Master's thesis

NTNU
Norwegian University of Science and Technology

Candidate 10002 / Caroline Overvåg

Supply Chain Management by simulation modelling: A Case study of Ahlsell AS

Thesis Project

Master's thesis in IP501909 MSc thesis, discipline oriented master
Supervisor: Henrique M. Gaspar
December 2020

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Scientific Theory and Methods: MSc Project Proposal

NTNU – Ålesund
Norwegian University of Science and Technology

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Supply Chain Management by simulation modelling: A Case study of Ahlsell AS

Introduction

Norway is one of the biggest leading nation in the maritime industry with a strong position in the market worldwide. Today's market is turbulent and dynamic which leads to higher demands from the companies. Customers' requirements may change unexpectedly and unpredictable fast, and they also are different and demands differently. This means that products and services vary, and the company need to deal with customization, multiple product varieties and segmented markets. Supply Chain Management (SCM) can provide major source of competitive advantage in the current industry market and is the main theme in this master thesis. Basis for this thesis was to investigate Ahlsell`s supply chain management, focusing on their corporation with their suppliers and customers and their issues on correct inventory stock in the fluctuating industry market.

Motivation

Studying in the middle of a thriving business community in the maritime industry in Møre og Romsdal, which is very vulnerable to turbulent market needs, was the main motivation to learn more about SCM and the impact it may have. As a salesman at Ahlsell AS, it felt natural to choose this topic to gain a greater understanding of the choice of item volume in stock.

Scope

The scope of the project is to find the best potential solution how to satisfy the customers and to avoid overstocking. An evaluation of current SCM in Ahlsell will be investigated, looking for improvements.

Objectives

Different stakeholder`s need to be considered to investigate Ahlsells` SCM. The stakeholders' need to be defined based on their different role, requirements, needs and expectations in each process. Current SCM in Ahlsell needs to be thoroughly mapped holistically. Following research questions (RQ) are proposed:

- RQ 1: How does Ahlsell organize the handling of customers demand and supplies till producer and sub suppliers?
- RQ 2: Where are the main weaknesses in Ahlsell`s SCM?
- RQ 3: Is the change of supplier the best choice, both for Ahlsell and the customer?
- RQ 4: How can Simulation Arena help to improve Ahlsell`s warehouse stock?
- RQ 5: What does it take for Ahlsell to become supplier of choice?

Milestones

Tasks:

1. Identification of research questions, scope and objective.
2. Define stakeholders and map Sales Process Flowchart.
3. Literature study of Supply Chain Management and Simulation methods.
4. Methodology of how to do a simulations, definitions on modelling concepts and advantages and disadvantages of using the tools.

5. Simulation tool Arena Simulation.
6. Study case
7. Results
8. Discussion
9. Conclusion
10. Report

Schedule

Task	Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Identification												
2	Specification												
3	Literature												
4	Methodology												
5	Learning tool												
6	Study Case												
7	Result												
8	Discussion												
9	Conclusion												
10	Report												

In addition to the specified tasks, an A3 poster should be prepared and delivered together with this proposal, and a conference paper will be handled at the end of the research.

Delivery:
Final Thesis + Article (21th December)

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Preface

This report concluded the work done during the final semester of my Master of Science degree in Product and System Design at Norwegian University of Science and Technology (NTNU) in Ålesund. Objective of the thesis is to investigate Supply Chain Management (SCM) and the role it has in a company. The thesis is written in corporation with Ahlsell AS.

Studying in the middle of a thriving business community in the maritime industry in Møre og Romsdal, which is very vulnerable to turbulent market needs, made me want to learn more about SCM and the impact it may have. As a salesman at Ahlsell AS, it felt natural to choose this topic as I want to gain a greater understanding of the choice of item volume in stock.

I would particularly like to thank my supervisor, Henrique Gaspar. Without his supervision and continuous guidance this work has not been possible. Furthermore, my thanks go to my employer Ahlsell AS who provided me with information and answered all my questions and gave me the freedom one day a week last two months before submission of the task to finish it.

Finally, I would like to extend my grateful and thanks to my fiancée, my children and family for their patience and encouragement throughout the process of this Master Thesis.

Abstract

Problems of Inventory and lack of adaptability related to turbulent market needs is not unusual today, especially in the maritime industry, and is one of the biggest reasons to failures. SCM is a popular topic used by companies worldwide and can help businesses to meet these difficult issues to achieve success.

The aim of this master thesis is to investigate the benefit of the SCM and explore it further by a case study done by using a simulation program called Arena Simulation, where the main goal is to investigate a company`s inventory with upstream and downstream of order goods.

Stock out happens due to uncertain needs and demands, which cost extra money for the company and causes longer delivery time and unsatisfied customers. This is one of the reasons why developing a model to figure out how to build an inventory model of an item that will optimize the inventory level and minimize cost and stock out. Cost is not included in this paper.

To achieve this, a literature study is conducted, which resulted in the development of a framework and subsequently a model used in the study case. Based on how much literature is to be found on this topic, the findings of this study must be seen in light of some limitations, so there may be something very important literature missing.

The case study is for the wholesaler Ahlsell AS, with their main warehouse located in one of the busiest locations in Norway, nearby Norway`s biggest and main Airport, at Gardermoen. Over the years, they have managed to build up a good reputation among customers and suppliers, but like all other companies, they always want to make it even better. An evaluation of current SCM in Ahlsell will be investigated, looking for improvements. The company is currently facing some problems with batch size, target stock and reorder point based on their maritime customers, which will be mapped and investigated in this report. Customers Value Lost Percentage will be the main point of interest, since it is a major important for the company to maintain their good reputation.

The developed simulation model represents Ahlsell`s inventory of only one specific item, with orders from only one customer. The system begins from the customer order is received and ends up when the customer has received their purchased goods. After modelling the system it was found out that it was difficult to come up with a solution for the company based on many unpredictable factors who affect target stock, re-order point and batch size, as simplicity cannot be implemented with lack of real data from the company and lack of knowledge of the program. The developed model is set to be a basic tool for future work and enables the company to further develop and advance the model to a desired need. However, this requires dedication from the company to utilise the model. The thesis will present recommendations for future work to the company in order to minimize lost customers and stock out situations.

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Acronyms and Abbreviations

SCM	Supply Chain Management
SPF	Sales Process Flowchart
JIT	Just In Time
S&OP	Sales and Operations Planning
BE	Bullwhip Effect
FIFO	First In First Out
SH	Special Handling department
BPP	Basic Process Panel
APP	Advanced Process Panel
ATP	Advanced Transfer Panels
RNG	Random Number Generator
CSR	Corporate Social Responsibility

1 Introduction

This chapter presents background and motivation for choice of topic, followed by research environment, scope and last objectives.

1.1 Background

Norway is one of the biggest leading nations in the maritime industry with a strong position in the market worldwide. The Offshore Sector is extremely important for many local communities, especially for the county Møre & Romsdal since it is the biggest county within shipbuilding industry. Today's market is turbulent and dynamic which leads to higher demands from the companies. Customers' requirements may change unexpectedly and unpredictably fast, and they also are different and demands differently. This means that products and services vary, and the company needs to deal with customization, multiple product varieties and segmented markets.

In 2016 there was a slowdown in the global economy, which has had dramatic effect in the shipping industry worldwide (Isaksen 2001). Therefore, the market had to be more innovative to be more cost effective to adapt to difficult times. Today, those who survived the challenging years are much more positive for the future and stronger after implementing better business strategies, especially on automation, cost reduction, efficiency and logistics. For the Norwegian suppliers, the long-term efforts to develop a strong Norwegian based service and supply industry has been successful. (Viken 2019)

Many wholesalers have issues to keep up with their own and customer’s expectations. The main reasons are often their suppliers or manufactures. It may come from bad deals, lack of communication, low expectations or other factors. Bad deals with suppliers and manufactures make the competitors stronger. Another thing is warehouse stock, which is a problem for the wholesalers; over storage, low storage, lack of enough product options and lack of knowledge of their employees. All these reasons are often the cause of delayed delivery time, higher prices and freight charges. The last problem statement is planning by the customer. If they had planned it better, it would have made the job much better for a salesman.

Based on all these different requirements from the market, terms, conditions, and globalization, companies are pushed to make their internal processes more effective. It is no longer worth working alone, but with theirs partners, suppliers and customer to be effectively succeed. Therefore, companies should go into the depth of their logistics and look at the process between their suppliers and customers to make changes, if needed, based on them. Companies are usually parts of supply chains that connect the process steps such as acquiring raw materials, manufacturing, assembly and delivery to end customer. Whether a company succeeds in being competitive and creating good results does not only depend on its internal performance, but also on the performance of its collaborating partners. (Christopher 2005)

SCM can provide major source of competitive advantage in the current industry market and is the main theme in this master thesis. The basis for this thesis was to investigate Ahlsell`s supply chain management, focusing on their corporation with their suppliers and customers and their issues on correct inventory stock in the fluctuating industry market. Based on the huge various scale of products Ahlsell have in stock, the focus is on valves. Thus, the objective of this master thesis (described and provided in Chapter 1.5 The Objective) was to investigate these challenges and suggest improvements. The following targets were identified; (1) Investigate Ahlsell`s SCM, (2) Determine strengths and weaknesses in Ahlsell`s SCM, and (3) Propose further solutions.

1.2 Research environment

Ahlsell is the Nordic market-leading distributor of installation products within HVAC (Heating, Ventilation and Air Conditioning), Plumbing, Electrical, Tools, Supplies and Industry. They score high on their logistics, which is well known to customers. Since they do not produce items themselves, but has manufacturers who do it for them, it is important to have a close relationship with them so Ahlsell maintains the good logistics. Based on the globalizations, it forced the company to adapt their supply to get more effective ways to coordinate the flow of products into and out of the company.

Another factor that plays in is the delivery time, where the customer expects just-in-time (JIT) delivery. The delivery is carried out by Ahlsell itself rather than being picked up by the customer, which means that Ahlsell is controlling their complete central supply chain. With long production time, and not least long distances and shipping goods, delivery time can be quite challenging. The customers have very short production time, and expect short delivery time. This is no longer seen as a competitive advantage since they simply require a defect-free product fast and reliably than the competition. This is not easy to achieve when an item has more than six months delivery time from China.

An important product for Ahlsell, and especially in the maritime industry, are the valves. They are originally manufactured in Europe, but much of the production was eventually moved east from 1990 and beyond. The market has therefore characterized "cheap valves" from the east (China) and quality valves from Europe. In Europe, the production is mostly in Germany, Netherland, France, Spain and Italy. Turkey has also gradually become a major producer. The prices have increased in recent years in china, as well as eventually restrictions and environmental requirements; meaning that in the future it may be a challenge to be dependent on Chinese suppliers. As mentioned above, the Chinese valves have long delivery time, which is crucial when the customers have varying needs. In urgency, the valves can be transported with air flight, but that is expensive.

The summer 2018, Ahlsell replaced their Chinese valve manufacturer to a valve manufacturer in Spain. This was based on delivery time, quality and to reduce claims. The valves that replace the old ones are of better quality and have a considerably faster delivery time. By establishing close cooperation with a European supplier, they can maintain all environmental, sustainability and Code of Conduct requirements while maintaining the stringent requirements for quick delivery time from the customers. After

the slowdown in 2016, there have been a change in which boat types are being built at Norwegian yards. This also led to a larger product range, and in many cases also a greater depth on variants. With a closer supplier, they manage to deliver many more variants faster without building a larger store in Ahlsell to have it in stock.

However, they are more expensive. As well known, price is an important factor today. Will the customer pay more for better quality, or would they rather have the cheaper one but with longer delivery time? An important factor to take account is international regulations applicable laws and regulations such as quality, human rights, HSE (Health, Safety and Environment) and Code of Conduct. This is important for yards take into account, not only the supplier since ship-owners require it. Ahlsell do still use the Chinese manufacturer, where the plan is to gradually move more and more away from them and onto the new one. With this change, delivery time has drastically changed to the better.

After replacing the old producer with a new one, the company is currently facing some problems with batch size, target stock and reorder point based on their maritime customers, which will be mapped and investigated in this report. Customers Value Lost Percentage will be the main point of interest, since it is a major important for the company to maintain their good reputation.

A literature research and case study by analysing Ahlsell`s stakeholders, identify the situation and address the problems, may lead to better communication in the organization, connection between the producer and customers and better lead time.

1.3 Scope

The scope of the thesis is shown in Figure 1 below as the intersection between these subjects, where earth is illustrating the globalized market. An evaluation of current SCM in Ahlsell will be investigated, looking for improvements.

Figure 1 An illustration of globalized market

1.4 Objectives

Different stakeholder`s need to be considered to investigate Ahlsells` SCM. The stakeholders' need to be defined based on their different roles, needs, requirements, and expectations in each process. Current SCM in Ahlsell needs to be thoroughly mapped holistically. Following research questions (RQ) are proposed:

- **RQ 1:** How does Ahlsell organize the handling of customers demand and supplies to producer and sub suppliers?
- **RQ 2:** Where are the main weaknesses in Ahlsell`s SCM?
- **RQ 3:** Is the change of supplier the best choice, both for Ahlsell and the customer?
- **RQ 4:** How can Simulation Arena help to improve Ahlsell`s warehouse stock?
- **RQ 5:** What does it take for Ahlsell to become supplier of choice?

1.5 Structure

The thesis is organized as following. It starts with context, chapter 2, that describes the context for the area of study and address Ahlsell`s different stakeholder`s based on their different roles, requirements, needs and expectations in each process. Ahlsell`s Sales Process Flowchart will be presented as well, with detailed explanation of each step.

The theoretical background, chapter 3, will provide an overview of the literature on supply chain management and simulation methods to be able to answer the research questions. In the category *Supply Chain Management*, it will be focused on subcategories on demand, time delays, flexibility losses, delivery times and delivery time, operational dependencies, transaction costs and capital tied up. All these factors affect the operations to the company and their corporation partners. These subcategories are necessary to investigate to answer the research questions. In the category *Simulation Methods,* a brief presenting on how to do a simulation, definitions on modelling concepts and advantages and disadvantages of using the tools.

The software Arena will be used to resolve the research questions, so an instruction of the software program will be presented in chapter 4 with step-by-step of creating the case model.

In Chapter 5, further work on the case will be presented. A brief explanation of the stakeholders in the case will be presented before experimental design and analysis, and discussion of the result.

In chapter 6, discussion around the case results and how it relates to the findings in the literature review and the research questions, will be presented. Research questions will be answered as well.

The thesis finalizes with future work and opportunities.

2 Context

2.1 Stakeholders

2.1.1 User

The user, or the customer, are from yards, ship-owners and offshore worldwide. It is a broad composition of customers and projects which makes Ahlsell`s industrial department accustomed to work interdisciplinary. They purchase everything from toilet paper and coffee machines to valves and pipes in large quantum. Ahlsell´s biggest yard customers, are Ulstein Yard, Kleven Yard and Havyard Group. The market varies and the competition is big among the yards, but brighter times are waiting. The order books are now very up and down for the yards, and it is difficult times for them all, but they still have large orders, especially valves, upcoming. Based on a customer pricing agreement for agreed-upon price in a fixed period, the mentioned customer has most direct orders without inquiries.

It is a tough market with big competition among suppliers, and the user expect good price and short delivery time. Delays are expensive, so it is important for both Ahlsell and the yard to plan larger orders. In a perfect world, planning by customers of larger orders had been great for a salesman. With planning, it is much easier to deliver on time with the right prices and low cost. This is rarely done, where orders are often made in the last minute. Occasionally, they can be lucky that everything is in stock, but that is rare. Sometimes one has to take from other vendors, which makes it much more expensive for Ahlsell and the customer because of price differences, poor coverage and shipping. With lack of time, the customer often needs the order to reach the dry-docking in time.

2.1.2 Sales Management

In Ahlsell, there are 5700 workers and the industrial department consist of 23 sellers, with 12 sellers in Møre og Romsdal, located in Ulsteinvik, Ålesund and Kristiansund. These are sellers with broad experience in the market, and they offer the widest product range (electrical, plumbing and heating, road, water and drainage development, tools, protective equipment and industry). They are all strategic located near the biggest customers, and the biggest industry market is in Ulsteinvik where Ulstein Yard and Kleven Yard are located, among many others ship owners and offshore customers. Here, you have seven salesmen ready to support the customers.

2.1.3 Warehouse

Ahlsell is in seven countries, where Norway is the second biggest after Sweden. The rest is; Finland, Denmark, Estonia, Poland and Russia. In Norway, sellers and 210 stores are located all over the country as shown in figure 2 below. The Norwegian central

warehouse is strategically located at Gardermoen, with their 150,000m^2 warehouse and 220 employees. Here they have good road and flight connections and great expansion opportunities. The Warehouse is equivalent of five and a half football courts, and in total storage area is equivalent of 15 football courts.

They offer day and night delivery, express delivery, special handling department, pick up point and 24/7 service. Ahlsell Norway have two other warehouses, which is the regional warehouse in Bodø and the Swedish central warehouse at Hallsberg. The Hallsberg warehouse have a delivery time of four days to the Norwegian central warehouse. In total, there are 250,000 stocked items and they can offer one million products. Transit time at Gardermoen warehouse is four days.

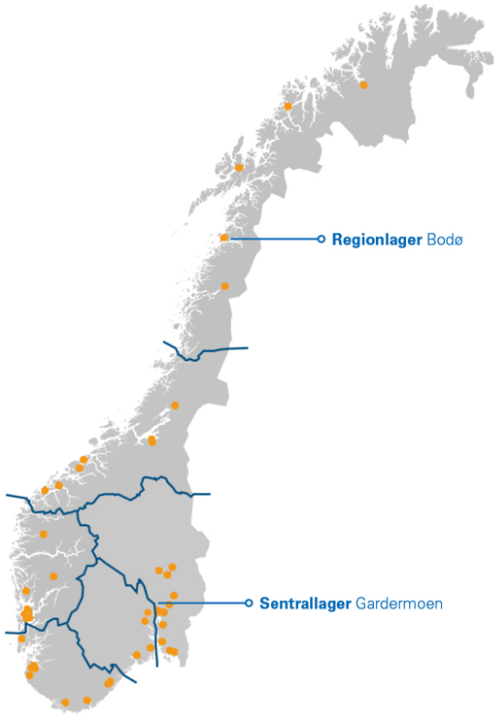


Figure 2 Central warehouse Gardermoen and regional warehouse Bodø in Norway

At Gardermoen, they have a special handling department (SH), often used by the industry market. Here they pick every order manually, on the basis that the order need the following services;

- Certificate handling of articles subject to certification
- Pressure testing of valves
- Assembly
- Export order management
- Packing and labelling of deliveries according to customers wishes.
- Own concept on effective construction site
- Cable cutting up to K26

The warehouse requires punctuality from the sellers to avoid extra work because of changes or faults. This is important, since extra work leads to extra costs and longer delivery times.

2.1.4 Manufacturers and Suppliers

As a wholesaler, they are very dependent on a large selection of suppliers and manufactures that can deliver. Ahlsell have many suppliers, and today they have around 6000 registered in their system.

Ahlsell score high on the logistics, which is well known to customers. Since Ahlsell does not produce goods themselves, but has manufacturers who do it for them, it is important that the connection between the two different companies work in the best possible way, so that Ahlsell maintains the good logistics.

Today, Ahlsell has problems with delivery of valves as it is difficult to predict the market. In the summer of 2018, Ahlsell switched valves that were manufactured in China, to valves from Spain. The Chinese manufacturer Shandong has been used for many years, but because of long delivery, among other reasons, they have been replaced by the Spanish manufacture Sigeval. Both are still in use, but Sigeval valves will take over more and more.

Sigeval was established in 1974 in Madrid, Spain, for production of butterfly valves. They have also a fabrication in Moscow and Russia. Sigeval trades products all over the world through distributors and agents, 85% abroad and 15% Spain, as shown in figure 3 below. Sales abroad is shown in figure 4.

Figure 3 Sigeval Sales(Trigales 2018)

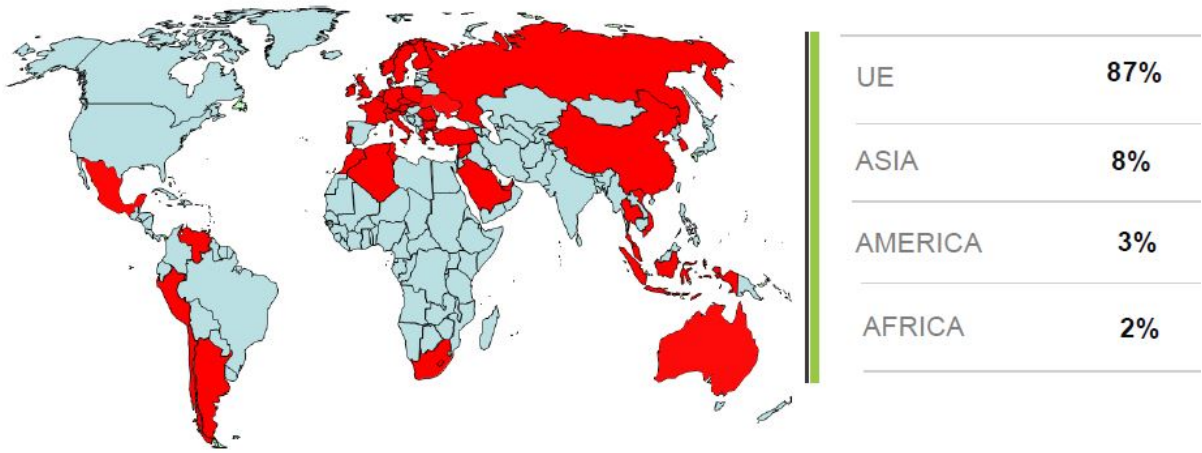


Figure 4 Sigeval Sales Abroad(Trigales 2018)

Shandong Huaan Machinery Co. was established 1999 in Qingdao, China. Very little information about the manufacturer has been found, but they produce the same valves as Sigeval.

2.1.5 Transportation

Transport is an important element in a sales process, where it is critical that the goods arrive in time, at right place and in good condition. Ahlsell have the country's best logistics when it comes to delivery. Mainly the order deadline is 16.00 PM with delivery the following day, often before 07.00 AM. In total, 100 containers are transported into and out of the warehouse every day, and around 36 000 tonnes of gods every year. With over 200 driving routes and 21 distribution terminals, they can largely deliver anywhere in the country. The three largest distribution terminals used, is; Schenker, Collicare and Nidaros.

2.2 Sales Process Flowchart

A Sales Process Flowchart (SPF) shows the different stages and possible actions for a sale of a product and is a good tool to train new employees. A representation of Ahlsell`s SPF, the process from the customer send their request to the shipment is sent, is shown in figure 5 below with a further detailed explanation of each step A, B, and C.

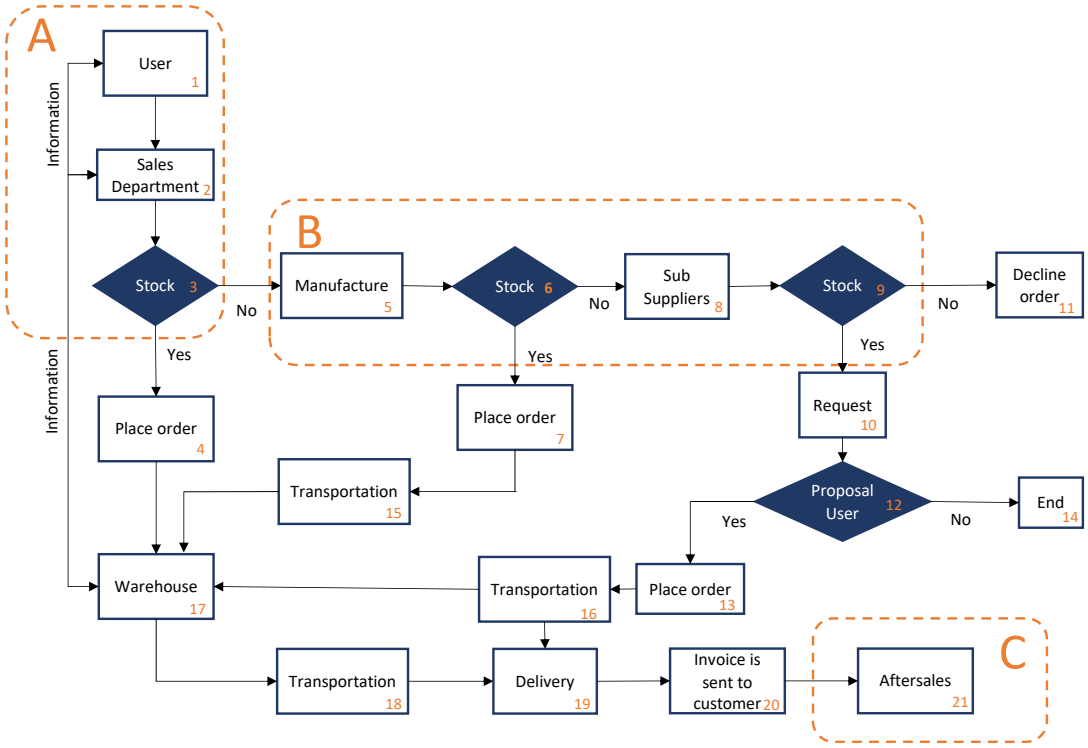


Figure 5 Sales Process phase

When the customer (1) send their purchase order through email or phone to the sales department (2), the salesman need to ensure if they have enough and correct information from the supplier of what they really want before proceeding the process. A good information flow between the user and the sales department, is important to avoid misunderstanding. If they have what they need of information, the salesman always checks the stock (3) first. The order is placed if there is enough in stock, if not the salesman has to take contact with the manufacture (5). If the supplier has in stock or can produce in short time (6), the order will be placed (7). If not, the salesman must contact alternative suppliers. In this case, it will be an alternative product and price and delivery time can vary. If they have an alternative in stock (9), price and delivery time (10) will be asked. When this is received, a proposal will be sent to the user (1). If the proposal is approved, an order will be placed (13) with the alternative supplier, if not, the order from the user will be declined and the process ends (14). If the salesman is not able to find alternative product from suppliers, the order from the user will be declined (11). Sometimes if the delivery time is long and the purchase order from the user is urgent, a local alternative with short delivery time will be used, independent of price (8). Transportation is important based on delivery time, so the customer receives their items as expected. Transportation from the manufacture (15) will be sent to the warehouse (17) first because of the freight charges. Transportation from the supplier (16) is often sent to the warehouse, to add labels, documentations or if it should be mounted with another product. If it is urgent, or it is a simple purchase order, without any specific additions, the supplier will send direct to the customer, so point 16 and 17 will be eliminated. Often, if the supplier is local, this is a better way to do it.

The warehouse (17) have a special handling department, where everything is picked manually. They do everything that needs to be done by hand, as assembly, labels, etc. This department is especially used for the yards and offshore customers, since almost everything needs to have labels, certifications or a commercial invoice for ships sailing abroad. When the order is picked and ready for shipment, the transportation to the customer (18) is the next step. This only takes one day within Norway. When the order is delivered and all invoices from the suppliers are received, the invoice is ready to be sent out to the customer (20). The last and most important step is aftersales (21).

There are three dotted boxes, A, B and C in the figure as well. These boxes are the most critical areas in sales process and must consider where an evaluation will be done. After evaluation, a detailed research based on SCM methods will be carried out to find opportunities for improvement.

A

Box A, shown in figure 6 below, is a more detailed explanation of how the customer sends their request to the sales department. Based on short delivery time and high flexibility of products, a wholesaler needs inside information about future demands to plan inventory. The customer also has needs for inside information of available stock for planning and in case of short reaction time. More information, besides forecasts and demand history, leads to more efficiency and reduced costs for both parts. If the item is in stock, delivery time is often delivered one to two days after, and the customer is very satisfied.

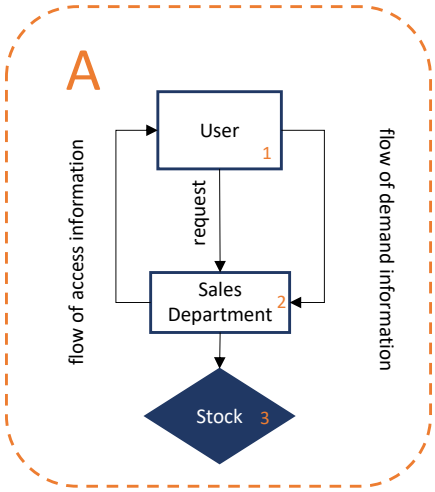


Figure 6 Step A in the Sales Process

B

Box B, shown in figure 7 below, has much of the same dialog as step A, which is explained above. This information is just as important as information flow in step A and have the same benefits; leads to more efficiency and reduced costs for both parts. If flow of information between customer and wholesaler had been excellent, step B had been

much less of. This step is often very time consuming for the sales department which goes beyond the customer response time. If the manufacturer do not have it, the salesman need to go to other sub suppliers, which is even more time consuming, more expensive for the customer, less profit for the company but it may have shorter delivery time since the sub suppliers often is located nearby in Norway. Worst case scenario is that no sub suppliers have any replacement, and that the seller must reject the customer's request. This is a defeat for a salesman and can have costly consequences for the company in the long run if this happens several times. Customers do not appreciate being rejected too many times, and then often the process begins that they start asking and using other competitors.

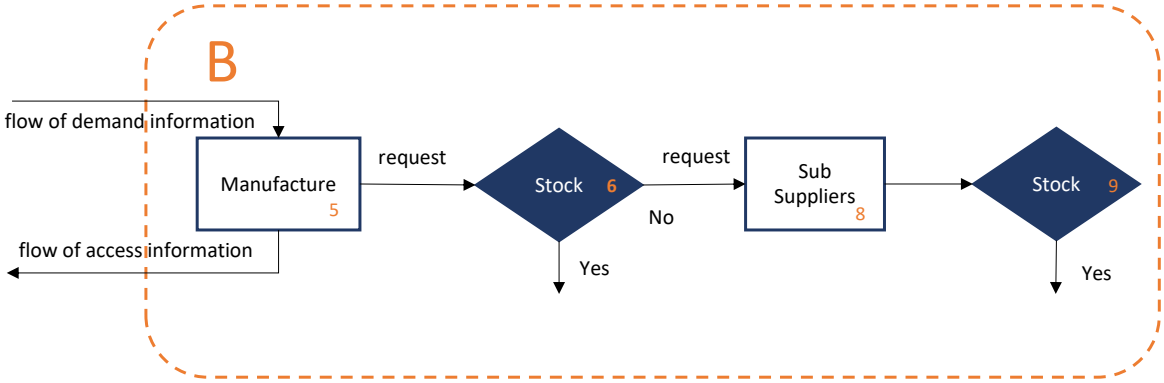


Figure 7 Step B in the Sales Process

C

The mistake some companies makes is that they forget box C, shown in figure 8 below, where the order is closing and followed up. This is where the company establish the long relationship to the customer, creating brand value and maybe already place a new order (more sales). The salesman has a great opportunity to get information of demand, which is mentioned in step A and B above. Aftersales can be done differently, but basically, these steps below are suitable for the wholesaler Ahlsell;

- Service or product fulfilment
- Be thankful
- More sales
- Keep the communication open

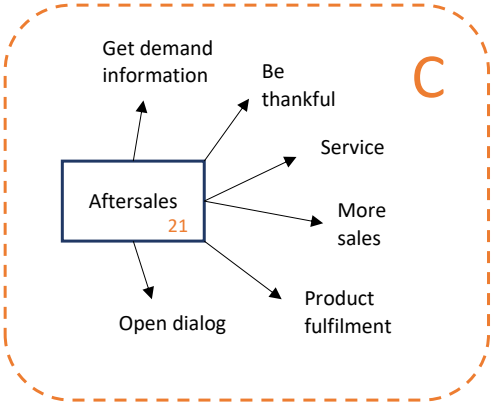


Figure 8 Step C in the Sales Process

3 Literature Review

3.1 Supply Chain Management

SCM is a popular topic for authors and organizations in every sector and industry and is a high priority on their agenda. Based on its popularity, it is important to introduce more than one definition, since writers approaches the phenomenon from different points of view. To understand the dynamic in SCM it is important to first address the definition of *logistics* and *supply chain* since it builds up the framework for SCM.

"Logistics are the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders". (Christopher 2005)

By this it is meant that the logistics of a business are various drives that must go through a complex process in a flawless and efficient way. Information- and material flow are therefore crucial to achieve success. Today`s globalized market requires more flexible chains that response quickly and are no longer simple and short. Customers' expectations are daily increasing and supply chain is constantly evolving and becoming more and more advanced. Supply chain was defined in 1970`s as; "a logistic pipeline encompassing all suppliers to customer material flow activities that add value to the final product" (Coyle 1992). (Mattsson 2002) defines supply chain like;

"By a supply chain is meant a sequence of actors through which materials, information and payments flow. It aims to create and deliver value in the form of products and services and it starts with raw material suppliers and ends with consuming end customers."

In figure 9 below, shows an illustration on how a supply chain can look like.

Figure 9 A principal supply chain (Mattsson 2002)

Global competition forces managers in every company to make more and more attention on supply chain in their businesses and meet customers' requirements to be cheaper, better and faster. In other words, they recognise the necessity to have the focus on the relationship across external companies, which has an impact on enhancing SCM performance. The businesses who have implemented this has driven tremendous benefits. "In today`s marketplace the order-winning criteria are more likely to be

service-based than product-based" (Christopher 2005). Only option to meet the global increasing requirements, is to adopt a wider supply chain.

As the Professor Christopher (Christopher 2005) writes in his book that supply chains are, in reality, networks.

"These networks are complex webs of independent – but interdependent – organizations. As a result of increased out-sourcing of tasks that were once performed in-house, the complexity of these webs has grown and, hence, with it the need for active co-ordination of the network" (Christopher 2005).

A good network is something the company need to invest in the long-term where every stakeholder work together in a way that processes are integrated and managed smoothly, and not stand-alone-attitude. By this it is meant that good relationship between all parties in the chain will be profitable for them all, a win-win situation. An illustration is shown in figure 10 below of a network between a company in centre of customers and suppliers. To achieve higher performance of the supply chain, it is important that companies work through or around these links in order to achieve desired goal.

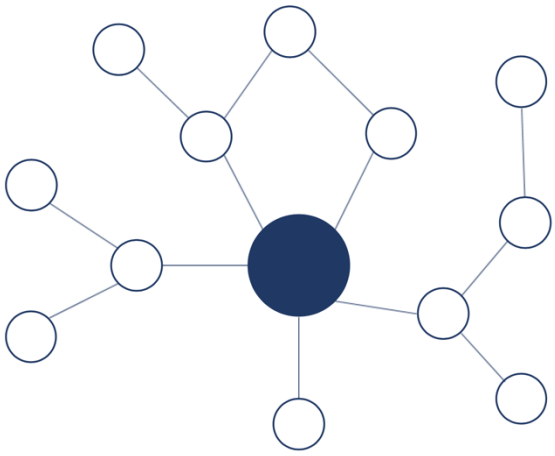


Figure 10 The supply chain network (Christopher 2005)

The words upstream and downstream will be mentioned a couple of times in this thesis and are therefore necessary to describe. Upstream is material or product inputs from manufacturers and sub suppliers to the main warehouse and downstream is finished product out to the customers. (Christopher 2005) defines it like;

"The supply chain is the network of organizations that are involved through upstream and downstream linkages, in det different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer"

It is said that the purpose of supply chain is to get products and services where they are needed when they are desired (De Souza 2009). Formally, supply chain is to help the customer to create value at the lowest total cost. To achieve this, all stakeholders in the supply chain needs to synergize their activities and resources towards

accomplishing common supply chain goals, which aims to benefit all and not just a few among in the chain (Solvang 2001).

When it comes to supply chain management, it is a wide concept and it becomes more comprehensive. Two definitions will be presented below;

"Supply chain management is the integration of key business processes from end user through original suppliers that provides products, service, and information that add value for customers and other stakeholders." (Douglas M. Lambert 1998)

"By supply chain management is meant planning, development, coordination, organization, control and control of intra- and interorganizational processes from a holistic perspective and regarding flows of materials, services, information and payments in supply chains from the original raw material supplier to the final consumer. It stands for collaboration and integration between companies and its focus is the end consumer." (Mattsson 2002)

(Lambert 2014) concludes in his book that "since a supply chain is a network of companies, then the management of that network is supply chain management". He further concluded that "at the end of the day, supply chain management is about relationship management. A supply chain is managed, link-by-link, relationship-by-relationship, and the organizations that manage these relationships best will win."

(Mattsson 2002) have included different aspects in his definition, such as; (1) that the entire supply chain from original raw material produced to final consumer is considered, (2) that the supply chain is considered not only from within an individual company but also from a holistic perspective, (3) that collaboration and integration efforts between the companies in the chain are emphasized, and (4) that flows of services are also taken into account.

There are many different factors who affects the operations to the company and corporation partners in the supply chain. Similarly, the company's own actions impact the operation of other companies downstream and upstream supply chains. This is basically because of the increasing market (Mattsson 2002). Some of these factors will be presented further now, since they are important for this thesis.

3.1.1 Turbulence in market demand

As mentioned a couple of times earlier, demand is very varied from the increasing globalized market. The new world of global SCM is opening up new opportunities for the organizations, and if they apply fresh thinking and planning ahead with due care and attention they may gain market share (Tribe 2016).

When the economy in the turbulent environment will turn around, no one can accurately predict. What is certain is that when the dust settles, there will be winners and losers, and those companies that can effectively manage demand in supply chain will be in a better position (Gaeta and Stefanis 2009). (Gaeta and Stefanis 2009) writes further that operational planning and scenario-based supply chain evaluation is more important

than ever. Organizations in the whole supply chain are having difficult times financially, and they must tackle shutting down facilities and headcount reductions. This is something that happens occasionally, but often with an accurate controlled SCM and great network across the supply chain they may be able to rise again and will be better positioned to grow.

Market Signals are defined by (Porter 1998) as; market signals are indirect means of communicating in the marketplace, and most if not all of a competitor`s behaviour can carry information that can aid in competitor analysis and strategy formulation. Reading and understanding the market is of great importance and competitive advantage, which leads to future effective competitive move.

Turbulent conditions push managers in the company to seek for methods to reduce cost and increase sale, and the company has realized that this must be done, among other things, through good collaboration across the organization. Sales and operations planning (S&OP) is a planning process tool used of many organizations which involves multiple departments. A definition is shown below.

«Sales and operations planning (S&OP) is a process for better matching a manufacturer`s supply with demand by having the sales department collaborate with operations to create a single production plan. The broader goal is to align daily operations with corporate strategy.» (Rouse 2018)

This planning process gives companies several benefits, such as visibility of the demand and supply across the enterprise, increased promotional planning, increased accuracy in budget forecasting, and an improved product lifecycle management (Murray 2019). All in all, S&OP will be very profitable for the company to implement in their business to improve their SCM with increased customer satisfaction and higher sales. S&OP has seven steps (Step may vary from company to company) that the organization performs in monthly meetings (Rouse 2018);

1. **Data gathering:** gather important information, such as inventory, recent sales and budget;
2. **Demand planning:** analyse processes, predict, influence and demand, and including demand feeling and demand shaping;
3. **Production (in this case supply) planning:** production assessment and capacity of distribution and constraints;
4. **Reconciliation:** aligning demand and production plans, ensuring that they meet financial requirements and company objectives and preparing recommendations; and
5. **Executive meeting:** review the plan and approve a final version.

Tremendous inefficiencies happen by distorted information from one end of a supply chain to the other, which leads to excessive inventory investment, poor customer service, lost revenues, missed capacity plans, ineffective transportation, and missed production schedules. The bullwhip effect (BE) is a method used by many organizations to figure out how exaggerated order swings occur and how they can mitigate them (Lee, Padmanabhan et al. 1997). A definition of BE is shown below:

"The Bullwhip effect is short-hand term for a dynamical phenomenon in supply chains. It refers to the tendency of the variability of order rates to increase as they pass through the echelons of a supply chain towards producers and raw material suppliers." (Disney and Lambrecht 2008)

(Lee, Padmanabhan et al. 1997) have identified four major causes of the BE; demand forecast, order batching, price fluctuation and rationing and shortage gaming. They further claim that result of optimized behaviours from the players in the supply chain leads to arise demand distortion and mitigate the bullwhip effect. A solution is to exchange inventory status information and sales data. A small disturbance in one part of the chain can very quickly escalate and become a magnified problem further through the pipeline.

An example of an BE is shown in figure 11 below, which shows amplification of on request variety in a supply chain.

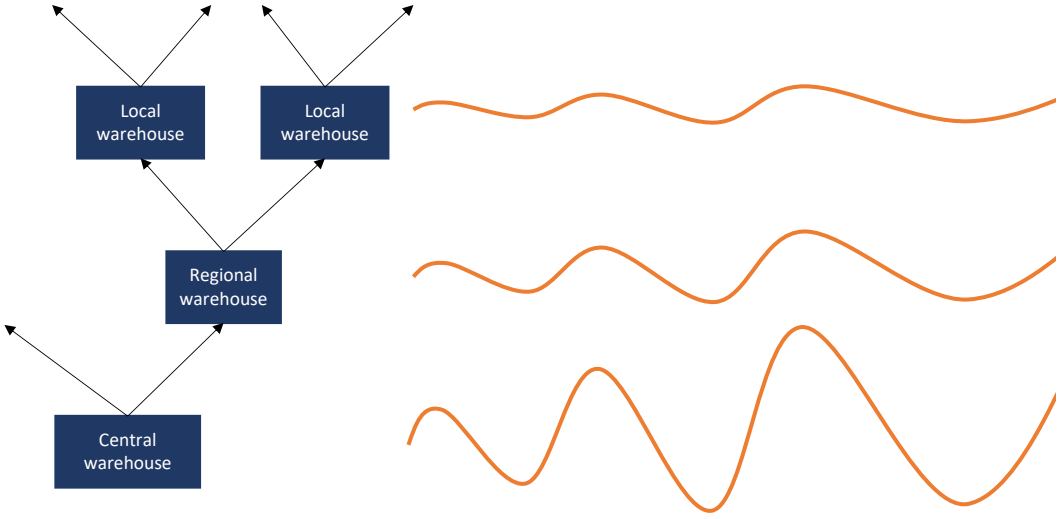


Figure 11 An example of Bullwhip Effect in Supply Chain (Mattsson 2002)

JIT method is a pull concept based upon the simple idea that wherever possible, no activity should take place in a system until there is a need for it. In other words, no item is ordered, or product is made before requirements from downstream is placed. This is widely used, where companies are very dependent upon suppliers. Push concept is buffers in company, where the warehouse is filled up and products are finished assembled or manufactured in batches. Pull concept is today highly recommended, but to be able to achieve success, it requires the highest level of flexibility of all the supply chain`s resources, including people. (Christopher 2005)

3.1.2 Flexibility losses

As competition is getting constantly intensified, companies are compelling to deliver customized products with more features, higher quality, lower price, in faster time, to satisfy the need of the market (Solvang 2001).

"By flexibility, we generally mean a company's ability to adapt in the short term and with limited resources to adapt to changing conditions. The clarification that adaptation can be done quickly and with limited resources is important here." (Mattsson 2002)

The meaning of the definition above is that the company can not only focus on delivering the stability of good products, but be ready to adapt to the needs of the customer when it comes to what they can deliver, how and when. The following main types of flexibility can be distinguished (Mattsson 2002):

- **Product flexibility:** ability to develop and adapt products to market needs
- **Product mix flexibility:** ability to make changes to the product mix in production
- **Volume flexibility:** ability to produce and deliver in step with demand changes
- **Delivery flexibility:** ability to change delivery times and quantities within the delivery time

Companies should focus on the four points mentioned above to achieve high flexibility for their customers. They should have more focus on achieving a high degree of flexibility with their sub suppliers and/or their manufacturers than with their customers, as it will achieve a greater profit for all partners. The customer will benefit greatly from this, as they will get more punctuality on faster delivery of greater product flexibility in higher volume.

This is not easy to achieve, as it is not their own supply chain that need improvement, but someone else's. As suppliers are very globalized by the price pressure of the market, and it is not profitable to expand its own warehouse to meet all requirements, this has led suppliers to use cheaper sub suppliers and manufacturers, often situated in China. This does not make it easier to achieve flexibility, as the distance is larger. Longer delivery time, but also longer reaction time. Therefore, to expand their supply chain flexibility, suppliers relies on a good relationship with their sub suppliers and manufacturers. To achieve a high scale of supply chain flexibility is a tough nut to crack in today's rough market.

3.1.3 Delivery times

Based on what was discussed about distance of sub suppliers and manufacturers in flexible losses above; longer distances causes longer delivery times. With a longer supply chain and a higher rate of change, the more conditions for achieving efficient material flows are affected. The way information is exchanged between the customer and the supplier, relates to the effect. Today, a company and their suppliers communicate through purchasing order. This way of doing upstream supply chain, is time consuming and gnarly (Mattsson 2002). Misunderstanding may occur and can cause to incorrect information and actual needs, which may lead to longer delivery time, incorrect product and products number.

As (Mattsson 2002) writes in his book; delivery time is effected by value in supplier-level, even if the suppliers have items in stock. The more suppliers are involved in the value adding in the supply chain to produce a product, the more uncertainties are added. Risk of disruptions increases, causing lower ability to deliver in accordance with the customers agreement. Higher variation in the supply chain, with more sub suppliers, creates degraded precision in the delivery time. Material flow activities, such as production, quality control, stock refilling, stocking and picking from warehouse, plays an important role in SCM and on delivery time.

3.1.4 Capital tied up

The global market is driving prices as low as they have ever been. Companies need to figure out a way to reduce inventory to meet the downward pressure on price to be profitable. SCM affects possibilities of reducing tied capital in stocks, and this effect applies to both turnover stocks and various forms of security stock (Mattsson 2002). (Mattsson 2002) writes further that there are information gaps between customer and supplier. This means that the customer have information that the supplier does not have, and the opposite. Based on this, safety stock increases both on suppliers' warehouse and the sub suppliers based on missing information of needs in nearly future. Uncertainty stock because of the information gap is illustrated in figure 12 below.

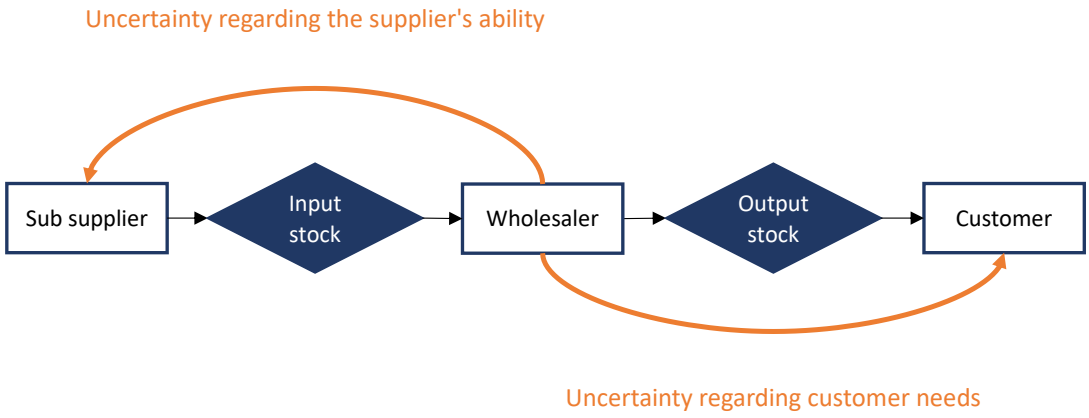


Figure 12 Information gap and uncertainty stock (Mattsson 2002)

Among other reasons mentioned earlier, it is not easy to use sub-suppliers based on long distances. Therefore, companies are nearly forced to increase their warehouses. This causes more safety stock and capital tied up.

Price and image are important, especially in industry market, but more important is availability. Out-of-stock has a bigger impact than many companies knows, and the potential loss of business for both manufacturer and suppliers is clearly significant (Christopher 2005). This means that customers must go to the competitor, if they need it now, which opens the door for competitors to be able to show their potential. If this happens several times or over a period of time, it can have costly consequences.

The fact that customers come and go is not abnormal in an industry and is difficult to avoid. Especially when it comes to smaller customers, as one often focuses on the larger ones. Sales team in the companies should annually review their customers and map the ones you have and those you have lost. "How many of the customers that we had 12 months ago, do we have today?". This is called measure of customer retention. (Christopher 2005)

3.1.5 Transaction costs

Transaction cost is important and controls a lot in the supply chain. This thesis will only mentioned it briefly cause it is not focused on.

Transaction costs are the costs of carrying out any exchange, and arise wherever there is any form of economic organization, like between firms in the market or a transfer of resources between stages in a vertically integrated firm. (Hobbs 1996)

3.1.6 Competitive advantage

Products does not sell themselves, and an effective SCM can open major source of competitive advantage, where the company can differentiate itself from their competitors. Brand and technology have declined, where customer service has increased of importance. Competitive advantage can be divided into cost advantage and value advantage. Companies who have succeeded either have a cost advantage, value advantage, or a combination of both. Cost advantage gives a lower cost profile and the value advantage gives the product or offering a differential 'plus' over competitive offerings. Cost advantage have a high sales volume to be low-cost producer and they may also have an incredible SCM based on fundamentally re-engineering logistics processes. Value advantage gives the customer benefit; the product is purchased, not for itself, but for the promise of what it will deliver. This may outperform its rivals by deliver service, after-sales service, financial packages and technical support besides, which is developing relationships with customers through provision of an augmented offer. Value differentiation gives a powerful defensible advantage in the market, where the company need to figure out what they do well. Different customers have different needs, and different views on what is important to them. With this, there will be many opportunities for companies to differentiate themselves an focus on specific segments. (Christopher 2005)

3.1.7 Key customers and suppliers

"People do not buy products, they buy benefits" (Levitt 1962)

Today, customers want to reduce the number of suppliers and create good relationships with the selected ones over longer periods. Then it is important that companies are awake and work strategically to become one of them. It then needs innovative ways to create new and even more value for key customers. One options is to invest in a more flexible supply chain. (Christopher 2005) suggest developing an

understanding of the service needs of customers through detailed research, which is summarized below;

1. Identify the key components of customer service
2. Establishing the relative importance of customer services components
3. Identify customer service segments

Customers today are more value conscious and expect good service. Below shows`4Rs, which represent good customer service (Christopher 2005):

1. **R**esponsiveness: meet the precise needs of customer in less time than ever before;
2. **R**eliability: meet customers delivery promise and supply chain visibility;
3. **R**esilience: ability of the supply chain to cope with unexpected disturbances; and
4. **R**elationships: collaboration across the supply chain.

An illustration on the core product is shown in figure 13 below, which is the basic product delivered to the customer. Outside the core product shows some of the added value that customer service and logistics provide. This shows that it takes more than branding to differentiate the product. (Christopher 2005)

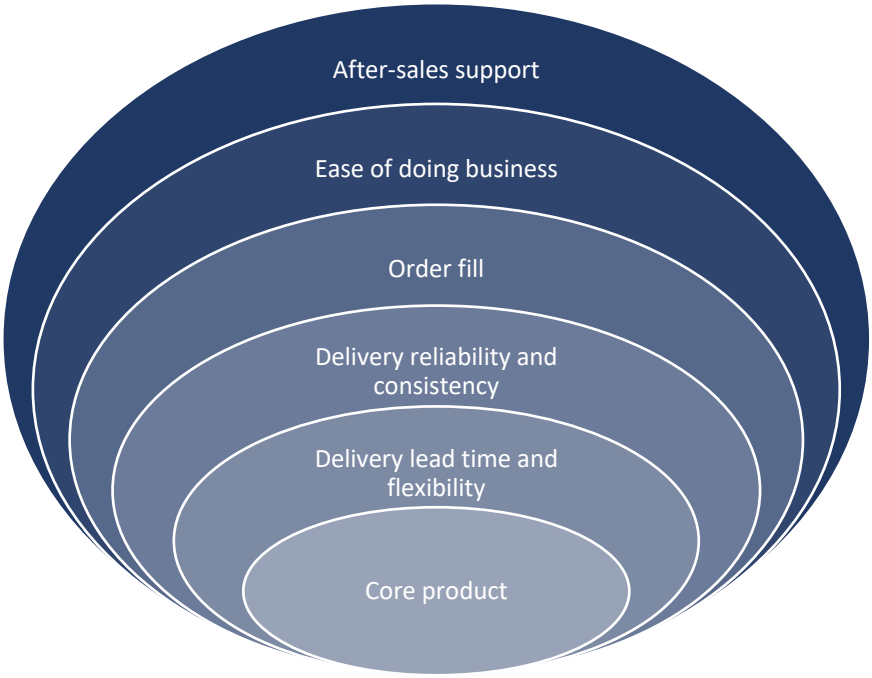


Figure 13 Using service to augment the core product (Christopher 2005)

In order to achieve success, a company is extremely dependent on their sub suppliers because of today's market requirements of customized products and volume, as mentioned a few times earlier in this report. It is therefore important to choose carefully and be critical. (Stević 2017) concludes that financial parameters, quality and delivery are the main criteria when evaluating sub suppliers, where smaller set criteria are as following;

- Communication system
- Reliability
- Flexibility
- Logistics capacity
- Reputation
- Speed of response to requirements

There are different points who need be to identified: the supply chain members, with whom it is critical to link; the processes that need to be linked with each of these key members; and, the type/level of integration that applies to each process link (Lambert 2014). Consequently, the company should invest in process integration and re-engineering initiatives to boost the total process efficiency and effectiveness across members of the supply chain (Lambert 2014). A summary of the main goals of supply chain management will be mentioned below;

- Eliminate the buffers of inventory
- Sharing information between stakeholders
- Lower costs and a faster production cycle
- Satisfy customer ever-changing requirements
- Strengthen the core supply chain against potential disruptions.
- most value in the supply chain network, not simply for the company.
- Reduced lead times
- Value-added services

3.2 Simulation Methods

"Simulation is the use of a numerical model to study the behavior of a system as it operates over time." (Kiviat 1967)

"When developing a simulation model, the modeler attempts to represent the system in such a way that the representation assumes or mimics the pertinent outwear qualities of the system. This representation is called a simulation model." (Rossetti 2015)

When a business wants to improve its supply chain, it is important to understand what the chain`s current performance is since it is a complexed system consisting different facilities, people and equipment (Lambert 2014). A simulation is a representation of a real system and how it will operate and act, by a simulation model. With this, it can be used to understand and improve the system`s performance. In general, simulations can take on many forms (Rossetti 2015). Simulation modeling has been applied to estimate performance metrics, to answer "what if" questions (Altiok and Melamed 2007). The biggest advantage of simulation modeling is that it has the capability of modeling the entire system and its complex interrelationships and imitates the behavior of the real system. Here, all the important interactions among the different stakeholders of the supply chain can be accounted for within the model (Rossetti 2015).

3.2.1 Definitions on Modelling Concepts

Following modelling concepts will be presented definitions below for better understanding before the next chapter;

System: is a set of interrelated components working together toward a common objective. (Blanchard 1990)

Variables: are user-defined data storage objects to store and modify state information at run initializations. (Altiok and Melamed 2007)

Resource: is objects that represent facilities, such as humans. (Altiok and Melamed 2007)

Expression: is specialized variables that store the value of an associated formula. (Altiok and Melamed 2007)

Seize: seizing by a transaction a service facility.(Altiok and Melamed 2007)

Release: make a resource or a facility available for other transactions. (Altiok and Melamed 2007)

Delay: put the entity off or postpone in a specified time. (Altiok and Melamed 2007)

Sets (System State): it changes entities states.

Model: is the enterprise of devising a simplified representation of a complex system with the goal of providing predictions of the system`s performance measures (metrics) of interest. (Altiok and Melamed 2007)

Entities: elements of the system being simulated and can be individually identified and processed. (Pidd 1988)

Attributes: Attributes are useful for a variety of purpose, where each entity may possess one or more attributes which convey extra information about the entity. (Pidd 1988)

Batch: collect a quantity of entities before proceeding the process. (Rockwell Automation 2010)

3.2.2 Types of simulation models

Simulation models can be classified in different types, shown in figure 14 below, as;

- *Stochastic versus Deterministic:* If the component in the system is random behavior, it is stochastic, and deterministic if not.
- *Static versus Dynamic: If the component does not change significantly with respect of time, it is static, and dynamic if it does.*

- *Continuous versus Discrete: If the system is dynamic and change continuously with time, it is continuous. The system is discrete if serves our purposes and changes occur only at separate points.*

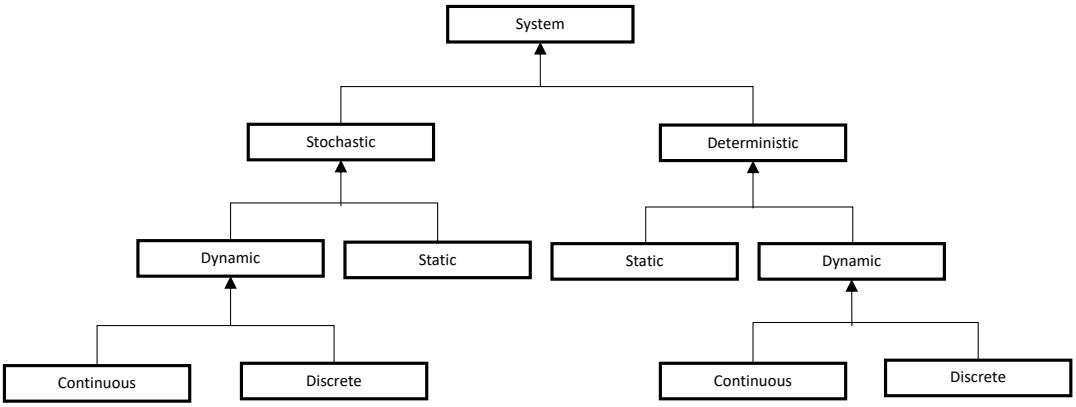


Figure 14 General type of systems (Rossetti 2015)

3.2.3 Advantages and Disadvantages

Simulation has the following advantages and disadvantages (Pidd 1988);

- *Cost:* Real experiments is much more time consuming and expensive in terms of skilled manpower, than through simulation - especially if something goes wrong. The simulation result may lead to no solution, which will be waste of money.
- *Time:* Big simulation models take a significant amount of time to produce, but it saves time. The possibility to simulate weeks, months or even years ahead is invaluable time saving.
- *Replication:* Simulations are precisely repeatable. Unfortunately, the real world is rarely kind enough to allow precise replication of an experiment.
- *Safety:* Simulation does no harm and is therefore very safe. Extreme conditions can be one of the goals of a simulation to study in an organization or situation and doing so in real life can be dangerous or even illegal.

3.3 A General methodology for solving problems

A general methodology, also called DEGREE methodology, will be presented in detail in table 1, and shown in figure 15. (Rossetti 2015)

STEP		DESCRIPTION
1	**D**efine the problem.	Formulate the problem and be sure it is correctly before starting. Five steps are recommended; (1) Define the problem; (2) Define the system; (3) Establish performance metrics; (4) Build conceptual model; and (5) Document model assumptions.
2	**E**stablish measures of performance for evaluation.	Be ensured to solve the problem for the right reason. When building models, you are either explicitly or implicitly developing certain design alternatives. Four steps are recommended; (1) Model translation; (2) Input data modeling; (3) Verification; and (4) Validation.
3	**G**enerate alternative solutions.	The correct solution is provided with help with these phases, where there can be more than one solution to the problem. These phases are experimental design and analysis, where these three steps are recommended; (1) Preliminary runs; (2) Final experiments; and (3) Analysis of results.
4	**R**ank alternative solutions.	
5	**E**valuate and iterate during process.	Analyze how the process is proceeding and allows for iteration, which recognize that the problem-solving process can be repeated until the desired degree of modeling fidelity has been achieved. It is important to start at a small level, and gradually build them up until desired goal. Go back and forth to ensure the model is representing reality. The fifth phase is evaluating and iterate, where these three steps are recommended; (1) Documentation; (2) Model manual; and (3) User manual.
6	**E**xecute and evaluate the solution.	This step is often overlooked, where simulation is often used to recommend a solution to a problem. Try to execute the solution by implementing the decisions. Finally, you should always follow up to ensure that the projected benefits of the solution were obtained.

Table 1 The DEGREE methodology for solving problems (Rossetti 2015)

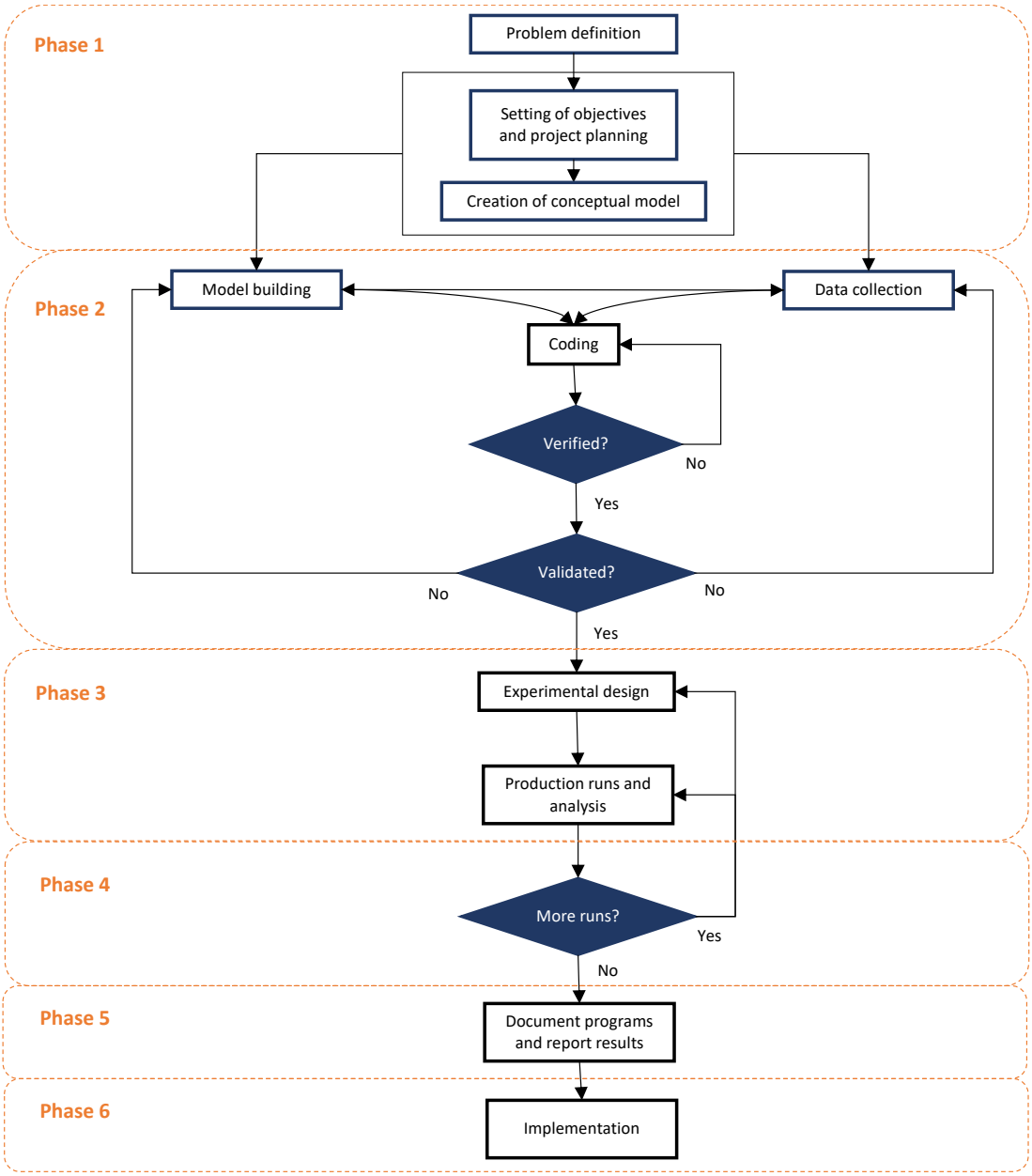


Figure 15 General simulation methodology (Rossetti 2015)

4 Methodology: Simulation with Arena

4.1 Arena Modelling

Arena software makes it possible to simulate almost any business strategy through computer simulation models that facilitate the development and implementation of the future. The program makes it possible to analyse the impact of changes in various processes, especially in SCM. With drag and drop flowchart methodology (SIMAN), the possibility is sky high to create complex models in the smallest details.

Arena software is selected for this research based on its customized templates to define user and systems and the availability of student versions of the software. A brief and simple explanation of the software program is that it is a template where modules (processes or logic) in different shapes, sizes and with specific actions are placed, connected with lines (flows of entities) to represent real-life objects. After simulation, a report with results hopefully will give an indication of how the system works and the opportunities that lie there. In short, arena software can answer the questions "What if..?" and "Is it possible to..?". Furthermore, a simple explanation of how to model in Arena will be presented so that is readable for beginners at Arena Simulation.

When Arena is started, a new model window will be open. Here, the modelling is divided into three main area; **Project Bar**, **Spreadsheet view** and **Flowchart view** as shown below in figure 16.

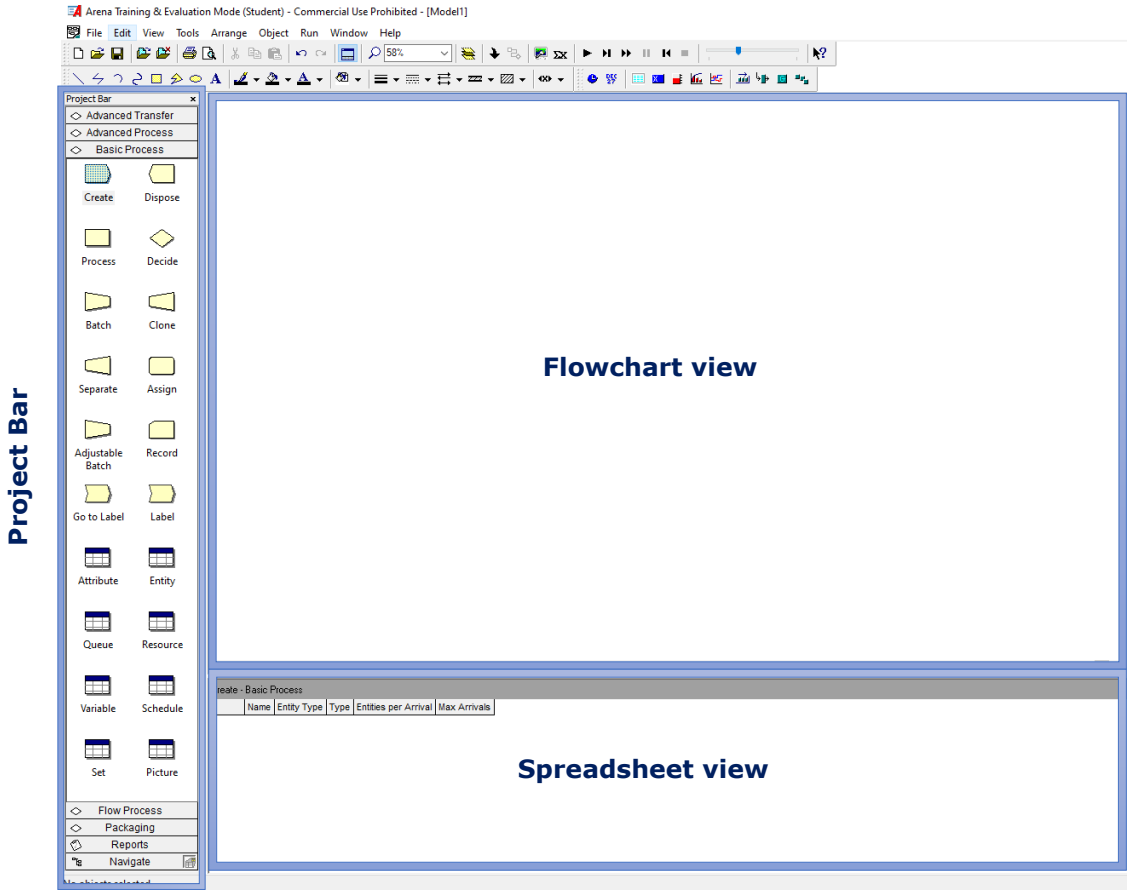


Figure 16 Arena Simulation window

The project bar shows different panels, such as objects used to create the model. Following is a brief explanation of the different panels.

- *Basic Process Panel* (BPP), *Advanced Process Panel* (APP) and *Advanced Transfer Panels* (ATP): Different levels of modelling of shapes by modules to make the process of the system.
- *Reports panel*: Reports of result of simulation runs.
- *Navigate panel*: Hierarchical sub models also shows different perspective of created model.

The objects, flowchart modules, are dragged from the panel into the Flowchart. Flowchart view is where the model is created, where animation and process flowchart are shown as well. Data is shown in the flowchart view, as costs, time and amounts. In this report, only BPP will be used except one flowchart module and data module from APP with a brief explanation.

4.2 Case modelling

4.2.1 Flowchart modules

Before modeling the system, it is important to define the problem, which was done earlier in this report. The basis for this thesis was to investigate Ahlsell`s supply chain management, focusing on their corporation with their suppliers and customers and their issues on correct inventory stock in the fluctuating industry market. Based on the huge various scale of products Ahlsell have in stock, the focus is on valves. The system is based on the figure 5, Ahlsell`s SPF.

When modeling the system, it is requisite to explain choices that have been made along the way to make sure it is solving the problem for the right reason, which is establishing measures of performance for evaluation. This step will be executed beneath while modeling the case.

When mapping the system to be drawn, the flow will be of great importance; The flow of entities through the system. In this case, the entity who flows through the system, is order/valve. Before model the flowchart, it can be helpful to see the system in the entities perspective and go through questions like;

- Where does it enter the system?
- What happens in each step of the system?
- What do they need (resources) to do the work?

Further in this chapter, modelling of the system will take place. Each flowchart module will be explained in detail and their additional functionality in the simulation. Create modul is first up since it is the beginning of the system where the entity enters. As shown in figure 17 below, the system is in two different processes; **Customer Demand** and **Supply from Producer**. Customer Demand will be detailed explained before a briefer explanation for the Supply from Producer will be presented since almost every module is already explained well.

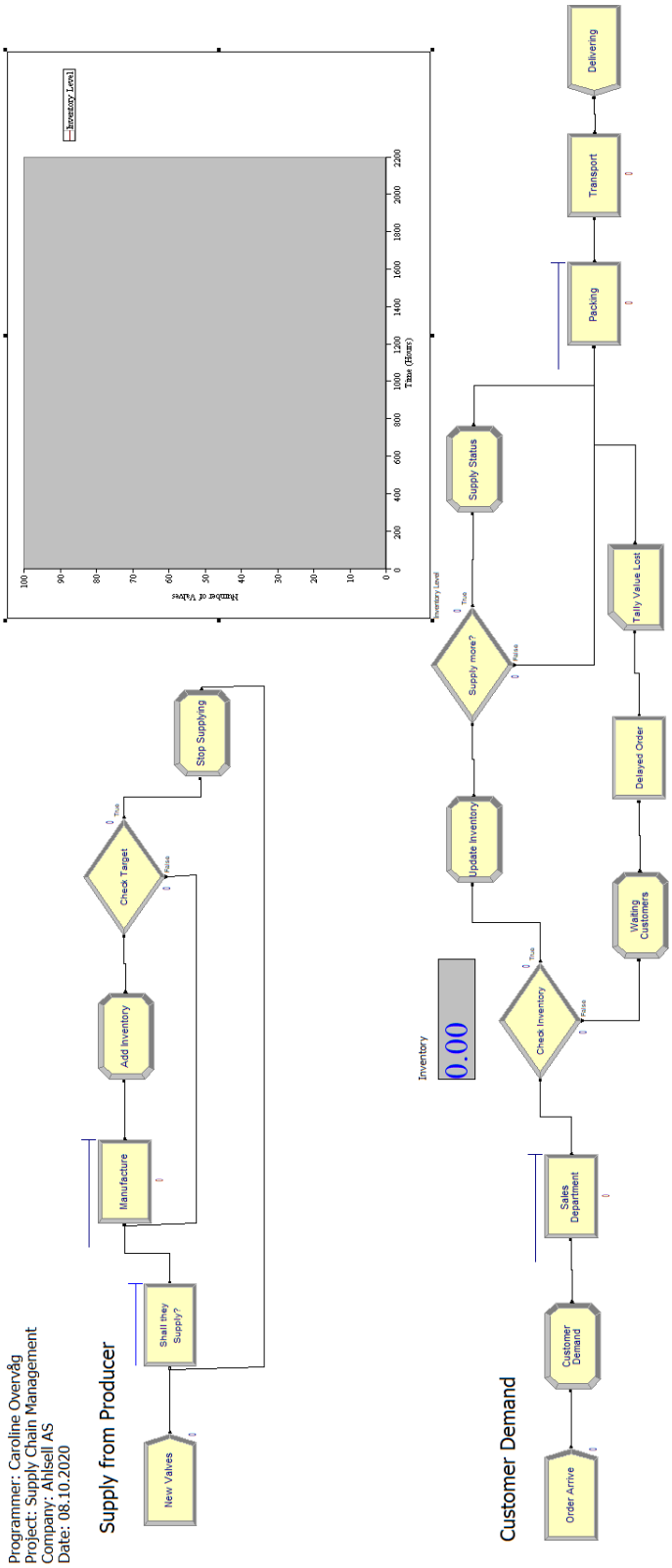


Figure 17 Case model in Arena Simulation

Create module

Create module is the starting point in the system and creates entities that go through other modules. Figure 18 below shows a dialog box where data is entered to determine how the logic in the system should be executed. The module *Name* is **Order Arrive** since the system start where the customer has placed an order, and the *Entity Type* is **Valve** which is what the customer orders. Orders normally do not arrive at fixed times, and that means time and date, even though the customer has received an offer and have given approximately time when the purchase order will arrive. Therefore, *Expression* is chosen in this system, where the *Expression* is **UNIF(1,15)** and *Units* **Hours.** By this is meant that order arrives between 1 to 15 hours, which is a very random number. *Max Arrivals* is chosen to be **Infinite** since there are no limit.

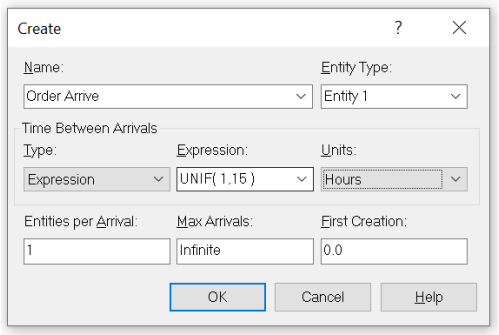


Figure 18 Create module Order Arrive

Assign module

Assign module is next, shown in figure 19. Here, changing, adding and initializing variables happens, same as variables spreadsheet. In this case, *Variables* are already put in *Variables Spreadsheet* and it will be mentioned later on. This module is called **Customer Demand**, here two *Variables* will be added. Click *Add* to create new variables. First up is **Demand** where *New Value* is **UNIF(1,25),** which means that the customer will order between 1 to 25 valves in each order. Next *Variables* are **Total Customers** with *New Value* **Total Customers + 1**. Every time a new entity passes this assign module, it will execute this code.

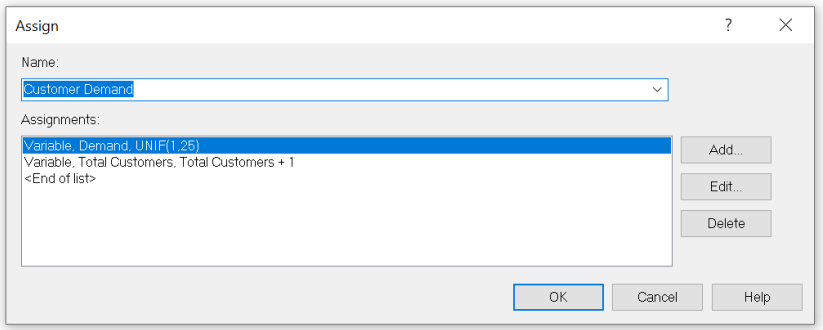


Figure 19 Assign module Customer Demand

Process module

Process module is a phase in the system where the entity will be served with an activity, so a resource is needed, and a delay will arise. This module is shown in figure 20 and called **Sales Department**, where a resource will handle the customer demand before proceeding. When choosing a resource, *Action* need to be defined. **Seize Delay Release** suites this task well since the order will seize a resource, a delay will occur, and then when the resource is finished it will be released for next entity. Push the button *Add..* and **Salesman** will be the *Resource Name* and click OK. *Priority* vary, so **Medium (2)** will stand as it is.

Furthermore, Chosen *Delay Type* for this case will be **Uniform** since it suited this task and *Units* to be **minutes**. By this, there is a need to specify *Minimum* time (**10**) how long the work will take, and *Maximum* time (**90**) for the process for the time delay. How long a salesman work on an order, vary. Even though Maximum is 90 minutes, little more than one quarter of a normal working day, it is not abnormal, and it can take a whole working day as well. The worker also can do it fast, like 10 minutes or less.

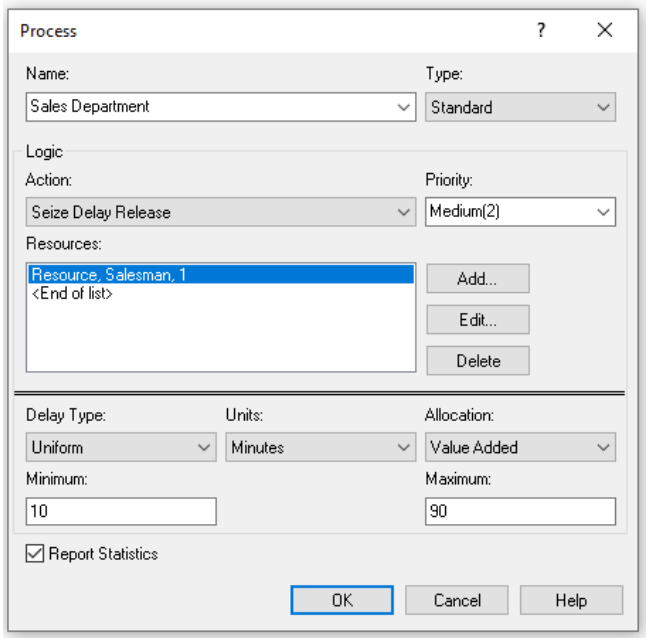


Figure 20 Process module Sales Department

Decide module

The salesman needs to know if he/she can meet the demand from the customer, so a Decide module will determinate if the inventory can meet the demand and it is stated as a question yes or no. This module is shown in figure 21 below and named **Check Inventory** and *Type* is chosen to be **2-way by Condition** since it is either met or not

met the demand. *Expression* will be **Inventory >= Demand**, to check the inventory. If Inventory met the demand, it is *true* and *false* if it did not meet it.

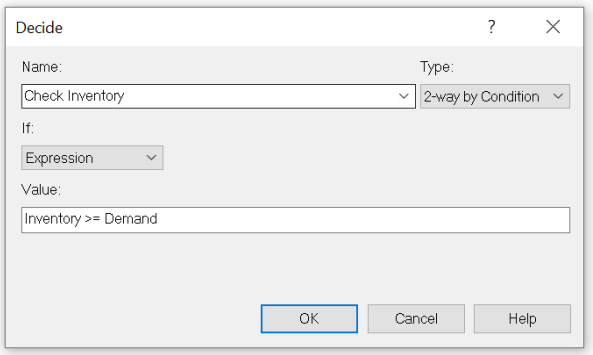


Figure 21 Decide module Check Inventory

Just to keep the flow in the process so the reader follows the process and for better understanding of the case, next up (if true) is a new Assign module where it is called **Update Inventory** shown in figure 22 below. Two *Variables* will be added, **Demand Met** and **Inventory**. For the first mentioned variable, *Expressions* **Demand Met + Demand** where number of the presents demand which are met will be increased by a new demand from the customer. Second *Expression* is **Inventory – Demand** where number of the present valves in the inventory will be reduced by the demand from the customer.

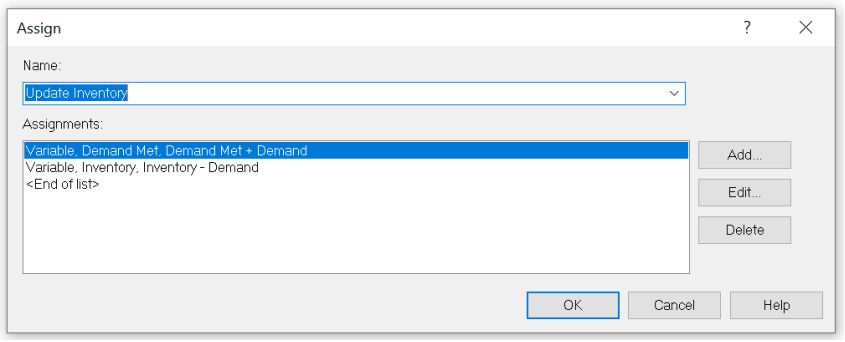


Figure 22 Assign module Update Inventory

If false, where demand do not meet the demand, it is a need to supply more from the supplier and the customer need to wait. A new Assign module is made, called **Waiting Customers** shown in figure 23 below, where two *Variables* are made; **Delayed** and **Value Lost**. Delayed has *Expression* **Delayed + 1**, which increases the number of delays. Value Lost has *Expression* **Value Lost + Demand**.

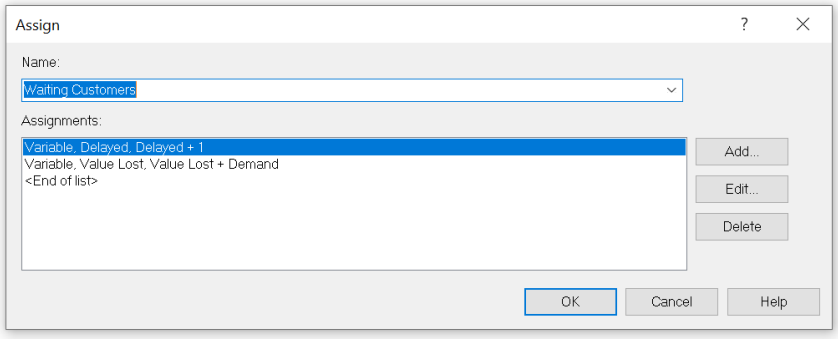


Figure 23 Assign module Waiting Customers

After Waiting Customers module, a new process module is made. This is called **Delayed Order**, shown in figure 24 below, where Delay Time between 7 to 14 days (*Expression* **UNIF(7,14)**) is added. Delay time is the most likely time to supply from the supplier based on delivery time.

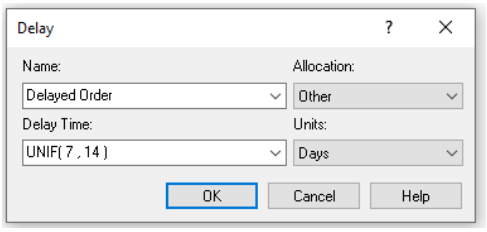


Figure 24 Delay module Delayed Order

Next up is a new Decide module, called **Supply more?** shown in figure 25 below. Here, a 2-way by condition with *Expression* **Inventory <= Reorder Point**. A new Assign module is made, called **Sypply Staus**, with variable **Supply** with value **1**.

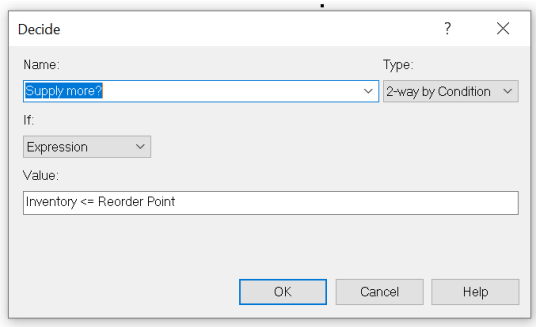


Figure 25 Decide module Supply more?

Furthemore, the order will continue to next module, named **Packing** shown in figure 26 below. A resource **Warehouse Worker** will be added, with Action **Seize Delay** Release. *Delay type* will be **Triangular**, with **Minimum 2, Most Likely 20 and Maximum 60** and *Units* **Minutes**.

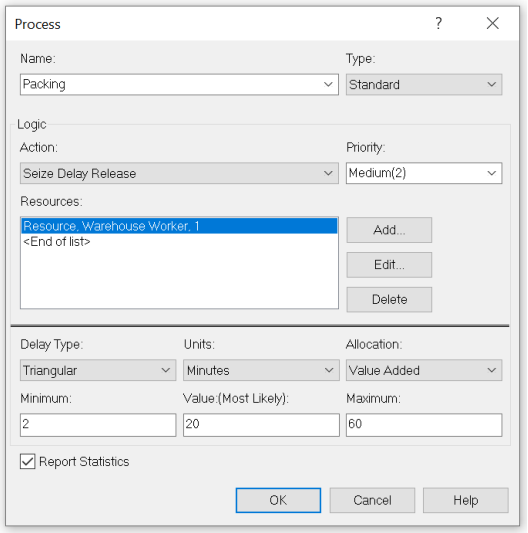


Figure 26 Process module Packing

After the warehouse worker is finished packing the order, it goes to the next module, named **Transport** shown in figure 27 below. *Action* here will only be **Delay** with *Delay Type* **Constant** since it is most likely fixed. *Value* is **1** and *Units* is **Days**, since Ahlsell only have one day delivery time after the order is packed and proceeded to transport. Last module is explained below.

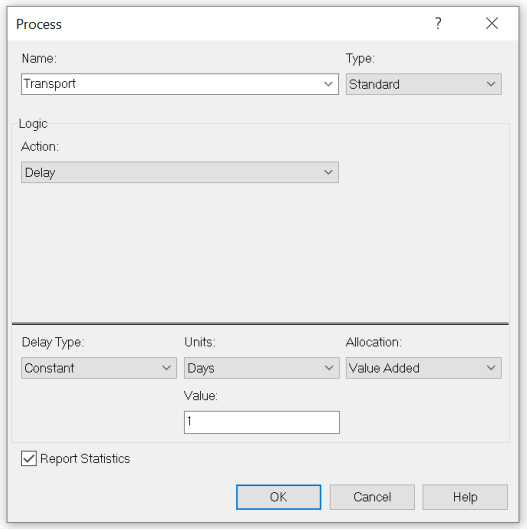


Figure 27 Process module Transport

Record module

Record module is a quick tally and account all entities who is passing through, shown in figure 28 below. This module was called **Tally Value Lost**, where the *Type* was chosen to **Count**.

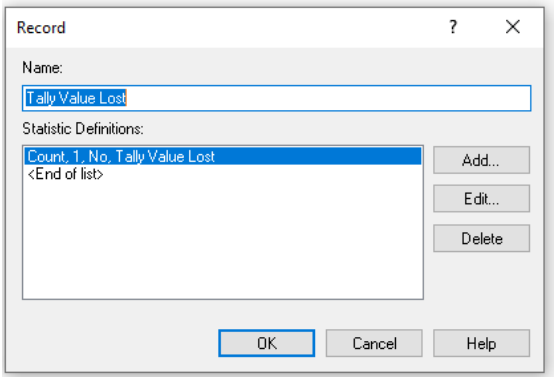


Figure 28 Record module Tally Value Lost

Dispose module

Dispose module is the last phase in the system where the entity is done executing the process, and in this case ends at the customer. Module is named **Delivering** and no more is needed to do with this box.

Now, the process of Customer Demand is finished modulated where the next process in this system, is Supply from Producer. This is modelled to show the process of entity going in and out of the Inventory. As mention, only a brief explanation will be presented of this process. First up, where it is most natural to start at, is the beginning of the system with an Create module.

Create module is called **Valves**, since this is the entity. *Type* is set to be *Expression* **1**. *Entities per Arrival* is **1** and *Max Arrival* is **1**. Units are not important here, since all it matters here is that it has created one entity in time zero and it allows the entity to come back and circulate through, over and over again. Next module is a Hold module from APP. As mentioned earlier in this report that it would only be used once. This module only allows entity to go out and start supplying if the Inventory is less than *Reorder Point*, which will be mentioned more in *Variables.* The Hold module will hold the entity intel until Supply is set on or = 1. This module is called **Shall we Supply?**. Since this module is not explained earlier, figure 29 below is shown. *Type* is **Scan for Condition** and *Condition* is set to **Supply == 1**. The rest stand as it is.

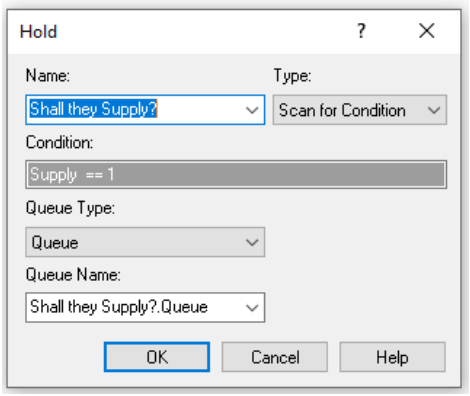


Figure 29 Hold module Shall they Supply?

Next is a Process module called **Manufacture**, with **Seize Delay Release** and *Resource* to be **Manufacture Cell** with *Value* **1**. *Delay* Type is *Expression* **UNIF(1,5)**, with Units to be **Hours**. In this stage, it is presenting that the supplier are preparing the goods ready for shipping to Ahlsell`s Warehouse, where they are using one to five hours. Assign module called **Add Inventory** is the next up with *Variable* to be **Inventory** and *Value* to be **Inventory + Batch Size**.

After adding the inventory and the inventory has reached Target Stock, next module will shut down supplying. It is a Decide module, called **Check Target**, with *Type* **2-way by Condition** with **Expression** with *Value* **Inventory >= Target Stock**. If the inventory is larger than the Target Stock, next assign module will stop it. Module is called **Stop Supplying** with *Variable* **Supply** and *Value* **0**. If the inventor is less than the Target Stock, a loop will be added with *false* back to Producer. Stop Supplying module will loop back to **Shall we supply?** module.

There are more modules in BPP but since they were not used in this thesis they will only be mentioned here; Batch, Clone, Separate, Adjustable Batch, Go to Label, Label, Attributes, Schedule and Set.

4.2.2 Data modules

Variables

Variables in this task was added after first Create module Order Arrive. In figure 30 shows all variables in a spreadsheet used in this task under the row *Name*, and in the row *Initial Values* shows *rows* where values for the specific variable can be added. **Inventory** (Initial Inventory) have **80** valves in current stock and **Target Stock** (R) is 80 pcs which tells that Inventory start as wanted when the simulation start. The **Batch Size** (Q)is **10**. **Reorder Point** (r) is **30**.

Variable - Basic Process

	Name	Comment	Rows	Columns	Data Type	Clear Option	File Name	Initial Values	Report Statistics
1	Inventory				Real	System		1 rows	☐
2	Target Stock				Real	System		1 rows	☐
3	Batch Size				Real	System		1 rows	☐
4	Reorder Point				Real	System		1 rows	☐
5	Demand				Real	System		0 rows	☐
6	Total Customers				Real	System		0 rows	☐
7	Value Lost				Real	System		0 rows	☐
8	Demand Met				Real	System		0 rows	☐
9	Supply				Real	System		0 rows	☐
10	Delayed				Real	System		0 rows	☐

Figure 30 Variable in Basic Process

Queue

Queues in this task are shown below in figure 31, all of them are of the type FIFO, First *In First Out,* which means that the first entity who goes into the module will be treated first by a resource before it goes out again and the next one in line will be taken care of.

Queue - Basic Process

	Name	Type	Shared	Report Statistics
1	Producer.Queue	First In First Out	☐	☑
2	Packing.Queue	First In First Out	☐	☑
3	Sales Office.Queue	First In First Out	☐	☑
4	Shall they Supply?.Queue	First In First Out	☐	☑

Figure 31 Queue in Basic Process

Resources

Resources in this task are shown below in figure 32 where everyone are of the type *Fixed Capacity* with default *Capacity* **1**.

Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	Manufacture Cell	Fixed Capacity	1	0.0	0.0	0.0		1 rows	☑
2	Warehouse Worker	Fixed Capacity	1	170	170	0.0		0 rows	☑
3	Salesman	Fixed Capacity	1	180	180	0.0		0 rows	☑

Figure 32 Resource in Basic Process

Entity

Entity in this task are Order and Valves, shown in spreadsheet below in figure 33. In the *Initial Picture* it is possible to change the picture of the entity who goes through the system to look like what it is supposed to represent. In this case, there was no valves, so a *Package* represent the valves and *Report* represent the Order.

Entity - Basic Process

	Entity Type	Initial Picture	Holding Cost / Hour	Initial VA Cost	Initial NVA Cost	Initial Waiting Cost	Initial Tran Cost	Initial Other Cost	Report Statistics
1	Purchase Order	Picture.Report	0.0	0.0	0.0	0.0	0.0	0.0	☑
2	Customer Order	Picture.Report	0.0	0.0	0.0	0.0	0.0	0.0	☑

Figure 33 Entity in Basic Process

Statistics

Statistics module is from APP and it is used to define additional statistics and specify output files, shown in figure 34 below.

Statistic - Advanced Process

	Name	Type	Expression	Frequency Type	Resource Name
1	Stock on Hand	Time-Persistent	Inventory	Value	
2	Process States	Frequency		State	Manufacture Cell
3	Production On	Time-Persistent	Supply==1	Value	
4	Lost Percentage	Output	Delayed/Total Customers	Value	

Figure 34 Statistics in Advanved Process

The whole system is shown in Appendix A, where further work on the case will be in the next chapter.

4.3 Case analysing

The case was analysed by three different analyser tools, Input Analyzer, Process Analyzer and Output Analyzer. This chapter will address these in a more detailed explanation.

Input Analyzer

In simulation modelling, Input Analyzer are key ingredients. Data taken from this analyser tool is used to initialize simulation parameters and variables, or construct models of the random components of the system under study (Altiok and Melamed 2007). This tool is part of the Arena simulation and has the capability to determine the best theoretical distribution fit for the observed data (Chung 2003);

- Determine the quality of fit of probability distribution functions to input data.
- Examine a total of 15 distributions for data fitting
- Calculate chi-square, Kolmogorov-smirnov, and square error tests
- Generate high-quality data plots.

In this case, parameter Customer Demand and Order Arrive in the system were defined by using Input Analyzer. First, a random number generator (RNG) were made in an excel sheet for both parameters, shown in table () and table () in appendix. These two RNG were further implemented into Input Analyzer where the tool provided the best distribution fit. Different distributions are shown in table B in appendix.

Process Analyzer

The Process Analyzer is a tool that supports parametric analysis of Arena models to create, run, and compare simulated scenarios, and observe the result and the effect it can have on the system (Altiok and Melamed 2007). In Process Analyzer, multiple scenarios were tested to find the best approximal Batch Size, Reorder Point (r) and Target stock (R) were the goal is to have low Inventory and no dissatisfaction customer (Value Lost).

Output Analyzer

Output Analyzer focuses on the analysis of simulation results, and is the modeling stage concerned with designing replications, computing statistics from them and presenting them in textual or graphical format (Altiok and Melamed 2007). The tool gives the main result that will help to understand system behavior and generate predictions for it in four different graphical statistics; plot, barchart, moving average and histogram. Output Analyzer was used to analyze the average amount of value lost per customer.

5 Case Study

5.1 Case Stakeholders

In the system *Customer Demand*, Ulstein Yard is the chosen stakeholder *User* in this case based on their direct purchase order without requests, which makes it more real for the desired task. They represent the first Create module, **Order Arrive**, where they only order a specific item, Butterfly Valve SIG23LT DN100. Stakeholder *Sales Management* represent the Process module **Sales Department**, which only have one salesman to handle the demand from the user, since today there are only one person who has the responsibility for this customer. Stakeholder *Warehouse* is the main warehouse at Gardermoen and it is shown in the Process module **Packing**. For the specific user, the SH at the warehouse is always used, based on their request on how they need their order to be handled. Their specific needs are; assembly, export order management, pressure testing, certificate handling of articles subject to certification and labelling on all ordered items according to customers wishes. The last-mentioned need is the most important part, since their goods often are further shipped to their shipyards in Poland who are building their hull. Warehouse work is only to put on correct label on the specific item, but it is the salesman's responsibility to make sure it is correctly added in the system when handling the order in the process **Sales Department**. Last stakeholder is *Transport*, shown as the Process module **Transport**.

In the system, *Supply from Producer* shows the process if Ahlsell needs to provide more valves. The stakeholder *Manufactures and Suppliers*, is the valve producer Sigeval, shown in the Process module **Manufacture**. It was chosen not to include a sub supplier in this system, as it is normally obtained from the main manufacturer. If it is very urgent, which may happen, sub suppliers are used, but in this case it was not.

All variables and values are already presented in previous chapter, with an explanation of each modules. The system is shown in figure 35 below.

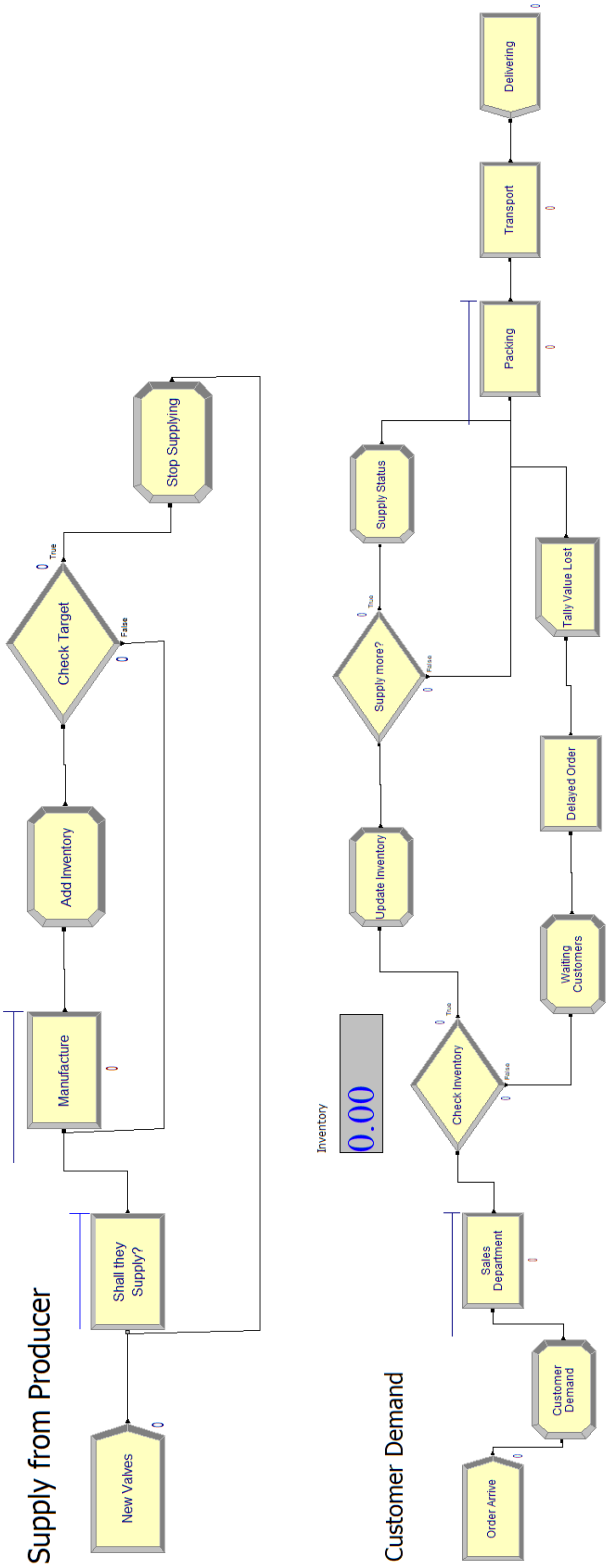


Figure 35 System of Case study Ahlsell SCM

5.2 Experimental Design and Analysis

In order to resolve the issue, the company is currently facing, experimental design and analysis will be solved now. After running the system for a specific time, where 90 days was chosen, Output-, Input- and Process analyzer are now used to analyze the result. These three tools help the programmer to analyze and adapt the model to the desired needs.

Data for Order Arrive and Customer Demand have been analyzed by using Arena`s Input Analyzer, where it has been observed different exponential distribution to find the best fit. Order Arrive was set to be from 1 to 15, with number of intervals to be 20. Different exponential distributions were observed, where distribution Beta was selected since it was the best fit. Customer Demand was set to be from 1 to 25, with number of intervals to be 20. Both histograms and distributions summary with RNG are shown in appendix C. Some expressions have been mentioned and someone will soon be mentioned, where a table in Appendix B shows the different statistical distributions that can be used. In this case, distribution Uniform, Beta and Triangular have been used.

Expression for Order Arrive is **1+ 14 * BETA (1.01, 1.05)**, with Square Error= 0.002845 and corresponding p-value = 0.156 which is acceptable as it is greater than 0.1. Expression for Customer Demand is **1+ 24 * BETA (0.89, 0.97)**, with Square Error= 0.001044 and corresponding p-value > 0.75 which is acceptable as it is also greater than 0.1.

In Process Analyzer, different scenarios were tested to find the best approximal Batch Size, Reorder Point (r) and Target stock (R) were the goal is to have low Inventory and no dissatisfaction customer (Value Lost). As shown in figure 36 below, under the row *Controls* are what was implemented and under the row *Responses* shows the result to investigate. Different variables were tested, but the best numbers who gave lowest Delays, Value Lost and had a low Inventory, was **Scenario 4**. In this system, following variables were chosen to use:

- Batch Size: 10
- Reorder Point: 30
- Target Stock: 80

	Scenario Properties				Controls			Responses		
	S	Name	Program File	Reps	Batch Size	Reorder Point	Target Stock	Delayed	Value Lost	Inventory
1		Scenario 1	6 : SCM.p	1	5.0000	20.0000	200.0000	8.000	154.584	98.480
2		Scenario 2	6 : SCM.p	1	10.0000	0.0000	200.0000	70.000	1010.166	0.639
3		Scenario 3	6 : SCM.p	1	10.0000	10.0000	200.0000	1.000	15.354	129.443
4		Scenario 4	6 : SCM.p	1	10.0000	30.0000	80.0000	0.000	0.000	29.857
5		Scenario 5	6 : SCM.p	1	10.0000	20.0000	200.0000	1.000	15.545	189.822

Figure 36 Process Analyzer with Scenario Properties

After implementing Scenario 4 in the system, a simulation run gave good results as shown in figure 37 below. Warehouse average inventory is 48.0676 valve units, percentage of customers dissatisfaction to be 2.53% (0.02527076*100) and the amount of value lost per order is 7 (number 6 is finished orders and the last one is still waiting

for their order in the system). Manual calculation is shown below, where considering the Customer Value Lost over the interval [0,T]. L T_{VL} is the total Value Lost over [0,T] and T the Total Customer Order.

$$Percentage\ of\ Customers\ dissatisfaction = \frac{T_{VL}}{T} = \frac{7}{277} = 0{,}02527076$$

Supply Chain Management Replications: 1

Replication 1 Start Time: 0,00 Stop Time: 2 160,00 Time Units: Hours

Counter

Count	Value
Tally Value Lost	6.0000

Time Persistent

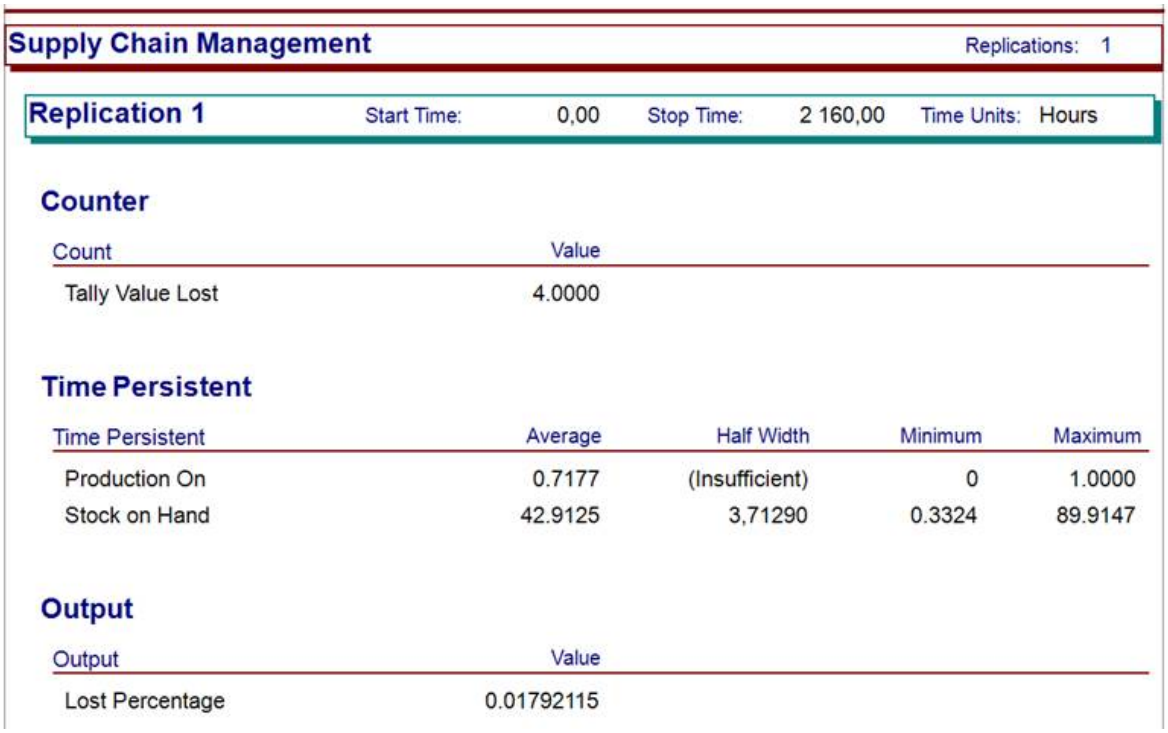
Time Persistent	Average	Half Width	Minimum	Maximum
Production On	0.6551	(Insufficient)	0	1.0000
Stock on Hand	48.0676	3,38327	0.6101	89.5875

Output

Output	Value
Lost Percentage	0.02527076

Figure 37 Simulation run first result

After the first results, an evaluation was done to make sure if every input data, parameters, distributions in the input analyzer and joints between the modules were correct. After verification, new parameters for Order Arrive and Customer Demand were tried out to check if it made any better results, with no success. Multiple options were tried out, but the best option was a minor change where parameter for Order Arrive was changed to Triangular distribution **TRIA(1, 8, 15)** and Customer Demand to **1 + 24*BETA(1, 1)**. Warehouse average inventory is 42.9125 valve units, percentage of customers dissatisfaction to be 0.18% (0.01792115*100) and the amount of value lost per order is 4. See the result in figure 38 below.



Supply Chain Management Replications: 1

Replication 1 Start Time: 0,00 Stop Time: 2 160,00 Time Units: Hours

Counter

Count	Value
Tally Value Lost	4.0000

Time Persistent

Time Persistent	Average	Half Width	Minimum	Maximum
Production On	0.7177	(Insufficient)	0	1.0000
Stock on Hand	42.9125	3,71290	0.3324	89.9147

Output

Output	Value
Lost Percentage	0.01792115

Figure 38 Simulation run second result

As shown in figure 37 and 38 above, it may tell that the first obtained parameters may be the best for this case based on it was made in and recommended fit by Input Analyzer. Furthermore, after experimental design and analysis of the case, an evaluation of the final results tells that Batch size, Target stock and Reorder Point have a major impact on the system.

Output Analyzer was used to analyze the average amount of value lost per customer, where the results are to find in Appendix D. The variable Delayed was divided by the variable Total Customers to get accurate requisite percentage. This was made in Statistic in Advanced Process, where it further was implemented in Output Analyzer. Histogram for Lost Percentage clearly shows that value lost is between 1 and 2 percent. Highest percentage of replication is 33.33 percent who shows that Value Lost lies between 2.4 and 2.6 percent. Analysis of 95% confidence interval was also created in Output Analyzer, which is very important since it determines whether or not the graph is good. Value Lost lies between 0.72% and 3.55% indicated by 95% confidence interval, meaning that you can be 95% certain it contains the truth. Average Value Lost for interval is 2.14%, between 1.61% and 2.68%, and Standard deviation is 0.744%.

There is more than one solution to model this system, and after running multiple simulations, the chosen modeled system worked very well but it needed more details in the packing apartment SH. As the chosen stakeholder User is Ulstein Yard, they always require labels on every part in an order. This Process module *Labelling* was added, with a delay type Triangular between minimum 5 minutes to maximum 60 minutes and most likely 15 minutes. Further on, five more Process modules were added with Decide modules with *2-way by chance* in *Percent True (0-100),* action *delay* and delay type

Triangular. Added percent and Triangular variables of each modules were only an assumption, shown in table 2 below;

Process Module	Percent True [%]	Triangular (min., most likely, max.)	Units
Assembly	25	(5,15,120)	minutes
Export order Management	1	(5,10,15)	minutes
Pressure testing	4	(10,15,60)	minutes
Certificate handling	40	(5,10,20)	minutes
Cable cutting	1	(5,10,20)	minutes

Table 2 Order handling services at SH

Assembly of valves and actuators are very normal, but the percentage becomes low considering the volume of customers order. Export order Management is a rare case, only when it is very urgent, and the items need to be shipped direct to Poland where the Hull is made. Pressure testing is not daily task for the SH, but it is not unusual. Certificate handling is normal, where documents often needed to be added in the shipment with the items. DNV is contacted if the warehouse is out of stock of pre-certified valves. This is very rare, and it is not considered in this case, since it is time consuming and expensive. Cable cutting is not rare, but for the maritime department it is. Figure 39 below shows the new adapted system.

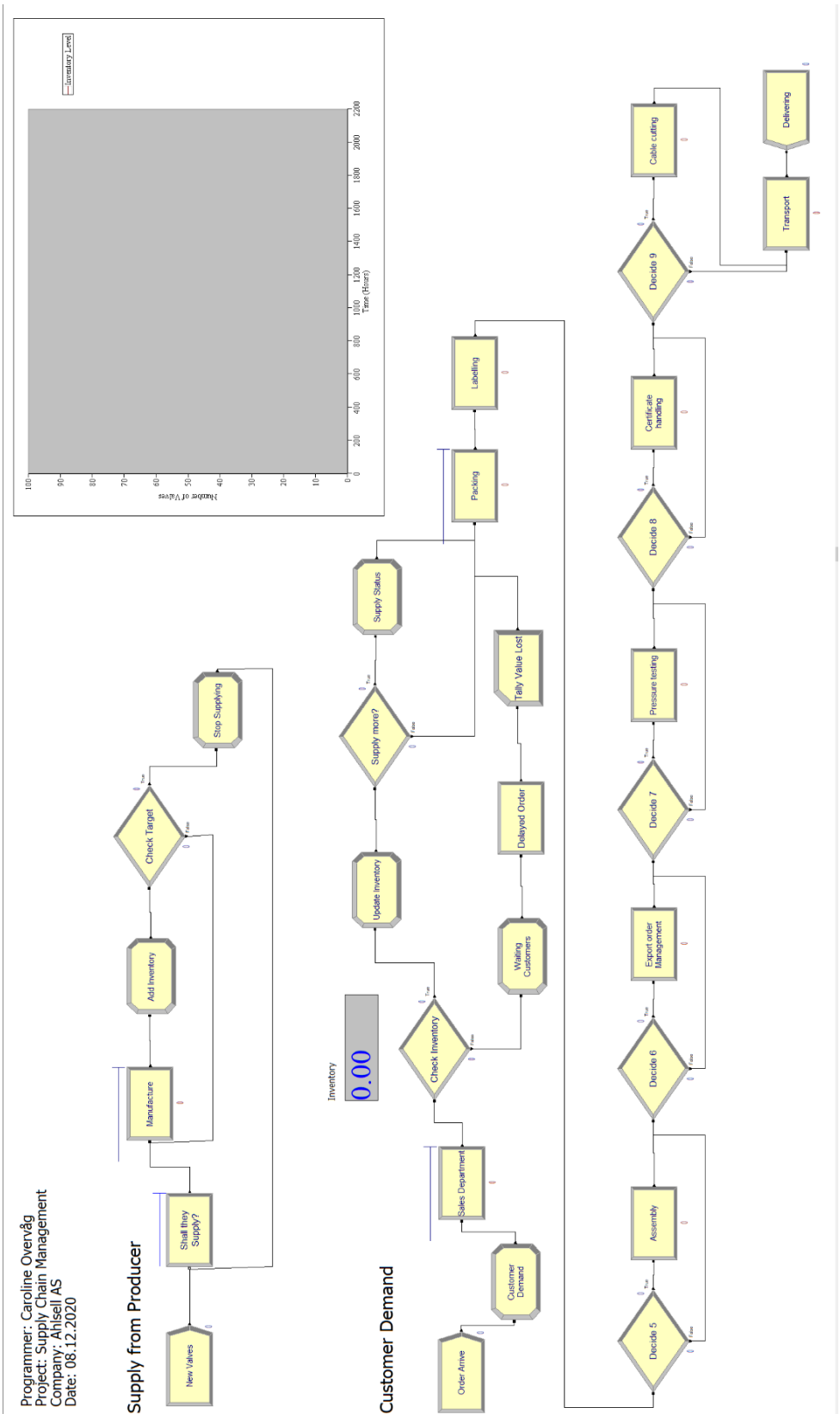
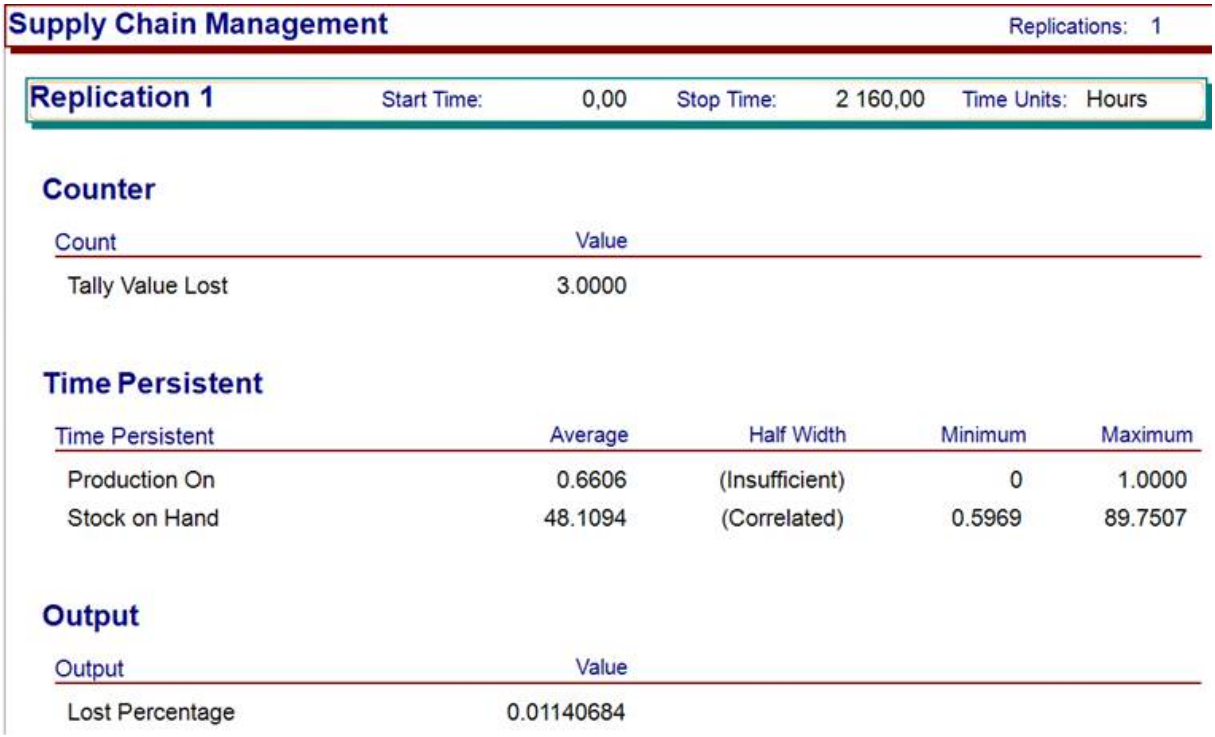


Figure 39 Adapted Case study in SH department

These changes made it more accurately for the real case and after running a new simulation, figure 40 below shows that it did not make much changes. Warehouse average inventory is 48.1094 valve units, percentage of customers dissatisfaction to be 1.14% (0.01140684*100) and the amount of value lost per order is 6 (three finished orders and three are in transport module). After this new adaption, customer satisfaction got better with 1.39% (0.02527076 - 0.01140684 * 100). The graph shown in appendix A shows the number of the specific valve in stock in the inventory after a simulation run for 90 days.



Supply Chain Management Replications: 1

Replication 1 Start Time: 0,00 Stop Time: 2 160,00 Time Units: Hours

Counter

Count	Value
Tally Value Lost	3.0000

Time Persistent

Time Persistent	Average	Half Width	Minimum	Maximum
Production On	0.6606	(Insufficient)	0	1.0000
Stock on Hand	48.1094	(Correlated)	0.5969	89.7507

Output

Output	Value
Lost Percentage	0.01140684

Figure 40 Simulation run third result

6 Discussion and Conclusion

To answer research questions, it was a good idea to begin with an investigation of Ahlsell`s SPF, to understand how they organize the handling of customers demand and supplies till producer and sub suppliers. As a result, a good insight of their current SCM was obtained and next was to understand the dynamic of it.

Today Ahlsell has one big centralized warehouse, which is more profitable both for the companies and the customers. They have learned along the way that it is not necessary and profitable to have stores close to all customer. Some places it is enough to have sales departments only, to be near and available for the customers. A bigger quantity and more options in a few larger warehouses give the customer more desirable production and delivery flexibility. This also leads to prerequisite for more advanced and efficient manufacturing technology, less capital tied up, and less overcapacity and less buff stock. Companies service levels are rising, and they get more happy and satisfied customers.

Globalization is the main cause of success since it forces all businesses to constantly strive for improvements, be flexible and response quickly to changes, and failures of those who could not adapt in time. Based on Ahlsell has a growth at 9% the past 15 years, they show that their ability to adopt quickly to demand changes with their broad product portfolio with attractive profitability. Furthermore, without globalization, the company had not been where they are today, especially within technology. A negative point of it, is that it is hard for wholesalers and suppliers to use local partners which had been a great effect on most points on upstream and downstream, such as; delivery time, flexibility, capacity, the local community, etc. Today, wider supply chain is better, even though the chain becomes more vulnerable to external factors.

The fact that this is my employer and I have days where I hoped to have more valves in stock to avoid loss of order, I had the opportunity to find their weaknesses in warehouse stocking, and find how they can maintain their good reputation in the market in this demanding globalized market. Ahlsell´s main weaknesses in SCM is mostly inventory level upstream, and mostly been the target stock and reorder point. This has mainly been improved already after they changed the Chinese valve for the Spanish ones. The main reason for switching supplier is that they wanted to improve their delivery ability to the customer without increasing the capital tied up in their warehouse. Today, it is a higher demand on the customer on their value chain, so increasingly demand on documentation on how Ahlsell relates to sustainability, Corporate Social Responsibility (CSR), code of conduct (ethical guidelines, human rights, employee rights, etc.) where Ahlsell is also audited in this area. By changing supplier, it gives greater security both to customers and themselves that these conditions can be documented backwards throughout the value chain, by producing in Europe. The four points of achieve high flexibility of their customers which was mentioned in chapter three, is something Ahlsell is good at based on the choice of its supplier Sigeval. Based on short delivery time and a manufacture who has short reaction time, it is easy for Ahlsell to be

flexible for their customers. Especially, when they also have their SH department who pack all orders manual based on customer's needs.

A discussion with the product manager in Ahlsell gave crystal clear answer that was the most profitable for both the company and the customer. Delivery reliability from the warehouse is significantly improved. China valve had a coverage of 39% with a capital tied up of about NOK 16 million and a turnover rate of around one (the turnover rate in stock). Over the past 15 years, great values have been scrapped, which takes place at the bottom line in the accounts. When the company scrap for NOK 1 million, it corresponds to approximately the same as having to sell for NOK 6-7 million with coverage of 37-39% including all costs. Sigeval has about a coverage of 30% with a capital tied up of about 5 million, and a turnover rate of three. This makes Sigeval an outstanding winner financially. Every Friday, a purchaser registers all order lines registered by salesmen and an order is placed to the supplier Sigeval. Turnover has maintained, with slightly fewer valves since Sigeval has higher prices. Nothing is scrapped on Sigeval parts, because they take returns. Complaints have almost disappeared after the transition, and the technical backup is on a completely different level which scores high for sale. The result is; far better quality, delivery time has increased from six months to four weeks, better communication between the company and the producer, much better financial solution for both Ahlsell and customer and it is a security for sales.

In this thesis, the simulation tool Arena has been found to be a great way to understand more of the dynamics of SCM; Resource utilization, analyse operational strategies, and identify the systems structure, bottlenecks and new alternatives way. To find a tool for the company to investigate batch size, target stock and reorder point, and knowing it may work, has been satisfying. In this case, batch size, target stock and reorder point were easy to figure out which numbers worked well for the system to get good results, but it is not that easy to achieve in real life. Many unpredictable factors affect these numbers, especially in the maritime sector, as simplicity cannot be implemented. It was found out that it was difficult to come up with a solution for the company, but the conclusion is that the simulation tool will work well for other less unpredictable sectors. After using the simulation tool, it was very clear that Batch size, Target stock and Reorder Point have a major impact on the system.

After talking to the product manager in Ahlsell, it was difficult to get specific numbers of these three elements for the system, in order to optimize the model to make it as realistic as possible. Therefore, it became difficult to get concrete and good results back to the company. The batch size is affected by three elements; minimum order quantum required by the supplier, physical limitations by rules on how much can be sent in a pallet (weight and size), and Ahlsell`s own requirements on minimum order quantum. The last one is based on freight charges, were Ahlsell do not want to pay for a whole truck when it is only half full. Here, environment is also considered. Re-order point indicated how many units they have decided to have minimum in stock. When it is reached, the purchaser get informed with an order proposal calculated based on the forecasts that according to delivery time (production and shipping time) the quantity comes as far as possible to the safety stock as possible before they get new goods in stock. Target stock is based on expected turnover rate, and Ahlsell`s requirements are

that all goods must have a turnover of eight. That is, if we have an average stock of 100.000 then it is expected that 800.000 will be sold in stock value on the range per year. As mentioned earlier, this method is not easy to achieve based on the industrial market. Target stock can be interpreted as a service grade, where Ahlsell have stated that they in certain range should have a service grade of 98%. They need to fine-tune the stock (at article level) so that the sellers in 98% of cases get the goods delivered on the promised date stated in their conditions (the day after, or within 2-3 days in Northern Norway). This applies to the goods they have decided are "milk and bread", as valves from Sigeval.

To become supplier of choice, Ahlsell need to focus on some specific areas. (Lambert 2014) concludes in his book that "since a supply chain is a network of companies, then the management of that network is supply chain management". He further concluded that "at the end of the day, supply chain management is about relationship management. A supply chain is managed, link-by-link, relationship-by-relationship, and the organizations that manage these relationships best will win." The company need to invest in their network; relationship to their sub suppliers and customers. A solution is to exchange of inventory status information, sales data, order coordination and simplified pricing schemes with the manufacturers and suppliers, and maybe with the customers. This is something Ahlsell should work on, especially with their Customers and have aftersales in focus. Safety stock may be up to 50% in the total stock in many cases because of the uncertainty. With a good relationship with the customer, important information can be caught up of what the customer actual needs now, and in the future, to reduce overstocking. This information is crucial to achieve success in the business, where a solution could be an up-to-date information available for the customer on needs and assets.

Aftersale is extremely important when it comes to relationship with the customer, and as I said earlier in this thesis, this is often forgotten by companies. A salesman should use time on this; Ask the customer if they are satisfied, need any type of service or the product met their expectations. Don't forget to be thankful. All in all, the product quality is fulfilled when aftersales are completed correctly. After an initial sale, it is important to have a good communication with the user's satisfaction and retention. A happy customer, makes loyal customers, and increases the brand value. It leads to more individuals and more revenues and is important for Ahlsell for long term.

Despite the fact of the popularity of this theme, it is in general very little research about measurement of market needs in the industry. Predict the market needs of the industrial consumer is very difficult, especially today. As the company could not give realistic data at a practical level for the model in Arena Simulation, it became very difficult to make the model real enough to get a desired answer back to them. The final model of case study had been more advanced and accurate with more time and proper lecture on the simulation program, and maybe a better solution could be obtained. The conclusion is that the simulation tool will work well for other less unpredictable sectors, and it is a cornerstone for further work for the company.

In conclusion, SCM success is depending on good information- and material flow to go through a complex process in a flawless and efficient way.

7 Future work and Opportunities

After this exploratory approach to the problem, some recommendations for future work and opportunities will be presented below;

- This thesis is mostly theoretical to achieve a greater understanding of the topic, with a simple case study of Ahlsell`s SCM of order handling by a customer. It had been of great interest to implement a more detailed and realistic system with more customers and sub suppliers, more different items, urgent orders and risks (human-, logistic- and machine failures).
- Relationship has been concluded to be an important point for success in this task, so it would be interesting to get a feedback from the customer Ulstein Yard to get more depth in the task, not just from the company`s point of view. Maybe it had led to a new open door of corporation or a new information of important feedback till the company. Since it is hard to maintain the good dialog between customers and the company based on uncertainty in the globalized marked, this had been very interesting to implement in the task.
- A brief dialog with the producer Sigeval was conducted, but only about information of their business and their opinion of the producer in China. Since relationship is so important, maybe a more detailed feedback from Sigeval about the corporation and discuss potential for improvement should been obtained, not only from the customer.
- The goal of the company is to be a leader in delivery capability, at the lowest possible cost. Costs and incomes drive all businesses, where overstocking is a critical issue among companies. It had been very interesting to find out what impact costs have on the SCM based on capital costs, inventory costs, costs of backorders, etc. where they need to ensure the most efficient execution of procurement (integrated interaction with manufactures and suppliers from start to finish.) through flexible cost structure (leased locations, outsourced transportation, IT, etc.).
- Try the method S&OP with the seven step every month; data gathering, demand planning, supply planning, reconciliation and executive meeting.
- Since there is no new solution to Ahlsell`s problem of batch size, target stock and re-order point on valves from Sigeval based on the unpredictable market, it would still have been very interesting to continue the work even more with closer corporation with the purchaser and product manager and how they work.
- As it is well known that it is difficult to make good overview of all lost orders, Ahlsell should use time on making a good data analysis of all orders, where including delays (all the times they need to supply more outside the planned purchase order with the supplier Sigeval) and when they need to go to sub suppliers. Maybe they can see a pattern based on season when the order volume increases or shrinks and maybe they can adjust warehouse stock based on previous pattern. This may be analysed some years before it may be useful.
- Supply chain vulnerability could have been very interesting to move forward with in this task.

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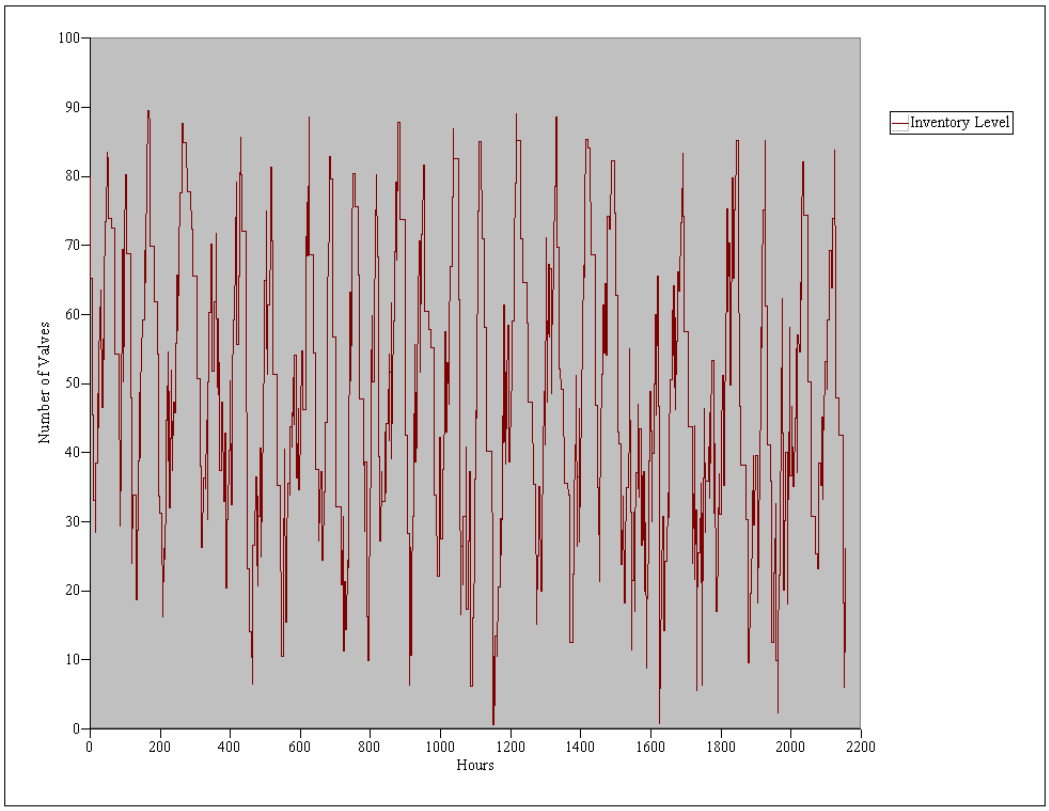
Appendices

Appendix A: Inventory graph after simulation run

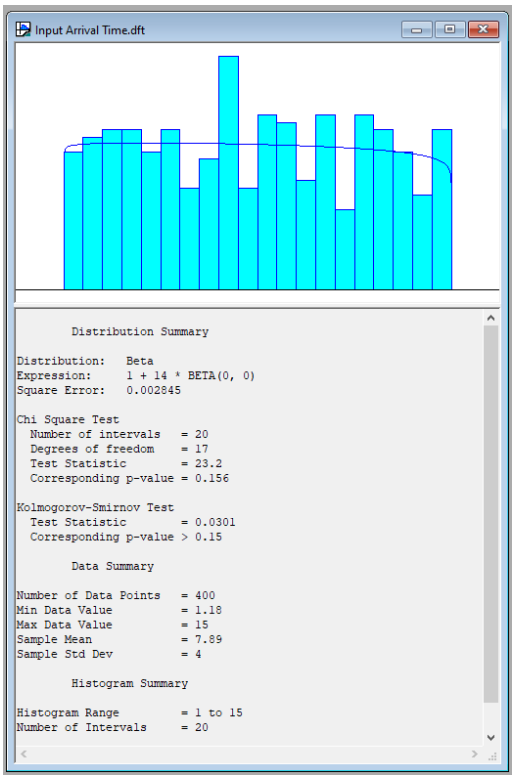


Appendix B: Statistical distributions

Distribution	Arena name	Arena parameters
Exponential	EXPO	Mean
Normal	NORM	Mean, StdDev
Triangular	TRIA	Min, Mode, Max
Uniform	UNIF	Min, Max
Erland	ERLA	ExpoMean, k
Beta	BETA	Beta, Alpha
Gamma	GAMM	Beta, Alpha
Johnson	JOHN	G, D, L, X
Log-normal	LOGN	LogMean, LogStdDev
Poisson	POIS	Mean
Weibull	WEIB	Beta, Alpha
Continuous	CONT	P1, V1,…
Discrete	DISC	P1, V1,…

Appendix C: Probability distribution analysis

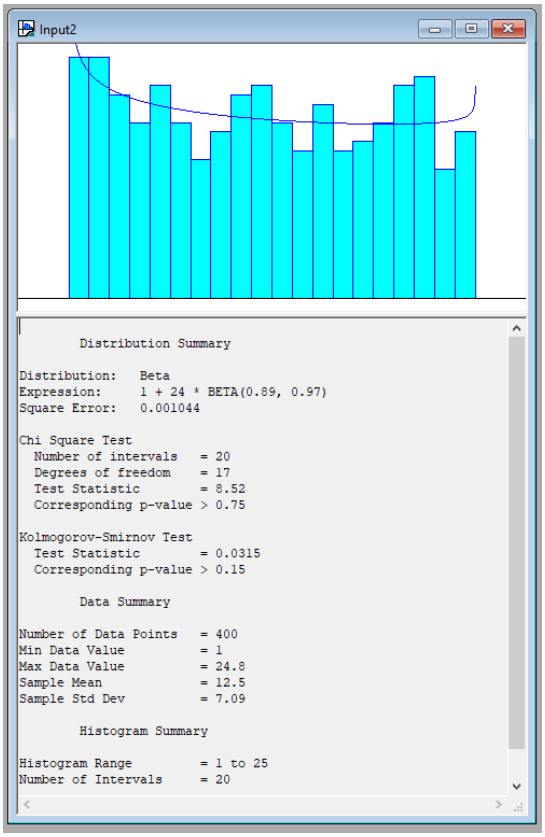
Order Arrive Histogram with distribution summary:



Order Arrive RNG:

12.48387097	3.622089297	12.28391369	5.798974578	6.556932279	3.953642384	7.002990814	8.381756035	4.92608417	7.475539415
12.73766289	8.097201453	8.877376629	6.769707327	10.96667379	2.03952147	4.969664602	1.30549028	7.193121128	9.021790216
13.02349925	13.0187994	4.692373424	1.828882717	7.532364879	13.32386242	3.531083102	12.31681265	6.274086734	10.83977783
8.175817133	4.221961119	12.20786157	8.594103824	9.256782739	4.245033113	10.02371288	12.43943602	4.992736595	11.76393933
6.300149541	8.776116214	13.05639821	12.63426618	9.015381329	14.42448195	11.85195471	7.666524247	3.752403333	4.439436018
6.208716086	3.426831874	10.45524461	14.94360179	6.893612476	13.39649648	2.034821619	13.06707968	9.963469344	11.78572954
8.244178594	2.876094852	4.109591968	3.970732749	11.85110019	2.371074557	11.67421491	6.137363811	11.73445845	6.676992096
1.176030763	9.840418714	1.789574877	13.64302499	9.394360179	7.963042085	4.52232429	13.84212775	12.50993377	12.7731254
14.86114078	5.825037385	6.761162145	1.823755608	5.954069643	13.8164922	13.84853664	4.767143773	6.348429823	5.441358684
13.34907071	14.54924162	11.25635548	4.645802179	1.641315958	9.074770348	12.78167058	6.841059603	4.521042512	8.706045717
12.12967315	10.9602649	5.180730613	7.145695364	2.085238197	3.627643666	10.32407605	10.0433668	7.125614185	7.161503952
12.20145268	1.77846614	2.233069857	13.65157018	5.028199103	7.070925016	4.218543046	4.553514206	2.395428327	12.78893399
8.650929289	8.50267037	8.633838923	10.34885708	2.371929075	3.319589831	2.861140782	7.768211921	13.39948729	3.611835078
2.434736167	12.82183294	6.644947661	9.471694082	3.360179449	1.810510575	13.43964965	10.62529374	8.8128605	4.130100406
7.045716727	1.362743004	4.069429609	7.549455245	7.584490493	1.233283486	12.49455245	4.678273873	5.452467421	10.46763512
6.752189703	1.719931639	11.92287973	5.149967956	3.502029481	2.7239906	6.083101901	6.350566118	11.25891903	2.17239906
12.10361034	8.694936979	1.453749199	4.558641316	5.155522324	6.464217048	13.73873104	1.811365093	10.41593677	9.608417005
1.37940611	14.69237342	10.71544542	6.825678274	6.775261696	2.617603076	13.40760521	8.913266396	3.296517838	2.871395001
5.681478317	1.201666311	3.857936338	8.624439222	7.958769494	2.544541765	3.555009613	11.62166204	8.917966247	5.173467208
14.34202094	7.313608203	3.349497971	6.353984191	3.108951079	9.230719932	9.628498184	5.380260628	14.59453108	14.62614826
5.61098056	11.865627	14.08053835	8.61589404	4.125827815	13.27216407	10.72142705	12.96411023	3.701132237	4.390301218
9.532792138	13.60243538	4.8128605	9.239265114	5.831873531	7.297799615	1.600726341	14.29673147	7.269173254	14.54496902
14.69109165	12.91412091	4.657765435	1.957914975	10.14975433	1.231147191	10.2117069	12.00491348	1.190557573	10.63896603
9.658406323	11.85024567	13.1589404	6.054475539	10.48130741	8.121127964	10.65263833	9.069643239	11.69173254	11.48365734
13.93697928	8.59581286	12.68938261	10.62187567	13.90493484	6.656056398	4.079683828	1.343516343	4.245460372	2.565477462
12.31296731	7.152958769	11.15808588	9.197393719	9.027771844	4.360820338	12.88036744	3.786584063	2.611194189	7.68959624
1.570818201	11.95492416	3.911770989	10.79577013	4.631702628	14.40910062	11.97799615	13.29566332	6.099337748	9.929288614
11.74556719	14.85302286	14.53044221	10.28519547	8.298867763	2.495834223	5.964323862	10.05789361	1.253791925	9.324716941
13.10809656	2.909421064	3.187994018	6.039948729	3.203802606	7.208502457	5.743003632	8.372783593	7.145695364	7.762230293
5.069215979	8.441999573	12.28733177	5.804956206	2.265114292	14.32663961	1.372997223	6.873531297	2.451399274	12.47703482
2.189062166	5.744285409	2.02969451	10.71800897	13.83571886	12.49626148	6.795770135	3.0888699	9.521683401	2.612048708
3.476393933	11.93398846	11.63405255	2.416364025	12.12625507	6.712881863	7.140140996	6.284768212	1.606280709	6.276650288
10.17111728	14.35441145	14.87096774	7.175176244	12.54582354	11.0512711	10.28647725	3.515274514	6.446272164	8.534287545
10.19547105	11.97714164	7.614825892	10.00747703	9.146977142	7.072206793	5.383251442	8.832941679	2.399700919	5.764366588
8.45823542	3.234565264	4.092074343	2.668446913	14.36680197	1.361033967	1.995941038	10.58256783	8.304422132	10.83294168
7.203802606	11.72463149	3.514847255	8.499679556	14.24375134	14.61674856	8.583422346	2.727835932	5.254646443	2.50737022
1.59089938	10.22409742	9.79299295	4.047639393	9.307199316	9.737876522	11.98355052	13.13843196	7.484939116	1.555436872
6.68980987	2.449262978	12.00491348	14.40226447	10.3193762	11.34778893	12.60179449	6.780388806	4.545823542	14.96795557
13.08246101	10.99829096	8.316812647	8.181798761	5.061525315	4.182653279	8.983336894	10.75005341	7.963469344	2.732963042
13.26062807	6.913693655	9.042298654	9.114932707	3.350352489	2.797479171	14.4595172	3.07904294	8.561204871	14.61845759

Customer Demand Histogram with distribution summary:

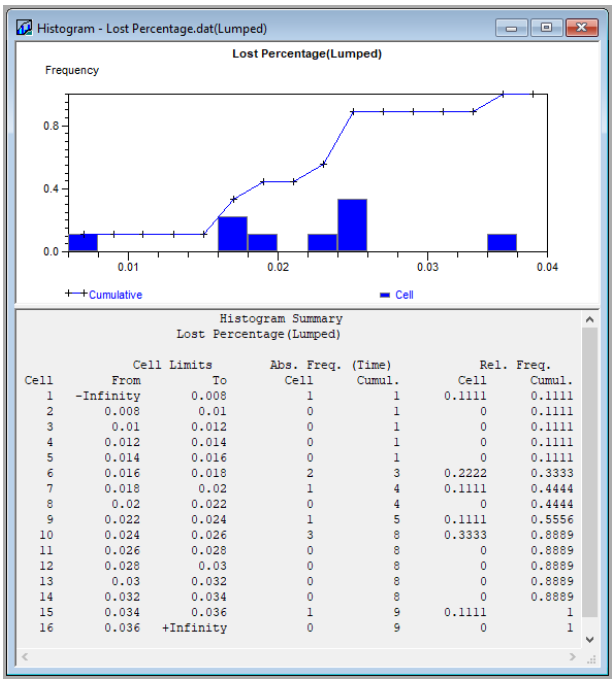


Customer Demand RNG:

15.98507645	20.30210273	1.244636372	16.2509537	3.171697134	2.27005829	18.36039308	23.0209357	15.0021363	18.90972625
6.907162694	3.316721091	24.39939573	7.555375835	10.88213752	22.50236518	6.878597369	19.93148595	22.54191717	8.458479568
16.03488266	13.28748436	4.728141118	4.954466384	8.191869869	24.02804651	15.97628712	17.47413556	21.83217872	3.568681906
21.22937712	7.137882626	3.923917356	13.98110904	18.69072542	19.53596606	9.239265114	11.93026521	14.89739677	13.55043184
6.956968902	4.665150914	6.999450667	6.389324625	22.73235267	9.097903378	7.044129765	12.40195929	15.74263741	4.466658528
23.0773339	11.18610187	1.34644612	21.985992	2.957090976	14.61174352	22.22403638	20.81041902	5.350718711	13.12561419
4.790398877	8.666493728	18.33988464	22.81218909	12.73815119	21.48207038	10.02957244	17.00244148	15.36469619	19.05401776
14.52311777	1.092287973	12.23862423	19.44294565	4.280617695	17.28077029	7.146671957	24.72093875	17.17529832	16.20920438
18.47318949	15.81661428	15.13763848	17.14160588	5.169072542	17.14819788	22.49650563	10.1797235	1.197759941	18.17142247
2.585009308	22.64519181	10.70854823	13.62294382	20.0647908	1.670918912	22.59245582	1.002929777	19.05987732	6.575365459
20.69103061	8.405011139	13.49256874	4.179540391	6.338053529	17.00170904	6.195226905	9.269295328	21.4593646	12.51988281
19.57478561	24.75389874	12.49131748	9.914578692	20.36655782	2.956358531	7.006775109	2.415082247	8.454817347	4.71642201
17.71510971	14.95818964	1.799829096	12.83117161	19.25690481	6.852961821	19.16608173	9.753440962	12.91906491	14.12540056
2.437788018	5.423230689	21.04406873	5.538956877	14.73772393	12.82677694	20.29184851	8.344218268	1.915555284	24.81322672
2.253212073	11.69954527	20.35190893	15.31562243	15.97701956	20.3877987	14.82122257	11.98007141	8.751457259	12.81066317
11.10187078	4.719351787	24.63963744	22.27384259	2.067171239	9.95413068	8.397686697	7.028015992	4.445417646	22.6964629
5.286996063	7.027283547	3.925382244	15.39399396	8.938230537	21.13122959	4.049165319	14.88201544	13.37537767	15.66280099
17.81545457	16.73729667	20.45884579	10.16580706	19.43122654	5.462782678	2.921933653	20.7752617	5.839991455	2.824518571
6.918881802	20.97814875	11.37946715	7.583208716	5.308236946	15.42402417	4.302591021	24.69823298	24.29905087	5.503799554
11.49446089	12.5711539	17.68727683	6.256019776	1.925809503	7.397900327	11.6966155	2.180700095	4.029389325	20.25083163
14.41691336	9.851588488	6.74016541	3.291817988	13.58412427	14.0748619	4.879024628	24.50193793	22.93597217	7.498245186
12.30674154	11.42268136	19.72347179	20.98840297	13.35560167	3.789880062	9.819360942	23.9086581	4.579454939	7.331247902
21.83217872	4.89147618	1.358165227	9.44288461	21.46156194	18.42411573	18.98590045	23.4398938	14.19058809	21.99478133
4.898800623	3.015686514	13.93203528	20.11899167	20.53941465	22.98138371	2.609912412	24.66307566	10.28006836	10.31009857
3.09479049	1.702414014	7.716513565	16.21140172	18.96832179	22.43351543	11.46223334	2.217322306	12.08261361	1.114261299
2.711722159	3.932706687	4.206640828	21.93765069	2.001251259	19.3096408	7.071962645	8.147923215	17.55177465	6.278725547
21.82045961	1.536881619	21.77797784	12.55504013	12.70226142	13.90273751	20.12558367	11.72664571	18.9038667	1.073976867
6.138096255	2.589403974	8.518539995	22.87371441	9.422376171	2.825983459	1.774193548	12.50230415	14.45133824	11.66438795
20.45225379	12.15439314	10.98248238	3.991302225	22.57780694	15.68843654	16.63109226	16.34324168	23.496292	1.440198981
10.32474746	6.143223365	3.614825892	2.026886807	17.47193823	1.618915372	22.17203284	4.205175939	3.006164739	3.978118229
4.860713523	22.03799554	15.59761345	20.57090976	9.91604358	13.41492965	3.31818598	11.39338359	8.846675008	2.348429823
11.26227607	22.21085238	3.865321818	20.63756218	9.397473067	21.03308206	18.9470809	15.04901273	20.30869472	2.535935545
15.9345378	13.61708426	13.05310221	19.83993042	24.5429548	18.20145268	17.05298013	11.6270333	10.67851802	16.72264779
14.88421278	7.587603381	23.10150456	24.55394147	17.62575152	17.88796655	7.357615894	6.105868709	18.61162145	20.17538987
8.172826319	15.48481704	1.292977691	20.81481368	18.87969604	24.37595752	16.06930754	6.682302316	11.04547258	5.493545335
1.157475509	23.96725364	15.46137883	21.7010712	23.34907071	9.699240089	3.578203681	10.69829402	12.41880551	5.973296304
19.28400525	1.613055818	13.11389508	12.94689779	1.039551988	6.193762017	9.816431166	3.554765465	2.927060762	19.81868954
11.1765801	24.65794855	11.23664052	10.54887539	3.121158483	6.895443587	12.04379406	4.362651448	12.58287301	18.97125156
6.773125401	21.57875301	13.51161229	24.09543138	22.91912595	1.55958739	23.80172124	12.06942961	9.820093387	22.29801325
21.25867489	16.30442213	15.71407208	19.58577227	2.454634236	8.035126804	15.79317606	5.827539903	11.39558092	8.884762108

Appendix D

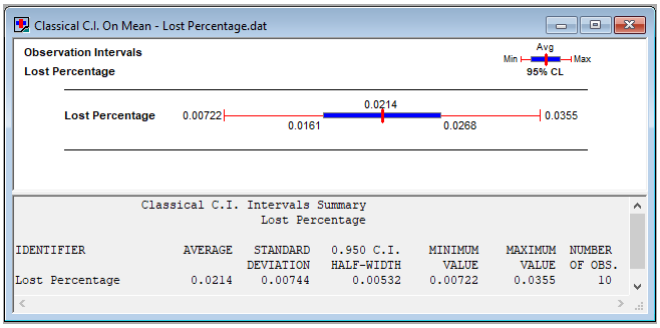
Histogram for Lost Percentage:



Histogram Summary
Lost Percentage (Lumped)

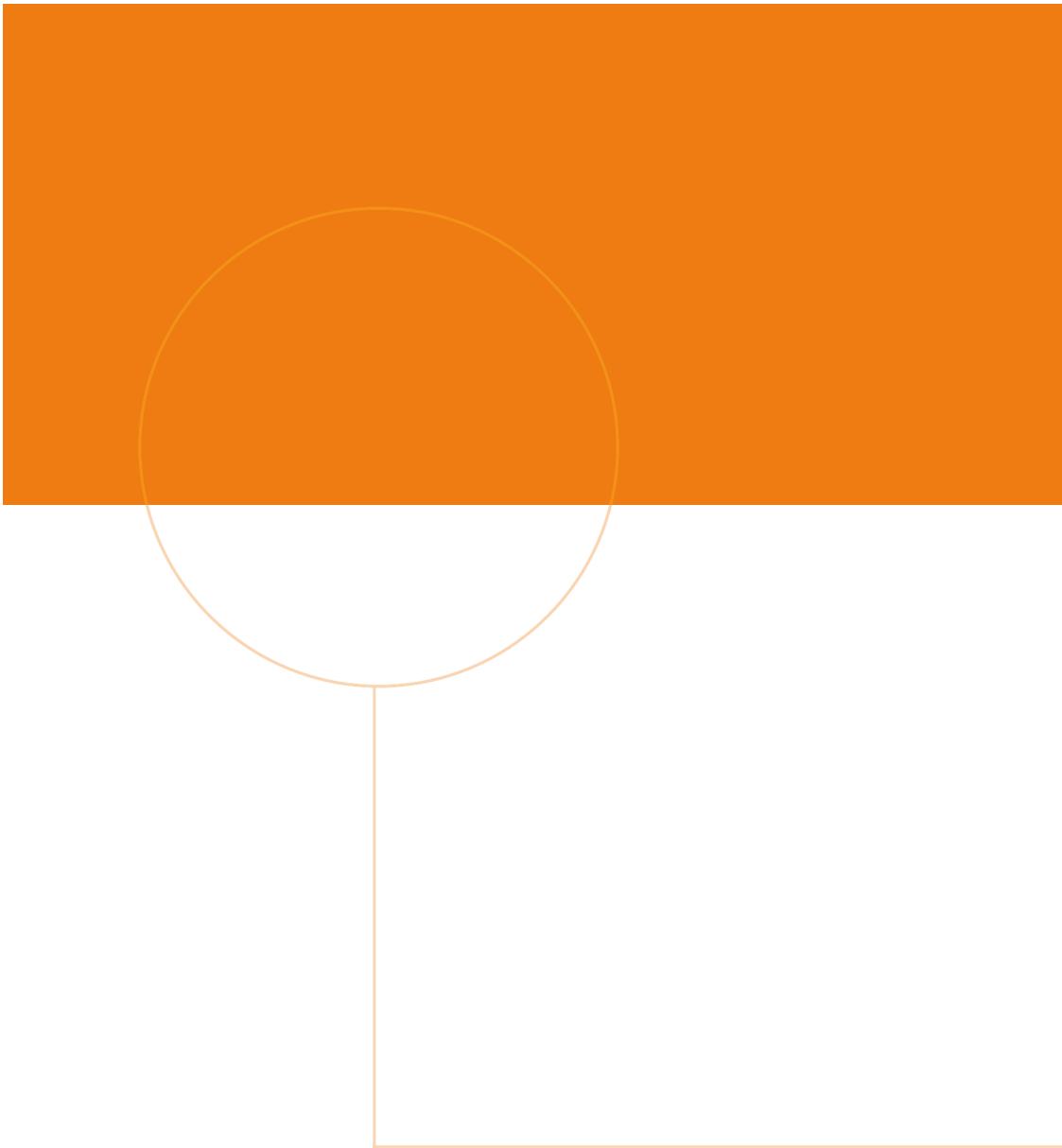
Cell	Cell Limits From	To	Abs. Freq. (Time) Cell	Cumul.	Rel. Freq. Cell	Cumul.
1	-Infinity	0.008	1	1	0.1111	0.1111
2	0.008	0.01	0	1	0	0.1111
3	0.01	0.012	0	1	0	0.1111
4	0.012	0.014	0	1	0	0.1111
5	0.014	0.016	0	1	0	0.1111
6	0.016	0.018	2	3	0.2222	0.3333
7	0.018	0.02	1	4	0.1111	0.4444
8	0.02	0.022	0	4	0	0.4444
9	0.022	0.024	1	5	0.1111	0.5556
10	0.024	0.026	3	8	0.3333	0.8889
11	0.026	0.028	0	8	0	0.8889
12	0.028	0.03	0	8	0	0.8889
13	0.03	0.032	0	8	0	0.8889
14	0.032	0.034	0	8	0	0.8889
15	0.034	0.036	1	9	0.1111	1
16	0.036	+Infinity	0	9	0	1

Classical Confidence Interval On Mean for Lost Percentage:



Classical C.I. Intervals Summary
Lost Percentage

IDENTIFIER	AVERAGE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS.
Lost Percentage	0.0214	0.00744	0.00532	0.00722	0.0355	10



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