULATION MODEL

4.1 An Overview of Simulation Modeling

Before introducing our simulation model it is necessary to explain steps and parts of a simulation study. The steps in a simulation study are shown in Figure 6. Simulation studies do not have to follow a cut and dries formula, but there are some steps that used commonly. The forgoing paragraphs will be mainly based on Banks et al. (2005) and Kelton et al. (2010) discussions. As they suggest: First of all the problem must be described clearly. There are occasions where the problem must be further reformulated as the study progresses.

Secondly, if simulation is the appropriate tool for the problem; the overall project plan should include a statement of the alternative systems to be considered, and a method for evaluating the effectiveness of these alternatives.

Data collection is an important and time taking part of the model development stage. As the complexity of the model changes, the required data elements may also change. The objectives of the study is to collect various data.

The real-world system models require an enormous information, storage and computation, the model must be entered into a computer-recognizable format. In that case the developer of the model must decide whether to program the model in a simulation language or use a simulation software. Simulation languages are powerful and flexible. However, with a simulation software, the model development time is reduced. After this step, the model must be verified and validated.

Verification is for checking if the computer program performing properly. If the input parameters and logical structure of the model are correctly represented in the computer, verification has been completed.

Validation is the determination that a model is an accurate representation of the real system. Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behavior and using the discrepancies between the two, and the insights concerning the length of waiting lines under current conditions.

After finishing the steps of verification and validation, the alternatives that are to be simulated must be determined. Frequently, the decision concerning which alternatives to simulate may be related with the runs that have been completed and analyzed. For each system design that is simulated, decisions need to be made concerning the length of the initialization period, the length of simulation runs, and the number of replications to be made of each run.

Production runs, and their subsequent analysis, are used to estimate measures of performance for the system designs that are being simulated. Based on the analysis of runs that have been completed, the analyst determines if additional runs are needed and what design those additional experiments should follow.

There are two types of documentation: program and progress. If the program is going to be used again by the same or different analysts, it may be necessary to understand how the program operates. This will build confidence in the program, so that model users and policy makers can make decisions based on the analysis. Also, if the program is to be revised, this can be done by adequate documentation. Another reason for documenting a program is so that model users can change parameters at will in an effort to determine the relationships between input parameters and output measures of performance, or to determine the input parameters that optimize some output measure of performance. Possibilities prior to the final report include a model specification, prototype demonstrations, animations, training results, intermediate analyses, program documentation, progress reports, and presentations.

The final step is implementation. The accomplishment of the implementation phase depends on how the previous eleven steps have been performed. It is also dependent upon how carefully the analyst has involved the last user during the whole simulation process.

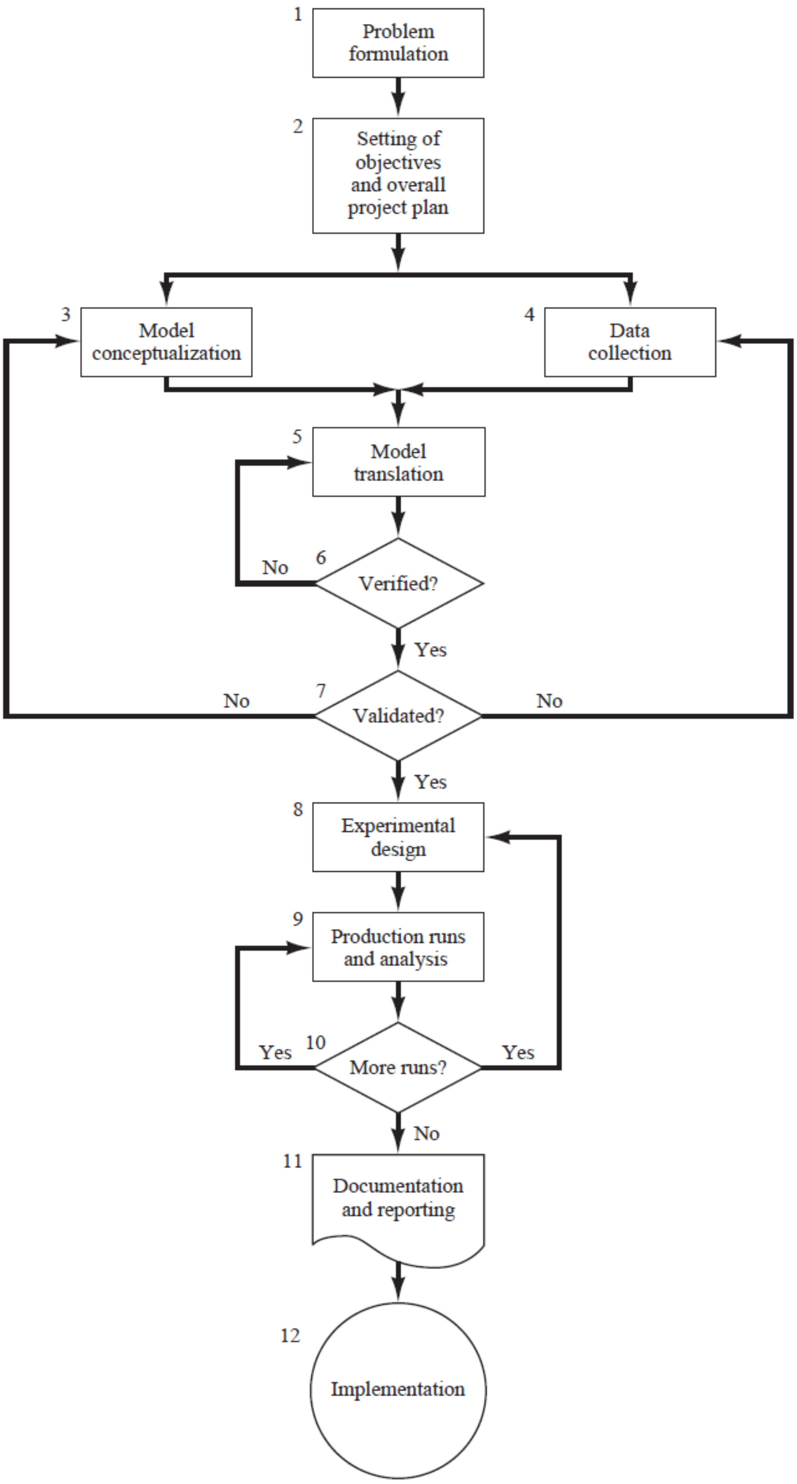

Figure 6. Steps in a simulation study, (Banks et al., 2005)

Having discussed the steps of a simulation study it is necessary to explain the elements/pieces of a simulation model. Most of simulation models have players that called entities. Entities are move around, change status, affect each others, state of the system and performance measures. They are dynamic; usually, they are created, move around and disposed. Most entities represents real things in a simulation. They are the first thing that must be decided while modeling a system.

To individualize entities, attributes are attached to them. An attribute is a common characteristic of all entities, but with a specific value that can differ from one entity to another. The most important thing to remember about attributes is that their values are tied to specific entities. The same attribute will generally have different values for different entities; just as different parts have different due dates, priorities, and color codes. An analogy to traditional computer programming is that attributes are local variables-in this case, local to each individual entity.

A variable is information that reflects some characteristic of the system, regardless of how many entities are in the system. Although variables in a model are different, each one is unique. Compare to attributes, variables are not tied to any specific entity, but rather concern the system at large. They're accessible by all entities, and most of them can be changed by any entity.

Entities often compete with each other for service from resources that represent things like personnel, equipment, or space in a storage area of limited size. An entity seizes a resource when available and releases it when finished. A resource can represent a group of several individual servers, each of which is called unit of that resource. The number of available units of a resource can be scheduled.

When an entity can't move on, it needs a place to wait, which is the purpose of a queue. Queues can also have capacities.

To get the output performance measures, it is necessary to keep track of various intermediate statistical-accumulator variables as the simulation progress.

An event is something that happens at an instant of simulation time and may change attributes, variables, or statistical accumulators, such as arrival, departure and the end. In a discrete-event model, the variables that describe the system don't change between successive events. Most of the work in event-driven simulation involves getting the logic right for what happens with each kind of event.

The current value of time in the simulation is simply held in a variable called the simulation clock. Unlike real time, the simulation clock does not take on all values and flow continuously. It starts from the time of one event to the time of the next event scheduled to happen. Since nothing changes between events, there is no need to waste time looking at times that do not important. The simulation clock interacts closely with the event calendar. At beginning of the simulation, and then after executing each event, the event calendar's top record is taken off the calendar. The simulation clock shifts forward to time of that event, and the information in the removed event record is used to execute the event at that instant of simulated time.

An important issue in a simulation is how it will start and stop. The suitable starting conditions, duration of a run, and whether it should stop at a particular time or whether it should stop related with a condition should be determined. It is critical to think about this and make assumptions consistent with the model; these decisions can have just as important effect on the results.

To evaluate the performance of the supply chain and store under different scenarios, a discrete event system simulation model is built with a commercial software package ARENA (version: 13.9). A detailed description of the supply chain conceptual model must be made for understanding the simulation model and how does it work. The input parameters, the output performance measures and the way they are calculated are discussed below in detail.

As stated in the previous chapter; our supply chain conceptual model consists of a store, distribution centers and suppliers as main components. The forward flow in our supply chain begins with one or more suppliers and ends with customer purchase from the store. By using these three types of nodes of the network, we model the main flows and interactions of the whole supply chain. Some product families flow via direct supply from suppliers/producers to the store whereas other product families use a consolidation hub/distribution center before being shipped to the store. One can assume that products that are imported or those have a long replenishment lead time use the distribution center. This also helps better manage inventory and use distribution center inventory as safety stock.

We develop a modular design in our simulation model. Each module interacts with each other. Even with the modular structure, the simulation model is a complicated one due to the excessive number of variables and the interaction inside and between modules. We first develop a base model, then modify the model in order to enhance the analysis of various scenarios. In the next section, we present the datails of the base scenario and corresponding simulation model. We make use of flow charts to describe the processes involved. The performance of the system with respect to different scenarios are monitored via supply chain, and store performance measures.

4.2 Base Model

Assuming a push type flow, the processes in the supply chain are triggered by the suppliers. Although there are small number of modules representing suppliers, each supplier can accomodate a variety of product families along with various production and replenishment policies. In the base model two of the suppliers are working under EOQ replenishment policy and one them is working under the periodic review (s,S) policy. In the EOQ case, the supplier ships the EOQ amount in each shipment. In the (s,S) policy model, the supplier ships varying amounts each time where the order size is defined by S minus the inventory level at the time of review. Associated with each supplier and for each product family, we have interested in production rate and shipment interval parameters. We assume that all suppliers are equipped with relevant technology and sufficient capacity to obey a range of replenishment policies under consideration.

For the first type of suppliers that ship products with respect to EOQ policy, the model is as follows: An entity is created based on defined intervals at the supplier module. The interval is the shipment interval of the particular product family and increases the supplier inventory by the produced amount after each production and decreases the supplier inventory by the shipped amount (i.e. EOQ) after each shipment. The inventory level at the distribution center is updated accordingly, of course following the appropriate lead time. For the second type of suppliers produce products that are managed by a periodic review policy. For such suppliers, we create an entity that represents the production batches. Hence, upon creation, the entity increases the inventory level of the supplier by the production lot size. Shipments from the supplier to the store are modeled by an entity that comes from the backstore and decreases the inventory level by the replenishment amount while increasing that of the backstore, after a time period equal to the transportation lead time. The backstore entity also acts to represent the periodic inventory review and order size calculation at the backstore.

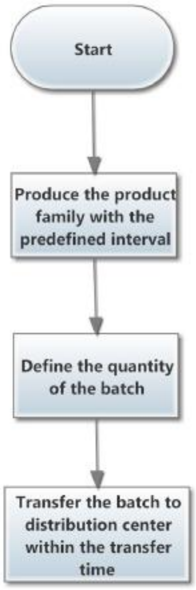

Figure 7. Flowchart of first type of suppliers

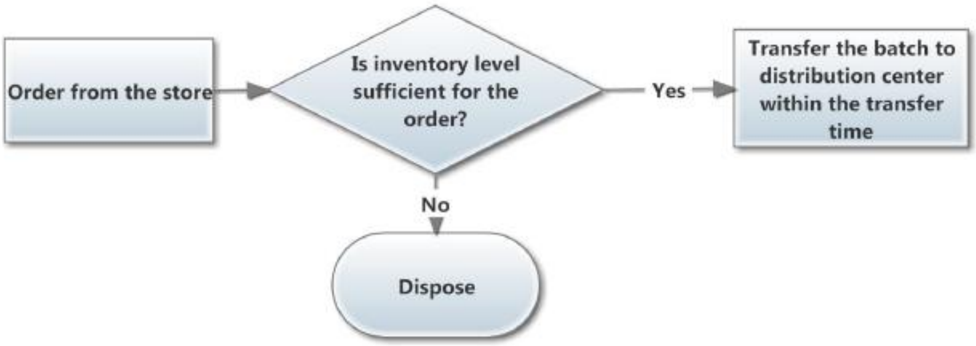

Figure 8. Flowchart of second type of supplier

Entities representing product families come to distribution center after they are produced at the suppliers. distribution center has a limited capacity and receives the products with the first come first served policy. When a product arrives at distribution center, the available storage capacity of the distribution center is controlled by a global variable. The entity that is created at the supplier module checks this varible. If there is enough avaible space, inventory level of the distribution center is updated by the same entity, whereafter the entity is disposed. Overall inventory level of the distribution center and the particular product are controlled by global variables and can be reached and changed by any entity in the simulation model. If there is not enough space for the products that are transferred from suppliers, then, the inventory level updated only by the amount that can actually be stored to capacity.

For the base model, the distribution center is also assumed to ship products to the store based on an EOQ policy. To represent this process, an entity is created that periodically decreases the inventory level of the store, following the transportation lead time. In the case that the distribution center does not have enough inventory at the time of shipment, a partial shipment is made to the store and the amount that could not be shipped due to insufficient inventory is recorded. The flow chart below, Figure 9, shows the detailed process flow for the distribution center.

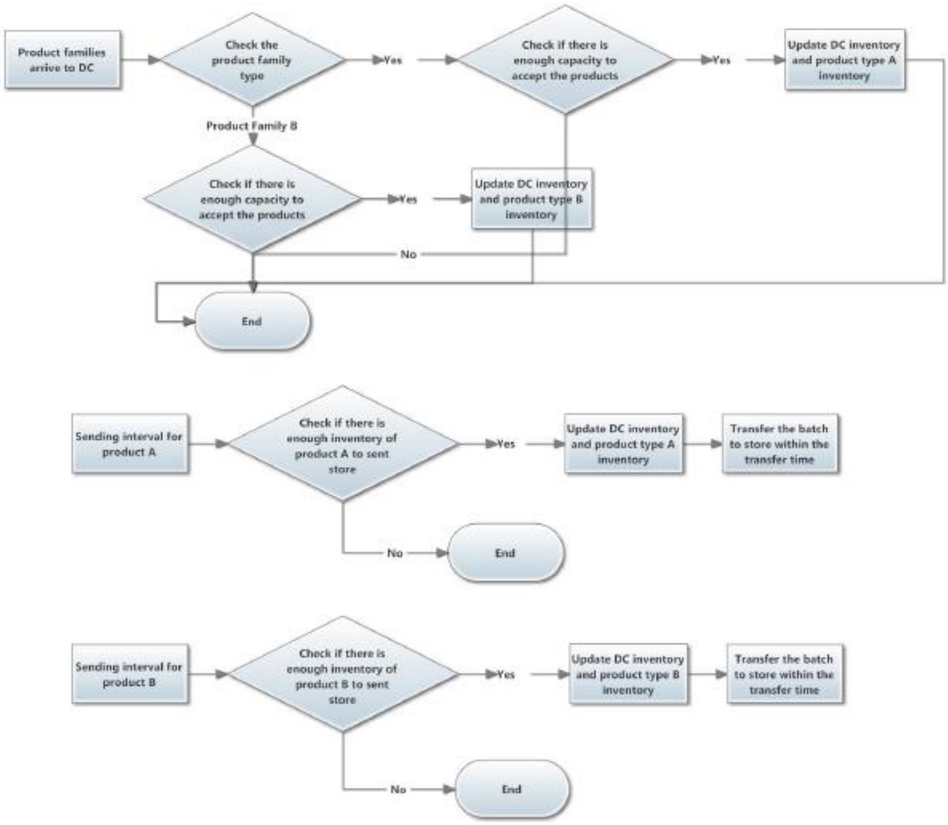

Figure 9. Flowchart of distribution center processes

The store component of the model is the most significant one, since it is taken to be the focal point of the supply chain under consideration. Store consist of two parts: the backstore that also doubles as a warehouse and the mainstore that is the store room with the shelves from where the customers pick-up and purchase their orders.

Products from distribution centers and suppliers arrive at the backstore with respect to predefined replenishment policies. The store accomodates a number of resources, namely workers and equipments that serve for in-store logistics. Both workers and equipments are shared by the backstore and the mainstore. Upon receipt of the product batches at the receiving of the backstore, the products are placed on the shelves. Since products families vary in physical characteristics, each product requires a different number of resources and time for filling into shelves. In doing so, the backstore capacity need to checked. In the case that the received product batch connot be fully placed on backstore shelves due to insufficient capacity, the remaining products are kept in a temporary waiting area of the backstore, until there is available shelf capacity. We assume the batch/casepack do not need to be opened and partially stacked to the backstore shelves and the shelves has sufficient dimensions for all product type's case packs.

Products on the backstore shelves are used to replenish mainstore shelves, based on customer orders and the policy. For the inventory balance and updates, we utilize global system variables. We also use dummy entities and their attributes to control and represent batches, over-capacity, partial lots etc.

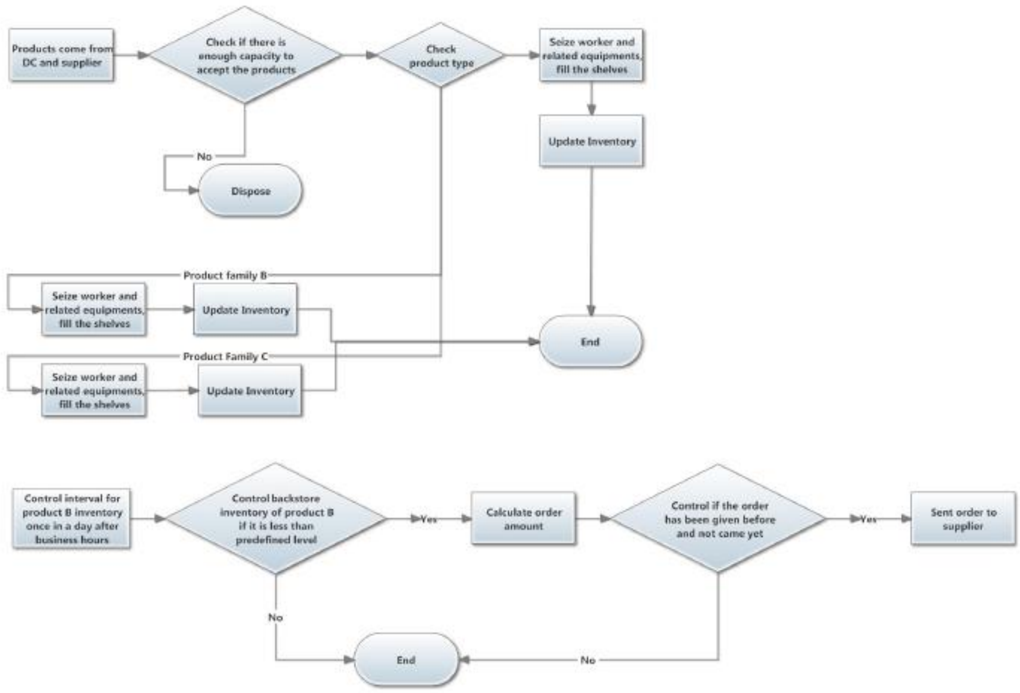

Figure 10. Flowchart of backstore processes

Replenishment of the mainstore shelves using backstore inventory takes place as follows: After the open hours of the store, when all customers leave, the inventory level on the store shelves are controlled by workers assigned to shelf replenishment. The inventory level of each product is checked. For products whose inventory level in the mainstore falls below a predefined shelf safety stock level, replenishment from the backstore needs to be made. For this, the store workers check backstore inventory and if the required product is available in backstore inventory, they fill the shelves immediately either fully or partially (in case backstore does not have sufficient inventory for full replenishment) with the use of related equipment.

The time required for the replenishment, the workforce and equipment needs are determined based on product characteristics. Zelst et al. (2006) states that, there are mainly three different ways to fill a shelf: Unit filling regime is putting the individual customer units on the shelf. Tray filling regime is putting casepack directly on the shelf. Loose filling regime is dumping items without arranging. In an attempt to reveal the effect of shelf filling regimes on the store performance and the overall system performance, we test the model under various shelf filling regimes for the product types.

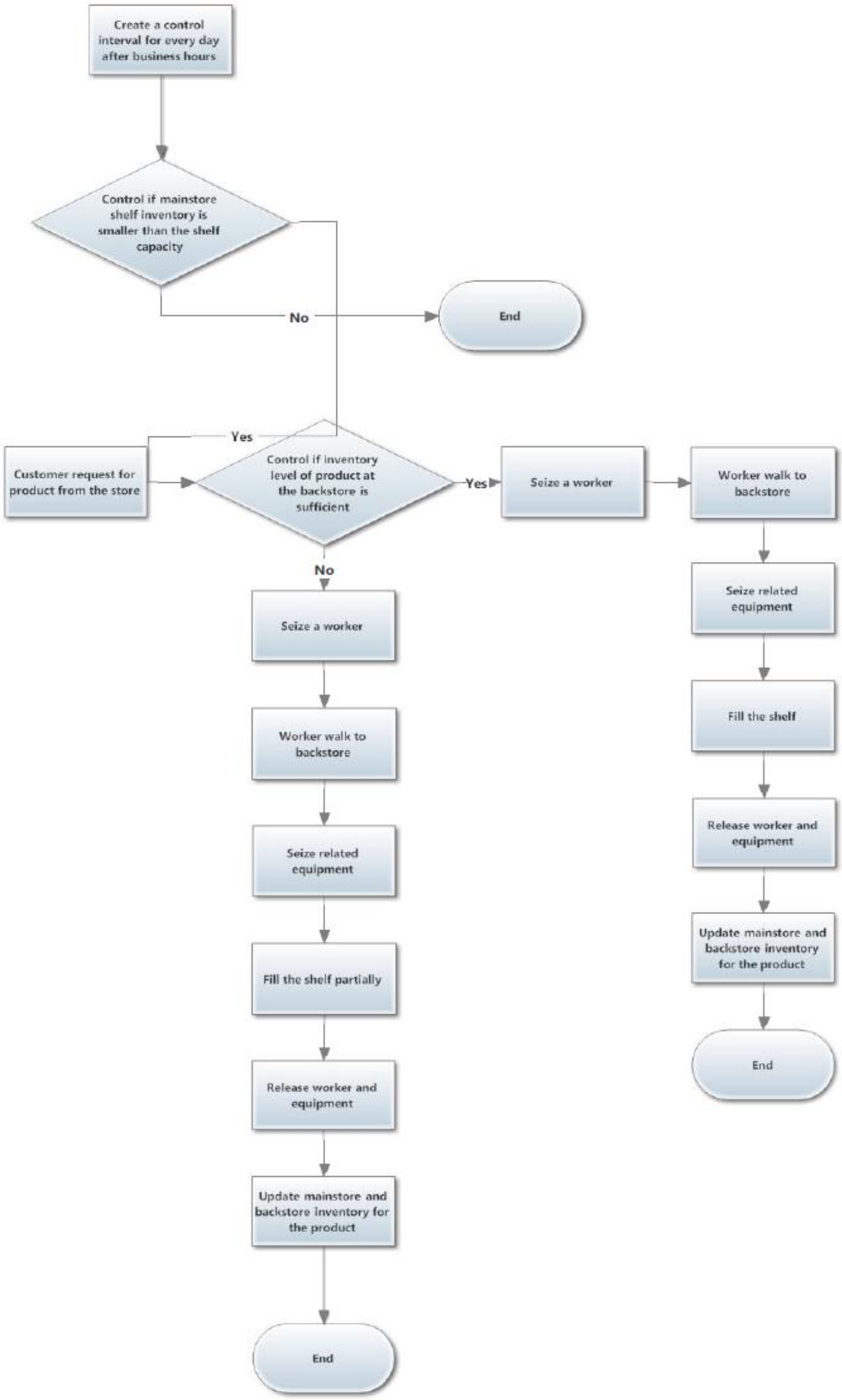

Figure 11. Flow chart of mainstore shelf replenishment

The store process is triggered by the customer demands. In our model, we assume that customers arrive between 10:00 AM to 10:00 PM. Each customer may have a demand for each type of product. The quantity required by customers for each item has different levels of intensity and variability. Once the customer arrives at store, the quantity demanded for a product is compared with the inventory on the store shelves. If there is enough inventory on store shelves the order is immediatelly satisfied. In such case, the customer only needs to go to the associated shelf, grasp the product and pay. In case of insufficient store inventory, however, the situation is a little bir more complicated: In some cases, the customer may decide not to buy the product and leave the store without making the related purchase. In other cases, the customer asks the store personnel for the product. The personnel has the backstore inventory checked, and the shelf inventory replenished, of course, based on availability of the product at the backstore. Clearly, these activities take time, and the customer may or may not have the patience and time to wait for the replenishment. In the latter case, the customer leaves the store without making the purchase of the product he/she asked for. Customer order fill rate and lost sales are recorded in order to track store and supply chain performances.

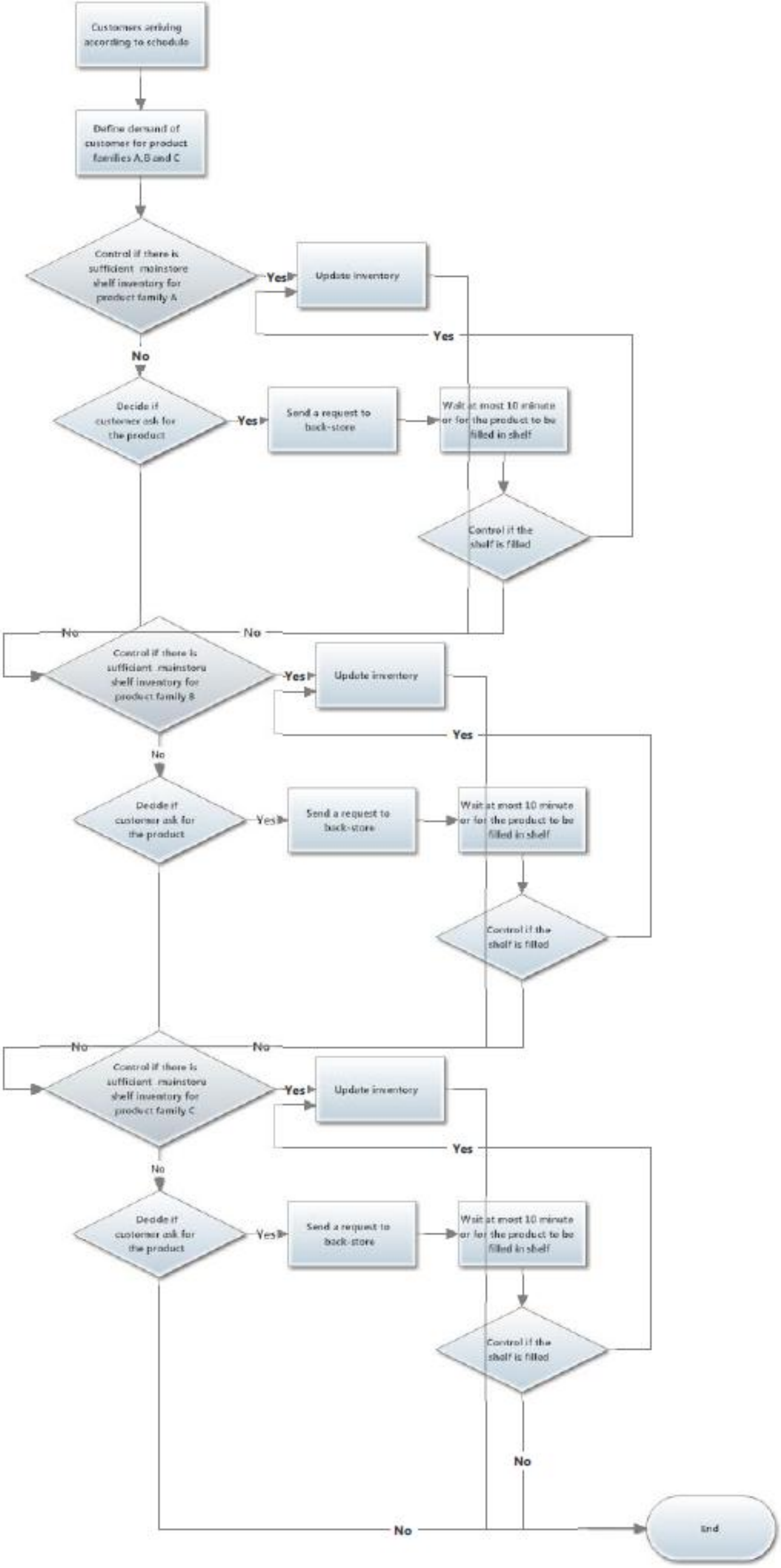

Figure 12. Flowchart of mainstore check-out

For the verification, we monitor the varying input parameters and their expected behaviour with parameter updates. We mainly analyze the relationship between customer demand rate, in-flow rate and inventory build-up. We make use of extreme scenarios such as no capacity restrictions and tight capacity for distribution center and store, low and very high demand for customers, then we look for the expected responses from the model. At the end of the verification process with monitoring the parameter updates, we were convinced that the input parameters and logical structure of the model are correctly represented.

The animation possibility of the Arena Software turned out to be very helpful for model validation. The simulation model was coded in a modular way, with each module representing a process. Namely, we have one set of modules that duplicates the production inventory and shipping processes at the suppliers, one module to represent the inventory, replenishment and shipping processes at the distribution center, one module for backstore replenishment, one module for store replenishment and finally one module to simulate the customer purchase, inventory and shelf management processes at the main store. For each module, we kept track of system variables and the animation with the progress of the simulation run, in order to make sure that the model represent the associated process accurately, both in terms of numeric values and in terms of physical flows. We went through a long validation process with a set of parameters each time to define a different supply chain setting. In result, we were convinced that the model provided an accurate representation of the overall system.

CHAPTER V

NUMERIC RESULTS

5.1 Scenarios

The experimental setup aims to identify the relationships between system parameters and performance measures. The analysis is carried out via scenarios, where each scenario represent a different supply chain setting. The performance measures, we choose to reflect how well the supply chain and the store are performing; lost sales, utilization of workers and equipments in store, average shelf replenishment time of mainstore, number of customers whose ask and wait for the shelf replenishment, number of replenishments for mainstore shelves, average inventory and inventory turnover rate of distribution center and backstore, inventory in waiting area of the backstore, number of incoming products batch that waiting in the backstore for the replenishment to backstore shelves (Table 5).

Table 5. Performance measures

• Sales per product
• Lost sales per product
• Number of satisfied customers per product
• Number of unsatisfied customers per product
• Number of customers who ask for a product in the mainstore
• Number of customers who ask for a product and buy that product
• Number of customers who ask for a product and could not buy that product
• Average mainstore shelf replenishment time
• Average mainstore shelf inventory per product
• Average backstore inventory
• Average waiting area inventory
• Average distribution center inventory
• Number of times that distribution center partially satisfy backstore demand
• Number of times that backstore partially satisfy mainstore demand
• Number of times that distribution center cannot receive shipments from the suppliers because of insufficient capacity

Table 6. Parameters that does not change and varying parameters of the modules

Parameters	Do not varying	Varying
Customer check-out	• Customer arrival schedule • Percent of customer who ask for the product replenishment • Maximum time that a customer wait for the product replenishment • Customer product retrieval time	• Customer demand
Mainstore shelf replenishment	• Number of workers and equipments • Time spent to control inventory level by a worker • Time interval to check inventory level • Shelf replenishment policy	• Shelf filling regime • Product shelf capacity
Backstore	• Time interval to check inventory level • Number of workers and equipments • Time spent to control inventory level by a worker • Time spent to carry products to waiting area by a worker and equipment	• Shelf filling regime • Backstore capacity
Distribution Center	• Time interval for shipments and batch sizes from distribution center to backstore	• Time to transfer products from distribution center to backstore • Capacity of the distribution center
Supplier (EOQ policy)	• Time between production runs and shipments	• Production and shipment batch size • Time to transfer products from supplier to distribution center
Supplier (S,s Poicy)	• Percent of capability of the supplier to satisfy store demand	• Amount of s and S • Time to transfer products from supplier to backstore

A scenario is defined by a complete specification of these parameters, and varying each combination of parameters result in a separate scenario. In our experimental design, we take some parameters as constant and we vary some of them in order to test the performances. The varying and not varying parameters according to their modules in the simulation model is shown in Table 6.

We start with customer side, that is with the store since the whole supply chain activities are trigered by customer demands. On the customer side we have, customer arrival schedule, customer demand, percent of customer who ask for the product replenishment, maximum time that a customer wait for the product replenishment, customer product retrieval time. We use the same values for customer arrival schedule, percent of customer who ask for the product replenishment, maximum time that a customer waits for the product replenishment, customer product retrieval time in each scenario. We test how varying customer demands affect supply chain and store performances under various management policies by using different scenarios. For the purposes of this study, we basicly take two values of demands; the first one stands for a typical demand rate that we expect to see the under low and high variability, and the second refers to a higher level of demand under low and high variability. Clearly, a larger set of demand values may result in a more insightful analysis. However, this would further increase the size of the experimental study. To this end, we try to demonstrate a compherensive analysis in terms of the parameters involved, whereas we follow a rather limited analysis in terms of variation of parameters. We would like to remark, however, that the model and the experimental setup we present is capable of carrying out a much more detailed analysis.

Concerning the mainstore shelf replenishment, we have number of workers and equipments, time spent to control inventory level, time interval to check inventory level; as shelf replenishment policy parameters, however following the initial set of test runs, we tend to believe that these will not have a defining effect on the store and supply chain performances, therefore, we choose not to vary them in the experimental study. On the other hand, we vary the shelf filling regimes because, we suspect that this may have an effect both for the downstream and upstream. As an example, in unit filling regime the time spent to fill the shelves increases however, which may as well increase customer demand since with unit filling regime, products on shelves may look more appealing to customers. Moreover, we wish to question the capacity effect of mainstore shelves on the customer satisfaction and backstore, distribution center and supplier performances.

In the backstore area, number of workers and equipments, time required to control inventory levels, scheduled time interval to check inventory levels, shelf replenishment policy, time to carry products to waiting area are the parameters that we keep as constant. On the other side, shelf filling regimes of the backstore may have an effect both for the shelf replenishment of mainstore and on the upstream mainly distribution center performance measures. Moreover, we believe that backstore capacity may have a drastic effect on the overall supply chain performance metrics, since backstore is located between suppliers and customer.

Having decided on the customer and store side parameters and performance measures, we now move to the distribution center. In our supply chain setting distribution center feed the backstore and accept batches from the supplier. The distribution capacity is a critical point since it is on the midway for the flow from suppliers to the store. Therefore, it interactively affects many significant supply chain parameters such as supplier safety stock requirements, inventory costs and customer service levels. We take two values of distribution center capacities, which can be named as normal and high. Time to transfer products from distribution center to backstore can change according to many uncertainties involved, the risks on the routes. In many cases, the system is set up in a way to properly operate under average values. So, we test the effects of low and high variability for the product transfer times. Time intervals for shipments from distribution center to backstore and associated batch sizes are taken as constant values since they are mainly defined by an economic order quantity type of policy.

On the supplier side, the batch sizes are determined according to the replenishment policies for the supplier. We test two different replenishment policies, economic order quantity (EOQ) replenishment policy for two product families and periodic review (s,S) replenishment policy for one product family. For the former class, "normal" and "high" EOQ batch sizes for the two of the product families along with low and high variability is tested. Time between production runs and shipments is out of scope of this study, therefore they are taken to be constant. We further investigate the effects of normal and high demand rate in (s,S) policy, for one product family. However, we assume that the percentage of times that the supplier has sufficient inventory to make the shipment on time does not vary. Time to transfer products from suppliers to backstore varies according to supplier locations. The suppliers may be local or international. We analyze both cases with low and high variations of transfer times.

In the next section we give numerical details about the parameters that we have introduced.

5.1.1 Parameters that do not Change Across Scenarios

The table below (Table 7) summarize the set of parameters according to their modules. We did not vary these parameters mainly because we believe that they will not have significant effects on the performance metrics.

The store is open between 10 a.m. to 10 p.m. every day. Customers visit the store between these operating hours according to varying arrival rates. The rush hours, for example induce more customer visit per unit time the store. We further assume that customers arrive as batches of three people on the average. The time required to search and buy a product on the shopping list (if it is available on shelf) takes on average of 3 minutes. When a customer faces with a stock-out situation, he/she may ask for the product (with a probability of 0.5) and in such case, wait maximum 10 minutes for the shelf replenishment.

The workers and equipments are the resources of the system and they are shared by both mainstore and backstore. We do not vary the number of the workers and equipments, since the model does not include sufficient level of details for these resources other than grabbing the products and filling the shelves.

Shelves are replenished after the daily routine inventory control or via customer request. Shelf replenishment requires that workers walk to the backstore or to the waiting area. This time is included in the model by a random variable that is the same for all product families. Likewise, we do not vary time to check inventory level and time spent to carry products to waiting area by a worker and equipment. A flat damage rate percentage to reflect losses caused by thefts or perishability is also included in the model.

The average time between production runs and shipments and time interval for shipments and batch sizes from distribution center to backstore are the same and it is 2 days since, we assume that we work with a system where products flows balanced.

Table7 . The value of parameters that do not change across scenarios

Module	Parameter	Value
Customer check-out	Customer arrival schedule	Frequency varies based on scenario. Batches of 3 people. No arrival between10 p.m to 10 a.m.
	Percent of customer who ask for the product replenishment	50%
	Maximum time that a customer wait for the product replenishment	10 mins
	Customer product retrieval time	3 mins average
Mainstore shelf replenishment	Number of workers and equipments	2 workers between 10 a.m.-10p.m. – 3 worker between 10p.m-10a.m. 2 equipment
	Time spent to control inventory level by a worker	5 mins average
	Time interval to check inventory level	Once every day after business hours
	Shelf replenishment policy	Triggered by inventory control and customer request
	Percent of damage in mainstore shelves	5%
Backstore	Time interval to check inventory level	Once every day after business hours
	Number of workers and equipments	2 workers between 10 a.m.-10p.m. – 3 worker between 10p.m-10a.m. 2 equipment
	Time spent to control inventory level by a worker	5 mins average
	Time spent to carry products to waiting area by a worker and equipment	10 mins average
Distribution Center	Time interval for shipments and batch sizes from distribution center to backstore	2 days (average)
Supplier (EOQ policy)	Time between production runs and shipments	2 days (average)
Supplier (S,s Policy)	Percent of cases where supplier has sufficient inventory to cover store order	80 %

5.1.2 Parameters that Change Across Scenarios

Scenarios are characterized by varying levels of parameters. The main actors that determine the scenarios are product types. We assume that there are three product families. We name these product families as A, B and C. Product family A refers to such products with relatively lower demand. We assume that it is produced by a set of suppliers then transfered to the store through a distribution center. We expect to see the effects of this multi step structure and the induced variability on the system performance metrics. Product family B has highest demand among all product types. After it is produced by another set of suppliers, it is directly transfered to the store. This is the product type that is expected to have the lowest effect due to parameter variability. However, we expect to observe more frequent occurences of stock-outs due to high demand. Product family C is the one with medium demand. As with product family A it also follows the route from supplier to distribution center than to the store. Next, we discuss the detail of the scenarios.

The two different partial scenarios that are performed by daily high and low demand are given in the table below. (Table 8)

Table 8. Daily demand rate of customer for each product family **(Parameter 1)**

Demand		Product Family A	Product Family B	Product Family C
Scenario DR1	Normal	100	500	350
	With low variation	10	50	35
Scenario DR2	High	200	1000	600
	With low variation	20	100	60

In the first scenario about the backstore capacity, we take the capacity to be 80% of the 10-day demand cover, wheras in the second one, we take the capacity to be 2 times of the 10-day demand cover. Related values are shown in Table 9.

Table 9. Backstore capacity **(Parameter 2)**

Backstore Capacity	Unit
Scenario BC1	12000
Scenario BC2	30000

Time to fill the mainstore shelves according to the filling regime along with their assumed effects on the demand rate is shown in Table 10 These parameters induce consider two different classes of scenarios.

Table 10 Time to fill the mainstore shelves according to the filling regime **(Parameter 3)**

Mainstore Shelf Filling Regime	Product Family A	Product Family B	Product Family C
Scenario SFR1	Tray Filling Regime	Tray Filling Regime	Loose Filling Regime
	6 min	10 min	3 min
Scenario SFR2	Unit Filling Regime (with 10 % higher demand)	Unit Filling Regime (with 10 % higher demand)	Unit Filling Regime (with 10 % higher demand)
	12 min	20 min	16 min

Table 11 demonstrates two partial scenarios. These are related with the time required to fill the backstore shelves (according to the filling regime) and their effects on the product retrieval time. Here, we consider two of the three main different filling regimes.

Table 11. Time to fill the backstore shelves according to the filling regime **(Parameter 4)**

Backstore Shelf Filling Regime	Product Family A	Product Family B	Product Family C
Scenario SF1	Tray Filling Regime	Tray Filling Regime	Tray Filling Regime
	8 min	8 min	6 min
Scenario SF2	Unit Filling Regime (with 20 % lower retrieval time)	Unit Filling Regime (with 20 % lower retrieval time)	Unit Filling Regime (with 20 % lower retrieval time)
	15 min	15 min	12 min

The first scenario of the mainstore shelf capacity for each product family is based on the average daily demand of the customer. In the second scenario, we consider three days' demand (Table 12).

Table 12. Mainstore shelf capacity for each product family**(Parameter 5)**

Mainstore Shelf Capacity	Product Family A	Product Family B	Product Family C
Scenario SC1	100	500	350
Scenario SC2	300	1500	1000

Regarding the distribution center capacity, in the first scenario we assume that the capacity of the distribution center is equal to the average of 10 days demand. The second scenario reflects the distribution center capacity for a month. (Table 13)

Table 13. Distribution center capacity **(Parameter 6)**

Distribution Center Capacity	Unit
Scenario DC1	10000
Scenario DC2	30000

Values for low and high variability of transfer time from distribution center to store is shown in the Table 14 below.

Table 14. Transfer time from distribution center to store **(Parameter 7)**

Transfer time from distribution center to store		36 Hours
Scenario TTD1	Low Variability	4 Hours
Scenario TTD2	High Variability	10 Hours

We consider two different scenario related with EOQ batch sizes of suppliers. Two different scenario with reorder point and order-up-to values (s,S) for a product family is shown in Table 15.

Table 15. EOQ production and shipment batch size of suppliers and s,S amounts **(Parameter 8)**

Production and Shipment Batch Size	Product Family A	Product Family C	Product Family B	
			S	s
Scenario P1 (Normal)	500	1500	2000	1000
Scenario P2 (High)	1000	3000	6000	3000

Supliers may be local or international. To represent these two situations, we vary the transfer times from suppliers to distribution center. The first scenario is for working with local suppliers and the second one is the case with internartional suppliers. Related values for these scenarios are shown in Table 16 below. Supplier may be distant or close to the store. To represent this situation, we basicly take two values of transfer time from supplier to store.

Table 16. Transfer time from supplier to distribution center **(Parameter 9)**

Transfer time from Supplier to distribution center	Product Family A	Product Family C
Scenario TTS1	2 days (with avg. 6 hours variation)	2 days (with avg. 6 hours variation)
Scenario TTS2	10 days (with avg. 2 days variation)	10 days (with avg. 2 days variation)

5.2 Results

In this section, we present a selection of our findings, based on the experimental study. Based on the scenarios defined earlier in section 5.1 we made 512 run of the model. Every run corresponds to a scenario that is a complete specification of all system parameters. Each run corresponds to 90 days of the store operations. We did not use a warm up period since we start with a typical state of the store even the supply chain. The results we present are mainly related with the performance measures that show significant variations across scenarios. With this idea in mind, we are interested in namely:

- sales and lost sales of each product,
- average inventory level of mainstore shelves,
- average inventory of backstore, waiting area of the backstore and distribution center,
- number of times that mainstore shelves are filled partially (which means the demand of the mainstore cannot be satisfied fully by the backstore),
- number of times that distribution center partially satisfies backstore demand,
- number of times that distribution center cannot receive the whole shipments (because of the insufficient capacity)

In our discussion, we emphasize the cases with the highest lowest values of the performance metrics, along with the scenarios that contribute to these performance measures, jointly or independently. We also emphasize the deviations, that is, the variations from the average values of the performance measures.

We begin with the analysis of lost sales. Although this is a negative performance measure, it is accepted as one of the best measures that define performance since; it is related with the customer satisfaction.

The highest value of lost sales for product family A is attained when replenishment sizes, order sizes and order-up-to levels are increased at the same time and the mainstore shelf filling regime changed to unit filling. We believe that this situation can be explained by the fact that increasing the replenishment sizes, order sizes and order-up-to levels affect negatively the synchronization of shelf replenishment interval. These changes induce higher replenishment intervals that most probably cause higher stock outs due to variations in lead times. The change shelf filling regime, from tray to unit regime increases shelf filling time for mainstore and has a positive effect on the customer demand via higher appeal. It is important here to remark that a collection of strategic (as in replenishment policies) and operational (as in shelf filling regime) affect a set of critical performance measure jointly.

The lowest value of lost sales for product family A occur when distribution center capacity increases and mainstore and backstore filling regimes are changed to unit filling regime. This result is also an example of the case where the strategic and operational parameters act together, to form the most favorable conditions for a critical performance measure. It also points out to a case where upstream parameters of the supply chain are main determinants of store-related performance measures.

Highest lost sales levels for product families B and C are similarly affected mainly by the joint effect of increases in replenishment and order sizes and changing the shelf filling regimes (from tray regime to unit filling regime). Here, we observe that the effect of rate of shelf filling regime for product C is higher, since it is replenished by the periodic review (s,S) replenishment policy and an intermediate distribution center is not used for its shipment. Since the demand rate for product family C is higher than product family A the effect is reflected at a higher magnitude.

The lowest levels of lost sales for product family C is observed when backstore and mainstore shelf capacities are increased beyond their base scenario level. Recalling that high mainstore shelf capacity for product family B also was one of the main drivers in decreasing the lost sales amount, we can say once more that all product types, with various characteristics, agree on a set of operational and strategic parameters as main determinants of performance. Moreover, upstream (external) and downstream (internal) parameters simultaneously affect the performance in the last meters of the supply chain, that is, the store.

Even though lost sales and sales amounts seem to be related with, even dependent on each other, they may point to different aspects of performance. Next, we analyze the effects of system parameters on sales volumes.

Sales for product type A attain its highest value when mainstore filling regime is unit and distribution center capacity is high as compared to the base scenario. We would like to note, however, that there is not a significant variation between the average sales volume and the highest sales volume; that is the sales for product type A are not very much sensitive –in the positive direction- to changes in the parameters. When we consider the lowest values of sales, the order replenishment sizes are the most effective parameters.

For product family B, order replenishment sizes and shelf filling regimes are the parameters that have the highest effect on the sales volumes. This is in agreement with what we observe for product family A.

The sales volume for product family C, the product family with the highest demand, is affected mostly from a more strategic decision, that is, supplier selection. With a higher share of international suppliers that induce higher transfer lead times and higher variability in transfer lead times, shelf availability and sales are negatively affected. With closer suppliers and the flexibility advantage of these suppliers, the sales volume increases.

Next, we focus on inventory-related performance measures. Inventories are important in two ways. First of all, inventory means cost, and therefore inventory reduction is usually one of the main areas of concentration in companies. On the other hand inventory serves as a means of flexibility to meet customer demand. This becomes even more important from a store point of view. In the ideal case, store managers want to use backstore as a cross-docking center. The aim here is to run backstore with as low of inventory as possible, while keeping the store with full mainstore shelves as possible.

Our experimental results show that, lowest inventories are attained with the high levels of replenishment batch sizes and order levels (that is, economic order quantity and (S, s) levels. However, previous analysis on sales and lost sales shows that this is not a desirable from a systems approach perspective, since lost sales increase and sales decrease under such conditions.

Backstore inventory level is primarily affected by upstream system parameters; that is replenishment sizes and distribution center capacity. As distribution center capacity increases, it is capable of handling a wider range of replenishments without any capacity problems. This, coupled with a high capacity of backstore, inventory levels in the waiting area decrease.

The waiting area in the backstore is used for batches or partial batches that are received by the backstore, but cannot be placed on backstore shelves due to insufficient shelf space. The inventory stays in the waiting area until there is available space in the backstore shelves. Therefore, the behavior of the inventory levels in the waiting area gives a signal about problems with backstore capacity. Highest level of inventory in the waiting area is observed with the joint effect of several policy parameters. These are increasing mainstore shelf capacities, high variability of transfer time from distribution center to backstore, and high order batch sizes.

We would expect to see a decrease in the waiting area inventory when mainstore shelf capacity increases, since this would ease the flow downstream. However, the effects of the mainstore shelf capacity remain limited. On the other hand, upstream parameters, namely replenishment policy from suppliers and distribution center, transfer time from supplier to distribution center have a considerable effect on the waiting area inventory level.

The distribution center plays a central role in the supply chain. It is functionally in the midpoint between suppliers and the store. Any problems with distribution center capacity may have important effect on supply chain performance metrics. As we expected, the experimental studies show that capacity problems with the distribution center arise with increasing replenishment batch sizes. We would also expect to see the effects of supplier selection on distribution center capacity problems, however, when the system is appropriately set up, supplier selection (local or international) do not affect performances negatively.

We also look at a similar performance measure, that is an indicator capacity problem with the backstore. That is the mainstore partial shelf replenishment, which measures the incidents of the inability of meeting the demand of the mainstore from the backstore. Highest occurrences of such a case is realized when an operational parameter, shelf filing regime is changed from tray filling regime to unit filling regime. This is most probably due to increased operation times, thus lower efficiency. For product family C, which has the highest demand, the strategic parameter, supplier selection has a critical effect.

Table 17. Selected scenarios (inducing extreme values of performance measures) and corresponding performance measures

Parameters									Performance Measures										
1	2	3	4	5	6	7	8	9	Insufficient Distribution Center Capacity	Number of Partially Satisfied Demand (From distribution center to store)	Average Backstore Inventory	Average Distribution Center Inventory	Lost Sales Product A	Lost Sales Product B	Lost sales Product C	Sales Product A	Sales Product B	Sales Product C	Average Inventory in Waiting Area
1	1	1	1	1	1	1	2	1	77.00	5.00	3040.89	9589.98	1694.66	6719.66	3202.59	1717.53	10372.64	7043.79	2053.11
1	1	1	1	2	1	2	2	1	76.00	9.00	8395.60	9221.86	445.80	89.93	1554.83	3148.15	17898.21	9199.11	2666.34
1	1	1	1	2	2	1	2	1	0.00	28.00	11086.63	6954.99	612.41	5199.21	228.77	2971.40	12737.94	10524.01	510.32
1	1	1	2	1	1	2	2	1	90.00	6.00	5823.66	9375.84	864.19	667.10	3474.23	2635.65	16831.13	7033.55	963.14
1	1	1	2	2	2	1	2	1	5.00	16.00	11104.29	15142.85	290.49	564.35	228.42	3241.45	17109.96	10358.45	582.13
1	1	2	1	1	1	1	2	1	86.00	5.00	10330.12	9346.05	2809.83	802.56	1255.90	957.40	19984.73	10988.85	1959.61
1	1	2	1	1	1	2	2	2	69.00	6.00	4860.67	8558.43	1153.62	8917.37	2844.63	2438.86	10835.30	8835.79	1979.61
1	1	2	1	1	2	2	2	1	19.00	11.00	11138.96	13689.77	287.85	7642.95	499.50	3509.95	13248.52	11808.52	294.96
1	1	2	2	1	1	2	2	1	0.00	38.00	10617.67	3487.79	299.83	4692.64	324.82	3207.30	14593.01	11068.42	276.86
1	1	2	2	2	1	2	1	1	5.00	22.00	9257.67	5798.66	411.87	3073.48	381.22	3350.50	17588.23	11829.90	452.10
1	1	2	2	2	1	2	2	2	85.00	4.00	3649.30	8790.32	1451.69	864.55	5655.92	2099.23	18719.14	5887.74	0.00
1	1	2	2	2	2	2	2	2	39.00	12.00	9675.96	21553.75	1166.21	826.36	1619.50	2353.50	18548.19	9826.65	816.26
1	2	1	1	1	1	1	2	1	83.00	5.00	9672.26	9595.61	1092.87	127.51	909.50	2272.01	16737.85	9170.81	0.00
1	2	1	1	1	1	1	2	2	68.00	8.00	11299.24	8384.48	839.10	2651.08	1513.98	2682.03	14953.44	9044.21	0.00
1	2	1	1	1	2	1	2	1	8.00	15.00	27545.25	15892.05	273.67	716.14	391.57	3165.66	16461.54	9933.40	361.33
1	2	1	1	2	1	1	2	1	65.00	15.00	25333.69	8293.94	290.49	1864.98	228.42	3158.75	15384.78	10108.21	2089.95
1	2	1	1	2	1	1	2	2	38.00	17.00	22836.86	6404.00	885.55	0.00	1160.35	2412.45	16523.69	8735.47	666.27
1	2	1	1	2	1	2	1	1	0.00	32.00	18360.83	2361.83	238.01	54.33	276.72	3195.45	17155.43	10025.68	143.62
Min									0.00	4.00	3040.89	2361.83	238.01	0.00	228.42	957.40	10372.64	5887.74	0.00
Max									90.00	38.00	27545.25	21553.75	2809.83	8917.37	5655.92	3509.95	19984.73	11829.90	2666.34
Average									45.17	14.11	11890.53	9580.12	839.34	2526.34	1430.60	2695.40	15871.32	9523.48	878.64

CHAPTER VII

CONCLUSION & FURTHER RESEARCH

This thesis aims to provide a viewpoint that pictures the supply chain as a whole, with the store in the focus. We identify key parameters of the store, through a supply chain perspective, that affect the performances of the store along with its impacts on the whole supply chain, concentrating on its capability to serve customers. The approach that is employed in this thesis, therefore, calls for a two-way analysis. That is, looking from the store upstream to the distirbution centers, suppliers, the associated logistics network etc., and looking from suppliers, distribution centers, strategic management decisons downstream to the store.

We question the interaction between in-store logistics parameters such as inventory management policies, stock filling regimes, shelf capacities, as well as supply chain parameters such as supplier locations, distribution center capacities on supply chain and in-store logistics performances. We start with the identifying supply chain structure and defining the environmental parameters; whereafter we employ simulation as an analytical tool for our research. We use ARENA Simulation Software version 13.9.

Several performance metrics are commonly used for evaluating store performances. Some are related with customers such as number of customers who wait for shelf replenishment, lost sales. Some have direct effect on customer service, however are more on the backstore side such as average inventory and inventory turnover rate of distribution center and backstore, inventory in waiting area of the backstore, number of incoming products batch that waiting in the backstore for the replenishment to backstore. The ones that related with DC may be average inventory of DC and inventory turnover rate of DC. Primarily, we aim to identify the effects of in-store logistics parameters on the performance metrics. Having identified these interactions, we further aim to construct an ordering of impact list of parameters with respect to in-store logistics performance metrics. That is, we aim to identify a "critical" set of parameters for in-store logistics.

We did not vary some of the parameters as we select the ones that we believe has more drastic effects on the performance metrics. Comprising all the parameters would make the analysis more complicated and it would be hard to draw conclusions. However, the analysis can be done by using our model and parameters.

As we anticipate previously; strategic, operational, upstream and downstream supply chain parameters affect store and supply chain performances simultaneously. Usually, the strategic decisions are taken once, most probably with an upper management perspective, and the (future) implementation phase is taken for granted. The possible effect of jointly considering strategic and store-operational decisions is usually overlooked. This leaves out the chance of improving the whole supply chain performance via the signals obtained from the store itself. However, by monitoring store performance, supply chain strategies can be determined. This will bring benefits for both store and supply chain as whole.

As a future work, we can modify this model and related analysis to different industries. It is possible to conduct a field study and collect data from real life. Managers have different approaches while managing a component of the supply chain. Some managers have a vision dedicated to operational parameters, whereas some others have a vision on design parameters. It would be a contribution to show the interrelation between the two approaches.

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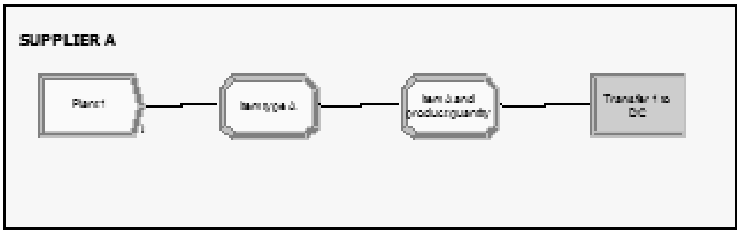
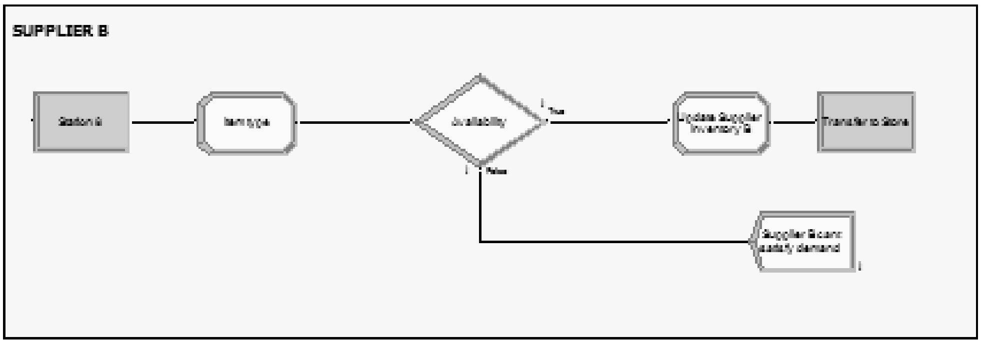
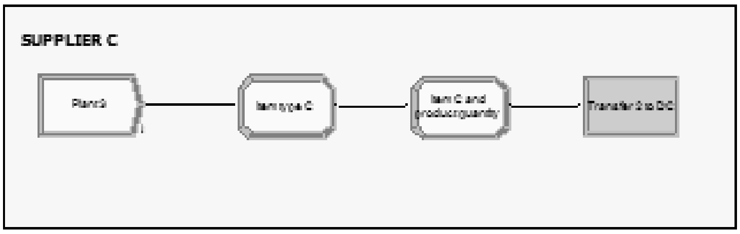
APPENDIX

Appendix-A. Simulation Model

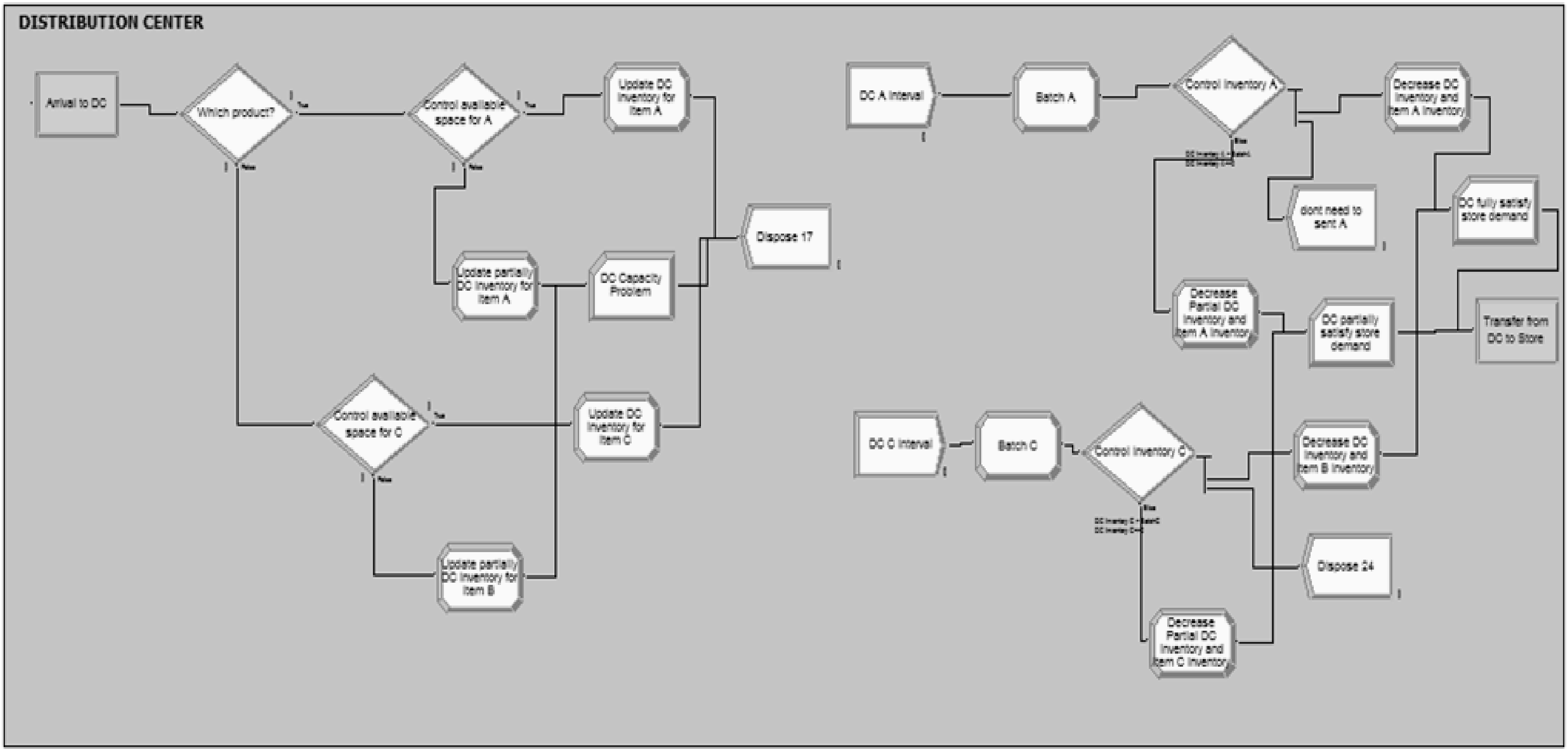
Supplier Module



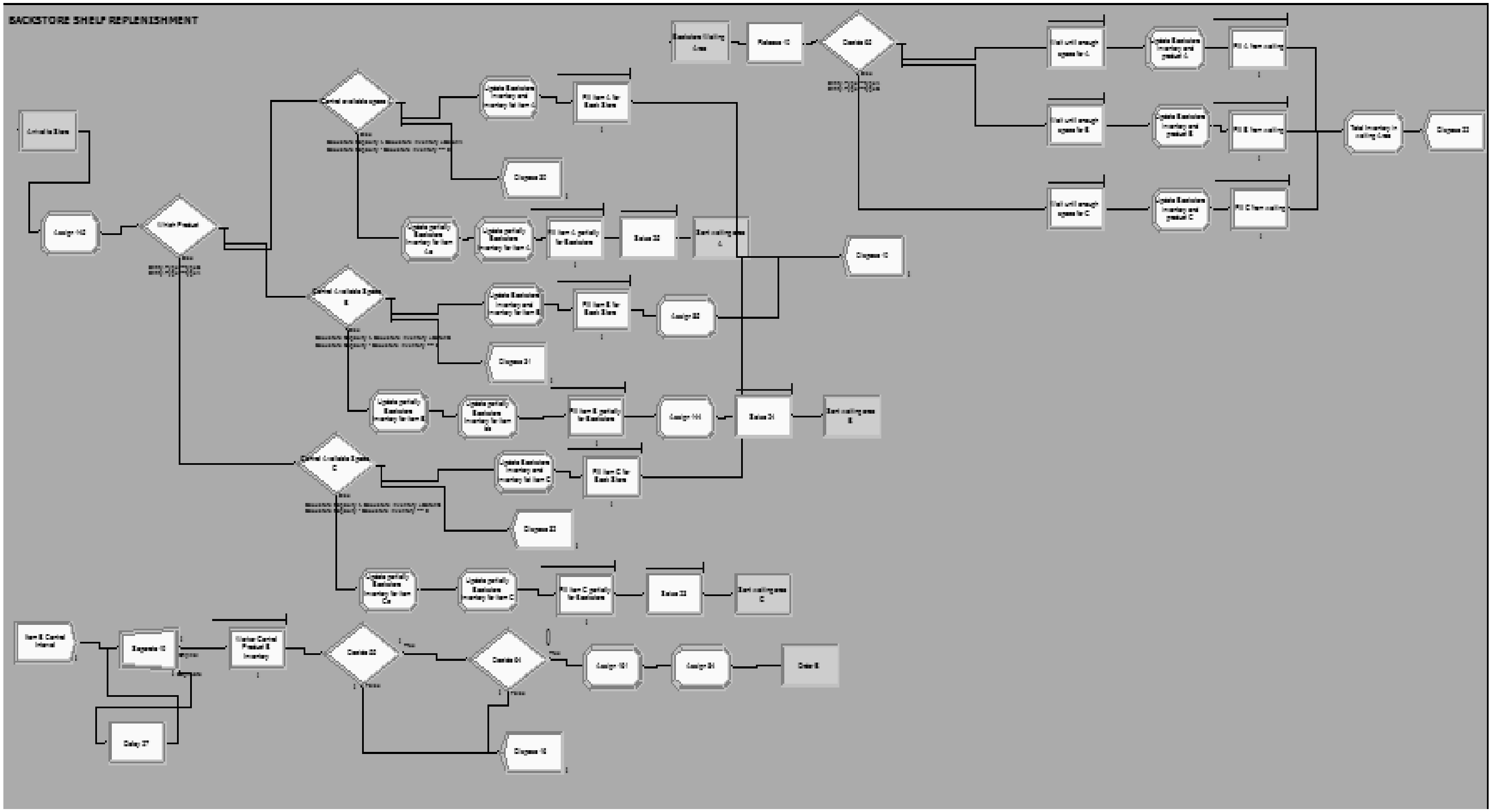




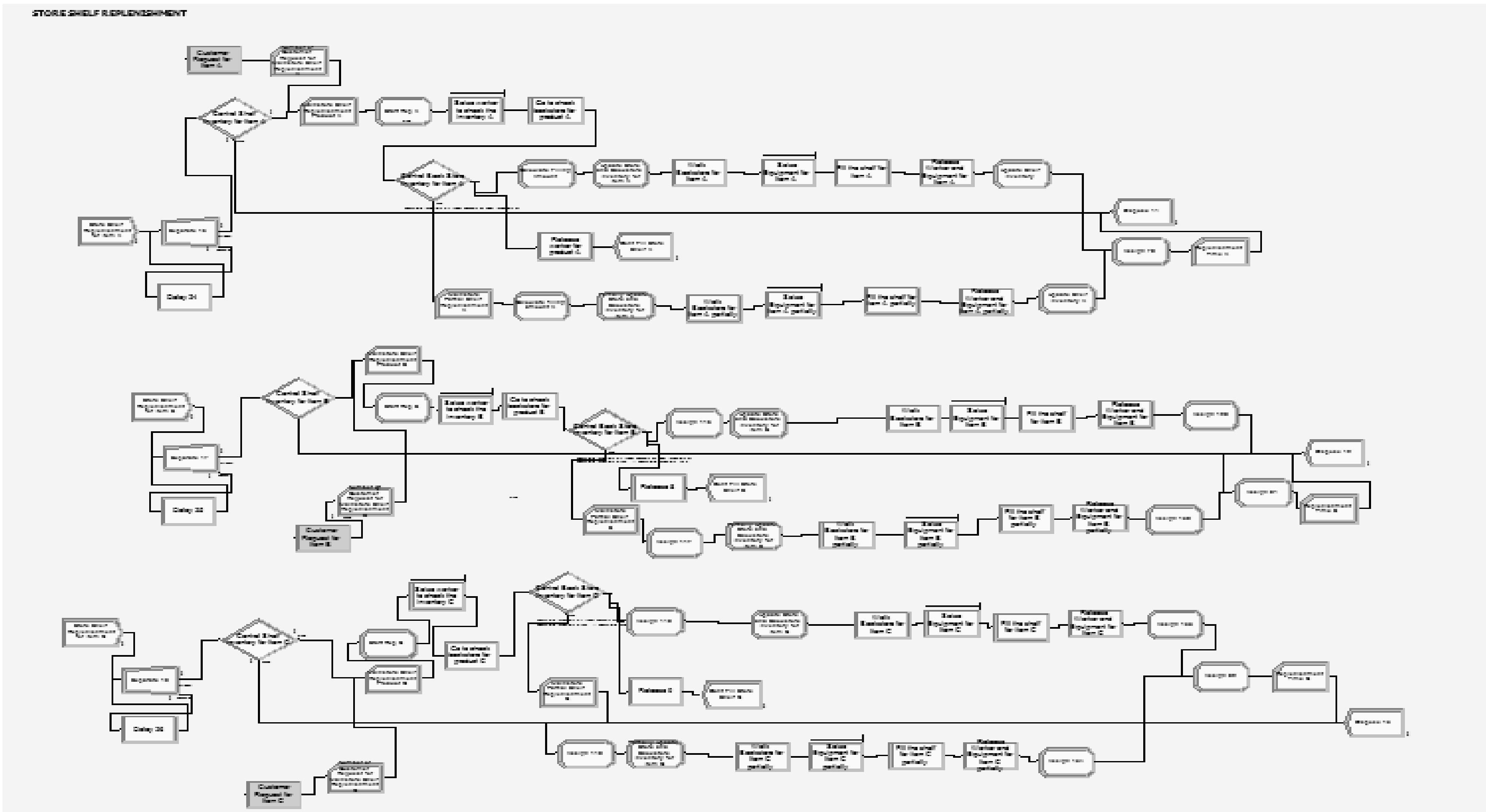
Distribution Center Module



Backstore Shelf Replenishment Module



Mainstore Shelf Replenishment Module



Customer Check-out Module