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# Achieving a holistic inventory management process:

## Analyzing the role of cross-functional integration, process management, planning environment and planning level alignment

*Master of Science Thesis in the Master Degree Programme, Supply Chain Management*

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# Preface

This master's thesis project has been performed at the manufacturing company GMC, which has been assigned the fictive name Global Manufacturing Company. This master's thesis is a concluding part of our studies in the Supply Chain Management master's program at Chalmers University of Technology. The thesis was conducted during the winter of 2013/2014.

Firstly we would like to thank GMC for giving us the opportunity to write this master's thesis. Moreover we would like to thank our supervisor at the company for the support and feedback that we have received during the course of our work. We also wish to thank all employees of GMC that has shared their knowledge and time by letting us interview them during our empirical investigation. Our supervisor Anna Fredriksson from Chalmers University of Technology deserves many thanks for the time she has put aside for our supervision and the pieces of advice we have received which helped us improve our report.

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# Abstract

Materials management i.e. management or planning of material flows has received an increasing interest for decades. The competitiveness of companies is greatly affected by the companies' ability to respond to market pressures for increased customization and short lead times. The trade-offs for increased product variety and shortened lead times are increased costs for storage and purchasing of materials. GMC is a manufacturing company, which is working actively to fulfill customer demands on product variety and short lead times. This puts pressure on the company's materials management systems to ensure that material flows and inventories are both flexible and cost efficient. GMC therefore created an inventory management process, which aims to reduce tied-up capital in inventory and improve the service level towards customers. GMC are however experiencing some challenges with this process. The process incorporates both the production function and purchasing function and extends across different planning levels, which creates communication barriers. The company furthermore has both MTS and MTO manufacturing strategies for its products and uses several different planning methods to manage the material flows. This makes it important to ensure that the planning methods are used in a suitable context. The aim of this thesis is to investigate the process and provide suggestions for improvements.

The study was based on three research questions relating to the challenges experienced at GMC. The research method has been qualitative with data collection focusing on interviews. The empirical investigation presents a mapping of the process in its current state. The investigation shows that the planning methods kanban, MRP and consignment stock are used in appropriate contexts, but that there is no process that continuously ensures fit between planning methods and individual parts. It was also discovered that the challenges experienced with achieving functional integration in the process to a large degree were caused by ambiguities and uncertainties of the process boundaries and unclear division of responsibilities within the process. The investigation furthermore highlighted the fact that decisions regarding safety stock levels were almost entirely managed on operative level and that there was little transparency of these decisions to higher planning levels.

The recommendations to GMC are: create a process for continuous matching between individual parts and planning methods; improve the functional integration through improved process management and monitoring; and lastly to improve the alignment between operative and strategic planning levels regarding safety stock decisions by implementing documentation routines and an inventory classification system to increase the transparency of decisions behind the safety stock levels.



Keywords: Cross-Functional Integration, Planning Level Alignment, Process Management, Materials Management.

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# Abbreviations

| | |
|---|---|
| ATS | Assemble-to-stock |
| BOM | Bill of material |
| CFT | Cross-functional team |
| DSI | Days supply of inventory |
| ERP | Enterprise resource planning |
| GIT | Goods in transit |
| GMC | Global Manufacturing Company |
| JIT | Just-in-time |
| LISC | Line item shipped correctly |
| MPC | Manufacturing planning and control |
| MPS | Master production scheduling |
| MRP | Material requirements planning |
| MTO | Make-to-order |
| MTS | Make-to-stock |
| OEM | Original equipment manufacturer |
| PFEP | Plan for every part |
| S&OP | Sales and operations planning |
| STF | Short term forecast |
| WIP | Work-in-process |

# 1 Introduction

*This introductory chapter firstly provides a background to the subject of the report. The background is divided into a case company background and a theoretical background. Thereafter is the purpose of the report presented. This is followed by a problem discussion relating to the company which will be further investigated. The research questions that will be answered to fulfill the purpose are then introduced. The scope and limitations of the report are described as well as a disposition, which finalizes the introduction.*

## 1.1 Case Company Background

The case company, which has been investigated in this report, is a global manufacturing company, consisting of a number of divisions. Each division comprises several smaller business units. The specific business unit that has been investigated is situated in Sweden. This business unit has three different product lines. The fictive name Global Manufacturing Company (GMC) is used when referring to this business unit. GMC is a publicly listed company and there is a constant pressure on keeping costs low and increasing profitability. GMC is also experiencing pressure from customers to deliver a large variety of products within short lead times. For this reason, GMC has been working actively to make their production processes flexible enough to produce the many different product variants that their customers require as well as producing them within the required lead time. Although GMC has reduced set-up times and lead times in their production, customers are still demanding deliveries within lead times that are shorter than the aggregated lead time for procurement, transportation, production and delivery to customer. When it is not possible to further reduce lead times for procurement and manufacturing, companies must hold materials in inventory or they will fail to deliver within the lead time required by customers (Lutz, Löedding & Wiendahl, 2003). Since inventories are directly connected to costs they should be reduced or minimized (ibid.). This means that GMC needs to manage material flows and inventories efficiently to be both cost efficient and flexible which is a necessity to be competitive and profitable in the long term.

GMC has set a goal for the service level towards customers of 93% for its product lines and they wish to perform at this service level without having too high costs for inventories. To ensure efficient management of inventories GMC has created a process called plan for every part (PFEP). The goal of the process is to improve the inventory management through cross-functional integration. This to ensure that inventory levels are kept at optimal levels through continuous evaluation of inventory values and run-out times for all parts. The process also incorporates the choice of appropriate planning methods to optimize the material planning for all different parts. The inputs and outputs of the PFEP process as well as the inputs from different planning levels are shown in Figure 1 below.

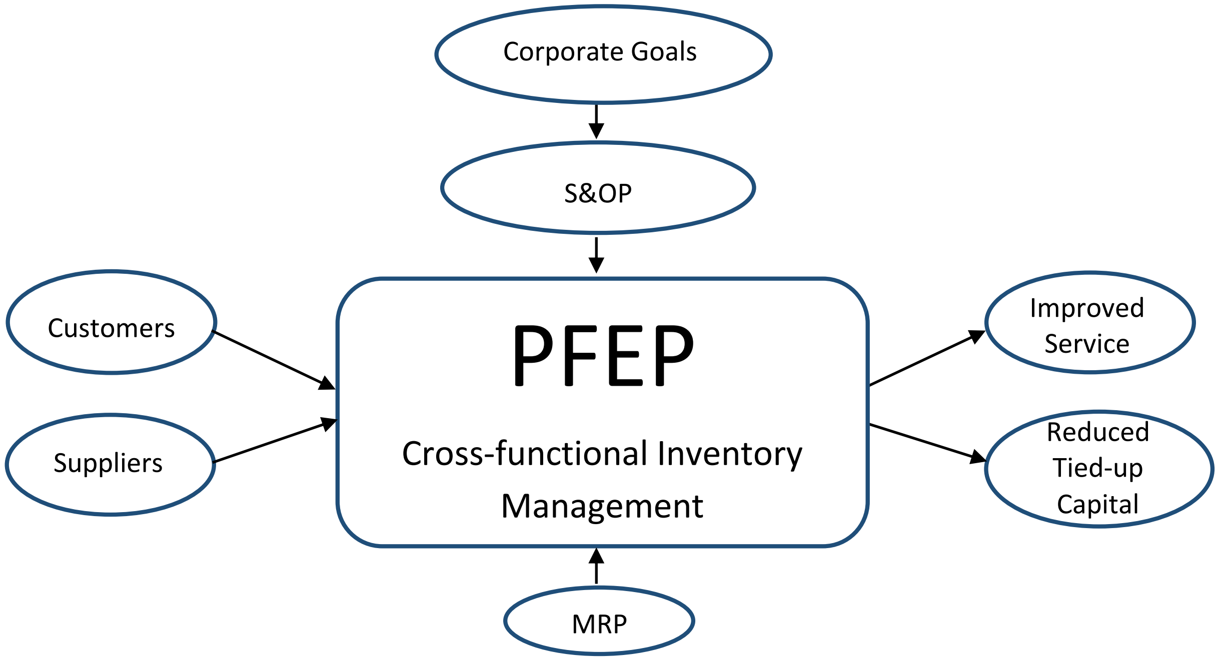


*Figure 1. Overview of the main inputs and outputs to the PFEP process.*

Inputs to the process are mainly customer orders and requirements and supplier agreements. The inputs from the planning levels, illustrated in Figure 1 shows the relation between the planning levels and the PFEP process. The highest planning level is goals that are set on a corporate level regarding service level and inventory run-out-time. Thereafter follow decisions established in sales and operations planning (S&OP). Finally, material requirements planning (MRP) provides input to the process from an operative level. The sought outputs of the process are improved service level and reduced tied-up capital in inventory.

GMC is experiencing some challenges with the process and the results produced by the process are not entirely satisfying. One of the challenges is that there are uncertainties regarding how well the actual process conforms to the written process. The process furthermore involves many different people from different functions and planning levels who all have different responsibilities and priorities, which influence their view on how the material flows are best managed. These different views make it important for GMC to ensure that all functions and planning levels are working in an integrated way. This to create a common view on the management of material flows and inventories, to prevent the functions from counteracting each other.

## 1.2 Theoretical Background

The theoretical background is divided into sections addressing materials management, inventory management, hierarchical planning levels and functional collaboration.

### 1.2.1 Materials Management

Materials management (i.e. management or planning of material flows) has received an increasing interest and development during decades. Materials management includes planning, controlling and following-up of material flows all the way from supplier to customer (Jonsson & Mattsson, 2009). Already in the end of the 70's, Slater (1979) wrote that external and internal pressures were forcing companies to focus more on their materials management operations to reduce costs and improve quality of both supplies and delivery performance. Also in more recent years have materials management received a lot of attention, especially in relation to lean manufacturing concepts that many companies have started to use and develop in inspiration of Japanese and North American automobile industries (Yoho & Rappold, 2011). This development has resulted in many companies moving away from large-scale mass production towards single-unit production and flexible processes, which in turn requires new materials management approaches (ibid.). Parallel to this development it is suggested by Amaro, Hendry and Kingsman (1999) that an increased degree of customization is demanded which also puts pressure on materials management. This since increased product variety allows a closer match between customer demand and offered products, but the trade-off is increased cost of raw material, component procurement, storage and distribution of finished goods (Benjaafar, Kim & Vishwanadham, 2004). Lutz, Löedding and Wiendahl (2003) emphasize that materials management affects the competitiveness of companies since it has an impact on companies' ability to answer to the tougher customer demands on lead time and service level. An important factor that affects how efficiently a company becomes in managing and planning its material flows is according to Jonsson and Mattsson (2003) the degree of fit between the planning environment and the planning methods used.

### 1.2.2 Inventory Management

Several different variables express the materials management performance such as stock service level, delivery precision, delivery lead time, flexibility, logistics costs and tied-up capital (Jonsson & Mattsson, 2009). A challenge in materials management is to find a balance between the different variables since some of them are contradictory to each other. An example of such trade-off relationship is between low tied-up capital in inventory and high service level, since having a high service level requires holding a lot of inventory (ibid.). The term inventory management includes business management concepts that handle these trade-offs (Bonney, 1994). The main decisions of inventory management relate to what items to stock, where to stock it, when to order and how large batches to order (ibid.). Different uncertainties such as demand quantities, demand timing and supply lead times make inventory decisions complex and the result is that different inventory strategies are often required for different types of items (Hautaniemi & Pirttilä, 1999).

### 1.2.3 Hierarchical Planning Levels

Inventory management should be aligned with overall strategies of investments, working capital and customer service (Bonney, 1994). It is however common that operative inventory decisions are in focus (ibid.), even though there is a hierarchical planning level logic for inventory management in similarity to production and distribution planning (Miller, 2002). This means that inventory decisions made at a strategic or tactical planning level create boundaries and requirements for decisions at operative level (ibid.).

### 1.2.4 Functional Collaboration

Slater (1979) mentions poor communication and conflicting goals between different departments as an internal challenge to achieve successful management of material flows. Toomey (2000) moreover describes that there are strong relationships and dependencies between inventory management and functions such as purchasing, marketing, engineering etc., which result in that teamwork between the functions is essential. Collaboration between departments is thus a prerequisite for efficient and effective inventory management. Purchasing for example has control of supplier choices, agreements and delivery follow-ups (ibid.), which greatly affects how inventories are managed. This since supplier agreements decide what batch quantities can be ordered from suppliers and thereby affects the inventory costs.

## 1.3 Purpose

The purpose of this report is to investigate the challenges experienced in the current PFEP process and propose possible improvements, which will help GMC achieve a clearly structured and effective process for inventory management. This will in turn help GMC to reduce tied-up capital in their purchased component inventory while maintaining the current service level.

Inventory management in this report is defined as decisions and activities in relation to inventory and safety stock levels, lot sizing and ordering of materials.

## 1.4 Problem Discussion

The planning environment of GMC in the current state can be described by short lead times, both make-to-stock (MTS) and make-to-order (MTO) strategies, high product variety and a relatively complex bill of material (BOM). Planning and replenishment of purchased items at GMC are handled through material requirements planning (MRP), kanban and consignment stocks. GMC operates with several different planning methods due to the high number of end product variants consisting of parts with different characteristics. Short lead times, customized products and high product variety lead to complicated material planning processes and difficulties in having the right type and amount of material at the right time and place. An effect of procuring and managing an increased number of items are difficulties to estimate demand for individual items. This in turn, can lead to unnecessary tied-up capital in inventory to compensate for the demand uncertainties. Another risk is that too aggressive inventory reduction efforts result in poor inventory service level. To find a balance between tied-up capital in inventory and service level, it is necessary to ensure that the planning methods used are suitable for the specific context of the company and the characteristics of individual parts.

Several different functions are involved in the PFEP process, such as supply chain and production. The production function is henceforth called the product line. Three different positions are engaged from supply chain. These are operative purchasing, strategic purchasing and the inventory control manager which all have different views than the production function. Strategic and operative purchasing are in first hand responsible for procuring materials to the right price and quality. They however also have large impact on inventory levels since they affect the order quantities that are entered into supplier agreements. The product line is mainly working to ensure production efficiency and effectiveness to achieve a high service level towards customers. It is furthermore the product line that owns the inventory and is thus striving to keep inventory levels and inventory costs down without venturing the service level. The different views and perspectives of the different functions can sometimes create communication barriers and conflicts, which in turn affects the results produced by the process. These barriers are also a possible reason to the differences mentioned above regarding operatively suitable order quantities and the order quantities in the supplier agreements. Concretely, it means that large order quantities that are appealing from a purchase cost perspective leads to high inventory levels and infrequent replenishments which are unappealing from a product line perspective.

The PFEP process ranges across multiple planning levels. There is partly a relatively long term perspective of handling order quantities for externally purchased parts and other tactical or strategic questions relating to supplier agreements. The process also encompasses the daily operative work, in which the order placer places orders with suppliers. The order placer moreover makes adjustments to safety stock levels, in response to daily activities and problems such as supplier delivery performance and demand variations. There is currently an uncertainty regarding how well the work on operative level conforms with decisions and goals of higher planning levels. The communication of decisions and objectives from higher to lower planning levels and vice versa thus seem to be a problem area. It is furthermore experienced to be a gap between the operative conditions and the strategic decisions made on order quantities in the supplier agreements. This is observed for some parts, for which the order quantities are very large in relation to the consumption of that part.

## 1.5 Research Questions

The challenges and conditions addressed in the problem discussion above led to the identification of three different areas to be further investigated and answered to fulfill the purpose of this report. The research questions are presented below.

**RQ1: How can GMC ensure that the material planning methods suit the planning environment?**

**RQ2: How can GMC improve the PFEP process to ensure that the production and purchasing functions cooperate and work towards a common goal?**

**RQ3: How should inventory levels be managed at operative planning levels to be aligned with objectives of higher planning levels?**

To answer the research questions an investigation will be performed to map the current state of the PFEP process. The aim of this mapping is to identify who is involved in the PFEP process and what perspectives the functions have on the process. The activities performed will also be investigated, as well as who is responsible for the results of these activities and the process as a whole. The results of the mapping are presented in the empirical findings in the form of process maps and descriptions of specific activities that are related to the three research questions.

## 1.6 Scope and Limitations

The investigation will be limited to the purchased component inventory for the assembly station of the blue product line, which is one of three product lines at GMC. This product line is both the most complex within the business unit and has the largest impact on profits. Therefore is the blue product line most relevant to investigate since it has large potential gains from material flow improvements.

## 1.7 Disposition

The report structure is built upon a number of chapters. The first chapter which is the introduction chapter, is followed by a methodology chapter presenting the research strategy and methods used to perform the study. The theoretical framework is then presented and ends with a description of the analytical framework that was created for the report. The fourth chapter presents the empirical findings from the data collection and process mapping. Thereafter follows the analysis chapter. In this chapter the empirical findings are analyzed using the theoretical framework to form the basis for development of recommendations to the case company. The results and recommendations are presented in the subsequent chapter. A discussion chapter concerning the challenges with fulfilling the purpose of the thesis then follows. The report is ended with the conclusions resulting from the thesis.

# 2 Methodology

*This chapter describes the research strategy and the research design used in this case study. A description is given of the data collection and how this was performed by both collecting primary and secondary qualitative data. A description of the data analysis and a discussion regarding the reliability and validity of this research finalizes the methodology chapter.*

## 2.1 Research Strategy

Two main research strategies that classify the nature of the research are qualitative and quantitative, according to Bryman (2002). The two strategies are either combined or applied separately depending on the characteristics' of the research. Bryman and Bell (2007) mention the importance of choosing an appropriate strategy since it sets the guidelines for how the research is performed. Quantitative research is characterized by a strategy that requires counting and measuring data (Gillham, 2010). This strategy consists of a deductive view on the relationship between the theory and practical research (Bryman, 2002). Gillham (2010) states that the collected and analyzed data give a clearer view of the reality and is practically useful. Qualitative research focuses on verbal data that give understanding of the research study (ibid.). This strategy is preferable when trying to understand and explain complex situations and how involved people interpret different situations. Qualitative research furthermore stresses an inductive view of the relationship between theory and practical research where the focus is on generating the theory (ibid.).

The choice of research strategy was based on the purpose and research questions of this study. The purpose is to investigate how GMC works with the PFEP process and identify possible improvements to the process. This was achieved by mapping the process of the current state to gain a better understanding and overview of the whole process. For this research was a qualitative approach chosen since qualitative data were required for mapping the current state of the process (Creswell, 2009). The qualitative approach was regarded most appropriate due to the focus of verbal data that provides a clearer overview and understanding of the situation (Gillham, 2010), which quantitative data would not provide. The chosen research strategy requires a close examination and understanding of the internal environment of the organization. The authors of this master thesis were therefore situated mostly at GMC to attain a close connection to the people involved in the PFEP process, to facilitate the process of answering the research questions. This can be related to Creswell (1994) who states that qualitative research involves the researches being physically available in the investigated area for observation and data collection from its natural setting.

### 2.1.1 Abductive Approach

Bryman and Bell (2007) explain that a research can have an inductive or deductive approach depending on the nature of the research in relation to theory. Deductive research consists of theoretical argumentation that is tested through empirical observations while inductive research focuses on the collection and analysis of empirical data to generate new theories (Järvensivu and Törnroos, 2010). Considering the nature of this research a combination of inductive and deductive approach was suitable. Since the study was performed through simultaneous and iterative collection and analysis of empirical and theoretical information, it mostly resembles an abductive research strategy. Dubois and Gadde (2002) describe abduction as a systematic combining of inductive and deductive approach. An abductive approach puts effort in matching theory and reality through a process where the theoretical framework, empirical fieldwork and analysis are developed simultaneously (ibid.). The authors mention that by changing back and forth between different research activities, empirical observations and theory, possibilities in expanding the researchers' understanding of both theory and empirical phenomena will be attained (ibid.). One of the main objectives of any research, as well for this study, was to confront theory with the empirical reality (Dubois & Gadde, 2002). This confrontation was performed continuously throughout this research, as in an abductive approach (ibid.).

## 2.2 Research Design

To identify how the research should be executed and to achieve the purpose of the study, a research design needs to be chosen (ibid.). The research design represents the structure of the methods and how the methods used in the research need to be accomplished and controlled (ibid.). The research design of this thesis can be associated with a case study where GMC as a particular organization was investigated (Bryman & Bell, 2007). Dubois and Gibbert (2010) define a case study as a research situation where the main interest is collecting variables instead of data points. These data are collected from multiple resources and consist of qualitative research techniques such as interviews, document analysis and various modes of observation (ibid.). The data collection for this research was similar to the data collection performed in a case study. This case study aims to investigate the PFEP process for GMC from different aspects based on the research questions. This is accomplished by studying the design and execution of the process and collaboration between the involved functions at GMC, to compare the real-life context with theory.

### 2.2.1 Process Mapping

There are different ways of performing process mapping and in this report the process mapping procedure was based on the steps described by Keller and Jacka (1999). The steps described in their approach are:

- Establish process boundaries
- Develop the data gathering plan
- Interview the process participants
- Generate the process map
- Analyze and use the process map

The process mapping in this study was performed by first establishing the process boundaries in order to clarify the input and output of the PFEP process. This was followed by developing the plan for collecting data, which is described in Section 2.3. The documented information from the interviews and observations resulted in creating a cross-functional process map of the PFEP process. The design of the cross-functional map was inspired by Damelio (1996).

## 2.3 Data Collection

The data collection forms the base of the empirical study and supports the analysis presented in this research. The main advantage with data collection is that it provides knowledge about the organization, people, relationships, resources and important material for the research (Bryman & Bell, 2007). Collection of data has mainly been performed through interviews, observations and organizational documents. The data collection has been conducted during a large part of the case study to ensure that all necessary data have been collected to achieve high quality of the results.

Interviews has as mentioned above been a source of information. These have been performed with people working at the case company that have some relation to or knowledge about the PFEP process. The interviewees have been people from positions such as order placer, order planner, purchaser, product line manager etc. During the data collection it happened that the knowledge acquired led to the realization that there were more people who were interesting to interview, due to their connection to the process. When collecting qualitative data from organizational documents, interviews etc. it is important to consider the origin of the information (ibid.). This since, the sources of the organizational documents and interviewees might have different positions in the organization and thereby different perspectives (ibid.). During analysis of such data it should thus be considered that the authors' and interviewees' perspectives might be reflected in the collected documents or interview answers.

The data collection for this study was based on both primary and secondary information. Primary data are data that have been collected first-hand by the researchers themselves (Bryman, 2002). The different sources of data and types of data that were collected during the study are summarized in Table 1.

| Source of data | Primary or secondary data |
|---|---|
| **Interviews** | Primary |
| **Observations** | Primary |
| **Organizational documents** | Secondary |

*Table 1. Sources of data and categorization of data by type.*

Considering the nature of this research the main focus was collecting primary data of a qualitative nature. The primary data collection gave the authors the possibility to create their own view of the PFEP process and create a map of the current state, instead of relying only on secondary data. Organizational documents have been the main source of secondary data. The organizational documents that have been collected are:

- Organizational charts
- Meeting minutes
- Process maps
- Excel documents with historical part information
- Instructions for activities relating to the PFEP process

### 2.3.1 Interviews

Semi-structured interview means that the researcher has prepared questions that cover specific topics, often referred to as an interview guide (Bryman & Bell, 2007). The questions are not asked in a certain order and questions that are not included may be added during the interview (ibid.). This type of interview provides flexibility by allowing unprepared questions to be discussed during the meeting. Semi-structured interviews was performed during this case study since it allowed flexibility to collect more data than what was expected beforehand, which might be useful for the analysis. When using this type of interview, there are risks of the interview shifting from the main topic. Such risks are however necessary to provide the flexibility of the method. The interview guide was utilized as support in order to adhere to the topic. The interviews were furthermore recorded in order to ensure that no information was lost if it was not written down during the interview. Recording also enabled the researchers to listen through the interviews again and analyze the answers if something was unclear.

The approach that was used for selecting what people to interview can be likened to snowball sampling. Snowball sampling is described as an approach in which the researcher uses the social connections of a small sample group to find additional respondents that are relevant to interview (Bryman, 2002; Biernacki & Waldorf, 1981). This approach was necessary since the starting point was a limited knowledge of the studied object and the people and functions involved. The interviews have been held with people from different functions of the company and of different management levels. The people that have been interviewed are presented in Appendix II. In total were 20 interviews performed with 12 different people. Some people were interviewed more than once, to gather more information and to double-check information from previous interviews.

During each interview, questions were asked regarding what the person works with and what his/her relationship to the PFEP process is. Depending on the degree of involvement in the PFEP process and the management level of the interviewee the focus of the interviews were somewhat different. Regarding interviews with people working directly in the process these interviews focused on the day-to-day activities that were performed in relation to PFEP and what problems the interviewees were experiencing etc. People that have an indirect connection to PFEP was asked questions on a less detailed level. This means questions about their knowledge of the process, its purpose and their perception of any existing problems within the process. An example of this would be an interview with the purchasing manager who is not directly involved in the PFEP process. Considering that the process requires resources in the form of time of purchasers, the purchasing manager is however aware of and affected by the PFEP process.

**Interview Guide**

An interview guide is useful as a support for the interviewer to remember what questions or subjects to ask during interviews (Trost, 1997). The questions to include in the interview guide are decided or guided by the aim of the research (Eriksson & Widersheim-Paul, 2006). It is however important to reflect upon what questions are necessary since there is a limit of how much time is feasible to demand from the interviewee (ibid.). The questions must also be adapted to the interviewee in the sense that it is no point in asking questions that the interviewee does not have any ability to answer (ibid.). The questions should not be too detailed but instead wide enough to let the interviewee speak freely and lead the direction of the interview (Trost, 1997; Bryman, 2002). There are also other important aspects to consider when creating the questions for an interview. Leading questions and questions that give yes or no answers should be avoided since the interviewer is then taking too much control of the interview and what answers are received (Eriksson & Widersheim-Paul, 2006). Furthermore should the interviewer avoid: questions that are really a statement, asking several questions at once and questions that are very complicated (ibid.). Bryman (2002) suggests that questions that are somehow related to each other should be ordered in a way that gives a flow, but he also states that it must be possible to change this order during the interview. The interview guide for each interview has been prepared considering the aspects mentioned above. The interview guides were created with the aim of creating a logical order and flow to the interview. This order was not considered imperative, since one reason for the interviews being semi-structured was to be flexible during the interviews. An interview guide with general questions about the PFEP process was firstly created (see Appendix I) and depending on the position of the interviewee more specific question were added.

### 2.3.2 Observations

Observations were used as a data collection method for activities in the PFEP process that are performed regularly and operatively and therefore are possible to observe. The form of observation used was unstructured observations, which according to Bryman (2002) allows the observer to carefully observe the behavior and actions of people and to narratively describe this. The observations were primarily comprised of attendance at meetings that were part of or closely related to the PFEP process. These meetings are S&OP meetings and PFEP meetings within the product line and between the product line and purchasing function.

## 2.4 Literature Review

The literature review was performed mainly through search in library databases and Google scholar. The search was based on keywords that are related to the literature areas of interest. The most relevant books and articles were chosen based on their abstracts. The literature was then studied more closely and new keywords were sometimes identified to use for further literature search. The main keywords for literature search were inventory management, hierarchical planning levels, material planning, planning methods, planning environment, cross-functional integration and process management. Within the area of inventory management for example, more keywords were identified such as safety stock, inventory levels and service level.

Search and review of literature were performed continuously during the study, since new relevant literature areas were recognized while working with data collection and analysis. This approach has been inspired by Bryman and Bell (2007). To answer the research questions, three main research areas were identified for further investigation to create the theoretical framework:

- Effects of fit between planning environment and planning methods
- Functional integration between production and purchasing
- Alignment of inventory management across planning levels

These three research areas were further divided into subareas with different focuses. The theoretical areas and their connection to the different research questions are depicted in Figure 2.

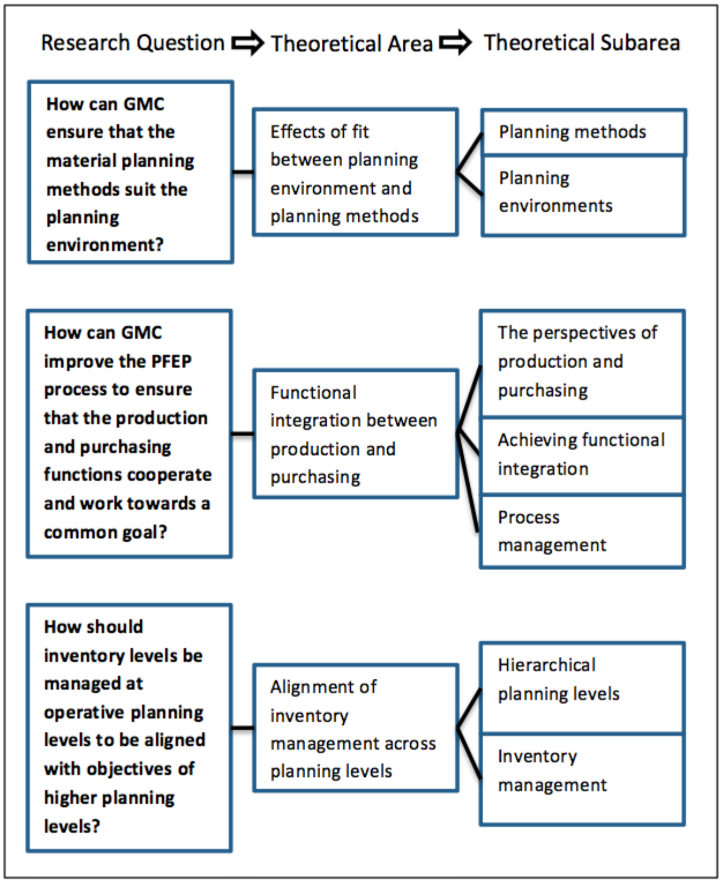


*Figure 2. Relationship between research questions and theoretical framework.*

## 2.5 Data Analysis

The data analysis was based on the three research areas presented in Figure 2. One part of the analysis was to analyze the fit between GMC's planning environment and planning methods. This was performed by classifying the company's planning environment and investigating the suitability of their planning methods according to the theoretical framework. Another part was to use the process map that was created through the process mapping. The process map was compared to existing documents and the process map that described the process as it is intended to be, called the official PFEP process. The comparison with the official PFEP process made it possible to identify differences in the current process. Strengths and weaknesses in the current state were thereafter identified and investigated, either by analysis of the already collected data or by collecting more data if needed. The last part of the analysis was to analyze the alignment of inventory management across different planning levels. Decisions regarding safety stock and kanban stock adjustments as well as lot sizing decisions were analyzed in this part. This analysis part aimed to identify gaps between the planning levels regarding inventory decisions.

The data was structured by firstly transcribing the interviews. The different aspects to analyze were defined using the analytical framework and empirical findings to define the headlines for the analysis. Processing of the transcribed interviews and other documents were performed through a review of all interviews and documents to sort the information and connect the information to the most relevant analysis area. One example is that for the analysis of safety stock adjustments, all interview answers that were related to safety stock adjustments were gathered in one place, to facilitate the analysis of the information.

## 2.6 Reliability and Validity

The reliability of a study is related to how repeatable and consistent its results are (Bryman & Bell, 2007). Reliability is mainly of importance for quantitative studies but it can also be applied to qualitative research (ibid.). Reliability of the results of this study was ensured through providing information that can be used to replicate the study. Such information is for example what people were interviewed and the interview guide which was used during the interviews. External reliability is defined as replicability and internal reliability is defined as the extent to which two observers agree about what has been observed (ibid.). Both researchers have attended interviews and participated in processing and documenting of these interviews, to ensure that information have been interpreted in the same way by both researchers. The purpose of this is to assure the internal reliability continuously through the study. Triangulation is the concept of using methods related to one research strategy to cross check the results from methods of another (Bryman & Bell, 2007). Triangulation was applied when it was regarded feasible during the study. Thurmond (2001) describes different types of triangulation. In this research was within-method triangulation (Thurmond, 2001) used to cross check some results from interviews with information acquired from process-related documents and thus to ensure consistency i.e. reliability of the results.

The validity of research is related to the integrity of the conclusions drawn from the research (Bryman & Bell, 2007). Validity has a number of different aspects. Some aspects of validity are external and ecological validity. External validity is related to the generalizability of the research results, while ecological validity relates to how well the research results conform with the normal situation (ibid.). Ecological validity can for example be reduced when the study is performed in settings that differ a lot from the natural setting of the study object, such as laboratories or special interview rooms (ibid.). When, as in this report, only one case is studied it is difficult to achieve a high degree of generalizability (external validity) since the results are specific for only this case. The analysis was performed so that generalizability was still achievable to some degree, through the identification of certain characteristics of the case company that facilitates comparison to other companies. Such characteristics are for example the product variety, lead times, production process etc., which Jonsson and Mattsson (2003) use to define different planning environments. Furthermore, ecological validity is preserved by as far as possible, observing and interviewing people in their normal working environment.

# 3 Theoretical Framework

*The theoretical framework is presented in this chapter. It addresses theories within the areas of hierarchical planning, inventory management, planning methods, planning environments, the perspectives of production and purchasing, achieving functional integration and process management. The headlines represent the seven theoretical subareas that were presented in Figure 2. The chapter ends with a description of the analytical framework.*

## 3.1 Hierarchical Planning Levels

Planning of material flows and production include decisions ranging from short-term decisions on individual manufacturing orders to long-term decisions regarding supplier delivery agreements (Jonsson & Mattsson, 2009). Planning processes are usually classified into different planning levels depending on the time horizon of the planning process and the level of detail of the information that is required (Jonsson & Mattsson, 2009; Fleischmann, Meyer & Wagner, 2008). Some different models exist to describe these different planning levels.

Jonsson and Mattsson (2009) use a four-level model that divides planning processes into sales and operations planning (S&OP), master production scheduling (MPS), order planning and execution and control. The difference in level of detail in every planning level is exemplified by the fact that planning is performed for different planning objects. The planning objects range from whole product groups to individual production operations (ibid.). Increasing degree of detail in lower planning levels is reached through disaggregating information and results from higher levels (Fleischmann, Meyer & Wagner, 2008). Product groups are for example disaggregated into individual products or items and long time periods are divided into shorter periods (ibid.). An important characteristic of the planning levels is that they are hierarchical, which means that decisions made at one planning level are limited to decisions made at a higher planning level (Jonsson & Mattsson, 2009; Fleischmann, Meyer & Wagner, 2008). Jonsson and Mattsson (2009) state two conditions that are necessary for a hierarchical planning structure to operate sufficiently. The first condition is that the decisions at lower planning levels are made within the constraints of a higher planning level (ibid.). The second condition is that decisions made at a higher planning level must be transferable to a lower planning level (ibid.). This is interpreted as, decisions made at higher planning levels should be expressed using variables which are possible to translate into meaningful variables for planning in lower planning levels.

According to Jonsson and Mattsson (2009), S&OP is the highest planning level, since it is the most long term and strategic level. MPS is more detailed and has a shorter planning horizon and is subordinate to sales and production plans that have been set on S&OP level (ibid.). Order planning is next in the hierarchy, while execution and control has the highest level of detail and the shortest horizon and thus is placed lowest in the planning hierarchy (ibid.). Fleischmann, Meyer and Wagner (2008) suggest a categorization of planning horizons into three different planning levels: long-term, mid-term and short-term. The terms strategic, tactical and operational are sometimes also used to describe these three planning levels (ibid.). Lapide (2011) however suggests that S&OP is a medium-term tactical planning process, which is guided by strategic planning performed for time horizons of three to five years. The use of the term strategic for S&OP can therefore be misleading (ibid.).

### 3.1.1 Hierarchical Inventory Decisions

Inventory decisions are as many other decisions imposed to constraints that occur due to decisions at hierarchically higher planning levels (Miller, 2002). It is important that the consequences of decisions made at a higher planning level is communicated upwards from operative levels (ibid.). This to ensure that decision-makers at the higher planning levels comprehend what effects their decisions have in reality. Lapide (2011) mentions a need for integration between planning levels but give no specific suggestions on how to achieve satisfying integration between planning levels. Miller (2002) provides examples of some inventory decisions that are related to different planning levels and also state that some decisions are related to more than one planning level. These decisions are shown in Table 2.

| Planning level | Inventory related decisions |
|---|---|
| **Strategic planning level** | Balancing inventory investment between finished goods, work-in-process and raw materials |
| | Deciding optimal customer service fill rate |
| | Deciding overall inventory investment level |
| **Strategic and Tactical planning level** | Deciding optimal balance between inventory investment costs and transportation costs |
| **Tactical planning level** | Deciding the optimal customer service fill rate by major product grouping Balancing inventory investment between finished goods, work-in –process and raw materials, by major product grouping |
| | Deciding optimal inventory level, by major product grouping |
| **Tactical and Operational planning level** | Deciding the optimal customer service fill rate by product or product grouping, by location |
| **Operational planning level** | Deciding how slow-moving inventory should be disposed of |

*Table 2. Hierarchical inventory decisions. Adapted from Miller (2002).*

## 3.2 Inventory Management

There are several different rationales for companies to have inventory. It has great impact on companies' flexibility in terms of being able to quickly change production levels (Bonney, 1994). Inventory is also a way to reduce lead times and provide good delivery service to customers (ibid.). Moreover, inventory creates a possibility for companies to increase capacity utilization and "store" capacity, by producing to inventory at times when demand is low and to consume the inventory at times when demand is higher than capacity (ibid.). Other reasons for having inventory are to co-ordinate deliveries for multiple items that are purchased from one supplier in order to reduce the costs for transportation (Jonsson & Mattsson, 2009).

Inventories are divided into different types depending on the purpose of the inventory (Minner, 2000). Cycle stocks are for example created due to financial or technical reasons, which make it necessary to order and/or produce in batches (Minner, 2000; Jonsson & Mattsson, 2009). Stocks that are created to build inventory before seasonal demand peaks are called anticipation stocks or leveling stocks when the stock is also created to level out the production burden over time (Minner, 2000). Safety stocks are stocks that exist to prevent shortages caused by unpredictable disruptions in supply or sudden demand surges (Dillon, 1990; Jonsson & Mattsson, 2009). The concept of safety stocks and their connection to service level is described further in Section 3.2.3 below.

There are some different drawbacks and costs of having inventory. Inventory ties up working capital as well as physical space in a factory or warehouse (Bonney, 1994). Inventories can also become obsolescent or deteriorated, which means that they will be scrapped or require extra work to fix inventory that has received impaired functionality (ibid.). The costs for inventory should be balanced against the gains. The main decisions to make concerning inventory are deciding what to stock, where to store it, when to order and how much to order at each occasion (Bonney, 1994). These decisions should be made with consideration to overall strategies on investments, working capital and customer service (ibid.). It is common that focus is shifted towards decisions on when and how much to order since this is necessary in the day-to-day operations (ibid.).

### 3.2.1 Inventory Levels and Replenishment Systems

A replenishment strategy is used to decide the appropriate inventory level in relation to demand characteristics, replenishment lead time, replenishment costs and storing costs (Gudehus & Kotzab, 2012). This implies that parts with differing demand characteristics, replenishment lead times etc. will be subjected to different replenishment strategies. Inventory replenishment systems aim to balance inventory costs and customer requirements (Rushton, Croucher & Baker, 2010). More specifically this means to decide when, what and how much to order to minimize the different costs related to inventories, which were mentioned previously. There is a large variety of replenishment systems or planning methods that can be used to manage inventory levels, for example periodic ordering, re-order point, run-out time planning and material requirements planning (MRP) systems (Rushton, Croucher & Baker, 2010; Jonsson & Mattsson, 2009).

### 3.2.2 Lot Sizing

Lot sizing means to determine what quantity to order from a supplier by balancing factors such as customer service, production capacity utilization and tied-up capital (Jonsson & Mattsson, 2009). Lot sizing is required since it is not possible or suitable to produce or procure the exact quantity that is required by customers in each point in time (ibid.). Large order quantities (i.e. lot sizes) give rise to high inventory levels (Rushton, Croucher & Baker, 2010). Small lot sizes induce lower tied-up capital in inventory but on the other hand create higher costs for delivery handling and order administration (ibid.). Lot sizing relates to procurement of materials for future needs and must thus consider the risks of the actual needs differing from the expected and forecasted needs (Jonsson & Mattsson, 2009). Inventory which is created by ordering in batches are as mentioned earlier called cycle stock (Minner, 2000). Several different lot sizing methods are mentioned in the literature (Rushton, Croucher & Baker, 2010; Jonsson & Mattsson, 2009). Some common methods are estimated order quantity, economic order quantity, lot-for-lot, estimated run-out time and economic run-out time (Jonsson & Mattsson, 2009). The methods all have different benefits and drawbacks since they consider different aspects and involve varying degrees of calculation (ibid.).

### 3.2.3 Safety Stock Levels and Service Level

Safety stocks are inventories that are held to compensate for uncertainties in demand quantities and/or supply lead times (Dillon, 1990; Dolgui & Prodhon, 2007). The size of safety stock levels can be determined either using manual and experience-based methods or advanced calculations (Jonsson & Mattsson, 2009). This, in order to minimize shortage and holding costs and to guarantee a given service level (Dolgui & Prodhon, 2007). Shortage costs are all costs that arise as a result of material shortages, such as lost revenues, delay fees and express transports (Jonsson & Mattsson, 2009). Since the actual shortage costs are very difficult to estimate, policy-determined service levels are commonly used to decide safety stock levels (ibid.).

Manual estimations of appropriate safety stocks can include considerations of tied-up capital, cost effects of inventories as well as consequences of shortages and late deliveries (Jonsson & Mattsson, 2009). The method however requires manual revision of safety stock levels for every item in the ERP system and this work can thus become quite resource consuming (ibid.). More advanced safety stock calculations are based on the assumption that demand variations are related to standard distribution functions (ibid.). The normal distribution is most commonly used for calculations that use a specific service level to calculate the safety stock levels (Jonsson & Mattsson, 2009; Gudehus & Kotzab, 2012). Examples of such policy-determined service levels are cycle service and fill rate service (Jonsson & Mattsson, 2009). Cycle service describes the probability of delivery directly from stock during an inventory cycle (between two replenishments), while the fill rate service describes the proportion of demand that is fulfilled directly from stock (ibid.).

There is another method that can be used to decide the safety stock level. This method consists of calculating the safety stock as a percentage of demand during the lead time (ibid.). The method makes it simple to automatically update safety stocks when demand or lead time changes (ibid.). It also facilitates differentiation of safety stocks for items with different characteristics (ibid.). The fact that this method does not consider the size of demand variation or forecast errors is a disadvantage (ibid.).

A common way to balance the costs for safety stocks and service level is to differentiate the service level for different types of items (Jonsson & Mattsson, 2009; Teunter, Babai & Syntetos, 2010). The demand value and demand volume are the most common criteria used when classifying different types of items (Teunter, Babai & Syntetos, 2010). Criticality or inventory holding costs are also alternative criterion to use (ibid.). A usual approach is to set a very high service level (i.e. safety stock) for low value items and set a lower service level for high value items (ibid.). Higher stock levels for low value items that are relatively cheap to stock means that they will not cause disruptions in production and thereby will not result in failures to deliver to customers. For high value items on the other hand, inventory carrying costs are greater which in turn makes the shortage risks more worthwhile. This approach is commonly called ABC-classification and the main purpose is to facilitate inventory management by creating categories or classes of items instead of managing the inventory for each individual item separately (Teunter, Babai & Syntetos, 2010).

## 3.3 Planning Methods

The planning methods MRP, kanban and consignment stock are described below.

### 3.3.1 Material Requirements Planning

MRP is, according to Jonsson and Mattsson (2009), a planning method that is based on points in time for scheduling new deliveries. Scheduling is based on calculations of when additional demand of material occurs. This means that, when the calculated stock on hand becomes negative, an order must be scheduled to be delivered at this time to avoid shortages. When using this method, orders are not scheduled until there is a net requirement and the release of orders are calculated as the delivery time minus lead time for the item (ibid.). To achieve a functioning MRP system it is crucial that the right type of data are transferred into the system from sales, forecasters, buyers, engineers etc. (Hall & Vollmann, 1978).

The parameters that Jonsson and Mattsson (2009) mention as the right type of data are mainly length of planning horizons, planning frequency, types of orders, handling of rescheduling and planning time fences. The planning horizon must as a minimum be equal to the longest accumulated time for manufacturing and purchasing of all items included in the end products. Otherwise will the planned orders for purchased items at the lowest product structure levels not be planned early enough (ibid.). Planning frequency means how frequently new planned orders are generated and existing planned orders are rescheduled (ibid.). Orders planned far in the future are based on forecasts while orders planned in the near future instead are based on actual orders. When forecasts change it affects the MRP since rescheduling of orders needs to be done (ibid.). Planning time fences are used to minimize the costs associated with rescheduling by gaining control over the automatic generation of new master production schedules through deciding rules for when and how rescheduling is supposed to be performed (ibid.).

### 3.3.2 Kanban Systems

A kanban system is a control system that manages the flow of parts according to the rules of JIT production and initiates signals for replenishment (Sylvain et al., 2000). The system is based on a pull replenishment logic by feeding production resources the right material, in the right quantity at the right time (Gupta, Al-Turki & Perry, 1999). This is typically conducted through the use of kanban cards that contain information such as component name and number, kanban type, quantity of the component, station location and destination station (ibid.).

An advantage of kanban is its ability to control production by not overproducing (ibid.), since kanban is based on JIT principles which aim to produce the quantities that both internal and external customers demand (Chan, 2001). Another advantage is that it provides simplicity in production scheduling and facilitates identification of parts using the kanban card attached to containers and thereby provides a reduction in paper work (ibid.). Kanban can furthermore lead to fewer inventories as well as shorter lead times depending on the size of the kanban. Kanban can also operate as a tool for continuous improvement by reducing the number of cards in the system, which facilitates the identification of problems (Chan, 2001; Gupta, Al-Turki & Perry, 1999). A drawback of kanban is that it is sensitive in environments where uncertainties in processing time variation, demand variation and breakdowns occur (Gupta, Al-Turki & Perry (1999). The system is therefore suitable in environments with constant processing times and an even and stable demand (ibid.).

To obtain the advantages of kanban, parameters such as the size of the kanban (the quantity specified on the kanban card) are very important. The size of kanban decides both the level of inventory and the lead time (Chan, 2001). A large kanban size generally gives higher inventory levels but shorter lead times resulting from a reduced number of set-ups (ibid.). This however affects the product variety, and to provide a satisfying product mix to customers a smaller kanban size might be required (ibid.). Small kanban sizes furthermore imply higher risks for shortages and longer lead times (ibid.). It is important to strive for an appropriate kanban size that is able to fulfill the customers' demands on product variety while keeping the inventory level as low as possible (ibid.).

### 3.3.3 Consignment Stocks

A consignment stock means that a buying company physically holds the inventory, while the ownership stays with the supplier until the items have been used in production or sold by the buyer (Wallin, Rungtusanatham and Rabinovich, 2006; Rungtusanatham et al., 2007). A benefit of such inventory management approach is that the buyer can get immediate access to the items without obsolescence risks or having tied-up capital in inventory (Wallin, Rungtusanatham & Rabinovich, 2006). A drawback on the other hand is that the buyer will have costs for handling and storing the items (ibid.). It is the responsibility of the supplier to ensure that the inventory levels are consistent with the agreed upon inventory level (ibid.). The supplier will perform replenishments at regular intervals when the inventory level is also reviewed (Rungtusanatham et al., 2007).

Consignment stock systems are according to Battini et al. (2010) suitable for items characterized by low unit price, high annual consumption, small dimensions and ease of storage. Items with such characteristics are for example small metal components, small electronic components, plastic fasteners, other small parts and small tools (ibid.) The reason why items with such characteristics are preferable for consignment stock management, is that studies have proven it to be effective even in the presence of variable demand, obsolescence risk and constraints in the space available in the buyer's plant (ibid.).

## 3.4 Effects of Fit Between Planning Environment and Planning Methods

Theories with respect to planning environments are presented in this section.

### 3.4.1 Planning Environments

Demand, products and manufacturing characteristics are important variables that implicate what type of manufacturing planning and control methods are suitable in different situations (Jonsson & Mattsson, 2003). Even if one method works well in one situation it can be the completely wrong approach in another (ibid.). Berry and Hill (1992) stress how important it is to understand the characteristics of the planning environment. This because a mismatch between market requirements, manufacturing process design and choice of planning method will lead to poor performance of manufacturing firms (ibid.). It is also mentioned by Jonsson and Mattsson (2003) that the consequences of not using suitable planning methods for an organization's planning environment will be poor performance of the manufacturing planning and control systems and unfulfilled production goals. They furthermore state that incorrect use of planning methods will also contribute to these consequences. Examples of incorrect use of planning methods are reviewing parameters too seldom or using lot sizing methods that are not optimal (Jonsson & Mattsson, 2003).

To identify the planning environment of a company, there are many different characteristics that can be used to distinguish one planning environment from the other. Jonsson and Mattsson (2003) use three main variables and multiple sub variables to define planning environments. These variables are summarized in Table 3.

| Demand related variables | Manufacturing variables | Product related variables |
|---|---|---|
| **Ratio between product- and- delivery lead time** | Manufacturing mix | BOM complexity |
| **Manufactured volume/frequency** | Shop floor layout | Product variety |
| **Type of procurement ordering** | Batch size | Degree of value added at order entry |
| **Demand characteristics** | Throughput time | Proportion of customer specific items |
| **Demand type** | Number of operations | Product data accuracy |
| **Time distributed demand** | Sequencing dependency | Level of process planning |
| **Source of demand** | | |
| **Inventory accuracy** | | |

*Table 3. Variables used to characterize planning environments.*

Jonsson and Mattsson (2003) describe the following four categories of planning environments:

- Type 1 - Complex customer products
- Type 2 - Configure to order products
- Type 3 - Batch production of standardized products
- Type 4 - Repetitive mass production

Type 1 production environments are constituted by low volumes, low standardization and high product variety (ibid.). Products are in this environment generally very complex and engineered to order (ibid.). Batch sizes are furthermore very small and lead times long (ibid.). Type 2 is defined by less complex products that are produced in small batches (although larger batches than type 1) usually with an ATO or MTO approach in cellular or line production layouts (ibid.). Characteristic to this type is that a wide variety of product variants can be produced through combining of different components and semi-finished items at a much shorter lead time, than in the type 1 environment (ibid.). Distinctive for the type 3 environment is MTS production in medium to large batches and lead times that are shorter than for type 1 but longer than for type 4 (ibid.). Standardized products that are repetitively or continuously produced in large volumes in a line layout characterize the type 4 environment (ibid.). The product complexity is low and type 4 production is performed either using MTS or ATS strategies with very short lead times (ibid.).

Jonsson and Mattsson (2003) present a method for categorizing companies into the four planning environment types. Only seven of the environmental variables presented in Table 3 are used. Table 4 presents the classification of planning environments using these seven variables.

| Environmental variable | Type 1 | Type 2 | Type 3 | Type 4 |
|---|---|---|---|---|
| ***Product characteristics*** | | | | |
| **Product (BOM) complexity** | High | Medium | Medium | Low |
| **Degree of value added at order entry** | ETO | ATO/MTO | **MTS** | MTS/ATS |
| ***Demand characteristics*** | | | | |
| **Volume/frequency** | Few/small | Many/medium | Many/large | Call-offs |
| ***Manufacturing Process characteristics*** | | | | |
| **Production process** | One-off | | Batch | Mass |
| **Shop floor layout** | Functional | Cellular/line | Cellular/functional | Line |
| **Batch sizes** | Small | Small | Medium/Large | |
| **Lead times** | Long | Short | Medium | Short |

*Table 4. Classification of planning environments. Source: Jonsson and Mattsson (2003).*

### 3.4.2 Fit Between Planning Environment and Planning Methods

MRP is suitable for planning environments with complex product structures, dependent demand, long lead times and erratic demand (Jonsson & Mattsson, 2003). MRP is described as a planning method that is applicable in most planning environments, especially with respect to its ability to plan dependent demand (ibid.). Planning environments characterized by complex standard products, long lead times and uneven demand was stated to have the highest degree of fit with MRP (ibid.). The key prerequisites for successful use of kanban are short lead times, small batches and even demand for products with low complexity (i.e. few BOM-levels) (ibid.). Long lead times in combination with kanban would result in waste in the form of high inventory levels (Cimorelli, 2013). This indicates a conceptual match between kanban and planning environment type 4. However in cases with small order quantities or batches also type 2 and 3 have shown to be a good fit with kanban (ibid.). Jonsson and Mattsson (2003) summarize the conceptual fit between planning methods and planning environments in Table 5. The symbol "– " represents mismatch, "+" represents poor fit and "++" represents good fit.

| Planning Method | Type 1 | Type 2 | Type 3 | Type 4 |
|---|---|---|---|---|
| **MRP** | + | ++ | ++ | + |
| **Kanban** | - | + | + | ++ |

*Table 5. Conceptual fit between planning methods and planning environment. Source: Jonsson and Mattsson (2003).*

Jonsson & Mattsson (2003) tested their hypothesis of the conceptual fit between planning methods and planning environment empirically. The results showed that MRP was not only suitable in type 2 and 3 environments. Companies with type 1 or type 4 environments were also satisfied with the method (ibid.). Otherwise, the results from their empirical investigation proved to coincide well with the conceptual fit (ibid.). Companies using the methods that conformed to the conceptual fit were more satisfied than companies using a method which according to the hypothesis did not fit their planning environment (ibid.).

Vollmann et al. (2005) present a classification of manufacturing planning and control (MPC) systems relative to the complexity of products (expressed in terms of number of subparts) and the repetitive nature of production (expressed through time between successive units). This relationship is presented in Figure 3. These variables are similar to Jonsson and Mattsson's (2003) product complexity variable and manufacturing process variables. Vollmann et al. (2005) and Jonsson and Mattsson (2003) thus agree that increasing product complexity and lead times imply better fit with MRP, while shorter lead times and lower product complexity imply a high degree of fit with kanban (i.e. JIT approaches).

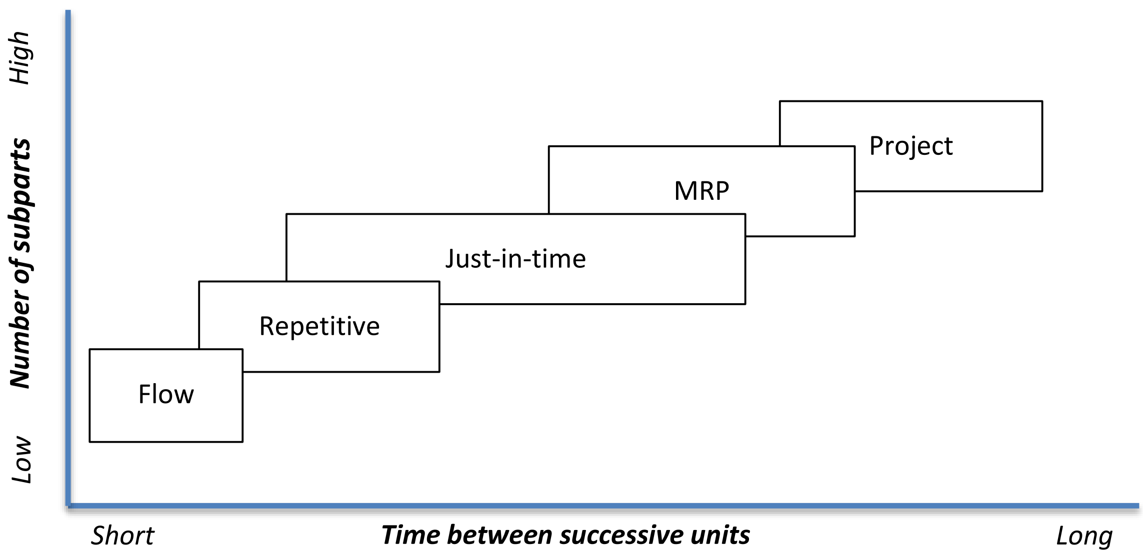


*Figure 3. Classification of MPC systems. Source: Vollmann et al. (2005).*

The figure shows that different MPC systems are associated more or less with different production processes (time between successive units) and product characteristics (number of subparts). Vollmann et al. (2005) furthermore state that JIT and MRP systems have large application areas and that more companies are trying to move away from the traditional MRP environment with relatively long lead times and high product complexity towards more lean-inspired production systems with short lead times, low inventory and small batches. It is suggested that MRP systems are possible to combine with the use of JIT approaches for planning and controlling those parts of production that are more appropriate such as high volume and repetitive production (ibid.). Kanban is an example of a JIT approach (Jonsson & Mattsson, 2009).

Companies must consider that the planning environment is not static, since the market situation changes continuously with new customer requirements, changed competitive conditions and supplier capabilities (Vollmann et al., 2005). To ensure that MPC systems are matching the current market situation, should the MPC be consistent with and focused on the company's long-term strategy (ibid.). If the strategy changes to adapt to changed market conditions, the MPC systems must also be adapted (ibid.).

## 3.5 The Perspectives of Production and Purchasing

The perspectives of the functions and their performance measurements are described below.

**Production Function Perspective**

The production function’s responsibilities are often described under the term operations management. Operations management describes the way that an organization produces goods and services, arrange and manage their resources, activities and decisions regarding the production staff (Brooks, 1998). The goal of operations management must correspond to the strategic directions of the organization such as for example producing goods and services to the lowest possible cost. Managing the staff, plant, processes and products are also important to production management in order to achieve its goal (ibid.). The purpose of the production function is to fulfill the customers’ demands for products and service by managing activities that produce and deliver products and services to the customers (Slack, Chambers & Johnston, 2010).

The production function affects the success of a company by providing the ability to respond to the customers’ demands and develop capabilities that will enhance their position in relation to competitors (ibid.). Since the performance of the production function is important for the whole organization it is of interest for all organizations to assess the performance of their production operations (ibid.). Production performance measurement is based on five objectives, quality, speed, dependability, flexibility and cost (ibid.). Quality is about performing the right things without any mistakes in order to satisfy the customers by offering error-free products and services (ibid.). Speed means operating quickly by minimizing the time between a customer asks for a product and the time the customer receives it (ibid.). Dependability consists of performing things on time and keeping the promised delivery time to customers (ibid.). Flexibility allows production to make changes by varying or adapting the production activities to handle unexpected circumstances or offer customers individual treatment (ibid.). Finally, cost means producing goods and services at a cost that allows companies to offer products at low prices while still being profitable (ibid.).

**Purchasing Function Perspective**

The goal of purchasing is to support the organization’s efficiency-seeking goals, by providing purchased materials at the lowest costs along with managing the supplier relationships (Svahn

& Westerlund, 2009). One of many companies' most valuable assets is the relationships with suppliers, since many buying companies attempt to use supplier relationships to achieve higher efficiency or effectiveness in their operations (ibid.). Besides from offering items to low costs, the selected suppliers must also be able to fulfill requirements that that the buyer has on for example lead time or quality (ibid.). Most companies purchase parts and services for more than half of their sales turnover (van Weele, 2010). The responsibilities of purchasing is to manage external resources so that the supply of goods, services, capabilities and knowledge which are necessary for running, are retained under the most favorable conditions (ibid.). Van Weele (2010) mentions a number of main activities that the purchasing functions covers:

- Determining the required quality and quantity of goods and service to be purchased.
- Selecting the best suppliers and developing procedures and routines.
- Preparing and conducting negotiations with suppliers to establish agreements and write the legal contract.
- Placing orders with selected suppliers or developing efficient purchase order and handling routines.
- Monitoring and control of orders to secure supply.
- Performing follow-ups and evaluations.

Purchasing can be divided into the three different levels, strategic, tactical and operational (ibid.). Strategic purchasers are normally responsible for planning, implementing, evaluating and controlling strategic and operational purchasing decisions, by guiding all activities of the purchasing function towards opportunities that correspond to the company's long-term goals (Castaldi, ten Kate & den Braber, 2011). This means that strategic purchasing should consider data on purchasing expenditure, information about products and processes, information about production and inventory levels and identify key and commercial suppliers to differentiate supplier strategies (van Weele, 2010; Castaldi, ten Kate & den Braber, 2011). Tactical purchasing is constrained by the supplier strategy determined at the strategic level (van Weele, 2010). Standardized purchasing processes, sharing of effective information links with suppliers and continuous supplier performance improvements are performed at the tactical level (ibid.). At the operational level the main responsibility is to secure efficient material supply from their suppliers on time, at the right quality, at the right quantity and at the lowest overall cost (ibid.). This is performed through purchase orders consisting of documentation with information regarding the order quantities and time for delivery (Jonsson & Mattsson, 2009). Purchase orders are commonly placed in the form of call-offs made within the frames of supplier agreements (ibid.).

Achieving effectiveness and efficiency in the purchasing organization is connected to the way the organization is organized, how systems are being used, the procedures and guidelines that are in place and the purchasing staff (ibid.). Van Weele 2010 presents four dimensions for measuring and evaluating purchasing activities:

- Price/cost dimension
- Logistics dimension
- Product/quality dimension
- Organizational dimension

The price/cost and logistics dimension have the clearest connection to material planning and inventory management and these two dimensions are therefore described more in detail. Price/cost mainly includes monitoring and evaluating of purchasing prices to avoid losing control over increasing prices (ibid.). The second dimension is logistics that should provide efficient incoming flows of purchased materials (ibid.). Activities involved in this dimension are control of the timely and accurate handling of purchasing requisitions, by measuring the average order backlog and number of orders issued (ibid.). Other logistics activities are to control the timely delivery by suppliers through monitoring of supplier delivery reliability, material shortages, over/under delivery and number of JIT-deliveries (ibid.). The logistics dimension also incorporates control of the quantities delivered meaning that the inventory turnover ratio, number of over/under deliveries, average order size etc. are measured (ibid.).

## 3.6 Achieving Functional Integration

In a cross-functional team (CFT), individuals from various functional areas work together to achieve a specific goal (Webber, 2002). The various perspectives and knowledge that are present in a CFT influence the team performance positively (Horwitz, 2005). The time that a CFT work together is limited and the members are also part of other teams (Webber, 2002). The diversity of the CFT members and their specialized expertise also mean a variation in knowledge and perspectives that can result in communication barriers and conflicts in the CFT. It is therefore important that the internal dynamics of the CFT support collaborative interactions among members, otherwise will the full potential of the CFT’s diversity not be utilized (Daspit et al., 2013). A challenge with integrating different functions is disagreements between managers since they have different perspectives and priorities (Kathuria, Porth, & Joshi, 1999). Moreover, achieving integration within a function also enhances the performance of the function, because intra-functional differences in strategic and operational priorities can occur between managerial and operational employees (Pagell, 2004).

Pagell (2004) mentions several factors that are important to consider in order to achieve functional integration:

- Information technology
- Communication
- Strategic consensus
- Job rotation performance
- Measurement and rewards
- Top management support

Information technology and communication are important factors that enhance the integration between purchasing functions and operational functions (ibid.). A study performed by Pagell (2004) shows that ERP systems improve the integration when they work properly, meaning that the right information is provided (ibid.). Informal meetings, open communication and face-to-face interaction between the people involved also result in better team performance since issues can be addressed in more casual situations (ibid.). Reaching strategic consensus is the key to integration, meaning that managers from different functions agree on the business strategy and to support each other (ibid.). Strategic integration is reinforced when knowledge and capabilities of one function are united with the other functional areas (van Weele, 2010). Job rotation helps spreading organizational knowledge and understanding from function to function and it can be applied both for managers and employees with customer contacts (Pagell, 2004). Studies show that people perform their tasks better when they are rewarded, which gives a clear linkage between measurement, rewards and performance. Finally, the key factor to integration is top management support which enables higher levels of integration between functions (ibid.).

## 3.7 Process Management

A process is according to Bergman and Klefsjö (2010) “a network of activities that are repeated in time, whose objective is to create value to external or internal customers”. A process should include a first and last activity, a customer and a supplier, a network of activities; and should be repeated in time (ibid.). Customers can either be internal or external, where internal customers are for example a department or a specific employee while external customers are an external party bringing profits to the organization (ibid.).

A process requires continuous monitoring and management or else it will eventually fail to produce the sought results (Romero, 2011). Romero (2011) suggests four different activities that must be performed in a continuous cycle to manage a process; ensuring process compliance, process monitoring, process assessment and process improvement. Ensuring process compliance does not mean forcing employees to comply with the process. Instead, it should already in the process design phase, be ensured that the activities in the process are feasible to execute and satisfy the process customers’ needs (ibid.). Monitoring of a process should be the responsibility of a process owner who ensures that the process fulfills business objectives (ibid.). This requires performance metrics that are measuring the right things. Romero (2011) describes some characteristics of metrics that are a prerequisite for successfully monitoring process performance. These characteristics are presented and described in Table 6.

| Metric characteristic | Description |
|---|---|
| **Controllable** | Something that is possible for employees to directly influence |
| **Accurate** | Actually expresses what is sought to measure |
| **Objective** | Not subject to dispute |
| **Easy** | Not difficult or expensive to attain |
| **Timely** | Available in time to react and make a difference |
| **Comprehensive** | Easily communicated and understandable |
| **Harmless** | Does not induce dysfunctional behavior |

*Table 6. Important characteristics of process performance metrics. Adapted from Romero (2011).*

A useful metric is a metric for which it is easy to state the decisions that are associated with that specific metric (ibid.). Process performance monitoring are used to assess the performance of the process and identify performance gaps between the required results and the actual results obtained by the process (ibid.). When such gaps are identified, process improvement can be done either through improvement of the execution of the process or by redesigning the process (ibid.). The root causes for poor process execution can be poor communication or training, attitudes, personalities etc. but a multitude of other things are also possible causes (ibid.). Improving the process design sometimes requires to completely redesign the entire process but it can also be to only make some smaller adaptations (ibid.).

Different roles are identified as important parts of process management. Bergman and Klefsjö (2010) mention the process owner, process manager and competence supplier as three important roles. Romero (2011) discusses the role of the process owner, process administrator, resource manager and process team members. The process owner has strategic responsibilities of the process and should provide the process design, monitor the process and commence actions to improve the process if process performance is unsatisfactory (Romero, 2011; Bergman & Klefsjö, 2010). The process manager's responsibility is according to Bergman and Klefsjö (2010) to support the process owner by managing the process operatively and lead improvement work. In large and complex processes, smaller sub-processes are created for which the responsibility is divided between several process managers (ibid.). Romero (2011) describes the process administrator role as a person taking care of day-to-day process execution, since this is not something that the process owner should or can devote time to, considering that the process owner likely also has ownership of several other processes. The process administrator should be a resource with process knowledge and should perform activities related to documentation management, procedure maintenance, providing performance result reports, management of problems and escalations (ibid.). The resource manager develops and assists employees, administers performance management of employees and assesses demand and provides staff to the process (ibid.). Competence suppliers are according to Bergman and Klefsjö (2010) responsible for supplying the process with the required competence. Ljungberg (2002) uses the term resource owner to describe a similar role and furthermore states that since different skills are required to manage people with different competencies, resource ownership is often divided among more than one person. Process team members are the ones to actually execute the activities of the process but team members also have more responsibilities such as: acting with understanding of the customer, business and process; solve problems and have ownership of results (Romero, 2011). Team members should also have a common purpose and work towards a common goal with other team members (ibid.).

The role concept is by Romero (2011) and Bergman and Klefsjö (2010) regarded important but they use quite different terms and definitions to describe the different roles. The terms used to define the roles in a process however, are not critical for the success of the process. It is however important that the different roles, which can be formal or unwritten, are clearly associated with responsibility and authority that is divided among process participants (Bergman & Klefsjö, 2010). This, to avoid confusion of who is responsible for what activities in the process (ibid.).

## 3.8 Analytical Framework

This section describes the analytical framework that has been created based on the theoretical framework. The analysis will be divided into three areas relating to the research questions. The analytical framework is illustrated in Figure 4. A brief description of how the theoretical and empirical findings will be analyzed to answer the research questions is provided below.

- **Effects of fit between planning environment and planning methods**

The analysis for this area will be performed in four parts. The company's planning environment is firstly identified. Secondly is the fit between the identified planning environment and the planning methods used at the case company analyzed. The third part of the analysis is to determine if the different planning methods on individual part level are applied for parts with suitable characteristics in terms of demand, value, lead time etc. Moreover the third part investigates how reviews of parameters for individual items are executed, to continuously ensure that all items are managed with the most suitable planning method. The last part focuses on the connection between long-term strategy and operative planning methods.

- **Functional integration between production and purchasing**

The different perspectives of the product line and purchasing function are analyzed in order to identify any obstacles to achieve functional integration. The strength and weaknesses with the current process will be analyzed to identify possible improvements. The analysis will be based on aspects such as communication, process management and responsibility division; and process performance measurements. The aim of the analysis is to examine how GMC can ensure that the different functions work in a more integrated way by supporting the PFEP process and by working towards common goals and avoiding conflicts.

- **Alignment of inventory management across planning levels**

The analysis will focus on identifying what structures and routines that exist for communicating inventory decisions and objectives, from top to bottom and vice versa, in relation to the PFEP process. The theoretical framework indicates that lot sizing decisions and safety stock levels are important aspects of inventory management. The analysis therefore addresses how GMC works to align lot sizing and safety stock decisions between strategic and operative planning levels.

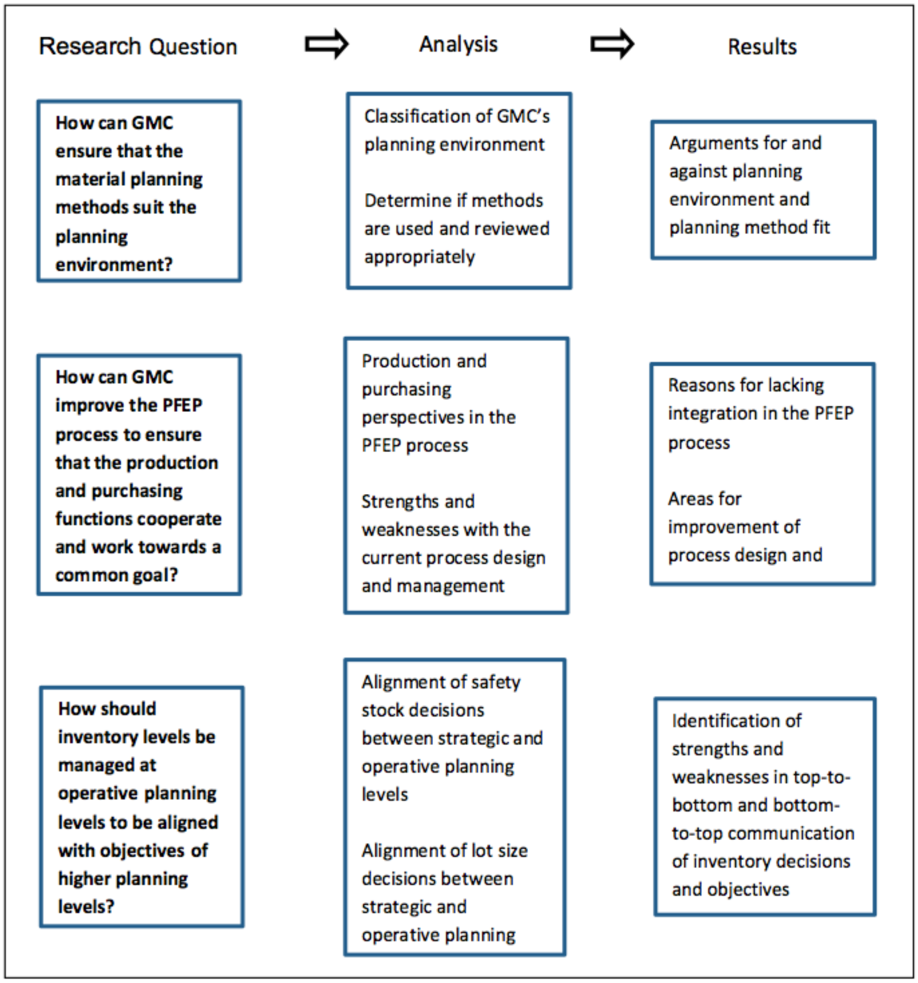


*Figure 4. Analytical model showing the connection between research questions, theoretical framework and analysis.*

# 4 Empirical Findings

*This chapter presents the empirical findings from the interviews and other data collection that was performed at the case company. The chapter firstly presents the organization of the case company and the sections are thereafter focused on the different research questions.*

## 4.1 The Organization of GMC

GMC is operating as a matrix organization with their three product lines as the starting point. The product lines are supported by a production function, technique function, market function and a supply chain function. Every one of these functions supports all three product lines. An example of how this organization works is that the purchasing function, which is a part of the supply chain function, has allocated one strategic purchaser who is responsible for each product line. The purchasing function as a whole is however responsible for purchasing matters in all product lines.

The supply chain function and the blue product line are directly involved in the PFEP process and are thus of particular interest to this report. These functions are marked by a dashed black frame in Figure 5 and they are also depicted with a higher degree of detail than the other functions in the figure. The positions that are directly involved in the process are marked with a black frame in Figure 5.

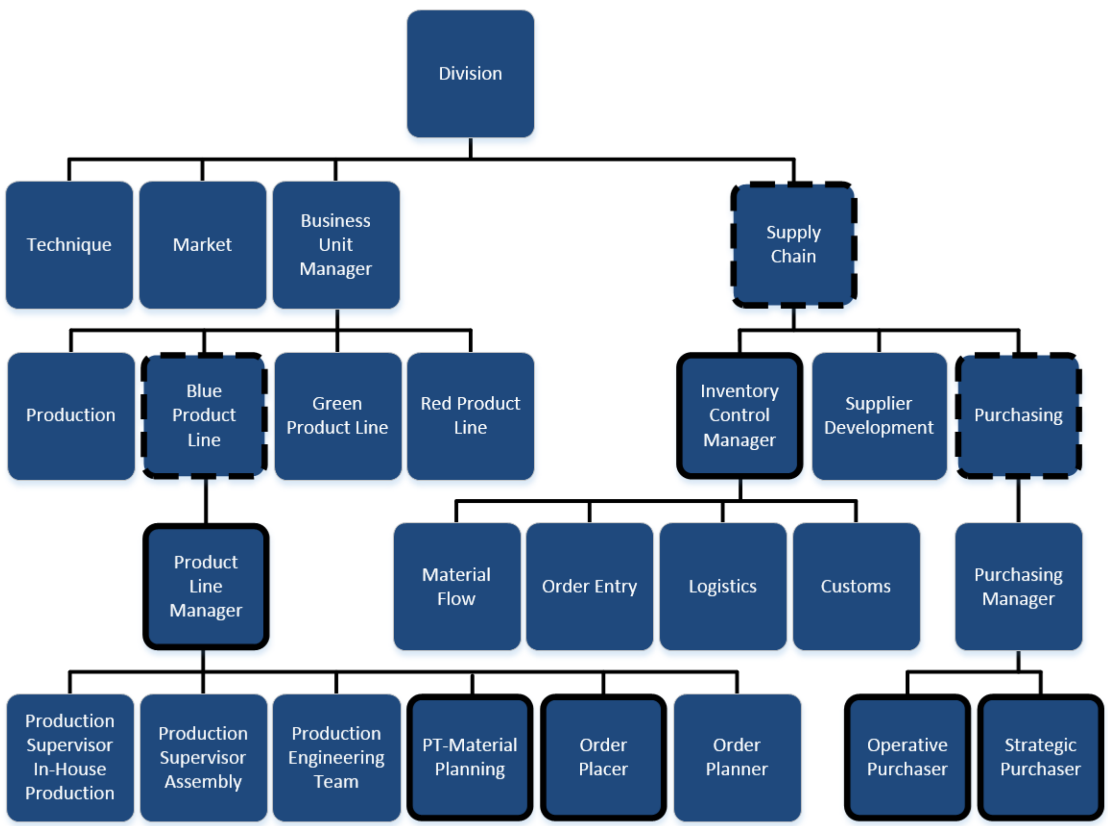


*Figure 5. Blue product line and supply chain organization scheme.*

### 4.1.1 Functions Involved in the PFEP Process

The product line function and supply chain function are involved in the PFEP process. The responsibilities of the people from these functions that are part of the process are described below. The production engineering team, order planner and order receivers are not regular participants of the PFEP process, but since they have some connections to the process, these positions are also described in this section.

***Product Line Function***

The product line consists of several positions with different responsibilities. The positions that are important in relation to the PFEP process are the product line manager, order placer, order planner and the production technician (PT-material planning). A detailed description of these positions is given below.

*Product Line Manager*

The product line manager has a wide range of responsibilities. The main responsibility is to achieve the required results in form of service level, low costs, low inventory levels and satisfied customers. This means that the product line manager has the overall responsibility for ensuring smooth operations in production by managing capacity and resources in production, to be able to produce quantities that conforms with the plan that are established at the S&OP level. Furthermore should the inventory costs and production costs be kept as low as possible. The product line manager also has the responsibility to report the results of the product line's work to higher management levels in the organization.

*Order Planner*

The order planner is responsible for releasing manufacturing orders to the assembly cell. The order planner mainly works with MRP using the company's ERP system. The main responsibility of the order planner is to process all manufacturing orders that require attention. This work means deciding dates for manufacturing orders to be released to the shop floor so that the manufacturing orders will be finished in time; meaning that the customers will receive their products within the promised lead time.

*Order Placer*

The order placer calls off material on a weekly basis based on the current demand for material, according to the MRP. A frame agreement that the purchasing department develops with the supplier contains information such as the quantity that GMC will purchase in one year, lead times, order frequency, batch quantities etc. These supplier agreements set the base for the order placer's work. The order placer receives a suggestion from the ERP system on how much to order which is based on the MRP. An evaluation of the suggestion is thereafter done, by considering if the suggestion seems feasible and also considering other factors than what the system does. Such factors are for example the history of supplier delivery performance and demand characteristics for different product groups and the risks with the current safety stock.

*Production Technician (PT-material planning)*

PT-material planning is responsible for material flows on the shop floor. The PT-material planning is for example responsible for finding suitable storage locations and storage racks for materials. Furthermore the PT-material planning also works as a production technician to some degree on the shop floor by supporting the daily operations and ensuring that production operations run smoothly. For example, if in-house produced materials are delayed to the assembly station the PT-material planning review the parameters in the ERP system to find the reason for the delay. The PT-material planning is moreover capable of replacing the order placer and the order planner during illness, vacation etc.

*Production Engineering Team and Production Supervisors*

The production engineering team consists of product designers, tool designers and production technicians. The production supervisors control the production. The operators in the production cells report to the supervisors who in turn report directly to the product line manager.

**Supply Chain Function**

The supply chain function consists of a supply chain manager, purchasing department, supplier development department and inventory control manager. The purchasing department and the inventory control manager are directly involved in the PFEP process and their work is described further below.

*Inventory Control Manager*

The inventory control manager is responsible for four different areas: order entry, logistics, customs and material flow. The PFEP process is mainly related to the materials flow part of the inventory control manager's responsibilities. The inventory control manager works continuously with S&OP and is the person who has created the design of the PFEP process in its current state. The main responsibility of the inventory control manager is to be part of the S&OP process, create forecasts for inventory levels, follow-up on inventory levels and report the inventory levels to higher management levels. If inventory targets are missed, part of the work is to explain to higher managers why inventory targets are not met and what is being done in the product line to improve the inventory levels. The inventory control manager has continuous communication with the product line manager regarding the inventory situation.

*Material Manager (Vacant position)*

The person working in the material manager position should report to the inventory control manager under the area material flow. This position has the responsibility to manage the material flows in the long term, develop and monitor the use of planning methods etc.

*Order Receiver*

The order receivers are responsible for handling and confirming incoming customer orders. They belong to the "Order Entry" position in Figure 5 and report to the inventory control manager.

*Purchasing Function*

A purchasing manager, three strategic purchasers and two operative purchasers constitute the purchasing function. The purchasing manager is in charge of the strategic and operative purchasers that purchase most of all the materials used in the company. This includes both direct and indirect materials. Direct materials are items that are used in the products while examples of indirect materials are machines and tools.

*Strategic Purchasing*

Strategic purchasing owns the agreements with the suppliers. The strategic purchasers negotiate with suppliers and write the commercial agreements. They are also responsible for sourcing activities, such as finding new suppliers and deciding what parts to source and from where.

*Operative Purchasing*

The main responsibility of operative purchasing is to be a support to the order placer working in the product line. Operative purchasing is responsible of handling issues or questions regarding suppliers that are not able to fulfill the required delivery performance or the demanded quality of the purchased items. The operative purchasers therefore have frequent contact with suppliers. If an operative purchaser raises a question with a supplier it is not always in the supplier's interest to prioritize this request. This leads to a need of involving strategic purchasing to handle the issue on a more strategic level. Operative purchasing also prepares new items in the system to make them purchasable for the order placer who makes the actual call-offs.

## 4.2 Planning Environment and Planning Methods

This section provides a description of GMC's planning environment and the planning methods used. The methods are MRP, kanban and consignment stock.

### 4.2.1 Planning Environment

The products are manufactured and assembled in-house using the manufacturing strategies MTS and MTO. The products have a relatively complex BOM, consisting of four levels. The different manufacturing strategies are used depending on if the product is considered standardized, with high sales volumes, or if the product is customized and ordered less frequently in smaller volumes. This divided manufacturing strategy complicates the planning process and therefore requires classification of the products. Decisions regarding classification for individual products are made by the order receivers and the product line manager. The products are classified either as A or B. A is used for standardized products with short lead time and high sales volumes. These products are produced to stock in small quantities to create a small safety stock that is able to meet the customers' demand. The more customized products are classified as B products. B products are assigned longer lead times and are only produced to order. The customers however, often have different views than GMC regarding a product being standardized or customized. This leads to customers demanding short lead times for products that in their eyes are standardized but from GMC's point of view are customized.

Customer demands for customization pressure GMC into providing many different product variants. This leads to increased amounts of items to procure and manage inventory for. The large number of product variants furthermore makes it more difficult to estimate demand for individual products and consequently also for individual items. The volume and size of customer orders in the product line are characterized by a large number of customer orders of medium to small quantities. The customers are recognized as large companies, original equipment manufacturers (OEMs) companies and smaller companies. It is a strategic decision to have a mixed customer base to not let one company account for too large parts of the total sales volume.

The layout of the assembly station is recognized as a cellular layout with kanban boxes placed next to the station. GMC has a more or less frequent batch production for the standardized products and one-off or infrequent batch production for the more customized products. The batch sizes produced are a mix between batches equivalent to customer order quantities and small batch sizes. The reasons for this mixed batch size strategy are to level out the production load and achieve a smooth flow in the assembly station.

### 4.2.2 Planning Methods

The planning methods MRP, kanban and consignment stocks are presented below.

**Material Requirements Planning**

MRP is used for planning of parts for which the lead time from suppliers is longer than the customer delivery lead time. When the internal lead time of a supplier is long GMC must forecast the demand in order to provide the supplier with material call-offs according to the estimated need. Forecasts and customer orders are the input to the MRP which is performed through the company's ERP system. MRP is handled by the order planner who works with the MRP system that creates so-called messages. The order planner reviews the messages and decides if a manufacturing order should be planned or rescheduled. The messages are generated by the system for several different reasons. The different message types are described in Table 7.

| Message Type | Description of Message type | Actions |
|---|---|---|
| **B** | The customer demands the product within the lead time | If possible the order planner will rush the order |
| **T** | An already started order is late | The order planner cannot affect this order since it is already started |
| **D** | Postponement of order | The order planner decides whether or not the order should be postponed |
| **E** | Rescheduling of an order to an earlier time | The order planner decides whether or not the order should be planned to an earlier point in time |
| **A** | General Message | Not relevant for planning |

*Table 7. Description of message types in MRP system.*

The order planner processes all new messages daily, often even twice a day. The planning horizon for the MRP is set to a certain number of time units. This means that the order planner can see orders that are planned further in the future but the system only generates messages for orders that are planned within the planning horizon. Sometimes customers change their requirements after the order has been planned which generate rescheduling in order to fulfill the new customer demands. The rescheduling can include actions such as postponing orders, planning orders forwards in time or changing the quantity of the order. Rescheduling is allowed at any time which means that the order planner is not restricted to make rescheduling outside of any certain time fence. It is possible for the order planner also to plan an order to a date which has already passed, if that is what a customer requires. This will generate problems for the order placer and in-house production cells that did not have enough time to plan capacity and order material for such orders and the result can thus be that the order will not be finished in time. It is the responsibility of the order placer to ensure material availability according to the MRP while a production supervisor is responsible for the capacity.

**Kanban**

Parameters that affect the decision on what items should be controlled by kanban are mainly the lead time, delivery performance and sales volumes. Items that have short lead times, high delivery performance and are high runners are managed by kanban. Moreover items with few variants are also items that are controlled by kanban.

The order placer is in charge of the daily kanban process by making sure that the right amount of cards are in motion and that the signals for replenishment of material are sent to the suppliers correctly. According to the S&OP process instructions, kanban card adjustments should be performed once a month after a new frame plane has been set. The S&OP process and frame plan meetings are described further in Section 4.5.1. There are no specific instructions for adjustments of the kanban cards other than an instruction with mathematical formulas for kanban card calculations based on numbers from the frame plan. In practice are kanban cards not adjusted according to every new frame plan but instead the order placer looks at the amount of incoming orders on different product variants to see if there is a need to adjust the number of kanban cards. No formal calculations are normally performed when adjustments are made. The order placer works in closeness to the order planner, which makes it possible for them to discuss the current orders and production situation. This helps the order placer in deciding whether to increase or decrease the number of kanban cards. Large adjustment of kanban are mainly performed before holidays while small adjustments are performed more rarely in order to avoid disruptions in the kanban process. Sometimes cards disappear due to misplacement. It does not happen very often and is not regarded to be a problem since it is usually discovered quickly. The order placer normally verifies the number of kanban cards once a year, before the vacation.

**Consignment Stock**

Consignment stocks are applied in first hand for standard parts with low value. Also some high value parts are managed with consignment. The criteria for high value parts are that the supplier cannot deliver within the requested lead time. It can also be that the variation in demand is such that it is very difficult to forecast the need and make agreements on batch quantities with the supplier. These criteria make it appropriate to let the supplier own and manage the inventories at GMC, to achieve a better material flow. There is also one exception supplier for which consignment stocks are used, due to lacking delivery performance of the supplier, caused by difficulties for the supplier to match their production process to GMC's needs.

**Re-evaluation of Planning Methods**

It is the responsibility of the material manager to ensure that the right planning method is used for the right part. Since the material manager position is currently vacant it has implicitly been the responsibility of the inventory control manager. However there is no official process for how this should be managed and the criteria used is not defined in detail for each planning method. Thus there is no continuous re-evaluation to ensure that the right method is used for the right part. Some changes have been made over time based on observations and experience. One such example is that many more parts than today were earlier using kanban. Due to different reasons kanban did not work well with some of the parts and decisions were then made to change from kanban to one of the other methods. The decisions have been experience-based. Factors that have been considered are for example that very uneven customer withdrawals are not suitable for the use of kanban. Thus it exists no quantitative classification process to determine the right planning method for different parts.

## 4.3 Current State of the PFEP Process

It is difficult to describe exactly what the PFEP process is at GMC. The view of PFEP varies greatly from person to person within the company. Some people state that it is a continuous balancing between safety stocks and service level. Others describe collaboration between purchasing and the product line as a key aspect of PFEP. Everyone however agrees that the purpose of PFEP is to achieve a high service-level and low tied-up capital. The PFEP process will therefore be described in two parts. One part is a process which is designed as a two-month loop. The loop describes a structure for the product line and purchasing function to work together. Different aspects of this loop are described in Sections 4.4. First is the official process map presented and described, followed by a current state description. The main differences between the official process map and the current execution of the process are thereafter presented. The process design and responsibility division is then addressed. Process performance measurements finalize the description of the PFEP process loop. The other part of the PFEP process is more related to the ongoing work of adjusting safety stock levels and following up material shortages. Section 4.5 therefore presents how safety stock adjustments on the operative level relate to the plans and decisions made at higher planning levels.

### 4.3.1 The Official PFEP Process Loop at GMC

The aim of the PFEP process is that every individual part number should have a plan or a strategy regarding lead time, run-out time, planning horizon, order batch quantity, load carrier, delivery reliability and planning method. For every part should information be available and updated in the ERP system in terms of lead time, supplier agreements, planning horizon, safety stock, weight, inventory location, owner, supplier, order batch quantity, packaging type and price. All these pieces of information are together called part care. If the part care is poorly updated, manual intervention is required and there are risks of poor delivery service as a consequence. The supplier agreements for purchased parts are binding for part care. The PFEP process in theory means that all parts should be planned according to their specific needs or characteristics to use appropriate planning methods and decide order quantities that are feasible in relation to consumption, supplier location, weight, price, etc., which affects the costs of keeping or not keeping the part stocked. Since GMC has a large amount of different part numbers to control it is not possible to continually and manually review the PFEP for each individual part. Therefore GMC created a process for reviewing and updating the parameters for the different part numbers. This process has in its current form been designed by the inventory control manager and the plan for how the process should be performed is depicted in Figure 6. A larger version of the official process map is presented in Appendix III.

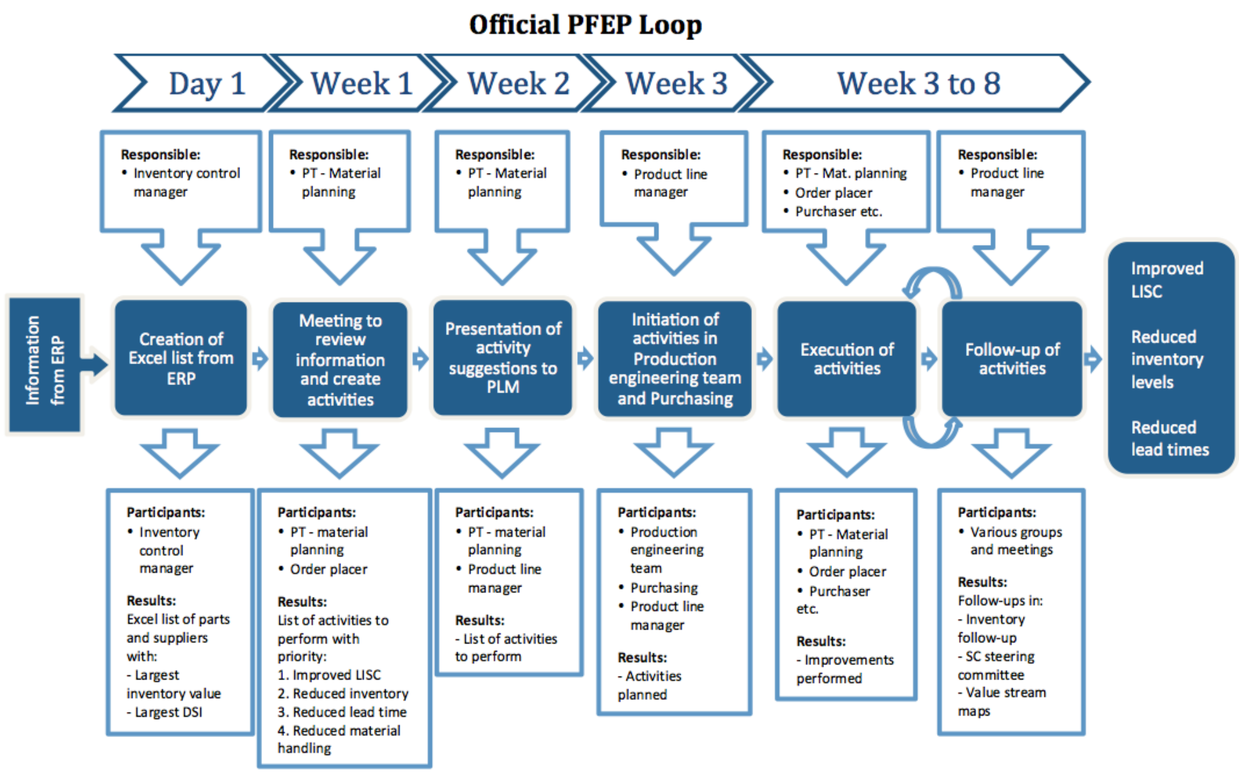


Figure 6. The official PFEP process loop.

The official process of PFEP is described through a two-month (8 weeks) loop, which is divided into six steps. The process starts with the inventory control manager who creates an Excel sheet containing information about all parts that are purchased or produced at GMC. The sheet is then sorted to create a list of the 100 parts that have the highest inventory value and the 100 parts that have been stored the longest. The oldest parts are defined as the parts with the highest days supply of inventory (DSI). The DSI measure is described more in detail in relation to supply chain performance in Section 4.4.2. The next step is a meeting between the PT-material planning and order placer in which the lists are discussed to identify some activities that should be performed to improve the material flow and inventory levels. Some different parameters should be prioritized when improving the material flow in the PFEP process and these are: improved line item shipped correctly (LISC), reduced inventory level, reduced lead time and lastly material handling. LISC is described in Section 4.4.1 in relation to product line performance. The next step (week two) to be executed is a meeting in which the PT-material planning presents the list with suggestions of activities that needs to be performed to the product line manager. Then they should make a decision together regarding what and how many activities to choose. In step four should then the product line manager initiate these activities together with the production engineering team and the purchasing function.

From week three to week eight there should be iteration between the fifth and sixth process steps, which are execution of activities and follow up of those activities. The number of meetings and persons involved in these steps can thus differ from time to time depending on the nature of the specific improvement activities and what people are involved in this step. The end results are then followed up and presented at the supply chain steering committees' meetings, inventory follow-up meetings and value stream maps. The expected output from the PFEP process is, as shown in Figure 6, improved LISC, reduced inventory levels and reduced lead time. Input to the process is according to the process map the information about all parts that is available in the ERP system.

### 4.3.2 Current State Description and Mapping of PFEP Process Loop

In the current situation the PFEP process loop is carried out with focus on batch quantity reduction. The process of ordering materials from suppliers using delivery schedules is therefore briefly described, followed by the current state mapping.

**Lot Sizing Decisions**

The agreements with the suppliers that are established by the strategic purchasers include information such as estimation of yearly consumption, order quantities, order frequency, lead time, packaging, costs and price. This information works as a framework for the order placer's daily work since the orders must follow these agreements. The supplier agreements include so-called frame agreements that are based on a number of aspects such as price, volume, lead time, packaging instructions, continuous improvement etc. GMC estimates how much the company will purchase during a certain time period in units and in economic terms. This volume is called frame volume and is included in the agreement. Some supplier agreements furthermore define the order quantity while some does not specify fixed order quantities.

Information regarding the supplier and agreements is available in the ERP system. A delivery plan is used to communicate GMC's needs to suppliers. The delivery plan is generated from the planned and forecasted manufacturing orders in the MRP. GMC's demands for a certain number of time periods are presented in the delivery plan. The order placer makes the actual decisions on what to order from the suppliers based on the delivery plan. Orders are placed by the order placer for the nearest time in the delivery plan. The time periods in the absolute nearest future represent frozen orders that were placed by the order placer the previous time period. The time periods most far in the future present GMC's forecasted needs to the supplier and are not binding orders.

The order placer decides how much of each part to be ordered. As mentioned before, this decision is however limited to the batch quantities stated in the supplier agreements. It occurs that the batch quantities are not conforming very well to GMC's needs. If the agreed order quantity for example is 100 pieces and the GMC requirement are 120 pieces, the order placer is forced to call off a quantity of 200 pieces. This leads to difficulties in achieving optimal inventory levels and a continuous material flow.

**Current State Mapping**

A cross-functional process map is illustrated in Figure 7. However the PFEP process is difficult to visualize in a process map since the activities can shift from one time to another and the number of meetings and participants at meetings also vary from case to case. The current way of working with the PFEP process has similarities to the official process but there are some differences. The cross-functional process map in Figure 7 shows that both the product line and supply chain/purchasing function are involved in the process but that it also sometimes involves other functions. Depending on the nature of a specific activity, different people from the purchasing function will be involved. When a purchasing issue is raised in the PFEP process, operative issues are handled by operative purchasing while more strategic and agreement related issues are handled by strategic purchasing. A description of the current state is presented below.

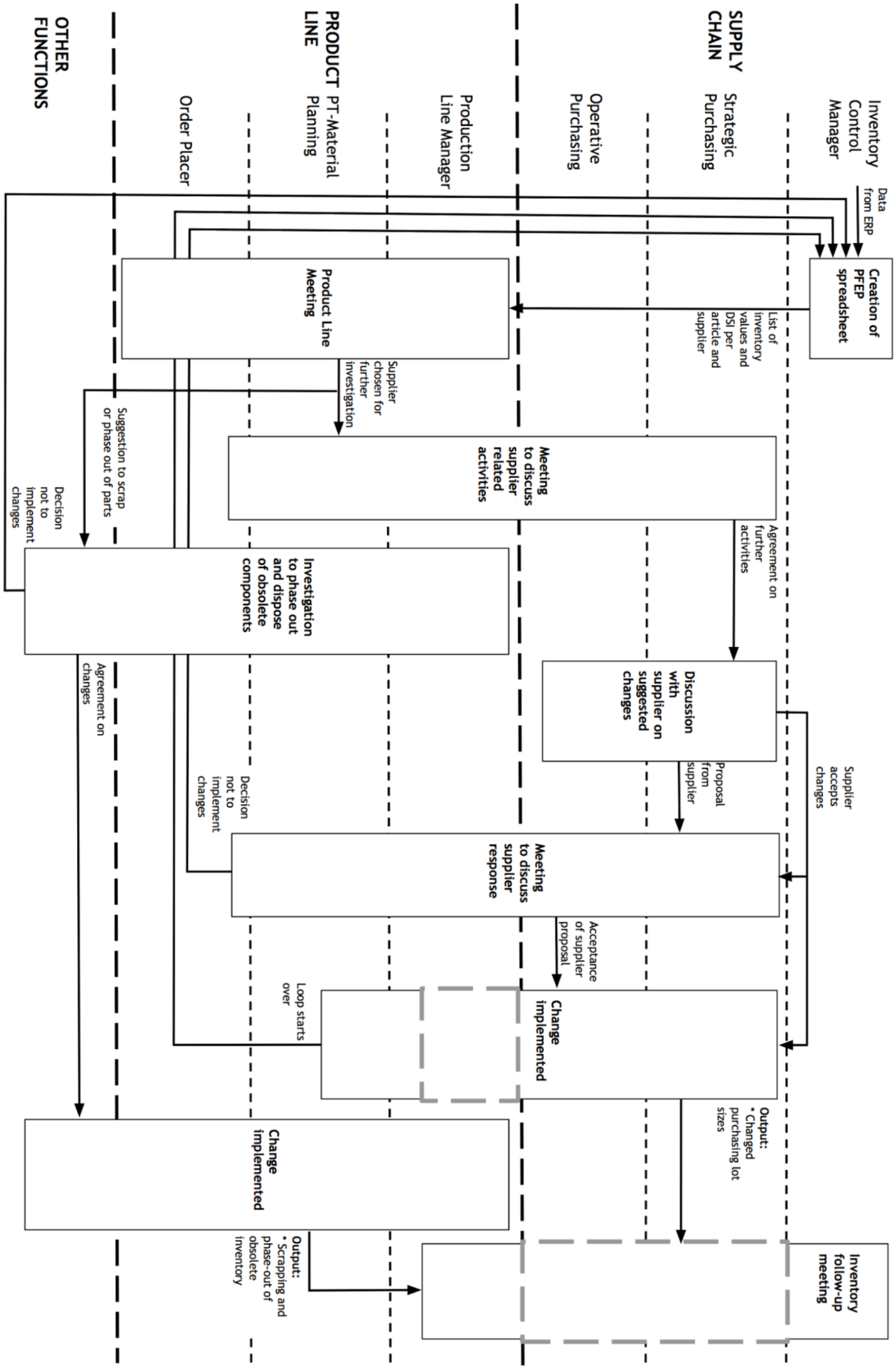


*Figure 7. Cross-functional PFEP process map of the PFEP process loop.*

The first step in the process loop is performed by the inventory control manager who creates a new PFEP Excel sheet. This is done every second month in accordance with the official process. The Excel sheet includes the PFEP information regarding all parts for all the product lines. The inventory control manager e-mails the Excel sheet with comments and suggestions for parts or suppliers that the product line could examine closer. Sometimes the inventory control manager also uses the data to create lists and diagrams of the suppliers and parts with the highest inventory values and DSI. These lists and diagrams are then attached to the Excel sheet which is e-mailed to the product line.

In the next step of the process, which is the product line meeting, the product line creates its own Excel sheet. The PT-material planning creates the product line PFEP Excel sheet before the product line meeting (see Figure 7), in every new process cycle. This Excel sheet only includes information about suppliers and parts for the product line and is considered to be less cumbersome to work with. The product line then analyzes the PFEP Excel sheet with regards to for example suppliers with the highest DSI and inventory value. The way that the product line analyzes the PFEP Excel sheet differs from time to time since there is no standard developed regarding this analysis. Furthermore the Excel analysis was not performed in the same way that the inventory control manager did the analysis. Instead the product line sorted the data quite randomly before making a decision on a supplier for further investigation. The product line seemed to experience this step as somewhat difficult and time-consuming.

The suppliers with the highest inventory value or DSI are then analyzed based on the batch quantities related to the demand. The product line makes a decision one supplier to investigate further. The decision is based on the inventory and DSI values but also depend on if the product line considers that any improvements are possible for this supplier. Parts that have not been used for a long time are sometimes also analyzed and discussed during the product line meeting. This leads to the initiation of another process which is not a part of the PFEP process loop, a so-called phase-out process. This process consists of 18 steps that involve multiple functions such as market, finance and product designers who all have different inputs to the decision whether or not an item can be phased-out or scrapped.

The purchasing function is involved firstly when the product line has decided on some changes to suggest, based on a deeper analysis of the parts and the batch quantities for the chosen supplier. The product line invites the purchasers that are responsible for the specific supplier. This means one of the operative purchasers and one of the strategic purchasers. During this meeting are the product line’s wishes raised regarding changes in the supplier agreements. The purchasing function is after this meeting responsible for addressing these suggestions with the supplier. The outcome can however be that the supplier will not agree to fulfill GMC’s demand without increasing the price. This is then communicated back to the product line. Due to different corporate goals and guidelines price increases are not acceptable. The product line together with the purchasers must thus consider if they are in any position to negotiate with the supplier to agree on reduced batch quantities for only some parts or if the product line can do something for the supplier in return. This step is visualized in figure 7 as the step "meeting to discuss supplier response". A concrete example of how one cycle of the PFEP process loop was executed is a case in which the product line decided to investigate one supplier because it placed high both on the inventory value list and DSI list. The product line analyzed the reasons for the high inventory levels and identified large order batch quantities as a root cause. The product line then held a meeting with both operative and strategic purchasing and presented their concerns with the large batch quantity. The purchasers then brought the question of reducing the batch quantity to the supplier. The supplier responded that since GMC is purchasing so many different variants of items it makes it difficult and unfeasible for the supplier to keep all variants in stock to be able to deliver smaller batch quantities to GMC within the agreed lead time. This made the product line investigate if all different item variants were actually necessary. The product line then explored the possibilities to reduce the number of item variants used in production and offered as spare parts to their customers. This was done through discussions with the market function and product designers from the production engineering team.

It proved to be practicable to combine two pieces of one item variant or two different item variants to achieve the functionality of another item. This would however make the assembly operations more cumbersome since operators then must handle two items instead of one. The product line therefore found that the production staff was very reluctant to reduce the number of items. The purchasing functions goal with reducing the number of items was to be able to aggregate the demand to the items most used by GMC. The items that the product line in the end was willing to eliminate were not items with any significant demands. The items that were standard for GMC were not standard to the supplier. The scrapping and phase-out of these items thus led to reducing the number of active items in the system for both GMC and the supplier, but it did not give any negotiation advantages. The next step was then for the strategic purchaser to negotiate with the supplier to reduce batch quantities. These negotiations were however not finalized before this report was finished. A very small price increase from a supplier might in another case have been accepted. In this case the purchased items are standard items and the purchasing function is convinced that there are alternative suppliers that would be able to give GMC a better offer. Thus if the current supplier is not willing to collaborate with GMC it is likely that GMC will move their business to another supplier.

The output of the process in cases where a change is implemented are in the current state mainly:

- **Reduced batch quantities** is one output which in turn leads to reduced inventory levels. This since it eliminates the need to order large batches of relatively slow-moving items which will stay in inventory for several years before they are consumed or scrapped.
- **Scrapping and phase-out of obsolete inventory** occurs when the product line identifies that some items purchased from the investigated supplier has not been used for many years and can phased-out or scrapped.

In a situation where it is impossible to persuade a supplier to reduce the batch quantity without unfeasible price increases there is no actual output of the process. In such situations the loop will start over without any implemented changes. An inventory follow-up meeting is held regularly. At this meeting are the PFEP efforts (among other things) presented with motivations to why any improvements could not be done regarding materials purchased from a specific supplier. When a change has been implemented this is also communicated during the inventory follow-up meetings.

**Inventory Follow-up Meeting**

This meeting is held every second week between the product line manager, inventory control manager and supply chain manager. The purpose of this meeting is to evaluate the performance of the product line by mainly focusing on the inventory levels, backlogs and customer orders. The inventory follow-up meetings discuss the goals that have been decided at the corporate level of GMC and how the product line is currently performing in relation to these goals. The product line performance is then reported back to higher management levels.

The inventory goals mainly focus on the tied-up capital in inventory and how the trend of the inventory levels seems to be developing. Since the product line manager owns the inventory it is the product line manager that has the responsibility to achieve inventory levels that are consistent with the goals. If the inventory levels exceed the allowed levels it is the product line manager's responsibility to explain the reason for that and make sure to address the underlying causes. Before holidays are the inventory levels for example increased in order to ensure that enough material is stocked during and after the holidays to avoid disruptions in production. Other subjects such as backlog status are also discussed during the inventory follow-up meeting along with production capacity and how the intake of orders has been. These factors affect the inventory levels and are therefore important to analyze together with the inventory levels.

### 4.3.3 Differences Between Process Design and Execution

To facilitate comparison between the current state mapping and the official process loop the process map in Figure 8 has been constructed in the same way as the official process map which was presented in Figure 6. Figure 8 depicts the process for a situation with a strictly purchasing-related issue with focus on batch quantity reduction. A larger version of the current state map is provided in Appendix IV.

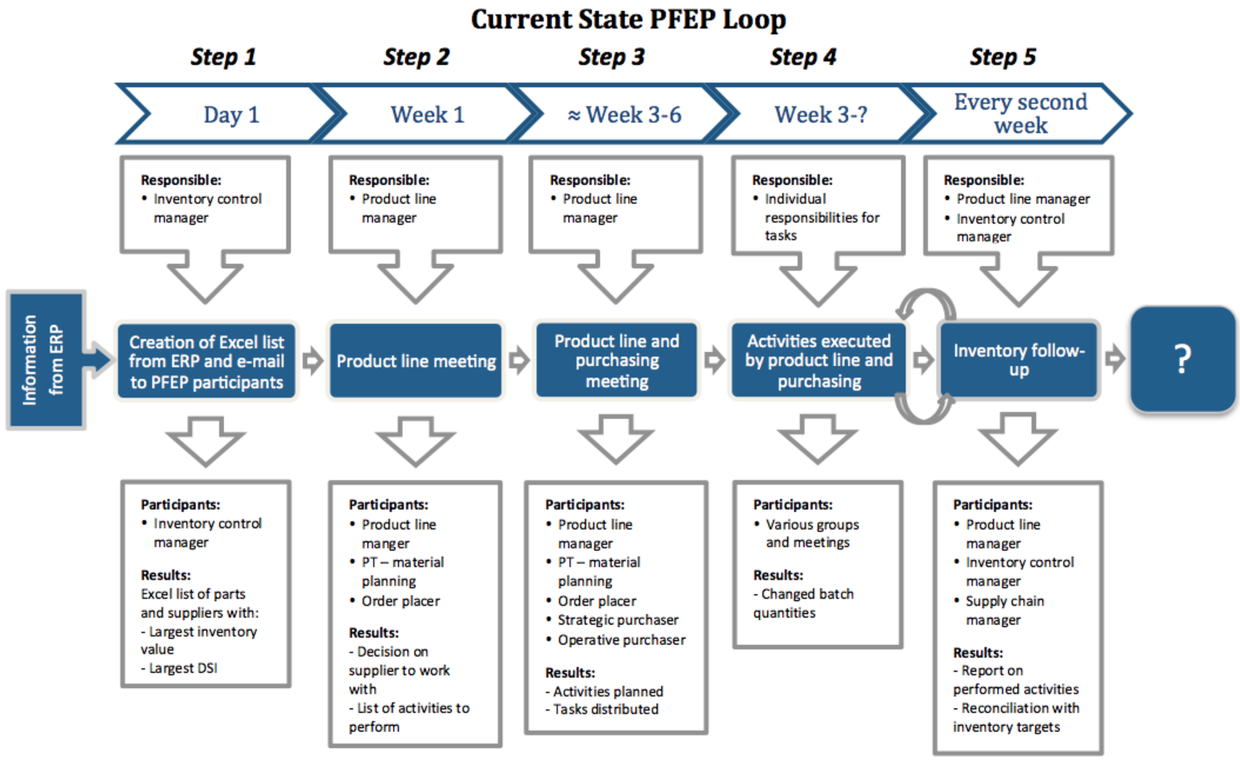


Figure 8. Current state of the PFEP process loop.

There are some differences between the official process map and the current state of the process. The first deviation is identified in step two which in the current state comprises a product line meeting involving the product line manager, order placer and PT-material planning. In the official process this step was divided into two steps in week one and two which in practice have been merged into one meeting. The people taking responsibility for the different steps also differ somewhat. An example is that it is the product line manager who summons people to the different meetings both within the product line and with purchasing. It is thus not done by the PT-material planning as stated in the official process map. The times for execution of the different steps of the process vary quite a bit and meetings have not been held exactly in the weeks stated in the official process. One reason for this is difficulties in finding a meeting time that suits all members involved in the process. Difficulties with scheduling meetings regarding this was observed when a meeting between the product line and purchasing had to be postponed several times due to scheduling conflicts and sickness absence. The product line furthermore does not initiate work with a new supplier every eighth week, as is the plan according to the official PFEP process. This to completely or almost completely finalize work with one supplier at a time. No specific efforts to reduce lead times or improve the service level (LISC) were observed during the empirical investigation. Regarding the follow-up step of the official PFEP process loop, SC steering committee meetings and value stream maps were not found to be part of the PFEP process loop in the current state.

### 4.3.4 Process Management and Responsibility Division

The supply chain function is the owner of the official PFEP process and the process was initiated in its current state by the inventory control manager about 10 months ago. Around the same time that the inventory control manager position was introduced the material manager switched jobs and since then the material manager position has been vacant. This was about 1.5 years ago. Earlier there was no official process for PFEP. Instead the material manager was responsible for the material flow and alone performed analysis and identification of improvement activities. Then the material manager worked together with the product line and/or purchasing to make these improvements. The common perception about the process is that after the material manager quit and before the new process design was introduced, the work with the process had been somewhat dormant. Before this report was finished the inventory control manager switched jobs and thus was no longer working with the PFEP process. A person was recently employed to replace the material manager and will within short time start working at the supply chain function. The new material manager will take over some of the responsibilities of the inventory control manager and some of the previous material manager responsibilities.

The inventory control manager has been holding meetings with the order placer, PT-material planning, strategic purchasing and operative purchasing to discuss how the work with the new official process design has progressed. These meetings have occurred approximately every third month but it is uncertain if these meetings will continue since the new process has now been in place for a while and the perception of the inventory control manager is that the involved people are becoming used to this way of working. There is however an impression that the process structure is not completely set and that it still needs some fine adjustments. There are furthermore no instructions or guidelines describing what is expected of the product line or purchasing function in any of the process steps. It is thus very much completely up to the process participants to decide how they approach the Excel sheet analysis and what improvements they wish to make.

### 4.3.5 Process Performance Measurements

Documentation of activities performed in the PFEP process is in large part missing. The existing documentation is more or less completely consisting of meeting protocols. There is no documentation of the specific changes that have been made through the PFEP process. Moreover documentation of previous conditions is also missing and explanations of why any changes needed to be done. This leads to difficulties to follow-up the consequences of changes that have been made and the actual results these changes have given. Activities that did not lead to any actual changes are not documented either.

Follow-up of the results of the PFEP process is performed to some extent in the inventory follow-up meetings. The inventory follow-up meeting was described in Section 4.3.2. There is however no continuous follow-up done that is focused entirely on PFEP activities and results. This is partly due to the fact that no changes are documented and it is thus impossible to follow-up in retrospect what has been done and why it was done. The changes that have been implemented as a result of the PFEP process are regarded to have led to improvements but it is very difficult to confirm. The performance measurements used at GMC are mainly inventory value and service level which are measures that are affected by a large number of factors in addition to activities in the PFEP process.

## 4.4 The Functional Perspectives of the PFEP Process

The perspectives and performance measurements of the production and purchasing functions are presented below.

### 4.4.1 Product Line Perspective

The order placer decides the safety stocks levels and when to order material depending on the information shown in the ERP system. The short lead times promised to the customer puts pressure on the order placer to have the right material and quantities available at the right time in order to fulfill the customer demand and reach the service level of 93 percent. The large product variety, short lead times to customer and pressure on keeping the inventory levels as low as possible makes the material planning complicated. This can lead to increased tied-up capital. It is therefore important for the product line to have small batch quantities and short lead times from their suppliers, that are adapted to GMC's customers' demand. Small batch sizes are however difficult to attain without prices increases from suppliers. The product line must therefore balance small batch sizes with inventory costs and service level but must at the same time consider corporate guidelines that do not approve of increases in purchase prices.

Some customer orders are furthermore acknowledged by the order receivers within a lead time shorter than the accumulated time for procurement and production of all items included in the end product. This means that the product line must either hold the included items in stock or contact the supplier to convince them to send the items earlier if possible. GMC will otherwise fail to deliver within promised time, which will affect the service level. The lead times from suppliers are in such cases an important factor that influences the flexibility of GMC and if GMC is able to fulfill the customer demands in time.

**Product Line Performance**

The product line is responsible for the inventory levels, meaning that the product line owns the inventory. The product line manager is responsible for keeping the inventory costs as low as possible and at the same making sure that the service level is satisfactory. The performance of the whole product line is measured through the inventory levels (tied-up capital) and backlogs that affect the service level. The main focus is on the measurement of the tied-up capital. It is mainly the product line manager and the order placer that are actively working with keeping inventories within the limits that have been established by top management.

The inventory measurements are done for weekly buckets and are discussed at the inventory follow-up meetings. The product line is also measured by the LISC, which indicate the performance of the product line's service level. The LISC measures all order lines that have been delivered correctly for every customer order. Meaning if the right items have been delivered with the right quantities to the right place at the right time. The goal is to have service level of 93 percent in order to keep the customers satisfied. The LISC does not measure if GMC succeeds to deliver within the standard lead time but instead if delivery is done within the lead time that was requested by the customer for every specific order.

### 4.4.2 Purchasing and Supply Chain Perspective

Purchasing must consider the different characteristics of suppliers' production processes. Some suppliers have production processes with very long throughput times, which make it impossible to order materials when GMC has a customer requesting delivery within the lead time of the supplier. For such parts GMC must provide the supplier with forecasts so that the supplier gets a chance to plan their production and be able to deliver any parts at all within a decent lead time. Good forecasts are thus important to minimize the needs of either GMC or the supplier being forced to keep high inventories. The consequence will otherwise be failure to deliver to GMC's customers on time, due to the supplier not being able to answer quickly enough to GMC's orders.

Other aspects also complicate the process of ordering materials in the exact quantities that GMC wants because they are appropriate from for example an economic perspective or space limitations. One aspect is for example a supplier who packs items into packages of 50 units, which makes it unfeasible for GMC to order 45 units, since that would increase the costs for the supplier and in the end result in a higher purchase price for GMC. However, the importance of GMC as a customer to the supplier also affects how great GMC's bargaining power is. For suppliers to whom GMC constitute a very small part of the sales, it is not feasible to ask the supplier to deliver in special boxes, smaller quantities or get shorter lead times than the supplier's standard offer. In the end it is the product line manager who decides if a certain price is acceptable and has the last say.

**Purchasing Performance**

Strategic purchasing is measured continuously on their performance in terms of a purchase price index (PPI) which describes the price development over time for purchased parts. A PPI of 1.0 means that prices have not changed while an index of 1.1 instead represents an average price increase of ten percent. The goal is to each year have a PPI of 0.98 which represents a price reduction of two percent during the year.

Purchasing performance is also measured on more than the PPI. The supply chain function is measured on DSI, and purchasing activities affect the DSI value through for example the choice to source from suppliers in different geographical locations. This since a longer distance and lead time gives higher safety stocks and DSI. Since DSI is an important performance measure for the supply chain function, which purchasing is part of, purchasing also consider factors such as delivery precision, quality and delivery frequency in relation to their effect on tied-up capital, however it is not the main concern for purchasing. The DSI measure itself is described more thoroughly below.

**Supply Chain Performance**

Since GMC is publicly listed it is regarded very important to continuously free up capital to allow for investment in possible business opportunities, instead of keeping it tied-up in for example inventories. For the inventory control manager the most important performance measure is the DSI, which represents the pace at which the company turns inventory into sales. When sales increase it is allowed to have more gross inventory without the DSI increasing. The DSI is calculated by dividing the inventory value with the current sales (represented by the average cost of sales for the last three months). DSI is thus a moving measure in the sense that it is neutral to sales volumes.

A high DSI means that the inventory lasts for a long time. High DSI can be caused by safety stocks that are used to compensate for uncertainties during a long delivery lead time but it can also be caused by high ordering quantities. A low DSI is good from an economic perspective since it means that little or no unnecessary capital is tied-up in inventory however it also means that the inventory might be so small that any supply disturbances or unusually high customer order quantities will result in material shortages.

The DSI measure is consolidated which means that it includes goods in inventory in the business unit, inventory at sales companies, goods in transit (GIT) and work-in-process (WIP). Top management sets the inventory target for the consolidated DSI and the inventory control manager has further divided the target into two parts. One part represents only the inventory in the business unit and the other part represents the GIT and sales companies' inventories. The DSI target is the same from year to year. The inventory control manager has however been able to negotiate with top management to set a higher target for this year since it was regarded too difficult to reach the regular target.

### 4.4.3 Perspectives of the PFEP Process

The view of the PFEP process loop differ somewhat between the product line and the purchasing function. The purchasing function's view is that purchasing is only part of the process when the product line asks something directly related to a specific supplier and supplier agreement. Meaning that their mission is to support the product line rather than being a regular and key part of the PFEP process. The product line on the other hand considers the purchasing role in PFEP to be greater than that. The product line's view is that purchasing should contact the product line regarding suitable batch quantities when they write new supplier agreements or re-negotiate old agreements.

The main performance measures that were mentioned during the empirical investigation were for the product line the tied-up capital in inventory and service level. It was however also found that corporate goals and guidelines regarding the PPI also applied for the product line.

## 4.5 Inventory Management Across Planning Levels

This section provides a deeper understanding of how the planning levels are structured and the decisions performed at each level regarding inventory management. Furthermore how these decisions and feedbacks are communicated across the planning levels.

### 4.5.1 Planning Level Structure and Communication

Information regarding S&OP, frame plan meetings and safety stock decisions is described below.

**S&OP**

S&OP meetings are held every month. Participants are the inventory control manager, product line managers, order receivers, purchasing manager and the business unit manager. The business unit manager is normally present during the first part of the meeting when the short term forecast (STF) is discussed. The STF is the sales plan made by the business unit manager which is an input to the S&OP. During the S&OP meeting it is discussed whether or not the STF seems feasible considering the current customer order situation, forecasts and also other factors such as market conditions that might affect future sales. The S&OP is conducted in monthly buckets, and the focus for every meeting is on the coming month, but plans for the coming three months are also discussed. The main output from S&OP is decisions on production paces for all three product lines expressed in produced units per month. It is the product line managers who have the last say and makes the final decision on production volumes for their own product line in the S&OP meeting.

**Frame Plan Meetings**

The S&OP provides input to the frame plan meeting. Frame plan meetings are held for every product line monthly with participants from the product line as well as representatives from the quality and environment department, business development department and division sales organization. The product line manager and production supervisors from both the in-house production and assembly cells, are representatives from the product line. The suggested production volumes from S&OP is discussed during the frame plan meeting in order to adjust the production plan to the limitations in capacity that exist in production. If there is not enough capacity to produce the volumes decided in S&OP there is no point in setting the frame plan to those levels. Except for discussing production capacity during the frame plan meeting, are also changes in the world economy and their expected effects on future order intake, addressed.

The product line decides the production pace (frame plan) on a four-month horizon, expressed in produced units per week for the whole product line. Forecasts for demand for individual part numbers for the four coming months are derived from the frame plan. This is done using historic consumption statistics to distribute production volumes for individual product variants, and in turn automatically obtain a percentage distribution for each individual component in the MRP respectively ERP system.

### 4.5.2 Safety Stock Decisions

The product line performance is as mentioned mainly measured by the tied-up capital and the service level, which have a connection to the safety stock levels. The term safety stock is here used for the inventories that are held for the purchased items that are managed with MRP and delivery schedules. The product line manager can take final decisions regarding the safety stock levels, however these decisions are usually discussed with the order placer or more correctly stated, managed completely by the order placer. The reason is that the order placer has enough experience and knowledge to make these decisions and changes in the safety stock without the permission of the product line manager. However, there are some situations where the order placer need to have a discussion with the product line manager before making some final changes, for example when large adjustments of the safety stock levels are required. Moreover is the inventory control manager also permitted to influence decisions regarding adjustment of safety stock levels or have a discussion with the order placer.

The main function of the safety stock is to secure available material for unexpected orders, delayed materials from suppliers etc. It also indicates a replenishment signal for the order placer when the inventory level falls below the safety stock level. The order placer usually adjust the safety stock levels when it is necessary and not continuously. No documentation is created when changes are performed; this means that the ERP system does not show the history of the previous safety stock level for each item. Moreover the ERP system does not show who is responsible for the change, which means if someone else other than the order placer has performed any changes in the ERP system it will not appear. There are no instructions or rules of how the adjustments of the safety stock levels should be conducted. The order placer instead considers parameters such as the supplier reliability, standardization, lead time, consumption, value of the component, supplier location and logistical factors. If suppliers fails to keep a high delivery performance numerous time and no improvements are conducted from the supplier’s side a higher safety stock level is established for these items. Standardized items with high frequency, long lead time and low value might have higher safety stock levels in order to avoid disruptions in the production. Suppliers that are located close to GMC and have high delivery performance usually give rise to low safety stock levels. The logistical factor such as the transportation also influences the level of the safety stock. Even if the supplier has a high delivery performance, the transport carrier (a third party) might fail to deliver on time. If delays occur several times, a higher safety stock level is established for these items until the delivery performance of the transport carrier has been improved.

### 4.5.3 Planning Level Feedback Structures

Meetings that are held with regards to material supply and material problems are described below.

**Daily Material Supply Meeting**

The order planners, order placers and PT-material planning from all product lines as well as order receivers and operative purchasing meet for about 10 minutes every day. This to discuss any problems that have occurred regarding material supply and to discuss if earlier problems have been solved. For every part that is discussed at this meeting someone is appointed the responsibility to investigate what the problem is and if possible also to resolve it. If this person is unable to find a solution the problem is “escalated” to someone else at a higher planning or management level. The escalation process continues until the problem has been solved.

**Escalation Procedure for Recurring Material Problems**

Previously there have been no standard procedure for documentation of supplier related material problems and follow-up of recurring problems. A new procedure was implemented in December 2013. This procedure means that whenever a problem arises with a purchased part that the order placer is not able to handle him- or herself, an escalation form should be written and handed over to an operative or strategic purchaser. The escalation form should then be filled in with information about how the problem was handled and resolved, by the purchaser who handled the problem. Every second week should the daily material supply meeting be prolonged for discussion regarding the status of the latest escalated material problems and outcomes. This new procedure also involves that the information collected during the material supply meetings are summarized in a pareto diagram of the suppliers with the most recurring material problems and that the responsibility for follow-up of these problems is placed on the purchasing manager.

# 5 Analysis

*This chapter presents the analysis of the empirical findings, based on the analytical framework that was presented in Section 3.7. The chapter is divided into three sections, which each aims to analyze the empirical findings in relation to one of the research question.*

## 5.1 Fit Between Planning Environment and Planning Methods

The fit between GMC's planning environment and the planning methods used are analyzed below. Firstly GMC's planning environment is defined and then is the fit between planning environment and planning methods discussed. The criteria used for appointing planning methods for individual items are analyzed, to determine if they are theoretically substantiated and if reviews are done continuously.

### 5.1.1 Classification of GMC’s Planning Environment

According to the classification of planning environments created by Jonsson and Mattsson (2003) GMC falls both under the planning environment type 2 and type 3. See section 3.4.1 for descriptions of the different planning environments. The ambiguous planning environment is caused by the mixed manufacturing strategies with both MTO and MTS products. The cellular production layout and MTO strategy with customer-equivalent batch sizes suggests a greater match with the type 2 environment for the customized products. The MTS strategy and more or less frequent batch production, for standard products cause a shift towards the type 3 environment.

### 5.1.2 Suitability of Planning Methods and GMC’s Planning Environment

The conceptual fit between MRP and planning environments is high for both type 2 and type 3, according to Jonsson and Mattsson (2003). This corresponds well to the situation at GMC, irrespective of the use of MTS or MTO strategy. An important characteristic of MRP is its ability to plan dependent demand, which is useful to GMC due to the high number of product variants and components. Vollmann et al. (2005) suggests a higher degree of fit between higher numbers of subparts, longer time between successive units in production and MRP. GMC's use of MRP for planning of more customized products with longer lead times is thus also consistent with this reasoning.

Kanban however, has the theoretically greatest fit with planning environment type 4, while kanban also proved suitable in other planning environments with quite small order quantities. A high level of repetitiveness and standardization indicates greater success for the use of kanban systems. The high volume and standard product variants’ components are managed using kanban, which also follows the logic of Vollmann et al. (2005) for increased fit with increasing repetitiveness. The fit between MRP, kanban and GMC's planning environment is thus good according to the theoretical framework.

There are other factors than merely the planning environment that affect the success of using a certain planning method. The method has to be applied to the right type of parts and executed in the right way in terms of planning frequency and parameter reviews (Jonsson & Mattsson, 2009). An important aspect of kanban systems is ensuring that the size of the kanban is appropriately balanced considering inventory costs and customer service level (Chan, 2001). At GMC the guidelines for adjustment of kanban size state that calculations should be made to update the number of kanban cards regularly, in connection to every new frame plan. These guidelines for monthly adjustments are however not followed. The consequence of not reviewing the number of kanban cards regularly is a risk of having too many active cards in the material flow, which is equal to having more inventory than necessary.

### 5.1.3 Criteria to Determine and Review Planning Method for Each Part

In PFEP every individual stock-keeping item has been assigned one of the three planning methods that are used at GMC. The main criterion to determine if a part should be managed with MRP is the lead time of the part. Jonsson and Mattsson (2003) stated that long lead times, dependent demand and erratic demand patterns are characteristics that have a good fit with MRP. Thus GMC has applied MRP for their parts based on the same logic. The criteria used at GMC to decide what planning method to use for individual parts are summarized in Table 8.

| Planning Method | Criteria |
|---|---|
| **MRP** | • Long procurement lead time |
| **Kanban** | • High volume part<br>• Short lead time<br>• High delivery performance |
| **Consignment Stock** | • Low value part<br>• High value part<br>  ○ Poor delivery performance<br>  ○ Large batch quantities<br>  ○ Uneven demand<br>  ○ Long procurement lead time |

*Table 8. Criteria used at GMC to decide planning method for individual parts.*

Material planning and replenishment are performed using kanban for those parts that are high volume, have short lead time and high delivery performance from the supplier. This is consistent with Jonsson and Mattsson (2003) who states that even demand and short lead time implies suitability with kanban.

A consignment stock approach is used for low value parts as well as some high value parts that fulfill some additional criteria. Battini et al. (2010) states that low value parts are appropriate to keep in consignment stocks to reduce obsolescence risks for the buyer and reduce the negative effects of uneven demand. The criteria used for assigning parts to consignment stocks are appropriate considering that low value parts have proven to be effectively managed through consignment (ibid.). The additional high value criteria used by GMC is also regarded appropriate since it solves problems with some parts that would be difficult to manage effectively with MRP.

The different planning methods are regarded to be applied for the right type of parts. There is however the question if the planning method decision is reviewed regularly enough, since GMC has no standard process or procedure to ensure this. In time the demand characteristics, lead time and delivery performance might change. Changed conditions means changed fit between a specific part and the planning method (Jonsson & Mattsson, 2003). It could for example happen that demand decreases for a previous high volume part. A review of the planning methods used for all parts would then uncover that kanban is no longer suitable for some parts. It is considered that without continuous matching between the part characteristics and the planning method there are risks of material shortages or inducing unnecessarily high inventory costs.

### 5.1.4 Alignment of Planning Methods and Long Term Strategy

Some reasons for material shortages that create problems at GMC is acceptance of customer orders within the standard lead time. The result of this is that purchase orders (i.e. call-offs) have not been placed early enough. Materials are then either not available in time to finish a specific customer order or materials have to be shipped quickly with extra costs as a consequence. This, since MRP systems cannot plan the material acquisition within the accumulated lead time for procurement and production (Jonsson & Mattsson, 2009). In turn will this result in either a failure to deliver to customer (i.e. poor service level) or delivering to customer at a higher cost. It is not possible for the order planner and order placer to solve the issues with acceptance of quick orders. Instead it is up to higher planning levels to consider and balance the effects it has on costs and/or service level. The power and responsibility to decide this does however not lie within the PFEP process or any of its participants since the goal of 93 % service level is set on a corporate level. The market conditions are constantly changing and to be successful companies must make sure to adjust their long term strategies as well as material planning and control systems to new conditions (Vollmann et al., 2005).

## 5.2 Functional Integration in the PFEP Process

The different functional perspectives in the PFEP process are discussed in this section. The strengths and weaknesses of the current process design and management are also addressed.

### 5.2.1 The Different Perspectives of the Product Line and Purchasing Function

According to Slack, Chambers and Johnston (2010) the production function focuses on the five performance objectives speed, quality, dependability, flexibility and cost. In the PFEP process it is mainly speed, flexibility and cost that are of interest. At GMC the product line wishes to be flexible in the sense that many different product variants are offered to satisfy the customers. Speed is sought after to deliver within the lead times requested by customers. Costs are also very important to the product line since the efforts to be both flexible and quick must be balanced against the costs that they induce. Inventory levels are managed in the PFEP process to find a balance between flexibility, speed and tied-up capital in inventory (i.e. cost).

The purchasing function has four performance dimensions according to van Weele (2010). The price/cost and logistics dimensions are strongly connected to inventory management and thus also the PFEP process. Neither the product line nor the purchasing function wish to have high costs for the procured materials. Lower purchase price is of special interest to the purchasing function since purchasing performance is measured on PPI. It is however the product line that owns the inventory and in the end is responsible for the costs incurred by the product line's inventories. Lower costs for each purchased item leads to lower tied-up capital in inventory, which thus is positive also from a product line perspective, as long as a low purchase price does not result in very large batch quantities. To achieve flexibility the product line needs to order small batch quantities to keep inventory and DSI levels down. No real goal conflicts were however discovered between the functions since the product line and not only the purchasing function are obliged to follow the PPI strategy, to reduce purchase prices yearly. Thus there seem to be strategic consensus between the product line and purchasing function, which is a requirement to achieve integration between the two functions (Pagell, 2004).

### 5.2.2 Strengths and Weaknesses in the Current Process Design and Management

The product line and purchasing functions have different perspectives and work together for limited times in the PFEP process. This is consistent with Webber's (2002) description of a CFT. The aim with a CFT is to utilize the different knowledge possessed by the team members to achieve a specific goal (ibid.). The goal of the PFEP process is to improve the inventory management within GMC and more specifically to improve the service level (LISC), reduce inventory levels and reduce lead times. Except for strategic consensus, it is in any CFT also necessary to have good communication, measurements and rewards and top management support (Pagell, 2004). These factors are considered and analyzed further in the next section in relation to the strengths and weaknesses of the PFEP process design and management.

**Communication**

Communication is as mentioned an important factor to achieve functional integration (Pagell, 2004). The daily supply material meetings and the escalation procedure are examples of opportunities for communication between the product line and purchasing function, which leads to better integration between the functions. This since the daily material supply meetings means face-to-face communication in an informal and casual atmosphere which enables open communication between the functions (ibid.). These communication channels are however mainly constructed to handle urgent problems with the material supply. These communication channels are not used to the same extent for communication of inventory management issues, aiming to ensure appropriate levels of tied-up capital in inventory.

Since the product line is responsible for the inventory levels, the batch quantities and lead times that are established in the supplier agreements affect the product line performance. The purchasing function must thus try to fulfill the product line's requirements with regards to these factors. The call-off position is traditionally a part of the purchasing function (Jonsson & Mattsson, 2009). At GMC the order placer who places the purchase or call-off orders is positioned in the production function. The order placer is located close to the production operations and therefore has a good understanding of the material needs. The knowledge possessed by the order placer is very valuable and should be shared with the purchasing function. Otherwise the purchasing function make decisions based on their own knowledge and experiences. The product line manager is also an important part of the team since the product line manager provides more strategic input than the order placer. The PFEP process loop itself enables dialogue and interaction between the purchasing function and product line since it creates a structure for how the product line's wishes regarding batch quantities and lead times are to be communicated to the purchasing function. The meetings that are held in the PFEP process loop does not stop the product line and purchasing function to have open communication also in casual situations without formal meeting structures, which is highlighted by Pagell (2004).

**Process Management and Responsibility Division**

The differences between the current state and the official process map are mostly small. One example of a small difference is that the product line manager participates already in the first meeting and that it is the product line manager who summons to meetings. A difference with greater significance for the results of the process is that a new loop is not initiated every eighth week. The official process furthermore states that the activities to be executed should aim to improve LISC, reduce inventory levels and reduce lead times. Reviews of batch quantities have been observed in the PFEP process as well as analyses of obsolete and slow-moving parts, which both contribute to reduce inventory levels. Activities to improve the LISC are only required if the LISC falls below the target level of 93%. Discussions regarding lead time reduction and safety stock levels were however not observed or mentioned specifically during the empirical investigation of the PFEP process loop. This could be an indication that the expectations of the process and the responsibility for these activities are not clearly described and divided, which Bergman and Klefsjö (2010) emphasize to be crucial for successful process management.

The time between the steps is in the current state longer than in the official process map. This means that each PFEP process loop takes longer than two months to accomplish. The process involves meetings between several different people who must have the time and opportunity to meet. One reason why the process execution takes longer than two months are scheduling conflicts among the process participants. The wait for an answer from an external supplier can also cause delays in the PFEP process loop. The product line's approach to complete all activities with one supplier before initiating work with a new supplier has both benefits and drawbacks. One benefit is that it ensures that the work with one supplier is completed properly and is not forgotten as a result of initiating work with a new supplier. On the other hand there is a risk that much time passes before the work with one supplier is completed. Since GMC has a number of different suppliers it is not sufficient to dedicate several months to each supplier. This since it would lead to a number of suppliers that would not be reviewed for several years. This implies that the PFEP process participants need some routines or monitoring by an outside party to put pressure on the participants to comply with the process.

The inventory control manager is the process owner of the PFEP process, according to Romero's (2011) definition. The inventory control manager has strategic responsibilities of the process and has provided the design of the process. Moreover, the inventory control manager has monitored the process through the meetings held every third month with all product lines at the business unit. Romero (2011) mentions that processes without proper monitoring will fail to produce the sought results. The empirical investigation showed it true that the process requires continuous monitoring and management since the PFEP process became neglected after the material manager quit. This was experienced when the material manager switched position within the organization and was not replaced. Since the material manager supported and performed large part of the activities, the PFEP efforts were more or less nonexistent without the material manager.

It is according to Bergman and Klefsjö (2010) necessary to ensure that the different roles of the process team members are clearly associated with specific responsibilities and authority. This to avoid confusion of who is responsible for what activities in the process. The product line manager and purchasing manager are regarded to be competence suppliers since their subordinate employees are process team members (ibid.). Bergman and Klefsjö (2010) define that a process manager's responsibility is to support the process owner by managing the process operatively and lead improvement work. This position is missing in the current state which leads to increased pressure on the process owner and risks that the process is not managed operatively. The product line manager however takes responsibility to ensure that meetings are held in the PFEP process loop. The product line manager thus have some responsibilities related to the operative management of the process and thereof the process manager role (ibid.). The process manager role and responsibility should however be delegated more clearly to strengthen the understanding of the responsibility division in the process.

A role that is lacking in the current situation is that of a process administrator who performs activities such as documentation management, maintenance of procedures and provides performance results and reports (Romero, 2011). Documentation is in large part missing in the PFEP process in the current state. The only identified documents were meeting minutes with short descriptions that do not provide much information regarding the performed activities. Historical activities and changes that have been executed are thus not visible to outside parties. Not even the process owner was for example aware of how well the current state execution conforms to the official process. There are furthermore no written instructions for any of the different steps in the process that describe who is responsible for a specific step or what activities are to be performed. The only documented instruction that exists is the process loop map which is not particularly detailed. This is a possible reason for uncertainty within the product line regarding the execution of the Excel analysis. Since the analysis is performed with at least two months break it might be difficult to remember all the different ways in which the Excel sheet data can be sorted. Therefore it seems to be a risk that the analysis step becomes rushed and that some aspects are not analyzed in every loop. There are no guidelines regarding what aspects of the inventory and material planning should be addressed during every loop. That could be a reason to why no lead time reduction efforts were observed during the empirical investigation.

Bergman and Klefsjö (2010) state that every process should incorporate activities that are repeated in time and that a process should have a first and final activity. There is currently an uncertainty or unclearness regarding the scope of the PFEP process. In some situations the PFEP process seem to be only the two-month loop in which the purchasing function and product line cooperate to reduce batch sizes. At other times the view of the PFEP process is that it incorporate the continuous adjustments of safety stock levels and escalation procedure to follow-up material shortages. Bergman and Klefsjö (2010) emphasize the importance of ensuring that a process satisfies the customers' needs. This means that the PFEP process should satisfy the needs of the internal process customers. There are several parties that are interested in the results of the PFEP process, such as the inventory control manager, the product line manager and ultimately also the business unit manager. The business unit manager is a customer to the process since the material flow, tied-up capital in inventory and inventory costs affect the result of the whole business unit. No specific customer to the process was mentioned during the empirical investigation. The product line is however regarded to have the most to gain from the process, as the owner of the inventory. The ambiguity of the boundaries, customers and purpose of the PFEP process makes it extremely difficult or in fact impossible to measure the results produced by the process.

**Process Performance Measurements**

Measurements and rewards are mentioned as important factors to achieve functional integration (Pagell, 2004). Follow-up of the PFEP process results are performed to some degree during the inventory follow-up meeting between the product line manager, inventory control manager and supply chain manager. There is however no meeting that informs the other process participants about the result of the performed activities. Pagell (2004) states that people perform better when their work is clearly linked to measurement, reward and performance. The lack of process specific performance measurements and follow-up is thus regarded to be a weakness in the current PFEP process, since feedback to the process participants likely would make them more motivated.

The metrics used for process performance measurements should according to Romero (2011) be controllable and accurate. This means that the metrics must be possible to directly influence and that the metrics actually measure what was the purpose to measure. The performance metrics which are mentioned in relation to PFEP performance are mainly DSI, service level, inventory value and safety stock level. None of these metrics are however completely controllable in the PFEP process loop nor represent the results of the activities performed in the process. These metrics are affected by several other factors than those that are managed in the PFEP process. The service level is for example dependent upon the delivery performance of suppliers, production capacity etc., which are outside the control of PFEP. A metric such as the average batch quantity would on the other hand be controllable but does not explicitly show if the PFEP process performs well or poorly in economic terms.

## 5.3 Alignment of Inventory Management Across Planning Levels

This section presents the analysis of alignment of inventory decisions across planning levels. The inventory decisions in focus are safety stock and lot sizing decisions.

### 5.3.1 Alignment of Inventory Decisions Between Strategic and Operative Planning Levels

Lot sizing decisions regarding individual items are not mentioned by Miller (2002). The balance between inventory investment costs and transportation costs however, are generally tactical or strategic decisions (ibid.). At GMC this decision is partly made at a strategic level since the overall strategy is to reach a leveled material flow with small batches as far as possible. Furthermore is strategic purchasing affecting this cost balance when agreeing on batch quantities in the supplier agreements. The product line manager is responsible for deciding what end products will have a safety stock (i.e. high service level) and what parts that will not have a safety stock. The corresponding decision for individual items is made by the order placer on the operative level. The inventory management decisions regarding safety stocks and lot sizes at GMC have a strong connection to the planning levels addressed by Miller (2002). It is however important to ensure that these different decisions are aligned across planning levels.

### 5.3.2 Alignment of Lot Sizing Across Planning Levels

Alignment across planning levels requires that decisions at lower planning levels are constrained by decisions at higher planning levels and that decisions are transferable from higher levels to lower levels (Miller, 2002; Jonsson & Mattsson, 2009). These requirements are fulfilled through the current planning structure. This since, the material call-off at GMC is performed using delivery schedules, which are based on actual customer demands and the forecasts that were generated through S&OP and frame plan processes. This means that the decisions made at S&OP level are first broken down and considered when creating the frame plan for every product line and its product families. These plans are then further broken down to forecasts for the demands of individual items. In this way the plans that are made at S&OP level are transferred and translated from major product grouping down to individual item level.

The order placer and strategic purchasers operate on different planning levels which means they have different planning horizons. Strategic purchasing has a long-term approach and considers for example yearly consumption and purchase price when negotiating supplier agreements. The order placer's main concern is instead appropriate batch quantities for each order occasion, which for the order placer are small quantities that are adapted to the demands that GMC has. Miller (2002) mentions that it is important that the consequences of decisions made at a higher planning level is communicated upwards. Since the decisions on lot sizes are taken already in the supplier agreements it is important that the strategic purchasers and the product line have functioning structures for communicating and exchanging their different views on the optimal batch quantities. This is performed through the PFEP process that enables the product line and purchasing function to discuss batch quantities and make changes that in the end will align both operative and strategic levels.

Lot sizing decisions are needed since it often is unfeasible to purchase materials in the exact quantities that a manufacturing company needs at each point in time (Jonsson & Mattsson, 2003). When the product line wants to change a batch quantity for a supplier, batch quantities are in the current state not determined based on any formal calculation methods. This since there are so many different factors to contemplate. The suppliers' conditions, such as production processes with long lead times that might not allow production in small batch quantities, must for example be considered. GMC strategies and goals do not accept price increases, which furthermore limits the possibilities for the product line and purchasing function to reduce the batch quantities. To avoid price increases from a supplier, in response to lowering batch quantities the strategic purchaser and the product line instead try to find alternative ways. One example is the efforts observed in the PFEP process to reduce the number of item variants purchased from the supplier. Another example is that the strategic purchaser might search for new suppliers if the current supplier is too uncooperative.

### 5.3.3 Alignment of Safety Stock Adjustments Across Planning Levels

Individual safety stock levels for parts that are managed with MRP and delivery schedules are adjusted when the order placer considers it necessary. For example when shortages of an item has occurred several times. Adjustments take place continuously in response to the daily operations and are thus performed outside of the PFEP process loop. Every change is performed manually in the ERP system, which is considered to be both a strength and a weakness. Jonsson and Mattsson (2009) mention that manual revision of safety stock levels means that many different aspects can be regarded while the method can become very resource consuming. At GMC the manual adjustments of safety stocks are very dependent on the knowledge and experience of the person performing the adjustments. There is no documentation of the safety stock levels and no official system for how safety stocks are decided. This means that safety stock levels can be adapted to every specific item and situation but also that it is impossible for other people to understand the reasons for the current safety stock levels. Furthermore it is impossible to determine if the safety stock decisions are aligned to the objectives of higher planning levels. Since the responsibility lies entirely with the order placer it is only the order placer who knows exactly how the decision-making process is executed for safety stock levels. This could give repercussions if the order placer quits since the knowledge about the inventory situation in relation to suppliers and the production process follows the order placer.

The term safety stock is at GMC used to describe the inventory levels for all items and products that have inventory. This so-called safety stock is for some parts according to Minner (2000) actually cycle stock since the inventory sometimes exists only to last during the lead time or is created due to large batch sizes. Safety stocks are according to Dillon (1990) inventory that is held to compensate for uncertainties in lead times or demand quantities. That no difference is made between different types of inventory makes it more difficult to deduce the reasons for certain inventory levels. GMC has taken a first step in classifying their inventories to their different planning methods. However, since the knowledge of the individual items' safety stock levels is limited beyond the order placer, a further classification within the planning methods could be implemented. Some systematics in safety stock adjustments could enhance the simplicity of adjusting safety stock levels and increase the understanding of the safety stocks at higher planning levels. The situation is similar for the kanban inventories since kanban cards are managed by the order placer. Some documentation of the decisions behind kanban card adjustments would thus also lead to an increased understanding of the kanban inventories.

### 5.3.4 Feedback from Operative to Strategic Level

Upwards feedback from operative planning level to higher planning level is one requirement to achieve alignment across planning levels (Miller, 2002). An existing communication structure which enhances the alignment between the operative planning level and the strategic planning level at GMC is the escalation procedure for material shortages. The daily material supply meetings mainly create communication between the order placer and operative purchasers. Only if the problem cannot be solved on the operative level it is escalated and solved on the strategic purchasing level. The prolonged meeting every second week, functions as a feedback communication channel, in which the strategic level informs the operative level on the actions that have been taken. This is however considered to be a solution only for problems in the short term. Without proper follow-up on the historically worst problems the root causes will not be found and will thus not be prevented in the long term. A crucial factor for the escalation procedure to successfully align operative and strategic planning levels is therefore that the last step is properly executed. This means that the recurring problems must be identified and solved by the purchasing function on a strategic level since it is the purchasing function's responsibility to ensure that the suppliers are able to deliver what has been agreed.

# 6 Results and Recommendations

*This section presents recommendations for how GMC can improve the PFEP process. The recommendations are based on the analysis.*

## 6.1 Ensure Fit Between Planning Environment and Planning Methods

The investigation showed that GMC has fit between the planning methods and planning environment but that there is no process for re-evaluation of decisions on the use of the different planning methods. GMC should thus continuously evaluate the fit between the current planning methods and the individual parts' characteristics. GMC is recommended to create a process for categorizing different items and match them to the most appropriate planning method. Also the fit between long-term corporate strategies, product line strategies and the material planning approaches should be evaluated in the long term.

## 6.2 Achieve Functional Integration in the PFEP Process

The obstacles to achieve functional integration seem to have been mitigated through the PFEP process since it enforces communication and cooperation between the product line and purchasing function at GMC. Some weaknesses of the process have been identified which should be improved.

The current state mapping provides GMC with an understanding of the current execution of the process and shows that the process design is feasible and generally has been accepted by the process participants. It is suggested that a clear distinction is made regarding to what activities are part of PFEP and what activities are not considered to be part of PFEP. The next step is then to decide who the customer or customers are to the PFEP process loop in order to define appropriate performance metrics.

The following recommendations aim to improve the management and execution of the PFEP process loop:

- Define the boundaries for the PFEP process loop.
- Define the customer(s) of the process.
- Determine the main goal or goals of the PFEP process loop.
    - Decide appropriate metrics to measure the performance of the process loop.
    - Measure and follow up the metrics.
- Create a clearer division of responsibilities i.e. process owner, process manager etc.
- Create clear guidelines for the different process steps.
    - Guidelines and support for analysis of the PFEP Excel sheet and supplier choice.
    - Implement fixed meeting times to simplify meeting scheduling and ensure regular loop initiation.
    - Implement a specific follow-up meeting for the PFEP process loop.
    - More detailed meeting minutes would increase the transparency of the process

## 6.3 Improve the Alignment Between Planning Levels

The analysis showed that there is currently a gap between the operative adjustments of safety stocks for parts managed with MRP and delivery schedules; and the higher planning levels. This gap is constituted by a lack of transparency and systematics to the safety stock adjustments. A recommendation to GMC is therefore to implement some routines for documentation of safety stock adjustments as well as developing a clearer systematics for safety stock adjustments. The decision-making process behind kanban adjustments is also lacking transparency. Documentation on kanban card adjustments is therefore suggested in addition to documentation on safety stock adjustments.

The analysis also showed that there is alignment between the different planning levels in the product line and purchasing function regarding lot sizing decisions. This alignment is a result of the interaction and collaboration that is created in the PFEP process loop. Thus it is important for GMC to continue working with the process to uphold this collaboration. GMC should create a standard procedure for how strategic purchasers collect input from the product line at every negotiation that is affecting the batch quantities in supplier agreements.

The escalation procedure is performed independently of the PFEP process loop. The long-term follow-up of material shortages from suppliers is however regarded to be an important input to the adjustments of safety stocks. GMC is thus recommended to ensure that material shortages from suppliers are addressed and handled on a strategic level as was suggested in the recently created escalation procedure. This to not only solve material supply problems in the short term but to also give feedback to the operative level on improvements to the supply problems and thereby achieve better alignment between the planning levels.

## 6.4 Future State PFEP Process

The suggested future state of the PFEP process loop is depicted in Figure 9. The most important recommended changes to the process loop itself are presented below:

- **Guidelines** on how to analyze PFEP Excel sheet (for meeting in week 1).
- More **standardized agenda** for product line meeting and meetings between purchasing and the product line. The suggested meeting points to always address are:
    - Batch quantities
    - Lead times
    - Scrapping and phase-out of obsolete inventory
    - Material handling
- Implement **fixed meeting times** as far as possible (meetings in week 1-7 every second week and PFEP follow-up meeting every eighth week).
- **Meeting minutes** should provide information on the contents of the meeting. Meeting minutes should be stored in a clearly specified and accessible location (all meetings).
- **Follow-up meeting** held specifically for the PFEP loop (week 8).

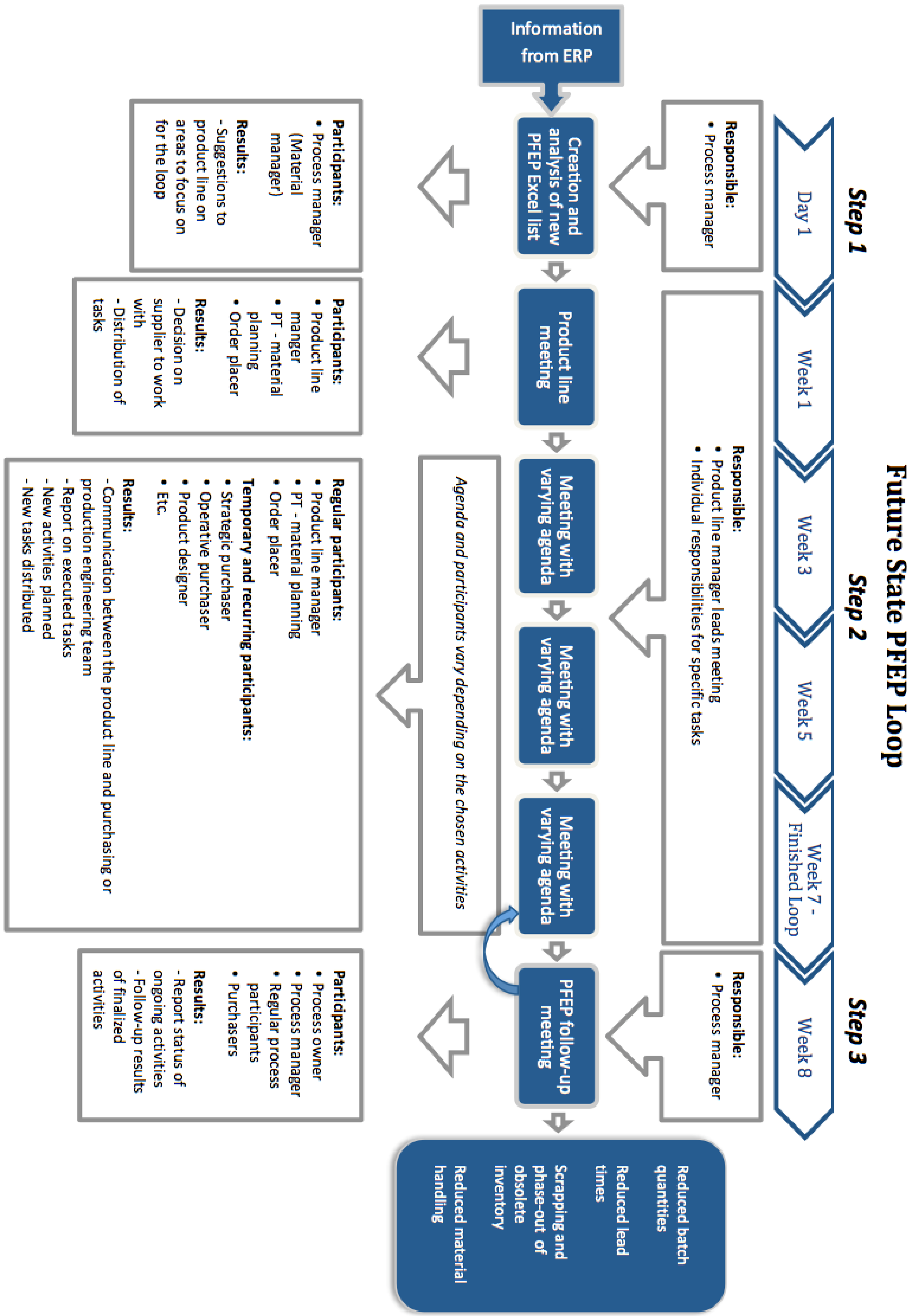


*Figure 9. Future state of the PFEP process loop.*

The activities that should be part of PFEP but are not necessary or appropriate to perform in the PFEP process loop are collectively called “continuous PFEP” and consist of re-evaluation of planning methods, safety stock and kanban card adjustments; and follow-up of recurring material shortages from suppliers. This part of PFEP should be separated from the PFEP process loop to avoid confusion and complicate follow-up of the PFEP results. Figure 10 depicts the constituents of the continuous PFEP.

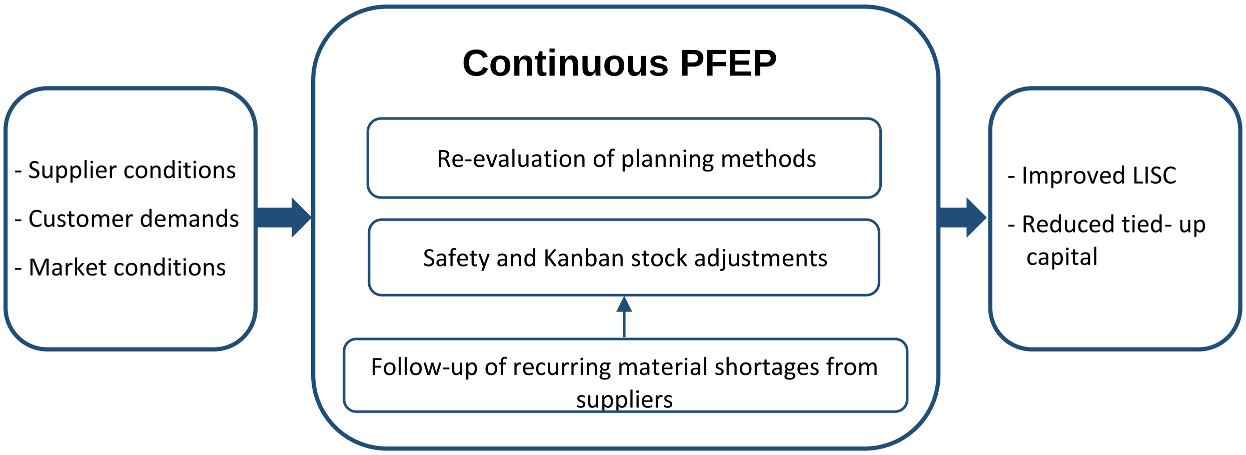


*Figure 10. The activities, input and output of the continuous PFEP.*

# 7 Discussion

*The purpose and generalizability of this case study is discussed in this chapter. The managerial and theoretical contributions of this research are also addressed below, followed by suggestions for future research.*

The purpose of this report was to investigate the challenges experienced in the current PFEP process and propose possible improvements, to help GMC achieve a clearly structured and effective process for inventory management. A challenge with improving an existing process such as the PFEP process, which a company has created to their specific demands, is finding literature that is relatable to the process and also to find a research angle that has academic relevance. Therefore is the generalizability of the report somewhat limited, in the sense that the analysis and recommendations are aimed at a specific process and company.

Some of the recommendations are based on the management of the process, since the empirical investigation enlightens problems that occurred when the position of the material manager was not replaced. This provides some understanding of how fragile the process is and that the risks are considerable that the same problems might occur if the process is not monitored and supported by a process owner. It has already been proven that the PFEP process is sensitive to changes in staff. Thus, if some participant of the PFEP process quits this person's responsibilities must be explicitly delegated to someone else

The recommendations also include deciding appropriate metrics that measures the performance of the PFEP-loop. Absence of performance measurements and follow-up means that there is no proof that any positive results have been achieved by the process. This might lead to difficulties in creating an understanding of outside parties, for example higher management, why it is worthwhile to work with the process. According to Pagell (2004) is top management support important when achieving functional integration. To achieve support from higher management a first step for GMC could be to increase the transparency to the process to create an interest and understanding of the process

GMC needs to develop clearer systematics for safety stock adjustments. An appropriate systematics could be an ABC classification which is normally used to facilitate inventory management for companies with many SKU:s by applying different stock control methods for different classes of inventory items (Teunter, Babai & Syntetos, 2010). This does not necessarily mean that the safety stock adjustments at GMC should be made automatic using mathematical methods to match item classes to a specific service level. It could however be useful to GMC to classify their inventory items based on some predetermined criteria, which would create a more transparent inventory system and ensure that the safety stock control conforms with strategic objectives. Jonsson and Mattsson (2009) mention a safety stock dimensioning method that consists of calculating safety stock levels as a percentage of demand during lead time. This method would facilitate adjustments of safety stock levels since it could be updated more automatically according to changes in demand or lead time. The risks of using a mathematical method such as the "percentage of demand during lead time" method are however that inventory levels might become greater or smaller than necessary, since the method does not consider demand variations (ibid.).

## 7.1 Contributions

The managerial contributions from this thesis are clear, since the investigation has its point of departure in the challenges experienced by GMC and aims to provide recommendations for improvement of the process. The main contributions to GMC are the concrete recommendations on how the PFEP process can be better managed, structured and measured; to ensure that the process produces the sought results through both aligning planning levels and improving the functional integration between purchasing and the product line. The recommendations aim to improve the current design of the PFEP process rather than to completely redesign the entire process. Since the recommendations have been created based on GMC's specific needs and situation, they are regarded to be feasible to implement fairly directly by the company.

The thesis also provides some theoretical contributions, such as contributing to increase the understanding of the challenges that are experienced for manufacturing companies to successfully integrate purchasing and production functions. The thesis also exemplifies how some common mistakes of process management can appear in a real-life-context. The study furthermore shows that even a company that manages to match its planning methods and planning environment can forget to monitor the need to adjust its methods, as conditions change. Regarding alignment of inventory management across planning levels it was difficult to find suitable literature. There was no existing literature that suggested how companies can work to achieve alignment between planning levels. The only suggestions found in literature were that decisions must be made within the constraints of higher planning levels, transferable from higher to lower levels and that feedback should be provided from lower to higher levels. The contributions from this thesis is thus to identify gaps between planning levels and provide some concrete suggestions on how to reduce these gaps i.e. improve alignment between planning levels. The thesis suggests that alignment could be improved by improving the transparency of decisions from lower planning levels to higher planning levels.

## 7.2 Future Research

This research showed that the results of the PFEP process are affected both by the functional collaboration within GMC but also by external parties such as suppliers. An example of such situation is the lot sizing decisions, which ultimately are dependent on what the supplier is willing to offer. Reduced batch quantities, which is an output of the PFEP process, often leads to the supplier requiring an increased price that GMC cannot accept. The investigation therefore showed how important the role of the supplier is for successful materials management. An area for future research could therefore be to investigate the PFEP process with focus on the suppliers, especially suppliers that are not willing to compromise regarding price increases. This could be performed by continuously working with developing the supplier relationships. GMC should encourage their suppliers to improve their processes to avoid price increases with reduced batch quantities.

# 8 Conclusion

*The conclusions obtained from this research are provided in this chapter. The three research questions addressed in the introductory chapter for this case study will be answered below.*

The purpose of this study was to improve the PFEP process by investigating the process to identify possible improvement areas and provide recommendations to the company. This to help GMC achieve an effective process for inventory management. In order to fulfill this purpose a case study combined with literature study has been performed. The study was based on three research questions that provided guidelines to the literature study and empirical investigation. The empirical findings have been analyzed according to the analytical framework presented in Section 3.7. This has contributed to the identification of problems in the PFEP process and creation of recommendations for improvements.

**RQ1: How can GMC ensure that the material planning methods suit the planning environment?**

The aim of this research question was to investigate the fit between GMC's planning methods and planning environment. Different planning methods are used for different items depending on the characteristics of the item. The studied planning methods are consignment stock, MRP and kanban. The planning environment is ambiguous and characterized by short lead times with both MTS and MTO manufacturing strategies. The investigation showed that the theory supports that there is fit between GMC's planning methods and planning environment. However the findings from this research showed that the planning methods are not reviewed continuously in relation to changed conditions. This is considered to be an obstacle to ensuring that inventory levels are kept at optimal levels, since the market conditions and demands for the products and parts change over time. Therefore GMC needs to establish procedures for continuously reviewing the different parts characteristics and match these to the most suitable planning method.

**RQ2: How can GMC improve the PFEP process to ensure that the production and purchasing functions cooperate and work towards a common goal?**

The analysis of the empirical findings identified some areas for improvements. The studied process consists of different functions. The theories relating to cross-functional integration emphasized the need to collaborate and work towards common goals to avoid conflicting goals. Any major conflicting goals causing problems within the PFEP process were however not identified. The main issue is instead regarded to be the uncertainty of what the constituents and purpose of the PFEP process actually is and what activities should be executed in the process. This indicates that a weakness is the lack of guidelines and instructions relating to the process. Process management is important since it sets the base for the process and follow-up of its performance. Without active management of the PFEP process the risk of failure increases. It is thus concluded that the process must have clear boundaries and guidelines that the process participants can follow. Finally must the results and performance of the process be measured in order to continuously identify possible improvements to the process and motivate the process participants.

**RQ3: How should inventory levels be managed at operative planning levels to be aligned with objectives of higher planning levels?**

To achieve alignment across planning levels the theory suggests that the decisions should be made within constraints of higher planning levels, transferable from higher to lower levels and that there is feedback from lower levels to higher levels. At GMC there are currently uncertainties regarding how well the safety stock adjustments and lot sizing decisions are aligned with higher planning levels' decisions and targets. The PFEP process loop showed to improve the alignment of lot sizing decisions operative to strategic level through the increased interaction between the product line and purchasing function. A gap between the strategic and operative planning levels was identified regarding the safety stock adjustments, which are performed on the operative level. This gap is regarded to be caused by missing transparency and systematics of the safety stock adjustments, which makes it difficult to interpret the safety stock levels and relate them to objectives and strategies of higher planning levels. GMC should therefore implement standardized routines for documentation of safety stock adjustments as well as kanban adjustments.

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# Appendix I Interview Guide

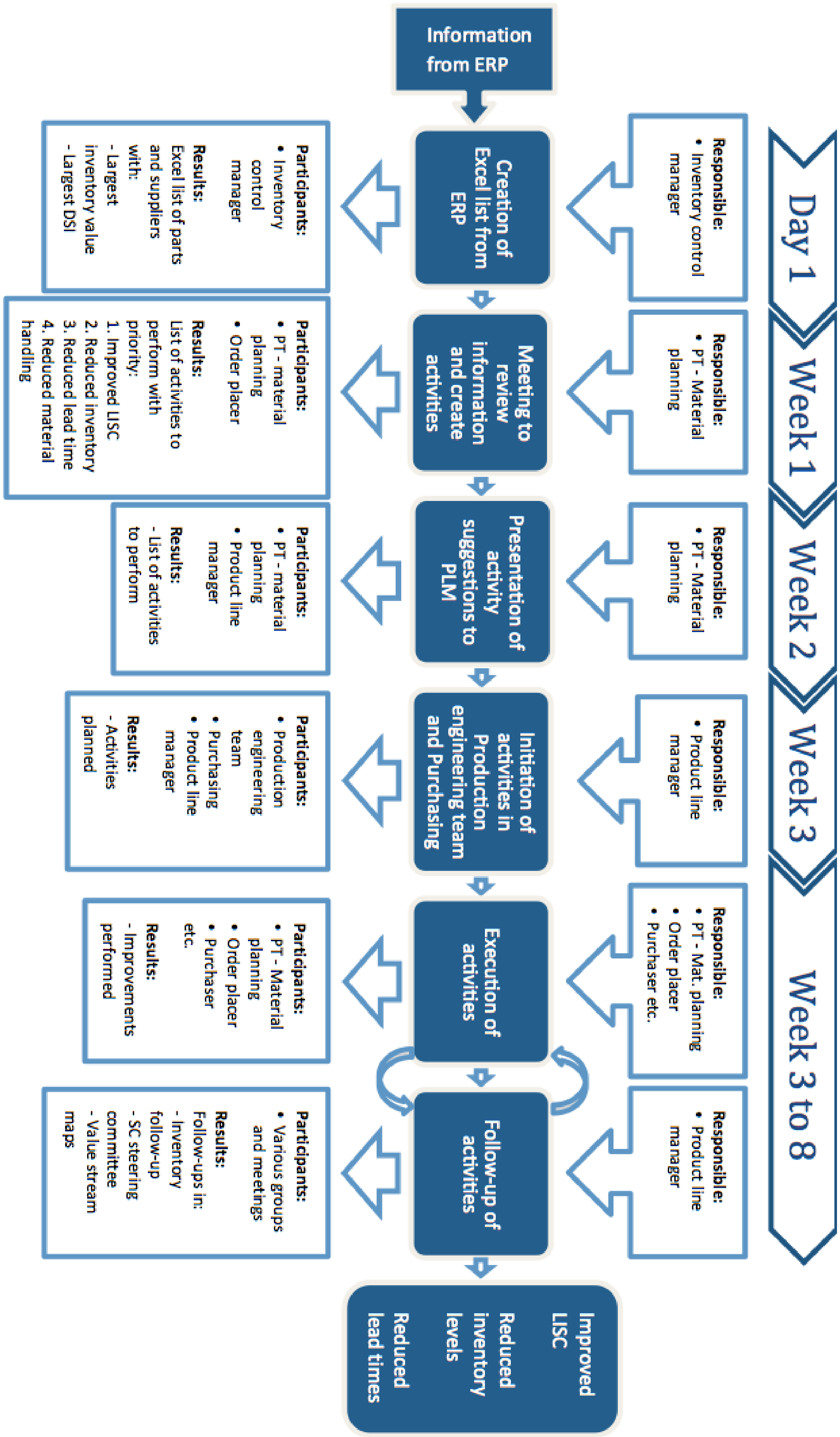
Interview guide for semi-structured interviews. This interview guide formed the basis for the different interviews and was slightly adjusted to suit the knowledge of the different interviewees in each interview.

- What position do you have in GMC and what are your responsibilities?
- What background do you have?
  - For how long have you been working as GMC?
- What is PFEP according to your perception?
  - What is the purpose of PFEP?
  - For how long have you worked with PFEP?
  - What did the process look like when you started working with it?
  - How much time do you devote to PFEP?
- What people/functions are involved in PFEP?
  - Do you think there is a function/person in PFEP that is missing in the current situation that should be included?
  - What people/functions do you consider have a key role in this process?
  - Who owns the process?
  - How important is your role in PFEP?
- What results have been achieved through PFEP?
  - How are the results from the PFEP activities measured?
- Are there any problems with PFEP in the current situation?
- Do you consider any improvements that should be implemented in PFEP?

# Appendix II List of Interviewed Employees

| Department | Position |
|---|---|
| Management | Business Unit Manager |
| Supply Chain Function | Inventory Control Manager |
| Supply Chain Function | Purchasing Manager |
| Supply Chain Function | Strategic Purchasers |
| Supply Chain Function | Operative Purchaser |
| Production | Inbound/Outbound Logistics |
| Product Line Blue | Product Line Manager |
| Product Line Blue | Production Technician (PT-material planning) |
| Product Line Blue | Order Planner |
| Product Line Blue | Order Placer |
| Product Line Red | Order Placer |

# Appendix III Large Official Process Map



# Appendix IV Large Current State Map