Investigation for Capacity Planning within the Supply Chain: A Case Study

A master thesis written in collaboration with PolyPeptide

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Thank you!

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Paulina Tengqvist

Abstract

Title

Investigation for Capacity Planning within the Supply Chain: A Case Study

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Background

Planning for capacity in not just the production, but also in the supply chain, is important. Strategic long-term planning for the supply chain will affect how the company will be able to meet the demand.

This Master Thesis will focus on the capacities within the supply chain at PolyPeptide and how they could be planned for in the future. PolyPeptide is a company that manufactures active pharmaceutical ingredients with peptide technology. The production plan that is set through an S&OP process sets the basis for the activities that is performed by the supply chain department. Often a high load on the production means a high load on the supply chain, but this is not always the case. Today the company does not have a model or tools to evaluate how the capacities in the SC will be affected by the production, which leads to difficulties in planning load and utilization.

Purpose

The purpose is to investigate and develop an understanding for future capacity planning within the supply chain at PolyPeptide in Malmö. This includes to identify what in the production that generates the workload on the supply chain and how to give a recommendation on how to precede with this.

Research Questions

RQ1: What capacities does the supply chain have?

RQ2: How is the production affecting the supply chain?

RQ3: Which activities in the production generate a high load on the supply chain and how?

Methodology

The methodology of this Master Thesis was chosen based on characteristics of the project and the research questions. The chosen methodology was a case study research which included gathering of both qualitative and quantitative data, with a focus on interviews for the qualitative data. A literature study was made to gather information in the area of capacity planning and other areas related to the project such as S&OP and supply chain management. The last step in the project included a conclusion and a recommendation for the future.

Conclusion

The conclusion of this project is a recommendation for PolyPeptide to use the mapping of time for the activities in the production plan when planning the production. This could minimize the peaks of workload in the warehouse or help to plan for the capacity needed in the warehouse. In order to ensure less fluctuation in capacity needed the projects that take the most time for the warehouse should be spread out. The specific transfer orders, that are related to the projects, that drives the most time for the warehouse, and the specific steps of these project could also be further investigated in the future.

Keywords

Capacity planning, supply chain capacity, capacity management, supply chain.

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Abbreviations

API – Active Pharmaceutical Ingredient

ERP – Enterprise Resource Planning

GMP – Good Manufacturing Practice

LPPS – Liquid Phase Peptide Synthesis

SPPS – Solid Phase Peptide Synthesis

S&OP – Sales and Operations Planning

WIP – Work In Progress

1. Introduction

In this section the background, problem description, purpose and goals will be presented. Research questions, delimitations and the disposition of the thesis will also be introduced.

1.1 Background

Capacity planning can be defined as a method that shows the production capabilities in a company and covers resources in form of both equipment, employees and facilities (Yong-Hui, 2009). In order to support the production, the capacities in the supply chain will be important to consider. Lack of capacity within a supply chain can lead to poorer delivery performance and in the long run also decrease the revenues (Yuan & Ashayeri, 2009).

This Master Thesis will focus on the capacity planning of the supply chain at PolyPeptide in Malmö, Sweden. PolyPeptide uses peptide technology to produce API, an active ingredient used in pharmaceuticals. The company are a world leader in this type of peptide manufacturing and manufactures more than one third of all peptide drug substances (PolyPeptide, 2020). The company has sites in several parts of the world, France, India, Belgium, Sweden and USA. This Thesis will focus on the site in Malmö.

The supply chain department at PolyPeptide supports the production and is responsible for:

- Sourcing: procurement of direct and indirect materials and material planning
- Planning of the production: also called Master Planning
- Warehousing such as receiving goods, quality control and put-away
- Logistics: internal inside the facilities and external outside
- Picking and weighing of raw materials to the production, orders prepared to the production from the warehouse are called transfer orders.

- Storage of WIP (intermediate) and API (end-product)
- Distribution to customer

There are currently sixteen employees at the supply chain department at PolyPeptide and the main areas are purchasing, warehousing and shipping. In order to plan the production Master Planning is used, which is a tactical plan with a timeframe of 0-12+ months. Decisions for the Master Planning are made during the monthly S&OP process and the production is then planned according to this. It is dictated by the capacity that exists within the production as well as inventory management of the end product and the customer needs. The plan therefore forms the basis for all activities and processes that the supply chain department carries out.

1.2 Problem Description

As the supply chain at PolyPeptide is a support function to the production, it is affected by how the production is planned and how the production is carried out compared to that plan. Generally, the higher load on the production the higher load on the supply chain activities, however this is not always the case.

The problem is to understand how the supply chain gets affected in terms of capacity and load and where the bottlenecks are in order to be able to meet a higher service level to both the production and the customers. The activities in the supply chain are not currently taken into consideration when planning the production and the supply chain does not have a model or tool for planning their own capacities and activities. In order to do so they would have to know what is affecting the supply chain flow, what factors has the most impact and on what parts of the supply chain? What methods could be used to get an understanding of the capacities of the supply chain? How can usage of time be optimized and improved from current situation? How much time does activities such as weighing and receiving materials take? What existing capacities are there in the supply chain?

1.3 Purpose

The purpose is to investigate and develop an understanding for future capacity planning within the supply chain at PolyPeptide in Malmö.

1.4 Research Questions

The following research questions are to be answered, based on the purpose of the Master Thesis:

RQ1: What capacities does the supply chain have?

RQ2: How is the production affecting the supply chain?

RQ3: Which activities in the production generate a high load on the supply chain and how?

1.5 Delimitations

The focus is the capacities within the supply chain at PolyPeptide, not the capacities in the production. Within the supply chain, warehousing is identified as the main area in need of an understanding of the capacities and the focus will therefore lay there. However, there will be some additional focus on purchasing connected to the receiving. The main area of problem in purchasing is the synchronization with the warehousing in terms of receiving and storage space. In warehousing the main problem area is the weighing of products and understanding how the production affects the transfer orders and weighing differently depending on project and step of the project. The area less known by the company is the transfer orders and what in the production that affects to load on the warehouse department. Therefor this will be the main focus in this project.

1.6 Report Structure

Chapter 1: Introduction

In this chapter the background of the Thesis as well as the purpose are being presented. It will also include an introduction to the company, the problem formulation and a list of the research questions chosen.

Chapter 2: Methodology

In this chapter the methodology chosen for the Thesis will be presented. The method will be described and motivated and a summary of the method will be shown. The aim is to give an overview of how the Thesis is structured.

Chapter 3: Theory

The theory chapter will describe several areas of relevant theory that was reviewed in order to get a deeper understanding of the subject of the Thesis as well as being able to reach the goal with the project.

Chapter 4: Empirical Data

The Empirical Data from PolyPeptide will be presented. This includes a description of the supply chain at PolyPeptide and its capacities. The current situation and identified problems are also included in this chapter.

Chapter 5: Analysis

This chapter will include a comparison of the current situation and the theory. Improvement areas regarding capacity planning will be given.

Chapter 6: Conclusion & Recommendation

In this chapter the research questions will be answered and further recommendations of suggested actions for PolyPeptide will be given. The contribution to theory will also be presented.

2. Methodology

The following section will explain the strategy and design of the research method for this Master Thesis. The chapter will also include the research approach as well as the data collection and the research quality.

2.1 Research Strategy

When conducting a research, the methodology should be chosen based on the type of research and the goal of the project. For projects there are four main purposes (Höst et al., 2006):

Descriptive – describe how the object studied works

Exploratory – understand the object studied, not just describe

Explanatory – explanations to the way the object studied works

Problem solving – solving an identified problem

This Thesis will have an exploratory purpose. In addition to this there are different research methods that can be used in a project, such as surveys, case study, action research and modelling (Kotzab et al., 2005). The strategies are all suitable for different projects and have different characteristics which will be explained in the following sections.

2.1.1 Action Research

Action research is a suitable research strategy when there is a highly unstructured problem and an exploratory research design is typically used for this (Kotzab et al., 2005). In an action research the object of study will be revised during the research and it is an interactive strategy. The strategy focuses on practical situations and could be described to follow a cyclical process that starts with observation and identification of a problem and then goes over to finding a solution and implementing it by using data gathering, data feedback, data analysis, action planning, implementation and evaluation. The last important step is monitoring, which is often done through all the cycles. Action research is not often used in research within the supply chain area (Kotzab et al., 2005).

2.1.2 Survey

A survey is based on collection of information from several people and the survey as research method is used to develop theory (Malhotra & Grover, 1998). The main three attributes of surveys are that you ask people for information in a structured way, it is a quantitative research method most of the time and last that the information is gathered from only a part of the population and therefore must be generalized (Malhotra & Grover, 1998).

2.1.3 Modelling

In supply chain management research quantitative model-driven research often include empirical data and simulation models (Kotzab et al., 2005). There are two categories of quantitative model-driven research, one that is focused towards logical proofs and mathematical models and the second one is focused on empirical findings and measurements. The research method used for modelling is descriptive.

2.1.4 Case Study

A case study research gives identification and description of variables that are critical and is therefore suitable to use in supply chain management research (Kotzab et al., 2005). It is foremost a qualitative research method that examines the phenomenon in a real-life context and are in-depth. The case study has six steps: Plan, design, prepare, collect, analyze and share (Yin, 2014). The case study research often includes several data sources, both qualitative and quantitative, such as interviews, archival data, survey data and observations (Eisenhardt, 2007).

Yin (2014) identifies five major researches, experiment, survey, archival analysis, history and case study. Different research methods and three conditions to select them based on according to Yin (2014) can be found in Table 2.1.

Table 2.1: Research methods based on three conditions (Yin, 2014, p. 9).

Method	**Form of research question**	**Requires control of behavioral events?**	**Focuses on contemporary events?**
Experient	How, why?	Yes	Yes
Survey	Who, what where, how many, how much?	No	Yes
Archival Analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case Study	How, why?	No	Yes

A case study is the preferred method to use in situations when you examine contemporary events, the research questions mainly are “how” or “why” and there is limited control over behavioral events (Yin, 2014).

2.1.5 Research Method for This Project

Based on an understanding of the purpose and the problem at hand a case study research was deemed the appropriate option as a research method. The study in this Thesis has a focus on investigate and develop an understanding for future capacity planning within specific context that is the supply chain at PolyPeptide. This is based on an understanding of how the production affect the supply chain flow and the load on activities in the supply chain. The main research questions are “how” and the project does not require control of behavioral events. This confirms that a case study is the preferred research strategy for this master thesis.

2.2 Research Design

Research design could be described as a way to present what questions that need to be studied in the case, what the relevant data there are, what data is needed to be collected and how to analyze the results (Yin, 2014). According to Voss et al. (2002), research design in operations management includes methods needed to be studied, methods used in order to study them and the data that needs to be collected. The research design should ensure that the evidence collected will address the research questions (Yin, 2014).

In a case study it is important that the focus is defined clearly at the beginning of the study in order to guide the collection of data (Voss et al., 2002). In order to do this a purpose should be stated based on the identified problem. When conducting a research triangulation could be used, this meaning using both qualitative and quantitative methods and cross-checking them on each other in order to validate finings (Malhotra & Grover, 1998).

2.3 Research Approach

There are two main approaches in research, quantitative and qualitative (Kotzab et al., 2005). The quantitative approach starts with a literature review that will build the ground of theory that explains the phenomenon. The second step includes building up formal theory based on the literature from the first step. The last step is to collect data, which is done in order to verify the previous formal theory.

In the qualitative approach the researcher wants to know first-hand experiences from the informants and the first step is data collection (Kotzab et al., 2005). Use of literature is in the qualitative approach a part of several steps and not its own, and often most of information is gathered from data rather than literature. The second step in the qualitative approach is description where multiple data sources such as interviews, documents, observations and the use of open-ended questions are often used in order to develop descriptions. The third step is substantive theory which is built from analyzing the qualitative data.

An inductive approach is often qualitative and conclusions are based on data while a deductive approach is often quantitative and is based on theories. When combining the two approaches a balanced approach is achieved (Kotzab et al., 2005). This includes two loops, one qualitative and one quantitative that complement each other, which can be seen in Figure 2.1.

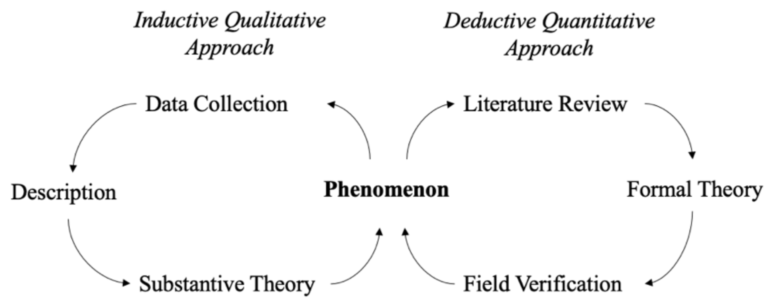

Figure 2.1: The Balanced Approach Model

In this Thesis a balanced approach will be used, a literature review will be done to gather knowledge about theory in the area but a data collection of qualitative data through interviews will be the most important part of the project.

2.4 Data Collection

A close collaboration with PolyPeptide for qualitative data in form of interviews as well as quantitative data from their ERP-system will be used in order to form the basis for this project in form of a current situation and a supply chain setup.

2.4.1 Literature Review

In order to generate a deeper understanding and a knowledge baser for the area of capacity planning and to resolve research objectives, a literature review will be used. This will be conducted by systematically researching articles, online sources and books relevant for the area. The literature review aims to give a critical and accurate understanding of today's knowledge in the area reviewed (Snyder, 2019). It should compare research studies to each other and indicate where there are gaps today and what could be further researched. There are four main phases in a literature review according to Snyder (2019):

1. *Design the review* – Why the review is conducted. Define purpose and research questions that the review will cover and decide the approach.

2. *Conduct the Review* – Test search terms on a small section. The final selection approach is either read whole literature or just abstracts and making selective choices of what to include.

3. *Analysis* – How will the articles be used? Abstracting relevant information from the articles.

4. *Writing the Review* – How the literature has been analyzed and reported. Could result in different uses such as development within a research field, agenda for future research or an effect or evidence.

The main focus for the literature review made for this Thesis will be to gather information within relevant areas to connect to the empirical data later on by using several articles and sources.

2.4.2 Interviews

According to Eisenhardt and Graebner (2007) interviews provide an efficient data gathering opportunity and to avoid bias it is preferred to use various informants with different knowledge and perspectives. There are different ways to set up an interview, it could be more or less structured. If the interview questions are too structured the interviewee may not give the best information. If instead using a less structured approach, the interviewee will guide the conversation and give insights that otherwise could have been missed (Stuart et al., 2002). When conducting an interview, it is important that the researcher holds certain skills such as being able to ask good questions, be a good listener, be knowledgably about the situation being studied, be flexible and to be unbiased (Yin, 2014).

Prolonged case study interviews are often used in case studies and resembles a guided conversation that does not need to be too structured, they are also often open-ended (Yin, 2014). Interviewees could provide important insights and explanations and also guide you to other people that the case study could benefit by including in interviews (Yin, 2014). Prolonged case study interviews are often over two hours and can be divided into several meetings. There are also shorter case study interviews which has similar characteristics but are conducted in around an hour (Yin, 2014).

In this Thesis both of these types of interviews will be used in order to get an overview of the current situation of the supply chain at PolyPeptide and to understand how the production plan is set. Notes were taken during the interviews and questions were asked as well as the interviewees sharing information they found relevant. In Table 2.2 the conducted interviews for this project can be found.

Table 2.2: Description of the interviews

Name	Position	Department	Date	Subject of meeting
Mikael Larsson	Planning Manager	Supply Chain	2020-09-16	S&OP and Production Planning
Martin Bern	Purchasing & Material Planning Lead	Supply Chain	2020-09-22	Purchasing and Material Planning
Eva Liv	Supply Chain Manager	Supply Chain	2020-09-22	Warehouse
Sergej Ivanovic	Warehouse worker	Supply Chain	2020-10-02	Receiving
Nelly Sahlin	Warehouse worker	Supply Chain	2020-10-02	Warehouse operations
Mikael Larsson	Planning Manager	Supply Chain	2020-10-07	Qualitative Data
Filip Jönsson	Warehouse worker	Supply Chain	2020-10-07	Warehouse, workload and projects
Mikael Larson	Planning Manager	Supply Chain	2020-11-25	Production Plan
Filip Jönsson	Warehouse worker	Supply Chain	2020-11-26	Warehouse, workload and projects
Filip Jönsson	Warehouse worker	Supply Chain	2020-12-02	Warehouse, workload and projects

For the first initial interviews a guide with some prewritten questions were used, see Appendix A, to ensure a basis of information. The later interviews were more specific and no interview guide was developed for these. All the interviews were however open ended and more specific questions was asked to each interviewee depending on where the interview headed and what type of information that was being relevant in each subject.

2.4.3 Quantitative Data

As a compliment to the qualitative interview data additional quantitative data was collected from Polypeptide's database QlikView. This data consists of lists of products and transfer orders as well as stock adjustments over time and comes from the ERP-system AXP that PolyPeptide uses for most of the transactions within the company. The quantitative data enables analysis through graphs and tables.

2.4.4 Data Analysis

Data collected through interviews were summarized right after the interview in order remember the details, and notes were taken during the interviews. In order to answer the research questions it was important to create an understanding for the supply chain at PolyPeptide and what operations that are time consuming. The collected data forms the description of the current situation at PolyPeptide and will later be analyzed to give an understanding of what in the production that is creating a high load on the supply chain. The qualitative and quantitative data together forms the analysis.

2.5 Research Quality

There are four tests that often are used to build quality in a case study research (Yin, 2014). The first one is construct validity and includes avoiding to influence the set of measures by being bias, which can be avoided by using evidence from several sources and to let key informants, such as the supervisors, review the draft of the case study report (Yin, 2014; Voss et al., 2002). This was done throughout this Thesis by interviewing several people and comparing their answers to quantitative data when possible. The second test is internal validity is mainly a concern when conducting an explanatory case study and refers to validity of the relationship of the cause and effect (Yin, 2014). The third test is external validity and includes knowing if the findings are generalizable, this can be ensured by using “how” and “why” research questions (Yin, 2014). In this Thesis the main research questions was “why”. The fourth test is reliability and refers to that if the same case study is repeated the findings would be the same and to achieve this a case study database could be created (Yin, 2014).

Another aspect that according to Yin (2014) should be considered in a case study research is Triangulation, which is a strategy to ensure that credibility is achieved. This involves using more than one type of source and gives a higher quality to the case study (Yin, 2014). Comparing the findings from different sources of evidence with each other can indicate whether they are credible or not. In this Thesis this will be used by comparing qualitative data from interviews with quantitative data from the ERP system and holding interviews with different people at the company to make sure that the information given are in line.

2.6 Summary

In order to give an overview of the methodology chosen a short summary of activities are shown in Table 2.3.

Table 2.3: Summary of methodology

Type	**Chosen Methodology**
Research Strategy	- Definition of: Action Research Survey Modelling Case Study - Motivation of choice of strategy in this Thesis -> *Case Study*, chosen strategy
Research Design	- Definition of research design and connection to Case Study

Research Approach	- Definition of qualitative and quantitative approach -> A *balanced approach* will be used in this Thesis
Data Collection	- Literature review: To gather knowledge about capacity planning and other relevant areas - Qualitative data: Interviews with employees at the company - Quantitative data: From the ERP system at PolyPeptide
Research Quality	- Interviewing several people - Comparing answers to quantitative data - Using several sources of data

3. Theory

In this section relevant theory regarding general supply chain management as well as capacity planning is presented to help understand current knowledge within the subject. Theory in areas related to capacities are also presented.

3.1 Supply Chain Management & Mapping

Supply chain can be defined as several entities or firms that are involved in the up or downstream flows of products, services or information from the start at the source to the end with the customer (Mentzer et al., 2001). Supply chain management on the other hand can be defined as a strategic approach to coordinate the operational and strategic capabilities within the whole supply chain and managing the flow of inventory (Mentzer et al., 2001). It also has the characteristic of focusing on creating customer value.

In order to understand the supply chain a good approach is to visualize by mapping out the activities (Gardner & Cooper, 2003). It can help understand and evaluate the current setup of the supply chain and if detailed it could signal possible constraints. A supply chain map could be used to describe the current situation or what can be if changes are made (Gardner & Cooper, 2003). There is a difference between strategic supply chain mapping and process mapping (Gardner & Cooper, 2003). The strategic supply chain mapping focus on the flow of goods, upstream and downstream, while the process mapping focus on one specific system or operation in a company. The process mapping is more detailed and the purpose is often tactical while a strategic supply chain map is less detailed and strategically focused.

3.2 Sales & Operations Planning

S&OP is defined as a business process that lets companies balance supply and demand and ties the strategic level to the operational (APICS, 2017; Grimson & Pyke, 2007; Olhager et al., 2001; Tavares Thomé et al., 2012). The process has been used for more than 25 years and according to Olhager et al. (2001)

S&OP is a technique used for quick adjustments when market and operation changes. The S&OP plan is often set for 1-18 months forward and companies in the pharmaceutical industry that often have long lead time for production usually has a longer S&OP plan (Grimson & Pyke, 2007).

According to Grimson and Pyke (2007) the S&OP process can be described by five steps where the first one is meeting within the sales department where the forecasted demand is set, which is based on the customers demand and not the production capabilities. The second step is that the operations department has meeting involving inventory strategy, internal capacity as well as supply chain capacity. This meeting leads to a supply plan, also called capacity plan, based on the forecast. The third step is a cross functional meeting with the S&OP team, including people from sales and operations as well as executives that can give authority to implement decisions. This meeting will be about the operating plan for the coming period. The S&OP meetings are often held monthly (Lapide, 2004; Grimson & Pyke, 2007; APICS, 2017). The fourth step involves implementing the S&OP plan which means that the production will have to fulfil the demanded quantity. The fifth step is to measure and analyze the results of the S&OP process, which is important in order to be able to improve the process in the future (Grimson & Pyke, 2007).

S&OP is a process that requires the company to change its culture and move away from the often-appearing silo thinking, where departments does not share information between themselves (Grimson & Pyke, 2007; Lapide, 2004). The cross functional work is central for the success of the process as well as structured agendas for the meetings (Lapide, 2004; Tavares Thomé et al., 2012). S&OP is a business process in which you have to balance the planning for sales and production and the decisions taken in order to achieve this is either changing demand to meet constraints in the production or change the supply to meet the sales plan (Olhager et al., 2001). As the S&OP process affects the production it will also affect the supply chain and the requirements on its capacities.

3.3 Capacity Planning

Capacity planning is a method that shows the capabilities for production in a company and covers resources in form of both equipment, employees and facilities (Yong-Hui, 2009). It could be divided into three timeframes, long-term, middle-term and short-term, where long-term is strategic planning (Yong-Hui, 2009; Friemann & Schönsleben, 2016). Most of the literature about capacity planning is connected to production capacity but it could also be about the capacities in the supply chain and the functions that are supporting the production with material. Strategic long-term planning for the supply chain will affect how the supply chain will be able to meet demand (Friemann & Schönsleben, 2016). When making decisions of capacities related to processes it is important to consider the role of the process in the whole supply chain and the impact it will have on other processes capacities (Krajewski et al., 2018).

Based on the expected capacity requirements a strategy is formed. A capacity strategy involves a long-term plan that indicates how much, when and what types of capacities that should be added or removed to improve the value creation in the company (Klibi & Martel, 2016). Capacity is defined as a limit on an activity within a technological system, where the limit could include material resources such as equipment and tools or land and buildings, or human resources (Klibi & Martel, 2016). The capacity of a technical system can be defined as "the quantity of products or services that it can produce with its resources per unit of time under its current configuration and methods" (Klibi & Martel, 2016, p. 290). In a company there will be different types of capacities that will need to be handled, for example storage capacity or packing capacity (Klibi & Martel, 2016).

It is important not only to increase or decrease a capacity but to ensure that the whole supply chain is effective, and the capacity decisions should be taken with long-term strategies and issues in mind (Krajewski et al., 2018). The future capacities are often not possible to forecast with certainty and therefore investing in capacity is somewhat risky as the money is invested before getting, possible, future benefits (Klibi & Martel, 2016).

3.3.1 Measures of Capacity

Different situations require different types of measurements, according to Krajewski et al. (2018) capacities could be measured as either input or output measures.

Output measures of capacities – works best when applied to individual processes within the company or when there are a few standardized products. An example of an output measure is cars produced per day.

Input measures of capacities – suits low volume, flexible processes. An input measure could for example be the number of workers. The problem with input measures are that you then need to convert the demand, which often is an output measure, into an input measure e.g. labor hours and the number of employees needed.

The *utilization rate* could also be calculated to get the degree to which the resource is used (Krajewski et al., 2018). Here the average output rate is divided by the maximum capacity and the output rate and capacity must be measured in the same unit for this formula to work. If wanting to operate over the capacity level you could for example use overtime and extra shifts, this is however just a short-term solution for peaks in demand but is not sustainable in the long run (Krajewski et al., 2018; Klibi & Martel 2016). It is proven that when employees work overtime over a long period of time the quality of their work decreases (Krajewski et al., 2018).

3.3.2 Capacity Strategies

There are three typical capacity strategies if the demand is growing linearly (Klibi & Martel, 2016). In the first one the capacity precedes demand and there is therefore always excess capacity. This means that the company is flexible and can take on new projects and opportunities quickly, but the downside is that it could be expensive. Olhager et al. (2001) presents this as capacity leading demand and an illustration of this can be found in Figure 3.1. In the second strategy capacity follows demand and here there are never any extra capacity and no flexibility which leads to that short-term compensation with overtime or outsourcing will be needed to be used. This is called capacity lagging demand (Olhager et al., 2001) and is shown in Figure 3.2. In the third strategy capacity overlaps demand, which is a mix of the previous two and can be seen in Figure 3.3. This is called capacity tracking demand (Olhager et al., 2001). In this strategy the problem is to find the best position between preceding and following demand.

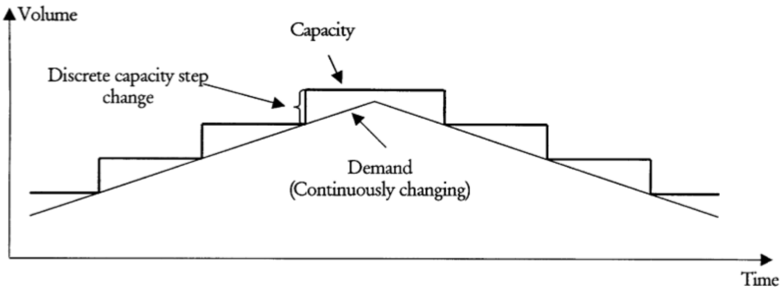

Figure 3.1: Capacity leading demand (Olhager et al., 2001, p. 217)

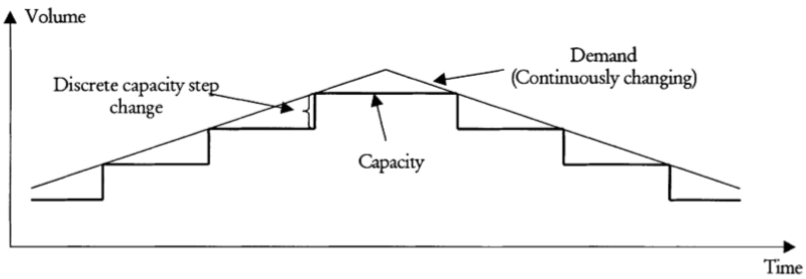

Figure 3.2: Capacity lagging demand (Olhager et al., 2001, p. 218)

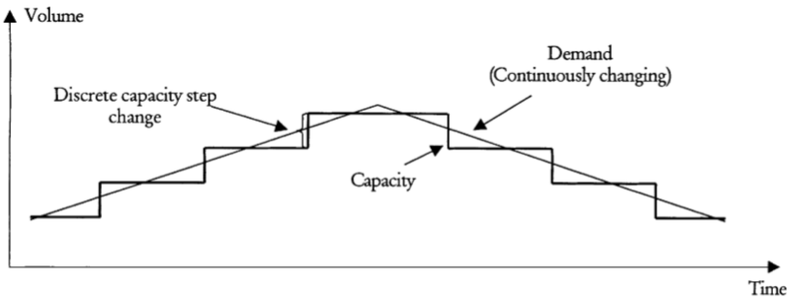

Figure 3.3: Capacity tracking demand (Olhager et al., 2001, p. 219)

The long-term effects on capacity decisions makes it important to adjust them after forecasts of the future needs (Klibi & Martel, 2016). The strategies presented by Klibi and Martel (2016) are based on a growing demand and expansion but can be adapted for a decreasing demand strategy as well. The framework presented by Olhager et al. (2001) includes decreasing demand as well.

3.3.3 Supply Chain Capacity

A company should analyze its supply chain processes for improvements and assess them in terms of capacity and bottlenecks (Krajewski et al., 2018). Lack of capacity within a supply chain can lead to poorer delivery performance and in the long run also decrease the revenues (Yuan & Ashayeri, 2009). When making decisions to increase capacity within the supply chain it is important to consider the structure of the supply chain and its flows as well as the resource requirements. The supply chain’s success is dependent on the available capacity (Yuan & Ashayeri, 2009).

Meyr et al. (2002) present a supply chain planning matrix where they divide the planning into three levels which can be viewed in Figure 3.4. The levels go from strategic long-term to operational short-term decisions with the tactical level in the middle that links the other two together. In order to fulfill the tactical plans, that are set to satisfy customer demand, all capacities in the supply chain need to be thought-through (Steinrücke & Jahr, 2012). Therefore, in order to support the production, it will be important to consider the rest of the supply chain.

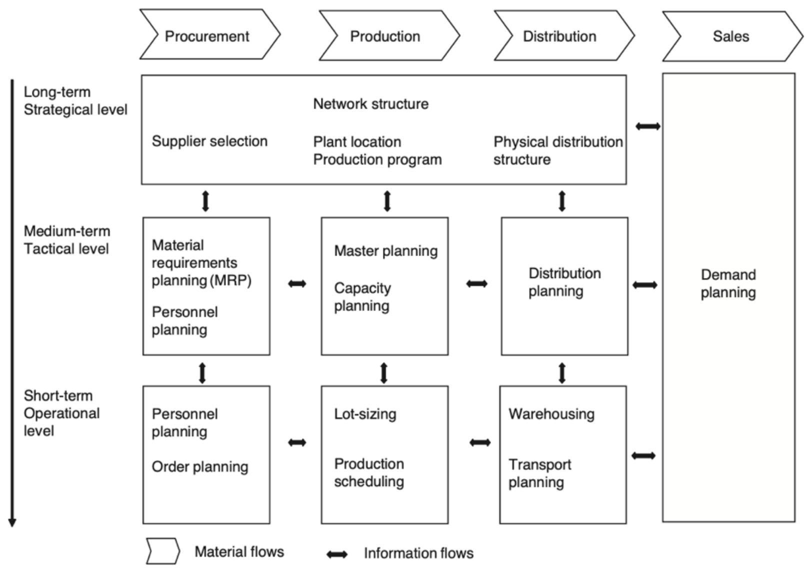

Figure 3.4. Supply chain planning matrix (Meyr et al., 2002, p. 99)

3.3.4 Long-term Capacity Decisions

A long-term capacity decision could for example be number of employees needed for a process or the number of workstations required. According to Krajewski et al. (2018) there are four steps that could help when making long-term capacity decisions. These are:

1. *Estimate future requirements* - When calculating the capacity requirement, output or input measures could be used. Example input measure:

$$\text{Capacity requirement} = \frac{\text{Processing hours required for demand}}{\text{Hours available from a single capacity unit}}$$

2. *Identify gaps by comparing requirements with available capacity* – the difference between current and the projected future demand is the capacity gap, this could be both positive and negative

3. *Develop alternative plans for reducing the gaps* – if demand is higher than capacity the company will lose orders if choosing to do nothing, they could also add more capacity or use temporary solutions such as overtime. If capacity is too high capacity could be lowered by for example reduce the number of employees or working hours.

4. *Evaluate each alternative, both qualitative and quantitative, and make a final choice* – how it fits the capacity strategy for the whole company, assumptions about worst case and best. Estimate changes in cash flow for the alternatives.

3.4 Constraints

In the short-term, managing constraints is a way of utilizing the existing capacities and get an understanding of the problems with the current setup of capacities (Krajewski et al., 2018). Theory of constraints is a method first presented by Goldratt and Cox (1984) used to identify and manage the constraints that hinder the company to use resources efficiently and reach its goal. The theory is later presented in the book "*Operations management: Processes and supply chains*" by Krajewski et al. (2018). The theory of constraints includes a focus on bottlenecks in the company as well as the improvement of overall flows and the importance of understanding the capacity measures on the operational level (Krajewski et al., 2018). A constraint is defined as any factor that limits the performance and output of a system and could be found along the supply chain in the forms of equipment or manpower as well as lack of demand or management. Further a constraint does not correspond with the company's desired performance. Capacity is defined as the highest rate of output from a process and is affected by the constraints along the supply chain (Krajewski et al., 2018). A type of constraint that is connected to a shortage of capacity in a process is called a bottleneck. The bottleneck and its capacity will affect the company and limit the possibilities to meet the demand, however companies always have at least one bottleneck, or else the market would control the output (Krajewski et al., 2018).

It is important for a company to identify and manage bottlenecks in the organization and understand how to relate the capacities in processes to one another (Krajewski et al., 2018). In the theory of constraints, it is assumed that the demand is higher or at level with the capacity of the processes, meaning that the constraints are internal. If the organization could produce more than the demand the constraints would lay externally.

The theory of constraints involves implementation in five steps according to Goldratt and Cox (1984):

1. *Identify the System Bottlenecks*: Find the factors with capacity constraints.
2. *Exploit the Bottlenecks*: The throughput of the bottlenecks should be maximized by creating schedules.
3. *Subordinate All Other Decisions to Step 2*: Non-bottleneck resources should not produce more than the bottleneck could handle, they should be scheduled to support the bottleneck.
4. *Elevate the Bottlenecks*: If the bottlenecks are still constraints, consider increasing the capacity of the bottleneck.
5. *Do Not Let Inertia Set In*: The constraints may shift and therefore the steps 1-4 should be repeated to identify new constraints.

3.5 Spackling

There are different methods to handle production of both specialized customer projects and ongoing manufacturing of standard products. The term spackling refers to a method where a company uses its flexible capacity for specialized customer orders and then “spackles” the rest of the production schedule with the ongoing operation or standard products that will be put to stock (Cattani et al., 2002). The opposite method is called focused strategy and involves using the efficient capacity of the production to make-to-stock and the flexible capacity for make-to-order (Cattani et al., 2002). Efficient capacity refers to make-to-stock of standard products, lower costs and production with a steady-state. Flexible capacity on the other hand includes the possibility for both standard products that are make-to-stock and customized products that are make-to-order. A focused strategy is often used when standard and customized products have demand of a certain quantity and the efficient capacity has a much lower cost than the flexible, one production line would then produce the standard products and one line would produce the customized products (Cattani et al., 2002).

If the cost of flexible capacity is in line with or lower than the efficient capacity, spackling is a good strategy to consider (Cattani et al., 2002). If using spackling as a strategy the customized make-to-order products will get the priority in the production, and in order to smooth out the production standard products will also be made with the flexible capacity, as can be seen in Figure 3.5 (Cattani et al., 2002).

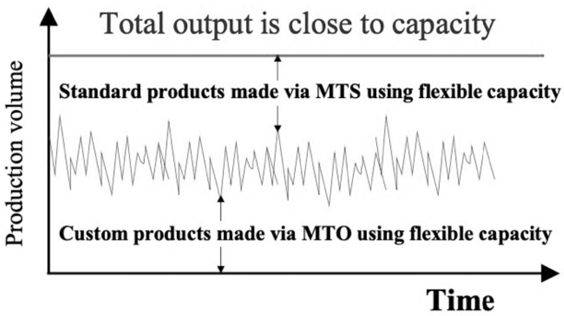

Figure 3.5: Spackling (Cattani et al., 2002, p. 5)

3.6 Summary of Theory

The theory will support the empirical data an analyze and provides a basis of knowledge within the area of capacity planning connected to supply chain. The topics of supply chain management and mapping provides an insight in why a mapping is useful and what defines a supply chain. The theory concerning S&OP gives a general understanding for the business process used when creating the production plan at PolyPeptide. The area of capacity planning including measures of capacity planning, capacity strategies, supply chain capacities and capacity decisions will provide knowledge to help understand and solve the formulated problem. The theory regarding constraints provides a method for identifying constraints and bottlenecks and how to manage them. The topic of spackling is brought up to build an understanding of different ways to handle a production with both customer projects and ongoing operation, like PolyPeptide has.

In order to get an overview of the areas reviewed and the questions answered by this a summary was done, as can be seen in Table 3.1. This summary includes the area that has been reviewed and the subjects that the theory covers.

Table 3.1: Summary of Theory

Area	**Theory Covering**
Supply Chain Management Supply Chain Mapping	- Definition of Supply Chain - Definition of Supply Chain Management - Why is mapping of the supply chain useful?
Sales & Operations Planning	- Definition of S&OP - The steps in the S&OP process - How is this connected to capacities in SC and production?
Capacity Planning Measures of Capacities Capacity Strategies Supply Chain Capacity Long-term Capacity Decisions	- What is capacity planning? - How do you measure capacities? - How can the supply chain be connected to capacity planning? - The importance of long-term strategy when changing capacities

Constraints Theory of Constraints	- Definition of constraint, bottleneck and capacity - How to manage constraints
Spackling	- Different methods for handling customer projects and ongoing operation/standard products

4. Empirical Data

The following chapter will describe the empirical data that has been collected through interviews and documents received. This will give an overview of the current situation and the identified problems.

4.1 Special Requirements

The pharmaceutical context makes the supply chain setting a bit more complex and it affects the possibilities to manage the capacities due to special requirements and regulations that are related to this type of production. When dealing with pharmaceutical ingredients the suppliers and Polypeptide need to fulfil "Good Manufacturing Practice" (GMP) which includes guidelines to manufacturing and documentation. New suppliers need to be approved to secure that they can deliver material with a certain quality and audits to the new suppliers are often made. This whole procedure takes a lot of time and is costly. Getting a new supplier for critical products such as amino acids could take years and due to this each new supplier decision must be evaluated and it may not be worth investing in.

When manufacturing API there are a lot of material going into the process and the actual product that is being shipped out to the customers are quite small. PolyPeptide produces around 450 kg product per year but there are a lot of solvents, several tons each week, and other materials along the way that is included in the making of the pharmaceutical ingredient, which becomes waste that has to be shipped out and being handled through recycle processes by suppliers.

Due to the sensitivity of the products it is very important to have a secure storing and the handling needs to be done in the right way. The site of PolyPeptide is located next to a residential area which means that they have restrictions on the site on how much chemicals and solvents they can store. Due to this lack of storage they have access to an additional warehouse facility nearby in Malmö from where they can have solvents and chemicals transported to the site.

The location of the site makes further expansions of the premises impossible, so not much more production or storage area can be built, however the current area could maybe be rearranged to enable more space. As the direct material, also called GMP products, purchased by PolyPeptide has strict rules for handling the receiving executes quality controls. This is an important step which takes time.

4.2 Supply Chain Mapping

Based on the empirical data the activities in the supply chain at PolyPeptide has been mapped out in Figure 4.1 where the focus area of the Thesis also is marked. This mapping was done to get an overview of the supply chain and get an understanding of the current situation.

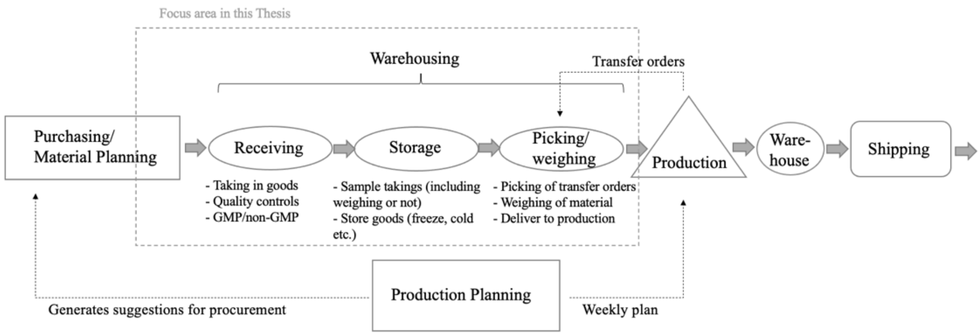

Figure 4.1: Mapping of the SC at PolyPeptide Malmö

4.3 Production Planning

The production plan is a weekly plan set and managed by the Planning Manager. A more detailed daily plan is then set by the production from this. There are two different types of projects that PolyPeptide does. The first one is customer projects, which is specific requests from customers and often smaller, and the second one is contract manufacturing, which is larger projects that are planned earlier and are an ongoing operation. Both of these are put into the production plan. There are around seven customer project per year as it is now.

4.3.1 S&OP process

Since a couple of years back PolyPeptide uses a S&OP process in order to plan the production. Using S&OP has many benefits and it was implemented in order to avoid decisions about the production being taken without mandate. With the S&OP process the communication is more structured and the silo thinking is avoided, which, as are discussed by Grimson and Pyke (2007), are one of the advantages with the S&OP process. The process goal is to find a balance between the sales side and the production side by an exchange of information and cooperation. This is done by using forecasts, internal meetings, action lists and production plans. The most important part with the S&OP is to have meetings where the production plan is discussed in a structured way and to get a joint vision. The S&OP process involves representatives from sales and production as well as executives and the Planning Manager. The Planning Manager are, organizational, a part of the Supply Chain Department. However the planning of capacities for the supply chain are not involved in the S&OP process.

4.3.2 Production Plan

The plan is set during the S&OP process with a timeframe of 0-12+ months, but can be changed when new customer projects are brought in. The ongoing operations is then sometimes postponed in order to give space to customer projects, much in line with the theory of spackling, presented by Cattani et al (2002), that gives the make-to-order projects priority. New projects can be added with a notice of just a few months or up to a year, year and a half. The production plan is often full and it can be hard to fit in new projects. As it looks now the PolyPeptide production has a lot to do, but they do not want to say no to new projects as it is very important to keep a good relationship with the customers. Even if there are additional PolyPeptide sites, the Malmö site is often requested by the customers due to their high level of competence in the product development department.

This year PolyPeptide has moved and rebuilt its warehouse area on the site and is adding a new production line which will make it easier to fit customer projects into the production plan. Increasing capacity in the production will make it important to evaluate future capacity requirements in the supply chain as well, as discussed by Krajewski et al. (2018).

The production scheduling uses a frozen zone of one week (5 days), meaning that no alterations to the production schedule are allowed to be done in that time. This is however not fully implemented yet, but when it is this would mean that the supply chain would know what should be done one week ahead and could plan better and know what capacities that are needed. The production planning does not take into account the capacities of the supply chain and the supply chain is therefore affected differently depending on what type of production that is run.

The production consists of different lines for steps in the projects which are: purification, fission or oxidation, Solid Phase Peptide Synthesis (SPPS), Liquid Phase Peptide Synthesis (LPPS) and freezing. The production plan shows these lines and the manufacturing projects that are planned out for each week. The manufacturing of the API has several steps beginning with the synthesizes. The synthesis then sometimes also has several steps that are needed to be done in a specific order and that are dependent on each other, the steps then need to be planned after each other. After the synthesis there is the purification phase and after that the freezing. Sometimes an oxidation or fission phase is set between the synthesis and the purification. The different phases are all planned by the fact that they are depending on each other. For some projects the synthesis phase is done by another company and PolyPeptide purchase that material from them.

It varies how often the contracted manufacturing projects are run. Some are run continuously and some only once or twice a year. The number of steps in the projects and the time it takes for them also vary. The contracted manufacturing projects can be seen in Table 4.1, where the column "occurring" refers to how often the projects appear in the production plan, where rarely means only once or twice a year. As soon as future projects are confirmed they are put into the production plan. The production plan shows the upcoming year and even further, however changes could still be made.

Table 4.1: The contracted manufacturing project

Project	**Phases**	**Occurring**
PPL1522	LPPS, oxidation, purification, freeze	Continuously
PPL1523	SPPS + LPPS, purification, freeze	Continuously
PPL1525	LPPS, purification, freeze	Continuously
PPL154	SPPS, fission, purification, freeze	Often
PPL169	SPPS, fission, purification, freeze	Rarely
PPL189	SPPS, purification, freeze	Continuously
PPL2787/88	Purification, freeze	Continuously
PPL1527	SPPS, purification, freeze	Often
PPL1529	SPPS, fission, purification, freeze	Rarely
PPL1554	SPPS, fission, purification, freeze	Rarely

4.4 Purchasing and Material Planning

The purchasing department consist of four employees, where everyone has their own category that they are responsible for. All of the procurements are done in the ERP system that is connected to the production plan. The ERP system gives suggestions for when to procure items and in what quantities, this is called "planned purchase order". Recently a segmentation based on frequency and volatility of the articles being removed from the warehouse was done. This gave the purchase department an overview of whether a product was a slow mover or fast mover and if they should be kept in stock or not. Based on this segmentation some of the material has a safety stock and some does not. There is a wide range of articles that all have different lead times, distributers etc. and nothing in particular links all of them together. There are nine different categories of products which are: solvents, packaging, primary packaging, gas, intermediates, resin, reagents, starting material and others.

As the ERP system is connected to the production plan, the suggested procurements will change if the production plan changes. If the changes are made with short notice the system may not be able to give all the signals to the procurer as it does when it has been planned for a longer time. This is a challenge for the purchasers, and it happens that non-forecasted customer projects uses material from the warehouse that was purchased to a contract manufacturing project. The system then adjusts and gives new suggestions for purchasing, but if it is a product with long lead time this could cause a problem. The purchasing department is also responsible for buying indirect material such as protection gear, chemical equipment etc. These are products that is not directly included in the production process.

Due to the complexity to approve new suppliers, PolyPeptide is somewhat dependent to use the ones that they have. New suppliers are however qualified and brought in relatively frequently. Overall it is important for PolyPeptide that the suppliers commit to their given lead times as delayed shipments could cause problems. Some of the suppliers are better than others to fulfil this. The lead times for the materials differs substantially, from a year to just five days. Within the suppliers there are different lead times, so it is not just some suppliers that has longer lead times and some that has shorter. To avoid delayed shipments the procurements are done as early as possible, based on the ERP system. The responsibility of the purchasing department ends when the material has been delivered to the site, then the receiving takes over.

A problem for the purchasing department is to know what the limitations of utilization of space in the warehouse is at certain times and knowing if there are capacities for the procured material. In order to plan the orders better they would need to know how the free space in the warehouse would look when the order should be delivered. They would like to know what the utilization rate in the warehouse is and be able to connect that to purchases. Today the system does not let them know how much space there is free at the warehouse and it makes it hard to plan the load on the warehouse. Another problem is that the purchasing department cannot take into consideration the load on the receiving when putting an order as they plan their procurements after the production plan and the suggested procurements from the system. As there are several purchasers that orders different articles it is also hard for them to know and synchronize with what specific day of the week the other purchasers order to, especially since some of the articles has a long lead time. Planning material is today not done on the basis of the capacity in the warehouse, but rather to meet the aggregated raw material demands from production and the outcome of the production plan. In addition to this the suppliers do not always keep their delivery dates which makes planning even more difficult. All of this result in an uneven flow for the receiving.

4.5 Warehousing

The warehouse consists of seven employees. Three of them works inside with preparing material, for example weighing up material for the production, and three of them works on the outside with receiving trucks, moving material and clearing out waste. The last employee works with receiving. The employees work in two shifts and there are two employees working in the morning and one in the afternoon both for the outside operation and the inside. The receiving only works day shift.

4.5.1 Receiving

The receiving performs quality controls and take in all products that arrive. This includes both GMP products and non-GMP products. The material that are GMP products takes more time as they have to be controlled by taking small samples from each sub-batch and test them. Receiving also controls and clean up the packaging of products, prints out labels and register the arrival. If the products are stored on a pallet they switch it to a plastic pallet, due to safety rules connected to pharmaceutical product handling. Some products do not take long to receive, could be around ten minutes, while others could take five hours. This depends a lot of how many products there are in the delivery and what type they are. As it is now, the flow of products varies every day and this makes it hard for the receiving to plan their week. It creates stress for the receiving to have the pressure of too many deliveries at the same time. The problem here is the uneven flow for the deliveries from the purchasing department as mentioned before.

4.5.2 Warehouse, Storage

The warehouse at PolyPeptide has several locations for the articles that differs in size. Some storage areas are for products with special requirements such as for example flammable, cold and freeze. As it is now PolyPeptide knows the number of storage locations, but they have no data of the volume and size of the articles that they purchase which they can relate to the warehouse locations. For example if there is one pallet or half a pallet location needed. As the articles are stored in batches and sub-batches it can vary for the same article what size of storage location that is needed. Locations can be used for different items and how many that fits depends on the volume of the specific items. Some of the chemicals are stored outside in the yard of the facility and there is also an external warehouse used for solvents. PolyPeptide have data on what they order, in what quantities and when it will be delivered but cannot relate this to the utilization of the warehouse and therefore have a problem with knowing if goods will fit when delivered and what their utilization of the warehouse is.

4.5.3 Warehouse, Preparing for Production

The warehouse personnel work with orders from the production called transfer orders and the time it takes to complete these depends a lot on the product. The employees pick and weigh the product, some have small quantities of just a couple of grams, and some are much larger. The nature of the pharmaceutical process makes the handling more complicated and it is important to follow all requirements. Some products you can just pick and it is ready and some are frozen and have to be taken out and be waited for to reach a certain temperature. Often the evening shift prepares the cold stored material by putting it outside for tempering, it has to stay in room temperature for 7 hours, and then the morning shift can weigh it when they come in.

Dealing with pharmaceutical ingredients also require protective gear when weighing sensitive and reactive products and thorough cleaning of equipment. The cleaning can also take different amount of time depending on the material handled. An order could take several hours but in the system an order is shown in the same way regardless the time it has taken to complete. The weighing of the raw material is the activity that takes the longest and is sometimes a bottleneck for the workflow. There is currently one room for weighing so only one of the employees can do this at a time, however there will be one more room for this soon to enable two people weighing at the same time. For further analysis an investigation of how this will affect the workflow and capacities will be done.

The amount of weighing's of material depends from day to day, sometimes it could be up to twenty times per day and sometimes just two. This affects the workload on the employees. During the day the employees get calls from the production asking for products that is not due now in the system but needed, this could for example be that the manufacturing process needs one more filter than usual, and this adds to the unpredictability of the day and takes time. The personnel in the warehouse also has some administrative work to do such as planning for what to pack and report what has been prepared and shipped to production in the system.

The employees working with preparing material for the production finds it hard to plan their days as they do not know how it will look like. Until recently there were only one person working with preparing material for the production on the morning shift and it was then hard for them to have time to both answer requests they got during the day and work with the planned tasks in the system. Now they are two people working but the workload is still high. When someone of the warehouse personnel is sick or have vacation, they have a problem with keeping up.

4.5.4 Warehouse, Outside Operation

The three employees working on the outside of the warehouse mainly works with moving of material. In this Thesis the focus will not be on this since the problems are more related to planning of the activities rather than lack of capacities or knowing their capacities. One issue is that the workers get request from the production of material that is needed with short notice and therefore cannot consolidate requests for the same type of material to save time. The intention is that requests should be made with one day's notice so that the planning will be more effective.

4.5.5 Overtime

The employees in the warehouse often works weekends to compensate for the high workload during the weeks, this is however not the initial plan. A table with the overtime for the seven warehouse workers can be seen in Table 4.2. The average overtime per month is 34.57 hours which means average 4.94 h per employee. Recently the warehouse was moved and rebuild and some of the overtime for the employees are due to this and not only caused by the usual operation. As mentioned by Krajewski et al. (2018) overtime is just a short-term solution and should not be made a regularity.

Table 4.2: The overtime for the employees in the warehouse, year 2020.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
h. of overtime	16.6	29.3	20.5	15.7	40.2	42.1	7.2	75.0	64.8
Avr. h/employee	2.27	4.18	2.92	2.24	5.8	6.01	1.03	10.7	9.26

4.6 Current Situation

The following sections will show the current situation and will present the problems and bottlenecks in the current setup in the supply chain at PolyPeptide and is based on the empirical data gathered through interviews.

The main area with problems in understanding the capacities and plan for the future setup is warehousing, and in particularly preparing material for the production. The main problem is the weighing when conducting transfer orders and the difference in time the orders take to fulfil. Here the capacities needed vary a lot and for further analysis the time spent on different materials and orders can be investigated. Another problem is the receiving area and the uneven flow of products. Here an investigation of the work hours needed and the flow of orders could be investigated. The receiving is connected to the purchasing where the main issue is that the flow is uneven due to purchases done based on the demand from the production plan. Problems are knowing receiving capacities and storage capacities in the future and be able to work from these. A summary of the problems identified can be found in Table 4.3 below.

Table 4.3: Summary of identified problems

Area	**Problems identified**
Purchasing	The flow of incoming goods - Knowing receiving capacities - Knowing warehouse utilization
Warehouse	Time overview, what projects drives transfer order time Bottleneck in weighing Uneven flow in receiving

Of these identified problems the time overview in the warehouse and what projects that drive the transfer orders were deemed to be the most important to analyze and will be the main focus in this project. The synchronization between purchasing and receiving is also interesting as it could help the receiving to plan their needed time better, therefore the flow of orders and the capacities will be mapped out. Knowing the warehouse utilization is also interesting but will not be further investigated in this project as it when discussed was deemed that no good way to realize this was available now and that is was not the priority.

The main focus is therefore to investigate the internal flows, the ones that the production drives from the warehouse in form of transfer orders.

5. Analysis and Discussion

This chapter will include an analysis of the capacities at PolyPeptide. The analysis is made in order to get an understanding of the capacities in the supply chain at PolyPeptide and enable planning for the future. The result will be the basis for the further recommendations.

5.1 Bottleneck in Weighing

As previous mentioned there is currently only one room for weighing and this is believed to be a bottleneck in the warehouse operations. There are going to be another room soon and in order to investigate how an additional weighing room will affect the flow and work in the warehouse one of the employees were interviewed. As it is now there are two employees working in the day shift, and one in the evening. An additional room would enable the employees to execute two weighing's at the same time, which would be possible at the day shift. According to the employees the occasions where both of them need to weigh at the same time are for the most part when incoming goods from receiving needs to be tested, which adds to the weighing needed to be done for the transfer orders from the production. A graph of the dates with number of orders of incoming goods that are tested by the warehouse employees in September 2020 could be seen in Figure 5.1 and a graph of the dates with the number of transfer orders requiring weighing in September 2020 can be seen in Figure 5.2. The dates are based on the when the transfer orders are marked shipped in the data sheet retrieved from the database. The Figure 5.1 includes the orders of the incoming goods that required to be tested and weighed by the employees working with preparing for production in September 2020, this does not include the incoming orders that the employee in the receiving tests or the incoming orders that does not require weighing.

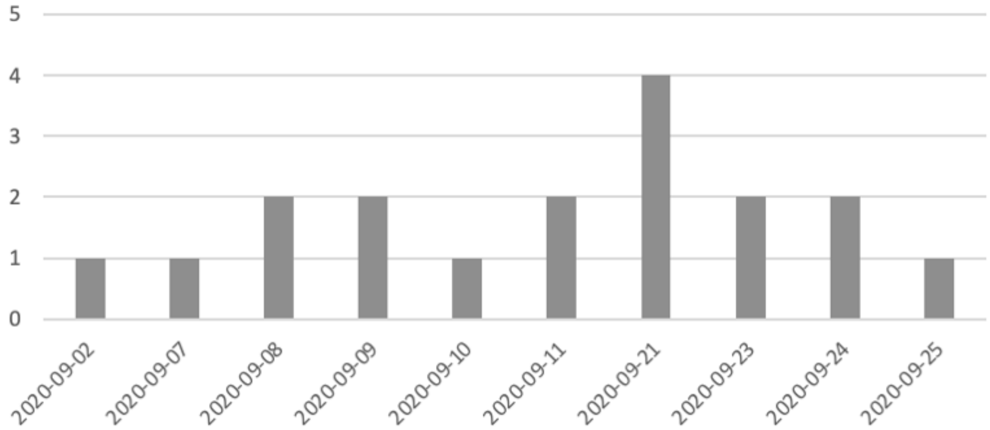

Figure 5.1: The orders of the incoming goods that was tested and weighted by the warehouse employees that prepare for production and not the employee in receiving, in Sept 2020

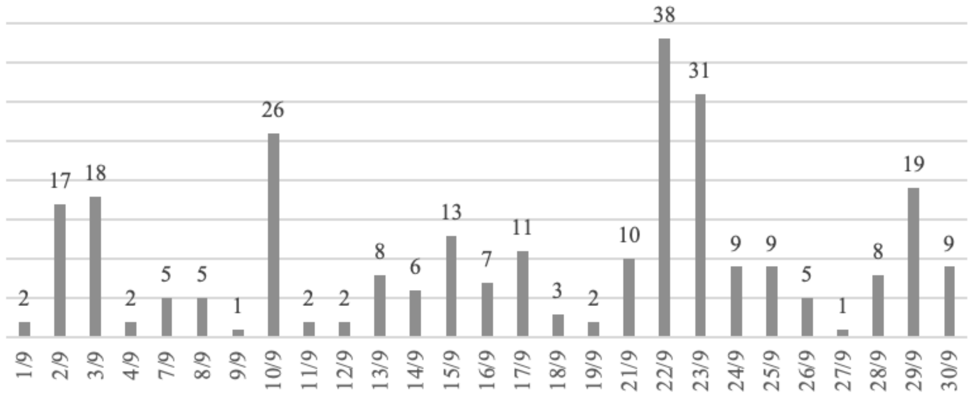

Figure 5.2: The number of transfer orders requiring weighing in Sept 2020

As seen in Figure 5.1 the dates requiring testing of incoming goods by the warehouse employees vary over the month. The average time for the testing of incoming goods that requires weighing are around 1 to 2 hours and this of course will add to the transfer orders with weighing. In the figure it is possible to see that the testing of incoming goods in September occurred at almost half of all the working days and thereby affect the capacity need of the weighing room and indicates that another room will be useful. In Figure 5.2 it is clear that the number of transfer orders that requires weighing vary each day and that there sometimes are higher peaks. Not all the weighing's takes the same time. The average time is 1 hour which when looking at Figure 5.2 means several days with high load on the weighing room.

An additional weighing room would help with the peaks of workload that arises when there are multiple weighing's needed to be done at the same time, but for most of the time the weighing of the transfer orders can be planned after each other and the employee that does not weigh can conduct other tasks related to the transfer orders. If the production would grow and the amount of transfer orders increase, additional personnel could be added and an additional room would be required.

From the interview it is clear that the employees in the warehouse think that there would need to be more employees in order to fully utilize an additional weighing room, but that it as it is now would be helpful at times. This is based on the warehouse employees' opinions and perception of the situation. They have discussed that the warehouse workers working with the outside operations could be trained to conduct the weighing's and then help the employees working on the inside when they have time to spare. In the five steps presented in the Theory of Constraints by Goldratt and Cox (1984) it is stated that if the bottleneck still is a constraint it should be considered to increase the capacity of it. This would mean to evaluate if increasing capacity in form of employees or workhours would be needed to utilize the additional weighing room.

In order to get an overview of what projects that drives most transfer orders that requires weighing a graph was made using the list of transfer orders for the year 2020 retrieved from the database and sorting on the ones that included weighing. The results of the projects with most weighing can be seen in Figure 5.3 below. The three projects requiring the most weighing is PPL154, PPL1522 and PPL189. PPL1522 and PPL189 are projects that are run continuously in the production and PPL154 is run often which will add to the ongoing capacity need of the weighing room and a difficulty to plan for the projects to not be at the same time and an additional weighing room would double the possible capacities to conduct weighing's.

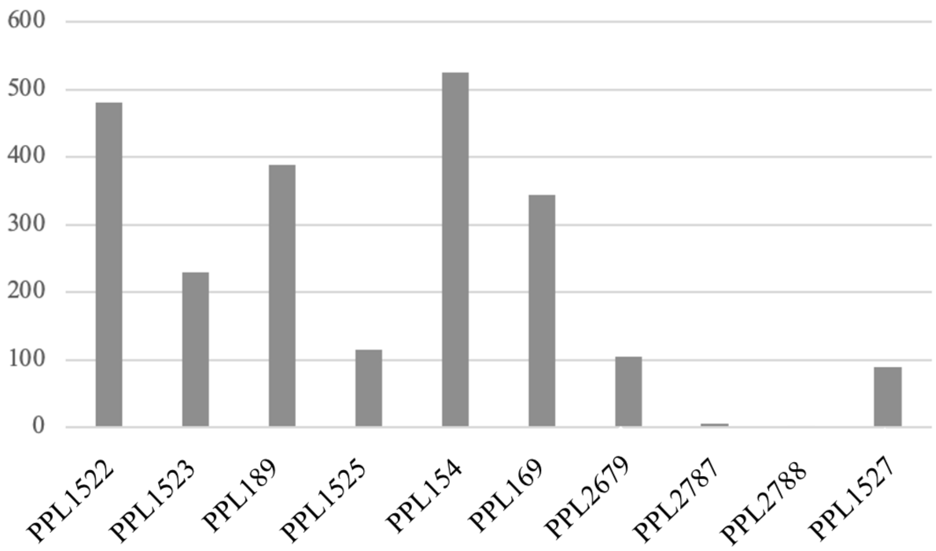

Figure 5.3: The number of transfer orders requiring weighing in 2020 divided to what projects they are related to.

5.2 Mapping of Time

In order to get a better overview of the time needed in receiving and the warehouse section that prepares material for the production, a mapping of the time was made. This shows the capacities in form of working hours that is needed as well as the working hours available. One month, September 2020, were analyzed to give an overview. Currently there is no data collected about the time orders and other tasks take, either in the receiving or picking/weighing. This mapping was made from quantitative data in form of lists of transfer orders and receiving as well as interviews with the employees working with these tasks that could give an estimation on how long time these orders and tasks takes. The list of the time used in average each month in the warehouse for each project in the production was done by one of the employees working with the transfer orders. This mapping will show what projects that consumes most time and later these projects will be further investigated and the individual steps in them mapped out to get a more details of what drives time in the warehouse and receiving.

5.2.1 Receiving

Together with the employee that is working in receiving all the activities performed were mapped out as well as all the specific incoming goods for September 2020 and how long time these to take in. The mapping of the time can be seen in Table 5.1. The receiving takes in all the incoming goods and perform quality checks and samples on some of the incoming goods. There was a total of 66 deliveries to the receiving in September 2020. A detailed list of the orders was retrieved from Qlik and used for mapping the time for taking in goods, including some that needs sample taking. There are also additional orders from the global warehouse where samples have to be taken. The samples take approximately 0.5h to perform and there are around 10 of these every month. The receiving is also responsible for non-GMP goods and this takes approximately 1h every day to handle, which would mean 22h in September 2020.

Table 5.1: Capacity in receiving, working hours – Sept 2020

Activity	**Time (h)**	**Quantity Sept 2020**	**Total Hours**
Taking in goods	*	66	79
Sample taking	0.5	Approx. 10	5
Non-GMP	1	/day	22
Total hours needed			*106*
Capacity, hours (1 employee)			*154*
Utilization = Hours needed/Available hours			*69%*

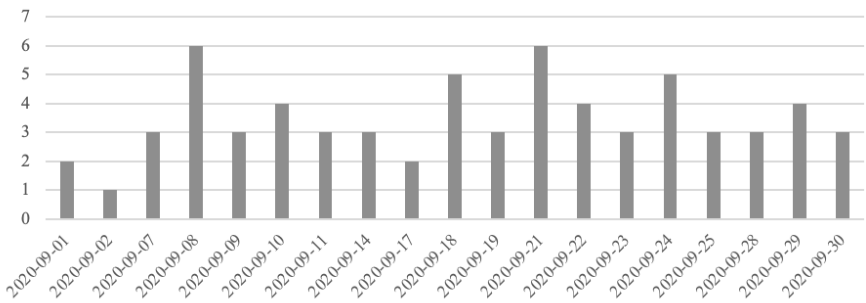

Figure 5.4: The orders delivered to receiving September 2020

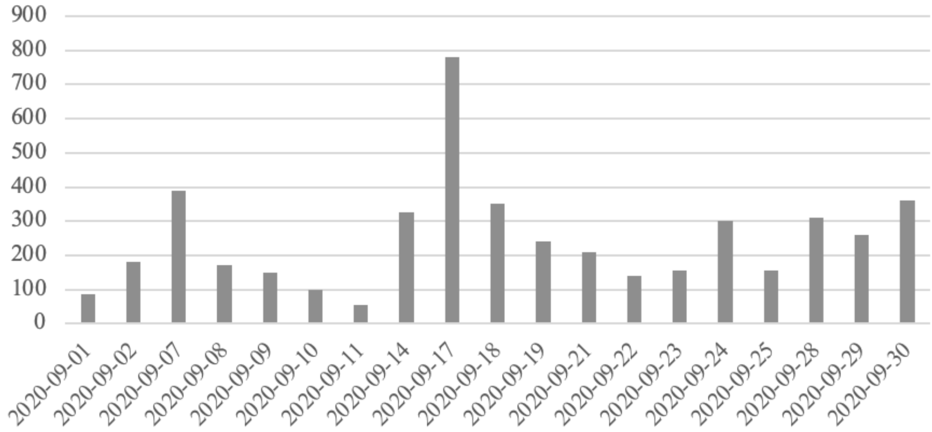

Figure 5.5: The time (minutes) of receiving orders September 2020

Figure 5.4 shows a graph over the number of orders delivered to the receiving in September 2020. From the list of deliveries, the time for each delivery was estimated by interviewing the employee working in receiving. The required time for different products is something that is not included in the database today and these estimations done here are based on the experience of the employee that has worked several years in receiving at PolyPeptide. Figure 5.5 shows a graph of the time required, based on the list made of the time, for the deliveries for each day in September 2020. As can be seen in Figure 5.4 and Figure 5.5 the flow of products and time needed vary a lot each day. It can be seen from the figures that the number of received orders are not related to how much time that is needed and instead it will depend on what type of goods that are delivered. In order for the receiving to be able to plan their day information on upcoming deliveries and what material they include are needed.

Overall, as can be seen in Table 5.1 the time for receiving of GMP and non-GMP products and taking samples are taking up approximately 70% of the working hours available during the month, which is calculated in accordance with measures of capacity presented by Krajewski et al (2018). This gives a good overview of how much time is spend doing actual receiving of goods and shows that the capacities for taking in goods exist. When interviewing the employee, it is clear that the problem is often when a lot of deliveries comes in at the same time or other activities such as requests from production and others which takes time and interrupts the work in receiving. If analyzing the detailed list of time spent on receiving products further, specific orders could be linked to the projects in the production.

5.2.2 Preparing for Production

Together with one of the employees working with transfer orders in the warehouse a mapping of the time was made. This mapping is based on the employee's experience as no data of the time spent on transfer orders or the projects exist today. The interview also provided information about the different task and activities that the personnel in the warehouse carries out. This only involves the three employees working with the operations inside the warehouse, not the receiving or the outside operations of moving goods. Like the previous mapping of the receiving, this mapping will be focused on September 2020 and later a more detailed mapping of the production plan and the different steps in the manufacturing projects will be made.

The warehouse workers on the inside helps receiving with taking samples on some of the incoming goods. Each of these samples takes around 1 to 2 hours to carry out and in September 2020 there were 18 sample takings. The warehouse workers also carry out transfer orders requested for projects in the production and a figure of the 815 transfer orders during September 2020 can be seen in Figure 5.6. This figure shows that the number of transfer orders vary each day.

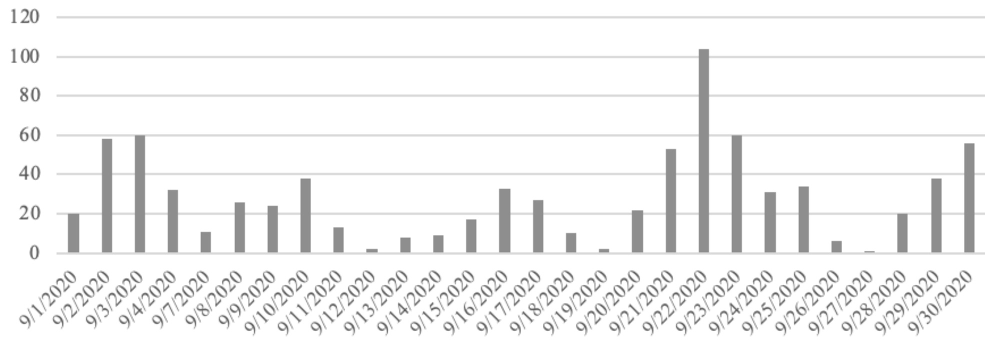

Figure 5.6: The transfer orders in September 2020 over time

The transfer orders all vary in time and a general mapping of the time spent on transfer orders every month connected to different projects was made and can be seen in Table 5.2. It is an approximation done by one of the employees in the warehouse of the time spent on different projects each month, based on experience and are not related to the specific number of transfer orders in September. Instead this mapping shows how much time that is spent in average on transfer orders connected to specific projects each month. It does not, however, show the different steps that exist in each project and is more of an indication for what projects from the production that drives most time in the warehouse and how much time that is spent every month. As can be seen in Table 5.2 these are PPL1522, PPL189 and PPL154, which are also the three projects that required the most weighing's (as shown in section 5.1). However, which projects that are scheduled vary over time and will not be the same each month. To fully understand what is driving the workload in the warehouse a further investigation of the different projects will later be done. The mapping done in Table 5.2 is based on an equal amount of time spent each month on transfer orders, and the reason that this is how it is perceived by the employees could be due to the planning of the production and how the projects are laid out. To be useful for future planning, it will be necessary to look further on the steps for each project and the time related to these since the actual time every month, and even week, will differ depending on what projects that are run then, even if some of them are run continuously.

Table 5.2: The time spent on projects in average every month

Project	**Average time every month (h)**
PPL1522	55
PPL189	56
PPL154	80
PPL1525	35
PPL1527	30
PPL1523	15
PPL2787 & PPL2788	40
Total	*311*

An additional task for the employees in the warehouse is to provide the production with acetic acid and ammonium acid, which takes around 45 min per order. In Sept 2020 there were 27 of these orders. There are also requests from the production outside of the transfer orders, and some of the requests require weighing that would take around 1 hour. The requests without weighing would take around 30 min. In September 2020 there were 9 requests that required weighing and 37 other requests. There is also time spent on storing the finished products when the production has manufactured it, this takes around 2.5 h every week. In addition to this each employee spend 20 min every day on meetings. A list of this mapping of time can be found in Table 5.3 which summarizes the activities discussed above.

Table 5.3: Capacity in the warehouse, working hours

Activity	**Time (h)**	**Quantity Sept 2020**	**Total Hours**
Samples in receiving	1.5	18	27
Transfer orders	*	815	311
Acetic acid & Ammonium acetate	0.75	27	20.25
Storage of Finished Product	2.5	/week	10
Requests (weighing)	1	9	9
Requests (no weighing)	0.5	37	18.5
Meetings	1	/day	22
Total hours needed			*417.75*
Capacity available, hours (3 employees)			*462*
Utilization = Hours needed/Available hours			*90%*

As can be seen in Table 5.3 the hours needed to complete the mapped activities are less than the hours available. Around 90% of the available time is spent on the listed activities, and therefore it should be sufficient to carry out the work in the warehouse. But as previous mentioned overtime is often occurred and this mapping is based on the average time spent on transfer orders and the steps in the projects will be analyzed further to get a more detailed view. The mapping is based on several qualitative data from the employees, and when interviewing them it is indicated that the work often are disturbed by calls from the production with questions, that often are not needed and that this requires unnecessary time, which is not accounted for in this mapping due to the difficulty to estimate. A reason for the overtime could also be that the number of hours needed vary each day and week and creates peaks in capacity need which could be difficult to cover, and additional capacity is needed to cover this.

5.3 Mapping of Projects in the Production

In the previous mapping the time spent on the projects in the production were estimated in average for each month, which gave an indication of the workload. But no details were given about what activities in the production that is actually driving the workload. In this section a further mapping will be made which will describe the different stages of each project, such as synthesis, fission and purification, and the time these takes for the warehouse to prepare. The hours in the mapping are not the production time, but is instead related to the warehouse activities such as picking, weighing and preparing the materials for that project in the production. This mapping will give a more detailed view of what in the production that drives the workload in the warehouse and where the focus should be if wanting to work more efficient and save time. But also to be able to plan to avoid high peaks in workload in the warehouse. Since the different steps in the projects presented are based on the ones existing in the production plan, this mapping could be used to estimate future capacity needs in the warehouse based on future setups of the production plan.

The customer projects are just occurring a few times per year and are thus changed often. They are therefore not included in this mapping. Instead this will include all the recurring and ongoing projects of contracted manufacturing, that will be in the production plan in the future as well. The mapping of the projects steps and the time this takes from the warehouse, was made through interviews to gain knowledge about the production plan as well as the activities in the warehouse connected to this (Table 5.4). The time is estimated by one of the employees and is based on experience with working with transfer orders.

Table 5.4: Time required in the warehouse for the projects broken down in steps

Step	**Time(h)**
PPL1522	
Synthesis (LPPS) – (1-7)	5
Synthesis (LPPS) – (8-9)	5
Synthesis (LPPS) – (1-9)	5
Red/ox	1.5
Purification	7
PPL1523	
Synthesis (SPPS) – 500015 (13)	10
Synthesis (SPPS) – 500011 (12)	10
Synthesis (LPPS) – 500012 (14)	5
Synthesis (LPPS) – 500013 (14)	5
Synthesis (LPPS) – 500014	5
Purification	5
PPL1525	
Synthesis (LPPS) – (1-2)	12
Synthesis (LPPS) – (1-3)	12
Synthesis (LPPS) – (4-7)	12
Synthesis (LPPS) – (5-7)	12
Synthesis (LPPS) – (1-7)	12
Synthesis (LPPS) – (8-9)	12
Synthesis (LPPS) – (1-9)	12
Purification	5

Step	**Time(h)**
PPL154	
Synthesis (SPSS)	18
Fission	6
Purification	8.5
PPL169	
Synthesis (SPSS)	35
Fission	6
Purification	6
PPL189	
Synthesis (SPPS)	15
Purification	6.5
PPL2787/88	
Purification	6.5
Freeze	2.5
PPL1527	
Synthesis (SPPS)	11
Purification	6
PPL1529	
Synthesis	6
Fission	5
Purification	5
PPL1554	
Synthesis	6
Fission	5
Purification	5

The mapping of the steps for the projects in Table 5.4 shows that the synthesis is often the step requiring the most time from the warehouse. Especially the synthesis for PPL154, PPL169 and PPL189 are time consuming. PPL189 is also one of the projects run most frequently and there is one purification for this project almost every week and synthesis several time each year. When looking at this table and the numbers, it is clear that some of the activities in the production drives a significant higher amount of time than other. Thus, a combination of several steps that requires a lot of time will cause peaks in the workload and capacity need in the warehouse. For example, the synthesis of PPL169 and PPL154 which, if scheduled and at the same time, would require 33 hours to prepare. If wanting to smooth out the peaks in capacity need in the warehouse, activities requiring a high amount of time should be avoided to be scheduled at the same time.

The steps requiring most time are:

- PPL169 Synthesis
- PPL154 Synthesis
- PPL189 Synthesis
- PPL1525 Synthesis

In order to view the difference in workload each week, depending on what projects that are planned for in the production, the mapping in Table 5.4 was used. It was used together with the production plan to map out different weeks this year. Table 5.5 show the mapping of September and it is specified which projects that were set to begin in the production plan every week, and what step of the project this includes. The mapping is based on what projects that started that week, as that is what the workload on the warehouse origins from. The projects could then be going on for more than one week but it is only the starting point that is shown here, as the focus is solely the workload on the warehouse and not the time in production.

Table 5.5: The projects run and the time required in the warehouse, Sept 2020

Week	Step	Projects	Hours
36	Synthesis	PPL1525, PPL1527	23
	Purification	PPL1527, PPL154, PPL189, PPL1525	26
	Total		*49*
37	Synthesis	PPL1522, PPL1522	10
	Red/ox	PPL1522	10.5
	Purification	PPL2787/88, PPL1522, PPL154, PPL189, PPL1525	33.5
	Total		*54*
38	Synthesis	PPL154, PPL189	33
	Purification	PPL1527, PPL154, PPL189, PPL1525	26
	Total		*59*
39	Synthesis	PPL154	18
	Purification	PPL2787/88, PPL1522, PPL154, PPL189, PPL1525	33.5
	Freeze	PPL2787/88	2.5
	Total		*54*
	Total Month		*216*

For a larger overview, the time in October and November for the different steps in the projects were mapped out (Table 5.6). This does not specify which projects but only the time, for an easier overview. This table shows that the time spent in the warehouse on preparing for the production can vary each week and that it creates an uneven flow. It can also be seen that the synthesis step is almost always the one requiring most time from the warehouse.

Table 5.6: Time mapped out for October and November in 2020

Month	**Oct**					**Nov**			
Week	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*
Purification	26	13.5	39.5	15	22	21.5	15	33.5	15
Red/ox/fission	18	0	0	0	18	0	0	0	18
Synthesis	30	45	0	23	57	18	27	40	24
Freeze	0	0	2,5	2,5	0	2.5	2.5	2.5	2.5
Total week	*74*	*58.5*	*42*	*40.5*	*97*	*42*	*44.5*	*76*	*59.5*
Total month	*312*					*222*			

It would be useful to further look into the transfer orders connected to the projects that demands the capacity in form of time. Based on the interviews with the employees, the weighing of the transfer orders is what requires most time. Most time is required when there is a lot of amino acids in the projects, like in PPL154 and PPL189, which is why they are projects that drives a lot of time.

6. Conclusion

This chapter will cover the answers to the research questions from the introduction chapter. The answers will be based on the empirical data and the analysis and a recommendation for the future will be given for future planning of capacities.

6.1 Research Questions

The research questions from the Introduction chapter were stated in order to establish the goals for the Thesis and will be the base for the recommendation that will be given later.

The research questions were:

RQ1: What capacities does the supply chain have?

RQ2: How is the production affecting the supply chain?

RQ3: Which activities in the production generate a high load on the supply chain and how?

6.1.1 Research Question 1

The first research question included to understand what the current capacities within the supply chain were at PolyPeptide and also to gain an understanding for where the constraints and bottlenecks were. It was made clear that the company had knowledge about some of the problem areas and their causes. Like the uneven flow in receiving which occurs due to the procurements being done from suggestions based on the production plan, as well as suppliers that not always deliver on time and where more strict agreements would be needed to be made. Another problem identified was connecting purchasing to the utilization of the warehouse. The identified capacity problem that became the focus of this project, due to the lack of knowledge and overview of this for the company, was the transfer orders time and their relations to the projects in the production plan. In order to get an overview of the capacity and time requirements the receiving and warehouse section that works with transfer orders to the production was mapped out. This showed that the receiving activities requires 70% of the available time, analyzed for September 2020 as a reference. It also showed that the warehouse activities, inside operations, requires 90% of the available time. At the same time, it was identified that overtime often occurred and when interviewing the employees it was clear that the workload seemed to be varying and that the variation in what projects that was set in the production plan resulted in different capacity needs from the warehouse.

A bottleneck in weighing was identified as the main concern in terms of being influenced by the production. Only one person can conduct the weighing's at the same time and this cause a constraint on the capacity. The decision to add an additional weighing room had already been made by the company, which would double the available capacity for conducting weighing's.

6.1.2 Research Question 2

The second research question included to understand how the production affected the supply chain. When researching the receiving and warehouse by conducting interviews with the employees about the workload, it was made clear that the production drives the transfer orders and that they all differ in how much time they require from the employees. The transfer orders will affect the workload on the warehouse personnel and they depend on what project that are being planned in the production. What projects and steps in the projects that are put in the production plan, as well as which of them that are being run at the same time, will also affects the number of weighing's that will be needed to be conducted by the warehouse employees. Different projects and steps require a different number of weighing's. The production will also affect what material that is being purchased and the receiving's workload and flow of incoming goods. As the main focus was the transfer orders and preparing material for the production, this was the majority of the parts later investigated.

6.1.3 Research Question 3

The last research question covered what activities in the production that generated a high load on the supply chain and how. As mentioned in research question 2, different projects in the production plan will affect the workload different depending on what projects that are run in the production. To answer this last research question an understanding for the production plan and the connection between the different steps in the processes was established. Each project was mapped out in what steps they included and how often they were occurring.

In order to understand what was affecting the requirements for capacity in the weighing room the projects requiring a lot of weighing's were identified and can be seen in Figure 6.1 below. This summarizes the transfer orders with weighing's to the different projects and shows that both PPL154 and PPL189, which includes a lot of amino acids, require the most weighing together with PPL1522, which is a project that are run continuously.

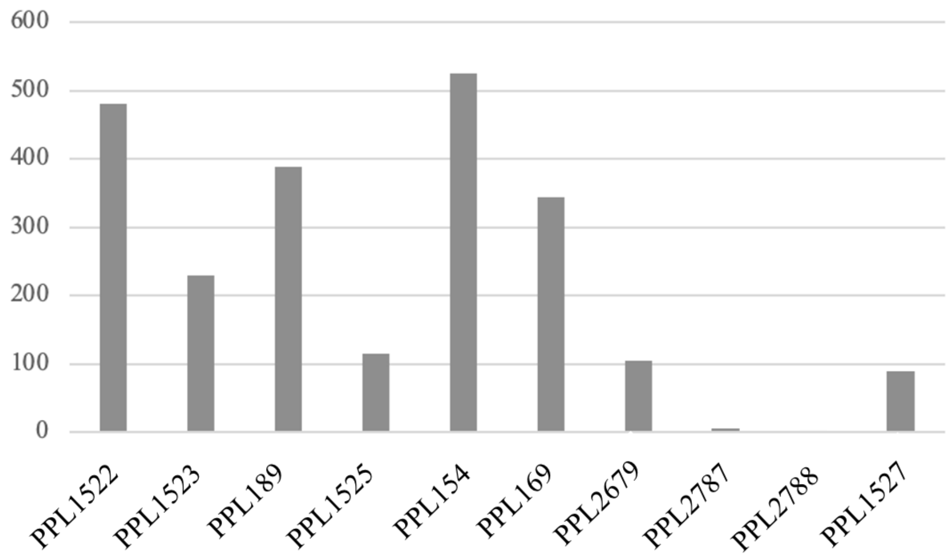

Figure 6.1: The number of transfer orders requiring weighing in 2020 divided to what projects they are related to.

In order to understand what activities in the production that generates a high load on the warehouse section that carries out transfer orders, an overview of the time spent on each project every month in the warehouse were made. This gave an initial view of the situation. After that, a more detailed mapping of the activities in the production was made in order to see how they affected the supply chain capacities in different ways. The results, seen in Table 6.1, shows that the synthesis step often is the one that drives to most time in the warehouse and particularly in some projects that has a very high number of hours required, with PPL169 being the highest.

Table 6.1: Summary of the required time in the warehouse to prepare for different steps in the projects sorted by time required

Project	Step	Time(h)
PPL169	Synthesis (SPSS)	35
PPL154	Synthesis (SPSS)	18
PPL189	Synthesis (SPPS)	15
PPL1525	Synthesis (LPPS) – (1-2),(1-3),(4-7),(5-7),(1-7),(8-9) or (1-9)	12
PPL1527	Synthesis (SPPS)	11
PPL1523	Synthesis (SPPS) – 500015 or 500011	10
PPL154	Purification	8,5
PPL1522	Purification	7
PPL189	Purification	6,5
PPL2787/88	Purification	6,5
PPL154	Fission	6
PPL169	Fission	6
PPL169	Purification	6
PPL1527	Purification	6
PPL1529	Synthesis	6
PPL1554	Synthesis	6
PPL1522	Synthesis (LPPS) – (1-7), (8-9),(1-9)	5
PPL1523	Synthesis (LPPS) – 500012, 500013 or 500014	5
PPL1523	Purification	5
PPL1525	Purification	5
PPL1529	Fission	5
PPL1529	Purification	5
PPL1554	Fission	5
PPL1554	Purification	5
PPL2787/88	Freeze	2,5
PPL1522	Red/ox (one)	1,5

This gave an understanding for how different the required time from the warehouse was, depending on what step in the production that was scheduled. This can be used to either plan the production more after to avoid peaks in capacity needed in the warehouse or to know in advance the need for capacities in the warehouse and plan the number of employees after this.

6.2 Recommendation

Based on the results and the analysis of this project it is recommended that PolyPeptide further investigate the specific transfer orders that are related to the projects that drives the most time for the warehouse, and the specific steps of these project. The identified steps requiring most capacity in form of working hours from the warehouse are:

- PPL189 – Synthesis, runs often, requires large amount of time to prepare
- PPL154 – Synthesis, runs less frequent, requires large amount of time to prepare
- PPL169 – Synthesis, does not run that frequently, requires the largest amount of time to prepare
- PPL1525 – Synthesis, runs often, requires quite much time to prepare

It is believed that these projects and steps listed are the ones where time and money could be saved if improving the way of working with these and planning more. Due to the large amount of transfer orders the recommendation is to focus on these.

Other projects that does not drive as much time from the warehouse to prepare for, but still is run often and therefor also are interesting to further analyze transfer orders for are:

- PPL1522 – Synthesis and purification, runs often, requires less time to prepare
- PPL189 – Purification, runs continuously
- PPL154 – Purification, runs continuously

The projects PPL1522, PPL154 and PPL 189 are also the projects that requires the most weighing's and since this is a time-consuming activity that can cause a bottleneck it is recommended to further analyze these projects.

Many of these projects are being run continuously or very often and if the transfer orders are investigated further and planned for more in advance it will be easier to plan for the capacity in warehouse. When conducting the interviews it was clear that the warehouse employees have a lot of knowledge of the transfer orders and the different steps in the production plan. The large amount of different transfer orders make it hard to add data about the required time for each of them as well as all the different weighing's, and it is therefore recommended that if further looking into the transfer orders, and what can be improved with the way they are planned or performed, this would have to be done in close collaboration with the warehouse employees who knows the problems and needed capacity.

Based on the analyze of the weighing room it is recommended that PolyPeptide evaluates the additional weighing room after it has been put into work, to see if it, as predicted, helps with the peaks of workload that the weighing creates. They should also further evaluate if an additional employee, or part-time hired labor, might be needed to be able to utilize the capacity of the weighing room fully as discussed in the analysis.

The next step for taking this project further could also be for PolyPeptide to look into what incoming goods that are critical and takes long time and see what projects they belong to. The mapping of time of incoming goods were only looked into for one month in this project but to be able to connect this to the different projects in the production more data on a longer period of time is needed. This would have to be done in collaboration with the employee working in receiving which has the knowledge of how time consuming different incoming goods are and could develop this data. If investigating the incoming goods for a longer period of time a correlation to the materials that take long time in the receiving and the projects that takes long time for the warehouse that prepares transfer orders for the production can be made. This would add to the knowledge about the steps in the projects and how much time they require in the warehouse.

Finally it is recommended that the list with the activities in the production plan and the time each step requires in the warehouse should be used when planning the production, to minimize the peaks of workload in the warehouse. The production plan has a lot of other things to consider as the projects have several steps that are dependent on each other and a set number of production lines. However, it is believed that having knowledge of the projects effect on the warehouse is valuable to have when planning for the production. This knowledge could help lower the peaks in workload, if the projects that takes the most time for the warehouse could be spread out to ensure less fluctuation in demanded capacity.

6.3 Contribution to Theory

The methodology used in this project could be used in several other setting as it includes general areas of interest of the method of case study research. This is also the case for the theoretical references which are connected to capacity planning. The Thesis provides an insight in the planning and mapping of capacities as well as how a supply chain gets affected by a production in an organization and the importance of being aware of how this is connected. In this project the analysis is specific to this case, but could be useful as inspiration for future research. There are limited studies on capacity planning in the supply chain, as was found when conducting the literature review, and the pharmaceutical context is a special sector where a lot of the focus is on the production and not the supply chain. This project could therefore contribute to this field in some way even if this project is specific to this case company. A future study and evaluation of the project would need to be done to strengthen the conclusion and the possible benefits.

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Appendix A

Guide for the initial general interviews

General
What is your title?
What responsibilities do you have in your daily work?

Capacity planning
How are you, in your role, working with capacity planning today?
Do you often have capacity problems?
What in the production is affecting you the most?
What are the consequences of these problems?
Is information about capacities collected today and if yes, how?
Do you feel like you have a good overview of the capacities?
Are there sections where you have too much/little capacity? If yes, what is the reason for this?