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Parameters influencing the inventory level and related measures

A case study within the automotive industry

Master of Science Thesis

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MASTER’S THESIS IN PRODUCTION ENGINEERING

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Abstract

This report summarizes parameters affecting the inventory. At manufacturing companies the inventory is a buffer to handle demand fluctuation, high component variety, low forecast precision and other uncertainties. At the same time the inventory generates tied-up capital, which is an incentive to strive towards a lower inventory. Within the organization the trade-offs must be balanced in order to find a compromise between cost drivers and efficient solutions. The approach used to identify what parameters affecting this balance, was a case study conducted at Volvo Cars. Through empirical and literature studies a framework for expected inventory behaviour and parameter categorization was developed. The parameters were categorized under suitable business units within the framework. Besides the parameters the strategic effects of the production and inventory strategies are also discussed since these decisions strongly affect how the inventory behaves. From a management perspective the responsibilities must be clearly defined for each part of the inventory, i.e. safety stock, cycle stock and in-transit material to handle the inventory efficiently. The idea behind this is to create a holistic view to minimize sub-optimization. From the complexity at the case company concerning the inventory management, challenging improvement areas was identified. These where connected to the theoretical framework and general conclusions were drawn. Concrete recommendations to improve the present situation for the case company are also presented in the report. The primary outcome from the thesis is suggestions for standardized working methods concerning the inventory management. In a long-term perspective a uniform safety stock calculation, categorization of the components and adequate KPIs should be used.

Keywords: Inventory, Supply chain, KPIs, Safety stock, Inventory parameters

Abbreviation list

3PL	Third-party logistics partner
8D	Supplier incident report
ARO	Arrival reorder system
ATO	Assembly to order
BSC	Balance scorecard
CS	Cycle stock
D	Demand
DMAIC	Define, measure, analyze, improve and control
DTL	Dedicated trailer load
EDI	Electronic data interchange
ETA	Expected transportation arrival
ETD	Expected transportation delivery
FTL	Full trailer load
JIT	Just in time
KPI	Key performance indicators
KRI	Key result indicators
LDOC	Last day of order change
LDOI	Last day of order intake
LT	Lead time
LTL	Less then full load
MP&L	Material planning and logistics
MPC	Manufacturing planning and control
MPS	Master production schedule
MRP	Material requirement planning
MTS	Make to stock

NWC	Normal weekly capacity
PI	Performance indicator
PLUS	MRP system at Volvo
QCDISME	Balance scorecard subject fields: Quality, cost, delivery, improvement, safety, morale, environment
R&D	Research and development
RA	Spare part warehouse
RDC	Redistribution centre
RI	Result indicators
S&OP	Sales and operation planning
SCC	Supply chain coordinator
SPFU	Supplier performance system
SS	Safety stock
TA	Body-plant at VCT
TA report	Torslanda administrative report
TB	Painting plant at VCT
TC	Assembly plant at VCT
TT report	Torslanda technical reports
VCC	Volvo Cars Corporative
VCG	Volvo Cars Ghent
VCMS	Volvo Cars Manufacturing System
VCT	Volvo Cars Torslanda

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1. Introduction

In this chapter the background of the studied area and the importance of the right inventory will be handled. Furthermore, a problem discussion about the inventory from the case company point of view will be described. This will lead to a definition of the purpose, scope and limitations.

1.1. Background

The automotive industry is struggling with fast changing markets as well as a high degree of product customization. These factors and popular manufacturing strategies such as order based production (Bellgran & Säfsten, 2010) set high demands on delivery performance and reliability of the supply-chains. Furthermore, the general inventory strategy has changed over the last decades due to the requirements of the global industry (Alessandria, Kaboski, & Midrigan, 2012). From using the inventory as a necessary damper for uncertainties to being something considered as waste (Bonney, 1994). Inventory is a major investment for most companies which strongly influence the organizational flexibility, for example by providing more accurate delivery to customers as well as simplifying changes in production level (Bonney, 1994). However, a warehouse containing a large amount of items will increase the tied-up capital as well as the administrative complexity and cost. Because of these drawbacks and the introduction of modern management philosophies the focus has been put on inventory reduction. Low inventory levels tend to generate less waste compared to companies stocking large amount of products or components needed in production. The traditional manufacturing approaches has used inventory in order to level out the variance in production. However, the modern manufacturing philosophies such as JIT try to include the entire supply chain to create a continuous flow (Bellgran & Säfsten, 2010). This means that the inventory environment has changed due to the introduction of new technology, management philosophies, economic situation and the customization of products, which has led to more complex parameters affecting the inventory level. Therefore, it is important to understand which variables that are inventory drivers. Having a good inventory management is no longer a competitive advantage it is an essential capability to survive in a global market (Özalp, 2011).

Inventory is mostly associated with something tangible, in this context, raw material, pre-manufactured components and finished products. The tangible characteristics increase the cost directly dependent of the volume. On the other hand, it protects against uncertainty in timing, quality and quantity, which minimize the risk for stops in production because of material supply problems. This is the main advantage by having an inventory. The most common disadvantage is that it ties up capital, space and labour. The inventory volume is important to control since it drives quality problems and obsolescence (Dillon, 1990). The uncertainties that the inventory should cover are often based on approximation of inaccurate information. These uncertainties affect the inventory and are very difficult to predict (Fleisch & Tellkamp, 2005). By identifying what parameters that control the inventory, sufficient quality of the information and an adequate measure may be ensured. In the long run it is important that the measurement of the parameters is comparable over time (Parmenter, 2010) to indicate the inventory performance and identify waste. These measures can be made on different levels, from key result indicators (KRI) to key performance indicators (KPI) and are often but together mixed in a balance scorecard. These are set as a standard value of the best know practices and are used as a benchmark in improvement work and performance of the order winning factors. The balance scorecard should contain performance measurements that are comparable over time (Bellgran & Säfsten, 2010). In the context of inventory this measurement is set as a maximum level of tied-up capital. The lower the inventory value is below this maximum level, the better the performance is considered to be. With this type of constant limit no production or demand parameters are considered. For example, the need for a larger stock is natural when the production volume increases. However, if this is expressed only in monetary terms the level of inventory will be higher compared to lower production volumes. Therefore, it is important to include the impact of parameters in the KPI to make it comparable over time.

The automotive market has in recent years changed dramatically due to the poor economic situation in Europe caused by the crisis (Lundin, 2012). The falling demand and decreasing price forced the manufactures to reduce waste and cut cost to become more efficient. The risk for stops in the production is interlinked to the performance of material supply, since the material availability is essential in order to maintain the production (Bellgran & Säfsten, 2010). The trade-off between inventory level and production up-time makes the inventory management important. By identifying the parameters that influence the inventory level, the parameters of tied up capital can be identified due to the direct link between these two.

1.2. Problem discussion

The case study was conducted at Volvo Cars Cooperation (VCC) concerning the area of inventory management. VCC have a common framework for processes, systems and methods that have been developed with the name Volvo Car Manufacturing System (VCMS). Within VCMS common performance measurement framework for the organization has been set to identify the targets, deployment and follow-up of the VCC strategy. The performance measurement areas are Quality, Cost, Delivery, Improvement, Safety, Morale, Environment (QCDISME) and Leadership. Within these performance areas balance scorecard with key performance indicators for each department has been identified. At the two departments material control and the logistic department at Volvo Cars Torslanda (VCT) the tied up capital of the inventory is used as a measurement both for economic performance (the Cost area) and individual employee performance. Goals associated with these measurements i.e. KPIs are used to optimize the inventory level and to reduce different type of waste. Today the limit of the tied up capital of the inventory has been set based on experience and it is unclear what an optimized inventory is. This makes the system sensitive and unpredictable since there are no guidelines of how to set an optimized inventory limit. The current limit is only set once a year by the manager of the material control department together with the finance department. This means that if there are significant changes during the period they will not be taken in consideration, resulting inaccuracy and a non-comparable goal which is not measurable over time. A analyze has to be made of what parameters that impact this level. Another interesting aspect is what a balanced level of inventory is from an overall VCT perspective taking into consideration the whole value flow. The material control department at VCT has a hard time to identify what a balanced inventory is and how this should be measured. By finding a suitable KPI and identify the parameters that affect the inventory level the real situation could more easily be controlled and a realistic goal can be set. The knowledge about the parameters affecting the KPI e.g. the inventory level could be used to see trends and notify affected parts of the organization.

What a balanced inventory is has to be decided with consideration to the strategy of the company and trade-offs between the other performance areas. Therefore, the sub-optimizations in the system have to be investigated. VCT has a complex planning environment where it is essential that production do not stop due to missing parts. The complexity originates from the large amount of parameters affecting the supply chain, both known and unknown. Analyzing this complex planning environment and relate this to literature within logistics, these parameters will be investigated and mapped. Further on from an academic point of view, it is of interest to detect inventory drivers. A KPI that measure and that reflect the inventory is also out of interest since it may guide the organization to better performance over a long-term perspective. With the understanding of these parameters it would be possible to incorporate relevant information in a measurement.

1.3. Purpose

The main purpose is to investigate what parameters influencing the inventory level and how the inventory can be evaluated.

1.4. Scope an limitations

The focus of the thesis will be to identify what parameters that affect the inventory level. In order to evaluate the inventory, the level will be related to a measure that is comparable in different parts of the organization. The inventory parts that will be analyzed is the physical available material at VCT and to some extent the in-transit material. Less focus will be put on parameters that have not a direct impact of the planning environment of the inventory, for example R&D. The inventory value that will be in consideration is from time that case company is the owner of the material to the point in time where it is sent to production i.e. tied-up capital of finished goods or work-in-process will not be included in the analysis. Further on material excluded from investigation is sequenced material due to the short time of ownership.

1.5. Expected outcomes

- A mapping of what parameters that directly may influence the inventory.
- Suggest a KPI that gives an overview of the present situation and that is comparable over time.
- Apply the parameters identified in a framework
- Through the framework present improvement suggestions to the case company

2. Methodology

This chapter will describe the research approach used for this project. In addition, it will provide a description of how and which research methodology was chosen. Moreover, a description of how the data was analyzed will be presented.

Literature studies and empirical analysis has been made within related topics to inventory management. Further on, a case study was decided to be conducted parallel with the literature study, this according to the scope i.e. due to the problem definition and time limit of the project. After the problem definition was set together with the case company, literature studies connected to the subject was made. From the literature studies a framework, containing the subject field out of interest. The literature study was made parallel with the case study due to the limited timeframe. After the case study the analytical framework was evaluated and additional subject fields was added. This analytical framework was used during the analysis of the case company. Further on, from the analysis and discussion recommended improvement actions are suggested. The methodological path can be seen in Figure 1, here the outcome from each step can also be seen.

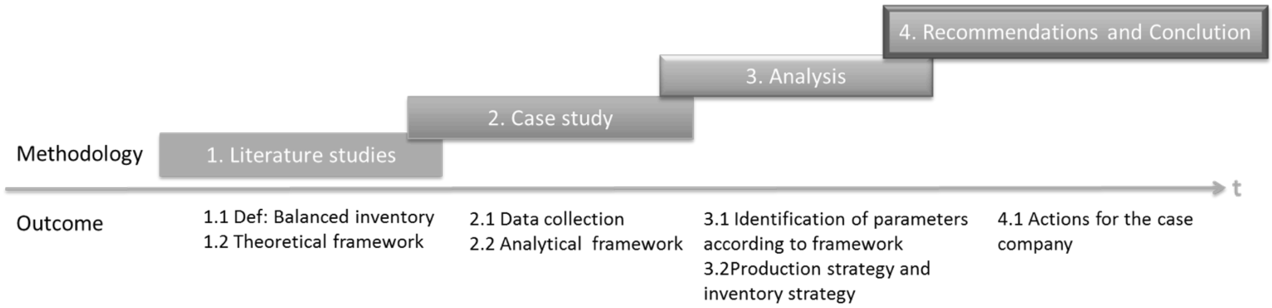

Figure 1 -The metrological path, the overlap between the different steps in the methodology and the outcome from each step.

2.1. Literature studies

In this thesis the abstraction level is important. A holistic view of the situation is an important factor in order to get an overview of the situation through the whole value chain. In order to get a perspective of the influencing parameters an analysis of different subject fields within the supply chain within studied. This to find an optimal and balanced inventory with a good compromise between trade-offs among the parameters. Example of areas that has been studied is described in Chapter 3. Studied areas are: forecasting, production, economics, supplier influence and development of a representative measurement. The main databases for collection of research material i.e. books and articles was held from the well-known databases Emerald, Scopus and Book24x7. Through the literature studies a theoretical framework was developed.

2.2. Validity and reliability

Case study research must be designed carefully in order to be valid and reliable. As a way to ensure the quality of a case study validity have to be considered from different angles, in the following list (Yin, 2009) important aspects are presented.

- ***Construct validity***
  - Use multiple sources of evidence
  - Establish chain of evidence
  - Have key informants review draft case study report
- ***Internal validity***
  - Do pattern matching
  - Do explanation building
  - Address rival explanations
  - Use logic models
- ***Eternal validity***
  - Use theory in singly-case studies
  - Use replication of logic in multiple case studies
- ***Reliability***
  - Use case study protocol
  - Develop case study database

The list above has been considered during the development of the theoretical framework as well as the preparation of the case study. By gather information and knowledge from different departments and theoretical sources, many of the guidelines in the list are fulfilled. The key informers have reviewed the data in order to ensure the correct information has been used.

Bell (2005) states in order to avoid plagiarism it is important to use references, if there are any citations or ideas used for inspiration. Therefore, it is highly important to ensure that the books and articles are from trustworthy sources, since the reliability is very important. In order to ensure the validity multiple sources that states similar knowledge is used when possible. Sources that have been used more than once are considered to be reliable due to their academic reputation. The Harvard citation method is used, since it is widely recognized.

2.3. Case study

The reason for choosing a case study as a method is since it gives appropriate possibility to conduct analysis of a limited number of events or conditions and their relationships. Further on, a case study contributes with knowledge of individuals, groups, organizational and process aspects (Yin, 2009) that has an impact on the inventory management. The case study is a typical single-case. The unique situation and the existing research within the subject field inventory management justify this approach. The methodological path for case studies is presented below together with which chapter in the report that can be related to the step (Yin, 2009).

1. Determine and define the research questions. (Chapter 1)
2. Select the cases and determine data gathering and analysis techniques. (Chapter 1 and 2)
3. Prepare to collect the data. (Chapter 3)
4. Collect data in the field. This has been conducted using multiple sources gathered through interviews, observations and history data.(Chapter 4)
5. Evaluate and analyze the data (Chapter 5-6)
6. Report the result (Chapter 7-8)

According to Yin (2009) usage of multiple sources of evidence is important when conducting an case study since it gives a reliability to the study. Therefore, the data gathering was mainly performed through a combination studying documents, interviews, observation and analysis of data. Interviews are considered as one of the most important sources of information in a case study (Yin, 2009). Interviews can be done either using a structured or unstructured approach. In a structured interview a set of fixed questions is followed and there is no room for deviating from the question frame. This compared to an unstructured interview where a question frame is not in use (Bell, 2005). Unstructured interviews were mainly used during the case study. This, since the knowledge about the organization was initially limited unstructured interview was used to gain knowledge about the organization and its impact on inventory management. Without this basic knowledge about the organization adequate questions are difficult to formulate.

Observation can either be participant or detached/structured (Gillham, 2010). Detached/ structured is considered being a quantitative method since the person is watching from the "outside" analyzing in a timed a specified way. Participant on the other hand means that the person is involved and has a descriptive approach i.e. qualitative (Gillham, 2010). During the case study the participant approach was used having an objective viewpoint from a production engineering perspective. The participant approach was used due the inventory performance depends on various situations. Further on, the data documented was limited and needed to fully understood and organized. After conducting the case study the framework of which categorizes that affect the inventory was extended. In the reference list the interviewed people are listed.

To ensure that the data gathered during the case study is valid, VCT personnel have verified the information in the case study correct. Through careful consideration to when in time the data was gathered the reliability of the data could be confirmed.

2.4. Analysis and framework development

From the literature study a theoretical framework was developed containing different subject fields to organize the identified parameters in a structured way. The fields of interest where chose due to interrelations between inventory and its performance. The framework was evaluated after the case study in order to ensure that important aspects were taken under consideration. The fields of subject that where added are highly impacted by the organization of case company. During the analysis each category within the framework was analyzed in order to identify what parameters affecting the inventory level. The parameters found are in cursive text in the continuous text and are summarized according to the framework. In the framework the parameters are identified whether they are related to a strategic, tactical or operational level and if they are qualitative or quantitative. The reason of this was to distinguish the parameters in the framework so that it can be used within various industries and within different levels of the organization. As a complement the identification of whether a parameter is qualitative or quantitative will give an indication of how measurements may be developed. Moreover, to understand the behaviour of the inventory level this was related to the production strategy. After the analysis and a discussion was made about way some parameters was identified.

2.5. Recommendations and conclusions

The mixture of industrial and academic approach is a good way to get a holistic approach of the overall inventory situation to reflect upon. It was noticed during the case study that the industry and the academy has different perceptions to use theory. From the framework the most important parameter for the case company were identified. These where recognized taking in consideration their specific situation. To be able to have a more theoretical approach short term and long term recommendations where given to the case company. The chapter Recommendations focus at practical solutions for the case company, while the chapter Conclusions on the other hand a more academic approach. The conclusions are also built upon the parameters identified in the analytical framework.

3. Theoretical framework

This chapter will give an introduction to literature that is the base for the theoretical framework. Further on, it will cover areas connected to the inventory, supply chain and describe performance measurements such as KPIs.

3.1. Balanced inventory approach

Supply chain management mission is to have a holistic approach for designing and steering the transportation, inventory and production processes in a network with suppliers, locations and customers (Jonsson & Mattson, 2009). According to Wild (2002) inventory control is about balancing the conflicting requirements between these. In order to find this balance, trade-offs has to be evaluated against each other. Therefore, the organization works towards an optimized inventory. The word optimization is defined as: "finding an alternative with the most cost effective or highest achievable performance under given constraints, by maximizing desired factors and minimizing undesired ones"[1]. To further measure the performance efficiency and effectiveness should be separated. Efficiency means to do the things right, while effectiveness is to do the right things (Bellgran & Säfsten, 2010). To identify what a balanced inventory level is, an inventory strategy has to be identified, containing the balance of the affecting parameters. With a holistic view of the parameters that affects inventory a combination of efficiency and effectiveness can be achieved

When analyzing the inventory level and the order system there are different calculations of how to calculate the safety stock and the order quantity. Further on these two have different purposes and characteristics, which mean that there may be different parameters affecting them.

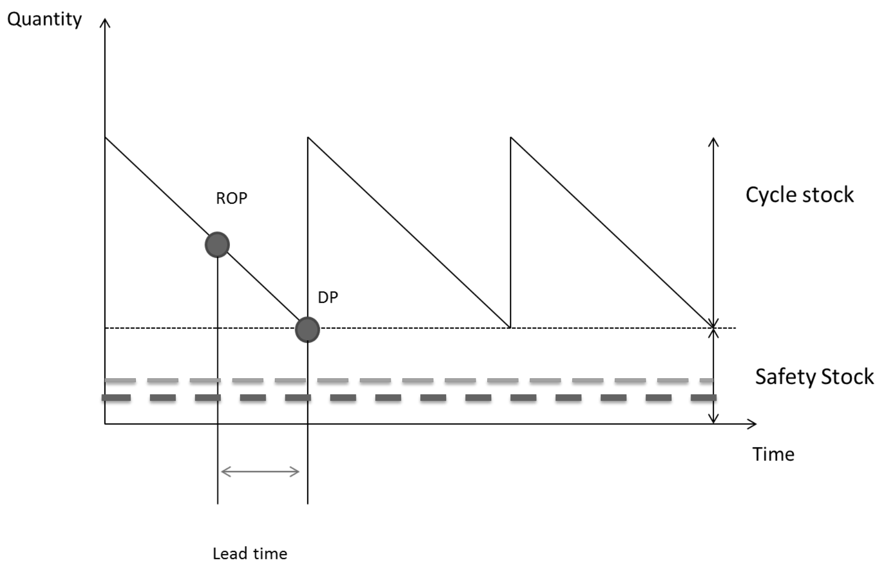

Figure 2- Illustration of the different characteristics of the inventory. The dashed lines represent different parameters affecting the safety stock.

[1] (Business Dictionary, 2012)

3.2. Strategic management of inventories

In order to meet the corporate goals, all internal processes must be adapted to strive against the same goals. The strategic inventory management is an important part. For example how an inventory should be adapted to meet not only the customer demand, but also other factors in order to fulfil the overall goals. Therefore, it is important to split up the corporate strategy to applicable targets for each department and ensure that these are communicated throughout the organization (Butler, Letza, & Neale, 1997). When the employees know why they are doing a certain task, it is more likely that they will commit decisions that are in line with the prevailing policy and goals (Bellgran & Säfsten, 2010). By breaking down the corporate goals to manageable day-to-day goals for each department, the daily work may be facilitated with a better performance as a result.

Strategic inventory can be both on a tactical and operational level. The operational level may be how to fulfil the goals on a daily basis using minimum amount of resources. While the tactical level may be how the inventory should be run to avoid overstocking, scrapping and obsolete articles (Jonsson & Mattson, 2009). The tactical level is also about evaluating the performance and set realistic goals. It is essential to understand some important relations, for example it is said that more inventory may worsen the delivery performance (Wild, 2002). Another important relationship is that inventory grows with production volume(Gaur & Kesavan, 2009), at a larger production volume more raw material and components will be needed. This result in more in-transit material as well as an increasing inventory level since all this material must pass through the warehouse. This means that with a larger production volume the inventory value will be greater. This must be taken in consideration when specifying the limits of the inventory value.

To avoid increasing inventory it is necessary to use standard inventory management principles for the total organization. One example may be the safety stock, without standards of how to set the safety stock random factors may be involved with an unstable process as a result. Standardized policies can help the process to stabilize with less unexpected variation as a result(Emiliani, 2008). Within a standardized framework the risk of self-protective behaviour due to incentives may be minimized. The right tools, authorities and information are needed to successfully work with a strategic inventory management. As mentioned above the corporate strategy should be translated to goals adapted to the supply chain department in order to facilitate the daily work and decision making for the employees.

3.3. Inventory performance

Supply chains are complex value flow systems that are difficult to overview. Because of the complexity it is difficult to understand the complete picture and therefore the holistic view might be lost. For example changes in one part of the supply chain may result in unwanted events in other part. Therefore, it is important to identify trade-offs in the supply chain, it is always about compromises between different factors (Glasserman & Wang, 1998). For example optimizing a supply chain to run under minimal cost might have effects of the overall performance such as poor response time or lack of flexibility (Beamon, 1999). Since there is a clear relationship between performance and cost, the performance levels should also be set to match the budget (Butler, Letza,

& Neale, 1997). The expected performance and cost must be within acceptable levels. It is also important to realize that a high performance level is not possible to achieve without costs, at least from a short-term perspective.

Inventory is often measured in terms of inventory turnover rate and the level of tied-up capital caused by the inventory. Inventory measurements consist of single performance measures and a problem with a single numerical measurement is that it might not represent the overall performance of the supply chain (Beamon, 1999). For this reason it is important to use a balanced approach between different types of KPIs. As suggested by Gunasekaran & C. Patel (2001) measures can also be divided into strategic, tactical and operational performance measures. There should also be a balance between financial measures and non-financial measures. Even though financial measures may hint about the profitability to managers these types of values may not be appropriate at the operational level (Gunasekaran & C. Patel, 2001). The indicators must be adapted to suit the context and the daily work. Each measure can also be investigated whether it measures internal or external performance and if it is qualitative or quantitative(Shepherd & Günter, 2006).

Another important aspect is the conformance between the measures and the corporate strategy. The link between these have to be emphasized since the measurements guides the employees. Measurements not in line with the corporate strategy will therefore guide the company in the wrong direction, since the used KPIs steer the organization direction (Beamon, 1999). This means that if the used KPIs are not aligned with the strategy the organization might focus on the wrong things. Hence, revisions of the used measures must be performed on regular basis (Beamon, 1999) to ensure the conformance with the goals.

There are several inventory measurements that can be used to analyze the performance. Bragg (2005) presents the following:

- Inventory availability (IAV), state whether the customer demand is satisfied according to delivery accuracy. It is defined as;

$$\boldsymbol{IAV} = \frac{\textit{Total number of completed orders recived on the required date}}{\textit{Total number of orders that should have been completed}} \qquad \textbf{Equation 1}$$

- Inventory accuracy (IAC), gives information about things are at the right location, in the right quantity, at the right time with the right description according to the system. It is defined as;

$$\boldsymbol{IAC} = \frac{\textit{Number of accurate checks}}{\textit{Total number of checks made}} \qquad \textbf{Equation 2}$$

- Inventory turnover rate (ITR), is used to detect if inventory items is used in a reasonable pace by the operations/production. If ITR is divided by 365 then the number of days of inventory is given. This equation takes no consideration to WIP or finished goods. It is defined as;

$$\boldsymbol{ITR} = \frac{\textit{Direct material expences}}{\textit{Raw material Inventory}} \qquad \textbf{Equation 3}$$

- Service level

$$SL = \frac{No.of\ inventory\ with\ shortages}{Total\ no\ of\ inventory\ cycle}$$ **Equation 4**

- Rate of change in inactive obsolete and Surplus inventory.
- Static inventory value. This means that the inventory is expected be lower than a budgeted limit. The measurement is either made at a single given point in time or as a mean value over a certain time horizon.

3.4. ABC categorization

An ABC analyze distinguish components depending on the component characteristics within the company, rather than grouping them altogether (Lun, Lai, & Cheng, 2010). Therefore, items included in the warehouse should not be handled in the same way. There are several factors that determinate how the items should be divided into different categories. The general categorization made is that items that have a high criticality for the company and its products are categorized as A, while B items have medium criticality and C items have low criticality. The A items should be regulated with a tight control, have frequent deliveries, a periodic review in the order system, have a high required service level and monitored on an daily basis. B items can be reviewed and have delivery with a lower level of frequency. Further on, a minimum–maximum system could be applied. C items are considered to have the lowest level of priority. The control and review of these can be simple and less frequent and a minimum-maximum system should be in use. How the company strategy and philosophy is applied impact as well. In a multi-criteria inventory classification there are several factors that divide the items into the different categories such as annual volume, value of the item, part criticality, lead time, obsolescence, durability, order size requirement, demand distribution and stock out penalty cost(Ramakrishnan, 2006). The Pareto rule is often used when analyzing how the categorization could be made. The Pareto rule has its origins form the Italian economist Vilfredo Pareto (1848-1923) but was not recognized until in the 1970:s. It deals with the fact that there is an unbalance between the input and the output of the system. The 80/20 rule state that 80% of the outcome is affected by 20% of the input. Jina et al (1997) argue that in order to handle today's short lead-time, make-to-order, high variety and low volume (HVLV) manufacturing, a categorization should be made for the lower demand parts. This categorization is similar to ABC and using the Pareto rule.

3.5. Manufacturing planning and control

Manufacturing Planning and Control belongs to the subject area of logistics and is defined as the planning, development, co-ordination, organization, management and control of material flow from raw materials suppliers to end-users (Jonsson & Mattson, 2009). In order for a company to be efficient and competitive, all the activities associated with these flows have to be coordinated. Depending on the problem analyzed and which decisions made in order achieve this co-ordination, the activities can be related to different level of control: strategic, tactical and operative (Jonsson & Mattson, 2009). Further on, these decisions are often made with high variance in time horizon and with different level of detail of information. The level of detail used to handle the time horizon is hierarchically structured as: sales and operations planning, master production scheduling, order planning and execution and control. How these are related to the level of control can be seen in Table 1.

Control level	Planning level	Planning object (level of detail)	Time Horizon	Period length	Rescheduling
Strategic	Sales and operation	Product group/ Product	1-2 years	Quarter/month	Quarterly/monthly
Tactical	Master production scheduling	Product	0.5-1 years	Month/week	Monthly/weekly
Operative	Order planning	Item	1-6 months	Week/day	Weekly/daily
Execution	Execution and control	Operation	1-4 weeks	Day/hour	Daily

Table 1 – Relations and characteristics of different planning processes

Sales and operation has the longest planning horizon and the lowest level of detail. At this level plans are made for sales based on forecasts and other estimates on future demand. The next level master production scheduling plans and production schedules are made based on customer orders and/or forecast(Jonsson & Mattson, 2009). The order planning is related to material supply, i.e to ensure that all raw materials, purchased components, parts and other semi-finished items are purchased or manufactured internally at the right quantities and at the right time, so the master productions can be carried out according to plan. The different levels have to be planed both from a material flow and a capacity point of view. Figure 3 summaries the manufacturing, planning and control (MPC) processes, where different level of material planning is corresponding to the capacity planning(Jonsson & Mattson, 2009). In Figure 3 the relationships and interactions between the different control levels are presented.

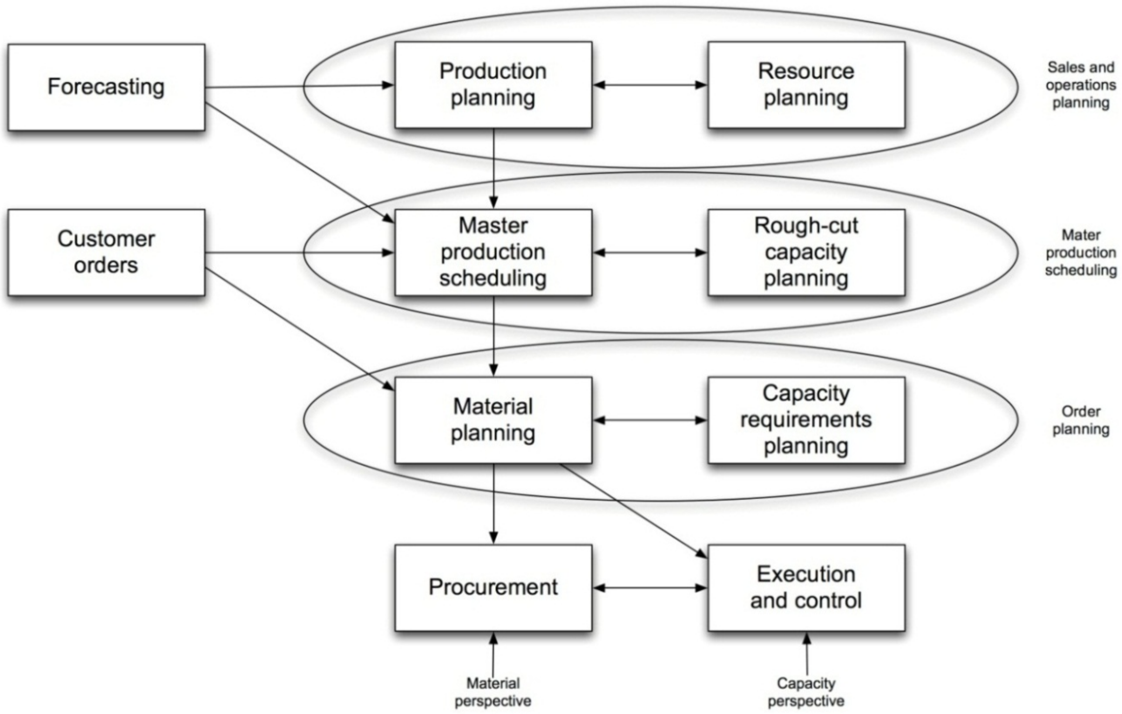

Figure 3 – Planning from material and capacity perspectives, MPC process (Jonsson & Mattson, 2009)

3.5.1. Forecasting

Similar to the control levels forecast can be organized as; strategic, tactical or operative and is used to assess the future demand of the product. The future volume is forecasted so that material and capacity plans can be made. These plans may be identical to the forecast, however the plans may also deviate from the forecast in order to provide sufficient capacity at an appropriate rate(Jonsson & Mattson, 2009). The forecasting can be made based on the concept of time series, which is a collection of historic demand data that shows the demand volume period for period. When analyzing the demand volume over the time series, various demand patterns can be identified such as random variance, tend or seasonal variance.

One of the most important aspects to take into consideration when conducting a forecast is the quality of the data, since this is the base for the forecast. Other aspects to take into account are the forecast horizon, which frequency the forecast should be made (this depends on the forecast period and planning frequency) and the level of aggregation (Jonsson & Mattson, 2009). The level of aggregation depends on the product and the independent demand between the products/ items. Table 1 gives an indication on what level this can be done depending on planning control, forecast horizon etc.

Forecast can be made through either qualitative or quantitative methods. Qualitative methods are built on subjective assessment by personnel with good knowledge of the market and the market development while the quantitative methods are based on more or less advance calculations(Jonsson & Mattson, 2009).

3.5.2. Time fences

Times fences are used for how and when rescheduling should be executed. Between different time fences there are often regulations of how the system is allowed to behave. Example of regulations between different time fences may be if the volume or if an order change is allowed. A frozen time period means that no changes in scheduling are allowed, while a half-frozen period refers to a phase when smaller changes are allowed, for instance sequencing. Time fences exist for all the three levels sales and operation, master production planning and order planning(Jonsson & Mattson, 2009). How these time fences are presented in Figure 4.

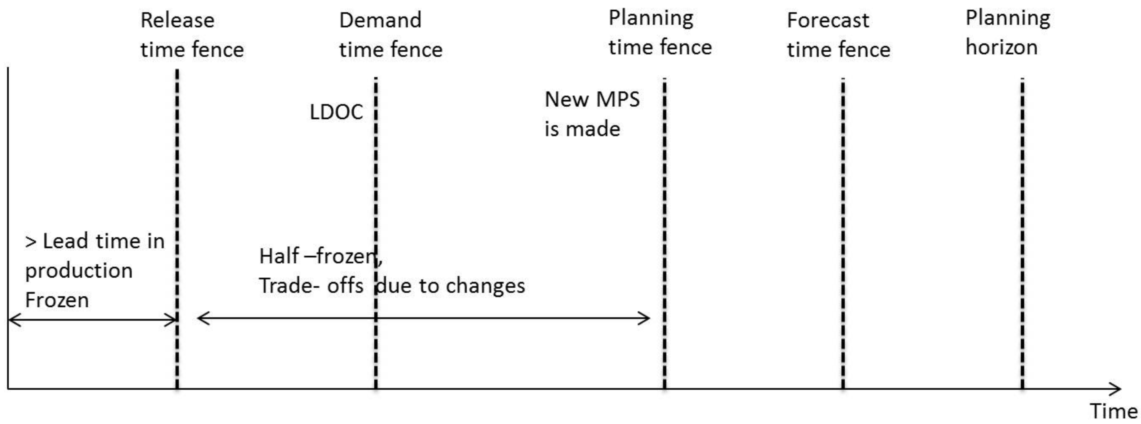

Figure 4 - Visualization of different time fences.(Jonsson & Mattson, 2009)

3.5.3. Order policy

If the material planning process (Figure 3) is simplified the main task is to establish an order planning as efficiently as possible for each product and component. The order quantity and when to order has to be decided with respect to the level of tied up capital in material flow, delivery service and the utilization of resources (Jonsson & Mattson, 2009). In other words find a cost-effective balance between supply and demand of materials. In order to do this as efficiently as possible the following questions has to be answered according to Jonsson & Mattson (2009):

1. For what items must new orders be planned? (item question)
2. How large must the quantity of each item in the order be? (quantity question)
3. When must the order for each item be delivered to stock, directly to another manufacturing department or directly to customer? (delivery time question)
4. When must the order for each item be placed with the supplier, or when must it be started in internal manufacture? (reorder point question)

The answers to these questions can be visualized in simplified model in Figure 5 below. The safety stock purpose is to handle demand uncertainties during production and lead-time.

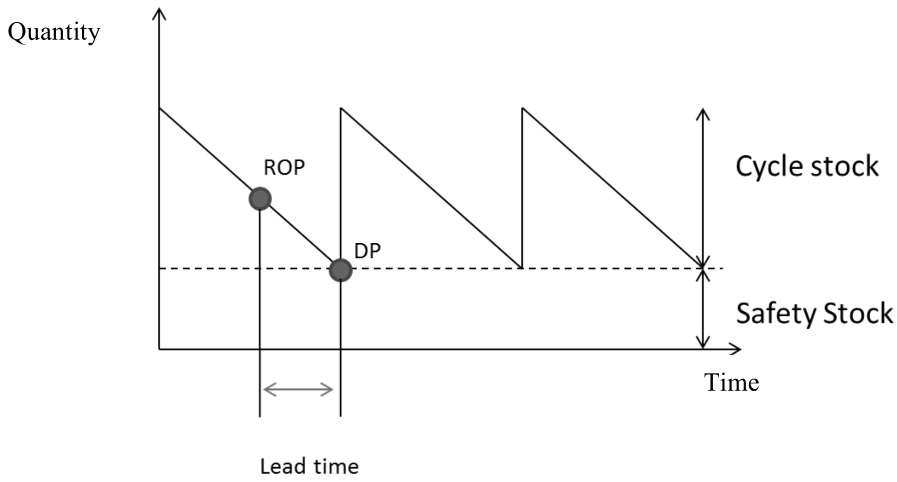

Figure 5 - Simplified visualization of the answers of quantity, the reorder point (ROP) and delivery time e.g. the delivery point (DP).

The true answer to the questions above depends on the purchase agreement to the suppliers, forecast, rescheduling and the lead-time. Material requirement planning (MRP) is one method used to answer these questions. MRPs most basic principal is to schedule a new order for delivery when there is a net requirement. This means that it is based on points in time for scheduling new deliveries when material requirement arise. The point in time to order is calculated as the delivery time minus the lead-time. To calculate these points in time, parameters have to be established in the system design. These concerns the length of time parameters used such as length of planning horizon, planning frequency, type of orders, rescheduling, pegging and planning time fences. Figure 6 gives an illustrative view of the parameters included in the calculation for the MRP. Execution and control is the planning level used for the detailed planning of orders, i.e. from the material capacity view it is the order release to the shop floor, sequencing and checking for material availability.

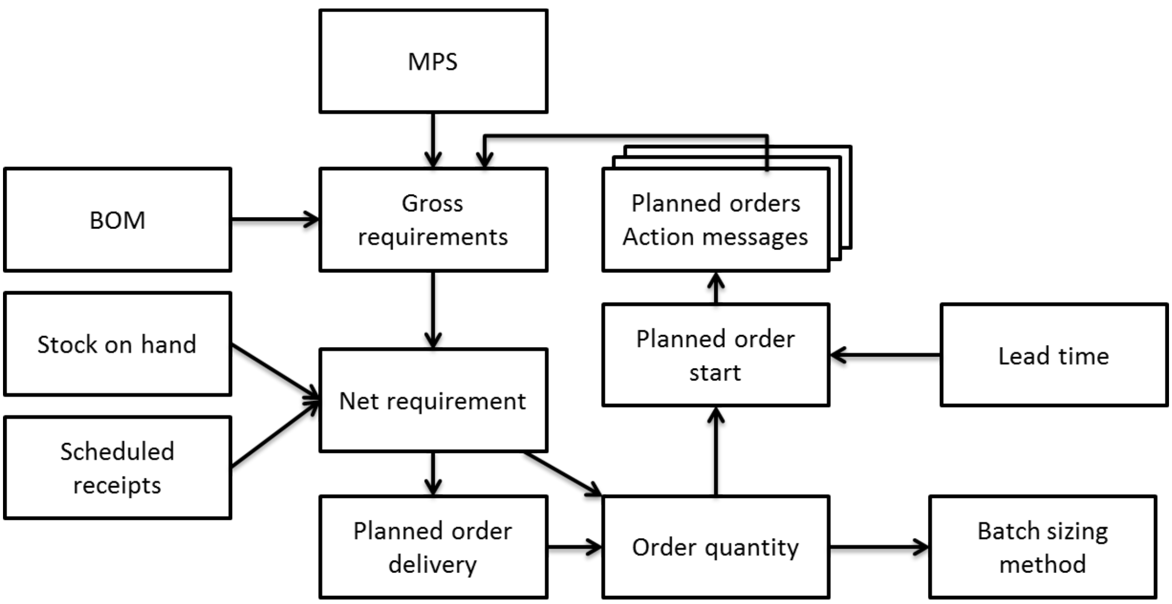

Figure 6 – Calculation for MRP (Jonsson & Mattson, 2009)

3.6. Safety stock

There are several methods of how to estimate the safety stock, where the simplest is to manually determinate the safety stock on experience. Two common and more advanced methods that would be appropriate to base the safety stock on is demand distribution and the use of either the service fill rate or the demand fill rate (Jonsson & Mattson, 2009). Through analysis of the data the statistics or the demand distribution per time period and the standard deviation during the lead-time can calculated. It is often assumed that the demand has a normal distribution. If the demand D has a normal distribution with the standard deviation σ_D and the lead-time (LT) has a normal distribution σ_{LT} then the standard deviation can be calculated (Jonsson & Mattson, 2009):

$$\sigma_{DDLT} = \sqrt{LT * \sigma_D^2 + \sigma_{LT}^2 * D^2} \qquad \textbf{Equation 5}$$

σ_{DDLT} represent the standard deviation of demand during the lead time and is used to calculate the safety stock with the factor wished to take into consideration, see Figure 7.

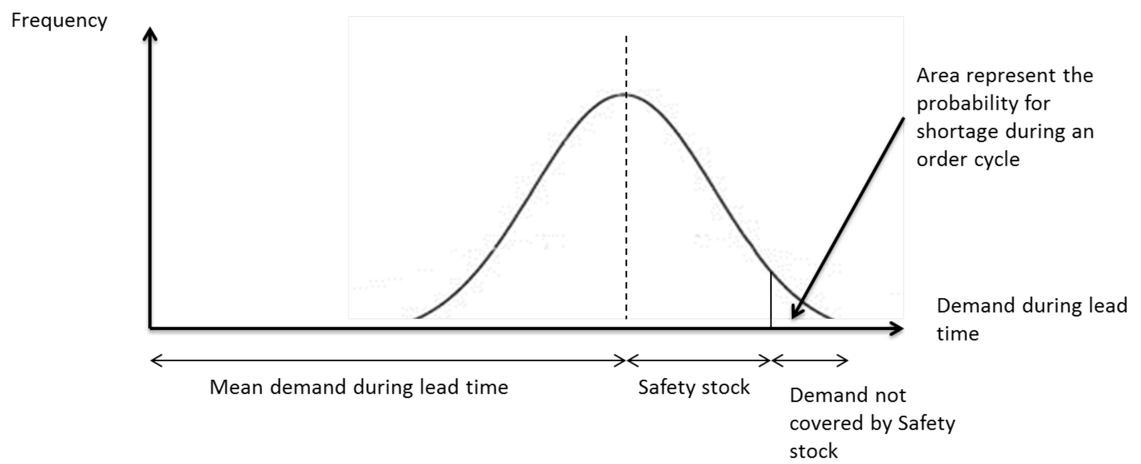

Figure 7- Illustration of demand variation during lead time. (Jonsson & Mattson, 2009)

The service level of the cycle service is the probability of being able to deliver directly from stock during one inventory cycle, this is expressed in percent. The service level is then translated into a factor k. The safety stock is then calculated:

$$SS = k * \sigma_{DDLT} \qquad \textbf{Equation 6}$$

The k factor has been carefully evaluated and can be obtained from tables when the required service level has been decided.

Another approach that can be taken when estimating the safety stock is to use the demand fill rate, which is defined as the proportion of demand that can be delivered directly from stock. This definition takes under consideration that the replenishments per year is different for different items (Jonsson & Mattson, 2009). The demand fill rate is calculated (Jonsson & Mattson, 2009):

$$\text{Demand fill rate} = 1 - \frac{\sigma_{DDLT} * E(z)}{Q} \qquad \textbf{Equation 7}$$

Where Q is the average demand, σ_{DDLT} is the standard deviation of demand during lead time and E(z) is the service loss function. E(z) shows different values for different safety factors Z which can obtained from tables taken into account the normal distribution of demand and lead time. The safety stock is then expressed as

$$SS = \sigma_{DDLT} * Z \qquad \textbf{Equation 8}$$

3.7. Financial aspects

The inventory tied up capital in the balance sheet helps to acknowledge whether the company is profitable or not. The finance department tends to budget and measure the inventory with a fixed value based on history and on "one single point" measurement. This does not represent the true inventory value over time. To budget the inventory for the balance sheet is difficult since there are so many aspects influencing such as seasonal demand, variance in purchasing volumes and product customization. Further on the inventory in the balance sheet can be divided into three areas namely raw material, work-in-process and finished goods. According to Bragg (2005) when budgeting for raw material inventory it has to determinate the amount physical units of the material required for each item for the budget period. Moreover, this should be related to the total physical units required for the entire production plan. After this, the quantity needed to fulfil the production plan and the safety stock has to be decided. The level of inventory on hand and quantity needed to be purchased has to be determined before a purchasing plan is made, to ensure that the material is available when needed. Here, factors such as economical sized orders, economy of transportation and safety stocks have to be carefully analyzed. To ensure the availability the budget can be tested towards the standard inventory turnover rates. The last step, after the budget in units has been reviewed, is to translate it to a currency by applying the cost/material unit (Bragg, 2005). As mentioned before, many difficulties exist when creating a budget plan. A high variance in items needed to be purchased, leads to a difficulty to handle information and inventory. Therefore, different categorizations for example a minimum and maximum inventory level can be applied depending of quantity and cost (Bragg, 2005). From a finance perspective the optimal level of inventory is when the inventory ties up as little capital as possible. The reasons for this are

- Inventory is considered as waste (Liker, 2005) .
- The inventory tied-up capital could yield profit by other allocation (Jaber, 2009) and affects the liquidity of the company.
- The inventory may be significant asset in the financial statement. Therefore, it is important to have as low tied-up capital as possible at the end of each accounting period since this determinates a company´s profit or loss(Business Dictionary, 2012)
- Inventory brings cost such as for storage area and direct work (Dillon, 1990).

The financial measure of inventory is directly correlated to a value or the inventory turn-over-rate. The inventory turn-over-rate is expressed as the cost of goods divided by the average inventory cost, please see equation 3. However, a time lag exists between the owned items and when the items are removed from the inventory. The quantity can differ if the production rate is not constant.

3.8. Transport

The globalization of the market has put new demands on how to handle the transportation of components. Lead times have become longer since a lower item price can be found in other part of the world, which affect the volumes transported to the production facilities. The transportation chain has to get more integrated with the information and logistic system to become more efficient and flexible (Sakchutchawan et al, 2011). The factors that determinate which transportation option that is the most cost efficient is the item cost, item volume, component variation, lead time and inventory interest rates (Trent, 2008). There will always be a trade-off between these factors form a transportation point of view. However, transportation should be more about supporting the supply chain and corporate objectives rather than achieving the lowest possible transportation cost (Trent, 2008).

There are planned and scheduled deliveries, but if there are for example shortages of important components extra transports are needed, these can be ordered to solve the problematic situation. The two most common ways for transporting goods by truck is either by full truckloads (FTL) or less than truckload (LTL). A FTL is when components from the same supplier fill up one truck. A FTL can be considered to be highly efficient and effective if a full-load do not adversely affect other supply chain units or cost categories (Trent, 2008). A LTL is when components are gathered from several suppliers and transported to one customer or to a hub where the components are redistributed once again. The LTL often follow a specific route with regular pick-up frequency. The transit time is therefore not directly related to the distance between the suppliers and the customer, instead it is affected by the network of suppliers and carriers along the transportation route.

Suppliers located far from their customers often have redistribution centres called hubs from where customer can collect the unit demand. A factor that may impact the delivery of items is that the suppliers have specific days of delivery as well as the internal goods reception. From a transportation point of view the most cost efficient way is to transport large volumes seldom. This may be verified by using the EOQ (economic order quantity) method (Burns et al, 1985).

3.9. Production

A production system is primarily given its characteristics depending on produced volume, level of product customization and lead-time to customer (Milgroma & Roberts, 1995). These together with geographical aspects and available technologies decide the production layout and the level of automation. Since the main focus is the automotive industry these types of characteristics will be further presented.

There are different production strategies in order to meet the demand. Two strategies that exist concerning the adjustments in capacity utilization are leveled and chased production (Jonsson & Mattson, 2009). Leveled production is when the production capacity is constant and variations are handled by the final product inventory. Chased production means that the capacity is continuously adapted in order to meet the demand. These two strategies are combined with either a lead or a lag strategy, which means that the capacity is either right above or right under the actual demand (Jonsson & Mattson, 2009). The trade-offs are either larger final product inventory or a longer lead to the end customer. Moreover, to meet the demand a pull or push strategy has to be match with the other production strategies.

Historically the car industry used a leveled make to stock (MTS) production system. Due to increasing product customization and shorter lead-times within the automotive industry new demands are set on the manufacturing systems. To handle this variation major improvement in terms of flexibility is needed, which can be achieved by using an assembly-to-order/make-to-order (ATO/MTO) system. ATO is therefore commonly used within the automotive industry (Miemczyk & Holweg, 2004). When using this manufacturing approach the production layout often used is a mix between a cell layout and a line based production system. The cells have a sequential order in a line where the product is moved through each cell. The cell layout offers a good compromise between flexibility and productivity(Bellgran & Säfsten, 2010). This type of layout also offers good possibilities to run an adjustable product mix, which is a condition to support an assembly to order strategy. However, the level of automation within the system has a great impact on the flexibility and productivity.

Production systems are, as mention before evaluated from production capacity, flexibility and cost. Figure 8 shows an illustration of the trade-off between cost and flexibility (Nigel & Lewis, 2011) in a production system. In this context the coupling, automation level and scale are important parameters, which affect the overall characteristics. The scale represents the volume, when producing high volumes the technology variation in the products tends to be low. This in general results in a higher level of automation in relation to human capital. The coupling represents the level of integration of activities either physical or virtual. A higher degree of physical coupling leads to less flexibility(Nigel & Lewis, 2011). However, the integration and improvement of software has increased the flexibility since information can be updated and continuously handled. ATO system within the automotive industry can be positioned in the middle of the range, though this depends on the customization level available. Companies that tend to have a high level of customization will therefore creep towards the right flank. A lower customization level will generate a lower unit cost.

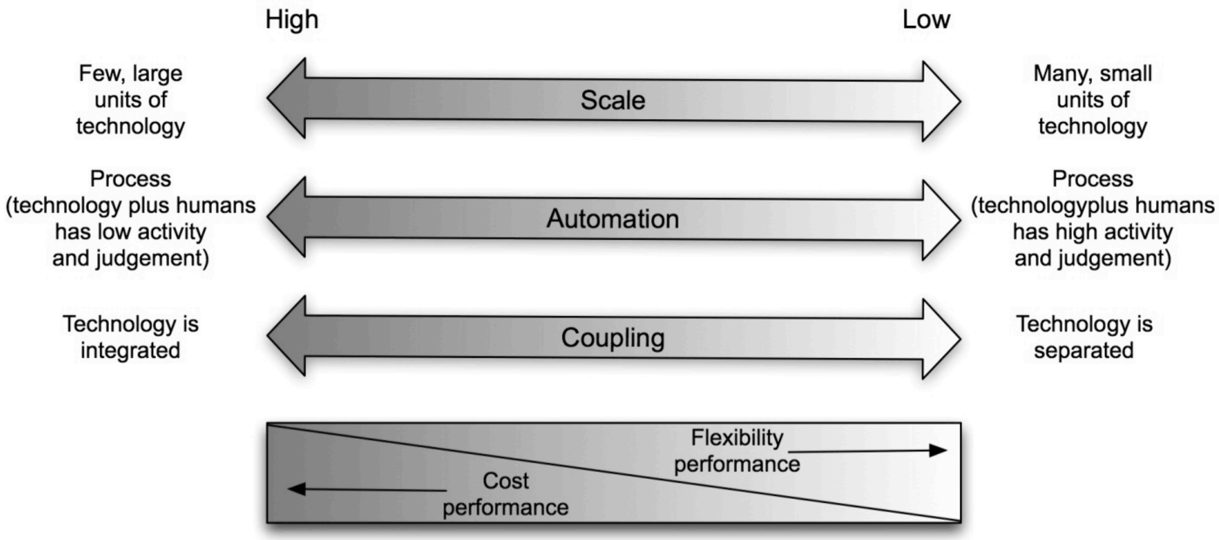

Figure 8 – Trade-off between cost and flexibility performance (Nigel & Lewis, 2011)

The capacity and the flexibility of the manufacturing determinates whether the system can meet the customer demand. Hence, depending on the level of scale, automation and flexibility a leveled or chased manufacturing strategy can be used (Bellgran & Säfsten, 2010). An ATO system often has a leveled production approach, e.g. the output is constant. Nevertheless, to meet the customer demand the production management can either adjust the cycle time or the working hours can be modified.

An ATO demands that the components are available when needed for assembly. Compared to other manufacturing strategies the material is already refined, considerably high value is already put to the component. Since the assembly through put time is relatively short it is critical to have the components in stock before the starting the assembly.

3.10. Supplier influence

The supplier performance reflects the performance of the business and has thus a great impact on the outcome. In recent years supply management has changed and become more important than ever due to increased dependence on outsourcing of goods and services, globalization, information technology, time and market responsiveness and performance improvement methodologies(Sherry, 2008). Therefore having supplier excellence is today of greater importance since it will lead to comparative advantages. What factors that influence the inventory depends whether it is a supplier-managed inventory or the company manage the inventory by themself. The supplier driven parameters that affects the inventory with; the net price per component, their ability to deliver on time, quality of the components, their capacity, responsiveness to change in time and service level (Kang & Lee, 2010). In return the supplier is dependent on accurate information about the forecast, packaging possibilities, transportation options etc. from the company. There are several evaluations methods that can be used to categorize the suppliers such as mathematical programing, linear weighting, statistical methods and total cost approach(Kang & Lee, 2010). When analyzing a supplier both qualitative and quantitative aspects have to be kept in mind. When choosing a supplier a risk analyze needs to be conducted, taking into consideration the influences of location of the supplier, lead-time, transport option etc. These parameters are used later, for example when setting the safety stock.

3.11. Performance measurements

Today there exist various ways of measuring the performance of organizations. Throughout history the focus of these measurements has changed. A measurement of performance that has always been in focus is the financial measurement. However, to capture the holistic view and the complexity of human interaction more aspects have become included such as quality, deliverability and flexibility. To handle different measures they can be grouped together into a performance measurement system (Bellgran & Säfsten, 2010). Balance scorecard (BSC), DMAIC and other performance measurement systems contain a mixture of different levels of Key performance indicators (KPIs) (Parmenter, 2010).

3.11.1. Key performance indicators

Key performance indicators (KPI) have become a way to measure performance on different levels within the organization. According to Parmenter (2010) there are four levels of performance measurement related to KPIs. The levels are Key result indicators (KRIs), Result indicators (RIs), Performance indicators (PIs) and Key performance indicators (KPIs), see Figure 9. KRIs should tell what the performance is of the critical success factors. They are monitored with a frequency of month/quarter and are typically analyzed by upper management. RIs should tell what have been done and PIs should tell what to do. These are important but not key indicators for the business. RIs are financial measurements while PIs are often nonfinancial and a complement to the KPIs. Parmenter (2010) argue that within organizations these four performance measurements have been grouped together and become misleading.

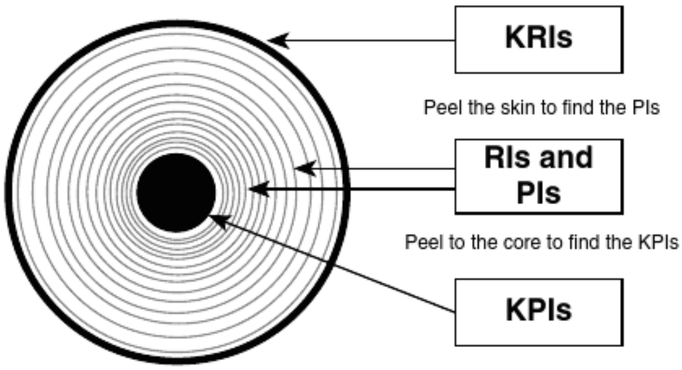

Figure 9 - Four types of performance measurements. (Parmenter, 2010)

A KPI should measure the aspects of the organizational performance that is the most critical for the current and future success for the organization i.e. show the "real-time" performance of what it measures. For a KPI to be relevant it has to be aligned with the company strategy as department strategies(Smith & Smith, 2006). In this way the KPI become a measures of how well the goals are fulfilled. KPIs not corresponding to organizational goals may show irrelevant information that leads the organization in the wrong direction. The KPI should in other words measure success and for evaluation, follow up, set targets for improvement and benchmarking both internal and external. The KPI should be monitored on daily or weekly basis (Parmenter, 2010).

Drawn from Kaplan & Norton (1996) a summary of the aspects a performance measure should cover has been identified. These are:

- Easy to understand
- Relevant to the goals
- Significant and positive affect e.g. promote the right behaviour to employee
- Measureable over time
- Employees must understand why it is being measured

For this to be achieved the KPI has to be updated and set on regular basis. It is also important to evaluate if the KPI is comparable over time when performing a follow up, if not the wrong conclusions may be drawn. Measuring on single performance might not give the guidance and the holistic view needed to strive for the company goal. Therefore, different types of KPIs are needed to give a complete view of the actual performance. A performance measurement system that is widely used to get a complete view is Balance scorecard (Bellgran & Säfsten, 2010).

3.11.2. Balance scorecard

Balance scorecard (BSC) was introduced in the beginning of the 1990 by Kaplan and Norton(Bellgran & Säfsten, 2010). BSC is considered to be a methodology that aligns a company´s vision and strategy into a set of objectives and performance measurements, comprising a mixture of different levels of KRIs, RIs, PIs and KPIs (Parmenter, 2010). It can be said that the BSC take theory and transform it to action, this by having a measurement that is make people feel that they are moving towards the strategy of the company. The original BSC has its performance measurements organized in four categories; financial, customer, internal business process and learning and growth. The four perspectives should help to find balance between short- and long term objectives, internal and external objectives, leading and lagging indicators, financial and non-financial measurements and financial and operational priorities (Nair, 2004).

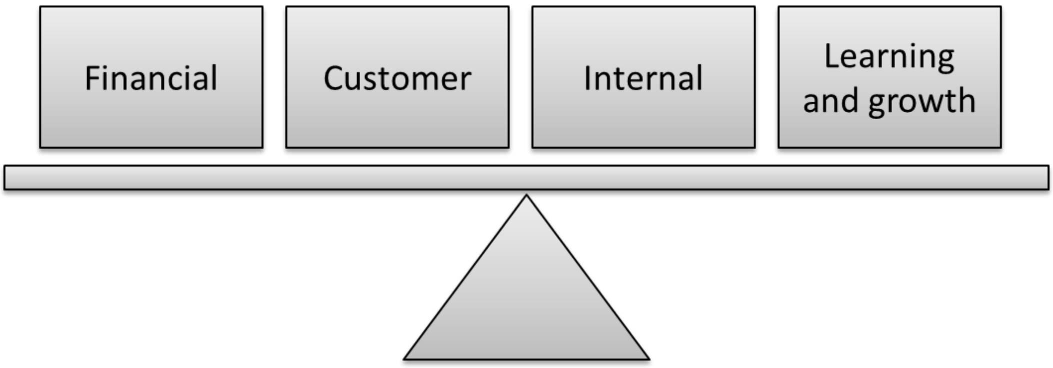

Figure 10- Balance of perspectives (Nair, 2004)

To be financial profitable is a vital goal for all companies. The financial measurements define the financial performance from the strategy and serves as the ultimate target for the objectives and measures of the other perspective of the scorecard (Kaplan & Norton, 1996). Therefore, the measurements on the other balance scorecard should be linked through a cause-and-effect relationship to the financial aspect. Depending of what stage the organization is in their lifecycle the performance measurement should have different viewpoints. The answers to the questions below will help to guide of what to measure in order to fulfil with goals within the different perspectives (Nair, 2004).

1. *Financial perspective*
    - What are the financial targets?
    - What drives these targets?
    - What kind of profit and revenue to achieve?
    - In a non-profit organization, what budget guides you?
2. *Customer perspective*
    - Who are the customers?
    - How do you delight them?
    - What segments do you wish to address?
    - What goals do you wish to achieve with partners?
    - What are your goals for the distribution channel?
3. *Internal perspective*
    - In which processes must we be the best to win customers?
    - What internal activities do we need to sustain competencies?
4. *Learning and growth perspective*
    - What must we be great in performing, and how do we train our people to get up to that level?
    - What climate and culture nurtures growth?
    - What do we have to do in developing and training our people to achieve the other objectives?

The customer perspective should describe which market segment and the position that the company aim to belong to. Further on, an alignment of the core customer to performance measurement of what the customer want should be done for different levels in the organization. Included in the internal perspective is to investigate which process that is the most critical for achieving customer and shareholder objective(Kaplan & Norton, 1996). This is the most significant difference from other performance measurement system and BSC. In the internal perspective it is important to acknowledge the fact that there is a difference of what the company see as successful compared to the customer. Related to the learning and growth category are the objectives and the measures related to how they should achieve the financial, customer and internal perspective. By using the balanced scorecard model, the overall performance from different point of view will be better covered, this is important when it comes to avoid sub-optimization. By using KPIs representing different stakeholders' point of view decreases the risk of sub-optimization.

3.12. Management by facts

In management philosophies like lean production, total quality management and sex sigma to mention a few, management by facts is an essential part. The concept is to do decision based on quantitative basis rather than qualitative (Liker, 2005). With help from systematic data collection and standardized methods of data analysis problems with processes may be monitored real-time (Liker, 2005). With a real-time supervision of critical processes problems may quickly be identified. The continuous data collection may also be used as a way to see trends from a long-term perspective. In some situations persons that are talented in speaking may better convince mangers that their aspects are the most important. Since communicational skills and conducting good analyses are not connected to each other they should not be treated that way. If there is no demand of presenting data before making a decision a charismatic person may influence the organization in a misleading direction. By identifying relevant data for a certain problem data can provide facts and give a chain of evidence (Yin, 2009).

3.13. Theoretical framework - Interrelations between different areas

There are several parameters affecting the inventory, e.g. reliability of suppliers in quality and deliverability, uncertainties in production and transportation. Through the literature study different subject fields where identified affecting a balanced inventory, these fields of subject have been grouped into different categorizations. The categorizations will create a framework when identifying what parameters affecting the inventory value. The framework will ease the identification of the parameters during the case study where a focus can be put on these areas.

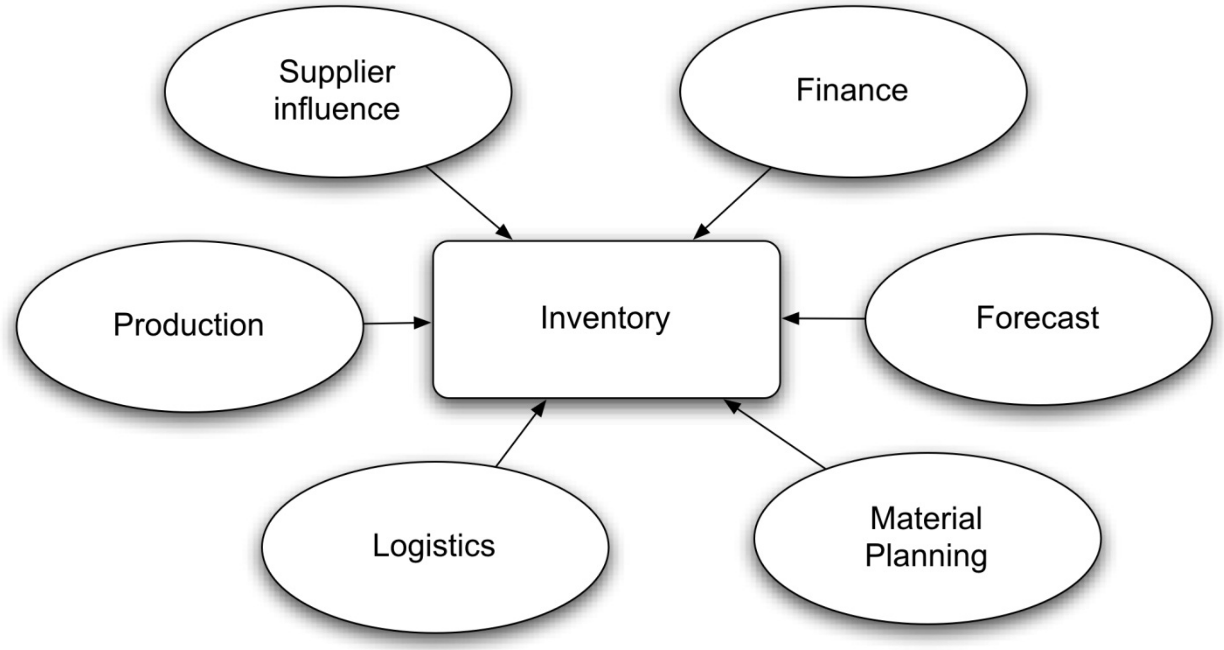

Figure 11- Interrelations between different areas of profession affecting the inventory level.

The categories identified were finance, forecasting, material planning, logistics, production and supplier influence, see Figure 11. A factor that was consider to affect all of these areas of profession is how the measurements where conducted. The areas that were identified will be used as a tool during the internal process mapping.

4. Case-study at Volvo cars

A case study was conducted at Volvo Cars Torslanda (VCT) mapping the internal processes in order to understand what parameters that affect the inventory. Volvo has undergone several ownership changes the past decade. This has strongly affected the handling of business processes. Moreover, the market orientation has also changed due to new customization and market segmentation. The manufacturing philosophies have in this time also changed during this time from a push to a pull production system. Through the case study the theoretical framework was extended, as a result of identification of new parameters due to additional insights.

4.1. Internal process mapping

In this chapter the internal processes that affect the inventory are described. The chapter will begin with a description of VCT and background to what affect the planning environment at the Supply chain department. The description will follow the MPC- process presented by Jonsson and Mattson.

4.1.1. VCC and VCT

VCC was sold to Ford Motor Company in 1999 from the previous owner Volvo Group. In 2010 the Chines company Zhejiang Geely Holding Group acquired it. After this VCC's new corporate and brand strategy became "Designed Around You". This strategy is the foundation and a guide for the business, the products and the corporate culture. From the strategy the vision; "To be the world´s most progressive and desired luxury car brand" was established. The mission was defined to: "Through the global success be driven by making life less complicated for people, while strengthening our commitment to safety and the environment". With these in mind VCC has a goal to in 2020 produce 800 000 cars per year[2]. The headquarters of VCC is located in Gothenburg Sweden. Currently there exist two car manufacturing plants VCT in Gothenburg Sweden and VCG in Ghent, Belgium and a third is planned in China. Except from this, VCC has an assembly plant for parts in Malaysia, an engine plant in Skövde, Sweden, body components in Olofström, Sweden and parts in Floby Sweden[2].

In 1964 an opening ceremony of the VCT was held plant by the then current king Gustav VI Adolf. The VCT factory consists of the body-plant TA, painting-plant TB and the assembly plant TC. Today VCT manufacture XC90, XC70, V70, S80 and V60. Additional S60 and the V60 Plug-in Hybrid will start to be produced during 2012[2]. The assembly plant TC has a build to order manufacturing system with a semi-automated production system. There are several limitations in the production due to assembly complexity and access to equipment. Hence, there are rules, which set the guidelines for the assembly sequence. At the production stations a limitation of access to two hours of production material has been set, this due to space limitations, the sequencing of products and the internal logistics. The supply chain coordinators (SCC) are the employees that have the daily contact with the suppliers about the material delivery.

The product e.g. the customized car is identified by a 34 number code. This code describes which model, engine type, sales version, gearbox, market, colour and other customization decisions made

[2] (Volvo Cars, 2012)

by the customer. This code is used in the forecasting and production processes in order to identify what shall be produced. VCC has a system called ARO that handle the order intake. The ARO-system contains information about the capacity of the plants i.e. the coming 60 weeks. When the order is received, it is in the ARO-system distributed to a plant and gets its production week. There exist a few parameters that decide to what plant the order is dedicated to. When the order has been dedicated to a plant and week the ARO system searches after the first available forecasted car code in the MPS for that week that is similar to the order. For an overview see Figure 12.

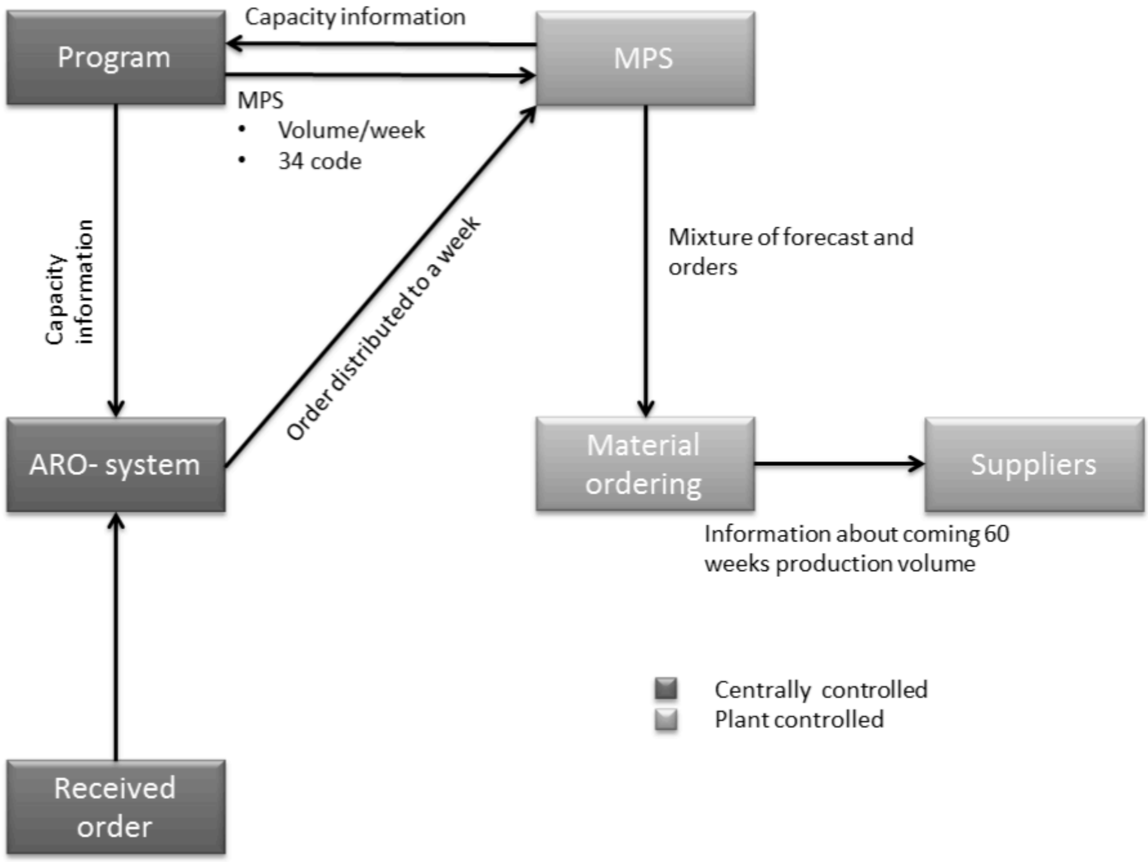

Figure 12 – Information stream of received order

Each year in week 20 there is a new release of the car models. The car models have undergone a product update where new components might have been introduced. In the production sequence there is a firm line when the old models is stopped being produced. This means that there is a phase-in and phase-out of the old and new components in the inventory.

4.1.2. Manufacturing requirement planning

The structure of this chapter will be related back to the MPC - process, (Figure 3) where the focus will be on the material planning perspective. The *forecasting* is made individually for each geographical market and is based on both qualitative and quantitative methods. The forecasting is done by market and sales department, who with their market knowledge and experience together with historical data build up a forecast model which is registered in the software called HERKULES. At the highest level of the forecasting an evaluation of the different markets are made on total volume, car model and type of engine. The second level of forecast covers the so called 12 number code. The 12 code cover a first estimation of the expected car and includes the car model, engine, sales variation, gearbox and market. The third level is a forecast for the 34 code which include the 12 code plus different percent estimations on colour and other the customization options. The forecast is made with a one year time horizon.

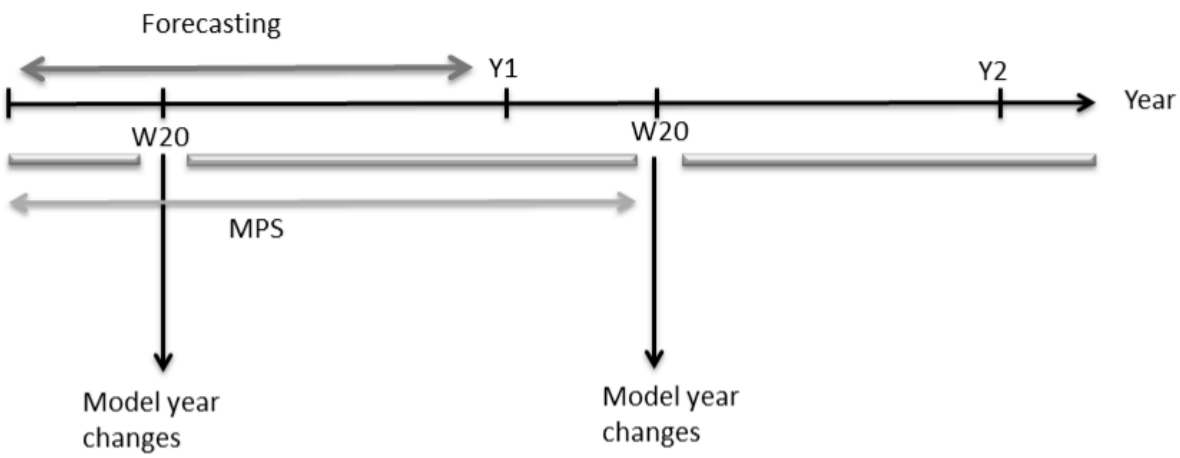

Figure 13 – Visualization of forecast period compared to MPS.

The *sales and operation (S&OP)* level is at VCC called the *program* where capacity distribution between the different plants is made. At the plant the department production planning and distribution make a capacity check related to car model and other specific parameters such as engine. The program together with the forecast results in a *MPS* covering the current and upcoming car model year (Figure 13). Then, the volume is distributed per week and contains the forecast of the car in the 34 code. The MPS is updated with a frequency of a month. Further on, the MPS is made once each month, for example in the end of April the MPS for June is made. When the MPS is updated the department production planning and distribution makes a more careful capacity check of the nearest future, e.g. with time horizon of 4-8 weeks. In this time span both orders and forecasts are available. The department production planning and distribution analyze the closest capacity taken into consideration some of the production limitations such as which engine, market and if it is right or left steered. Before the coming MPS is decided upon the material control department conduct a so called chimney check. The chimney check ensures that the ordered quantity is sufficient according to the MPS and supplier agreement.

The frozen *order planning* is made every week on Thursday for the Monday e.g. 6 working days away from Thursday. On this day the orders/forecasted orders are *divided into days* taking the production restrictions into consideration. However, this is not registered in the material order system and seen by the Supply Chain Coordinator, (SCC) until Friday. After the orders/forecasted orders have been divided into days the *sequencing* is made every day for the day 6 working days ahead (Figure 14).

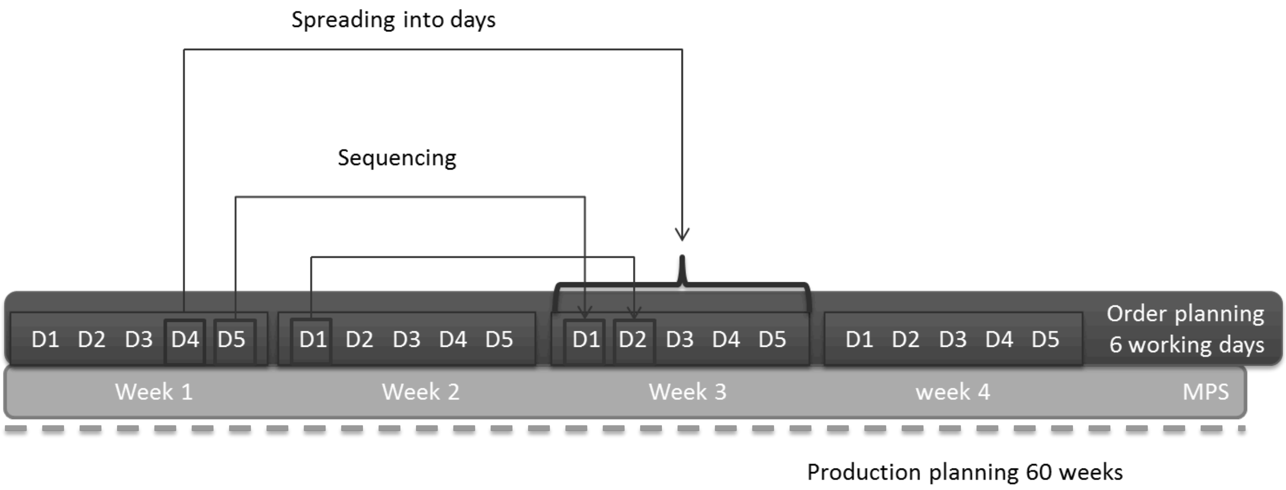

Figure 14 - The frozen order planning.

Execution and control i.e. the call-off is made four hours before the car goes on line. The batch material quantity for the suppliers is frozen two days before shipping. If there are any difficulties in production or lack of material then VCT employee can go in and manually block cars or get material either from ordering a premium transport or contact the spear-part centre RA. This means that the sequence of the cars will change. As mention before there are several limitations in the production system. If the blocked car changes the sequence so that the rules are broken the executer has to go in and replaced the blocked car with another one that do not break the rules. The executer can then use one of the first next coming 100 cars. However in extreme cases one of the 400 coming cars can be used. The LDOC (last day of order change) is one day before the distribution of the production volume into days. Furthermore, one week before the LDOC the LDOI (last day of order intake) has been set (Figure 15).

Table 2 gives information about the frozen days, i.e. different time fences are.

MRP	Frozen time
Capacity planning	1 month
Sequencing	6 days
Quantity information to suppliers	1-3 days

Table 2- Summary of the frozen days that exists within the different levels in the value chain.

4.1.3. Packaging

VCC has a guideline document where the packaging requirements for the production items are stated. The guideline is to help the supplier to select the right container for the shipping of the item. VCC has an approach where durable and standardized containers should be used. The term durable refers to that it can be used multiple times and a standard to the basic range of packaging containers is available. The containers are either so called blues boxes or pallets. The blue boxes are a Volvo standardized boxes and they are used for transport of various types of components. Further on a unit load is the number of item that can be transported in a container.

The suppliers are divided into different cost zone depending on where the supplier is located. Depending on the zone certain options of blue box and pallets are available for transportation of production gods. To decide the unit load and the optimal container according to VCC standards there are several steps to go through. If it fits within the standard, the zone has been identified and depending on the amount of shifts at the factory; the unit load needed for the two hours at the production can be calculated. The normal weekly capacity (NWC) is the expected amount of usage of a component per week. This is based on the forecast when the component is introduced and is it not reviewed frequently. The first step for deciding the unit load is to take the NWC and divide this with the total number of working hours for a week and multiply this by two. When this is done the smallest possible container can be identified. After this a weight check has to be made to ensure that the containers will not break and due to ergonomic reasons. If the weight is too high the supplier has to contact the VCC packaging department. There are also different alternatives if there is any need for any protective inner packaging. If the material cannot be delivered with the quantity needed for two hours then repackaging is done to meet the required demand. However this should be avoided if possible since it will lead to extra work and difficulties to identify who is responsible for quality issues.

4.1.4. Transportation

The transportation of the production material is done by Volvo car logistics (VLC). VLC is a separate company, which means that VCT buys the transportation service and VLC can be considered as a third-party logistics partner (3PL). One restriction that the purchase department has when negotiate with the suppliers is that the suppliers should be located in Europe. If the production is not located in Europe a HUB is demanded from VCT. The original reason behind this restriction is that the car body manufactured at VCT needs six working days to finish the car body part. When developing the strategy for setting the MPS, the frozen quantity plan to suppliers, sequencing and material-call-off to suppliers etc. it was decided that the transit time should not exceed three days and that the material should be delivered one day before usage. Figure 15 illustrates the relationship between the last day of order intake, order change, distribution, related to the call-off to suppliers and the production line.

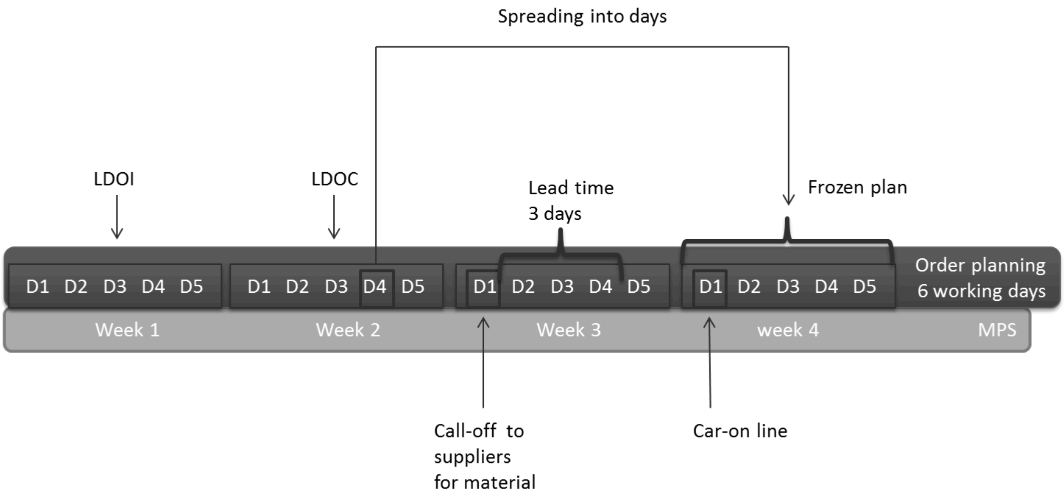

Figure 15- Visualization of the different time fences and the idle thought behind the 3 day lead time for transportation.

Due to cost optimization both concerning item price and transportation cost the transit time/ lead-time is in general between one to eight days. For suppliers located outside Europe, VCT demand a hub within Europe to ensure the lead-time to the production facility. Depending on the supplier and the amount of items, the parts are either transported through full trailer loads (FTL), dedicated trailer load (DTL) or milk rounds i.e. less than truckload (LTL). The parts are transported to an external logistic partner close to VCT. From there the parts needed in production are delivered to VCT according to a specific timetable. If the milk-round is a direct domestic transport then it is delivered straight to VCT. In reality the material is ordered by the MPC system so that the material is delivered before the safety stock is started to being used.

The call-off schedule for delivery is decided by central material planning and logistics (MP&L) and depends on the volume needed, capacity at the goods reception and the agreement that purchase has negotiated. A basic guideline is that if there are more than three pick-ups per week from a supplier or the weekly volume exceeds a volume full-load trucks are used. The criteria used when optimizing the transportation cost is the capital cost for the inventory, an interest rate of 19% is applied.

If material cannot be delivered through regular transport and material shortages occur, material can either be delivered from RA (the service centre), through premium transport or block the car to go on-line. The total number of premium transports for 2011 was 2139, Figure 16 describe the percentage distribution over the different causes.

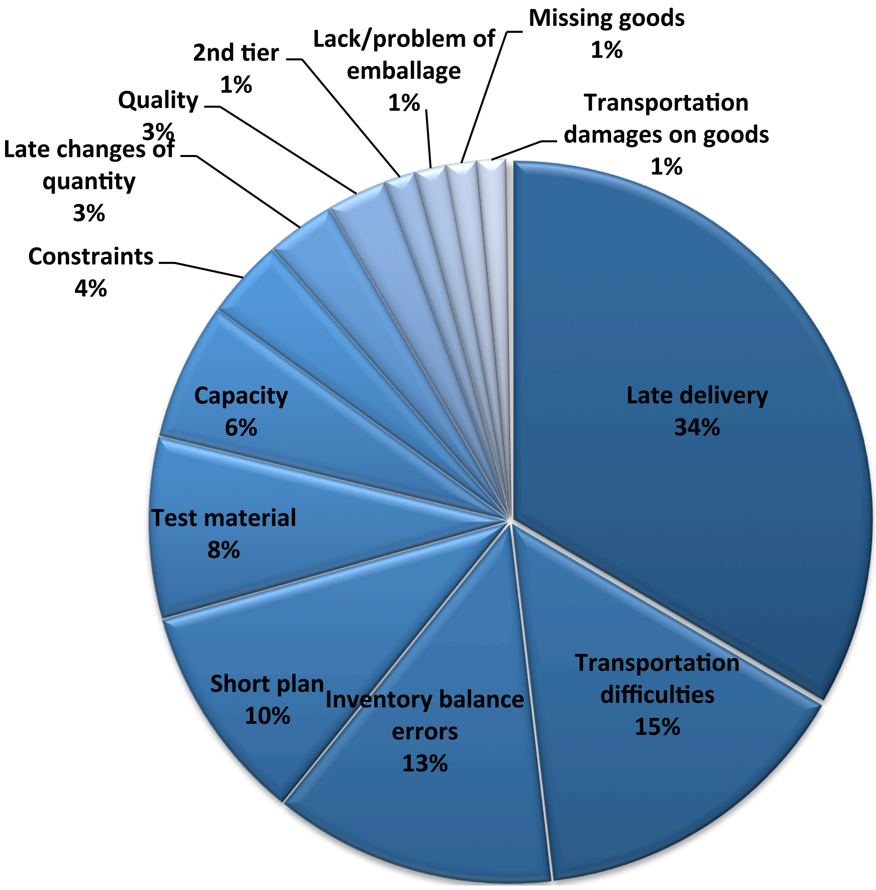

Figure 16- The percent distribution of the cause for premium transports during 2011. In total that year there where 2139.

4.1.5. Inventory handling

The material to VCT is either delivered to VCT as so called batch material or in sequence. The material that is sequenced from external companies to VCT are the panel door units, seats and dashboards. They are ordered four hours before the car goes online. As mentioned before, the batch material is delivered to a retail centre and later delivered to VCT according to the required sequence. For most of the items stored in VCT facilities, the sequencing to the production line is made though the concept "pick by voice". Pick by voice means that the employee has an earphone where the sequence is told and when the item has been gathered the employee confirms through the earphone and a new order is received. Further on, the principle of First-in-First-out is used, the item first delivered to the warehouse is the first on delivered to production line. Repackaging of items is necessary when the items are not delivered in the two-hour quantity needed for production. Because of the large amount of goods delivered to VCT there are specific standards of where the barcode and the notation paper have to be placed. If any deviations occur from the standard the supplier will receive a TA report (Torslanda Administrative report) and a fine. The TA report explains what the deviation is both in text and pictures. In response the supplier has to report back short and long term actions to prevent this from happening again, this report is called 8D.

When the inventory balance is reviewed the items are categorized according to function groups. These groups are reviewed twice per year. Function groups that contain items that are theft attractive are revised four times per year. During revision it is only the blue boxes that are counted, it is expected that the blue boxes contain the right number of items. At the end of each month there is a control with finance. It is believed that the main reason for the deviation in inventory is due to the cassation system. When an item is thrown away it has to be scanned otherwise the new item will not be registered as unavailable in the system.

4.1.6. Material delivery to line

The batch material to the line is delivered by forklift and if necessary repacked as mentioned before. The long-term goal is that there should only be two hours of material at the line. This together with the goals to reduce the non-value adding time at the assembly station, have quick change overs, increase flexibility, create a visual factory, stabilize the process, it has been decided that the material façade should have a 80% fill rate. The optimization of the material flow to the assembly stations is done with the line-back principal. This means that the material flow planning point is starting at the workplace and that all the supporting sub processes are planned right back to the supplier. How the material ordering is made from the production line has therefore a crucial impact on the entire supply chain and inventory.

4.1.7. Material planning

The Supply chain coordinator (SCC) at VCT uses the MRP system PLUS for control of material flows and delivery of the batch items. PLUS is connected to several other software systems where the necessary information about material requirement in time is located. PLUS is continuously updated with the information of the items delivered to VCT. However, some of the software's integrated with PLUS is only updated once per day.

PLUS compute plans and calculate the quantities needed, both short term and long term. These plans are established based on inventory level, pick-off tables or schedules for the suppliers, safety stock, the order plans and forecasts (see Figure 17). On a short-term basis, the actually day and the coming day, the SCC control the alarms that PLUS send out on shortages of items needed for production. Currently the components are not sorted in different categories and the used method is to organize the articles of one supplier as a group. The SCC has the possibility to control a few parameters by themselves, such as safety stock and multiples of blue containers for either on item level or supplier group level. What value these parameters are set to, depend on the SCC personnel experience of the supplier and the item. To determinate the safety stock for the items the SCC analyzes the lead-time, pick-up days, supplier country and the unit load. Additional help that exist to determinate an appropriate level of is supplier performance (SPFU) and turnover rate. However, there exists no standardized procedure of which parameters that the SCC should consider and each SCC has an amount of components which makes it difficult to find the time to manually regulate all off these with a high frequency. On a long-term bases the SCC has access to the production plan for the next coming 60 weeks, which is updated once a month. The SCC is responsible for the daily contact with its suppliers including sending the TA reports and follow up with the supplier preventive plan of actions.

When an item has a negative net requirement it triggers a supplier call-off. PLUS then scan the material requirements from the supplier that is needed to fulfil the transportation requirements and the needs of production. This means that different article numbers can be included in the scan for materials. The time limit in the future that PLUS scan to fill up the transportation option with is 60 weeks. If it is a FTL, then there is an iterative process between the components depending on the need until the truck is fully loaded. The number of components ordered is always ordered in a fixed unit load. The order steps in PLUS is illustrated in Figure 17. When the supplier has loaded the truck and it is on its way the supplier notify VCC. If this is not done at the planed time then there will be an alarm in PLUS. If there is a holiday on the pick-up day the delivery will be cancelled and moved to the next available pick-up date. This can lead to material shortages or access inventory. Currently there is a system update of PLUS where additional functions to ease the planning environment will be introduced. Example of functions that will be introduced is change of lead time due to public holidays in countries in Europe, safety stock function and ability to control low volume components to a higher degree.

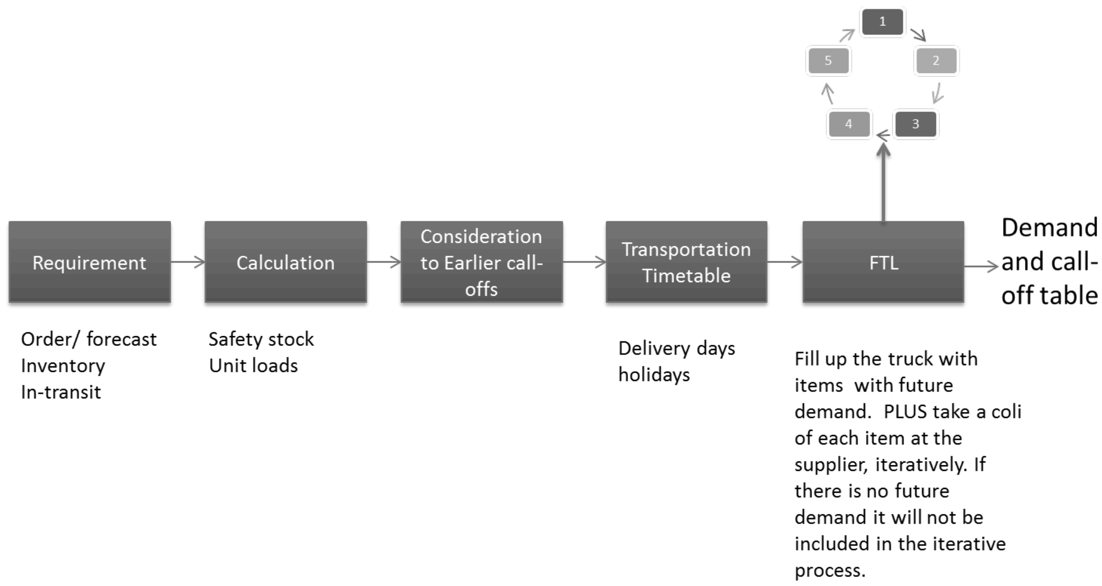

Figure 17- The flow of steps when PLUS is calculating the demand and call-off plan.

Through Electronic data interchange (EDI) system the suppliers get the information about the required order quantity that should be sent in order to arrive on time. The suppliers can see the order quantity for 60 weeks ahead and it is updated once a month and contains the expected volume per month with the aspect on car model. The production plan is sent to the suppliers in order to ease their production planning. As mentioned before, the material quantity is frozen two days before shipping. Material planning department has a meeting with the sequence suppliers after the production planning is released. The department of planning and distribution receives the production plan. After this the cars are distributed over the coming weeks, the process also includes a capacity check.

A difficulty that exists for the SCC is that they often have to order home material that has yet not been distributed to a specific day and that there often exist material that is on forecast.. This is due to the fact that the software PLUS calculate the order quantity according to the demand and due to the information requirement from the suppliers. This means that the total lead time has to be shorter than 6 days according to the guidelines. The parameters affecting this time limit are described in equation 9.

Frozen time (volume notice to suppliers) + Lead time + Safety stock (expressed in shifts) + days to the next pick up days < 6 days

Equation 9

This also leads to that the SCC sometimes has to order home material based on forecasts and not orders. If the incoming orders are different from the forecast then access material has been ordered and new material has to be ordered in to match the incoming orders.

4.1.8. Finance

The item purchased are owned by VCC from the moment VLC handle the material. This means that capital is tied up during the transportation. The financial department has the overview of the gathered cost for the redistribution centres (RDC), the transportation and the inventory level. The budget and the follow up for the coming year is made by the finance department and is based on historical data and experience. Today there exists no calculation model of what the inventory level should be. The finance department is responsible for organizing an inventory meeting each month. During this meeting the inventory level is discussed and the material control department will give an explanation if there are any historical abnormal trends. The main purpose of this meeting is to give an update of the current situation and discuss improvement areas. The inventory level is measured once a month at a single occurrence and they calculate the loss of having capital tied up as stock to be 7% due to the lost interest rate.

4.1.9. Quality control

The costs of the discarded items are divided to different departments depending if the quality issue can be related to the supplier, assembly station, internal logistics or transportations. If there is a quality problem discovered at an assembly station the component gets marked red if it is the assembly stations mistake, orange if it is considered to the suppliers cost, blue if the quality issue is related to internal logistics. The items are then put a side and pick up by a quality controller twice per shift. The quality controller registers the item in the system and analyze whether the item is correctly classified and write a TT (Torslanda Technical report) report if necessary. Depending on the quality problem they get blocked in the computer system using codes and the code decides whether new material needs to be ordered. It can often take up to 24 hours from when a component is disposed until it is showed in the computer system. The quality controller tries to inform the SCC if they believe that the item can become a constraint. The quality issues are included together with the deliverability in the Supplier performance follow up (SPFU) index which the SCC have access to. Item can also be picked from the shelves without being registered in the system, which results in inventory differentiation compared to the computer system.

4.1.10. Pareto rule

Figure 18 visualize an example of where 20 percent of the suppliers contain 80 percent of the tied up capital over a week in the inventory. Of the 599 suppliers that were included in the analysis 132 represent 80 percent of the total value. A second related perspective in inventory management is the cost per item. Out of the 9000 items included 660 items would represent 80 percent value. This indicates which type of article that has the highest item cost and how much to the total value of all the components that the item group represent.

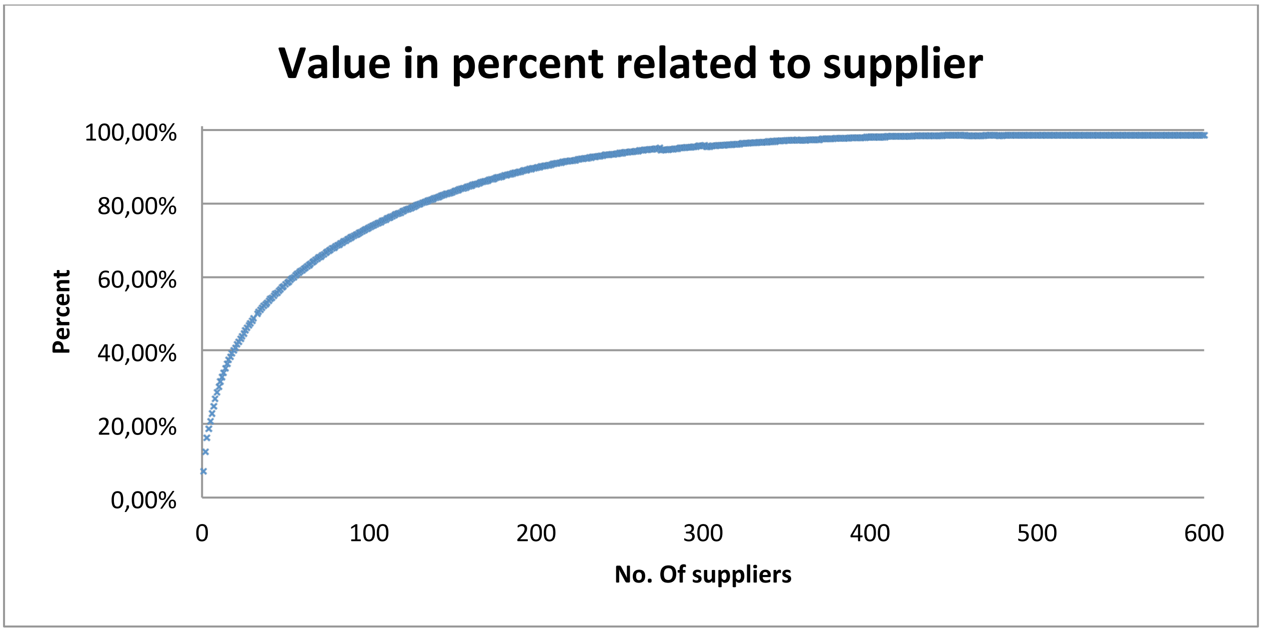

Figure 18 -Pareto diagram of the suppliers and their value in the inventory.

4.2. Performance measurements

The first balance scorecard named KLE which stands for Quality, Delivery and Economic was introduced between 1991-1993 at VCT. In 2006 VCMS (Volvo Cars Manufacturing system) was brought in to the organization, which included changes in the balance scorecard. Further aspects were added to the balance scorecard, which now included the areas Quality, Cost, Delivery, Improvement, Safety, Morale, Environment. Therefore, the balance scorecard is called QCDISME and is used companywide for target setting, deployment and follow up of the goals of the organization. QCDISME measure the total performance of the overall organization and the individual departments. A balance between these categories has to be found in order to reach the overall organizational goal. The departments have specific goals and KPIs, which are summaries on a category level. The measurements that are included in the different categories are visualized in Table 3.

Table 3 – A table with the QEDISME goals and measures for the material control department

BSC area	Goal Measure		
Quality	**Goal:**	**Cars off line with quality problems related to SCC/supplier**	**Missing parts of use/ period**
	Measurement:	No. of units	No. of units
Cost	**Goal :**	**Inventory optimization**	**Transportation cost**
	Measurement:	• Fixed value per week and month • Supplier top 10 • Supplier increase/decrease in SEK and % • Inventory turnover	• No. of Premium transportation • No. of extra outside of schedule • Extra because of VCT • Extra because of VCC • Extra because of supplier
Delivery	**Goal:**	**On time deliveries**	
	Measurement:	No. of stop minutes because of batch suppliers No. of stop minutes because of sequence suppliers	
Improvement	**Goal:**	**Supplier reliability**	
	Measurement:	No. of waiting for approval of D8 older than a week No. of TA-reports not related to a D8.	
Safety	**Goal:**	**Employee safety**	
	Measurement:	No of accidents	
Morale	**Goal:**	**Employee moral**	
	Measurement:	No of sick days Employee follow up	
Environment	**Goal:**	**Employee attitude**	
	Measurement:		

As seen the inventory optimization is included in the cost categorization. The inventory target level should be lower than the maximal target level, which is set in the beginning of each year. An analysis of the turnover rate is also made.

4.3. Inventory characteristics at the case company

The main goal of the material control department is to ensure that material is available and that the production never is jeopardized. This should of course be done with a cost efficient approach. The safety stock exists to cover the uncertainties that might occur in demand, during transportation and production. The cycle stock is there to satisfy orders. Nevertheless, the inventory is dependent on the corporate and production strategy. Therefore, the inventory strategy and expected goal should be related to these. Since there is a lack of conformance between the corporate strategy, production strategy and the inventory strategy, the estimated goal for the inventory has not been an adequate measurement at the case company. It is believed that at the case company a chased and lead production strategy is used.

As mention in chapter 3.2 the inventory level is highly related to the production volume. In order to decide the correlation to the inventory strategy and how the inventory is affected by the parameters the inventory in MSEK has been illustrated together with the production volume.

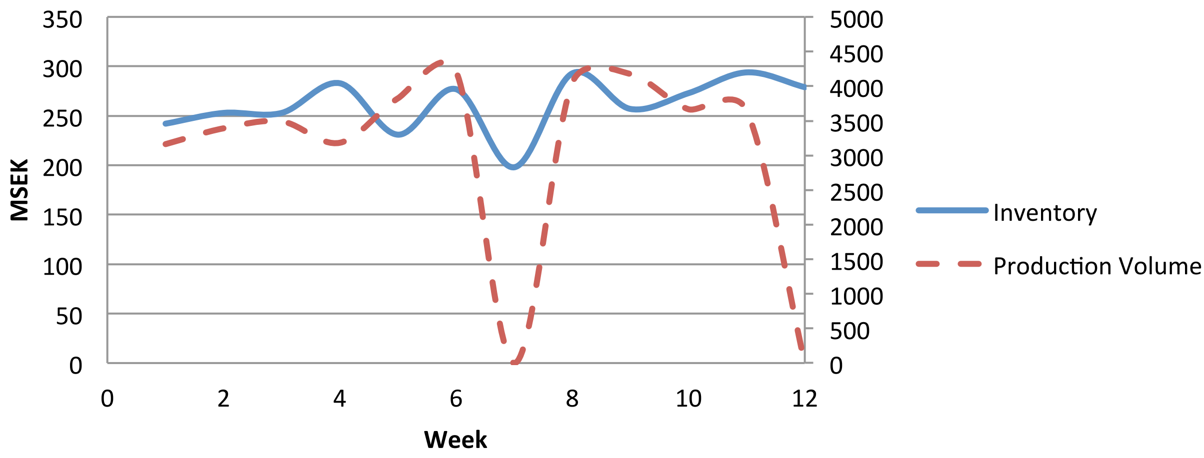

Figure 19- The correlation between inventory and production volume per month for 2011

Further on, to understand the impact of how and when the point in time the measurement is taken the correlation will be illustrated both per week and month. Figure 19 is measured per month in at one single point in time, while Figure 20 is the mean value for an entire week. The mean value has its origins from data that is collected daily at 06.30 am. When comparing Figure 19 with Figure 20 it is clearly noticeable that information is lost. Nevertheless, different level of detail is appropriate depending on the purpose and therefor department. However, it is important to consider that the measurement should represent the time period.

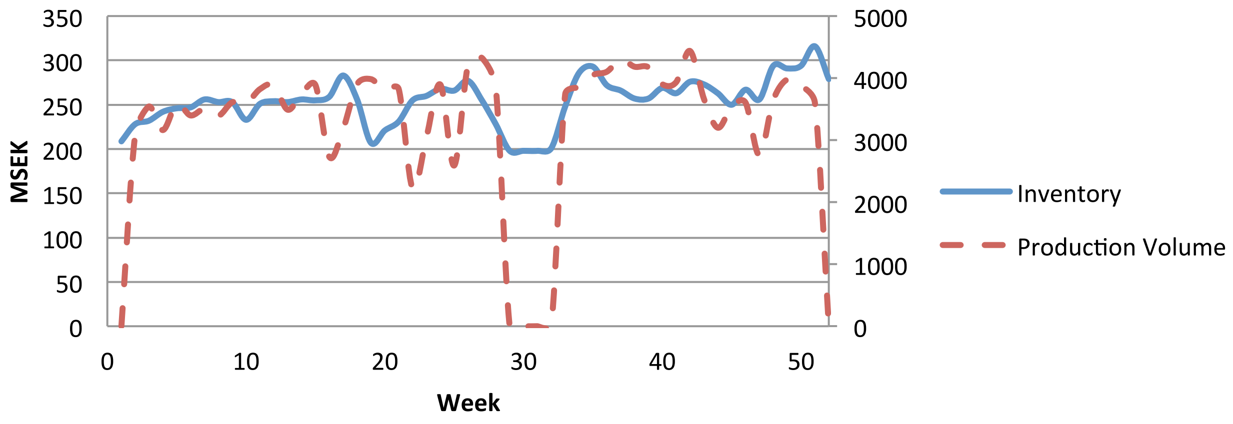

Figure 20- The correlation between inventory and production volume per week for 2011.

How things are measured has a great impact on the outcome, what analyzes that can be made from it and how easy it is to understand. VCC has a high level of customization of their products, several restrictions in the production system and a policy that is not to produce any cars they do not have an order for. This leads to a high variation in production volumes. When analyzing Figure 19 and Figure 20 it seems that until week 16 the inventory followed the production volume relatively good. Between week 16 and week 43 there were a turbulent period. There are several reasons for the turbulence in the inventory compared to the production volume. The first aspect is that around week 16 there are several holidays across Europe. This means that if a holiday occurs on a pick-up day, the items planner for this day is moved to the previous pick-up day causing excess inventory. During this time period of week 16 and week 43 the model change occurs in week 20 meaning there are new suppliers coming in, test material has to be brought in, item are being phased out, etc. Moreover, it is the Swedish industry vacation in week 29-32, which means that the plant and goods reception is closed. It is seen that before and after the vacation the inventory is higher due to the difficulty to ensure that material is at home in time when the production starts again. After week 43 the inventory follow the production volume with a slightly sift towards left. The shift to the left is the effect of the parameters lead-time, unit load etc.

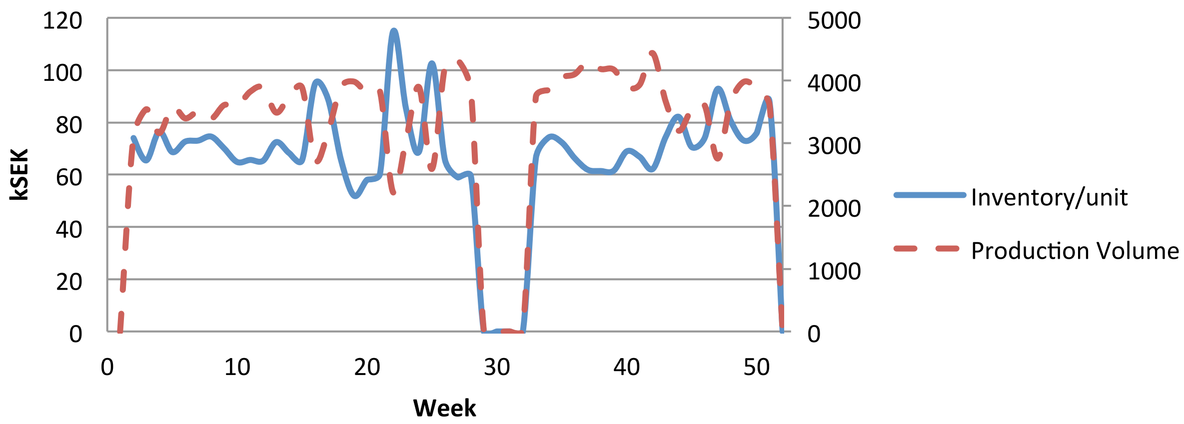

Figure 21- The correlation between inventory per unit and production volume per week for 2011.

An established measure within many departments at VCC is to represent as the cost per produced unit instead of the sum of total cost. Due to these reasons an approach that has been taking is to measure the inventory per unit. Figure 21 describe how the inventory acts when measured per unit. Here it is also illustrated together with the production volume. When comparing these one could see that the two lines are mirrors of each other. This is reflecting the strategy of maintaining a constant inventory level.

4.4. Framework for analysis

In chapter 3.13 an analytic framework was created taking in to consideration the areas of knowledge that was considered to have an impact on the inventory and its value. Through the case study additional categories were found to have a great interest when analyzing the inventory. The factors that where added is the impact of corporate strategy and organizational these are marked with a dashed line, see Figure 22. This framework was used for analyzing the case company and identifying what parameters affecting the inventory value. As mentioned in chapter 3.13 the factor of how to measure and with which aggregation level the measure is taken has a great influence on all of these categorizations.

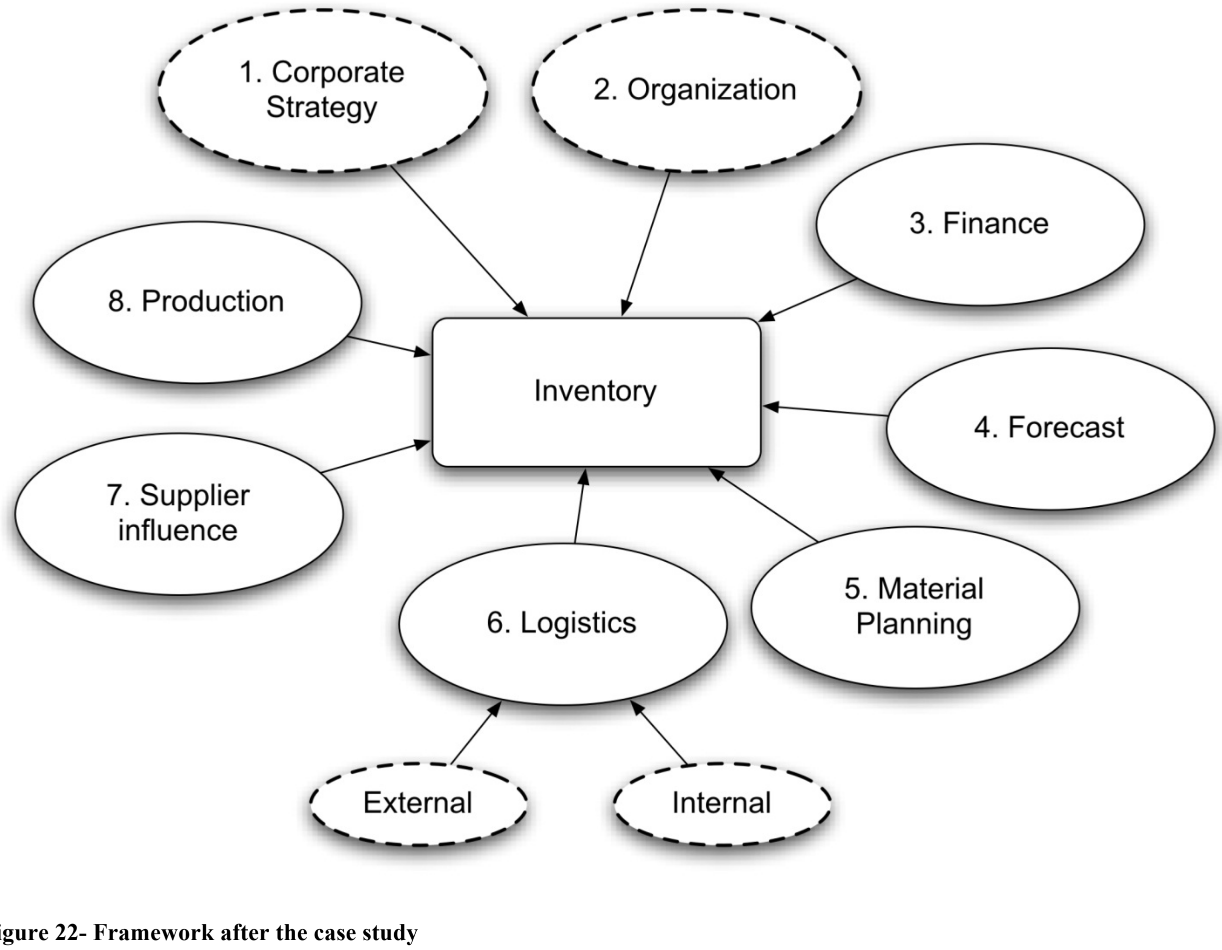

Figure 22- Framework after the case study

5. Result and Analysis

In this chapter the overall analysis of case company is conducted using the theoretical framework. In the analysis the headings in chapter 5.1 are corresponding to the numbers in the theoretical framework in chapter 4.4. The result of the analysis can be seen in Figure 33. When analyzing the relationship between the inventory value and the production volume, three scenarios were detected. These where further used evaluated the case company´s situation. As a complement a KPI analyze is executed.

5.1. Parameters affecting

There exists a great complexity when analyzing the inventory and the parameters that affect the inventory. In chapter 3.13 different areas of professions that have an impact on the inventory level was presented. Due to the production strategy and the future appropriate inventory strategy for the case company the parameters covered will be analyzed from this perspective.

5.1.1. Corporate strategy

The *corporate strategy* has an indirect impact on the inventory. For example, the high level of customization is a strategic decision that originates from the top management, this in order to attract a large customer segment. Even though this may give beneficial market effects it clearly affects the inventory levels. A greater *number of articles* present difficulties when considering forecasts. It is obvious that large product variety is less likely to be correctly predicted than a smaller. An incorrect *forecast* will generate problems related to the inventory. Some problems that are associated with this are, growing inventory levels, high scrap rate and occupation of space which all lead to expenses and instability in the process. With low forecast accuracy the material not immediately needed in production will be ordered and contribute to an unnecessarily high inventory. The decision to have a wide product range also contributes to a large inventory, a wide range of products increases the number of components needed hence the inventory will grow.

The total days of *order queue* must be longer than the supplier with the longest lead-time in order to minimize effect of forecast uncertainty, see equation 9 for further info.

5.1.2. Organization

Within the category organization several parameters affecting the inventory was found. These are *communication, documentation, process design, software* and usage of *KPIs*. These aspects are all integrated with each other.

The *communication* parameter is to be associated with the communication between the different departments. The communication on operational level between the different departments is believed to be good. However, the knowledge will stay at SCC and the entire information will not be documented. On a strategic and tactical level the information affecting specifically the material planning department needs to be summarized and documented in order to keep the knowledge within the department and to become more efficient. Moreover on a strategic and tactical level there is some lack of communication between several departments about the original though of the time plan of the material perspective, i.e. Figure 15. In order to get a well-functioning supply chain decisions need to be made with accordance to the corporate strategy taking the whole value flow under consideration.

Documentation of the inventory is only available 39 weeks back in time, if more data is needed the IT-division has to be involved. Further on the inventory data is either too detailed or filtrated, which means that it is rarely adapted to the organizational needs. Documentation on operational level i.e. late deliveries, extra transports etc. are considered to be good. The effects of these as well as quality issues can be found in the SPFU. At the material control department there are two different software´s used to gather data about the inventory. The finance department uses a third software to gather the data they need. These are based on the same original data but the show different time aspects, when comparing data from these measurements it is seen that they are not identical. Further on, there is a confusion of where the data originally is coming from.

A *process* that is closely related to the inventory level is the process of setting the safety stock. The process has no standardized method of which parameters that should be overviewed in order to set the safety stock. This means that there is a high difference between the different SCC of how the safety stock is set. A follow-up and discussion meeting is supposed to exist but due to reorganization these meeting has not been conducted.

The last parameter on an organizational level is called *measure usage*. This aspect covers how and when in time the measurement is done, but also how the measurement is used to benchmark the outcome. Currently depending on which department, when in time and which software that is used the measure will show different values. Moreover the benchmark for the inventory is based on experience and only a fixed value and neither is it adapted to the corporate strategy or relevant over time.

5.1.3. Finance

The financial department *budget* the inventory value in order to set the company´s estimated profitability and liquidity. The budget is based on previous year outcomes and experience of the employees. From a financial perspective it is of interest to lower the tied-up capital before each financial statement. Since this will make the number to look better. The finance department has a wish to identify what an optimal inventory from a Volvo cars perspective is and create procedures of how to better regulate the inventory in the future. The finance department has the possibility to evaluate the holistic view including, inventory, goods in transit and transportation cost. This viewpoint is necessary in order to create what is the best alternative. A parameter that finance could use in a better way to control the liquidity of the company is to change *the inventory rate* when evaluating different business cases.

5.1.4. Forecast

The parameters that have been identified within the area of forecasting are*; forecast precision*, *distribution and sequencing* and the *frozen days*. The effect of forecasting precision on the inventory is highly related to the order intake. In times when equation 9 is longer than the amount of orders the MRP system will order materials based on forecasts. When the order comes in then it might not match the forecast to a hundred percent. This will lead to excess material in inventory and might result in premium transportation since the material needed is not available. The same applies for the spreading and sequencing if equation 9 is longer than six days, see Chapter 4.1.7. In the manufacturing requirement planning there are several time fences freezing the quantity at different stages, see Table 2. The frozen days for sequencing have a great impact due to the distribution of orders into days. The one to three frozen days towards suppliers, is reasonable towards the suppliers. At the same time it effects equation 9 making the total time for deliver longer. The *pick-up frequency* may influence the total lead time, where both the time waiting for a pick-up day and the transportation. For example, if there is only one pick-up day each week and the material has to be ordered far in advanced then needed. If any of these occurrence take place so that equation 9 is not fulfilled according to the original thought than the system becomes instable and the different kind of waste will arise.

5.1.5. Material planning

At the material planning department the SCCs´ have a great knowledge and experience about their assortment of suppliers. They monitor and set a value of the parameters affecting the inventory level and transportation. Relating back to Figure 5 the *safety stock* is set to a number of shifts. As mention the SCC analyze the number of pick-up days, lead-time, SPFU, country and number of standard packages (blue boxes) to set the safety stock. The number of safety shifts determinates when the material needs to be delivered and as known a high safety stock leads to a high inventory level. There exist no standard methods to set the safety stock, which means there can be a high variance between the SCC´s. After the demand is set the *order quantity* of an item and per transportation to be delivered is decided by the number multiples of standard packages.

If there are any shortages of material one of the first approaches is to contact the spear-part centre RA (*component borrowing*). By collecting the material from there, they avoid ordering excess material. However, there is a lack of *documentation* at the material control department of which components that are collected from RA. This means that information about the performance of the inventory and the suppliers is lost. If there is a shortage of material premium transports can be ordered. Figure 16 shows the reasons for ordering a premium transport during 2011. In total during 2011 there were 2139 extra transports registered. The causes belonging to the material planning department is capacity which means that the order quantity of material has changed. Another parameter that might affect this is chimney check. The 8% of test material is the new material needed for the changes in production. Further on, with short plan means that there has not been enough information about the future demand of the component. A factor that should effect the SCC decision on what to set the safety stock to is the fact that 13% of the events causing a premium transport were due to *Inventory balance errors*. This is often a result of errors with the labelling of the products. The last option that existing when there is a lack of material is to block the car from going on-line. There is no summary of the actions taken to ensure that there is material available, i.e. items from RA, items from premium transports and number of items causing blocked cars.

The flexibility in PLUS is a strong parameter affecting the outcome of the inventory. The options in PLUS will ease the SCC possibility to change according to fresh information. New functions such as ability to change the ETD (estimated time for dispatch) and ETA (estimated time for arrival) due to holidays in the delivery countries or the possibility to more easily differentiate certain kind of components (*Call-off time*).

5.1.6. Logistics

When analyzing the logistics it was decided to divide the parameters between the internal and external logistics. A holistic viewpoint was taken when analyzing the parameters. The internal logistics concerns the *handling of the material* inside the facilities. The lack of storage area at the site has resulted in outsourcing to different warehouses. Further on, *repacking* has been introduced since the standard package does not match the need for material in the production. Repackaging has affected the quality negatively and created problems to assign quality issues to the supplier or Volvo due to the extra handling. This can be a future parameter when kitting is introduced. Generally, if kitting is introduced this may affect the inventory since the material has to be for a longer time in storage in order to be in the right kit-setup.

There are several external transport parameters that affect the inventory, numerous of which it is hard to control. Since Volvo cars own the material from the moment it is picked up from the supplier, the *lead-time* and number of *pick-up days* affects the inventory level significantly. Further on, the *type of transport* will affect the inventory level as well. FTL can possibly bring assess material for storage while LTL might have longer lead times. Out of premium transports made during 2011 15 percent is related to transportation difficulties (Figure 16).

The *unit load* should always match with the demand situation. This may be done by reviews of the unit load for a component during its life cycle. Unit loads adapted to the demand prevents unnecessary transportation and storage. As mentioned in the case study chapter the unit load at VCT is only set once, when a new component is introduced. This means that the unit load will only be suitable during a short period of the product life cycle. In Figure 23 the red marker illustrates a potential position for were the unit load is optimized, other volumes will weak match.

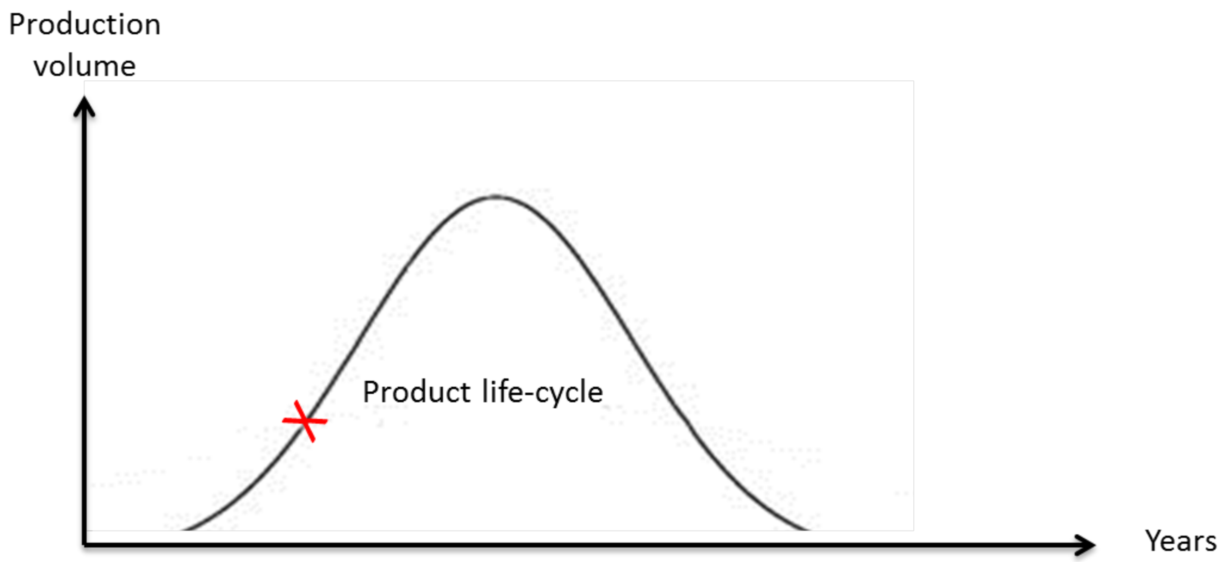

Figure 23 – The variation of the component demand during its life cycle

The transportation of the goods is highly influenced by the holiday calendar across Europe. If this occurred then in earlier versions of PLUS the SCC had to change the delivery day to the previous pick-up day. This resulted in a recalculations of order quantity in PLUS and excess material in inventory. However, with the upgrade of PLUS the effect of this parameter will be reduced.

The *delivery precision* is also essential in order to balances the inventory. Poor delivery precision will launch a negative chain reaction were premium transport is needed in order to get the components on time. These types of transports increase the expenses due to direct work, administration and an increased inventory as a result of double ordering of material. This is also interlinked with the number of pick-up days a supplier has as well how large the unit-loads are for each component type.

5.1.7. Supplier influence

It is a fact that the performance of the suppliers affects the performance of the company. In SPFU the supplier reliability is established upon *deliverability* and *quality* of the components. As seen in Figure 16 the number of percentages that can is related to late delivery is 34%. These are either caused by Volvo or the supplier, note that only was 3 % was related to quality. Another cost associated with the suppliers is the *label mistakes*, which are often made. In order to have an efficient goods reception and packaging to line the goods should be received according to the standards. If the supplier has late deliveries, then for that item the cycle stock will become lower, in transit higher and SS lower as an effect of usage. However, if this item is essential in the production the total inventory may be higher as an effect of units not being built. Further on, late deliveries may influence the inventory turnover rate positively, since the material will just shortly pass the warehouse and immediately be used in production.

5.1.8. Production

The production greatly impacts the inventory. As mentioned the *production volume* is closely associated with the inventory value, larger volumes means greater inventory value. Furthermore, to consider should also be the *takt time*. A proper match between the production volume and takt time is essential to create a stable inventory level. If the production pace is too high the order stock will more quickly be reduced while a too slow takt will build a queue, as mentioned previously the terminology is lead or lag strategy. From an inventory perspective the *production strategy* strongly influence the inventory level. With a lead strategy the intake of orders will be slower than the production pace. This means the order queue will get shorter and incoming orders that do not match the forecast will force the material control department to order new material. This will lead to excess material and premium transport in order to not jeopardize the production.

A build to order strategy is used at VCT, this means that only ordered cars are manufactured. The *production system* is dependent on a continuous material supply. With a too short order stock, the cars will be built just some days after they are ordered. If the time from point of order to production is shorter than the lead-time to any supplier this most cars will be built on material based on forecasts rather than on orders. The second issue is that there will not be enough time to use standard transports. Therefore, premium transports must be used if any components are missing. Both these issues result in additional costs compared to a situation were normal transports may be used. The usage of premium transports and material orders based on forecast also contribute to an unstable process.

The inventory is also influenced by the *production mix*. If the mix goes towards cars with more expensive components the inventory value will obviously increase. Further on, the production system has restriction either expressed per car model or in the 34 code. This information is known and should be used in order to set better measurements. The fact that there should only be two hours of production at the assembly stations (*level of material to production*) also affects the inventory level depending on whether repackaging is necessary or not. The *assembly layout* itself and the procedures there have an impact on the inventory level. The quality system in the inventory level could be better since 13% of the premium transports are caused by divergence in inventory.

The material planning system is adequate if there are no disturbances. The ideal case would be if there are no occurrences in the production system which leads to a *production stop*, the MRP system would reschedule when the material is needed so that no access material would be delivered. If this was possible the inventory level would reflect the production volume better not reflect specific situations in the production.

5.1.9. Production volume influence on inventory value.

Inventory and production volumes are related to each other through the volume and cost of the components needed for the decided production volume. The optimal situation would be when the inventory level follows the changes in the production volume. Analyzing relationships between the production volume and inventory level, three different scenarios were observed. The different scenarios are also related to different strategic goals, concerning both production and inventory. The purpose with the identification of the models is to combine different areas of knowledge, i.e. production system, inventory control, supply chain and way of measure. This to understand how the inventory would act depending on the production strategy and to identify the behaviour of the inventory during specific circumstances. Note that the inventory in this chapter is considered to be the safety stack and the cycle stock. The in transit material is not considered. The three scenarios identified are:

A. Scenario: Constant inventory over time with a varying production volume.
   Goal: Constant inventory value.
B. Scenario: Variance of the total inventory over time with a constant production volume.
   Goal: Leveled production.
C. Scenario: Variance of total inventory over time and production volume.
   Goal: Chased production.

As mention in chapter 3.2 the measurement of a situation has to be comparable over time and related to the goal of the organization. Further on, the production strategy has a high impact on the production volume and due to the high impact the production volume has on the inventory level. It was therefore decided to view the inventory from two perspectives. The first perspective will have the classical measurement of total inventory value as a fixed number (Muller, 2011) will be compared to production volume. The second perspective will express the inventory as inventory value per unit compared to the production volume.

The numbers in the graph below are estimated to give an adequate visualization. The term *total inventory* includes the total value in MSEK of the raw material and components purchased in order to meet the production demand. Moreover, when the term inventory value per unit is used, this referred the total inventory value divided by the number of manufactured units.

5.1.10. Constant inventory over time with variation of production volume

The goal to have a constant inventory level is based on that there should always be a certain number of component in storage in order to secure that there is always material available for production. Further on the goal to have a constant inventory level is often what is expressed when a goal is set without taking into consideration the affecting parameters. To estimate the inventory over the year a KPI with a fixed value of the inventory may be used. Figure 24 visualizes the relation of the inventory in this case and the production volume. Since there is often a divergence form the goal value then it is hard to optimize and understand why the inventory has a variation.

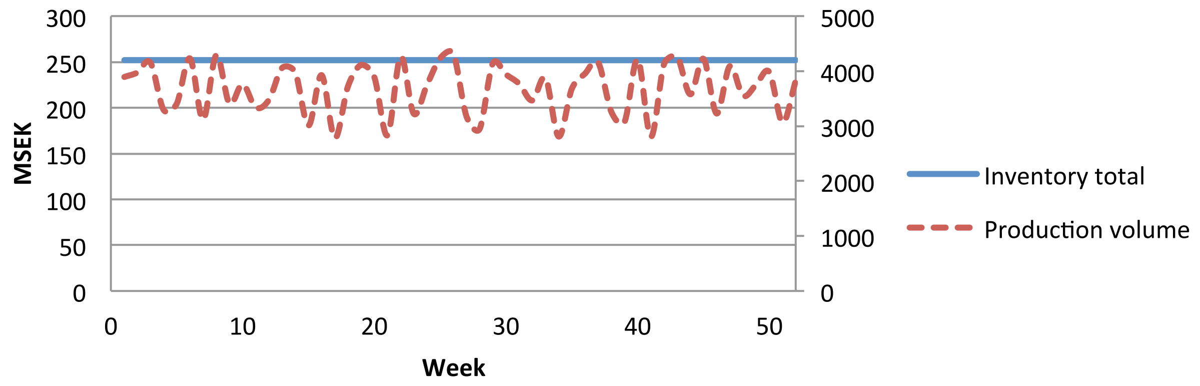

Figure 24 - Inventory and production fluctuations with the goal of a constant inventory level.

When comparing the inventory value per unit with the production volume for this scenario A that can be seen in Figure 25. Here the inventory value per unit is a mirror of the production volume. The inventory value per unit will be higher when the production volume is low and opposite when the production volume is high.

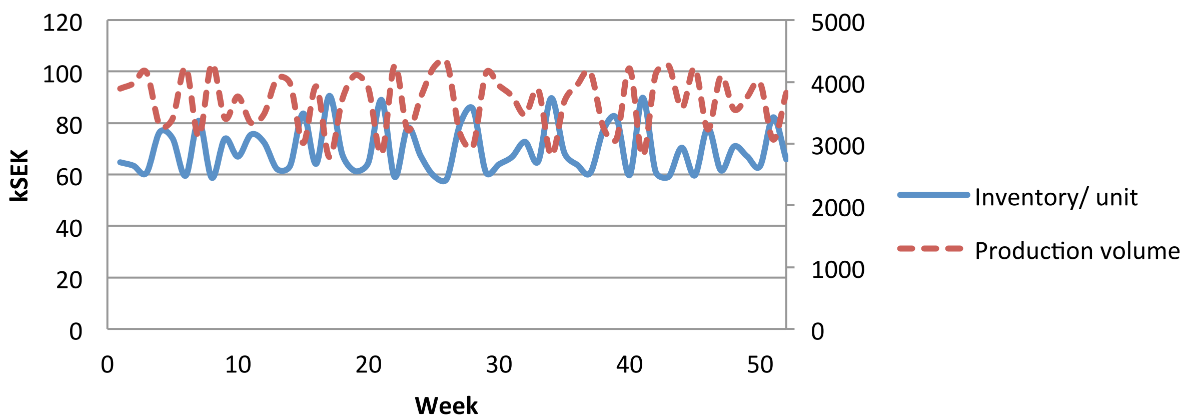

Figure 25- Inventory per unit and the production volume with the goal of constant inventory level.

5.1.11. Variation of total inventory over time with constant production volume

Leveled production is a common strategy where the market demands are fairly constant or a make to stock production system is used. When a leveled production strategy is used an optimal total inventory is when the inventory value holds a constant value. However, since due to parameter such as lead-time or purchase quantity there will be a variation in total inventory value (Figure 26).

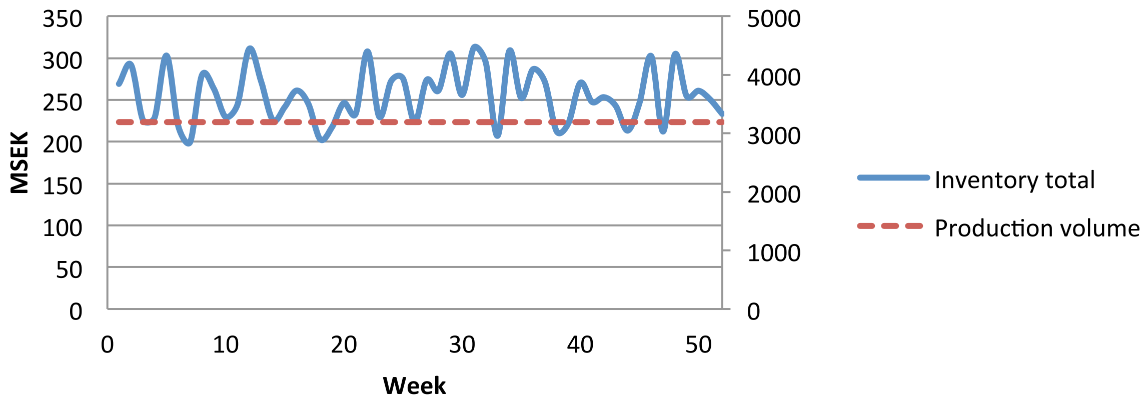

Figure 26- Inventory and production volume when using a leveled production strategy.

Figure 27 illustrates the inventory value per unit and the production volume. The visualization does not give any more information compared to Figure 26. Which means that is not preferable way to measure the inventory.

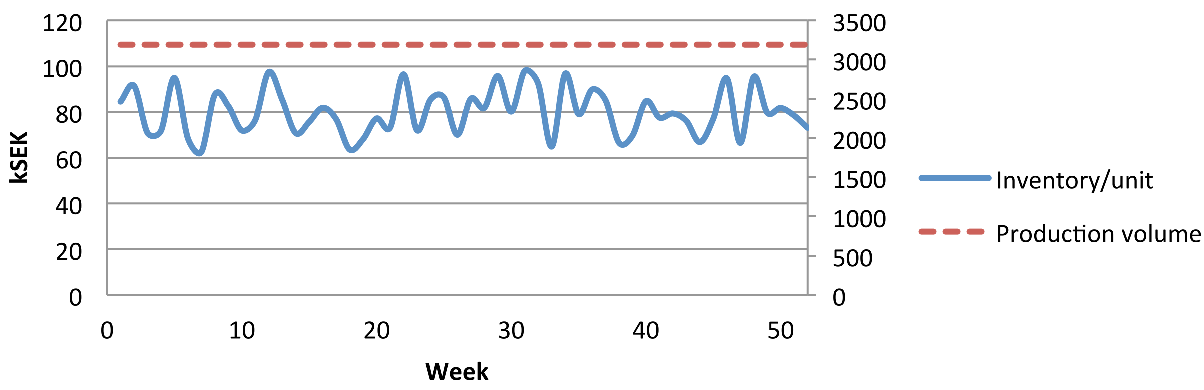

Figure 27- Inventory per unit and production volume when having a leveled production volume.

5.1.12. Variation of total inventory over time and production volume

Related to strategic visions and modern manufacturing philosophies is to have a chased production approach, this to prevent overproduction. The optimal situation for variations of the production volume is when the inventory level follows the changes in the production volume. Figure 28 indicates the optimal inventory level for this strategy, however there are parameters affecting such as lead-time, delivery days and supplier reliability. With this in consideration the inventory level may be shifted to the left compared to the production volume.

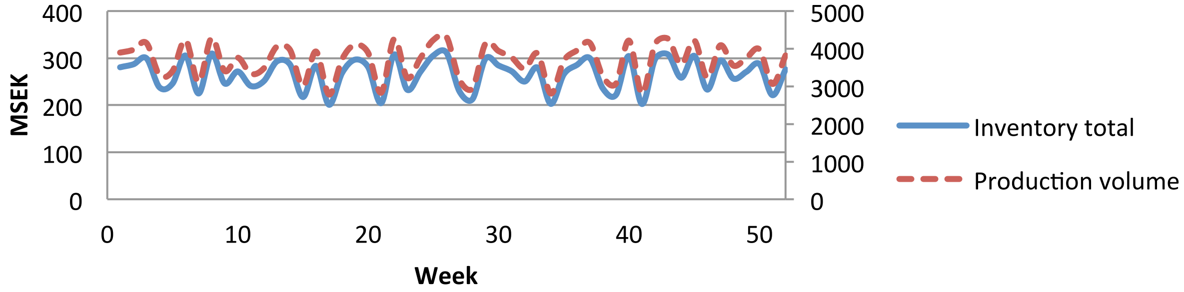

Figure 28- Optimal inventory level for chased production strategy when no parameter are affecting.

If this scenario is analyzed as inventory per unit the optimal case is to have a horizontal line (Figure 29). If this is used, then the aspect of fluctuation of the production volume is taken in consideration. Since ordering system of items make call-offs depending on the production schedule and lead time a reduction of the affecting parameters should be in place. I.e. the dependence of these parameters will be reduced.

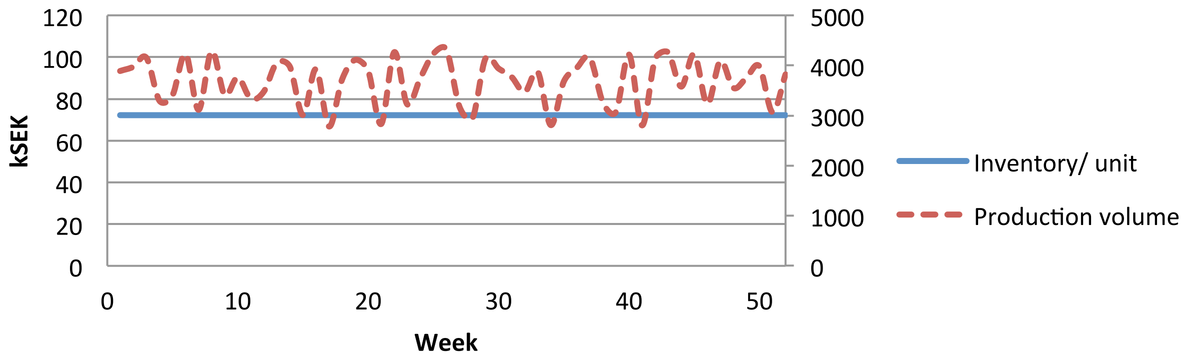

Figure 29- The optimal inventory per unit with a chased strategy without taking under consideration the affecting parameters.

If relating back to the inventory scenarios in chapter 5.1.9 then the inventory at the case company has a mixture of scenario A and C. During the turbulent period in Figure 21 indicates the result of trying to have a goal of keep a constant inventory level.

5.2. Conformance to Pareto rule

The Pareto rule can be used in various methods to identify where the highest impact is related to the outcome. The conclusion from the Pareto diagram could be used to quantify the SCC experience and knowledge, get the approach of management by facts and give indications where the effort from improvement should be put. When analyzing the available data and which factors that has a high impact on the cost and fluctuations in the inventory (besides form the production volume) several alternative approaches where identified. The parameters that would be of interest to investigate more closely either accordingly to Pareto or basic volume analyze could be:

- Inventory value related to specific suppliers

- Cost per item
- Component group that contribute to the highest inventory divergence
- Use the SPFU to see which has the lowest respectively the highest. This since the SPFU handle both the deliverability and quality of the supplier
- High volume items
- Low volume items
- Identify which items that often use their safety stock and relate this to the percentages of what is borrowed from RA, premium transports and blocked cars.
- Service level of the components
- Forecast error
- Scrap rate

5.3. Inventory level and KPI

When developing a measurement it is important to know what is being measured and how the measurement is performed. Moreover, to make it comparable over time certain parameters affecting the outcome of the measure have to be taken under consideration.

At the case company the physical available components in the warehouse is included in the inventory value. A goal existing is to lower the inventory level. The existing possibilities to lower the inventory are either to minimize the safety stock, cycle stock or the in-transit material. In the measure there is no differentiation between these. Since it is only the physical available stock that is being measured in the balance scorecard there is no visualization how large the safety stock, the cycle stock and the in-transit stock is, i.e. it is hard to see the total effect and the effect on optimization on spate inventories. If there is a differentiation of these, a holistic view of the entire value flows will be made. In additional, the effects on the optimizations on a stock will be seen as well as if there are any affects on the other stocks.

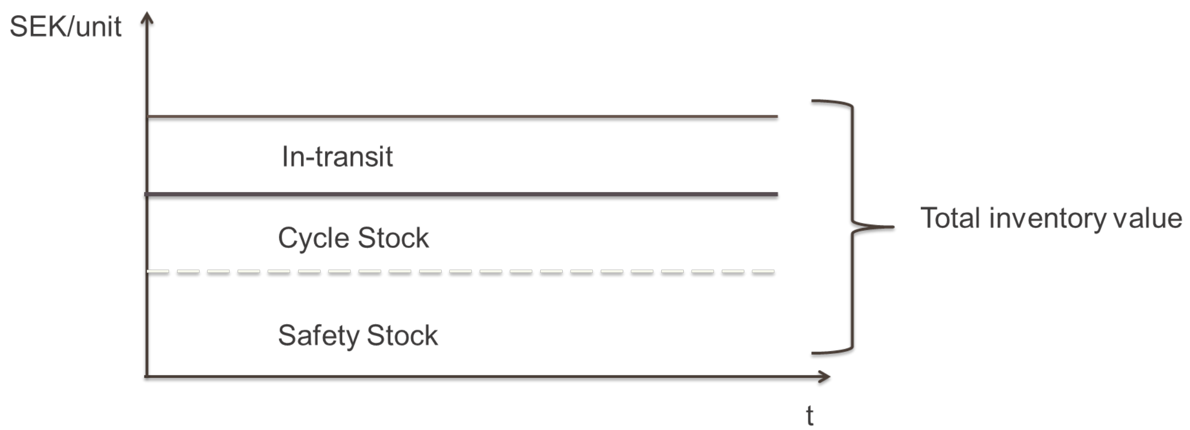

Figure 30- The different stocks should be measured separately to get a holistic view and to gain optimization.

At Volvo cars the production strategy is to have a chased production, this means that changes in takt time is made depending on the demand. Currently the targeted inventory level is set to a fixed value over the coming year that has been decided upon experience and previous year outcome. This is not representative over time. The purpose of the measurement and the data available will decided the trade-off of between time disposable to gather data and the accuracy needed of the measurement. The optimal case, as mentioned before, when the inventory can follow the variation of the production volume. One of the main parameters affecting the inventory level is the production volume, which in VCT case varied between 2223 and 4438 per week during 2011. In a chased production strategy the order quantity has to be flexible in order to meet the variation in the production volume.

When analyzing the value chain, the performance measurements and goals this is often stated in terms of units or percent per car model. At the highest level in the corporate strategy the sales mission is set in a number of units. In forecasting the car is at the first level described by the 12 code i.e. car model, engine and gearbox etc. The capacity of the plant is decided by the restriction on the production system and is at the highest level described per car model. When the sequencing is made the car model is the first rule that decide which day the order will be distributed to. Some departments use the unit cost/car to set a target of how much they should contribute to the final cost of the product. This is far easier to relate to compared to a fixed number. With these aspects in mind two approaches were used when analyzing possible measurements. These two measurements take into account different amount of parameters depending and different level of detail.

Table 4- Measurements on different levels in the organization.

Area	Measurement
Sales	Number of units
Forecasting	Units sorted as 12 code
Capacity planning	Units/ model
Sequencing	Units/model
Department	Cost/unit

The first measurement takes into consideration the parameters with the highest impact, namely the production volume. The unit of the KPI will therefore be cost/unit which was used when analyzing the different inventory scenarios in chapter 5.1.9-5.1.12. When this is done the inventory should react as scenario C. A illustrative view to describe the inventory characteristics would then be in inventory per unit, which should be constant according to Figure 31. As mentioned in the chapter 3.1 deviation between the safety stock and the flexible order quantity should be made. This, in order to see the results of the improvement work within the separate characteristics of the inventory level. The production volume is further as an input and output to the MRP system.

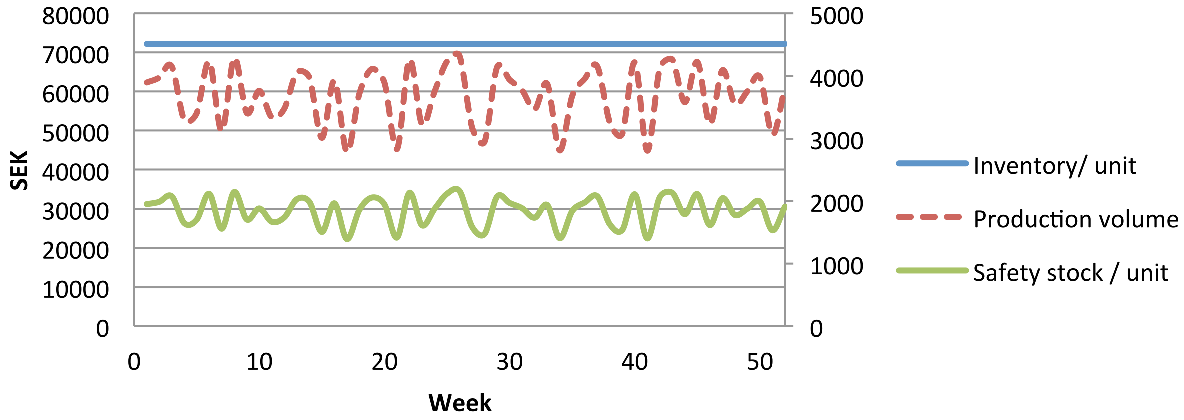

Figure 31 – Illustration of how the inventory could act (Scenario C) where the safety stock per unit is expressed as well.

The second measurement has a higher level of detail and is a further development of measurement number one. The parameters that will be taken into consideration here is:

- Production volume
- Product variation from a production system capacity view
- Production variation from item cost per car model perspective
- Safety stock

The forecasted inventory level per week would then be calculated as:

$$\text{Inventory/ car} = \frac{SS + \begin{bmatrix} \text{Average item value } S80 \\ \text{Average item value } V70 \\ \text{Average item value } XC70 \\ \text{Average item value } V60 \\ \text{Average item value } XC90 \end{bmatrix} * \begin{bmatrix} \%\text{ of } S80 \text{ in production} \\ \%\text{ of } V70 \text{ in production} \\ \%\text{ of } XC70 \text{ in production} \\ \%\text{ of } V60 \text{ in production} \\ \%\text{ of } XC90 \text{ in production} \end{bmatrix} * \text{Production volume}}{\text{Production volume}}$$

Equation 10

Since the safety stock is described per shift and it is dependent of the order intake the safety stock should be related to the production volume and follows the variation of this as well. Further on, in this calculation no consideration is taken to the unit load or transportation option.

The planned production volume per week for the coming year is set in September but is updated each month with a frozen time period of one month. Since the production volume is revaluated each month, a update of the future inventory goals should be reviewed as well.

The chosen KPI should both be used by the finance department and the material control department. These departments should in cooperation set a goal of the inventory value per unit. By setting this goal together a base for simplified communication is established and independent of internal goals this value will be unchanged over the year.

5.4. Categorization of measures

Because of the complex nature of the supply chains it is important to have a systematic approach to the performance measurement (Shepherd & Günter, 2006). There are several ways a performance measure can be categorized. The categorization is important in order to facilitate the comparability. A framework suggested by (Shepherd & Günter, 2006) will be used as inspiration to categorize the measures. In order to better match the scope of this thesis the framework is modified with the addition of which level in the company and whether the specific measure gauge internal or external factors. Figure 32 shows an example of how the categorizing may be used. By identifying were in the organization the measure is located the responsibilities are clarified. The categorization of internal respectively external measures immediately give the user a possibility to see if affects his or her department. To consider is also if a measure is qualitative (Q) or quantitative (N). If a certain measure is quantitative (N) or qualitative (Q) is interesting from many point of views. Not last the aspect of the reliability, quantitative measured may be considered as more accurate. Hence they actually origin from data collection and not someone's opinion and the way the information is interpreted. Not said that quantitative numbers are better, rather that the source of each measure must be understood in order to give a fair representation of the situation. S, T and O refers to what organizational level the measure belongs to, see Figure 32.

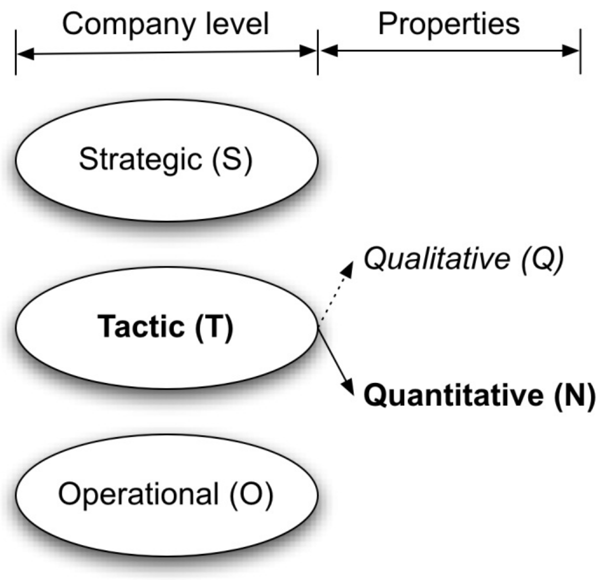

Figure 32 – Overview of the framework used to categorize measures and factors that impact the inventory performance.

5.5. Summary of parameters in the framework

Based on the analysis of the case company, each parameter is arranged into an appropriate context. Figure 33 shows a summary of the parameters put into the frameworks categorize which were presented in chapter 4.4. The letters in the brackets are used to divide the parameters according to the principles referred in chapter 5.4. The letters immediately show of which parameters it is possible to develop KPIs as well as to which level in the organization the KPI may concern.

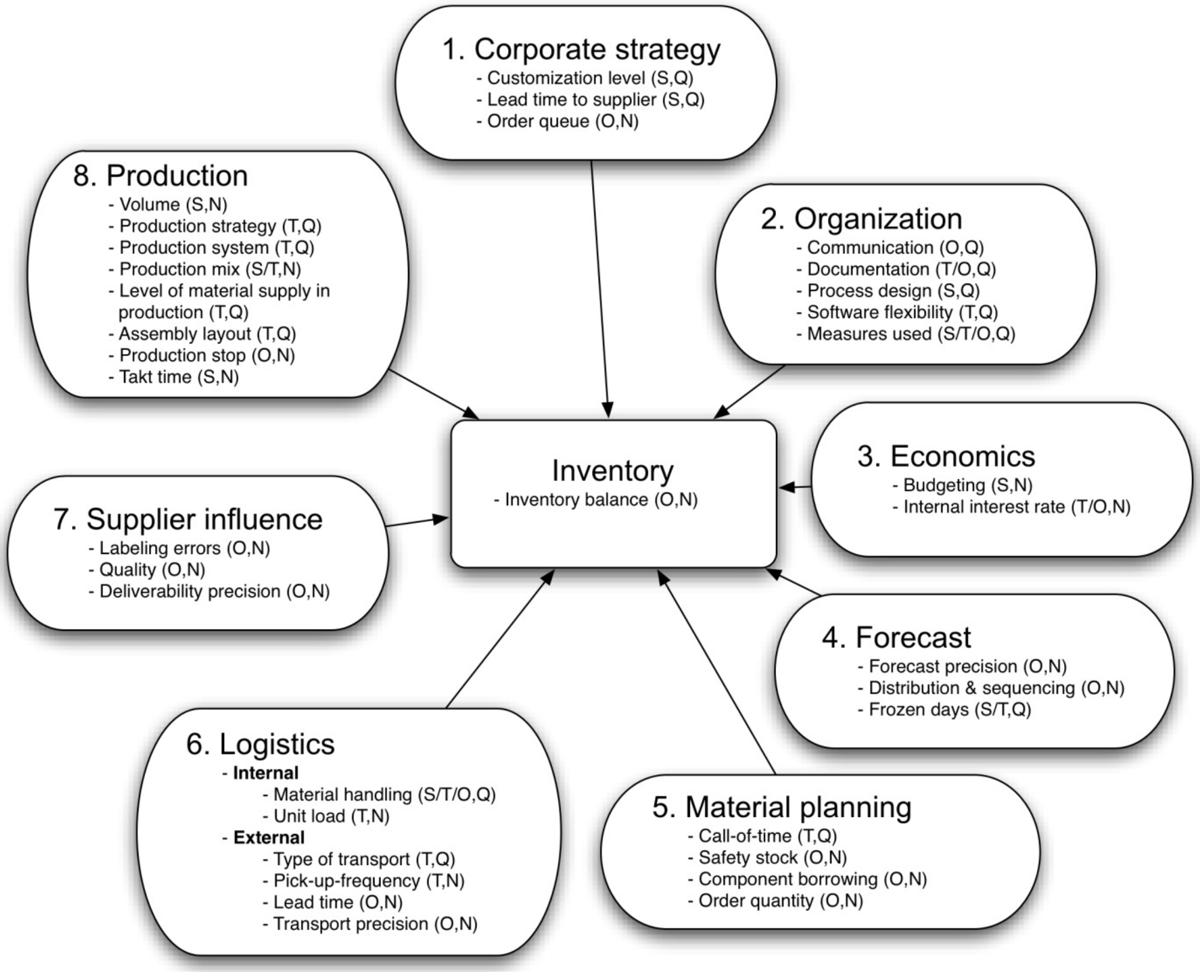

Figure 33 - Parameters affecting the inventory level.

6. Discussion

In this chapter the analysis and result is merged with the literature studies in order to critically examine the improvement possibilities. The areas chosen to discuss was identified from the improvement areas in the case study.

6.1. Management by facts

In order to do the correct decisions it is important that the information used as the foundation for the decision is correct and of a good enough quality. The decision process is also important, arbitrary and random factors should be avoided by analyzing high quality information. In the case of the difference between the measurements of inventory value mentioned in chapter 5.2 there is a risk that the wrong decisions are made. Since, the sampling rate was only once a month. Even though the data is based on measures the quality of the information may be questioned. In this case the intention probably is to manage the inventory value based on good information but the due to low data quality there is a risk of make the best decision for VCC.

Another interesting issue is the process for deciding the safety stock. As mentioned in Strategic management of inventories (chapter 3.2) the safety stock is not determined based on quantitative numbers. Instead the SCC set a proper value according to their experience, putting a high responsibility on the individuals. As a result of this high level of subjective influence the process becomes unstable. The instability is resource demanding, which also must be considered as an expense. In Figure 18 it is seen that a remarkable few articles stand for a majority of the inventory value. Assume that each article is handled with more or less the same amount of work by the SCC independently of the value. This means that the majority of work done by the SCC is made to handle the part of the stock with small capital intensity. As mentioned in chapter 3.2 an introduction of standardized ways of setting the safety stock could reduce the need for manual work. The standard could be based on lead time as well as delivery precision from the supplier to the manufacturing facility. In this way the material suppliers could focus on handling great problems only and not manually setting every safety stock. This way the safety stock also would be managed by real facts and not arbitrariness and people's experience. A risk with basing the present procedures on peoples' experience is that if a key figure quit, very important knowledge might be lost. Therefore, a process based approach would simplify in the long run with a smaller risk of losing competence within the organization.

6.2. Usage of data and comparability

Most decisions made within an organization are based on some kind of information. Often the data is quantitative, in this case it is important to know and understand the origin of the data and what the data actually represent. As shown in chapter 4.3 data may be used in different manners, various departments use different data collecting approaches. In this case the inventory value is either represented by a mean value or a single value picked at a specific moment once a month. For example, the finance department uses the first method and the material planning department the second. The finance department uses a single measurement, picking the inventory value once a month which may result in very misleading information. Hence, that very specific moment may not be representative at all for the now prevailing situation. Further on, the department uses different software's when they are gathering the inventory value. Even though they are built upon the same raw data there are remarkable many steps that differ in-between the two departments in the way of handling and collecting information that should be the same. If two departments discuss the inventory value for a certain period of time it is important that they use the same data. Due to difference in software, measurement frequency and visualization of the data there is a divergence in inventory value between the departments. An illustration of these affects can be seen in Figure 19 and Figure 20. The difference between Figure 20 and Figure 19 is significant, in Figure 20 the samples are taken once a month and in Figure 19 the values are based on average daily value over a time period over a week. Hence, there may be an issue to compare these two data sets that should show the same thing. The mean-value based graph gives a better overall summary of the information from an analytical point of view. One way to avoid this would be information unity, i.e. collect and do calculation in the same way at all the departments. In this manner the different versions of the same data would be avoided. Since the inventory tied-up capital generates significant expenses it is important that the decisions made are based on real facts and not incorrect data. By using different versions of data within the same organization the risk for mistakes increases.

Other comparability issues have been noticed concerning type of measurement used. As mentioned the inventory increases with an increasing production volume. This means that with changing production volumes the inventory is also expected to change. When using the total value of the inventory the most affecting parameters i.e. production volume and model variation is not taken into account. Therefore, the usage of cost per unit is suitable for the inventory value. This measure is fairly comparable over time and between different car models. Furthermore, to get a unity between the departments and a measurement that is easier to relate to this should be used.

6.3. Trade-offs between different parameters

Today´s automotive industry is forced to have increased product customization, which put demands on an increased flexibility in the production system. When this is done the entire supply chain has to increase their flexibility as well. The flexibility needed can be based on the either adapting the planning environment to the realistic facts of lead time, order queue, etc. or these factors can be adapted so that wished time from order to product delivery to customer is achieved. The relationship is described in equation 5. Here VCC has to identify the trade-offs that they are willing to make more clearly, especially between the different departments since currently they are working towards different goals, not thinking about the entire value chain. Currently with today´s economic situation the current takt time VCT is too high compared to the incoming order, which leads to short order queue. The short order queue has led to an unstable and unpredictable material planning situation, revealing the root causes for the excess inventory. This required process development to stabilize and manage the material planning situation. On the other hand process development is not always enough, for example external processes may not be influenced as much as internal processes. The trade-off between cost and flexibility is a fact that must be taken in consideration. It is simply not possible to design a system with a high level of flexibility that is low cost solution. Therefore it is important to have an open discussion about which parameters that must be compromised and which that should get a larger part of the resources. With an open discussion about the objectives, they might be set according to a realistic plan in line with the corporate goals.

By lowering the production capacity the order queue would be increased and be long enough to make the material ordering based on orders instead of forecasts. This would probably resolve the problem with the unstable and unpredictable process. Lowering of the capacity could be done in several ways. The takt time could be lowered or shortenings of the total production time could be executed. Changing the takt time requires significant engineering work and is associated with problems and uncertainties. Therefore shortening of the production time could be a solution. On the other hand a higher pace requires more workers due to a higher level of direct work. When choosing method there is a trade-off between significant re-engineering or an increased cost of direct work per unit.

At the assembly stations there is supposed to only be two hours of production. The two hour rule has been implemented for the unit loads that the blue boxes should contain. This is a good from a flow perspective. However, since the takt time affect the need to production the unit loads for the blue boxes has to be reviewed every time there is a takt change. Further on, since the normal weekly capacity (chapter 4.1.3) is based on the forecast and depending on the forecast precision these unit loads might not be reflecting the true demand. Therefore, a revision of the forecast outcome has to be made.

At the case company it is necessary that there exist a better understanding of the different departments and how they affect each other. Since this is not fully achieved at the case company a base of sub-optimization exists. For example, full-loads and inventory level, unit-load and demand, lead-time and purchasing cost, lead time and material planning environment. To go more into specific detail of one of these occurrences, the strategic decision made by the top management is that all suppliers to VCT should be located within Europe or at least have a hub for direct delivery. The underlying cause is that a short lead-time may reduce many problems and cut cost. Europe has a large geographical area and from several countries the transportation time may be relatively long. This indicates that the policy might not have had the intended impact.

The tuning of parameters is performed manually by the SCC. Hence, the process is dependent on the experience of each SCC; essential competence is lost each time someone quit. In order to create a stable process the SCC experience has to be quantified so that experienced can be transferred and settings between the different SCC more even. Due to the high level of manual work associated with the material control and decision based on experience (chapter 6.1) the SCCs have a high level of responsibility. The highest priority for a SCC is to ensure the material supply to the manufacturing. This is the most important work task for an SCCs which means that other optimizations is not of high priority. Further on, if material is not available the SCC will be responsible for the problems caused by the missing parts. This may contribute to protectionist behavior rather than perform the most profitable actions from a VCC perspective. With this in mind an automatic system might relive the high level of responsibility and encourage inventory optimization. An automated process could also act as a backup system and reduce the experience-based work that today is the foundation of the material planning process. To consider is also the amount of manual work that would be necessary to systematically handle all components with the today's system, which is not a sustainable situation from a long term perspective.

The MRP system PLUS influence the inventory level and the flexibility in the system to handle the uncertainties that occurs due to changes delivery and volumes of components needs to increase. However, since PLUS is robust system that well tested and reliable, there is no incentive to change MRP system.

Since, liquidity is a financial measure of the tied up capital in components, the level of inventory will make the economic situation look more or less favourable. Trimming the numbers means adapting the inventory to other goals than maintaining and securing a flow of components to the production. This is a type of sub-optimization that may be contra productive. The situation is difficult to solve but as mentioned in chapter 6.2 the usage of inventory cost per unit gives a better estimation if the inventory lies within an acceptable level. If cost per unit is acceptable the arguments from the financial department may not be as strong as without this measure. In chapter 5.1.9 the relationship between production volume and inventory value per car is described. It says that if the inventory performs well the cost/unit should be constant. This implies that a better overview of the inventory value is given when using the cost per unit instead of the total inventory cost.

6.4. KPI development

As mentioned in the literature chapter about the development of KPI´s they have to be representative over time and have goal related to the corporate strategy. During the case study it was evident that the production strategy of VCT has a great impact on what the inventory level should be. For a chased production strategy the production volume is changing depending on the demand. In addition, when discussing different manufacturing technologies these always have restriction concerning capacity. These restrictions are expressed in terms of car model. With these aspects in mind, an adequate inventory measurement which gives an indication better indication of the performance of the inventory can be created. Further on it will become easier to relate to if they are uniform.

The reason that two KPI´s with different level of aggregation is suggested is due to the available data. The production volume for the coming 60 weeks is known and the volume is updated each month, which is not complicated to update the KPI. The available data concerning the second development of the KPI needs some further separation and structure. This means that the average value of the components for the different car models are based on a mean value from about 5000 different alternatives (applied for the V60). Further on the mean value contains the sequenced items as well, which is difficult to separate from the mean cost value of the components.

A factor that was not taken into consideration when developing these KPI is the aspect of lead-time. Currently it is only the physical material available at VCT that is included in the inventory value. However, as mentioned VCC owns the material from the point in time when it is load on the trailers. A question that arises is what is the inventory measurement supposed to tell, what has happened or the current state. Balance scorecard that show the past time of inventory value and should therefore show the performance of the entire inventory inclusive the in-transit material. If only the physical material available at VCT is measured it do not say anything about the total inventory performance. It does tell how much the value of available material is but not the quantity of the components that are needed for production. Since the total inventory cost is the sum of the in-transit material and the physical material available, it should be included in the measurement in order to reflect the entire inventory cost. The in-transit inventory should be measured either at the material control department or at another department for example transportation. If the in-transit material was included then the effects of the lead time would be included since a longer lead time will result in a higher level of tied up capital.

6.5. Categorization of components

Currently the components are not sorted in different categories and the used method is to organize the articles of one supplier as a group. The parameters are updated manually by the SCCs. Each article has a set of delivery related parameters, read more about this in section 4.1.7. The manual handling creates an unstable and sensitive process. By using a categorization of components manual work could be reduced and the instability and uncertainties associated with the process could be decreased. Moreover, the case company has a large component portfolio which makes it time consuming to review the parameters for each component. In addition, the components have a wide range of characteristics, especially concerning demand and lead-time. The concept multi-criteria ABC categorization is presented in chapter 3.4, this method take the demand, lead time the service level into consideration. However, a fourth category D could also be used, containing the so-called "exceptions" which should be manually controlled. The D category would handle components that have demand behaviour that is not easily categorized. With a different organization then the today used, it would be possible to set the parameters for the whole category. Further on, by incorporating data from different systems the necessary safety stock and other parameters could be calculated instead of estimated manually. Because of manual management of the safety stock the process of handling and setting has become unstable. By creating a standardized process with minimal manual intervention the process stability could be improved. An implementation of such a system would probably reduce the inventory level in the long term, because of less complex and improved process stability. However, an implementation of a new component categorization is a large change to execute as well as implementing an automatic calculation of safety stock. Such implementation could take years to fully implement. With the change towards a automation significant cost reductions could made due to improved predictability. Even if an automatic system is not implemented a standardized inventory handling and categorization system could significantly improve the situation. Reorganization of the components and systematic work is also in line with the chapter 3.12 about were decisions are based in facts.

6.6. Validity and reliability

The chosen method was to conduct a single case study and relate this to a theoretical framework. Single case studies can suffer from validity and reliability problems. Due to the analytical nature of a case study, a single case study can represent a generalization if there exist support from theory. Inventory management is a necessary function and commonly used within the industrial sector.

Even though specific methods may vary on an operational level the overall situation has many similarities especially on a strategic and tactical level. This makes it possible to assume that the subjects mentioned in the case study may be suitable for other industrial companies with similar customization level and demand patterns, especial within the automotive industry. On the other hand this has not been verified by conducting multiple case studies. Further verification of the outcomes comparison against other companies can be made, both within the competitors and other industrial sectors. If comparison is made towards other industrial sectors, considerations about the inventory characteristics have to be made since these might differ and affect the outcome. By doing this conformation the validity and reliability gab can be decreased.

Since observation and unstructured interviews where mainly used as the information source, the personal chemistry between the informer and the interviewer can influence the judgment of the give information. To avoid this multiple employees were used in order to confirm the data and to get different point of views. As already mentioned a second approach to cover the reliability was to check against theory when applicable. Influences may put pressure on the individuals conducting the case study in such a way that they feel constrained to deliver a specific outcome. The feeling during the case study was that none of these issues were present. However this is of significance to mention from a reliability point of view. Corporate culture is also an aspect that may affect an outcome, in this particular case openness were encouraged.

All the above mentioned validity and reliability aspects may have influenced the objectiveness unconsciously. On the other hand we have strived against openness both towards theory and the case company. In order to maintain the objectiveness the theory has provided guidelines in contradictive situations concerning inventory management.

6.7. Methodology, framework and parameters

The methodology was to use a case study and a theoretical framework as the base for the development of an analytical framework. The analytical framework was then used to categorize the parameters affecting the inventory at the case company. This approach gave input from both empirical and theoretical. These two complement each other and strengthen the reliability. This method is from our perspective considered a good approach to break down the purpose from a holistic view. However, simultaneously it is a challenge to interpret the information in such a way that it reflects the complex situation. Further on, it is hard to determinate which information to present for the reader in order communicate the full context. If the case study was to be reproduced, the possibilities to redo the same study in the same order would require significant work. The observation technique used during the case study should be kept since it gives an indication of the underlying and real problems. Moreover, if the case was to be redone the unstructured interviews would be changed into structured interviews. The reason for this would be to have a more focused discussion about the actual problem. On the other hand this means that there is a need for better knowledge of the organizational structure of the case company in the beginning of the project.

The frameworks were based on the theory, which was carefully chosen to provide significant knowledge to understand and analyze the inventory situation. The subject fields identified was conformed during the case study. However, to provide a better chain of evidence about categories respectively parameters the provided data should have clearly divided into theoretical and empirical. The today used structure may be confusing if certain parts are not read carefully. This shortcoming should be considered if similar studies are made. The analytical framework could be further developed by adding external and internal parameters under each category. This way problems related to suppliers could be further incorporated and the framework could be more user friendly. On the other hand the set limitations of this study did not incorporate important subjects fields as purchasing influence and product development. Both these may strongly affect the possibilities to improve the inventory from a holistic point of view.

The parameter identified and presented in the framework is considered to be adequate and representative for the case company. If these parameters is to be used for other companies the parameters has to be modified. To strengthen the validity of the parameters detected a clear specification of how these were identified should be more specifically described. This is difficult to achieve due to personal gathered knowledge and experience about the subject.

7. Recommendations

In this section both short and long-term recommendations adapted for the case company's framework. The parameters from the framework are in cursive text (Figure 33).

7.1. Short term recommendations

From an inventory perspective it is important to know the actual performance of the involved processes. Therefore it recommended that the case company relate their inventory strategy to the *production strategy*. This is done by identification of KPI´s that represent the strategy. Introducing a KPI consisting of both total inventory level as well as *production volume* would make the KPI more representable over time and represent the actual performance. A second step to further develop this approach is to introduce a KPI where the *product mix* also is taken into account. When these are taken under consideration the inventory will be measured in SEK per unit and a differentiation between the safety stock and the cycle stock will be made. These should be used both when setting the inventory goal for the material planning department and for the finance department when the *budgeting* for the inventory. The budget may then be set independently of the material control department. This is desirable from a process efficiency point of view.

A third parameter that is affecting the inventory level is the *lead-time*. If the in-transit material were included in the evaluation of the inventory level the affects of the lead-time would be included. Example of how this should be visualized is seen in Figure 30. This would create a holistic view of the entire value flow. Further on, a discussion has to be made on what measurement that is important for the organization and what that measure should sate.

The *unit-loads* are set when the component is introduced and is based on the forecast. Currently there are no follow- up or standardized procedure to review whether is appropriate or not. Therefore, it is a recommendation that the unit load for each component is followed up on a frequent basis. The components that have a high divergence from the expected demand need to be immediately adjusted.

From an inventory perspective a systematic approach should be used to calculate the *safety stock.* An evaluation of different approach should be executed, equation 5-8 should both be evaluated in order to see which one that does best match the VCT reality. This should be done with a few articles within different categories. Note that these tests should be executed on components that are fairly predictable. This since will minimize the effect of unknown parameters. The data gathering for this would be a first step to implement a standardized way (*process stability*) of setting the safety stock. The data needed to be gathered for these articles would be whether the demand and lead-time has a normal distribution and find the standard deviation for the demand σ_D and the lead-time σ_{LT}.

7.2. Long term recommendation

When analyzing the value flow from *forecasting*, production planning, sequencing and order planning it is clear that several sub-optimizations has been made and that the thought conducted by central MP&L has not been communicated well enough. This has obstructed the *planning* environment at the material control department and led to access inventory, supplementary material handling and unexpected changes in inventory level. The root cause of these problems may be solved in several ways. Either the planning environment with the different time fences becomes larger so that the result of equation 9, i.e.1-3 days of volume notice to suppliers , safety stock, lead time, time until next pick- up day, is allowed to be more than six days. A second alternative is that the components of equation 9 become smaller so equation 9 fulfils the goal of six days. A third option would be to lower the takt time in order to build up an order queue long then the lead time to the most distant supplier. All these option contribute to the stabilization of the material handling process. An outcome form an unstable process is difficult to predict and to improve. As mention in chapter 3.2 standardized way of working for example when setting the safety stock would contribute to long-term stabilization. It is therefore recommended as a complement to implement management by facts to stabilize the process even further. One process where management by facts should be implemented is when setting the safety stock. By standardize this process and quantify the SCC´s knowledge the safety stock for each component would be based on the same parameters. These parameter can be identified and quantified, however to find a recommend value of the parameters is a time consuming task and since the parameters are strongly connected to each other an iterative process in needed. Taking these parameters in consideration in an automatic system would be a sustainable option from a long-term perspective. The equations mentioned takes into consideration the variance in demand, lead time and service level. In addition the service level is calculated per service cycle, i.e. from the case company´s point of view this would be between the different pick-up days. Using an equation will standardize the process and a uniform safety stock would be set and a base for improvement

8. Conclusions

The main purpose of this thesis is to investigate what parameters that influence the inventory level as well as how these can be evaluated. In this chapter the general conclusion based on the case study will be presented. The parameters from the framework are in cursive text (Figure 33).

One important parameter is from what abstraction level the entire supply chain is seen, the holistic view of the whole value flow from purchasing to en customer delivery is crucial to create the balanced inventory. The processes as well as the strategies affecting the inventory must be interlinked with each other in order to create a stable environment. The correct *production strategy* must be matched with the correct inventory strategy. If a chased strategy is used and there is a high variety in demand it is recommended that a lag production strategy is used, this in order to stabilize the processes further down in the value flow. If a lead strategy is used instead under circumstances were a lag strategy would be better suited there is a great risk of a decreasing order queue. A short *order queue* will create unnecessary instability to the connecting processes. The combination of uncertain demand and a high degree of customization requires that a holistic approach is taken for the inventory management and control. This means that the combination of *safety stock*, cycle stock, in transit material and transportation method must carefully be considered. The responsibilities for each inventory part should be clearly stated within the organization. To get the optimal overall situation the trade-offs between these have to be measured and compared, each parameter must lie within an acceptable level. This makes it possible to set adequate ranges and target levels for the involved departments. If the target levels are not set mutually together with the concerned parties there is a high risk of sub-optimization, this was noticed at the case company. As a result clear responsibilities for the total inventory level as well as the whole supply chain are important to delegate to a physical person. The delegations of responsibilities are in line with the holistic approach that strives to balance the inventory and related costs. When considering the holistic view of the combination safety stock, cycle stock, in transit material and transportation method a financial measurement would be well suited. However, each process needs to be evaluated from other aspects rather than financial measurement in order to find the optimal operation point for the inventory.

As mentioned above the *process stability* strongly affects the inventory level. A stable process is vital when initiating improvement efforts. Thus activities related to inventory handling should be standardized in order to improve the predictability. With a stable and predictable process material can be delivered in the right quantity at the right time. Therefore the inventory management should be based on quantifiable data and facts. Experience based inventory management creates process instability and is influenced by subjective judgments. The experience based approach put large amount of responsibility on the SCCs. A lower level of responsibility can create an environment with incentives to optimize the inventory level. For companies with a high component variety it is not feasible to review the parameters for each component manually. Therefore, an automatic system should be implemented to avoid low review frequency. An automatic system would also increase the possibility to work proactive with the suppliers rather than reactive. Preferably the system should automatically set the safety stock based on lead-time, demand and number of pick-up-days.

Material order based on *forecast* is only applicable if the forecast precision is relatively high. Otherwise excess material will be ordered and the inventory level will grow as a result. With growing inventory levels obsolete articles will increase as well as the handling cost. Therefore, it is essential to have a high level of forecast precision if material is to be ordered based on the forecast. Furthermore, for the present situation an adapted *planning* process must be used. This to ensure that material arrives in the right time and to minimize incorrect material ordered.

To establish a balanced inventory is complex, an inventory's close connections to various processes in a company result in numerous parameters affect the performance of the inventory. Within most firms the inventory is not of the highest priority. The inventory's task is to act as a buffer for uncertainties in the supply chain. With the today global market situation, excellent inventory management is essential to compete internationally. Therefore, it is important to align the inventory strategy with the corporate goals, improve forecast precision, reduce lead-time to suppliers and use adequate measures with adequate precision. Incorporating these in standardized, stable and predictable processes could improve the inventory performance in a balanced way.

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