PRINCIPLES FOR INVENTORY MANAGEMENT AT THE GNT GROUP

Master's Thesis performed at the
Department of Production Economics at
Linköping Institute of Technology
at the request of the GNT Group

by

Sara Berggren & John Eriksson

Reg nr: LiTH IPE Ex arb 2004:699

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PRINCIPER FÖR LAGERSTYRNING HOS GNT GROUP

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Title **Principles for inventory management at the GNT Group**

Titel Principer för lagerstyrning hos GNT Group

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Abstract
Sammanfattning

GNT Group is a Nordic/Baltic wholesaler that distributes products in the IT, entertainment and home electronics sector. GNT is facing problems with inaccurate inventory levels which can lead to unnecessarily high inventory carrying costs or lost sales. Currently the decisions about when and how many to order are made somewhat arbitrarily by the responsible personnel. Their decisions are based only on some brief sales history and on experience.

GNT wants to develop its ERP system to be able to support the purchaser in these and other related decisions. The purpose of this thesis is to give suggestions to what decisions the ERP system should support and how these decisions can be made.

The three main tasks in this thesis are to suggest how to calculate the optimal order quantity, how to calculate the optimal ordering point and how to decide whether it can be profitable to store an article in only one of GNT's warehouses.

The suggested solution is based on a volume value/demand frequency classification which also takes an item's life cycle characteristics into consideration. For the different classes suitable calculations and decisions are suggested concerning the three main tasks and issues related to them.

Keywords
Nyckelord

Inventory management, replenishment methods, safety stock, classification, EOQ, EOI

Everything should be made as simple as possible, but not simpler.
-Albert Einstein

Preface

This report is the result of our final thesis carried out at the GNT Group. With this work we finish our studies at Linköping Institute of Technology.

We would like to thank everybody at GNT Sweden's office at Pronova in Norrköping for their support and patience with our questions. A special thanks to our supervisors Esko Heinonen at GNT Finland and Martin West at the Department of Production Economics at Linköping Institute of Technology, for their help throughout the whole project.

We are also grateful to everyone else who has contributed with opinions regarding this report – you know who you are.

Norrköping, March 2004

Sara Berggren John Eriksson

Summary

GNT Group is a Nordic/Baltic wholesaler that distributes products in the IT, entertainment and home electronics sector. GNT is facing problems with inaccurate inventory levels, which can lead to unnecessarily high inventory carrying costs or lost sales. Currently the decisions about when and how many to order are made somewhat arbitrarily by the responsible personnel. Their decisions are based only on some brief sales history and on personal experiences.

GNT wants to develop its ERP system to be able to support the purchaser in these and other related decisions. The purpose of this thesis is to give suggestions to which decisions the ERP system should support and how these decisions can be made. Two of the main questions are as mentioned:

- How many to order each time?
- When to place an order?

An additional task is to consider the possibility to store an article in only one of GNT's warehouses and ship it to the entire market from there. This task is referred to as:

- Warehouse selection

The suggested solution presented is based on a classification. The idea is to be able to treat articles differently with the aim of focusing more on articles most likely to contribute a great deal to money saved on the improved inventory control. The fact that most of the articles in GNT's product portfolio have a short lifetime is also taken into consideration. A division of the life cycle time of a product will lead to that it is possible that it will belong to different classes in different periods of its lifetime.

The classification chosen is based on the volume value and demand frequency of the products. This will give a good starting point when deciding which products to put most effort into.

When examining the three points above it becomes clear that there are a number of additional issues involved with each of them. Examples of which are:

- Safety stock
- Quantity discounts
- Replenishment methods
- Mode of transportation
- Customer order products
- Simplified decisions for some classes

The implication of the classification idea is to focus more on certain classes and some of the decisions related to the listed points above are made only for some classes. For example the issue of customer order products. The idea behind customer order

products is that some products might be better not to keep in stock at all, but only to order them from a vendor when GNT gets an order from a customer. The calculations to support this decision are rather complicated and uncertain and therefore it is better to only make them for products that are likely to become customer order products. This implies that these calculations will only be made for products with high value and low demand frequency.

When the classification and possible safety stock and warehouse calculations are made it is then suggested that suitable products are placed together in a group. The idea is to be able to place joint orders for these products with a supplier. A minimum requirement for the products in a group is in other words that they are from the same supplier. This system will help levelling out the deliveries to GNT's warehouses, hence preventing large quantities arriving at the same time.

The suggested replenishment method is to use a combination of re-order-cycle policy, based on a periodic review of the inventory level and an ordering point system which is based on a continuous review. This method is referred to as a hybrid system and will minimize the safety stock and also take fluctuation in the demand into consideration. It will also prevent errors in the forecast to have a large effect on the inventory levels.

The results put forward in this thesis should be seen as proposals to how GNT's ERP system can be improved. Next step for GNT will be to evaluate the suggestions before any implementation is made.

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Sammanfattning

GNT Group är en nordisk/baltisk grossist som distribuerar IT-produkter. GNT har för tillfället problem med felaktiga lagernivåer, något som kan leda till onödigt höga lagerhållningskostnader eller förlorad försäljning. I dagsläget görs inköpsbesluten om hur många man ska beställa och när godtyckligt av inköparen. Beslutet grundar sig endast på viss säljhistorik och inköparens personliga erfarenheter.

GNT skulle vilja utveckla sitt affärssystem så att det stödjer inköparna i deras beslut. Syftet med denna rapport är att föreslå vilka beslut affärssystemet borde stödja och hur de kan tas. Två av huvudfrågorna är som nämnts ovan:

- Hur många ska man beställa varje gång?
- När ska man beställa?

En ytterligare uppgift för oss är att undersöka möjligheten att lagra en artikel bara i ett av GNTs lager och skicka den till hela marknaden därifrån. Denna fråga betecknas som:

- Val av lager

Den föreslagna lösningen som presenteras i rapporten är baserad på en klassificering. Idén är att kunna behandla artiklar olika i syfte att kunna fokusera mer på produkter med mest potential att spara pengar på hårdare styrning. Det tas även hänsyn till det faktum att de flesta artiklar i GNTs produktportfölj har kort livslängd. En uppdelning av en produkts livscykel gör det möjligt att en produkt tillhör olika klasser i olika perioder av dess livscykel.

Klassificeringen är baserad på produkternas volymvärde och efterfrågefrekvens. Detta ger ett bra utgångsläge när man bestämmer vilka produkter som ska satsas mest resurser på.

När man undersöker de tre nämnda punkterna ovan blir det uppenbart att i var och en ingår det ytterligare frågeställningar. Exempel på sådana är:

- Säkerhetslager
- Kvantitetsrabatter
- Återfyllnadsmetoder
- Transportslag från leverantör
- Kundorderprodukter
- Förenklade beslut för vissa klasser

I praktiken innebär beslutet om klassificering att man fokuserar mer på vissa klasser dvs. att vissa beslut relaterade till exemplen ovan bara görs för vissa klasser. Ett exempel är beslutet om kundorderprodukter. Tanken bakom detta är att det i vissa fall kanske är bättre att inte ha en produkt i lager över huvud taget, och istället beställa den

från sin leverantör när GNT får en order från en kund. Uträkningarna som är tänkta att stödja detta beslut är ganska komplicerade och osäkra och det är därför bättre att bara utföra dem på produkter som är sannolika att kunna bli kundorderprodukter. I detta fall innebär det att uträkningarna bara kommer att göras för produkter med högt värde och låg efterfrågefrekvens.

Efter att klassificeringen och eventuella uträkningar angående säkerhetslager och val av lager har genomförts placeras lämpliga produkter tillsammans i en grupp. Idén är att göra det möjligt att placera gemensamma order för dessa produkter. Eftersom en gemensam order måste placeras hos en leverantör är minimikravet att alla produkter i en grupp kommer från samma leverantör. En fördel med detta system är att det hjälper till att jämna ut inleveranserna till GNTs lager genom att sprida dem över tiden.

Den föreslagna metoden för lageråterfyllnad är att använda en kombination av ett periodbeställningssystem och ett beställningspunktssystem ett s.k. hybridsystem. Denna metod kommer att minimera säkerhetslagret och också ta hänsyn till fluktuationer i efterfrågan. Den motverkar också att felaktiga efterfrågeprognoser får stor effekt på lagernivåerna.

Resultaten i denna rapport bör ses som förslag på hur GNTs affärssystem kan förbättras. Innan de kan implementeras bör emellertid utvärderingar av dem göras.

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1 Introduction

This chapter contains background and purpose of the thesis. Furthermore the restrictions of our work are presented followed by reading directions to make the reading easier.

1.1 Background

GNT Group is a Nordic/Baltic wholesaler that distributes products in the IT, entertainment and home electronics sector. The company has four warehouses located in the Baltic's and in Tampere, Finland. A fifth warehouse is to be built in Norrköping, Sweden and is estimated to be in use by the end of 2004. GNT is facing problems with inaccurate inventory levels, which in turn lead to either high inventory carrying costs or lost sales when stocking out. Today, the purchasing decisions are made somewhat arbitrarily based on some brief sales history and on the purchaser's personal experience.

1.2 Purpose

GNT wants to develop its ERP system to be able to support the purchasers in their decisions. The purpose of this thesis is to give suggestions to what decisions the ERP system should support and how the decisions can be made.

1.3 Restrictions

Forecasting theories will not be discussed thoroughly in this thesis since that is carried out in a parallel project. There will not be any evaluations of the suggestions put forward and implementation and programming issues will not be addressed in this thesis.

1.4 Reading directions

A short description of the chapters' content in the report is presented below.

Chapter 1 - Introduction: This chapter gives an introduction to the work including a brief background to the thesis, purpose and restrictions of our work. This chapter is recommended to every reader who intends to read more than the abstract.

Chapter 2 - Problem background: The problem background consists of a presentation of the company and a short description of the business activities related to our task. This chapter is mainly intended for the reader unfamiliar with GNT and its business.

Chapter 3 - Problem description: In this chapter we outline the purpose and restrictions of the thesis in more detail and the information included in this chapter will hopefully help the reader understand the reason for the theories described in the frame of reference.

Chapter 4 - Frame of reference: The frame of reference is an important part in the report since it contains all the relevant theories that are the foundation for our continuous work. The chapter will help the reader to understand recommendations in following chapters. It is also possible for the reader to only read parts of particular interest.

Chapter 5 - Methodology: In this chapter we present the sequence of work that we have gone through during the project. The chapter also contains our possible sources of errors.

Chapter 6 – Suggestions for improvements: In this chapter we present our suggestions for improvements of GNT’s inventory control. The theories presented in the frame of reference are adapted to fit GNT. This chapter is the most important part for GNT to read.

Chapter 7 – Reflections: This chapter contains some of our reflections on the report and we also give recommendations for continuous work.

2 Problem background

This chapter contains a presentation of the company and its business activities, followed by a description of the current situation related to our specific task.

2.1 Presentation of GNT

GNT in its own words:
GNT delivers IT, entertainment and consumer electronic goods and services, which improve customers' competitiveness in the whole value chain. Our aim is to make our customers more successful and constantly develop profitable, high quality operations. World-class logistic services, customer oriented, effective and friendly customer service and electronic services are our main focus areas.

GNT Group is a Nordic/Baltic wholesaler that distributes computers and computer components. The GNT Group includes the companies GNT Finland Oy, GNT Sweden AB, GNT Estonia AS, GNT Latvia SIA and GNT Lithuania UAB. The GNT headquarter is located in Tampere, Finland together with the Finnish subsidiary. GNT Sweden AB is located in Norrköping.

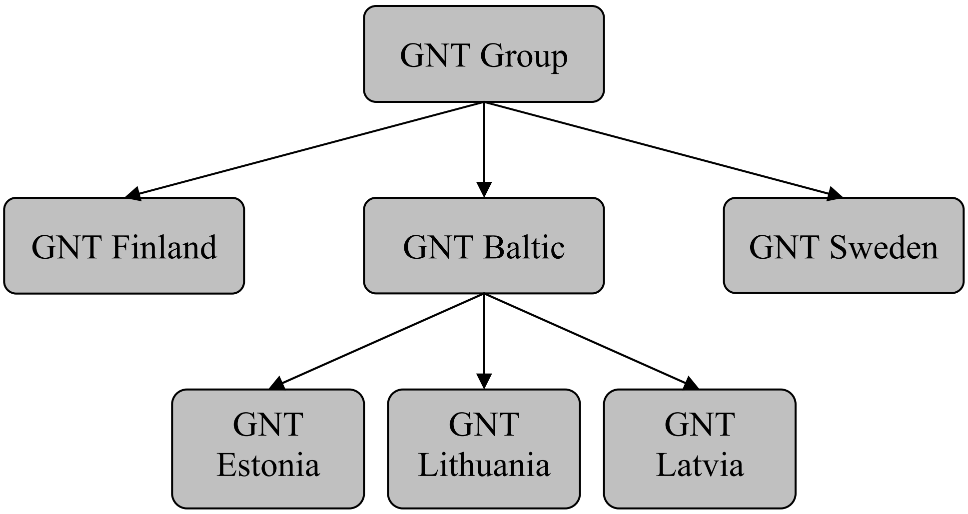

Figure 2.1 – Organisation chart

The business activities in Finland started in 1995, and the company changed owners in February 2000. In March the same year the company changed its name from GNT Finland Ltd to GNT Finland Oy. In November 2000 GNT started to expand to the Baltic countries and in the spring of 2001 GNT bought Gametech's wholesale business in the game market. During the spring of 2003, GNT established a full scale sales operation on the Swedish market. At the moment GNT has four warehouses, located in Finland, Estonia, Latvia and Lithuania. A fifth warehouse will be built in Sweden and is planned to be operating in the end of 2004. Until the Swedish warehouse is built, customers in Sweden, Norway and Denmark get their products from the Finnish warehouse.

GNT represents 70 vendors including Microsoft, IBM, HP and Canon. They are located all around the world although most of them have their production plants in Asia. Some of the products they supply are computers, printers, scanners, cameras and TV screens.

Due to the location of GNT's warehouses, most of the customers are located in the Nordic countries. GNT does not sell directly to end customer, but only to different kinds of retailers, e.g. Tieto Enator, Dustin, Mentor and Athea. GNT's foremost competitors are Scribona, Ingram Micro, Tech Data and Santech Micro Group.

There are on average between 40,000 and 50,000 SKUs in GNT's warehouses. The total value of all the products is on average approximately 30 m€.

The warehouse in Tampere, Finland is fully automated. It is 21 metres high and can hold up to 13,000 pallets at any time. The automatic cranes are able to handle 2,000 boxes and 180 pallets every hour and the warehouse is operating 24 hours a day. The planned Swedish warehouse will also be fully automated. It will be around 35 metres high and will be built in modules, which enables the company to expand the warehouse when needed. The warehouses in Estonia, Lithuania and Latvia are manual and represent a smaller part of GNT's total turnover.

GNT Finland has approximately 250 employees, GNT Baltic 150 in total and the Swedish sales office approximately 65. When the Swedish warehouse is operating the number of employees in Sweden will be about 150. In year 2002, the turnover for the GNT Group was €514.6 million, of which GNT Finland contributed with €354.8 million or almost 70%. The estimated turnover for 2003 is €600 million.

GNT has a 24 hours delivery policy for products that are kept in stock. In addition to reliable and fast deliveries and competitive prices, GNT focuses on offering partners and customers value adding services and additional profits. One important step in achieving this is the development of e-commerce which is one of the strategic areas GNT puts efforts into. The share of sales through e-commerce is currently around 65% and this is expected to grow even more in the future. One example of an offered service is something called WebINservice, where the products are sent directly to the end customer without passing through the retailer.

2.1.1 Sales organisation

GNT's policy is to have 2/3 of the employees involved in sales, i.e. to have a regular contact with the customers as this is an important part of GNT's business concept. Each customer has a dedicated sales person at GNT which establishes a long term trust. The sales personnel are divided between account sales, product sales and after sales.

Account sales
The account sales personnel have between 5 and 25 customers from whom they take orders and answer any questions their customers might have.

Product sales
The product sales personnel are specialized in one particular product group each and their task is to maximize the sales of that group. They also serve as experts to whom the account sales personnel can direct customer questions if necessary.

After sales
The after sales personnel handle everything that happens after an order has been placed. This could for example be problems with shipping, wrong items in shipments etc.

2.1.2 The Sales process

The customer has two options when placing an order. Either he/she places it over the phone or through GNTNet which is GNT's web based ordering system. When ordered through GNTNet, the customer searches GNT's product database and adds the products and quantities wanted. When handled over the phone the entering of the information is made by the sales person. Either way, the order is then handled by the account sales person dedicated to that specific customer. A confirmation is sent to the customer with the estimated delivery time. If everything is in stock and the order is placed before 2pm, next day delivery is promised. If some of the items in an order are not currently in stock a back log is created manually and an order is placed to the supplier of the missing items.

The ordering decision is made continuously when the system notifies the responsible person that the inventory level is too low. The decision of how many units and when to order is made somewhat arbitrary based on the sales person's experience and some brief sales history available in an Excel sheet for most SKUs. GNT also uses a kind of bonus system to push its sales personnel into making the supposedly correct decision. The basic idea is the closer they come to the optimal quantity, ordering time etc. based on criteria decided by a manager, the more bonus they get. However the issue concerning arbitrary ordering decisions remains as the bonus system criteria depend on the manager's subjectivity. Currently each individual country sales office is responsible for the replenishment of its own warehouse.

Transportation
The average transportation time from a vendor to one of GNT's warehouses is two weeks and is usually handled by the vendor or by a transportation company engaged by the vendor. For the transports between GNT's Finnish warehouse and its customers, more than 20 transportation companies are used. The customers can decide which company they prefer for each individual order. If they choose not to, GNT's ERP system decides the best forwarder based on delivery cost optimization.

Goods arrival

When the products arrive to the warehouse in Finland, everything is checked to make sure that every order is correct. This is mainly done by checking the weight of the pallets. The goods are then sent into the automatic warehouse and at the same time registered in the computer system. If there is a customer order on the arriving products they are sent directly to the outgoing dock without entering the warehouse.

3 Problem description

This chapter starts with a discussion about the main issue. We then outline the purpose of the study and the issues GNT wants to have evaluated. In the end of the chapter we elucidate the restrictions of our work and a summary of the key questions is listed. From these questions, our selection of necessary theory is made which is presented in the next chapter.

3.1 Inaccurate inventory levels

Having inaccurate inventory levels is a big problem for companies everywhere. This is especially true for a wholesaler like GNT as the business idea is to have warehouses. If the inventory levels are consistently too high, the capital costs become high and the obsolescence considerable. The opposite is having too low inventory levels, which lead to a low service level and lost sales when stocking out.

Inaccurate inventory levels depend on a number of problems. First there is the issue of what quantity to order every time. The next question is when to place an order. Both these issues lead to the problems mentioned above. Ordering too many, too early leads to high levels of inventory and ordering too few, too late leads to the opposite scenario. As described in the problem background GNT's personnel make these decisions somewhat arbitrarily. All they have to base their decision on is some brief sales history and their own experience.

3.2 Purpose of study

The purpose of the thesis is to give GNT suggestions to improvements of its inventory control system that will make the inventory levels more accurate and therefore more cost-effective. In practice, GNT wants to develop its ERP system to contain support tools that will help the personnel in making the optimal ordering decisions. To do this there are a large number of issues to take into consideration. The three main tasks are described below.

3.2.1 Calculate the optimal order quantity

As mentioned above one of the key issues is to decide the optimal order quantity. Instead of having this as a subjective decision, GNT wishes to base it more on facts and figures.

3.2.2 Calculate the optimal ordering point

In the discussion above the time of placing an order is described to have a big impact on the inventory levels. Since this decision is made in the same way as the order quantity decision, the same solution is wanted – to base it more on facts than it is today.

3.2.3 Warehouse selection

Another issue that has to be taken into consideration when a company has more than one warehouse is where the ordered products should be kept. When the product is ordered from the supplier, the decision where to ship the products must be made. The basic decision concerns weather the product should be kept in only one warehouse or in every warehouse. GNT wants to investigate for which products it is most cost-effective to store in only one warehouse and for which it will be better to have in every warehouse. Due to inbound and outbound transportation costs as well as the customer service aspect, this decision has to be made for each product and should also be based on facts and calculated more or less automatically.

3.3 Mode of procedure

In the work of finding possible suggestions to solve the above mentioned problems we will explore the contemporary theories concerning these issues in the next chapter. We will then discuss how these theories can be adjusted to work for GNT in the best possible way. Finally, our own reflections and recommendations for continuous work are presented in the last chapter of the thesis.

3.4 Restrictions

Although our main focus is to find possible solutions for the three key questions mentioned above, we will not perform any computer programming.

We will also only handle the sales forecast theory briefly as this work is carried out by doctoral students in Finland. We will however use forecasted demand as an important part in our discussions.

There will not be any implementation considerations in this thesis.

There will not be any company evaluation of our results in this thesis and therefore no information about the decision on whether how much of it will be used in the development of the software. This evaluation will be done after the completion of the thesis.

3.5 Summary

The key questions to be treated are accordingly:

Order quantity calculation

Ordering point calculation

Warehouse selection

4 Frame of reference

This chapter contains theories that constitute the foundation of our suggested solutions. The theories put forward are all in some way related to our task. This will enable the reader to get a comprehensive understanding of the thesis.

Contents

- Total cost model
- Economic Order Quantity
- Economic Order Interval
- Safety stock
- Replenishment methods
- Classification
- Product life cycle

4.1 Total Cost model

An analysis of the total costs is a way to find out the optimal balance between high customer service and low logistics costs (Persson and Virum, 1998). In the total cost model created by Lambert et al (1998) there are six main cost categories. The model is presented on the next page in figure 4.1. As seen in the figure, the different costs are connected with each other and when analysing what consequences different changes have to the total cost it is important to have an understanding of how they interact with each other. The basic idea of the model is to minimize the total cost instead of minimizing each cost individually. If the latter is done there is a big risk of sub optimization. For example, to understand the real value of air freight, the extra cost in transporting by air must be considered in relation to the cost savings in storage costs it leads to. (Persson and Virum, 1998)

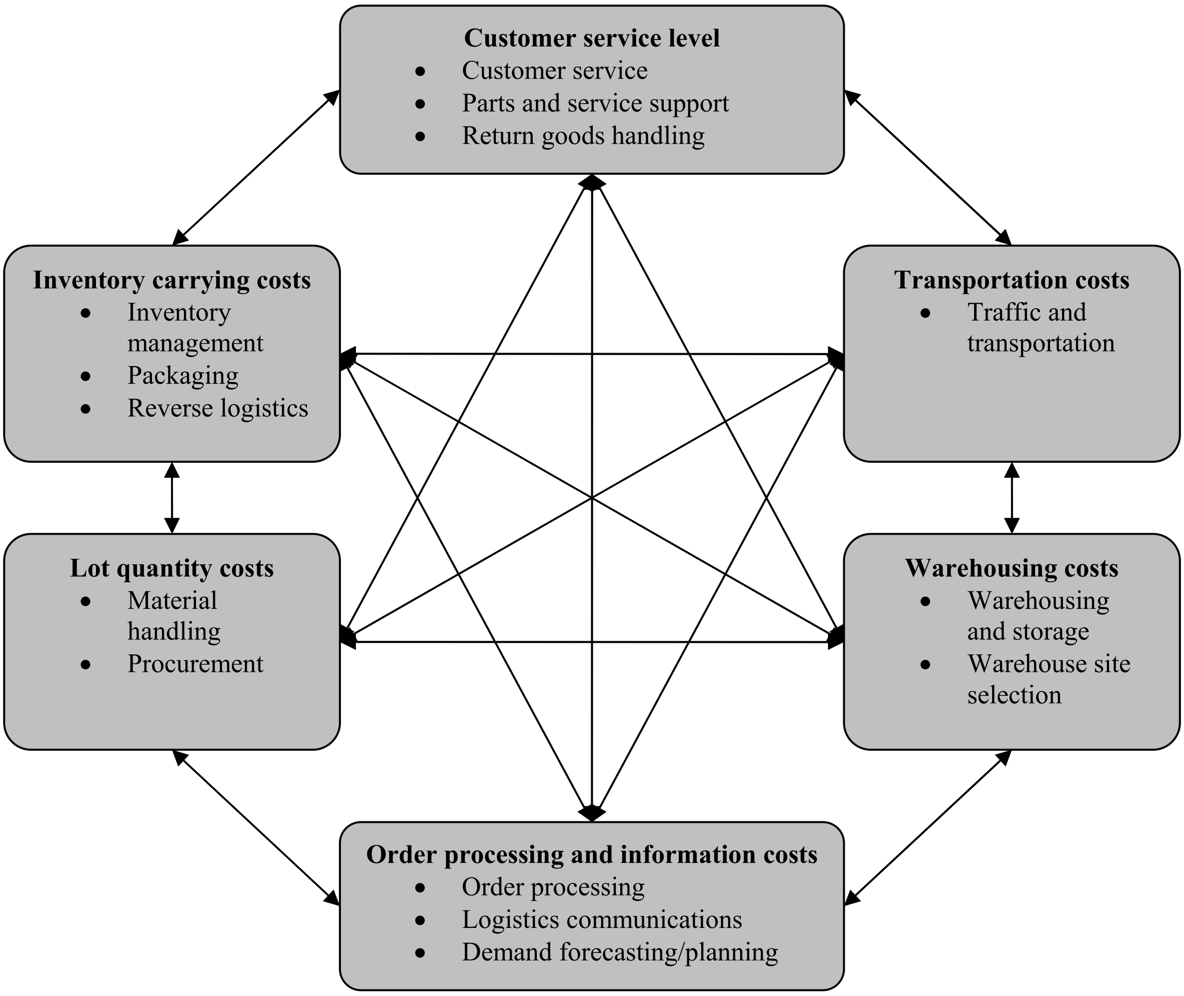

Figure 4.1 – The total cost model (Lambert et. al, 1998)

4.1.1 Customer Service level

Historically the ability for a company to compete on the market has had a lot to do with the product and its quality and features (Mattsson, 2002). This has changed and offering a quality, high-tech product is no longer enough to be competitive. The company also needs to offer a high level of customer service. This is illustrated in figure 4.2 on the next page.

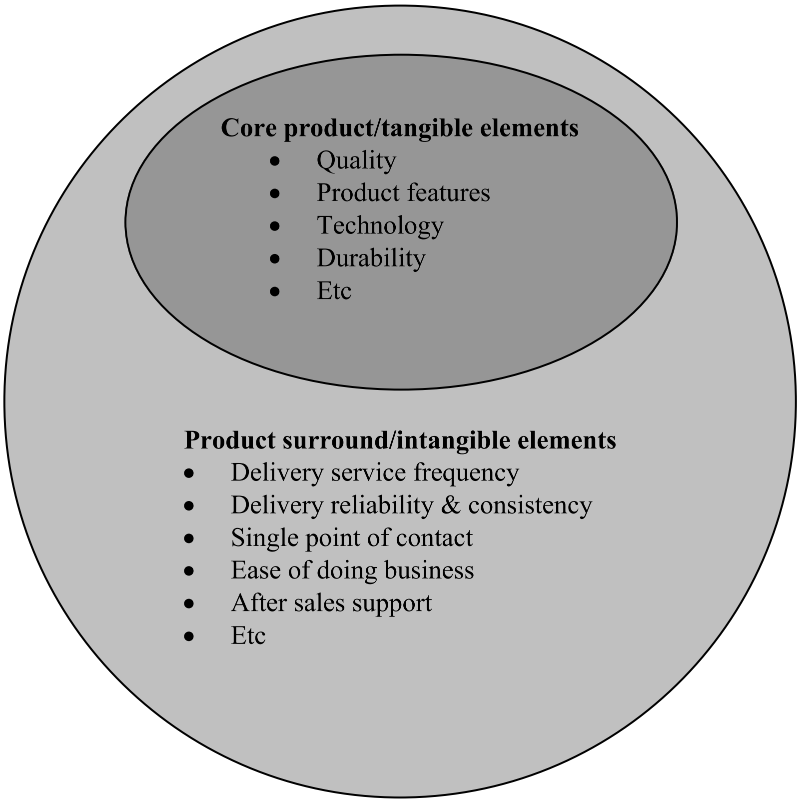

Figure 4.2 – Using service to augment the core product (Christopher, 1992)

Delivery service is one of the elements of Customer service. A known expression is the seven R's – delivering the right product in the right quantity, in the right condition, at the right place, at the right time, for the right customer at the right cost. According to Persson & Virum (1998) one of the most important logistics tasks is to develop the delivery service so that the customers feel that they are not only getting the right product, but they are also experiencing an added value by ordering from a special supplier.

Persson & Virum (1998) use the seven R's above as a starting point when they define delivery service. This definition can vary slightly between different branches of trade and different companies depending on the characteristics.

The different elements of delivery service according to the authors above are:

Level of service – The probability that the product is in stock when ordered
Delivery lead time – Time from placed order to delivery
Delivery reliability – Trustworthiness of the delivery time
Delivery certainty – The right product in the right quantity without damages
Information – Exchange of information in both directions
Customer adjustment – Ability to fulfil the customers' wishes
Flexibility – Ability to adapt to changed conditions

The delivery lead time is the most common element. It is important that this time is not too long and that the promised delivery lead time is kept.

One important thing to keep in mind is that there is a difference between actual service level and perceived service level by the customer. For example, it does not help to reduce the lead time from eight to four days if the customer demands a lead time of three days. The customer will neither acknowledge if the lead time is reduced to three days as this is considered normal from the customer's points of view (Persson and Virum, 1998). Looking at it the other way around it can be considered unnecessary to have a higher service level than what is expected by the customer.

According to Lambert et al (1998) the cost trade-off associated with having different customer service levels for different products is the cost of lost sales. The cost of lost sales includes not only the lost contribution of the current sale, but also the potential future sales to the customer and to other customers due to word-of-mouth negative publicity from former customers. Therefore it is no surprise that the true cost of customer service is extremely difficult to measure.

4.1.2 Transportation costs

In general, the transportation costs can be divided between fixed and variable costs. This division can sometimes vary. Usually terminal costs, equipment costs and administration costs are considered to be fixed. Fuel, labour and handling costs are typically considered to be variable. However, if looking at them over a longer period of time all costs can be considered to be variable.

Another way to divide transportation costs is the way Lumsden (1998) does it. He uses the terms actual costs and other costs. Actual costs can for example be salaries and fuel costs and other costs can for example be administration and toll costs. Therefore it is important to consider both costs when deciding how to transport the goods.

This knowledge is good to have and often necessary when deciding which transport company provider to hire if third part logistics is an option.

4.1.3 Warehousing costs

Warehousing costs are mainly fixed. Examples of costs of this kind are equipment, buildings and personnel. Since these costs are not directly influenced by fluctuations in the inventory level the costs remain the same. However, at a certain point the inventory level gets so high that it is necessary to make investments in for example a new warehouse which results in the warehousing costs making a leap to a new level where it will remain constant until any other similar change occurs.

4.1.4 Inventory carrying costs

Inventory carrying costs are in comparison to warehousing costs variable and depend mainly on the inventory level. A warehouse consists of a safety stock and a cycle stock. The inventory carrying costs can in other words be expressed as proportional to the order quantity and the size of the safety stock. The costs that are incurred by a specific inventory level are mainly due to the capital cost they cause plus insurances, markdowns of inventories (because of obsolescence, age etc) and other quantitative storage costs.

To decide the specific inventory carrying cost it is possible to use a general formula that is based on an inventory cost rate. This inventory cost rate includes the discount rate, which is the interest costs of the capital tied up and also the other costs mentioned above.

$$\textit{Inventory cost rate} = \textit{Discount rate} + \frac{\sum \textit{Other inventory carrying costs}}{\textit{Average inventory value}} \qquad (4.1)$$

where average inventory value is for the whole warehouse.

Inventory carrying costs for a product are then calculated in the following way

$$\textit{Inventory carrying cost} = \textit{Inventory cost rate} \cdot \textit{average inventory value} \qquad (4.2)$$

where the average inventory value is for the specific product.

4.1.5 Order Processing/Information Systems Costs

Order Processing/Information Systems Costs are for example order processing, distribution communications and forecasting demand. Order processing costs include order transmittal, order entry, processing the order and related internal and external costs such as notifying carriers and customers of shipping information and product availability (Lambert et al, 1998).

4.1.6 Lot Quantity Costs

For a wholesaler the major logistic lot quantity costs are due to procurement quantities. These costs include:

- Setup costs – Time required to locate a supplier and place an order
- Capacity lost due to changeover to a new supplier
- Materials handling, scheduling and expediting
- Price differentials due to buying different quantities (Investment buying)
- Order costs associated with order placement and handling

As mentioned in the introduction to the total cost model these costs must not be viewed in isolation since they also may affect many other costs. Lambert et al (1998) give the example of transportation costs rising as customers are sent partial or split shipments.

4.2 Economic Order Quantity (EOQ)

The purpose of inventory control is to minimize the total cost of keeping stock. In practice this implies that the replenishment issue is in focus. The parts that are included in the inventory control are explained in the following section.

The basic procedure when dealing with replenishment is that after a certain time, when the products in stock are out, replenishment is made with the quantity, Q. This turnover of products is called cycle stock and is shown in the figure below.

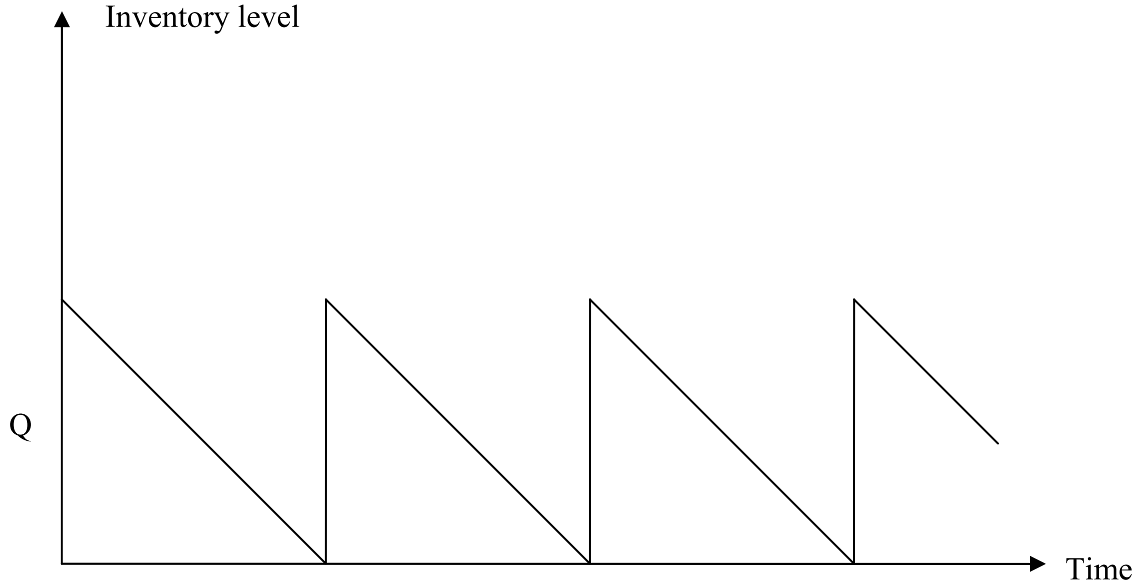

Figure 4.3 – Cycle stock (Lumsden, 1998)

The order quantity influences the size of the cycle stock and therefore also the cost of it. To know what quantity is the most optimal to order it is necessary to look at the total cost of keeping a cycle stock. The total cost is the sum of the inventory carrying cost and the ordering cost.

4.2.1 Inventory carrying costs

Ordering a large quantity with long intervals leads to a high average inventory level which in turn leads to that the inventory carrying cost becomes high. The inventory carrying cost for each product is calculated based on the average stock value of the product and the inventory cost rate.

4.2.2 Ordering cost

Placing an order is connected with different costs, e.g. administration costs and costs for receiving and controlling products. The total cost of each individual order is labelled as the ordering cost. To keep this cost to a minimum products are ordered few times in high quantities. To calculate how many orders that are placed in a period it is necessary to know the demand of that period and the quantity ordered each time.

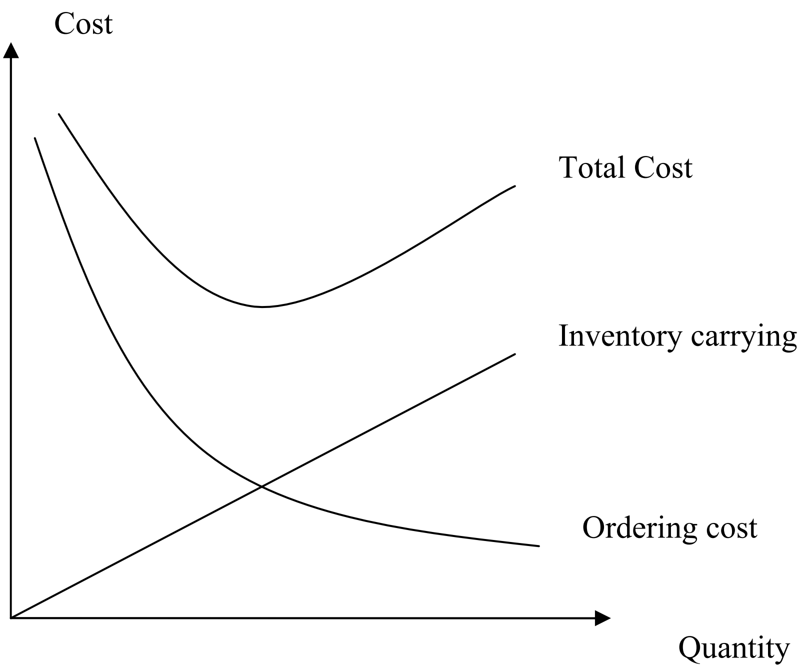

Figure 4.4 – Total cost graph (Lumsden, 1998)

As seen in figure 4.4 there is a conflict between the inventory carrying cost and the ordering cost when calculating the optimal order quantity. To optimize the total cost it is necessary to find the point of intersection between the two included costs. To do this the EOQ formula is often used.

The EOQ formula is based on the following factors:

D = Demand
S = Ordering cost
C = Purchase cost of the product
I = Inventory cost rate
Q = Order quantity

The ordering cost equation becomes:

$$OC = \frac{D}{Q} \cdot S \tag{4.3}$$

and the inventory carrying cost equation:

$$ICC = \frac{Q}{2} \cdot I \cdot C \tag{4.4}$$

Together they give the total cost equation:

$$TC = \frac{D}{Q} \cdot S + \frac{Q}{2} \cdot I \cdot C \tag{4.5}$$

To find the optimum, i.e. the minimum of the total cost equation it needs to be derived.

$$\frac{\partial TC}{\partial Q} = \frac{I \cdot C}{2} - \frac{D \cdot S}{Q^2} = 0 \Rightarrow Q = \pm\sqrt{\frac{2 \cdot D \cdot S}{I \cdot C}} \tag{4.6}$$

Since only positive order quantities can exist the optimal order quantity is:

$$Q_{opt} = \sqrt{\frac{2 \cdot D \cdot S}{I \cdot C}} \tag{4.7}$$

Restrictions of the EOQ formula

The reason that the EOQ formula is this simple is that it makes assumptions concerning the following factors:

- The demand is constant over time.
- The cost of each order is constant and independent of ordered quantity.
- The inventory cost per SKU is constant.
- Delivery of the entire quantity to the warehouse at one time.

As seen in figure 4.4 on the previous page, the angle of inclination of the total cost curve is small around the optimal quantity. This shows that the total cost will not vary much if the order quantity differs slightly from the optimum. This is also the case if the ingoing parameters are wrong. Olhager (2000) shows that an underestimate of the inventory cost with 50% leads to an increase of the total cost with only 6%.

4.3 Economic Order Interval (EOI)

Due to the restrictions in the EOQ formula it can be necessary to modify it to fit different situations. One way to modify the EOQ is to calculate the optimal time interval between orders instead of the optimal order quantity. This method is referred to as EOI, Economic Order Interval and could be modified to fit for one single SKU as well as for groups of products.

EOI is a fixed order interval system based on periodic rather than on continuous reviews of the inventory level. In an EOI system orders are placed equally spaced in time (at pre-determined points) and the order quantity is dependent upon the demand during lead time and demand until the next inventory inspection (Tersine, 1994).

4.3.1 EOI for single items

The economic order interval is just like EOQ based on minimizing the total annual cost. The connection between Q and order interval, T is

$$Q = DT \tag{4.8}$$

Replacing Q with DT in formula 4.7 will result in:

$$Q_{opt} = \sqrt{\frac{2 \cdot D \cdot S}{I \cdot C}} \Rightarrow Q = DT \Rightarrow T = \sqrt{\frac{2 \cdot S}{I \cdot C \cdot D}} \tag{4.9}$$

4.3.2 EOI for multiple items

In retailing and wholesaling, a separate order is rarely placed for each item. Frequently, a supplier provides numerous items, and it is more economical to place joint orders. When placing a joint order for a group of items, the optimal T can be calculated for the group as a whole. The total cost function will then be expressed as:

$$\mathrm{TC(T)} = \frac{S + ns}{T} + \frac{TI}{2} \sum_{i=1}^{n} \mathrm{C_i} D_i \tag{4.10}$$

where

D_i = Annual demand for item i
C_i = Purchase cost of item i
n = Total number of joint order items
S = Ordering cost for the joint order
s = Ordering cost associated with each individual item
T = Order interval in years
I = Inventory cost rate

The function is derived and gives the result:

$$\mathrm{T}^* = \sqrt{\frac{2(S + ns)}{I \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{C_i} D_i}} \tag{4.11}$$

4.4 Quantity discounts

In some cases price differentials due to buying different quantities, i.e. investment buying, can affect the optimal order quantity. In this section two kinds of quantity discounts are presented together with how the EOQ formula can be adapted to take these into consideration. Quantity discounts effect on the use of EOI is presented in section 4.4.3.

4.4.1 EOQ with discount on the entire order quantity

Olhager (2000) describes the calculations of the optimal order quantity when the discount is applied to the whole quantity:

The cost for an order quantity is:

$$\mathrm{S} + \mathrm{C_j Q} \quad \text{when} \quad \mathrm{N_{j-1}} \le \mathrm{Q} \le \mathrm{N_j}, \quad \mathrm{j} = 1,\ldots,\mathrm{J} \tag{4.12}$$

where
$\mathrm{C_j}$ = value per SKU in the order quantity interval $[\mathrm{N_{j-1}}, \mathrm{N_j}]$
$\mathrm{N_j}$ = quantity corresponding to the j : th discount borderline
$\mathrm{N_0}$ = minimum order quantity
$\mathrm{N_J}$ = maximum order quantity

Let

$$TC_{j,tot} = \frac{D}{Q} \cdot S + I \cdot C_j \frac{Q}{2} + C_j D, \quad j = 1,\ldots,J \tag{4.13}$$

$TC_{j,tot}$ *is valid for the* interval $N_{j-1} \le Q \le N_j, \quad j = 1,\ldots,J$

$$\textit{The total cost is}: TC_{tot} = C_{j,tot}, \textit{ when } N_{j-1} \le Q \le N_j,\ j = 1,\ldots,J \tag{4.14}$$

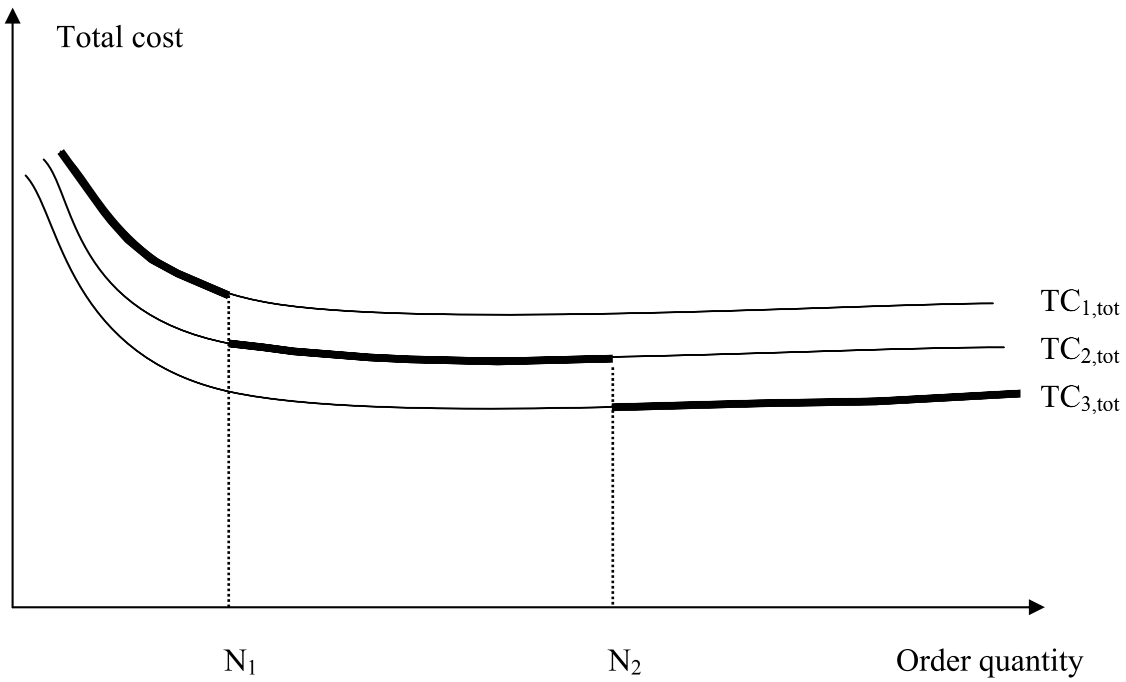

Figure 4.5 – Total cost curve with discount on entire order quantity (Olhager, 2000)

The figure shows the effect of two discount intervals with the borderlines N_1 and N_2. The wide lines represent the total cost, TC_{tot} at different order quantities and the thin lines show how $TC_{j,tot}$ looks outside its discount interval.

To find the optimal quantity each interval must be gone through. The lowest total cost in the interval [0, N_1] is found at the upper borderline. In the next interval the lowest total cost occurs in a point within the interval and in the last interval it occurs at the lower borderline. These three total costs are then compared and the lowest is chosen. In this example the optimal order quantity is N_2.

4.4.2 EOQ with incremental quantity discount

The information in the following section is taken from Tersine (1994). In a situation with incremental quantity discount, the buyer is presented with a price schedule consisting of quantity ranges such that the lower unit purchase costs only apply to the quantities in the particular discount quantity interval. The price schedule is as follows:

$$C_i = \begin{cases} C_0 & \text{for each } U_0 \text{ to } U_1 - 1 \\ C_1 & \text{for each of the next } U_1 \text{ to } U_2 - 1 \\ \ldots & \\ C_j & \text{for each of the next } U_j \text{ to } U_{j+1} \end{cases}$$

where

$U_1 \langle U_2 \langle \ldots \langle U_j$ is the sequence of integer quantities at which price breaks occur, and
$C_0 \rangle C_1 \rangle \ldots \rangle C_j$.

With the above discount schedule, the unit purchase cost is not constant for a lot size Q where $U_i \leq Q \langle U_{i+1}$. The purchase cost for a lot size of Q units is as follows:

$$M_i = P_i + C_i Q \tag{4.15}$$

where

$$P_i = \sum_{e=1}^{i} (U_e - 1)(C_{e-1} - C_e) \tag{4.16}$$

Since all units will not be purchased at the same unit purchase cost, P_i is the extra purchasing cost for the products in the C_{i-1} interval. P_i is an additional ordering cost since it is incurred each time an order is placed. The purchasing cost per unit is:

$$\frac{M_i}{Q} = \frac{P_i}{Q} + C_i \tag{4.17}$$

Thus, the total cost per year of a lot size of Q units is

TC(Q) = purchase cost + order cost + holding cost

$$= \left[C_i + \frac{P_i}{Q} \right] D + \frac{SD}{Q} + \frac{IQ}{2}\left[C_i + \frac{P_i}{Q} \right]$$

$$= C_i D + \frac{(S + P_i)D}{Q} + \frac{C_i IQ}{2} + \frac{IP_i}{2} \tag{4.18}$$

Deriving this function results in:

$$Q_i^* = \sqrt{\frac{2D\,(S + P_i)}{C_i I}} = \sqrt{\frac{2D\left[S + \sum_{e=1}^{i} (U_e - 1)\,(C_{e-1} - C_e) \right]}{C_i I}} \tag{4.19}$$

for i = 1, 2, … , j.

Since the total cost curve with incremental discounts is continuous, the minimum total cost will always occur at a valid EOQ. However, even if an EOQ is valid, it is not necessarily optimal, and larger valid EOQs are not necessarily more desirable than smaller valid EOQs. The optimum lot size is determined by calculating the total cost per year for each valid EOQ. An EOQ is valid if $U_i \;\leq\; Q_i^* \;\langle\; U_{i+1}$ (the EOQ must fall within the quantity range required for the price break.)

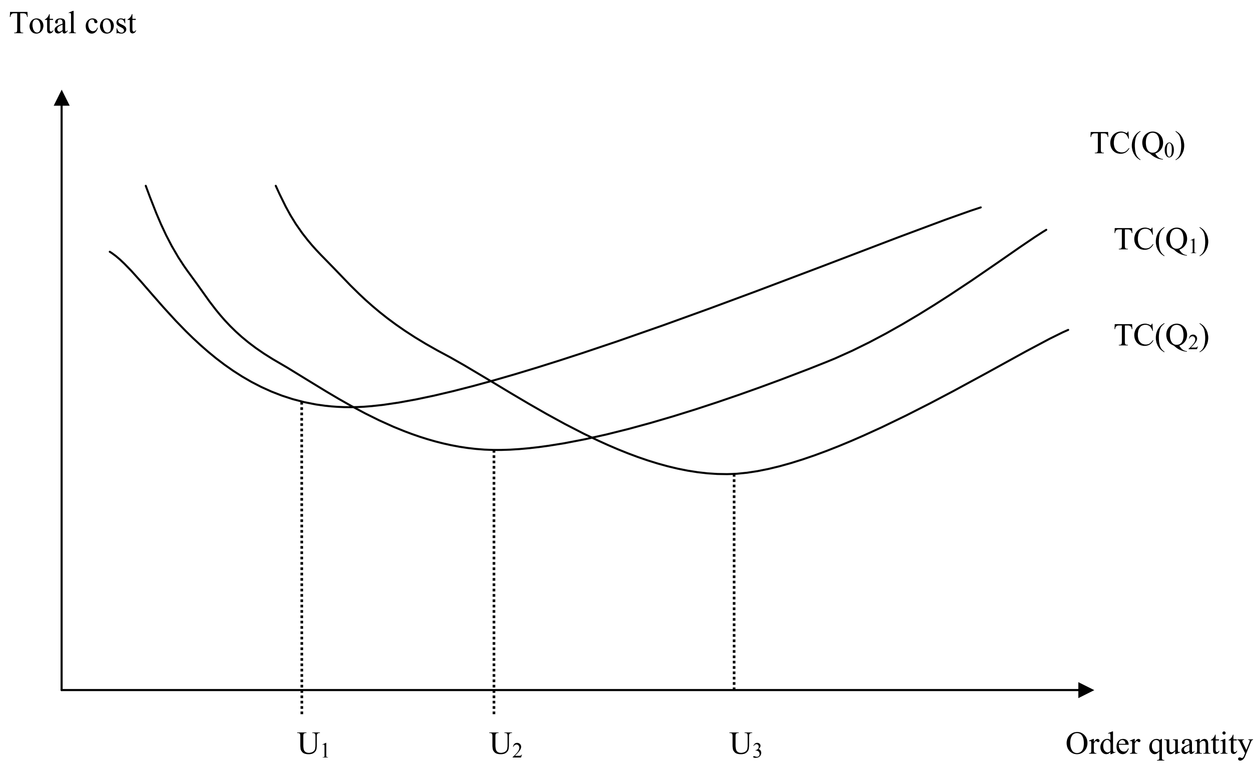

Figure 4.6 – Total cost curve with incremental quantity discount (Tersine, 1994)

The following procedure will determine the optimum lot size with incremental quantity discounts:

1. Calculate the EOQ for each unit purchase cost.
2. Determine which EOQs are valid.
3. Calculate the total cost for each valid EOQ.
4. Select the valid EOQ with the lowest total cost.

4.4.3 EOI with quantity discounts

Single EOI

Taking quantity discounts into consideration when using EOI is based on the same models as for EOQ. Either Q can be replaced by DT in the formulas 4.13 and 4.18 and all ingoing Q's be adjusted accordingly or there is a possibility to calculate EOQ and from that derive the optimal T. In the latter case the original models are used.

Multiple EOI

When calculating T in formula 4.11 the purchase cost of every ingoing item is brought into the calculation. If one or more of the ingoing items have a quantity discount it is the purchase cost that is affected. So for each of these discount items the calculation of optimal Q and therefore the purchase price has to be calculated before being put in formula 4.11. This is done in the same way as with the EOQ discount methods.

4.5 Safety stock

The main problem in inventory control is all the uncertainties that have to be considered. For example there can be fluctuations in demand, uncertain forecasts, unsure transport lead times and doubts regarding the current inventory level (Lumsden, 1998). The reason for having a safety stock is therefore to be able to guarantee a certain service level even when there are uncertainties. In other words, it is driven by the service aspect. The size of the safety stock depends on how the above mentioned uncertainties are valued. The important thing is to find the right balance between costs and service level.

When determining safety stock it is necessary to decide wanted service level for the product. Vollmann et al (1997) declare that one of the following two different methods is often used to define the service level:

SERV 1: The probability of stocking out in any given replenishment order cycle.
SERV 2: Service level measured in so-called fill rate, i.e. the percentage of demand that can be supplied directly out of the inventory.

The demand can be assumed to follow a normal distribution with an average demand and a spread in the demand, N(D, σ). Using this standard deviation of demand, σ, the safety stock calculation is:

$$SS = Z \cdot \sigma \cdot \sqrt{LT} \qquad (4.20)$$

where

SS=Safety stock
Z = Safety factor
LT = Lead time

The safety factor Z is defined by using the pre-calculated values corresponding to the determined service level for each product. This is shown in table 4.1 below.

Wanted service level (%)	Safety factor, Z
50	0,00
75	0,67
84	1,00
90	1,28
95	1,65
99	2,33
99,4	2,50
99,9	3,00
99,99	4,00

Table 4.1 – Relation between service level and safety factor (Lumsden, 1998)

All deviations towards less than estimated average demand do not need any safety stock since it is covered by the normal cycle stock, hence the service level when there is no safety stock is 50% (Lumsden, 1998). In this case the service factor is 0. An increase in service level from this minimum level leads to an increase of the service factor. An increase from a higher level leads to a substantial increase of the safety stock level compared to an increase from a lower level. When approaching a 100% service level the service factor grows towards infinity.

Apart from demand fluctuations, it is also possible that the lead time varies. This uncertainty leads to the need to increase the safety stock. The safety stock formula which takes both forecast deviation and lead time deviation into account is according to Lumsden (1998) and Olhager (2000):

$$SS = Z\sqrt{LT \cdot \sigma_D^2 + \sigma_{LT}^2 \cdot D^2} \tag{4.21}$$

It is also possible to take other factors into account. Piasecki (2003) suggests the order cycle factor. Since longer order cycles result in an inherent higher service level this factor can be used to compensate for this. The suggested formula for the order cycle factor is:

$$\textit{Order cycle factor} = \sqrt{\frac{FP}{OC}} \tag{4.22}$$

where

FP = Forecast period
OC = Order cycle time

Lumsden (1998) claims that the safety stock in short term can be optimized using calculations, but that it in the long term is better to minimize it through reducing the uncertainties.

4.5.1 Optimizing the service factor multiplier, Z

The service factor Z in the safety stock calculation is selected when the service level percentage is determined. The values of Z in table 4.1 are based on theoretical statistical applications which may not be totally compatible with real-world demand dynamics. Optimizing the Z factor can be made through a margin return analysis. To enable this, the user must have a viable mechanism for capturing and evaluating the impact of lost sales.

The following technique is based on Krupp (1997). The first step is to collect data on lost sales as varying values of k are applied to a population of control items. The collection of data is made by using data generated through a baseline of Z = 0 to determine the total value of potential lost sales through controlled experiments of recouped lost sales associated with each Z factor. A graphical model of the recouped sales versus Z is then constructed based on the data points and the mathematical relationship derived through curve-fitting techniques. As a general rule, the relationship between Z and the recouped sales is non-linear, i.e. elasticity changes along the curve. An increase of 1% in Z yields less in recouped sales at Z = 4 than at Z = 1. A graphical example of one plot of sample data is represented in figure 4.7.

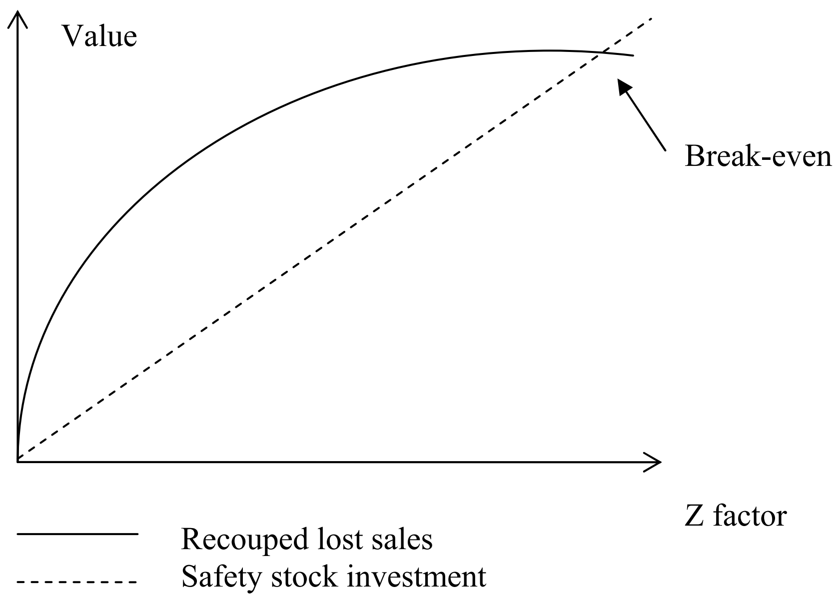

Figure 4.7 – Safety stock investment vs. recouped lost sales (Krupp, 1997)

The safety stock investment related to Z defines a linear relationship. The recouped lost sales curve for this example follows a non-linear curve typical for the relationship:

$$\textit{Lost Sales Recouped} = aZ - bZ^2, \tag{4.23}$$

where a and b are constants, a >> b

The point at which the two lines cross defines the Z level at which safety stock investment equals recouped lost sales; any Z factor less than this yields positive benefit, while investment at Z levels beyond this point yields negative returns. This initial analysis defines the relationship between gross inventory investment and gross sales, but this does not define the bottom-line financial benefit to the firm. To determine the net margin benefit that accrues from this approach, the profit realized from the recouped lost sales must be compared to the cost of carrying inventory for the related safety stock levels. This more detailed analysis defines the true cost/benefit return which can be realized from the application of increasing levels of safety stock.

The base relationship for recouped profit is defined by the equation:

$$\textit{Lost Profit Recouped} = p(aZ - bZ^2), \tag{4.24}$$

where p = profit margin, expressed as a decimal while the inventory carrying cost is defined by:

$$Cost\ of\ Carrying\ Safety\ Stock = I \cdot Value\ of\ Safety\ Stock \tag{4.25}$$

where I = Inventory cost rate

The bottom-line effect of the differential is defined by the relationship:

$$Margin\ Profit\ Impact\ (MPI) = Lost\ Profit\ Recouped\ \text{-}\ Cost\ of\ Carrying\ Safety\ Stock \tag{4.26}$$

This ultimately yields the relationship as follows:

$$MPI = p(aZ - bZ^2)\ \ I(k)(SD)(C_s)\sqrt{LT}\,, \tag{4.27}$$

where

SD = statistical deviation (i.e. σ)
C_s = standard cost per unit.

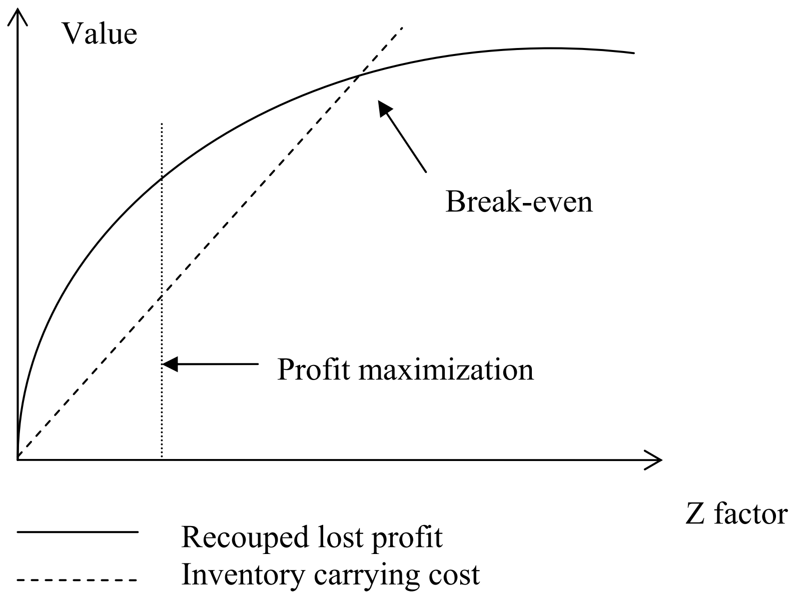

Figure 4.8 – Safety stock investment vs. recouped lost profit (Krupp, 1997)

Figure 4.8 presents a graphical representation of the above relationship. The intersection of the two curves, the break-even point, occurs at a lower Z value than that which occurs in figure 4.7. This shift is ascribed to the fact that in this specific example, the profit margin is assumed to be less than inventory carrying cost percentages. If profit percentage is greater than the inventory carrying cost factor, then the intersection would occur at a higher Z than the intersection defined by gross dollars.

The break-even point for this margin analysis can be derived by setting the equation for recouped lost profit equal to the equation for cost of carrying safety stock, and solving it for Z. If optimization, rather than maximization of the profit is wanted (without consideration to actual service performance), then the optimum point would lie at that value of Z (less than break-even) at which the maximum positive differential exists between recouped profit and inventory carrying costs. Using mathematical theory, this point can be derived by taking the first derivative of the expanded expression which correspond to marginal profit impact with respect to Z, and solving the equation for the Z value.

4.6 Replenishment methods

4.6.1 Ordering point system

One of the most common ways to replenish the warehouse is to use something called an ordering point system. This system works as when the inventory level sinks below a certain pre-defined level, called the ordering point, an order is initiated. The ordered quantity could for instance correspond to the EOQ. The products left in the warehouse are intended to cover the demand during the lead time. The lead time is the time between placed and received order. Worth noticing is that the safety stock is not supposed to be used under normal circumstances, it is what is left in the cycle stock that should last during the lead time. The safety stock is used only when the lead time is longer or if the demand is higher than forecasted.

The decision when to order is made with the rather simple formula:
Ordering point = forecasted demand during the lead time + safety stock (4.28)

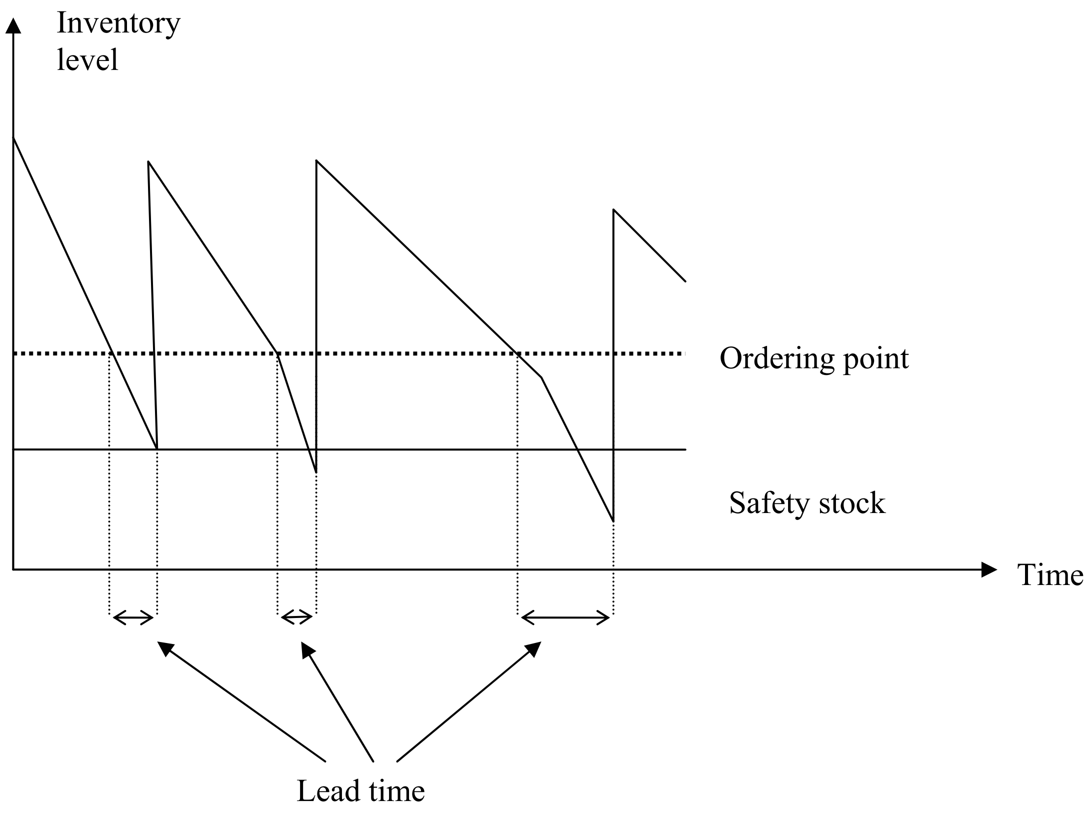

Figure 4.9 – Ordering point system (Lumsden, 1998)

4.6.2 Re-order cycle policy

Another way to replenish the warehouse is to use a re-order cycle policy with periodic review. In this method an inventory check is made at pre-defined moments, for example once a week or once a month. The time between the inspections could be the calculated EOI. When the inventory check is made the decided order quantity is the difference between the inventory level at that time and the pre-defined inventory level. The pre-defined inventory level is calculated by adding safety stock, demand during the order cycle period and demand during the lead time.

Order quantity = Pre-defined inventory level – Current inventory level (4.29)

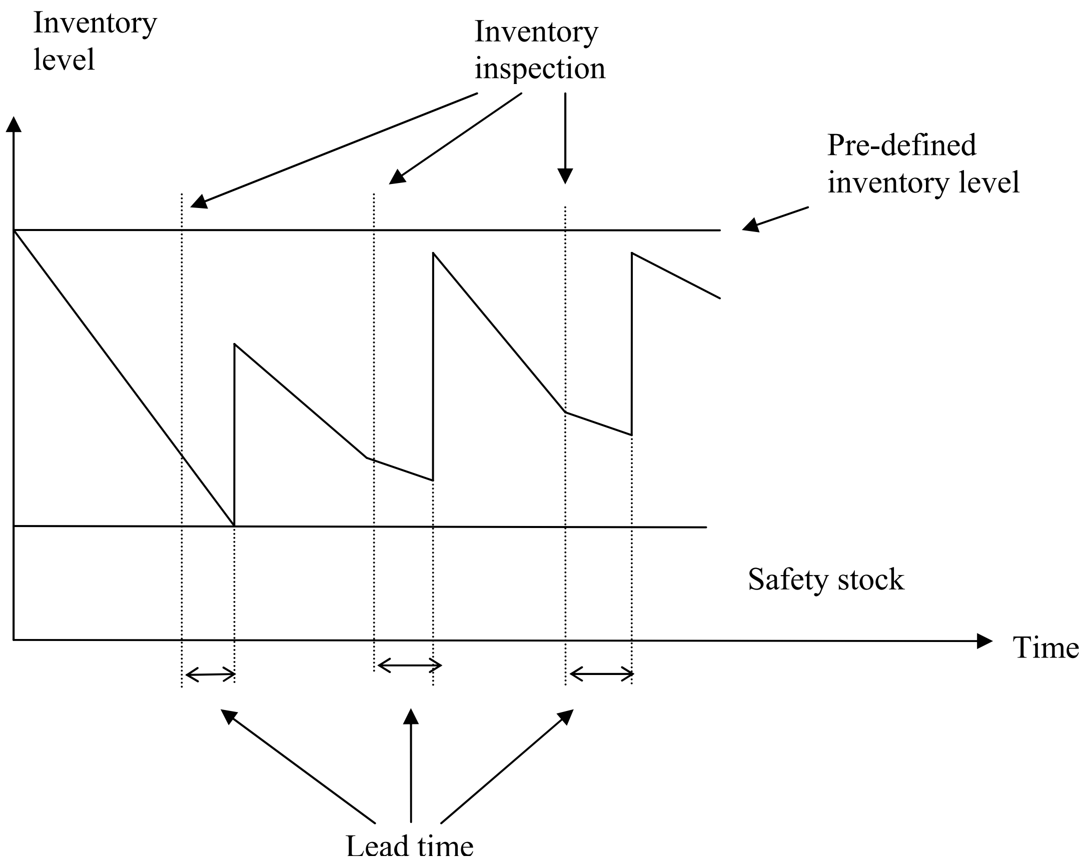

Figure 4.10 – Re-order cycle policy (Lumsden, 1998)

The advantage here is that the ordering point is known. However, the ordered quantities vary from time to time, which can lead to that order quantities that are a lot smaller than the optimal order size are ordered. This is why this method has been developed by eliminating the ability to order quantities less than a pre-defined optimum. If the optimum order quantity is not reached in an inspection, the required quantity is transferred to the next inspection. This leads to that the order cycle time and hence the time of uncertainty increase which leads to the need of a higher safety stock level (Lumsden, 1998).

4.6.3 Hybrid system

The two different replenishment methods described on the previous pages could be combined in a hybrid system. This way the advantages of having regular inspections are combined with the ordering point working as a safeguard if the demand would increase substantially between the inspections or if the previous inspection did not result in an order.

The pre-defined inventory level for each item must be large enough to satisfy demand during the subsequent order interval and also during the lead time. The amount to order of each individual item is simply the pre-defined inventory level minus the current inventory level.

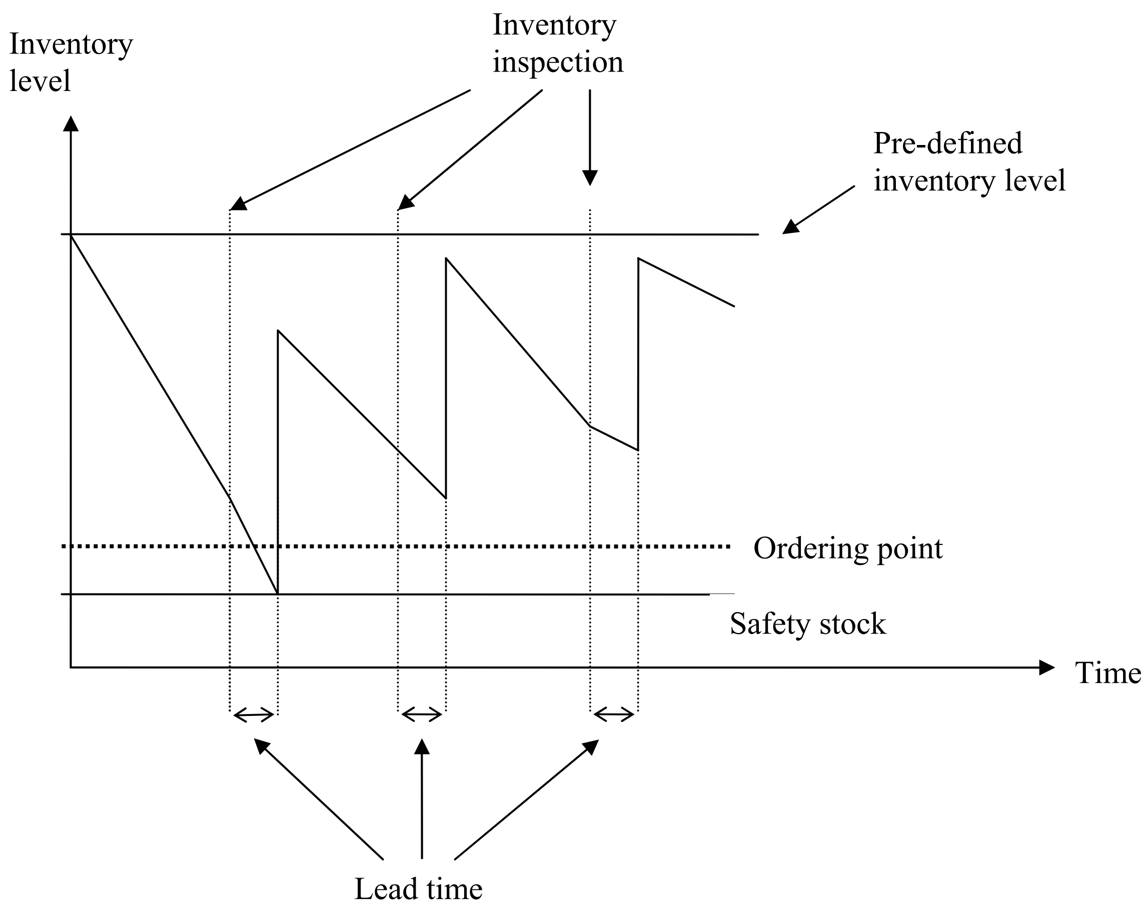

Figure 4.11 – Hybrid system (Lumsden, 1998)

4.7 Article classification

Article classification is made in order to be able to separate and group products with similarities and consequently be able to handle the products as efficiently as possible in respect of safety stock, warehouse selection, stock-taking or any other factor assessed as critical. The classification can also be applied on the company's customers. This enables the company to prioritize both products and customers in different ways.

In his study of the distribution of wealth in Milan, Villefredo Pareto found that 20 per cent of the people controlled 80 per cent of the wealth (Lambert et al 1998). This has later been applied to a lot of other areas, for example inventory management. In this area it suggests that 20 per cent of the company's customers or products account for 80 per cent of the sales or profits.

4.7.1 ABC classification

One of the most common ways to classify products is to use ABC classification. According to Olhager (2000) this is done by calculating a product's volume value by multiplying a product's demand over a year with its value. Doing this for each SKU will often reveal that a small number of the products is responsible for a big share of the turnover according to the 20/80 rule above. This way the products can be divided into three classes: A, B and C where A-products are few but of high value and C products are many but have low value. This is illustrated in figure 4.12 below and in table 4.2 on the next page.

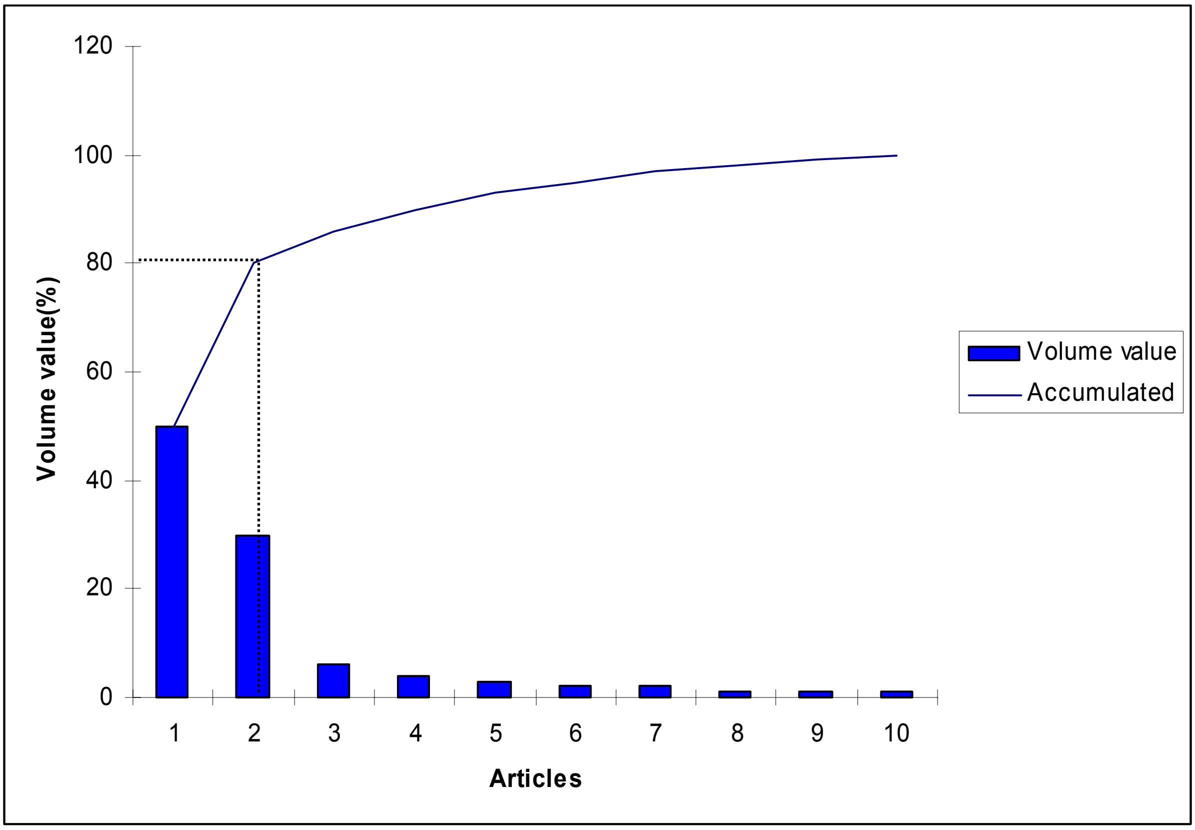

Figure 4.12 – Distribution of the volume value (Olhager, 2000)

Class	Article	Order of precedence	Volume value (year)	Accumulated % of volume value	Accumulated % of number of articles
A	34Q	1	11709.225	49.5	7.8
	19J	2	6576.09	77.3	17.9
B	42K	3	1632.195	84.2	26.3
	53O	4	922.545	88.1	34.8
	99J	5	756.96	91.3	43.1
C	31U	6	544.065	93.6	51.4
	27G	7	402.135	95.3	59.6
	56T	8	331.17	96.7	68.2
	79P	9	236.55	97.7	78.4
	83G	10	212.895	98.6	85.7
	17R	11	189.24	99.4	93.1
	36V	12	141.93	100	100

Table 4.2 – Distribution of the volume value (Olhager, 2000)

4.7.2 Multiple ABC classification

Using only one criterion, for instance volume value, can be considered insufficient. Vollmann et al (1992) and Olhager (2000) lists a number of other criteria that can be taken into consideration:

- Lead time
- Order coverage time
- Availability
- Demand frequency
- Criticalness
- Customer importance

The products are first classified for each individual criterion and are then combined in a multiple classification. This becomes very complex if more than two criteria are combined. If in the end there are too many classes some of them are joined with each other.

On the next page there are three examples where the volume value is combined with the demand frequency, the criticalness and the customer importance.

Example 1: Demand frequency
Even if two articles have the same volume value they can have different demand frequencies. Since it is easier to forecast articles with high demand frequency than with low, an integrated classification is appropriate. This is shown in table 4.3.

	Demand frequency	
Volume value	High	Low
High	A	B
Low	C	D

Table 4.3 – Classification volume value/demand frequency

The most effort should be put into the products with a high volume value. The rest can instead be handled with more simple control systems. The most important class in table 4.3 is B and the least C. The importance of optimizing the safety stock level for C-class products are not that crucial, as the capital tied up is relatively small. (Olhager, 2000)

Example 2: Criticalness
Some products in the company's product portfolio can be of greater importance than others. Hence they are in some way more critical. This importance is independent of the product's volume value and there is a possibility to combine these two criteria as shown in table 4.4.

		Criticalness	
Volume value	A	B	C
A	AA	AA	BB
B	AA	BB	CC
C	BB	CC	CC

Table 4.4 – Classification volume value/criticalness

Example 3: Customer importance
Even though companies officially do not make any difference between customers, this is most likely done in practice. If this is wanted, a combination of volume value and customer importance can be done. This is shown in table 4.5.

		Customer importance	
Volume value	A	B	C
A	AA	AA	BB
B	AA	BB	CC
C	BB	CC	CC

Table 4.5 – Classification volume value/customer importance

4.8 Product life cycle

A product or service is assumed to go through a number of phases during its lifetime (Olhager, 2000). This is referred to as a product's life cycle. There are four phases: introduction, growth, maturity and sales decline. The main varying factor is the volume but it is also likely that the product's value will vary during its lifetime. Figure 4.13 below shows a general graph of a product's life cycle. The curve can be different for different kinds of products, but the general model is still valid and the phases remain the same.

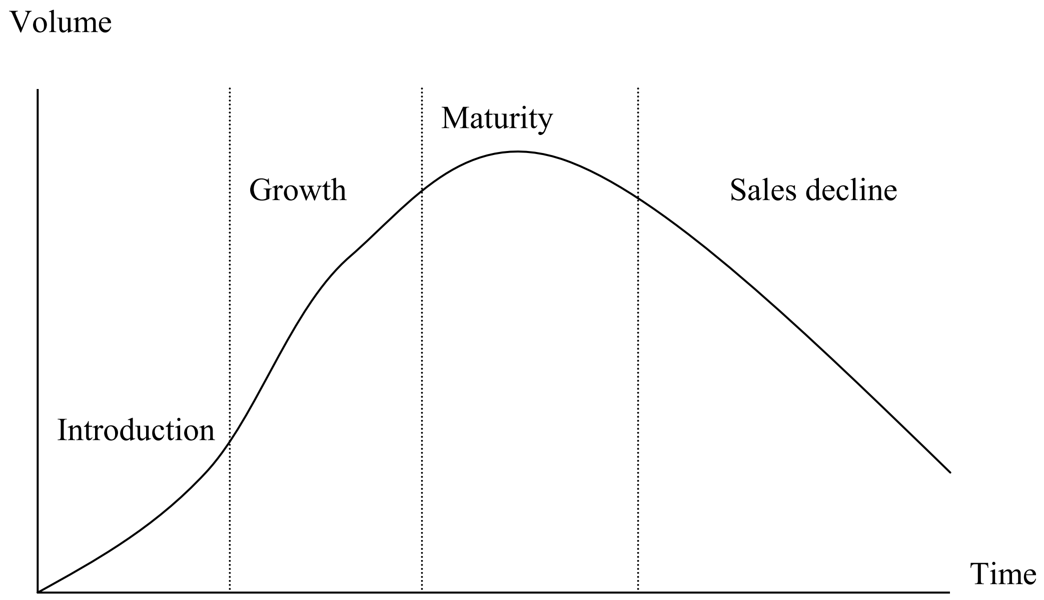

Figure 4.13 – Product life cycle (Olhager, 2000)

Introduction
In this phase the product is new on the market with uncertainty of demand, low volume and most likely a high price. There are few competitors with similar products. The product's features and news value are most important.

Growth
The volume increases and the price most likely decreases. Demand is larger than the supply which leads to that competitors are likely to introduce similar products. In this phase short delivery times can be an important way to compete.

Maturity
The demand reaches a maximum level. The competitiveness is at its peak and profit tends to decrease. This will make it more important to reduce costs. Companies compete mainly with price differences since the products now are fairly the same. The customers expect short delivery times.

Sales decline

Due to the introduction of new substitute products the sales are declining with a likely continuing decline in price. The price remains the most important competitive means. The demand for spare parts and accessories is likely to last after the product has been brought out of production. For these products it is important to have short delivery times.

5 Methodology

In this chapter we present the sequence of work that we have gone through during the project and what the different stages have involved. This chapter also contains what kind of research alignment we have used and in the section sources of errors we describe different kind of errors that could have influenced our work.

5.1 Mode of procedure

The sequence of work that we have gone through during the project is shown in figure 5.1. The phases will be described briefly in the text below.

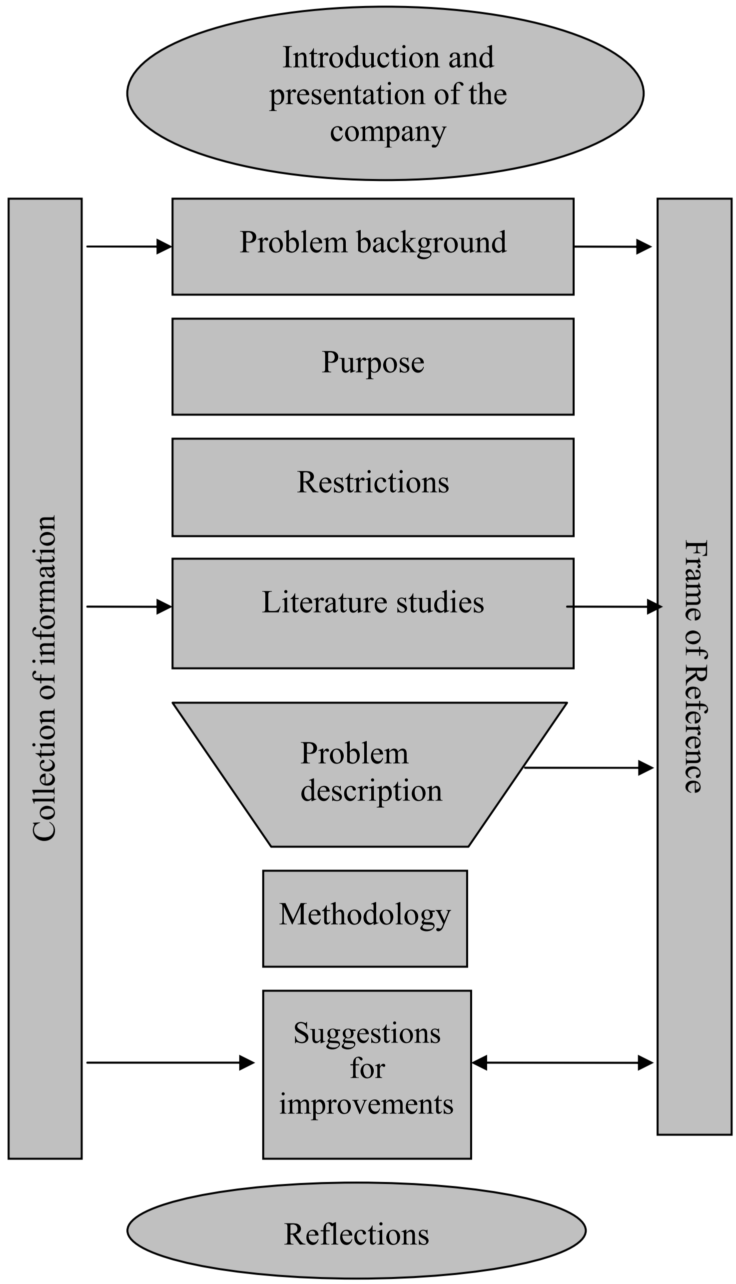

Figure 5.1 – Mode of procedure

Introduction and presentation of the company
This stage was necessary to begin with since we did not have enough knowledge of the company's activities and business to understand the background of the problem. To attain the information we were given an oral presentation of the company and we carried through discussions with the personnel and our mentor.

Problem background
We were given a short problem background description in a thesis guide handed out from our mentor at the company and discussions with him gave us deeper understanding of our task. Next step was to compile a survey of the company's current situation. We have mainly taken the issues that affect our work into consideration, which has been lead times, order handling, replenishment etc.

Collection of information
This stage has been an important stage in our project. The information about the company has been collected through discussions with personnel at GNT but also gathered from the company's homepage. The collection of information has also involved searching for relevant literature and theories concerning our project. Collection of information has been done continuously throughout the whole project time.

Purpose
When all the above stages were surveyed we were able to specify the purpose of our task.

Restrictions
When the purpose was clear we could set the limitations for our work.

Literature studies
To get a deeper understanding of inventory theories and logistical concept involved in our work we carried out a literature study. The literature used has foremost been books and articles found in the university's library database, and the literature study has been done through the whole project time.

Frame of reference
The frame of reference has been carried out with the problem background, literature studies and problem description as a starting point. We have put all the relevant and needed theory together to get a better foundation for our continuous work. The purpose with the frame of reference is to give the reader a deeper understanding of our task and of the concepts treated in the chapter containing our suggestions for improvements.

Problem description
The purpose describes our task in wide terms but to be more specific we discerned the problem down to a few questions at issue.

Methodology
This part of the report describes how we have moved towards the problem and which mode of procedure used. It also describes the problem solving approach used throughout the project.

Suggestions for improvements
This part is the most significant part of the thesis and contains our suggestions to which theories that should be adapted by GNT in order to make the purchasing decisions based on more accurate information. The theories used in this section are introduced in the frame of reference. This part of our project should be seen as a foundation for continuous work for GNT.

Reflections
The purpose of this chapter is to present some of our personal reflections of the thesis and also to give GNT recommendations for continuous work.

5.2 Analytical, Systematic and Normative approaches

Analytical approach
Our work can be seen as analytical since this approach assumes that existing theory is used to verify or reject hypotheses about the reality. The analytical approach's assumptions about the reality signify that the more proved causes, the better explanation of the situation. The results captured with an analytical approach are pure cause and effect connections, logical models and representative cases. The result has to be generalized to fit the requirements of continuous creation of knowledge.

Systematic approach
The systematic approach assumes an objective reality which is regarded as the primary field of work. According to the systematic approach the reality is built up of components that in many cases are dependent of each other and therefore cannot be treated independently. The structure of these components gives so-called synergism effects which imply that the entirety can be better than the sum of the added parts. This suggests that there is not only substance in the individual components but also in the way they are built up together. To give an explanation of a certain situation it is important to put it in an overall perspective.

Our project aims to present the relevant and needed theories that can be used as a foundation when looking for improvements in the company's inventory control system. The changes that can be made can result not only in minimizing inventory levels and capital costs but also in making the ordering processes more efficient and less time consuming. These effects are therefore seen as synergism effects. Since our suggestions hopefully will bring several synergism effects, in the end, this approach is also adapted.

Normative approach
Apart from analytical and systematic our task can also be seen as normative since a normative approach emphasizes how things should work or how the procedures should be carried through.

5.3 Collection of information

Qualitative approach
With a qualitative approach information is collected but not expressed in figures. The decisions made have been prepared through discussions about the information. In GNT's case this would imply that the problem we are studying and the results that will come out of the solution will not be appraised in figures. Instead the results would be judged on the basis of logical discussions.

Quantitative approach
When a quantitative approach is adapted the collected data is numerical and expressed in figures. Assuming that the figures are put correctly, decisions can be made concerning changes by comparing these values. For GNT a quantitative approach suggests that current costs and cash flows could be compared with corresponding costs and cash flows when the new concept has been implemented.

In our assignment we have focused on the qualitative approach. GNT is most interested in inventory optimization and consequently money saving but to get as far as being able to calculate and reach a quantitative point, a qualitative process has to be made beforehand.

The information collection has mainly been carried out through discussions and literature studies. We have consulted personnel at GNT both in Finland and in Sweden. We have been given an oral presentation of the company and a review of the software DBMi. The discussions have been carried out either by mailing direct questions to whom it concerns or by discussing issues in person. The literature study has been highly topical throughout the whole project and has been concentrated on logistic concepts and inventory theories in particular.

5.4 Sources of errors

The linguistic part is a possible source of errors in this project since much of the literature and also discussions have been in English. Since neither we nor the personnel in Finland have English as mother tongue the linguistic part is a two-way source of error.

Since much of the literature studied has dealt with logistics and manufacturing processes and not been specifically discussing wholesalers business, we might have drawn our own, wrong, conclusions. Some authors have focused on manufacturers and therefore the theory could have been adjusted too much on these kinds of firms.

We may have misjudged the purpose of the thesis since our mentor at GNT evidently is looking for tangible solutions concerning the problem and the examiner from the university is searching for a more academic consideration of the problem. The difficulties in balancing the combination of these two requests might have led to inadequate results.

Another source of error could be that we might not have been given all the necessary information connected to the problem due to pure oblivion or sensitive information that the company is reluctant to give out.

Since interviews have been a great part of the data and information collection, there might have slipped in some errors in that process. There is a possibility that our questions may have been asked to the wrong person, and that this person has tried to answer correctly but failed since the question did not belong to his or her area.

Finally, we cannot guarantee that our suggestions are feasible. They might work in theory, but not in practice. The next step for GNT should therefore be to evaluate our suggestions carefully before any implementation is considered.

6 Suggestions for improvements

This chapter contains our suggestions to how GNT can make improvements to its inventory control. First product classification is discussed together with the idea of product life cycle division. Then a flowchart with the suggested line of decision is presented along with a more detailed discussion of the ingoing concepts concerning the decisions to be made.

6.1 Classification

As mentioned in the frame of reference, article classification is made to be able to handle products in different ways depending on their characteristics. Due to the nature of classification, with numerous combinations possible, there are always alternatives to the one finally chosen. The main advantage with classification is that it allows focusing more on the company's most important products and not to waste time with products of lesser significance. The simplicity in classification could easily lead to articles being placed in the wrong classes. However, this argument is not good enough not to consider classification since the advantages still outweigh the disadvantages.

Our suggested classification is a combination of two types, a so-called multiple classification. The two suggested classifications are volume value and demand frequency. They are discussed more in detail in the following two sections.

6.1.1 Volume value classification

The first classification is the simple volume value division between products into the classes A, B and C. The reason for choosing three classes is that two classes will probably not be enough to be able to separate the articles in a good way. Having only two classes would result in having a wide spread of the volume value within a class. Four classes on the other hand would lead to more classes to keep track on and therefore increased complexity. Depending on the characteristics of GNT's product portfolio the best alternative can be evaluated.

The limits for the volume values that should belong to each of the classes have to be based on the specific products. Since the article classification is based on the Pareto rule it is likely to assume that the A-class will consist of a small part of the total number of articles with the largest volume value. The B-class will then consist of products with medium volume value leaving the remaining and biggest part to the C-class.

As we see it, there are two possible ways to decide the division between the classes; dynamically and statically. These will be outlined in section 6.3 due to that the concepts are connected to the life cycle division explained in section 6.2.

6.1.2 Demand frequency classification

The second part of the suggested multiple classification is based on demand frequency. In our opinion it is probably enough to have only two classes, one for products with high demand frequency, 1, and another for products with low demand frequency, 2.

The justification for this choice is that since the decision where the borderline between high and low frequency goes is very difficult to define, it is better to have only two classes since more would make it even more complicated. However, if it is felt necessary to have more frequency classes there is no actual impediment to introduce this.

Parallel to the calculations of volume value the division of demand frequency has to be made. The question where the line between high and low frequency goes is a highly complex one. The evaluation should probably be based on a consideration of how big part of a product's total demand that occurs in a short period of time. If this part is big enough the product should be labelled as a low frequency product.

Since the decision concerning where to set the limit between high and low demand frequency requires a number of qualitative issues as well as quantitative data, which we have not had access to, we are unable to give any more specific suggestions.

Combining volume value with demand frequency will lead to a similar result as table 4.3 in the frame of reference, where only the number of classes and designations differ. The specific multiple classification suggested is shown below in table 6.1.

	Demand frequency	
Volume value	1 (High)	2 (Low)
A (High)	A1	A2
B (Medium)	B1	B2
C (Low)	C1	C2

Table 6.1 – Suggested classification – Volume value/demand frequency

6.1.3 Exceptions from classification

As described above the classification will guide the calculations and therefore the decisions about for example warehouse selection. This decision will affect the delivery lead time to the customer to vary from the minimum one-day delivery to a maximum delivery time of several weeks for products sent by boat. However there are occasions where GNT would like to be able to override the normal classification. This is due to the fact that sometimes, for one reason or another, it is a must to have a one-day delivery for certain products. In practice this might lead to that it is impossible to store a product in only one warehouse, unless it is possible to serve the entire market from there in one day. The product can still have an actual class that can be considered in safety stock calculations, but it is not taken into consideration when deciding where to store the product.

6.2 Life cycle time division

As described in section 4.8 in the frame of reference a product is assumed to have different characteristics during different periods of its lifetime. For example the sales volume is likely to differ from period to period and also the value of the product will in most cases change as it matures. Also the uncertainties in the forecasted demand are likely to be higher in the beginning of a product's lifetime, hence affecting the safety stock calculations. If ignoring these facts when calculating safety stock levels, warehouse selection and so on, it is likely that the calculations will be inaccurate. This is why our suggestion is to take the life cycle into consideration already when classifying the products. This could for example lead to that a product would belong to class B2 in the first period, A1 the next etc.

Changing classes between periods will lead to that there will be made different calculations and maybe different decisions concerning safety stock, warehouse selection and so on in each period. This might sound confusing at first but hopefully the further explanations and examples in the following sections will clarify the advantages of using this kind of method. For a product with close to constant market characteristics the consequence will be that it will belong to the same class its entire lifetime.

6.3 Volume value division between classes

A stated in section 6.1 we have two suggestions to how the division of classes in respect of volume value can be done; dynamically and statically. The dynamic division is the original idea of the classification where every class consists of a certain percentage of the total number of articles ranging from few articles in the A-class to many in the C-class. However, when the volume value is constantly changing as a product enters the next period in its lifetime and these changes not necessarily take place at the same time for all products, it becomes more complex. The suggestion is to compare the average volume value for a product as it enters a new period and compare it to every other product's average volume value in the, for instance, first month of the new period. This is made in order to be able to decide what class the product will belong to in that period.

Static division on the other hand is to decide where the actual limits between the classes are in real volume value figures. If knowing these limits it is easy to divide the products into the classes. The difficulties appear when setting these limits. We suggest that if this method is used, the decision where the limits are should be made qualitatively considering at what (minimum) volume value it can be worth putting more effort into the product. Due to the fact that we do not have any data available for actual GNT products it is impossible for us to give a suggestion for actual limits, but hopefully this can be made by GNT later.

6.4 Example section 1

To clarify the ideas put forward above we will give an example. The data used in our examples are fabricated as we have not been able to get hold of satisfactory actual data from GNT. However, the principle is still the same as with actual data. A classification over the entire lifetime would probably lead to that the product, at least sometimes, is treated in a less efficient way. Figure 6.1 on the next page shows an example of the volume fluctuations of a product during its lifetime.

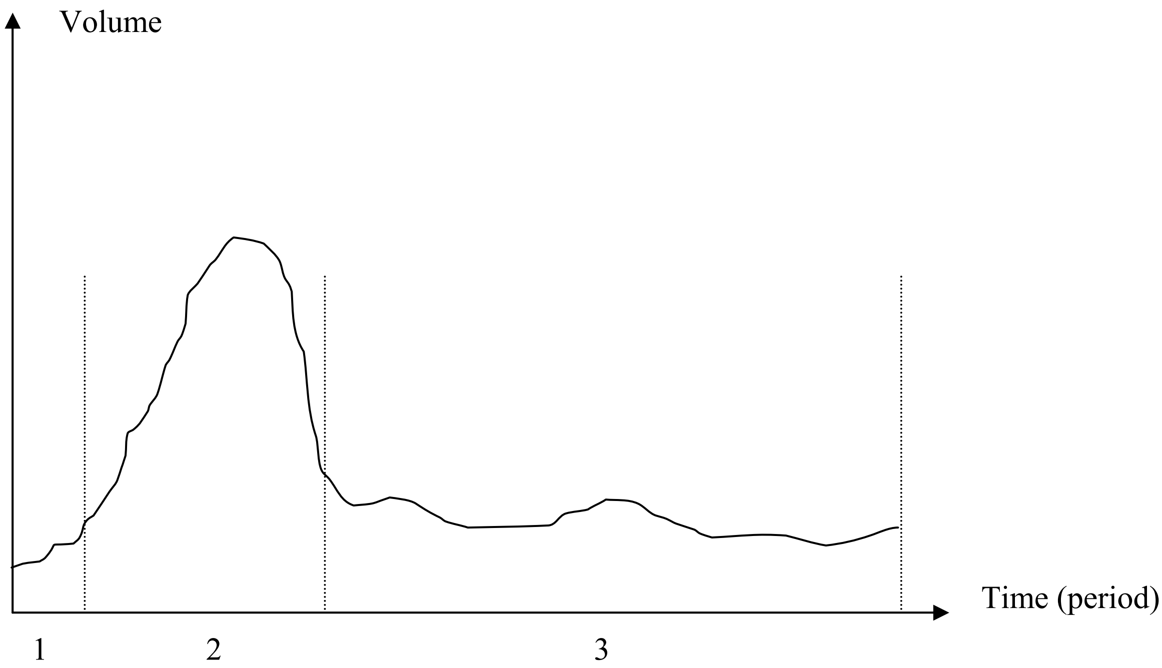

Figure 6.1 –Volume fluctuations of a product during its lifetime

It is obvious that using the entire lifetime when deciding class is likely to lead to a different result than if the suggested division above in three periods is made. How this division is made can be a matter of opinion. It is likely that a manual division of every singe article in GNT's product portfolio is too time-consuming and therefore our suggestion is that it should be possible to leave the division issue to some automated process where the forecasted sales volume is taken into account. However, we do not have any more detailed suggestion concerning how to make the life time divisions. This should therefore be subject to further investigation on GNT's behalf. Whatever method chosen to divide the lifecycle into shorter periods, it should be made so that the periods are an even multiple of a pre-defined time format, e.g. month. The reason for this will be explained below.

Considering figure 6.1 above with the additional information presented in table 6.2 on the next page the principle of volume value division between periods should be clearer.

Period	Month	Price	Demand	Volume value
1	1	1,200	100	120,000
2	2	1,000	300	300,000
	3	1,000	700	700,000
	4	1,000	500	500,000
3	5	800	200	160,000
	6	800	200	160,000
	7	800	250	200,000
	8	800	150	120,000
	9	800	100	80,000
	10	800	100	80,000

Table 6.2 – Product statistics

The total volume value of period 1 is 120,000.
The total volume value of period 2 is 300,000 + 700,000 + 500,000 = 1,500,000
The total volume value of period 3 is 160,000 + 160,000 + 200,000 + 120,000 + 80,000 + 80,000 = 800,000

To be able to compare the volume values, the different number of months in each period must be taken into account. This is done simply by dividing the total volume value for a period with the number of ingoing months in the same period. In the example above this will lead to the following:

Average volume value per month in period 1 is 120,000
Average volume value per month in period 2 is 500,000
Average volume value per month in period 3 is 133,000

This should be compared to calculation of the average volume value using one single period, which would be 231,000 per month. It is likely to assume that this difference would affect the classification, but to know for sure, it has to be decided at what volume value a product changes class.

Using the example above the volume value of that specific product would look as presented in table 6.3 on the next page during its lifetime.

Period 1	**Month**	1					
	Average volume value	120,000					
	Demand frequency	High					
Period 2	**Month**	2	3	4			
	Average volume value	500,000	500,000	500,000			
	Demand frequency	High	High	High			
Period 3	**Month**	5	6	7	8	9	10
	Average volume value	133,000	133,000	133,000	133,000	133,000	133,000
	Demand frequency	Low	Low	Low	Low	Low	Low

Table 6.3 – Overview of volume value and demand frequency

Having decided the division between classes in respect of volume value and demand frequency the classes in the periods can for example become:

Period 1: B1
Period 2: A1
Period 3: B2

The implications of this division will be explained in the next section.

6.5 Implications of classification and life cycle time division

As described in the sections above it should be possible to determine the different classes for a product for its entire life cycle as it enters the assortment. The idea is to be able to handle the product differently throughout its lifetime and in that way be as cost-effective as possible. The decisions that might be affected by the classification are numerous. The ones we suggest GNT to look closer at is:

- Safety stock
- Warehouse selection
- Replenishment methods
- Mode of transportation
- Customer order products
- Simplified decisions for some classes

6.5.1 Safety stock

Safety stock is intended to serve as a buffer against uncertainties in for example the forecast. Depending on their characteristics, different products have varying uncertainties. The classification will make it easier to focus the efforts for a decreased safety stock where it makes the most difference. For example, the future demands of products with low demand frequencies are more difficult to forecast and therefore the deviation of the demand will be bigger, thus increasing the safety stock. If the products for which this happens are high value products the increase will inevitably lead to more capital tied up. To prevent this from happening it is possible to focus more on these products with the intention of decreasing the uncertainties and thus saving money. If there would be no classification in use it would be necessary to make this effort for every single product, which would be too time-consuming. A more detailed discussion regarding safety stock is held in the safety stock section in this chapter.

6.5.2 Warehouse selection

When it comes to deciding whether to store products in one or several of GNT's warehouses, calculations need to be done to decide which alternative is the most cost-effective. The money saved on keeping the entire stock in one place is mainly due to the possible decreased safety stock level. Once again the classification helps in limiting the number of calculations needed since it allows focusing on the products that are most likely to have this cost decrease for. Issues concerning warehouse selection will be discussed further ahead.

6.5.3 Replenishment methods

There are a number of known replenishment methods. Also here the classification can help to single out the products that are most reasonable to spend time on.

6.5.4 Mode of transportation

An issue that can affect for example the safety stock and warehouse selection decisions is what mode of transportation chosen from the vendors. A decreased lead time might affect these two decisions. Once again it is more likely for products in some of the classes to be affected by a change of the mode of transportation and therefore the effort should be put on deciding mode of transportation for only these products.

6.5.5 Customer order products

Some articles in GNT's product portfolio are likely to be too risky to store even in small amounts. A solution for this can be to purchase these products to customer order. Once again, some classes are more likely to be customer order products than others. An extended discussion will be held further ahead.

6.5.6 Simplified decisions for some classes

For some of the least important products really simplified decisions can be used in order to save time. Suggested products and what these simplified decisions can be, are discussed later.

6.6 Flowchart

The following flowchart is supposed to visualize and make it easier to see where and when the different decisions are made. It also shows for which classes different decisions are intended to be made which makes the classification idea easier to understand. The first part of the flowchart consists of the life cycle division and classification discussed earlier in this chapter. The remaining issues are discussed after the flowchart. Below is a reference to in which section the discussion concerning respective issue is held.

Flowchart references

Safety stock calculations	6.6.1
Warehouse selection 1	6.6.2
Store cycle stock everywhere?	6.6.3
Customer order products	6.6.4
Free Transport Store everywhere (no calculation) Warehouse selection 2	6.6.5
Group products	6.6.6
EOI calculation	6.6.7
Replenishment calculations	6.6.8

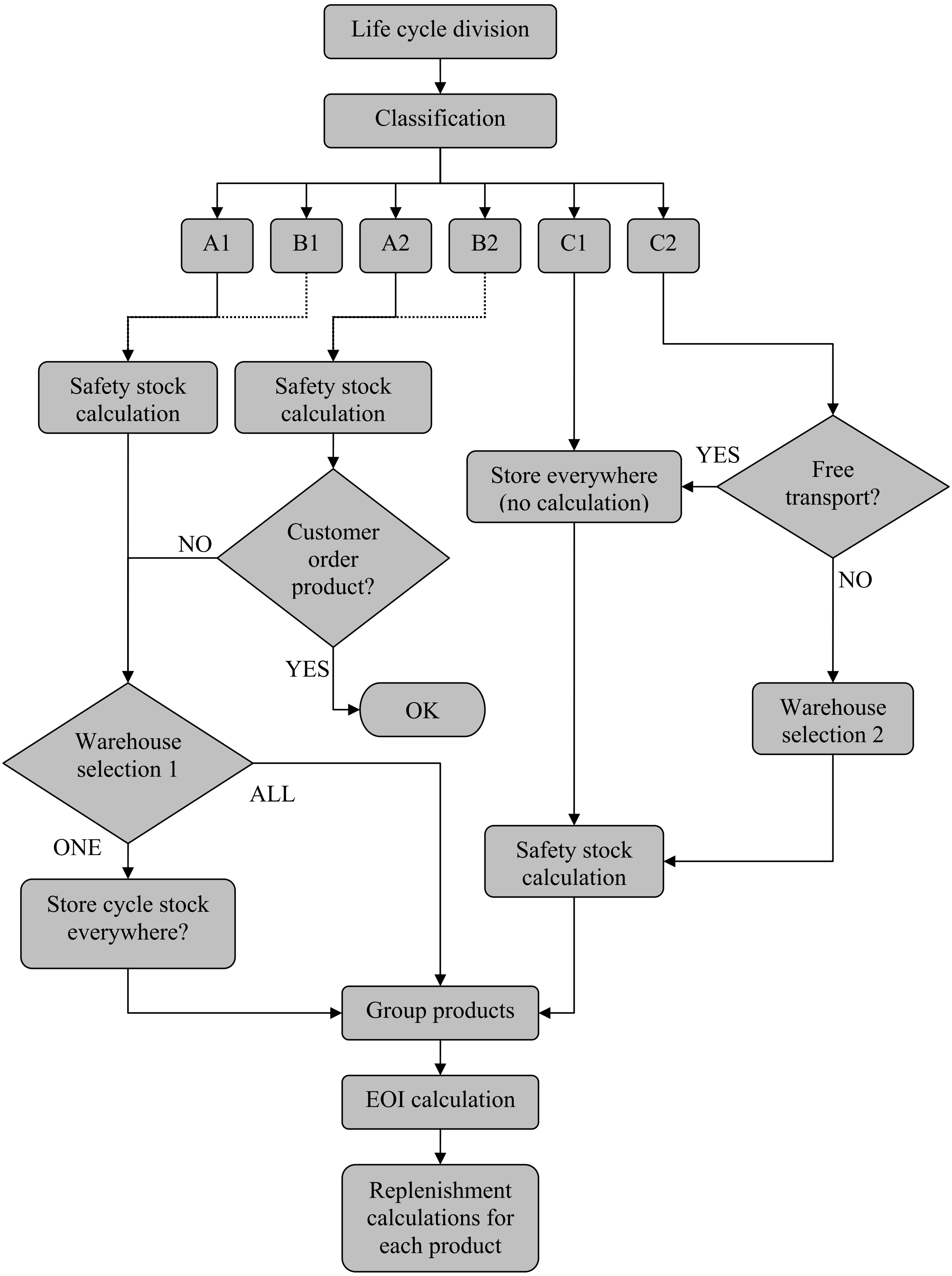

Figure 6.2 – Flowchart

The flowchart shows that the same decisions are made for A1 and B1 and for A2 and B2 respectively. In reality, these classes should be separated in order to make different decisions related to the different classes. Due to the fact that we have not had access to sufficient data, we have not been able to differentiate the A and B classes. However, the reason for separating these classes is to give GNT a clear picture of which products that contribute most to the company's turnover. The separation of A1 and B1 etc. could be useful in the future when there are any reasons for handling the products differently. To emphasize the fact that the suggested line of decision for B products is provisional the lines from B1 and B2 in the flowchart are dashed.

6.6.1 Safety stock calculations

For the A and B classes the safety stock is calculated as a first step. This is because it is an important parameter for deciding warehouse selection and customer order products. For the C class however, the safety stock calculation is made later since it is not an ingoing parameter for any of the C class decisions.

The reason for having a safety stock is to prevent stock-outs to occur due to uncertainties in demand and/or lead time. It is therefore more based on how the company values the service to its customers rather than pure costs, as the latter would probably lead to that there would be no safety stock. The other extreme is the objective to have 100% service level, which would lead to a need to have an infinite safety stock, which in practice is very inconvenient.

A key issue is to determine a suitable service level that takes both costs of keeping a safety stock and the costs of stocking out into consideration. One method of doing this is described in the frame of reference, the optimization of the safety factor. The basic idea is to compare recouped lost sales with safety stock investment. This method is very complicated and time-consuming and our judgement is that the investment in time will not pay back in a more accurate service level. Hence we do not recommend GNT to use it. The service level and therefore the safety factor can instead be set qualitatively without risking being too far from the optimum. It should be decided considering factors such as market characteristics, current period of life cycle etc. Once the service level is decided the safety factor can be collected from a table. Examples are given in table 4.1.

We recommend using formula 4.20:

$$\mathrm{SS} = \mathrm{Z} \cdot \sigma \cdot \sqrt{LT}$$

This formula is simplified in the sense that it only considers the deviation of the demand. If the deviation of the lead time is significant there is also a possibility to use formula 4.21:

$$SS = Z\sqrt{LT \cdot \sigma_D^2 + \sigma_{LT}^2 \cdot D^2}$$

The obvious disadvantage of this is that the safety stock level increases as more uncertainties are taken into account. It is therefore our suggestion that it is only used on low value products, as this would not increase the costs as much as it would with high value products.

In general it is more important trying to keep the safety stock to a minimum for the A and B classes, as they are the ones that it is possible to save most money on. This can for example be considered when determining the service level.

When the order cycle time is longer than the forecasted period the average service level increases. For example, if the forecasted period is one month and the order cycle time is two months the service level for the first month will practically be 100% as the cycle stock for month two can be considered as a safety stock for month one. The determined service level will only show in the end of month two, hence the average service level of the two months will be higher than the service level decided. To prevent this, the order cycle factor mentioned in the frame of reference can be used to decrease the safety stock level. The order cycle factor is formula 4.22 and is multiplied with the chosen formula above.

$$\text{Order cycle factor} = \sqrt{\frac{FP}{OC}}$$

We have already mentioned the importance of trying to decrease the safety stock for high value products. One possible way to do this is to decrease the lead time which can be done by using for example airfreight. As long as the decreased lead time results in more money saved on inventory than spent on airfreight it is recommended to do so. Keeping the efforts to a minimum our recommendation is to only consider airfreight for the classes A2 and B2 as shown in the flowcharts. Because of the products' high value and low frequency they are most likely to make airfreight cost-effective.

6.6.2 Warehouse selection 1

Even though GNT has several warehouses with the intention of being as close to the market as possible it might sometimes prove to be more cost-effective to keep a product in only one of the warehouses and serve all markets from there. The reason for this is that it is possible to decrease the safety stock level when having only one safety stock in one warehouse instead of, for instance, three. The money saved on the decreased safety stock level can instead be used for the increased number of inbound transports.

The following example shows that a decrease in the safety stock level is possible. The data in table 6.4 shows forecasted and actual demand for a product if supplied from three warehouses.

Warehouse	1		2			3		
Month	Forecast	Actual		Forecast	Actual		Forecast	Actual
1	200	230	1	525	496	1	100	150
2	180	222	2	345	380	2	95	110
3	250	190	3	456	470	3	120	100
4	350	320	4	424	450	4	200	150
5	256	300	5	654	600	5	180	210
6	190	210	6	234	300	6	110	150
7	234	200	7	567	553	7	160	140
8	289	270	8	344	386	8	180	140
9	315	300	9	562	530	9	140	200
10	379	300	10	233	300	10	120	140
11	210	287	11	545	580	11	127	100
12	187	150	12	355	288	12	90	80

Table 6.4 – Product demand divided between markets/warehouses

Using the safety stock formula 4.20 with a service level of 90% and a lead time of one month the safety stock level for each warehouse would become 58, 56 and 45 respectively, i.e. a total safety stock of 159.

Table 6.5 shows forecasted and actual demand for the three warehouses above put together to one.

Warehouse	1	
Month	Forecast	Actual
1	825	876
2	620	712
3	826	760
4	974	920
5	1090	1110
6	534	660
7	961	893
8	813	796
9	1017	1030
10	732	740
11	882	967
12	632	518

Table 6.5 – Product demand put together to one single market/warehouse

Using the same formula and inputs as above the safety stock level in this case would become 90, i.e. a decrease of more than 40%.

This is only an example and no assumption can be made that this scenario is true every time. In reality the calculation would take other things into account as mentioned in the safety stock section above. However, the basic idea is the same and our suggestion is that a comparison should be made for products in the classes that would save the most money, i.e. the A and B classes.

The next step is to calculate the increased transportation costs the decision to store in one place leads to. This is a fairly easy calculation to do because of the accurate data available from transport companies. A qualitative estimation however has to be made concerning the increased delivery time for the customers not close to the single warehouse chosen.

If the comparison shows that it is more cost-effective to store in only one place, the warehouse chosen should be the one on the market with the largest demand since the transport costs then would be as low as possible.

6.6.3 Store cycle stock everywhere?

Having decided to store a product in only one warehouse and if transportation from the vendor to GNT is free another possibility arises. If the transport from vendor is free of charge then it would be better to send products everywhere since the inbound transports would then be fewer. However, the suggestion is that only the cycle stock is sent to every warehouse whereas the total safety stock is stored in only one place. This would keep the advantages concerning lower inventory level etc. but decreasing the inbound transportation costs. There is however a drawback. Having no safety stock in some of the warehouses would lead to a service level of only 50%. Although, the service level would be 50% only for a delivery time of one day. If safety stock is required to use this product will be taken from the warehouse where it is stored, thus leading to only a couple of days delay and the service level is not violated greatly. In comparison, not shipping the cycle stock to every warehouse would lead to that the service level would be maybe 97% for a delivery of two or three days. In our opinion the first option is better although it alters the system a bit.

6.6.4 Customer order products

Some articles can be too risky to have in stock due to high inventory costs, risk of obsolescence etc. To avoid these risks it is possible only to purchase these products to customer order. In order to decide if a product should be a customer order product certain costs need to be put against each other. The money saved for not keeping a product in stock is fairly easy to calculate since it is only due to product value and the estimated inventory cost rate. The classes that are most likely to become customer order products are A2 and B2 for obvious reasons – they are the classes containing the high value and low demand frequency products, which makes it more likely that the increased transportation costs will not exceed money saved on inventory costs.

The difficulty with the customer order products decision is to determine the cost of the increased delivery time to customer, i.e. the cost of decreased customer service. If a customer places an order with GNT and the product is not in stock he has several choices. Either the customer waits for the product to be delivered from the vendor or he/she turns to a competitor to GNT and buys the product there. There is also the possibility that the customer wanted to order several other products from GNT, but due to this one missing item, he will turn to the competitor even if GNT had nine out of ten products in stock. In addition to possible lost sales the badwill that comes from this situation has to be added to the total cost of not having the product in stock. It is impossible to calculate this very accurately since there are many uncertainties involved.

One way to determine the cost of lost sales is to set this cost as the real costs that occur when placing a back-order. This however does not consider the cost of dissatisfied customers. One way to find this cost out is to ask the customers how they value the wait, but the effort put into determining this is not likely to prove worthwhile. The customers will probably not know how to set this value and basing decisions on flawed statistics can be worse than basing them on a hunch – at least the hunch is known to likely be wrong in opposite to statistics that we think tend to be more believed.

If an estimation of the lost sales cost is made it should be made so that it depends on the time the customer has to wait for the product, i.e. the cost would be higher if the customer has to wait for two weeks instead of three days. If this is done it is possible to put this cost against the money saved and a decision of whether to keep a product in stock can be made.

If the increased cost due to a longer wait is estimated after all, it would be possible to consider airfreight. This way the delivery time will be shorter compared to seafreight and the money lost will be less. This is then put against the increase in transportation costs that comes from using airfreight.

6.6.5 The C-class

The largest number of articles in GNT's product portfolio belongs to the C-class. But although they are many, they contribute only a small part of the total volume value. The idea is to be able to put as little effort as possible into these products as the effort is not likely to pay off. For the C1-class the usual decision will be to store the products everywhere. This is intended to be decided without any time-consuming calculations and even though there can be products in this class that should be calculated on, it is likely to be few. The time saved can instead be spent on products in the A and B classes. The reason for not considering storing C1 products in only one warehouse is the assumption that the high frequency in combination with low value will make it unlikely to be cost-effective.

When it comes to the C2 products there is a chance that it would be better to store them in a single warehouse. The reason is that the demand frequency is low and therefore the inbound transportation costs are likely to be less than for C1 products. The suggested calculation is a bit different from the warehouse selection calculation for A and B products. In this case we do not consider the safety stock cost due to the low value characteristics of the products but instead only focus on the transportation costs. If there is no transportation cost from vendor to GNT's warehouses the decision will be the same as for C1 products – send them to every warehouse. However if the transport from vendor is not free of charge this cost must be put against what the inbound transportation costs would be if storing in only one place. This will show which alternative is the most cost-effective and a decision can be made thereafter.

6.6.6 Product grouping

Product grouping is a preparation for the calculation EOI, Economic Order Interval described in the frame of reference and discussed in section 6.6.7. The idea with EOI is to be able to place joint orders. Therefore it is natural that all products in a group are ordered from the same vendor. Another condition is that all products in a group will be stored in the same warehouse. Due to the fact that the EOI calculation contains the variables product value and demand this will affect the period decided. This is why a product group that EOI is calculated for should not contain products of different classes as this would cause the EOI period to be less accurate since it then will be a kind of average best time between orders. To summarize: products that are placed in the same group should as far as it is possible have the same characteristics, which in this case implies same vendor, same warehouse and same class.

6.6.7 EOI – Economic Order Interval

Even though EOQ is a commonly used and simple method in inventory control system it has its obvious weaknesses such as constant and known demand and lead time. Using EOQ would result in that the recommended order quantity does not take the variations in forecasted demand into consideration. This might result in that only parts of the future periods' demand will be fulfilled. One way to get around this is to use EOI instead. EOI is based on total costs just like EOQ, but gives the opportunity to take the demand variations into consideration. EOI calculates the optimal order interval and the ordered quantity regards the next EOI number of periods' demand.

Having grouped products into suitable groups it should be decided what the order interval for that group should be. Using EOI for multiple items this is a fairly easy calculation to do if correct data for the inputs is available. If a product does not belong to a group EOI for single items is used. Both the formulas are explained in the frame of reference, section 4.3.

In the frame of reference, the two replenishment methods ordering point and re-order cycle policy could be used together with an EOI system, where the inspection interval is the calculated optimal T and the pre-defined inventory level is the forecasted demand plus the demand during lead time. The practical use of this combination is explained in the next section.

The main advantage with EOI is that products from the same source i.e. same supplier could form a group and have the same inspection interval. Spreading out the inspections for different product groups gives GNT the ability to co-ordinate the order placing and hence the incoming quantities are spread out evenly in time. This results in a more efficient handling of the arriving goods at the dock and it also enables a more efficient planning of the inventory and stock room activities. This will also result in a more efficient handling of the products from the suppliers' point of view. The supplier knows when to expect an order and can therefore plan the production and secure the delivery times. This might give GNT a better starting position in negotiations with the supplier.

6.6.8 Replenishment issues

After the grouping has been done there should be a number of groups consisting of varying amounts of products. Calculations will be made for each product individually and in the normal case they will not affect the other products in their group. There is however exceptions which we will come to.

The replenishment system that we recommend GNT to use is the hybrid system described in the frame of reference, section 4.6.3. However, this general model is based on the assumption that demand is constant. Since this seldom is the case there will be made alterations of the general model, e.g. the pre-defined inventory level and the ordering point will not be constant but change over time.

The general system is illustrated below in figure 6.3. It shows a product belonging to a group with inspection every other month. The example is also only of a single period of the life cycle division, which leads to that the safety stock level will be constant, as it only can change when entering another life cycle period.

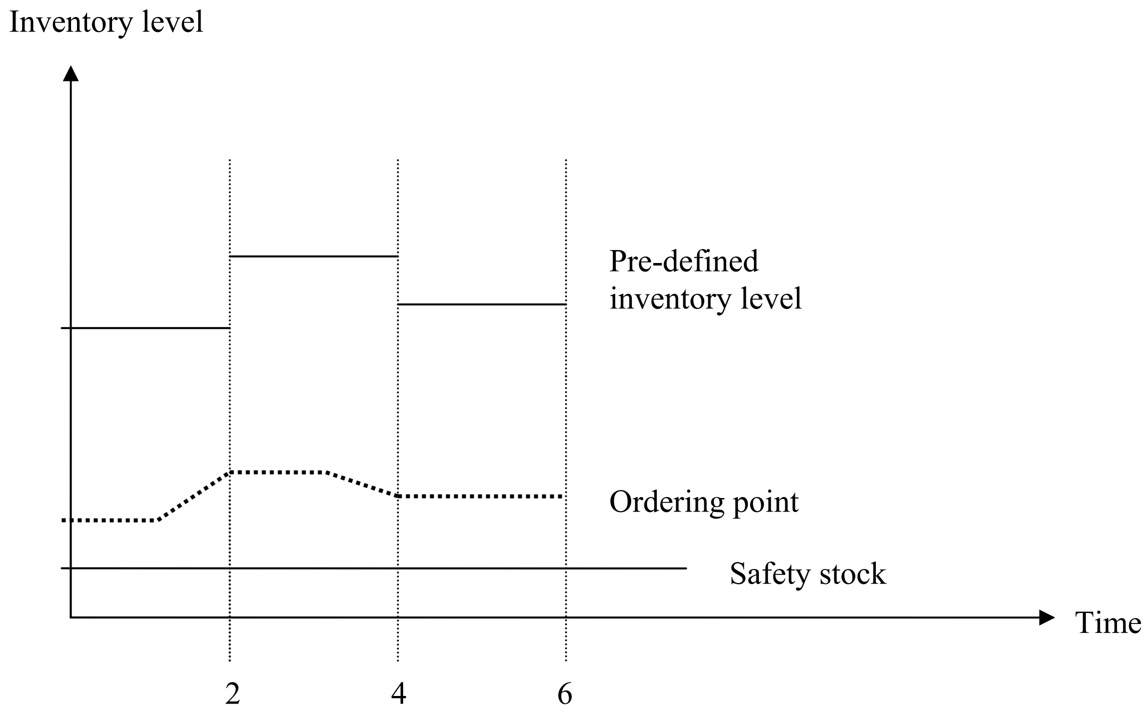

Figure 6.3 – Adjusted hybrid system

The pre-defined inventory level is calculated by adding safety stock, demand during the order cycle period and demand during the lead time. With fluctuating demand this will vary between periods as seen in the figure above. Also the ordering point will vary between periods as this derives from demand during the lead time.

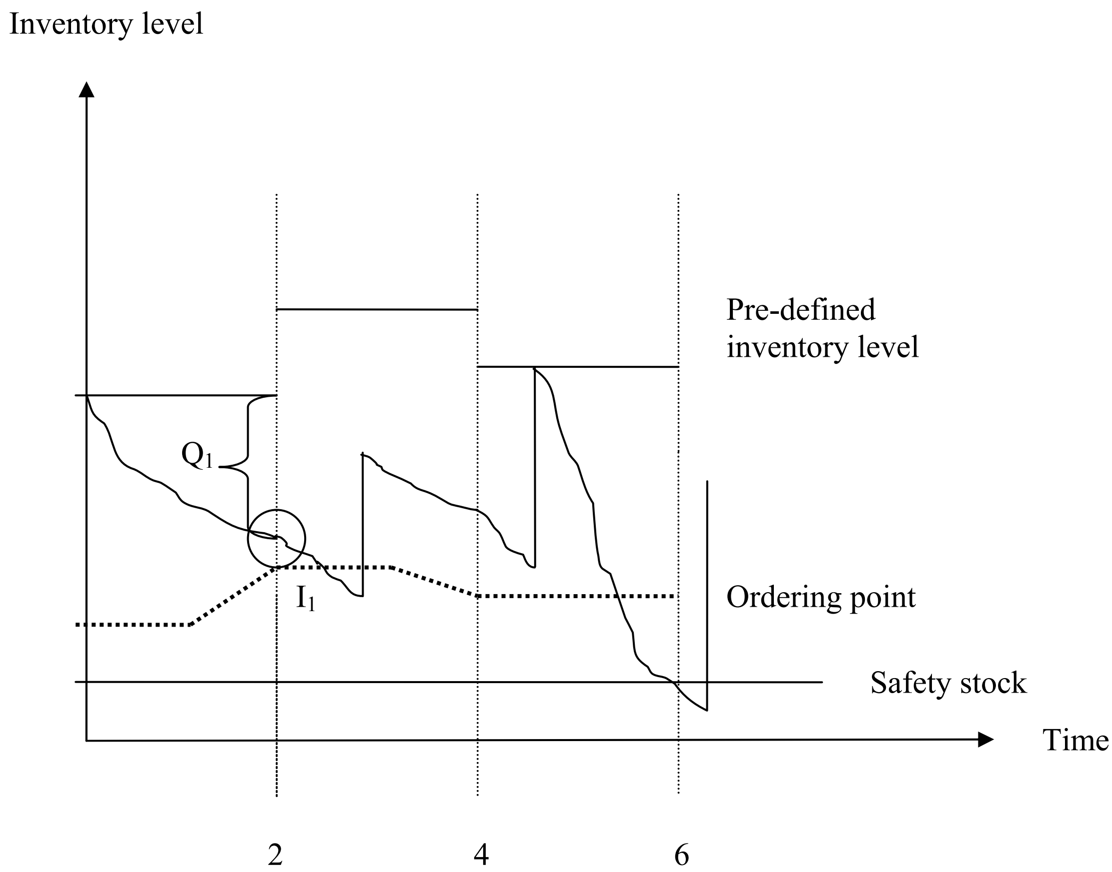

Figure 6.4 – Adjusted hybrid system in practise

At every inspection the inventory level for each product in the group is checked and an order is placed with the quantity: the pre-defined inventory level minus current inventory level. At the first inspection, I_1 for the product in figure 6.4, products will be ordered up to the first pre-defined inventory level, which leads to a quantity of Q_1. After the lead time this quantity is delivered. Even though the ordering point is passed during the lead time, this will not initiate an order since one is on the way. The procedure will be the same at the next inspection. If the demand is higher than normal as it is in month four to six in the above figure the ordering point will be reached before a new inspection is made. Also here an order will be placed up to the pre-defined inventory level and is delivered a lead time later. This time an order will not be placed at the third inspection since an order again is on the way.

Placing joint orders results in that at every inspection an order is placed for every product in that group up to the pre-defined inventory level. If any of the products reaches the ordering point between inspections, an order is also initiated for every product in that group up to the pre-defined inventory level.

Still, when the forecasted demand is inaccurate there can be times when the system suggests that an order is placed and the quantity up to the pre-defined inventory level is very small. Logically there is a limit for how few products that is justified to place in an order. It is very difficult to give a general formula for where this minimum order quantity should be. This is another advantage with placing joint orders. The ordering cost is then spread over more than one product, which will make the minimum quantity problem less critical. However, the issue should be recognised and if there is an awareness of it, ordering too few should never happen as this can be stopped when an order is checked before sent to a vendor.

Quantity discounts
There are basically two different scenarios for when a quantity discount is offered. It can either be a one-time opportunity or an always-existing offer.

If there always is a quantity discount and the discount schedule is known in advance this can be taken into account in the beginning of the whole inventory control process and the optimal T can be calculated from the discount conditions. This will increase the likelihood that GNT will accept a discount when ordering although it cannot be guaranteed since the ordered quantities differ from time to time when using periodic inspection. However, if a product has a quantity discount it is better to keep it as a single item and not include it in a group. This is because the order interval is likely to become longer than for products without quantity discount, and using a common T will probably lead to that it will not be accurate for any of the products.

In GNT’s case however, discounts offered from vendors are very uncommon. Instead this is something GNT tries to negotiate when placing a big order. Since it is not possible to negotiate every single time this can be considered to be a rather rare situation. The guideline that is possible to use in a quantity discount situation is to compare the total cost for accepting the discount offer compared to the total cost of turning it down. The advantages of quantity discount purchases are lower unit cost, lower ordering cost per year and fewer stock outs. The disadvantages of quantity discount purchases are a larger inventory, increased risk of obsolescence, slower inventory turnover and an older stock. When deciding whether larger quantities should be ordered the total costs for each scenario has to be calculated.

Our suggestion is that the total cost for the original quantity calculated without considering quantity discount is determined. This total cost is then compared to the total cost of a few chosen suitable quantities that are larger than the original one. What quantities this should be, is a qualitative decision and could be based on the discount intervals set by the vendor. Although this method is unlikely to find the absolute optimal quantity it will give a good estimation close to the optimum.

6.7 Example section 2

The example from section 6.4 resulted in the following classes for the product in the different periods:

Period 1: B1
Period 2: A1
Period 3: B2

Looking at the flowchart the same calculations will be made for the first two periods. This will not necessarily lead to the same results as the volume value is different in the two periods. The main choice to these two periods will be whether to store the product in every warehouse or in only one place. For the third period, when the products has low demand frequency, the additional question concerning customer order product arises. For example, the result of all these calculations could be that the product is stored in all warehouses the first period, in one warehouse (but with cycle stock everywhere) in period two and not storing it at all in period three.

6.8 Summary

As we have explained in this chapter, the basic idea is first to divide a product's life cycle time into suitable time intervals. For each of these intervals a classification is made from the product's volume value and demand frequency. The classification implies that different decisions and calculations are made on different classes in order to separate the products and handle them as efficient as possible.

The idea is to be able to focus more on products that are important for GNT and have a potential of decreasing costs instead of treating every product the same way. Placing products in different groups is intended to make the ordering procedure easier with benefits both to GNT and to the supplier. The replenishment method recommended is a so-called hybrid system which combines the advantages in a periodic review system with an ordering point system. In every step along the way it is possible to make calculations for products in classes not originally introduced. For example it is possible to add parameters that will bring a C-product into the calculation of customer order products.

7 Reflections

In this chapter we give recommendations for continuous work. We also present our own reflections about the thesis.

The next step before making improvements in GNT's ERP system would be to evaluate our suggested solutions presented in the previous chapter. If GNT finds it necessary, adjustments can easily be made to the model, e.g. more classes can be added or the calculations can be made for even more classes. Another possibility is to use only some or parts of our suggestions. Our hope however is that GNT will find all of it useful and that the ideas will be further developed and taken into consideration when updating its ERP system. One important step when evaluating is to use real data inputs to simulate what effects our model will have. We have been unable to do this, as useful data has not been available to us.

Though there are many models and theories regarding inventory control it is impossible to find a model that is completely compatible with the reality. Despite the fact that the simplified theoretical models are not absolutely correct in the strict sense, they can still serve as an accurate enough estimation. It is important to acknowledge this fact so that the models are neither believed to present the absolute truth, nor dismissed with the justification that they are not absolutely correct anyway.

The more complex a system is, the more difficult it becomes to implement. Except from the difficulties in getting the models to work, maybe the most difficult task is to get the employees using the models to trust them and use them in the correct way. This can be a problem when the models are close to incomprehensible. Therefore it is important to keep the balance between simplicity and correctness, or as our friend Albert Einstein put it: "Everything should be made as simple as possible, but not simpler."

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