



## **Delivery Reliability**

# **Analysis of Make-To-Order productions at Plastprent Ltd.**

Patrick Karl Winrow



**Faculty of Industrial Engineering, Mechanical  
Engineering & Computer Science  
University of Iceland  
2012**



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Plastprent Ltd.

Patrick Karl Winrow

30 ECTS thesis submitted in partial fulfilment of a  
*Magister Scientiarum* degree in Industrial Engineering

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Reykjavik, June 2012

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# Abstract

Supply chain management adopts a systematic and integrative approach to managing the operations and relationships in a supply chain. The objective of the manufacturers in the supply chain is to reduce inventory costs and increase customer satisfaction levels. One way of doing so is to improve delivery reliability. The purpose of this thesis is to analyse the delivery reliability of make-to-order productions at Plastprent Ltd. Furthermore, look into and introduce possible ways to improve the company's delivery reliability. Both qualitative and quantitative research methodology was utilised in the thesis. The qualitative research data consisted of interviews with employees of Plastprent. The quantitative research data was gathered from Plastprent information system from previous year's delivery reliability and statistical analysis conducted. Moreover, processes and factors that affect the delivery reliability of Plastprent make-to-order products were defined with the help of the supply chain operation reference model and improvements introduced with the model in mind. Principally, the analysis finds that 81% of orders in 2011 were delivered on-time or early. The author recommends that Plastprent defines its delivery reliability objectives to customers and continue improving the reliability. The overall conclusion is that Plastprent delivery reliability is satisfactory but can be improved. Improvements were introduced to help Plastprent achieve better delivery reliability of make-to-order productions.

**Keywords:** Delivery reliability, Delivery window, Supply chain management, Customer satisfaction, Make-to-order (MTO), Processes.





# Útdráttur

Áreiðanleiki afhendinga er þáttur sem framleiðslufyrirtæki reyna ná árangri í til þess að auka samkeppnisstöðu sína á markaði. Tilgangur ritgerðarinnar er að greina afhendingar áreiðanleika/öryggi sérframleiddra vara hjá Plastprent hf. Einnig koma með tillögur að betrubótum til að auka áreiðanleika í afhendingum. Verkefnið greinir þá ferla og þætti sem hafa áhrif á afhendingaröryggið með hjálp Supply chain operation reference líkaninu. Auk þess eru tillögur að betrubótum kynntar með hugmyndafræði líkansins til hliðsjónar. Helstu niðurstöður verkefnisins eru að afhendingaröryggi Plastprents er ásættanlegt og flestir viðskiptavinir fá vörur sínar afgreiddar á réttum tíma. Ritgerðin hefur skilgreint á skipulagðan hátt afhendingaröryggi sérframleiddrar vara hjá Plastprent undanfarin ár og greint þá ferla sem hafa áhrif á afhendingaröryggið. Einnig voru tillögur kynntar til þess að auka áreiðanleika afhendinga til viðskiptavina.

**Lykilorð:** Afhendingaröryggi, Afhendingargluggi, Vörustjórnun, Ánægja viðskiptavina, Sérframleiðslur, Ferlar.



*Dedication*

*I would like to dedicate this master's thesis to my family, especially my father – YNWA.*



# Preface

Delivery reliability is a subject that many companies are familiar with and try to achieve; however, many are unable to get to grips with it. Many published papers focus on the importance of achieving high delivery reliability as it not only benefits the company itself but also, the customer.

*“Early and late deliveries introduce waste in the form of excess cost into the supply chain; early deliveries contribute to excess inventory holding costs, while late deliveries may contribute to production stoppages costs and loss of goodwill.”*

(Guiffrida, 2006)

*“High delivery reliability is one of the order winning performance criteria for make-to-order (MTO) companies.”*

(Soepenbergh, 2008)

It is important for production companies to understand the importance of delivery reliability, introduce ways to improve it and to ask the question “What can be done to improve delivery reliability?”



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# Abbreviations

The following is a list of common abbreviations used in the thesis.

ISK	Icelandic Króna
MTO	Make-to-order
MTS	Make-to-stock
SCM	Supply chain management
SCOR	Supply Chain Operations Reference model



# Acknowledgements

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# 1 Introduction

## 1.1 Background

In competitive markets, such as in the packaging industry, it is widely acknowledged that manufacturing functions can help companies stay competitive. Therefore, manufacturing companies aim to achieve the highest levels of performance in manufacturing; more precisely, in quality, flexibility, delivery and costs. These, and other factors, are acknowledged being the key to success. Therefore, it is imperative to explore whether high-levels of performance along manufacturing capabilities can be accomplished.

An important aspect of manufacturing capability is known as delivery reliability and is the main focus of this thesis. In particular, the focus will be on delivery reliability of make-to-order productions at Plastprent Ltd.

High delivery reliability is one of the order winning performance criteria for make-to-order (MTO) companies (Soepenbergh, 2008). In today's global economy, competition is fierce and companies need a competitive advantage to be able to compete.

Plastprent is a plastics producer situated in Iceland and is very small compared to the global market. It serves a small but established market. It faces increasing competition from foreign firms who offer low prices, which is a manufacturing function that is hard to compete with. However, price is not the only factor in which firms compete; quality, flexibility and delivery are among the others. When a company cannot compete with low prices it needs to find a function that it can compete in. As for Plastprent, it is not always able to promise the lowest prices but the company can offer great quality, flexibility and reliable delivery. Their closeness to the market is an asset that is beneficial to them and their customers, since they can give quicker delivery times than foreign competitors.

Although, Plastprent has a relatively short delivery time compared to foreign competitors, Plastprent delivery reliability tends to vary, especially in peak demand periods. Plastprent values are simple: Good service, Cost-effective solutions and Reliability. Their goals are to offer good service and to deliver orders when promised. This thesis is the basis of helping Plastprent improve its delivery reliability and to get a better understanding of its delivery reliability in general.

## **1.2 Purpose**

The main purpose of the project is to analyse the delivery reliability of MTO productions at Plastprent Ltd. Moreover, define the processes and factors that have the most influence on the delivery reliability. Furthermore, look into and introduce possible ways to improve the delivery reliability of Plastprent MTO productions.

To fulfil the purpose the following research questions were put forth:

1. What is the delivery reliability of MTO productions at Plastprent?
2. What Processes and factors have the most influence on the delivery reliability of Plastprents MTO productions?
3. How can Plastprent improve the delivery reliability of its MTO productions?

## **1.3 Methodology**

The thesis was the subject of work done in the period of January to May, 2012. The author was employed during that time at Plastprent. To start with, an in-depth literature review was conducted to gather information about the concept delivery reliability. Further connected literature such as Supply chain management (SCM) and the Supply chain operations reference model (SCOR) was introduced. Data was gathered from Plastprent information system on their delivery reliability in previous years and analysed. The data was analysed with the help of Microsoft Excel, StatFit and EasyFit 5.5 professional. Interviews with Plastprent employees, who work in the production processes and other departments, were performed to gather qualitative data. The basis of this data collection is the foundation of the thesis. The SCOR models four management processes of plan, source, make and deliver were used to analyse the factors affecting the delivery reliability to Plastprents MTO productions. Improvements were then introduced in each of the management processes.

## **1.4 Scope and Limitations**

The author of this thesis is a graduate completing his M.Sc. studies in industrial engineering from the University of Iceland. Prior to this project the author had worked with Plastprent on improvement projects in their production department. Guðbrandur Sigurðsson, the CEO of Plastprent, initiated an internal project to look into the delivery reliability of Plastprent MTO productions. The thesis focus is on MTO productions at Plastprent and processes and factors that have an effect on the delivery reliability. The thesis does not consider make-to-stock (MTS) items and excludes any analysis of cost connected with the delivery reliability. This is done to simplify the analysis and improve the outcome of the thesis.

## **1.5 Thesis outline**

The thesis will cover the packaging industry in general so the reader gets additional background information. Plastprent will then be introduced so the reader will be better informed of the companies scale, activities and operations. A literature review of the concept delivery reliability and other literature used in the thesis will be presented. Data analysis of Plastprent current delivery reliability will be put forth. Thereafter, the focus will be on processes and factors that affect Plastprent delivery reliability. Lastly, possible improvements according to literature, which could benefit Plastprent delivery reliability, will be introduced. To sum up the main content of the thesis, a conclusion will be put forth. Lastly, a discussion chapter is added to benefit Plastprent.

## 2 Plastic – the raw material

Plastic is a type of synthetic or man-made polymer, similar in many ways to natural resins found in trees and other plants. Webster's Dictionary defines polymers as: any of various complex organic compounds produced by polymerization, capable of being moulded, extruded, cast into various shapes and films, or drawn into filaments and then used as textile fibres.

Plastic is a very modern material in comparison to other materials, even though its history goes back more than 100 years. The use of plastic has enabled society to make huge technological advances. From daily tasks to our most special requirements, plastics have increasingly provided characteristics that fulfil consumer needs. Plastics properties are so vast it can be used for a wide range of applications that benefit consumers. They are also unique in that their properties may be customized for each individual end use application.

Oil and natural gas are the major raw materials used to manufacture plastics. The plastics production process often begins by treating components of crude oil or natural gas in a "cracking process." This process results in the conversion of these components into hydrocarbon monomers, such as ethylene and propylene. Further processing leads to a wider range of monomers, such as styrene, vinyl chloride, ethylene glycol, terephthalic acid and many others. These monomers are then chemically bonded into chains called polymers. The different combinations of monomers yield plastics with a wide range of properties and characteristics.

There are different types of plastics with a variety of grades to help deliver specific properties for each application. There are five plastic types that stand out in terms of their market share:

1. Polyethylene – including low density (PE-LD), linear low density (PE-LLD) and high density (PE-HD)
2. Polypropylene (PP)
3. Polyvinyl chloride (PVC)
4. Polystyrene (solid PS and expandable PS)
5. Polyethylene terephthalate (PET)

Together, these five account for around 74% of the overall plastics demand in Europe. The top 3 resin types by market share are: PE (29%), PP (19%) and PVC (12%).

There are several different processing methods used to make plastic products. The main method, in which plastics are processed at Plastprent to form the products that consumers use, such as plastic film, bags and other products, is known as extrusion. Plastic pellets or granules are first loaded into a hopper and then fed into an extruder, which is a long heated chamber through which it is moved by the action of a continuously revolving screw. The

plastic is melted by a combination of heat from the mechanical work done and by the hot sidewall metal. At the end of the extruder, the molten plastic is forced out through a small opening or die, to shape the finished product. As the plastic product extrudes from the die, it is cooled by air. The other processing methods of plastic are injection moulding, blow moulding and rotational moulding.

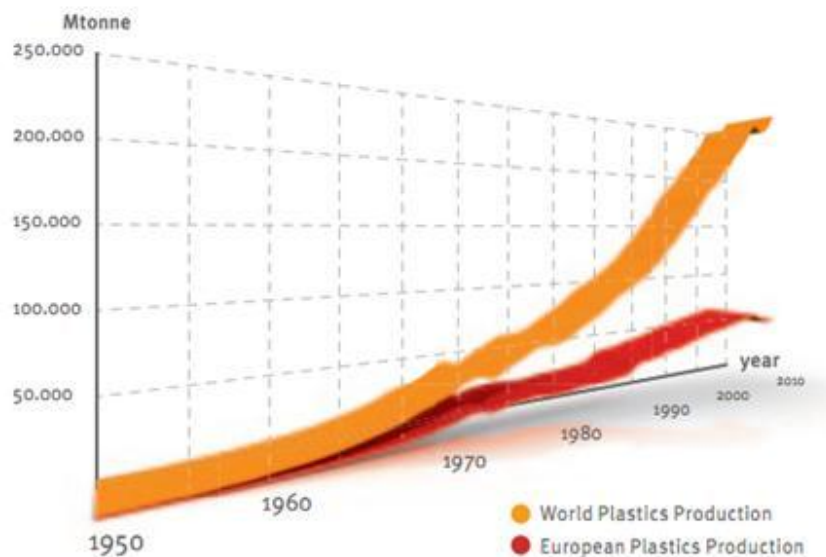
## 2.1 Plastic industry in Europe

*“The plastics industry: a key building block of the European economy”*

(PlasticsEurope, 2011)

The plastics industry in Europe is vast and contributes to 21.5% of the world’s total volume of plastics production and provides employment to about 1.6 million Europeans. In the past 20 years, the plastics production trend has increased around 5% annually. Thus confirming the important role of plastics in key European industries such as automotive, electrical, electronic, building, construction, food and beverage sectors.

The plastics industry contributes significantly to the welfare of Europe. Plastics drive innovation, improve quality of life, and facilitate resource efficiency and climate protection. More than 1.6 million people work in over 54,000 companies; 95% of them being small and medium-sized enterprises for the conversion sector. The industry generates turnover in the region of over 300 billion euros per year.



*Figure 1 Production of plastic (PlasticsEurope, 2011)*

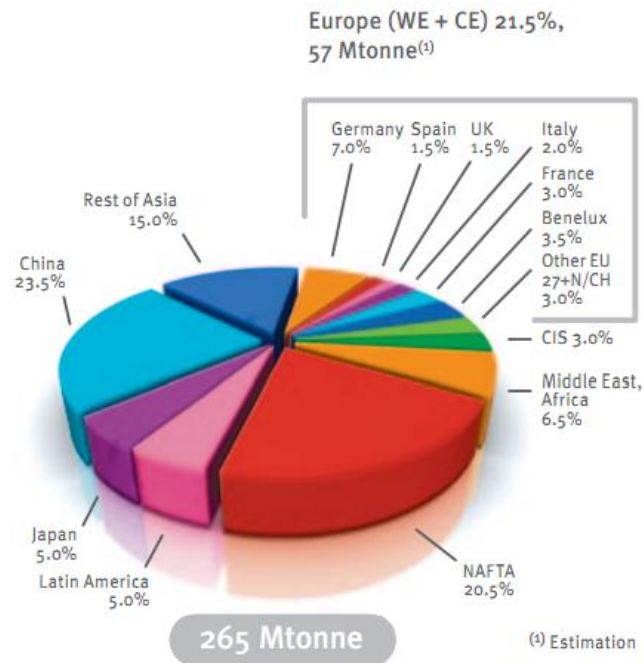


Figure 2 Where plastic is produced (PlasticsEurope, 2011)

## 2.2 Plastics application

Plastics can be applied in various ways but the most common is packaging, which remains the largest segment and representing 39% of overall demand. The packaging sector is followed by building & construction (20.6%), automotive (7.5%) and electrical & electronic equipment (5.6%). Others (27.3%) include health and safety, leisure, agriculture, machinery engineering, household appliances and furniture.

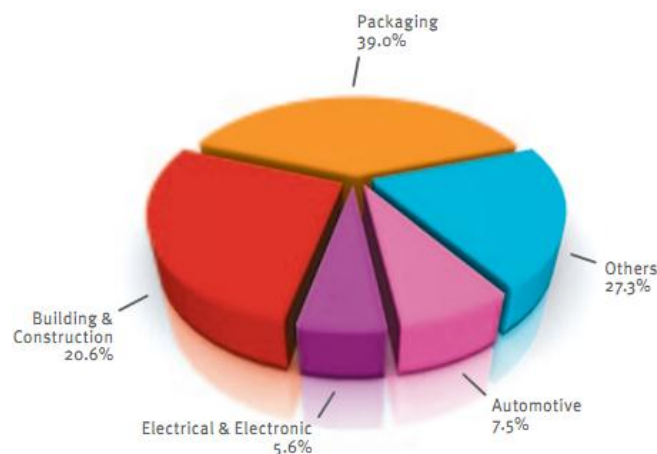


Figure 3 Plastics application (PlasticsEurope, 2011)

## 2.3 Lifecycle of plastic

The following figure shows the lifecycle of plastic, from converter demand to disposal and recovery. Converter demand reached 46.4 million tons in 2010; however, given the numerous long-life applications, only slightly more than half (24.7 million tons) of the converted plastics end up as waste each year.

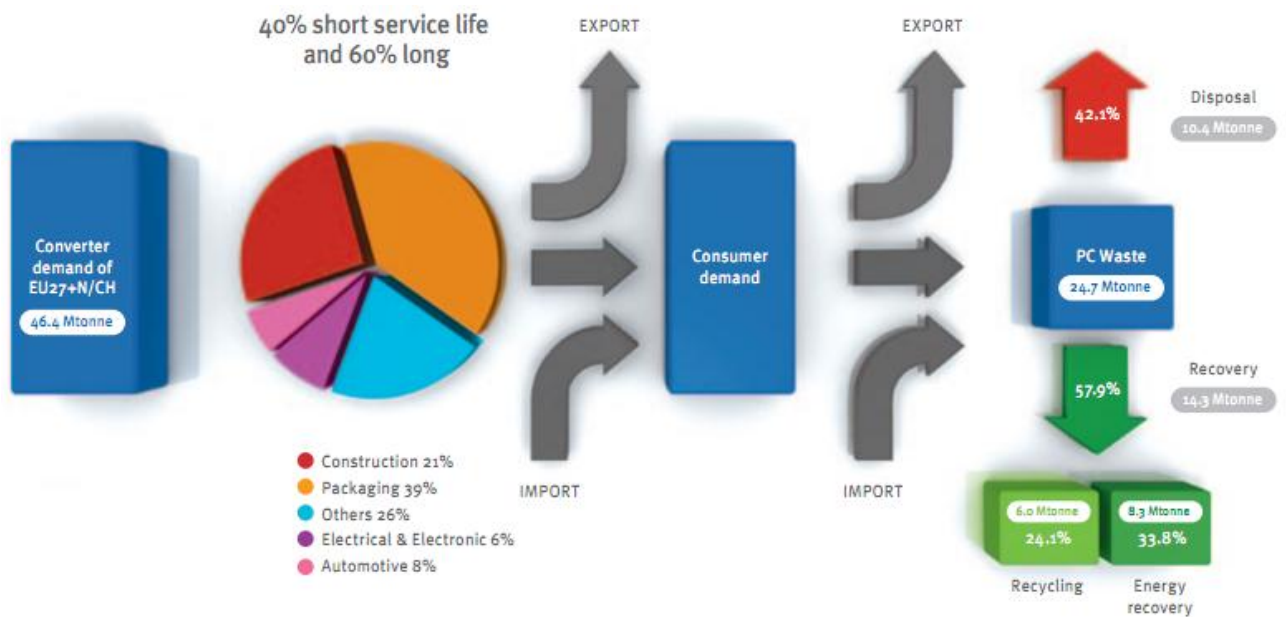


Figure 4 Lifecycle of plastic (PlasticsEurope, 2011)





## **3 Plastprent**

Plastprent specializes in packaging solutions. Packaging is a big part of our daily lives and serves to protect products or food until they go into use or consumption. Plastprent is an Icelandic company that has served local customers for over half a century. The company produces plastic films, plastic bags and various packaging; in addition, it has complete printing solutions that print on plastic with high quality. The core industry segments that Plastprent supplies to are; Fishing, Food industry, Agriculture, Retail and Consumer Goods.

Continuous developments in the market, changing diets and increasing consumer demands for convenience, call on continual development of packaging. The lifetime of most products is constantly shortening so it is important for companies to engage in product development that results in new and improved products. Packaging can be a crucial factor to achieve competitive advantage in the market by improving the interface of the product and to promote the important message to the consumer. Plastprent aim is to help its customers achieve better results by offering convenient and cost effective packaging solutions.

Plastprent offers comprehensive services in order to meet the increasing demands of the food industry. These services include professional packaging consultancy and both the manufacturing and provision of packaging, all according to the needs of each customer. Plastprent also takes an active part in the development of fast, efficient and professional solutions, in response to the needs of the buyers where packaging quality and attractiveness are concerned.

### **3.1 Production at Plastprent**

The factory and office facility is located in Reykjavik, Iceland. The company employs around 75 people and is considered a medium sized company in Iceland. The operations of the factory include extrusion, printing, cutting, lamination and conversion. Plastprent manufactures according to the standards of ISO 9001 and the BRC/IOP technical standard. The production includes polyethylene films and bags, converting and printing on plastic material and laminates. The company emphasizes on providing excellent service to its customers. Plastprent produces, among other products, the following:

- Packaging film, vertical form film. Horizontal flow wrap & laminated film
- Lidding film
- Bags and sacks
- Vacuum bags
- Carrier bags

- Pallet and cover liners
- Shrink film
- Stretch wrap

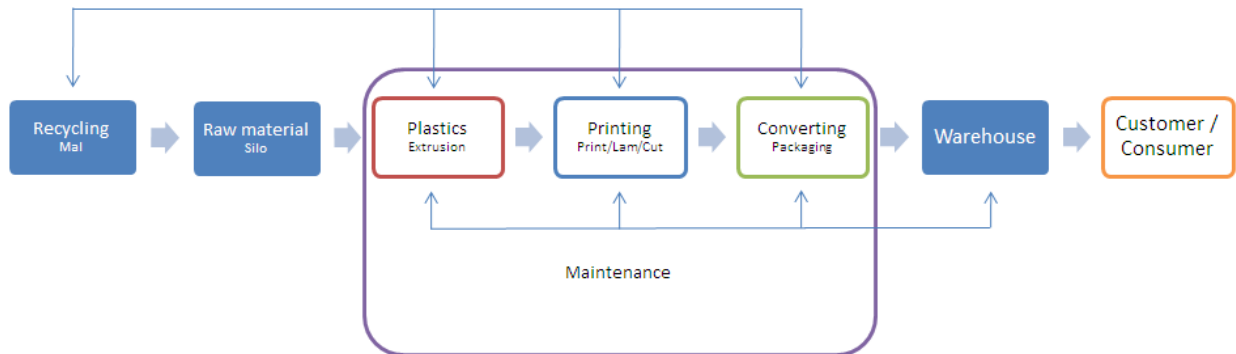


Figure 5 Simplified production structure at Plastprent

## 3.2 Organizational structure of Plastprent

The following figure illustrates the organizational matrix of Plastprent and gives a clear indication of the roles and responsibilities of the employees.

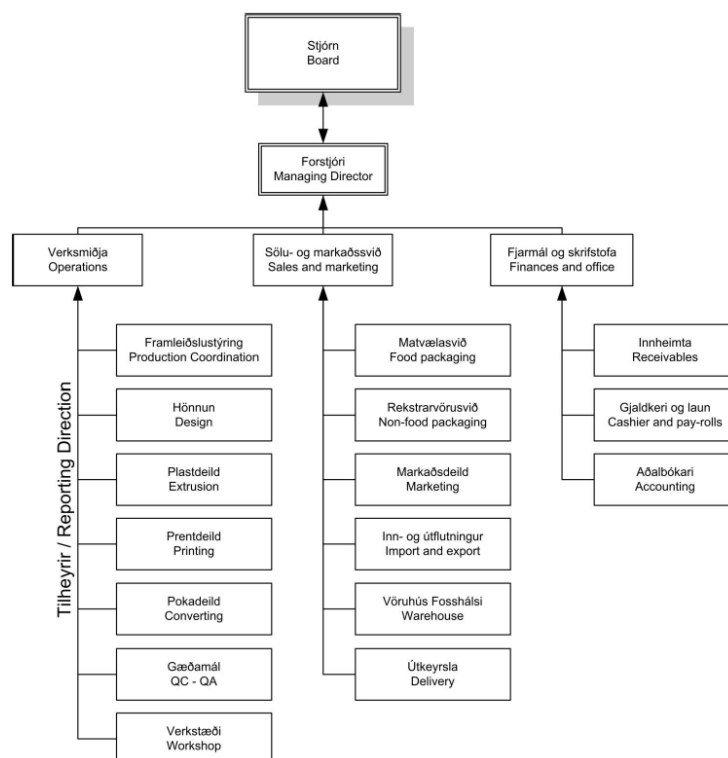


Figure 6 Organizational chart

### 3.3 Turnover 2008-2011

The figure displays the company's turnover during the period of 2008 to 2011. It gives an indication of the size of the company; the average turnover is approximately ISK 1.500 million annually.

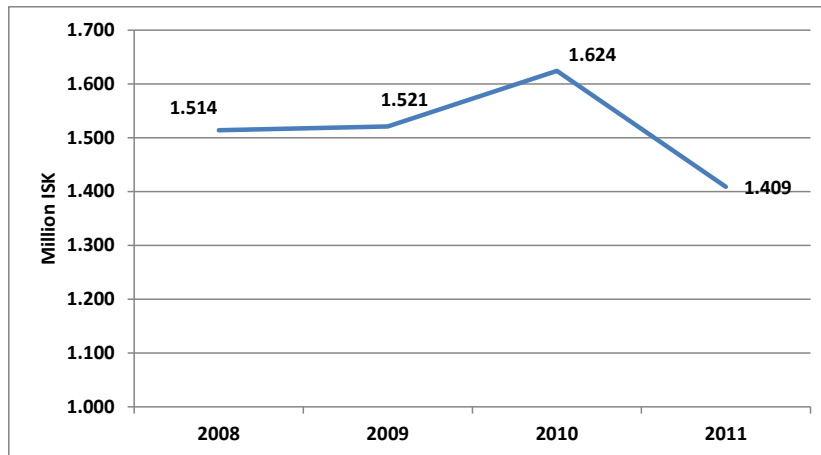


Figure 7 Turnover in 2008 to 2011

### 3.4 Business sector sales

This figure displays the development of sales during 2009-2011, divided after industry segments. The figure shows that the most important sectors of Plastprent are the fishing and food industry as most income comes from these two sectors.

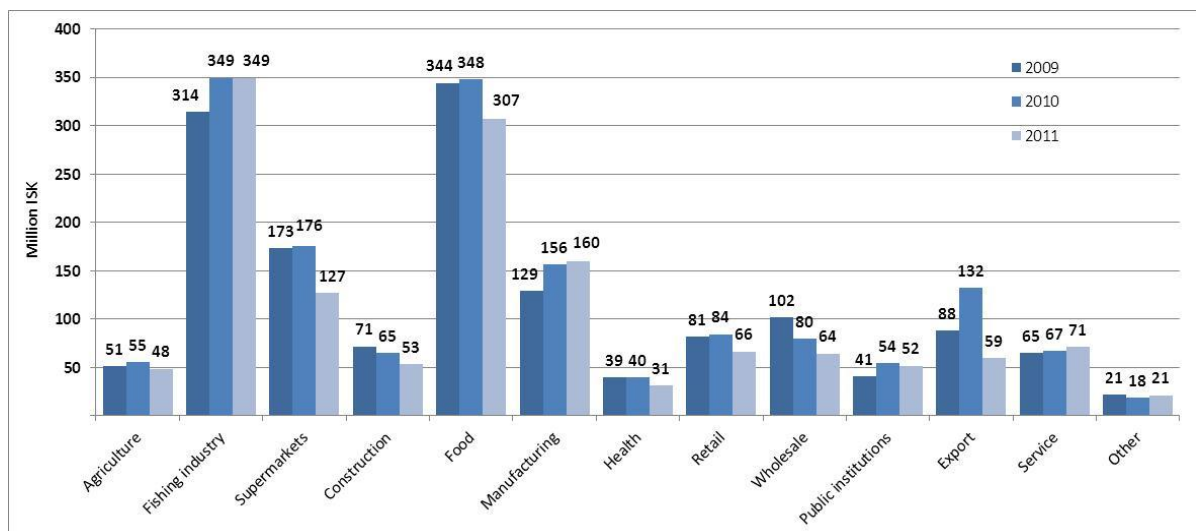


Figure 8 Business sector sales 2009 - 2011

### 3.5 Packaging market in Iceland

The following numbers are in-house estimates of the Icelandic packaging market. The packaging market estimated turnover in Iceland was ISK 14 billion in 2010, and can be divided into the following five sub-markets:

- *Flexible packaging*  
Size: ISK 5,5 billion, 39,3%  
Producers: Plastprent, PMT  
Import & distribution companies: Samhentir, Saltkaup, Plastco, Frjo-Quatro, Umbúðir og ráðgjöf, Pappír, Tandur, Nokk, Áfangar, Servida-Besta, Marvélar og umbúðir, Gnótt-Ölgerðin & Multivac
- *Corrugated paperboard and cartons*  
Size: ISK 4,5 billion, 32,1%  
Producers: Oddi (Kassagerðin) & Prentment  
Import & distribution companies: Samhentir, Saltkaup & Spírall
- *Labels and tape*  
Size: ISK 1,3 billion, 9,3%  
Producers: Vörumerking, Límmiðar, PMT & Ásprent  
Import & distribution companies: Parlogis
- *Rigid plastic packaging*  
Size: ISK 1,5 billion, 10,7%  
Producers: Bergplast, Sigurplast, Promens, Borgarplast, Plastiðjan & Bes
- *Packaging machines & robots*  
Size: ISK 1,2 billion, 8,6%  
Import & distribution companies: Plastprent, Plastco, PMT, Samhentir, Multivac á Íslandi & Samey

Plastprent estimated market share of the total packaging market is 11%. The company has the largest market share, or 27%, in flexible packaging. What characterizes the packaging market, especially in flexible packaging, is a large number of suppliers. It is likely that some consolidation will take place in the packaging market in Iceland, especially considering the experience of other comparable foreign markets. Larger purchasing units are better suited to provide professional advice and have a better chance of favourable procurement of raw materials or resale, for the benefit of the company itself and its customers.

## 4 Literature review

The objective of the following chapter is to give the reader insight into the literature presented in the thesis. Delivery reliability is the main concept of the thesis and is a concept widely used in Supply chain management (SCM) as a performance indicator. The supply chain operation reference model is used to simplify the implementation of SCM at manufacturing companies. Manufacturing planning and control (MPC), Master production Scheduling (MPS) and Material requirement planning (MRP) are all tools and concept within SCM. The Ishikawa diagram is introduced to help analyse cause and effects of delivery reliability. Lastly, the Sand cone model is presented to help improve manufacturing performance.

- Delivery reliability (DR)
  - Supply chain management (SCM)
  - Supply chain operations reference model (SCOR)
  - Manufacturing Planning and Control (MPC)
  - Master production schedule (MPS)
  - Material requirement planning (MRP)
- Ishikawa diagram
- The Sand cone model

### 4.1 Delivery reliability

*“Reliability is a customer focused attribute” - Supply chain council (SCC, 2012).*

Manufacturing capabilities can be referred to as the ability of a production system to compete on basic dimensions such as quality, cost, flexibility and time (Safizadeh, 2000). One author, in particular, discusses the various manufacturing “tasks” inherent to a production system. He states that short delivery cycles, superior product quality and reliability, dependable delivery promises and the ability to produce new products quickly, are performance areas that can be a source of competitiveness for manufacturing companies (Skinner, 1974). Further authors have offered similar views (Ferdows and De Meyer, 1990; Wood, 1990; Roth and Miller, 1992). The following factors: flexibility, quality, delivery and costs, are some of the manufacturing capabilities that can enhance the position of a company in the competitive market. However, each capability in itself can be divided into various sections. For instance, in terms of flexibility, you look at the ability to change production volumes or production mix. In regards to delivery, you look at the speed of delivery or delivery dependability. In terms of quality, you look at the quality of conformance specifications or quality of features of products and various other factors could be mentioned.

Since the thesis attention is on delivery reliability, a definition consistent with the aims of the thesis is described by Leong et al. (1990, p. 114) and Vickery et al. (1997, p. 321), respectively. Dependability of delivery is the ability to meet delivery schedules or promises. Also known as Delivery dependability, which is the ability to meet exactly quoted or anticipated delivery dates and quantities. Delivery time is also defined to be the elapsed time from the receipt of an order by the originating supplier in the supply network to the receipt of the product ordered by the final customer in the supply network. Delivery time is composed of a series of internal manufacturing and processing times at each stage plus the external distribution and transportation times found at various stages of the supply network (Gunasekaran, Lai and Cheng, 2008). Early and late deliveries have a negative effect on the supply chain; early deliveries contribute to excess inventory while late deliveries contribute to overtime costs, lost sales and the loss of goodwill. To protect against untimely deliveries, supply network managers often inflate process inventory levels and production flow buffers. These actions can contribute to excess operating and administrative costs (Guiffrida, 2006 and Yeung, 2006).

Other scholars have defined the concept as the following: delivery reliability may be expressed as the amount/percentage of orders that are delivered to the customer in the right quantity at the promised point in time (Zsidisin, 2003, p. 16). Also, defined as the ratio of the number of deliveries made without any error (regarding time, place, price, quantity, and/or quality) to the total number of deliveries in a period. It is clear that delivery reliability deals with the ability to meet dates/times and quantities of customer orders, which applies to the make-to-order environment and/or anticipated make-to-stock environment.

There is no denying that the importance of delivery reliability for a manufacturing company is significant. Strategically, it is very important, as Skinner (1969) states that there are some other ways to compete other than producing at low cost. Delivery reliability, in his view is a source of potential competitive advantage. Other authors, such as Hill (2000), comment that delivery reliability may in some cases be an order-qualifier instead of an order-winning criterion. The opinions of Hill (2000) are interesting, as he states that in some circumstances the ability to deliver orders on time is only sufficient to keeping them in business. In other words, in some circumstances, delivery reliability becomes a prerequisite for suppliers. This view is shared by Kumar and Sharman (1992). They comment that if customers do not receive orders on time, they may go elsewhere. Competition is very intense in most industries; therefore, the trend for more reliable delivery has increased.

Various studies, on how delivery reliability is perceived by companies, have shown its importance. In their cross-industry sample of the US manufacturers, Vokurka and Davis (2000) find that the ability to make dependable delivery promises ranks second amongst the competitive priorities in both focused and non-focused factories. Dangayach and Deshmukh (2003), in their study of Indian manufacturers, found that delivery reliability was ranked second and third in importance by companies in the machinery and process industries, respectively. These and other studies have found that delivery reliability ranks only second or third to quality and/or cost in terms of competitive capability.

Hence, as the delivery reliability of suppliers is significantly related to various manufacturing performance measures on the customers' side, it is only to be expected that

customers will demand high levels of delivery reliability performance from their suppliers. Therefore, the capability of providing dependable deliveries has important strategic implications that companies consistently consider important. The customers own performance can be affected by late deliveries and subsequently they demand higher levels of delivery reliability. Thus the importance of delivery reliability for manufacturing companies to achieve competitive advantage.

#### **4.1.1 Supply Chain Management (SCM)**

As a result of globalization, international trade has increased considerably in the past decades as the market place has become smaller. Countries are no longer bound to purchasing goods domestically but are able to purchase the same or similar goods internationally. The effectiveness of those Supply Chains have become crucial for competitive advantage in the international markets that have arisen due to the abolition of trade barriers and lower transportation costs. These markets have become crucial for economic growth and development. Supply chains have become important subjects for academics with a resultant increase of definitions and phrases. The following definitions are best suited to this thesis:

*“A structured manufacturing process wherein raw materials are transformed into finished goods, then delivered to end customers”.* (Beamon B., 1998).

*“A general description of the process integration involving organizations to transform raw materials into finished goods and to transport them to the end-user”.* (Pienaar W., 2009).

*“A connected set of resources and processes that starts with the raw materials sourcing and expands through the delivery of finished goods to the end consumer”.* (Bridgefield Group, 2006).

The above definitions draw on the main factors of an effective supply chain. They all have a similar overall approach that supply chains start with resources (raw materials), which are then transformed (processed) and to end with the finished goods are delivered to customers/consumers.

The utilization of the supply chain and connecting the various nodes effectively can contribute to the value of the resources and thus its success. If any node is not efficient it reduces the overall effectiveness of the whole supply chain. The study of utilizing the supply chain efficiently is known as Supply Chain Management (SCM). Supply Chain management is aimed at examining and managing Supply Chains. The rationale for this concept is the opportunity for cost savings and better customer service. An important objective is to improve a company's competitiveness in the global marketplace in spite of hard competitive forces and promptly changing customer needs (Langley, C., Coyle, J., Gibson, B., Novack, R. and Bardi, E., 2008).

Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer et al., 2001, p. 18).

Supply chain management encompasses materials/supply management from the supply of basic raw materials to final product and possibly recycling and re-use. Supply chain management focuses on how firms utilise their suppliers' processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimisation and efficiency (Tan, 1998).

A customer focused definition is given by Hines (2004, p76): "Supply chain strategies require a total systems view of the linkages in the chain that work together efficiently to create customer satisfaction at the end point of delivery to the consumer. As a consequence costs must be lowered throughout the chain by driving out unnecessary costs and focusing attention on adding value. Throughout efficiency must be increased, bottlenecks removed and performance measurement must focus on total systems efficiency and equitable reward distribution to those in the supply chain adding value. The supply chain system must be responsive to customer requirements".

#### **4.1.2 Supply Chain Operations Reference model (SCOR)**

The supply chain operations reference (SCOR) model, developed by the Supply Chain Council (SCC), is a strategic planning tool that was developed for companies to simplify the complexity of supply chain management. SCC objective was to develop a standard supply-chain process reference model to enable effective communication among the supply chain partners, by using standard terminology to better communicate and learn the supply chain issues and using standard metrics to compare and measure their performances (SCC, 2012).

The following scholars have reported the benefits of the model in literature as: potential for "strategic" level improvements in supply chain management through the use of the benchmarking tools (McGrath, 1997). Allnoch states that identification of points of leverage in the supply chain enables more effective allocation of resources (Allnoch, 1997). McGrath shared his views as, provision of clear standards, processes and performance measures for the management of a supply chain at the industry level (McGrath, 1997).

The model is based on four general supply chain management functions of plan, source, make and deliver. Across these four functions information and material flows are analysed at three separate levels. At level 1, a firm defines its performance targets and gathers the information needed to build its own SCOR model. At level 2, it creates its own "supply chain configuration" that takes into account assets, product volume and mix, and technology requirements. With this information a company can determine its expected performance so that at level 3 it can work on fine-tuning its performance (Saccomano, 1998, p. 1).

The SCOR model is based on the following five, level 1, management processes (SCC, 2012).

##### *Plan*

The Plan processes describe the planning activities associated with operating a supply chain. This includes gathering customer requirements, collecting information on available



resources, and balancing requirements and resources to determine planned capabilities and resource gaps. Then the actions required to correct any gaps are identified.

#### *Source*

The Source processes describe the ordering (or scheduling) and receipt of goods and services. The Source process includes issuing purchase orders, scheduling deliveries, receiving, shipment validation and storage, and accepting supplier invoices.

#### *Make*

The Make processes describe the activities associated with the conversion of materials or creation of the content for services. It focuses on conversion of materials rather than production or manufacturing because Make represents all types of material conversions: assembly, chemical processing, maintenance, repair, overhaul, recycling, refurbishment, remanufacturing, and other material conversion processes. As a general guideline, these processes are recognized by the fact that one or more item numbers go in, and one or more different item numbers come out of this process.

#### *Deliver*

The Deliver processes describe the activities associated with the creation, maintenance, and fulfilment of customer orders. It includes the receipt, validation, and creation of customer orders; scheduling order delivery; pick, pack, and shipment; and invoicing the customer.

#### *Return*

The Return processes describe the activities associated with the reverse flow of goods back from the customer. The Return process includes the identification of the need for a return, the disposition decision making, the scheduling of the return, and the shipment and receipt of the returned goods. (Repair, recycling, refurbishment, and remanufacturing processes are not described using Return process elements. See Make).

### **4.1.3 Manufacturing Planning and Control (MPC)**

The manufacturing planning and control (MPC) system is concerned with planning and controlling all aspects of manufacturing that include managing materials, scheduling machines and people, and coordinating suppliers and key customers. The development of an effective manufacturing planning and control system is key to the success of any production company. Moreover, truly effective MPC systems coordinate supply chains and utilize them efficiently. The MPC system is not performed once, it needs to be a continuous effort to be able to adapt and respond to changes in the company's environment, strategy, customer requirements, and new supply chain opportunities (Jacobs, 2011).

The essential task of the MPC system is to manage efficiently the flow of material and the utilization of people and equipment, and to respond to customer requirements by utilizing the capacity of suppliers, internal facilities, and in some cases, that of customers to meet customer demand. Important additional activities involve the attainment of information from customers on product needs and providing customers with information such as

delivery dates and product status. The MPC system provides the information upon which managers make effective decisions. The MPC system does not make decisions nor manage the operations; managers perform those activities based on support from the MPC system.

As classified by Jacobs et al. (2011) in the book of Manufacturing planning and control, the typical activities that are supported by MPC, can be divided into three time horizons.

- In the long term, the responsibility of the MPC system is to provide information for making decisions on the appropriate amount of capacity to meet the market demands of the future.
- In the intermediate term, the MPC system addresses the fundamental issue to match supply and demand in terms of both volume and product mix.
- In the short term, the resource's detail schedule is required to meet production requirements. For example, the master production schedule works as a statement for production with the detailed production planning.

#### *MPC system framework*

Illustrated in figure 9 is a schematic drawing of the general MPC system. It is very typical to have the MPC system imbedded in an enterprise resource planning (ERP) system. In terms of understanding the MPC system, the framework has been divided into three phases: front end, engine and back end.

The phase of front end, builds up the overall company's direction for manufacturing planning and control. Demand management assists all kinds of correlative activities in a supply chain to have demand on manufacturing capacity. Resource planning decides the needed capacity to produce the required products for now and the future; it provides the basis to match the manufacturing plans and capacity. Sales and operations planning determine the manufacturing role to meet the company strategy, it helps to balance the sales or marketing plans with available production resources. The master production schedule states the future type of the end product, which will be manufactured, its support is demanded by sales and operations plan (Jacobs et al. 2011).

The engine phase focuses on detailed material and capacity planning. For example, from the manufacturing company, which has a wide variety of products with many parts for every product, the material requirements planning (MRP) is used to fulfil the requirements of detailed material planning, since there may be thousands of managed parts and components. In other words, MRP determines the time-to-time plans for all required component parts and raw materials to produce all the products in the master production schedule (Jacobs et al. 2011).

Back end, which is the bottom phase of figure 9, draws the execution systems of MPC. Generally, the application of the products manufactured and production processes determines the configuration of the systems. There are two kinds of information for the supplier system to provide to the company's suppliers in the bottom phase of the MPC system, including updated priority information and future plans.

- The updated priority information helps the suppliers understand the company's current conditions for managing changes better.
- The future plans help the suppliers understand the company's expectation and requirements. It also helps the supplier to have a better production plan in order to provide the right material in a good time.

The shop-floor systems are used for managing the material utilization to produce machines in different work centres, and the routine events like starting and completing orders for parts are reflected in the schedule along with other problem conditions (Jacobs et al. 2011).

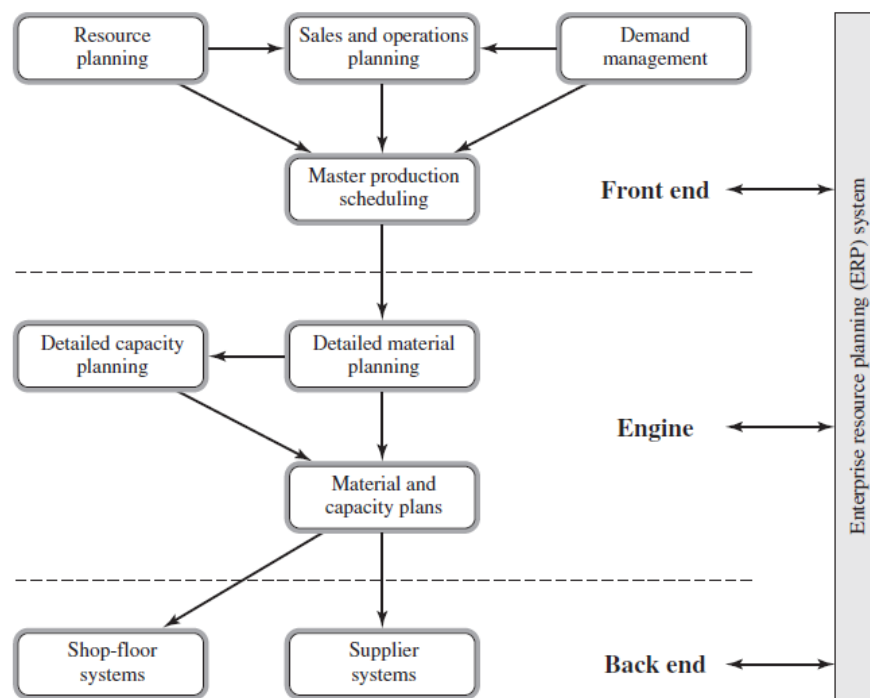


Figure 9 Manufacturing planning and control system (simplified)

#### 4.1.4 Master production schedule (MPS)

Normally, information from the past, such as previous yearly sales and productions, has an impact on the next year's utilization of production and marketing focus. The accuracy of the master production schedule plays a critical role for forecasting the future production volume, as well as the material requirement to fulfil the production requirements.

In the manufacturing planning and control system, the master production schedule can be seen as a statement of production. It specifies the products with the completed quantity, the completion time, the product type and the supplied solution to meet the future demand. Mainly, there are two considering levels for defining the master production schedule, (Jacobs et al. 2011, p.153):

- From the conceptual level, the MPS is the translation of the company's sales and production plan to the future plan for producing specific products.

- From the operational level, the focus is to have the MPS record for developing to be compatible with the material requirements planning system and to provide the information in order to coordinate with sales.

The MPS differs from the forecasts; it mainly concerns the production capacity and cost, sales and operation plan, material requirement plan, as well as other resource possibility.

#### **4.1.5 Material requirement planning (MRP)**

Materials Requirement Planning (MRP) is a technique for determining the quantity and timing for the acquisition of dependent demand items needed to satisfy master production schedule requirements (Kumar, 2007). On the other hand, MRP can be seen as a basic tool to carry out the detailed material planning function to meet the production requirements for achieving the end products. Its objective is to provide the proper material at the right time according to the schedule for the end products, by which it contributes as below:

- MRP defines exactly the needed component quantity with the right time for running the production; this helps to maintain the inventory level as low as possible.
- By MRP, the lead time both for manufacturing and customer order can be reduced since the due date identification for an order will help for calculating the schedule backwards.
- From MRP, the application of one planning interface contributes to the creation of more realistic delivery schedules.

## **4.2 Ishikawa diagram**

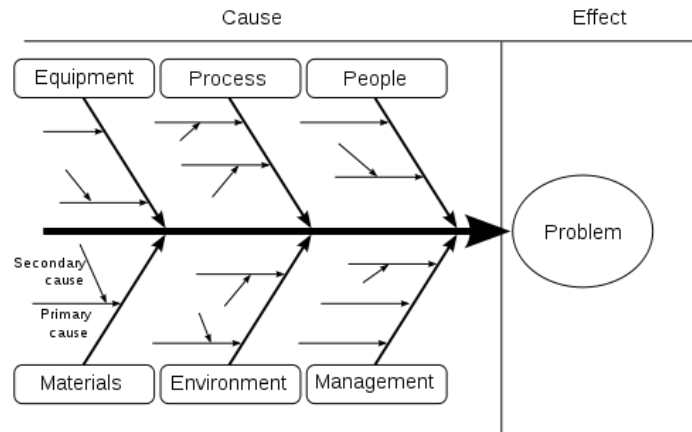
The Ishikawa diagram, also referred to as the cause and effect diagram or the fishbone diagram, is a problem-solving tool for identifying potential factors causing an overall effect. It is a method to determine the main causes and sub causes leading to an effect. The main objectives of this tool can be defined as following:

- Identify the root causes of a problem.
- Work out the major factors involved.
- Identify possible causes.
- Analyse the diagram.
- Recognize areas where there is lack of data.

Causes are usually grouped into major categories to identify these sources of variation. The categories typically include:

- People: Anyone involved with the process.
- Process: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws.
- Equipment: Any equipment, computers, tools etc. required to accomplish the job.

- Materials: Raw materials, parts, pens, paper, etc. used to produce the final product.
- Environment: The conditions, such as location, time, temperature and culture.
- Measurements: Data generated from the process that are used to evaluate its quality.

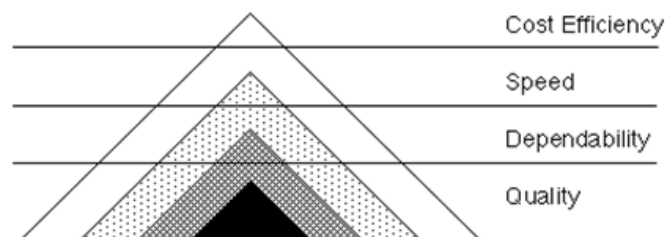


*Figure 10 Ishikawa diagram*

### 4.3 The Sand Cone model

The Sand Cone model suggests that, although in the short term, it is possible to trade off capabilities one against the other, there is actually a hierarchy amongst the four manufacturing capabilities. The model implies that to build cumulative and lasting manufacturing capability, management attention and resources should go first towards enhancing quality, then while the efforts to enhance quality are further expanded, attention should be paid to improve the dependability of the production system, and then again while efforts on the previous two are further enhanced the production flexibility should be improved, and finally, while all these efforts are further enlarged, direct attention can be paid to cost efficiency.

Most of the traditional management approaches for improving manufacturing performance are built on the trade-off theory. Ferdows and de Meyer (1990) suggest the trade-off theory does not apply in all cases. Rather, certain approaches change the trade-off relationship into a cumulative one i.e. one capability is built upon another, not in its place. Applying the sand cone model requires a long term approach, tolerance and patience. It requires believing that costs will eventually come down.



*Figure 11 The Sand Cone model*



## 5 Analysis

The following chapter contains an analysis of Plastprent delivery reliability. The data was collected from Plastprent information system and analysed with EasyFit 5.5 Professional data analysis and simulation application.

Plastprent is aiming to improve its delivery reliability to customers. The company services a wide range of customers and industries and has a vast collection of products to offer. Not all the products have the same production processes; some are simple and some very complex. Not all the products consist of the same raw materials. Hence, the production processes are many and differ. Consequently, not all products should be promised with the same delivery times.

The problem facing Plastprent is that orders are sometimes delivered late or early, which is not always welcome by customers since it can increase inventory-holding costs. Plastprent is a small plastics producer in comparison to foreign producers and service a small market in Iceland. One of its competitive advantages is being able to promise short delivery times and quantity flexibility. Icelandic companies look to Plastprent because of that. Its customers are able to source from overseas, but there they have to buy in bulk and expect long delivery times; hence the importance of reliable delivery. Hereafter is a statistical analysis of Plastprent delivery reliability during 2010 and 2011 and a more detailed analysis of their biggest customers.

Plastprent defines four weeks as the lead time for all MTO orders to all customers from the receipt of order. The four weeks defined means that if a product is ordered in week zero on a Monday, it will be delivered in week four but not necessarily on the Monday; it allows the whole week or possibly until the Friday, for variation. This is better known as a “delivery window” in supply chain management studies. The time begins when all specifications, designs and relevant data are in Plastprent hands and ready to use. The time does not include graphic work or the making of the printing plates. Therefore, “on-time” productions are defined as the productions that are delivered in the delivery window, or in 4 to 4,9 weeks or less, and “late” productions are those that are delivered later than five weeks. Some customers have priority contracts and in some cases can request orders in two to three weeks. The lead time is calculated in the following way; (order delivered - order received)/7(week) = lead time. e.g. (30.1.2011-1.1.2011)/7 = 4,1 weeks.

“Early” deliveries can be negative and costly for Plastprent and the customer; it can introduce additional holding cost for both. “On-time” deliveries are what Plastprent defines as their reliable deliveries and are where they want all of their orders to be. “Late” deliveries are bad for Plastprent as it can lead to loss of good-will and business. Also negative to the customer as it can delay productions and therefore the delivery reliability of the customers’ products. The following table gives a better representation of defined delivery times.

Table 1 Definition of delivery times

Week	Definition	Description
0 – 2,9	“Early”	Order is delivered early.
3 – 3,9	“On-time”	Order is delivered within the delivery window (specific customers).
4 – 4,9	“On-time”	Order is delivered within the delivery window.
5 +	“Late”	Order is delivered late to customer.

Since this thesis focus is on MTO productions a comparison of the MTO and MTS productions is performed. The following line chart shows the number of orders during 2010 and 2011 for MTO versus MTS productions. During that period 5.402 production orders were placed, 3.540 of them or 65,9% were MTO orders and 1.862 or 34,1% were MTS orders. This gives an indication of how the plant is utilized.

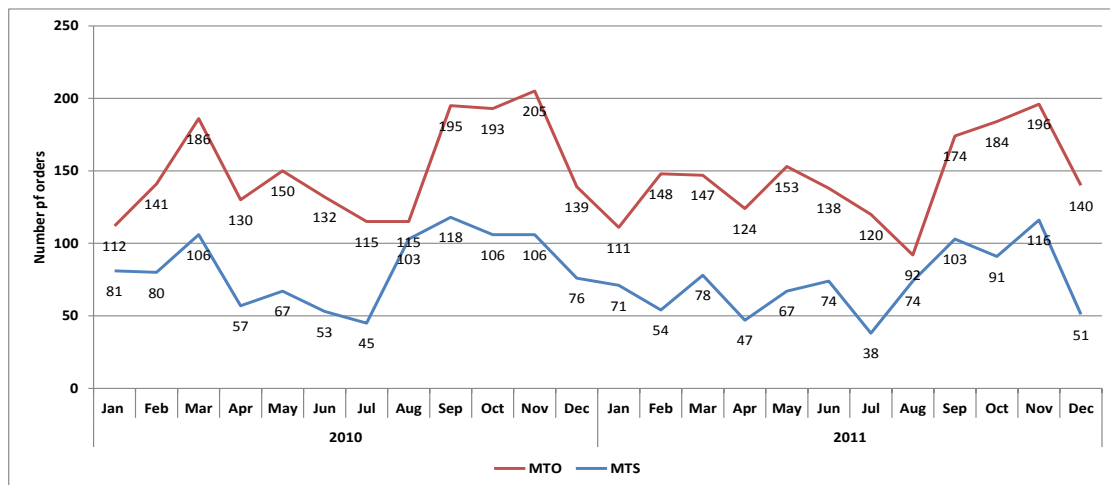


Figure 12 MTO vs. MTS orders

## 5.1 Overview of data analysis

The table below shows the overview of the data that is analysed in this section. The probability column indicates the percentage of orders that were delivered in the specific time frames. Data from 2010 and 2011 were analysed and also the biggest customers in terms of sales income for each of the years.



Table 2 Overview of Plastprent delivery reliability

Year	Comment	Average	Stdev	Mode	Median	Count	Probability			
							0 - 2,9	3 - 3,9	4 - 4,9	5 +
2010	MTO	4,60	2,82	3,14	4,14	1.759	31,57%	17,17%	15,04%	36,22%
2011	MTO	3,44	2,10	3,00	3,00	1.657	47,24%	19,86%	13,43%	19,46%
2010	Biggest customers	4,81	2,92	5,14	4,29	643	27,86%	17,47%	16,29%	38,39%
2011	Biggest customers	3,39	1,94	2,57	3,00	487	47,68%	22,98%	14,19%	15,15%

\*All numbers in weeks

### 5.1.1 Analysis of data in 2010

The following information is an analysis of the delivery reliability of Plastprent MTO orders for the year 2010. The year 2010 was difficult for the company as it was going through financial difficulties that lead to shortages in raw materials which affected the delivery reliability.

Table 3 Delivery reliability of Plastprent MTO orders in 2010

Year	Comment	Average	Stdev	Mode	Median	Count	Probability			
							0 - 2,9	3 - 3,9	4 - 4,9	5 +
2010	MTO	4,60	2,82	3,14	4,14	1.759	31,57%	17,17%	15,04%	36,22%

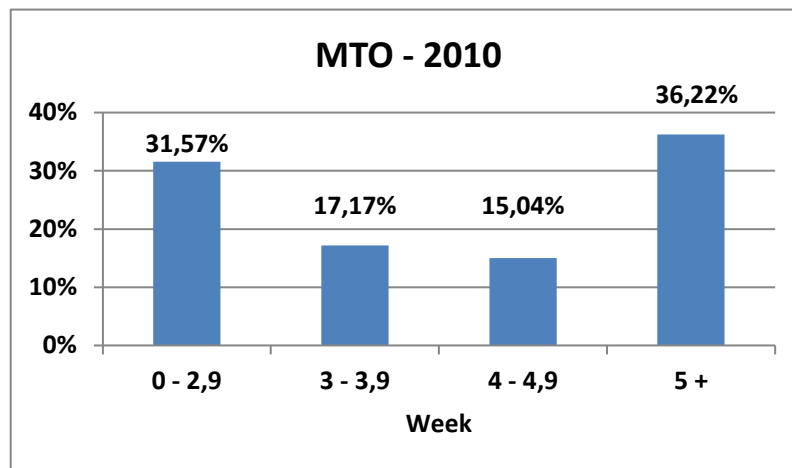
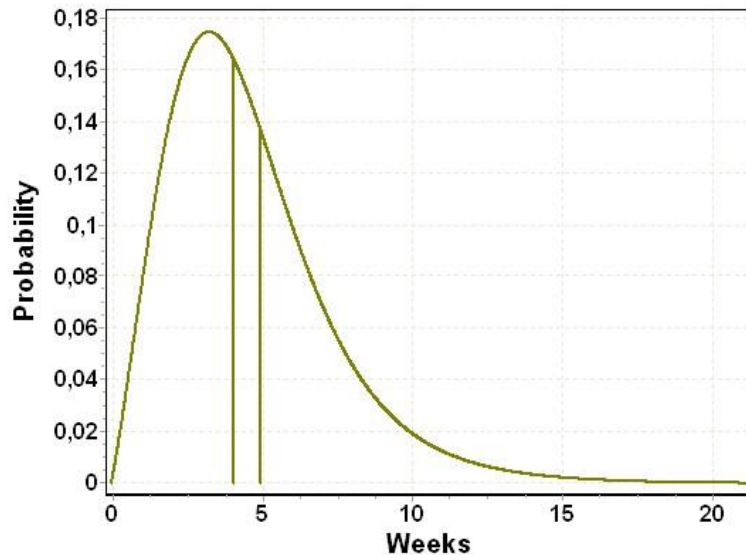


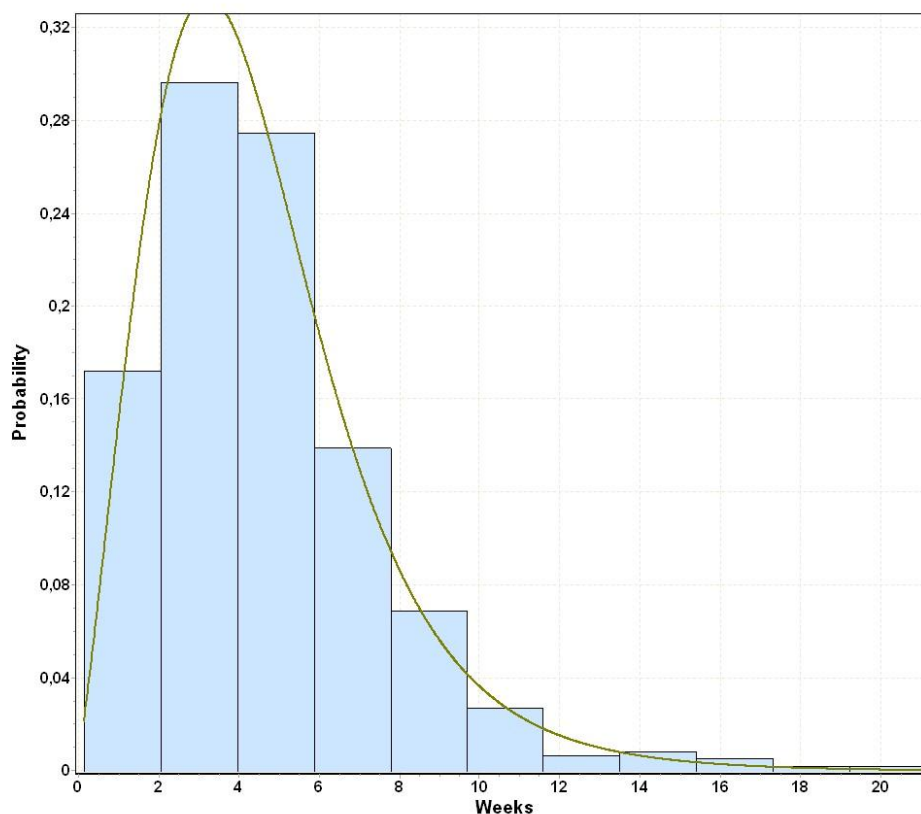
Figure 13 Probability of delivering orders

Plastprent objective is to deliver all orders “on-time” or in the defined 3 to 4,9 week columns, they managed to do so in 32,21% of orders in 2010. Orders delivered early were 31,57% and those delivered late were 36,22%. This is unsatisfactory and indicated that the delivery reliability of Plastprent was quite unreliable.



*Figure 14 Probability density function in 2010*

The above line chart shows the probability density function. As seen on the chart the density is positively skewed with some extremely high values. The vertical green lines indicate the 4 – 4,9 weeks delivery window set by Plastprent. It is apparent that Plastprent objective of delivering orders in the delivery window was not always attained. The average delivery time for the year was quite high. However, since the distribution is positively skewed the average can give a wrong representation of the delivery time; therefore, it is important to look at other measurements. Median and mode are more reliable indicators when looking at a skewed distribution with extremely high or low values. The mode was 3,14 weeks, which is in the window and gives a positive indication that customers were receiving their orders on time. The median was 4,14 weeks that is acceptable and below the average. Although the average is quite high, other indicators give a more positive outlook.



*Figure 15 Histogram of the probability density function in 2010*

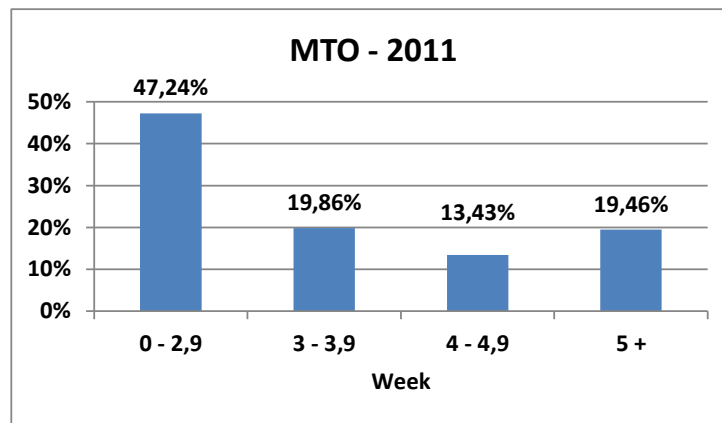
As can be seen on the histogram, Plastprent delivered most of their orders in between two and four weeks or in 29,5% of the time. It also shows there is a minor chance of receiving orders later than 10 weeks, these values are causing the density function to be skewed and elevating the average. The overall delivery reliability in 2010 was quite unreliable as almost 37% of customers received their orders late. This was mainly caused by the shortages of raw materials.

### **5.1.2 Analysis of data in 2011**

The following information is an analysis of the delivery reliability of Plastprent MTO orders for the year 2011.

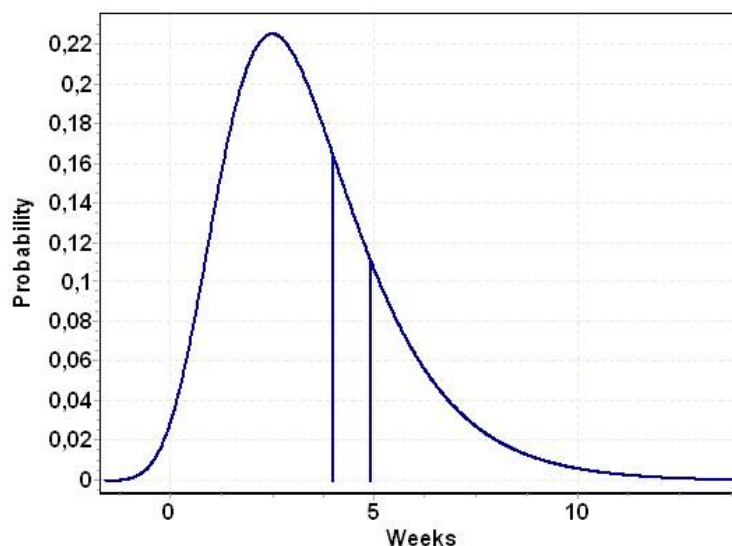
*Table 4 Delivery reliability of Plastprent MTO orders in 2011*

Year	Comment	Average	Stdev	Mode	Median	Count	Probability			
							0 - 2,9	3 - 3,9	4 - 4,9	5 +
2011	MTO	3,44	2,10	3,00	3,00	1.656	47,24%	19,86%	13,43%	19,46%



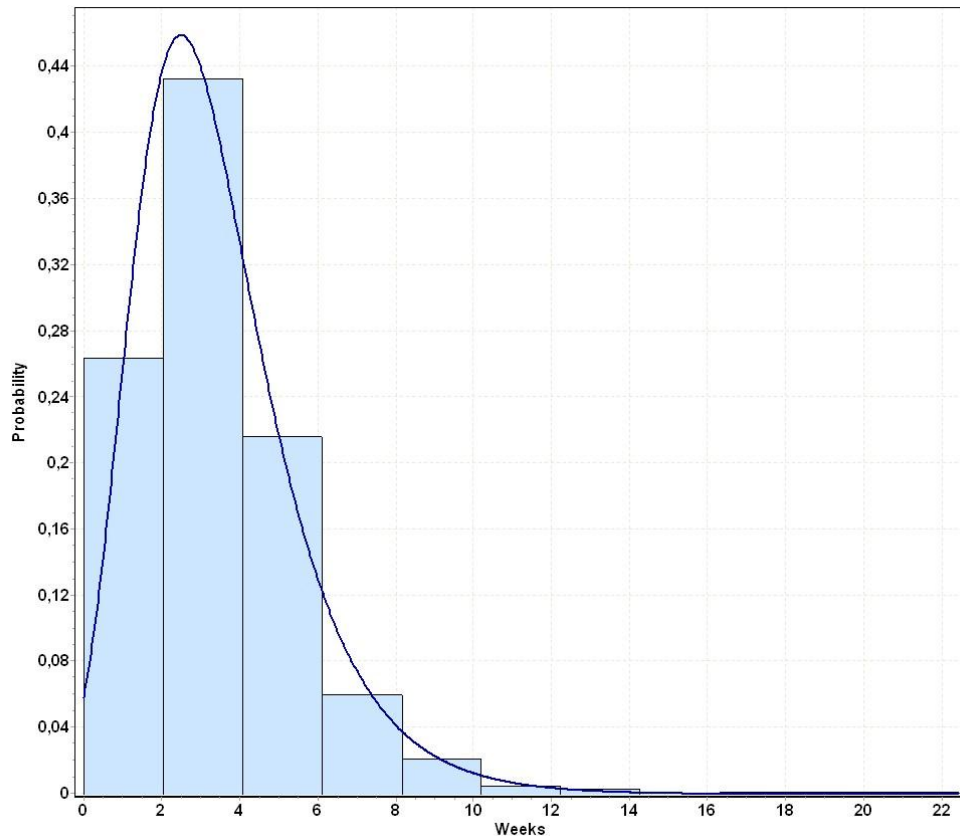
*Figure 16 Probability of delivering orders*

Plastprent objective is to deliver all orders “on-time” or in the defined 3 to 4,9 week columns, they managed to do so in 33,29% of orders in 2011. Orders delivered early were 47,24% and those delivered late were 19,46%. This is a considerably better performance from the previous year and indicates that Plastprents deliveries were reliable.



*Figure 17 Probability density function in 2011*

The above line chart shows the probability density function. The vertical blue lines indicate the 4 – 4,9 weeks delivery window set by Plastprent. In 2011 it is apparent that Plastprent were able to deliver most of their orders on time or early (80,53%). The average and the median for the year were both within the delivery window. The standard deviation was around two weeks which gives an indication that the delivery time was quite variable; however, in most cases within the window.



*Figure 18 Histogram of the probability density function in 2011*

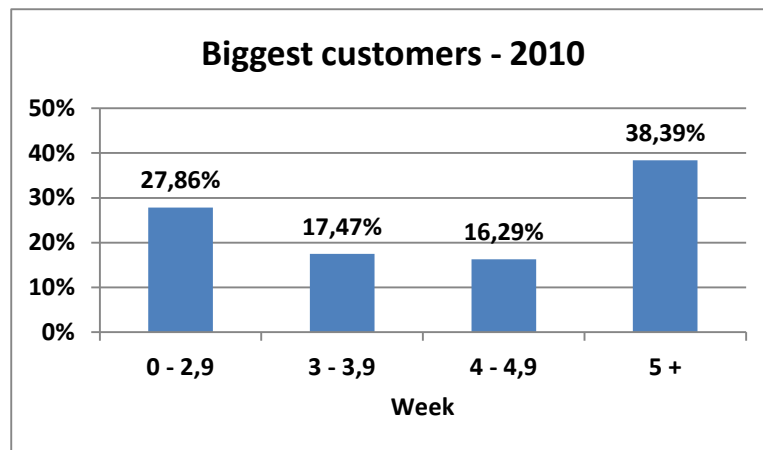
The above histogram shows that Plastprent delivers most of their orders in between two and four weeks or in 43% of the time.

### **5.1.3 Analysis of the biggest customers in 2010**

The following information is an analysis of the delivery reliability of Plastprent MTO orders to their biggest customers in the year 2010. It consists of around twenty of their largest customers in terms of income in sales.

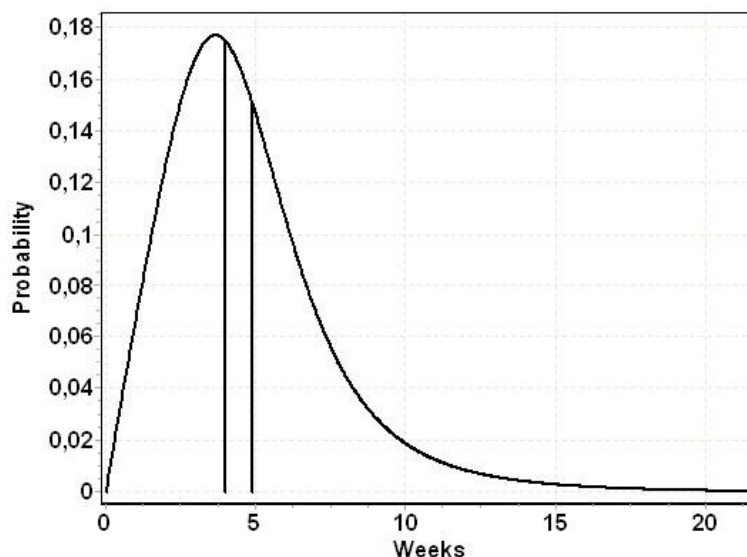
*Table 5 Delivery reliability of Plastprent MTO orders to their biggest customers in 2010*

Year	Comment	Average	Stdev	Mode	Median	Count	Probability			
							0 - 2,9	3 - 3,9	4 - 4,9	5 +
2010	Biggest customers	4,81	2,92	5,14	4,29	643	27,86%	17,47%	16,29%	38,39%



*Figure 19 Probability of delivering orders*

Plastprent objective is to deliver all orders “on-time” or in the defined 3 to 4,9 week columns, they managed to do so in 33,76% of orders in 2010. Orders delivered early were 27,86% and those delivered late were 38,39% which is unsatisfactory.



*Figure 20 Probability density function of biggest customers in 2010*

The above line chart shows the probability density function. The vertical black lines indicate the four weeks delivery window set by Plastprent. In 2010 it is apparent that Plastprent were unable to deliver most of their orders within the four week window as promised or only 33,76% were delivered “on-time”. The average for the year was 4,81 weeks. It is a cause for worry that the standard deviation was 2,93 weeks, which gives an indication that the delivery window defined was quite unreliable. The problem is with the data, as there are a lot of high values that make the density function positively skewed. The average is unreliable; the mode was higher or 5,14 weeks but the median was analysed and gives a better indication of the delivery reliability which was around 4,3 weeks. The histogram below gives a better representation of the data.

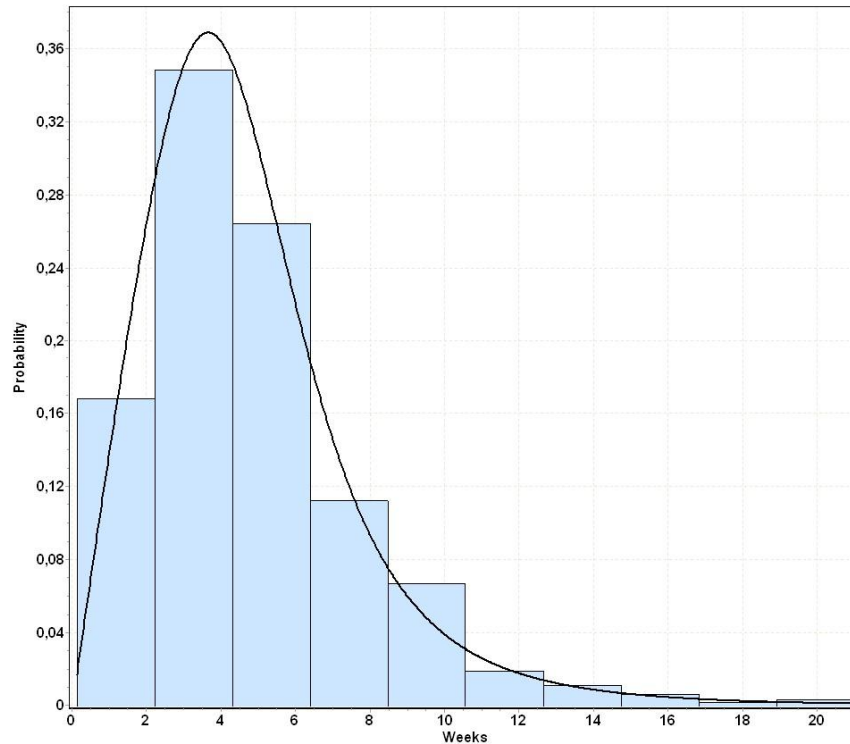


Figure 21 Histogram of probability density function of biggest customers in 2010

As can be seen on the histogram, Plastprent delivered most of their orders in between two and four weeks or in 35% of the time. It also shows the positively skewed data as a lot of orders were delivered later than 6 weeks, these values are causing the density function to be skewed and elevating the average.

The following table is an in depth analysis of the 15 biggest customers of 2010 in terms of sales income. It gives statistical data regarding the delivery reliability and quality issues.

Table 6 Delivery reliability of Plastprent 15 biggest customers in 2010

2010	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average	Total
Average	6,22	4,14	3,94	6,10	4,62	3,23	4,80	4,15	4,06	5,87	6,37	5,43	5,27	7,17	4,56	4,73	
Stdev	0,50	2,79	1,90	2,16	2,39	1,78	2,91	2,29	2,19	4,54	3,28	2,81	2,81	3,12	1,24	2,82	
Count	2	8	22	15	116	52	30	161	35	49	35	15	24	27	5	39,7	596
Sales (million ISK)	19	33	17	24	66	22	32	55	15	146	55	48	21	23	20	39,7	596
Productivity	39%	52%	17%	26%	11%	37%	41%	38%	32%	26%	32%	31%	41%	21%	45%	32,6%	
Complaints	2	1	1	0	2	0	0	8	7	15	2	1	0	0	0	2,6	39
Faults (Innhouse)	1	0	2	1	25	0	1	6	4	1	0	2	1	0	0	2,9	44
Comments	0	0	0	0	6	1	0	3	0	0	0	1	0	0	0	0,7	11
Complaints to supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	0
Total:	3	1	3	1	33	1	1	17	11	16	2	4	1	0	0	6,3	94
Faults/no. Productions:	150,0%	12,5%	13,6%	6,7%	28,4%	1,9%	3,3%	10,6%	31,4%	32,7%	5,7%	26,7%	4,2%	0,0%	0,0%	15,8%	15,8%
Material cost (Thousand ISK)	659	0	137	0	2.466	0	75	150	430	965	70	87	56	0	0	339,7	5.095
Work cost (Thousand ISK)	183	0	27	0	1.591	0	51	282	308	408	15	20	4	0	0	192,6	2.889
Credit given (Thousand ISK)	7	10	0	0	770	0	0	0	15	0	0	0	0	0	0	53,5	802
Total (Thousand ISK):	849	10	164	0	4.827	0	126	432	753	1.373	85	107	60	0	0	586	8.786
Fault cost/sales income	4,5%	0,0%	1,0%	0,0%	7,3%	0,0%	0,4%	0,8%	5,0%	0,9%	0,2%	0,2%	0,3%	0,0%	0,0%	1,5%	1,5%
No. Reproductions	0	0	0	0	6	0	0	3	2	1	0	0	0	0	0	0,8	12

Note: Due to anonymity the customers have been numbered.

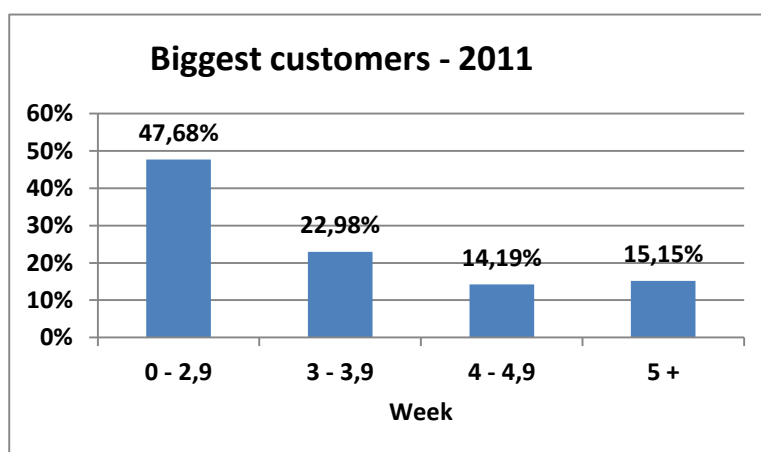
The customers displayed are some of the most important to Plastprent as almost 40% of their sales revenue is generated from them. It is not satisfactory that these customers received their orders in 4,73 weeks on average. To verify the average, it is wise to look at the mode and median. The mode was 4,86 weeks that is intact with the average but the median was lower or 4,14 weeks which is more positive. Comparing with Plastprent objective of delivering in the four-week window this performance is ok. Analysing the quality issues from these companies, it is apparent that Plastprent had problems with quality issues with some companies as faults costs versus sales income was well above the average. The issues with these companies were addressed and improvements made which had some benefits as can be seen in the analysis of the biggest customers of 2011.

#### 5.1.4 2011 Analysis of the biggest customers in 2011

The following information is an analysis of the delivery reliability of Plastprent MTO orders for their biggest customers in the year 2011. It consists of around twenty of their largest customers in terms of income in sales.

*Table 7 Delivery reliability of Plastprent MTO orders to their biggest customers in 2011*

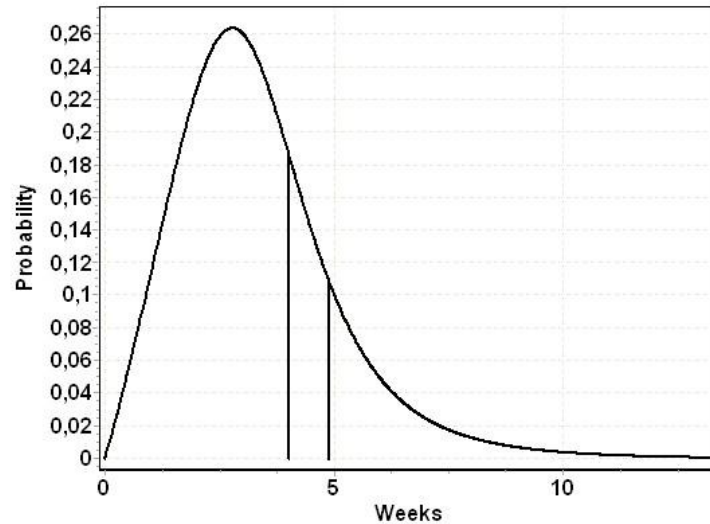
Year	Comment	Average	Stdev	Mode	Median	Count	Probability			
							0 - 2,9	3 - 3,9	4 - 4,9	5 +
2011	<i>Biggest customers</i>	3,40	1,93	2,57	3,00	485	47,68%	22,98%	14,19%	15,15%



*Figure 22 Probability of delivering orders*

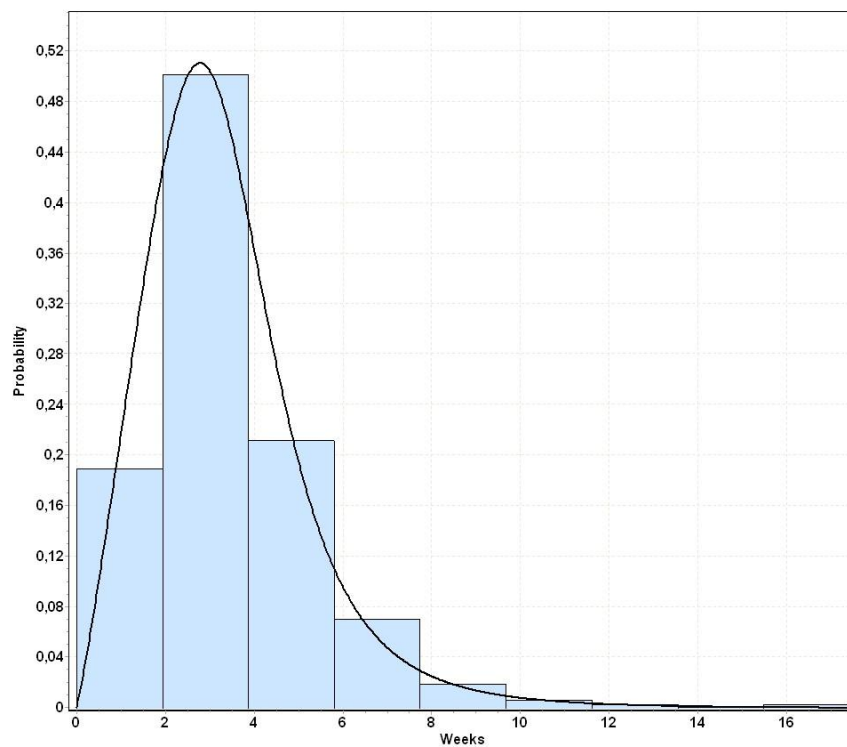
Plastprent objective is to deliver all orders “on-time” or in the defined 3 to 4,9 week columns, they managed to do so in 37,17% of orders in 2011. Orders delivered early were 47,68% and those delivered late were 15,15%. This is considerably better than in the previous year. The service level to customers was good.





*Figure 23 Probability density function of biggest customers in 2011*

The above line chart shows the probability density function. The vertical black lines indicate the delivery window defined by Plastprent. In 2011, Plastprent was able to improve the delivery reliability and most of its orders were delivered “on-time” and “early” or 84,85% of orders. The average delivery time for the year was under four weeks and the most frequent delivery time was under three weeks. The delivery reliability to the biggest customers in 2011 was very good.



*Figure 24 Histogram of probability density function of biggest customers in 2011*

The histogram is very positive and shows that Plastprent delivered most of its orders in between two and four weeks or in 50% of the time.

The following table is an in depth analysis of the 14 biggest customers of 2011 in terms of sales income. It gives statistical data regarding the delivery reliability and quality issues.

*Table 8 Delivery reliability of Plastprent 14 biggest customers in 2011*

2011	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average	Total
Average	5,55	3,53	3,60	3,64	2,86	4,03	3,89	3,01	3,47	3,71	2,36	3,73	2,89	2,43	3,31	
Stdev	3,12	1,62	1,54	2,98	1,39	2,03	2,14	1,42	2,04	2,12	1,10	1,67	1,48	1,45	1,86	
Count	6	10	16	29	45	21	19	157	37	62	11	8	10	8	31,36	439
Sales (million ISK)	28	34	18	26	19	20	18	51	22	138	107	27	22	23	39,5	553
Productivity	39%	40%	22%	28%	27%	27%	29%	36%	27%	22%	23%	34%	38%	35%	30,5%	
Complaints	0	0	0	0	1	0	8	13	3	6	7	1	1	2	3,0	42
Faults (Innhouse)	2	1	0	4	1	0	1	4	4	2	0	0	1	0	1,4	20
Comments	0	0	0	1	0	0	0	6	2	1	1	0	0	1	0,9	12
Complaints to supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0	0
Total:	2	1	0	5	2	0	9	23	9	9	8	1	2	3	5,3	74
Faults/no. Productions:	33,3%	10,0%	0,0%	17,2%	4,4%	0,0%	47,4%	14,6%	24,3%	14,5%	72,7%	12,5%	20,0%	37,5%	16,9%	16,9%
Material cost (Thousand ISK)	0	58	0	1.311	15	0	253	250	647	1.088	80	49	225	1	284,1	3.977
Work cost (Thousand ISK)	115	20	0	368	0	0	327	411	262	337	963	24	133	1	211,5	2.961
Credit given (Thousand ISK)	0	0	0	0	0	0	0	50	208	0	0	0	0	0	18,4	258
Total (Thousand ISK):	115	78	0	1.679	15	0	580	711	1.117	1.425	1.043	73	358	2	514	7.196
Fault cost/sales income	0,4%	0,2%	0,0%	6,5%	0,1%	0,0%	3,2%	1,4%	5,1%	1,0%	1,0%	0,3%	1,6%	0,0%	1,3%	1,3%
No. Reproductions	1	0	0	0	0	0	0	3	2	0	0	0	1	0	0,5	7

*Note: Due to anonymity the customers have been numbered.*

The customers displayed are some of the most important to Plastprent as almost 40% of its sales revenue is generated from them. 2011 was a considerably better year than 2010 in terms of delivery reliability to their biggest customers. Progress was made and can be seen by looking at the average delivery time that was 3,31 weeks and the median was 3,00 weeks, very positive indeed. These figures indicate the reliable delivery of Plastprent to their biggest customers in 2011. As previously stated, Plastprent wanted to improve their quality issues in 2011 and achieved almost 14% reduction in cost of faults versus sales income to their biggest customers. Although progress was made, there are still companies such as numbers 4, 7 and 9 where the ratio is around 3% to 6% that is too high and is possibly causing late deliveries. The overall delivery reliability to the 14 biggest customers in 2011 was very good.

## 5.2 Analysis of late delivery

The overall conclusion of the data in the previous chapter is positive for Plastprent; its four week defined delivery window was in most cases accurate. Nevertheless, Plastprent is experiencing difficulties with its reliability. A positive indication is that the reliability improved from the year 2010 to 2011. Plastprent needs to build upon that and define its objectives to be able to improve its delivery reliability.

What is causing the orders being delivered late? Late deliveries are defined as the orders delivered to customers later than the four weeks defined delivery window by Plastprent.

Are there issues with the supply chain, quality, down time, staff or raw materials? Any number of these factors can have an effect on the delivery reliability.

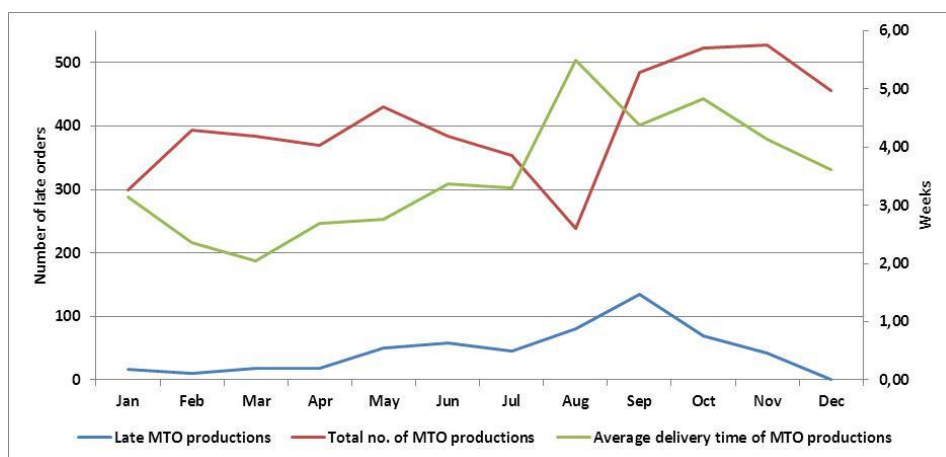
Hereafter is a more in depth analysis of orders delivered later than promised. The data was gathered from the information system of Plastprent and includes the requested receipt date from customers. In this case an analysis of all orders delivered later than the customer requested is introduced. The data is gathered from the year 2011.

*Table 9 Overview of late orders delivered to customers*

Year	Comment	Average	Stdev	Mode	Median	Min	Max	Count
2011	<i>Production</i>	<b>5,40</b>	<b>1,94</b>	<b>4,14</b>	<b>5,00</b>	<b>0,43</b>	<b>19,14</b>	<b>542</b>
2011	<i>Late</i>	<b>-1,98</b>	<b>2,67</b>	<b>-1,00</b>	<b>-1,29</b>	<b>-44,57</b>	<b>-0,14</b>	<b>542</b>

The table gives an overview of the production time and the lateness of the MTO productions that were delivered late to customers in 2011. The average lead time for these productions were 5,4 weeks, which is rather high. To verify this better it is wise to look at the mode and median, they give a better outlook of the lead time. The mode is 4,14 weeks and the median is 5,00 weeks, in most cases Plastprent broke their four week defined delivery window.

The data in the late row represent statistical analysis of how late the production were overall. The average was around two weeks late, to validate this, a closer attention must be made to the mode and median and they are more positive or around one week late. Plastprent are delivering most orders in five weeks, or one week late. A closer analysis was made to look for a common trend. Are Plastprent having problems in certain months or with certain product types?



*Figure 25 Analysis of orders in each month in 2011*

The line chart shows a distinct trend in the late orders in 2011. They occurred mostly towards the end of the year. Why is that? Plastprent closed the factory for three weeks in the end of July so the employees could take their holiday vacations. This obviously had an effect on the delivery reliability after the summer where backlogs of orders gathered up.

Also, in the latter months of the year the demand increased which has an effect. In 2011 there was also an issue with the summer closure as the wrong information was given to customers about the closing dates. Moreover, after the closures the manufacturing was not at full capacity as some employees were still away. This explains the high amount of late deliveries in August and September.

*Table 10 Plastprent MTO products are divided into the following four categories*

Category no.	Description	Total	%
400	400 - Food packaging and bags	258	47,6%
300	300 - Industrial and consumer	144	26,6%
100	100 - Carrier bags	140	25,8%
200	200 - household products	0	0,0%
		<b>542</b>	<b>100%</b>



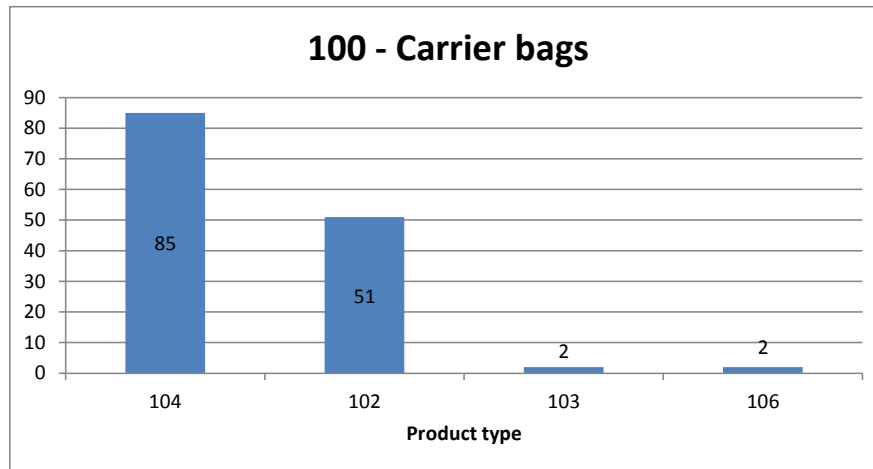
*Figure 26 Number of late orders by category*

The table and chart give an interesting view of the type of orders that are delivered late to customers. Most of the late orders or 47,6% are in the 400 category or food packaging and bags which are most often for the food industry which is one of Plastprent biggest market segments. The average orders were produced in 5,41 week and were delivered 1,93 weeks later than the customer requested.

The categories are broken down and each category analysed to look for trends. The product types that are delivered late most often will be further analysed to look for causes.

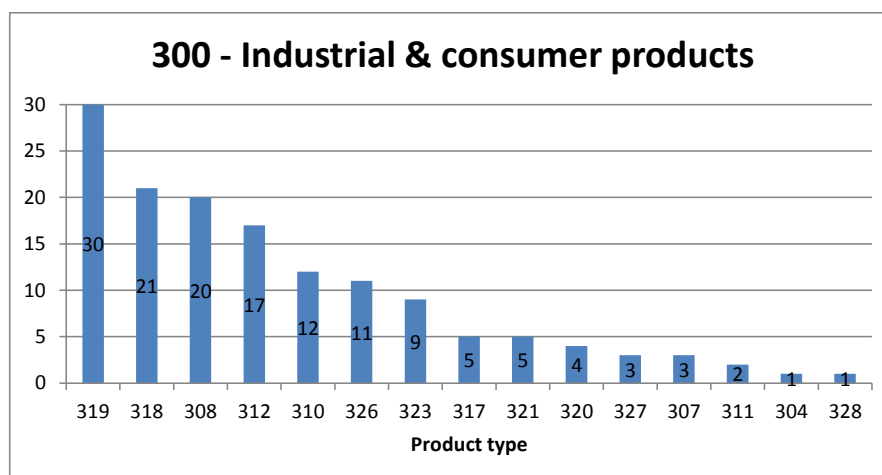
It is apparent that in the 100 category or carrier bags product types 104 and 102 are most often delivered late. Product type 104 refers to carrier bags with handles and print for stores. Product type 102 refers to carrier T-shirt bag with print for supermarkets. Product 104 is in demand and is produced quite a lot for customers that could explain why it is delivered late. Also it goes through machine 306 in the converting department and the load on the machine is considerable as other machines in the department cannot perform the

same tasks. Product type 102 has a different production process but goes through machine 309C which has a lot of projects which could explain why it is delivered late.



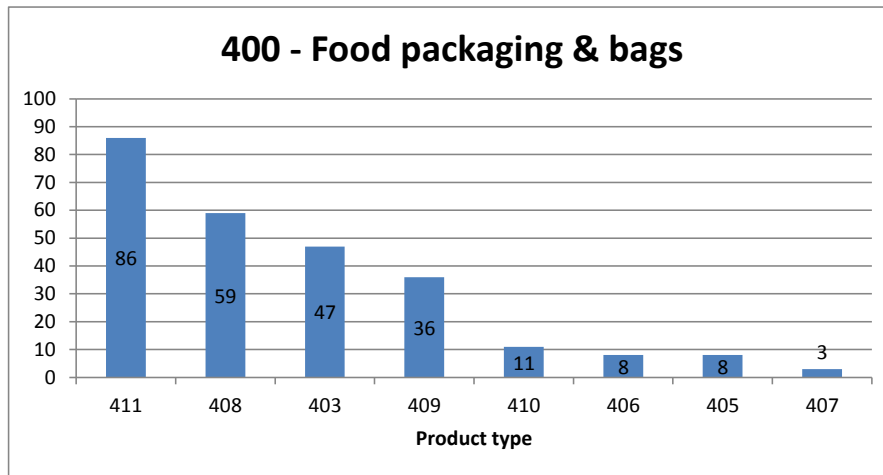
*Figure 27 Number of late orders in category 100*

The product type in category 300 that was most often delivered late was 319. Product type 319 refers to small bags with print (smaller than 500mm). This product is non-food and is for smaller customers. The batch sizes are very small and uneconomical because of the number of changeovers and calibrations, they are also time consuming. After looking at the data, 66% of the orders were delivered in last months of the year which explains why they were late.



*Figure 28 Number of late orders in category 300*

The product type in category 400 which was most often delivered late was 411. Product type 411 refers to printed packaging film. This film is laminated which means the production process is quite complex and it has to go through four to six operating steps all from cutting – printing – lamination – cutting. Also after lamination the product has to be cured for one week, which is the time the glue from the lamination process has to dry. Due to this complicated production process orders are being delivered late, it does not take a lot in the process to go wrong for the order to be delayed.



*Figure 29 Number of late orders in category 400*

All the above product types were delivered later than promised to customers, which is not satisfactory. After the analysing the reasons for the lateness of some product types it is apparent that the summer closure had the biggest effect on the delivery reliability of these products. Other factors were load on machinery and complicated production processes. This is not too worrying and factors that could be made to have less effect.

## 6 Factors that effect Plastprent delivery reliability

In order to be able to improve the delivery reliability of Plastprent MTO productions, a better understanding and analysis of the supply chain needs to be completed and factors that impact the delivery reliability need to be defined.

The SCOR model will be the basis of the analysis. The model is based on five general supply chain management functions of plan, source, make, deliver and return. The first four functions will be the focus of the analysis of Plastprent delivery reliability.

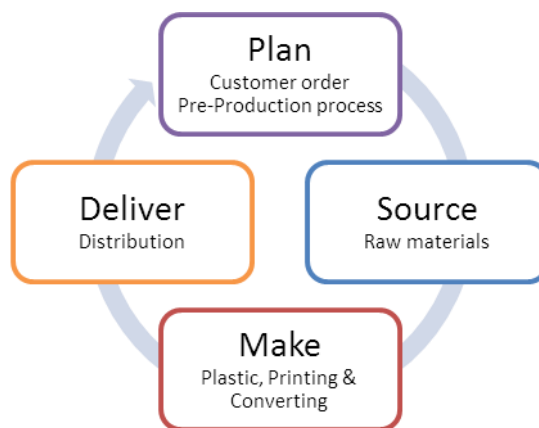


Figure 30 Illustrative view of the SCOR model

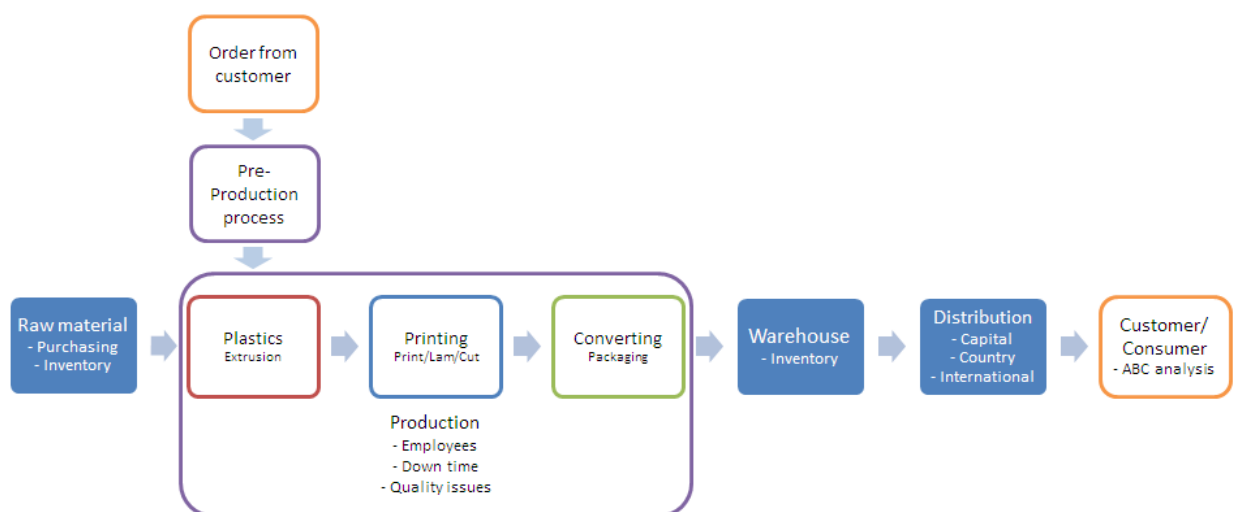


Figure 31 Plastprent supply chain (simplified)

The above diagram gives a basic layout of the supply chain. Plastprent produced a wide variety of products and not all of them take the same path through the supply chain, some are more complex than others.

Uncertainty exists at every level in the supply chain (Lee and Billington, 1995). For example, upstream uncertainty can be manifested through late deliveries by suppliers or poor quality of the incoming materials and parts (Davis, 1993). Looking downstream, uncertainty takes the form of unforeseen demand variability, which in turn creates problems in planning, scheduling, and control that jeopardize delivery performance (Fisher et al., 1997).

At the simplest level, uncertainty in a supply chain can be viewed as the reliability of a series of sequential and parallel tasks. The product of the components' reliability gives the reliability of such a system. In a supply chain, setting this is comparable to the number of echelons or to the horizontal dimension of the supply chain (Lambert et al., 1998). Hence upstream uncertainty will increase with the number of upstream echelons (Beamon, 1999).

The similarity of system reliability could be used here to understand the impact of the number of levels and suppliers at per level. Each supplier in a supply chain is similar to a machine processing in the production system. A supplier's failure to supply the right product at the right time (e.g. late delivery, poor quality) affects the reliability of the whole system. Looking downstream, the possible amplification of end-users demand variation upstream through the channel, known as the bullwhip effect (Lee et al., 1997), is a function of the number of levels in the supply chain.

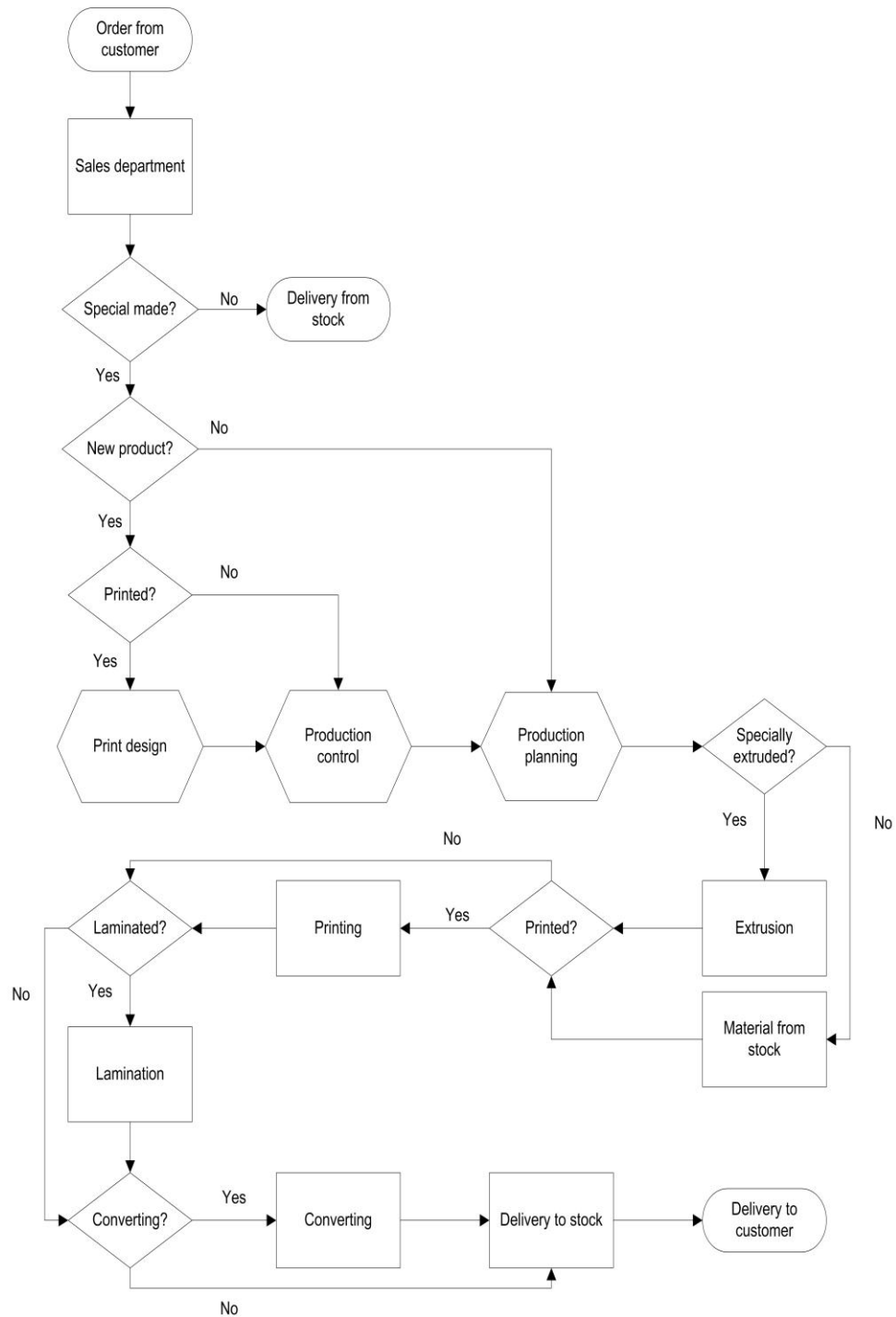
Supply chains are not simple to analyse; however, by focusing on the four supply chain operation reference model management factors: plan, source, make and deliver, it becomes easier to examine and thus identify factors that contribute to the delivery reliability of Plastprent MTO productions.

## **6.1 PLAN**

The Plan process describes the planning activities associated with operating a supply chain.

The schematic in figure 32 is the planned process of receiving orders from customers to delivering to the customer. Sales person receives customer orders and follows the process. All relevant information is attained from customer and the order is processed.



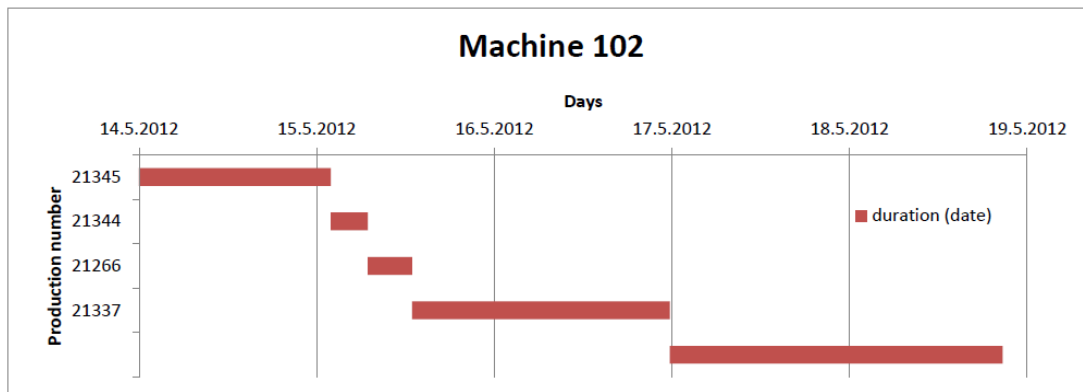


*Figure 32 Process from customer order to customer receipt*

The overall planning process of Plastprent production is not defined with an MPC system. No real objectives or sales and operation plan (S&OP) is carried out. The production operates on a basic manufacturing plan that is organized by the production team. The plan is done subjectively; therefore, experience is used to setup the production plan.

The Extrusion department plans their weekly production with a Gantt chart. Each machine is broken down and productions are ordered in the most convenient in relevance to

changeovers and such. This gives an indication to the other departments when they can expect orders to be available and allows staff to be better prepared for changeovers.



*Figure 33 Gantt chart of extrusion department production in machine 102*

The pre-production process is a factor that could contribute to Plastprent unreliable delivery. The sales department takes orders from customers and then follows the process in figure 34. If a customer needs a new product the specifications are sent to production control where the technical manager prepares a recipe for the product that includes the raw materials needed and the process it needs to take, i.e. what actions in the production need to be taken. The main problem in this stage is that one man or the technical manager is responsible for the recipe and if he is unavailable then the process takes longer time, but in specific cases the production managers can intervene and prepare the recipe. When the recipe is ready an order confirmation is made and printed out, the confirmation is printed when there are six to eight weeks until the date of delivery. That means the production department have an overview of productions for the next six to eight weeks. A backup list is made by the technical manager and is sent to the production managers weekly so they have a better overview and can plan the productions so there is quite high operation security.

There is not a priority plan in place at Plastprent to define priority requests from customers who wish to receive their orders earlier than the delivery window defines. These requests are affecting the production schedule and causing disruption in the production process. Therefore affecting the delivery reliability of other productions that get delayed because of the priority orders.

The following schematics contain the pre-production process and all relevant processes. By analysing the process and speaking with staff responsible, no obvious factors are affecting the delivery reliability. Note that in all the schematics the EBL which refer to the papers attached are defined in the first process it is mentioned, e.g. EBL 3.1.A – Product description.

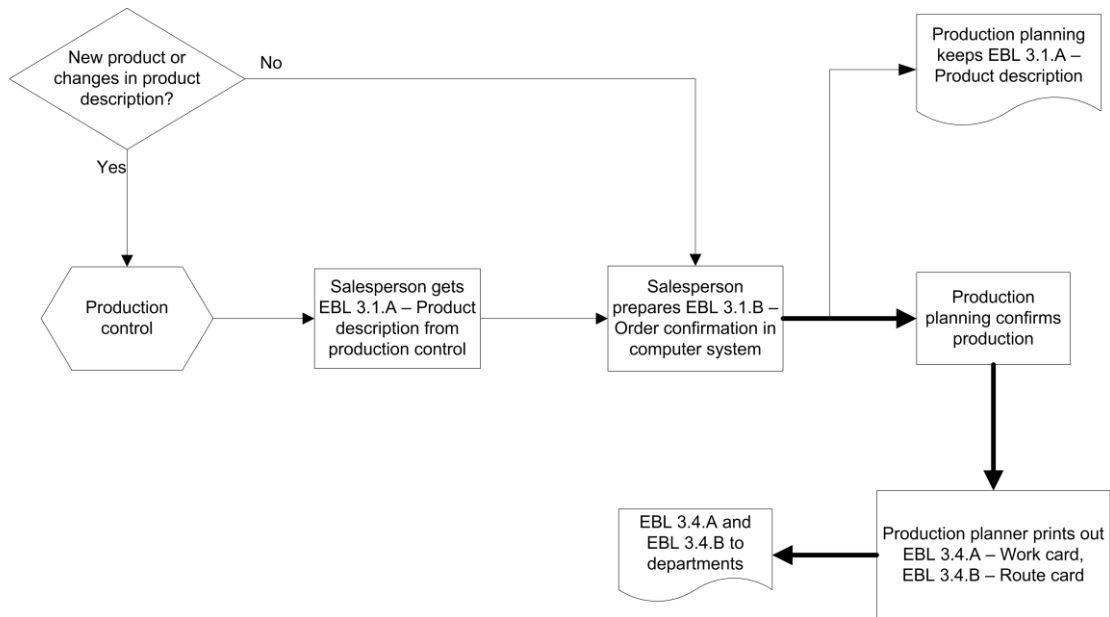


Figure 34 Pre-production process

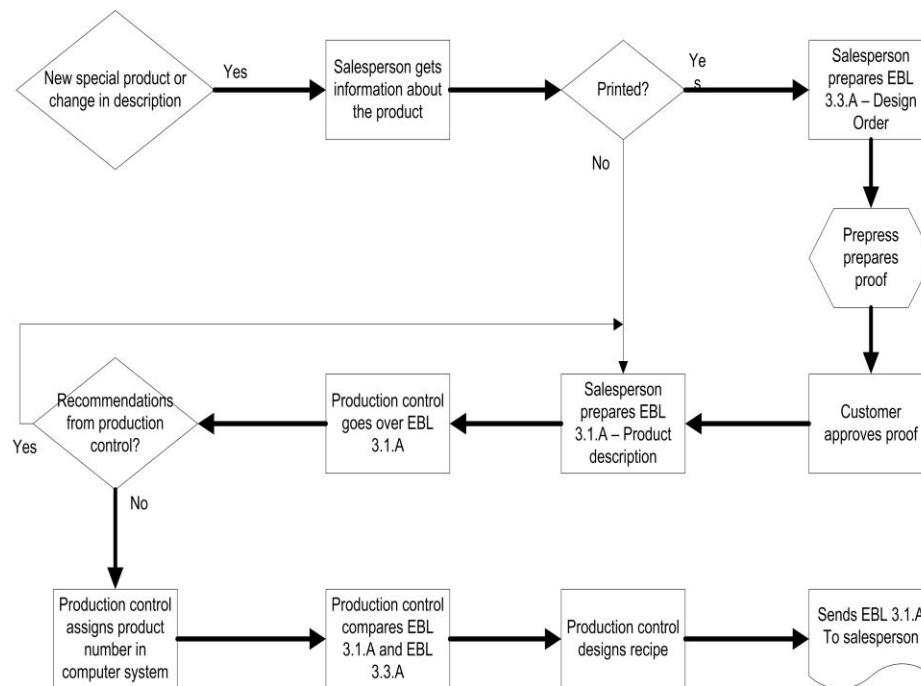
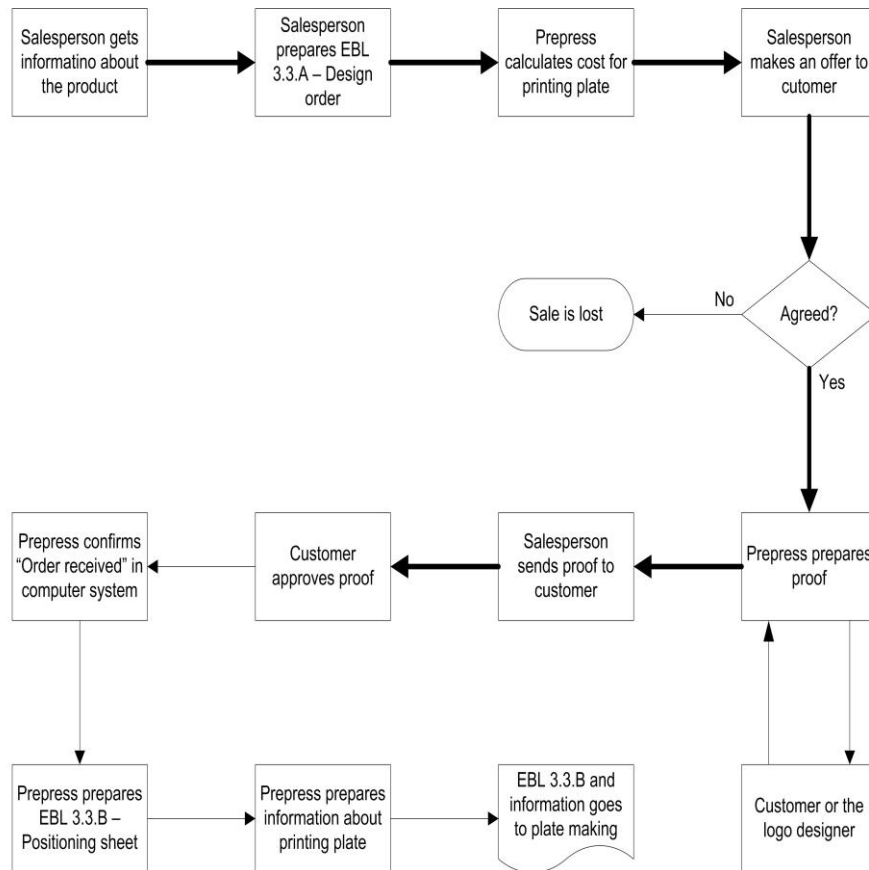


Figure 35 Production preparation process for new products



*Figure 36 Process for print design*

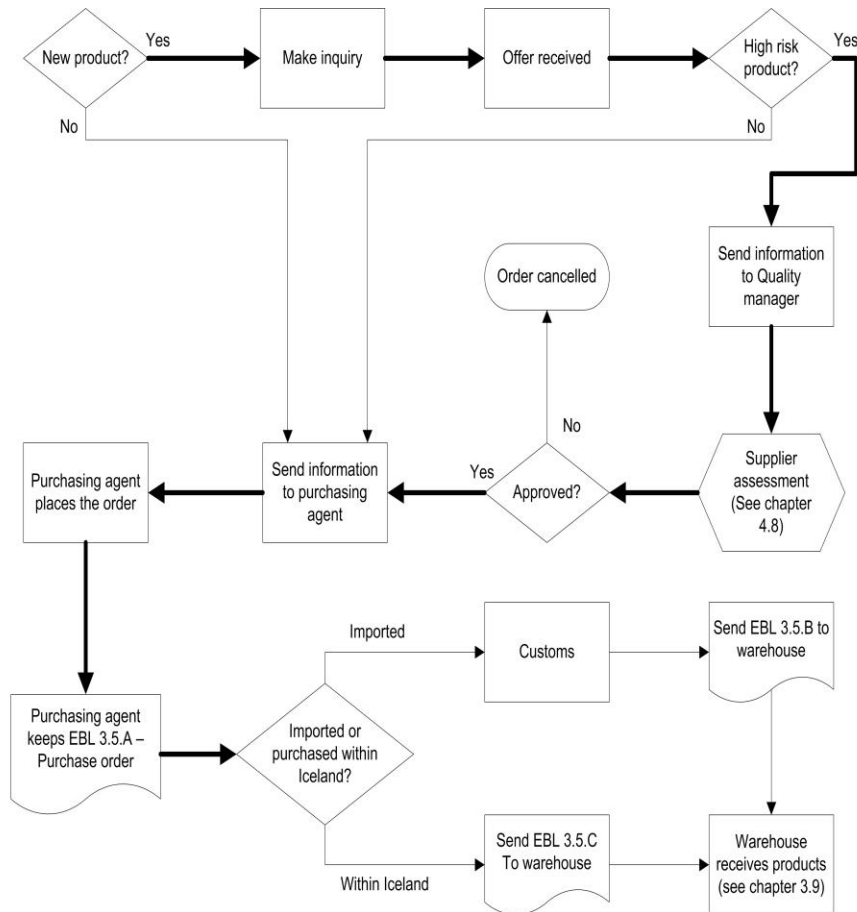
As the production processes are quite complicated and they have a wide product range at Plastprent, orders have to travel differently through the processes. The print design process can be time consuming, and most often it is the customer who slows the process down as they often take a long time in deciding the design. This can lengthen the delivery reliability, but in most cases it is the customer who is accountable.

To conclude, there are factors in the planning process, which are affecting the delivery reliability of Plastprent MTO orders. The highlighted factors in this section are the lack of an overall planning process and objectives and priority requests. Possible improvements are introduced in the Improvements chapter hereafter.

## 6.2 SOURCE

The Source process describes the ordering, scheduling and receipt of goods and services.

In order to for Plastprent to supply customers it needs raw materials to process into the products they sell. The process of purchasing is defined in the following schematic. The schematic shows the purchasing of new and old products. The purchasing manager is responsible for sending purchasing orders to suppliers. Purchases are done with advice from the sales department and the production managers.



*Figure 37 Purchasing process*

The purchasing is quite complex as the objective is to limit inventory to save cost but still be able to service customers with products. Also, a minimum quota of purchased products often applies and some of the purchased products have a lifetime and spoil if not used within a certain time. Therefore, the challenge is to buy an economical amount to save on transportation costs, and also buy the right quantities so it the material does not diminish whilst maintaining a good service level to customers.

Table 11 shows the lead time from Plastprent suppliers. In most cases it is above the four weeks delivery window Plastprent defines as their lead time to customers. Shortages in raw materials can have a big effect on Plastprent capability of promising orders in four weeks.

Purchasing is complex and could be the focus for another M.Sc. thesis so no quantitative data will be put forth, only qualitative. Plastprent purchasing of the following goods are in the hands of the production managers as they are responsible for utilizing them and have the best sense of how much is used and, therefore, how much is needed. They are doing a good job and are achieving fewer shortages whilst maintaining a low level of inventory.

*Table 11 Plastprent suppliers*

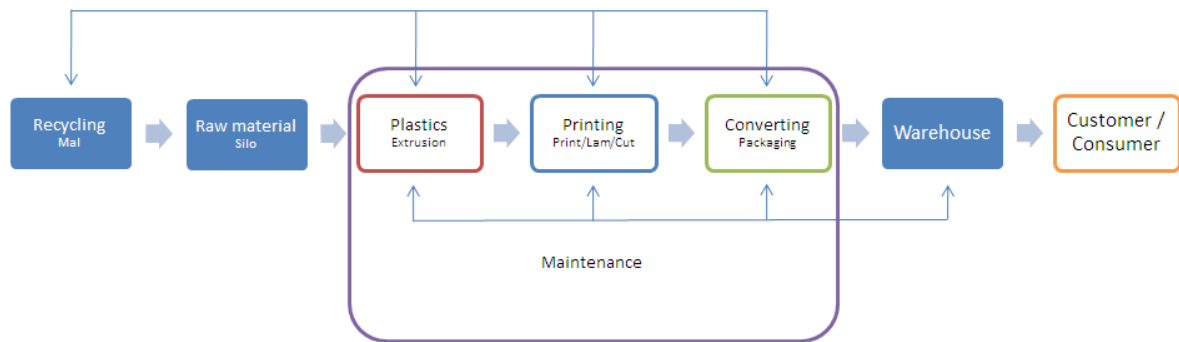
<b>Purchased goods</b>	<b>Suppliers</b>	<b>Lead time</b>	<b>Life time</b>
<b>Printing plates</b>	H. Pálsson	<i>6 weeks</i>	<i>Not applicable</i>
<b>Adhesives</b>	Henkel	<i>3 weeks</i>	<i>12 months</i>
<b>Colours</b>	Resino	<i>3 weeks</i>	<i>24-36 months</i>
<b>Film</b>	Super film	<i>7-8 weeks</i>	<i>6-12 months</i>
	Casfil	<i>5 weeks</i>	
	Innovia	<i>8 weeks</i>	
	Comoco	<i>5 weeks</i>	
	Amcor	<i>n/a</i>	
	Danpak	<i>n/a</i>	
	Rockwell	<i>n/a</i>	
	Camvac	<i>n/a</i>	
<b>Plastic granules</b>	Borealis AG (ÁRVÍK)	<i>3-4 weeks</i>	<i>Not applicable</i>
	Sabic	<i>3-4 weeks</i>	
	Telko Denmark A/S	<i>4-6 weeks</i>	

To conclude, there are factors in the Source process, which are affecting the delivery reliability of Plastprent MTO productions. The highlighted factors in this section are complicated purchasing and the need for better material resource planning. Possible improvements are introduced in the following Improvements chapter.

## 6.3 MAKE

The Make process describes the activities associated with the conversion of materials.

Plastprent production is divided into three production departments: Extrusion, Printing and Converting.



*Figure 38 Simplified production schematic for Plastprent*

The production departments all deal with similar problems, which are throughput, down time and staff utilization. Machinery at Plastprent is out dated and does not produce at maximum capacity anymore; they are also at risk of breaking down as the components in the machines are old. The factory operates with a minimum number of staff to save costs and if an employee is absent due to illness or is on holiday, it is very likely that the machine he/she operates will not be operated. That comes down on the throughput and slows down the production and contributes to longer a lead time, which in turn has an effect on the delivery reliability. As the market is small in Iceland, customers require smaller batches. Therefore, the flexibility in the production has to be high as there are a lot of different orders going through the system. For this reason, there is a lot of time that goes into changeovers and calibrations that are quite uneconomical since there is no value being created whilst the changeovers take place.

### 6.3.1 Extrusion department

The Extrusion department produces plastic in a process called blow film extrusion. The department has eight extruders and two recycling machines. The department operates with nine employees, five days a week with three shifts every day, eight hours each.

Production process in the Extrusion department is described in figure 39. The schematic gives a detailed flow of the product and all involved quality checks and relevant information sheets to be filled out.

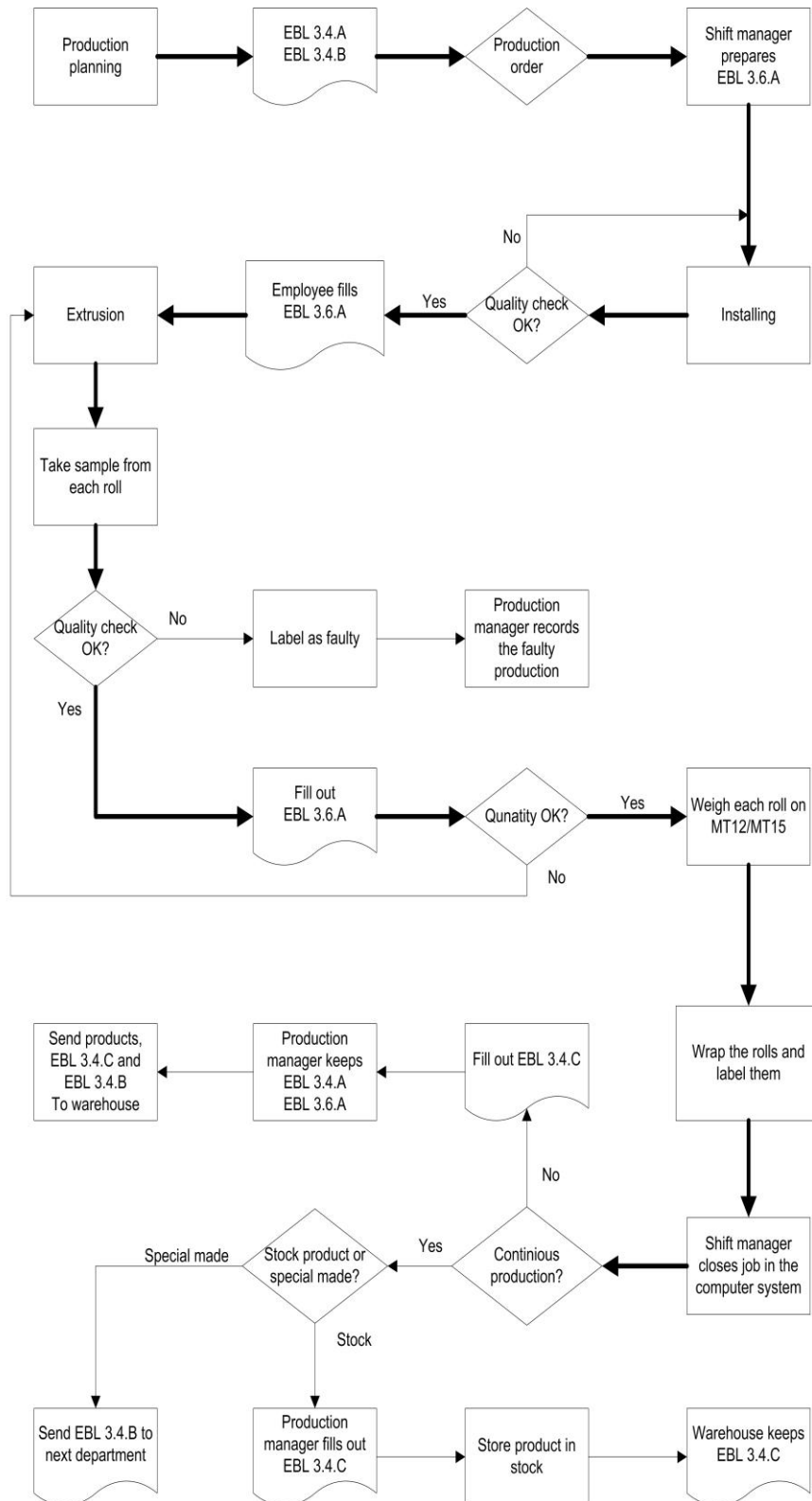


Figure 39 Production process in the extrusion department



*Table 12 Operating hours of the extrusion department in weeks 9 to 15 in 2012*

Machine	Kg.	Hours	Projected	Closed projects	Difference
101	53.301	411	365	17	45
102	75.140	623	574	24	49
103	22.540	433	179	44	254
104	37.655	669	352	39	317
105	42.791	554	435	52	119
106	67.262	725	591	7	134
108	6.290	385	339	8	46
109	17.985	480	256	23	224
<b>Total:</b>	<b>322.964</b>	<b>4.279</b>	<b>3.091</b>	<b>162</b>	<b>1.188</b>

The hours represent all productions, MTO and MTS. The projected column indicates what the production recipes estimated the time the productions would take. There is a big variance indicated in the difference column where 1.188 additional hours in the measured seven week period were used. This is an obvious indication that the hours projected and the actual hours used in the department are very wrong. This is caused by any number of reasons such as machinery down time and product recipes. The following tables show the staff utilization and the machinery down time in the same period. 4,3% of the time, a staff member was absent, this is not a worrying statistic, but it is vital to follow as with previous experience that there has been quite a high rate of absence. The machinery down time was 17,18% in this period which is very high. The department did suffer an abnormal amount of down time in this period, which is due to the old age of the machinery. The department is having problems with the recipes of products, because they predict a lot fewer hours than the department is using which is making it hard to plan productions. The department is also suffering from abnormally high down time, which is having a big effect on the lead time and therefore, the delivery reliability.

*Table 13 Staff utilization in the extrusion department in weeks 9 to 15 in 2012*

Staff utilization	Hours	%
Working hours	2.680	95,7%
Absence	120	4,3%
Holidays	0	0,0%
Over time	0	0,0%
<b>Total hours</b>	<b>2.800</b>	<b>100%</b>

*Table 14 Machinery down time in the extrusion department in weeks 9 to 15 in 2012*

Machine	Down time	Hours	%
<b>101</b>	51	411	12,4%
<b>102</b>	66	623	10,6%
<b>103</b>	23	433	5,3%
<b>104</b>	10	669	1,5%
<b>105</b>	279	554	50,4%
<b>106</b>	72	725	9,9%
<b>108</b>	192	385	49,9%
<b>109</b>	1	480	0,2%
<b>Motan</b>	0	-	-
<b>Recycling</b>	41	-	-
<b>Total:</b>	<b>735</b>	<b>4.279</b>	<b>17,18%</b>

### **6.3.2 Printing department**

The printing department prints, laminates and cuts the film, produced or imported by Plastprent. The department has three printing machines, two slitter (cutting) machines and a lamination machine. The department operates with 13 employees, five days a week with two shifts every day, eight hours each.

Production process in the Printing Department is described in figure 40. The schematic gives a detailed flow of the product and all involved quality checks and relevant information sheets to be filled out.

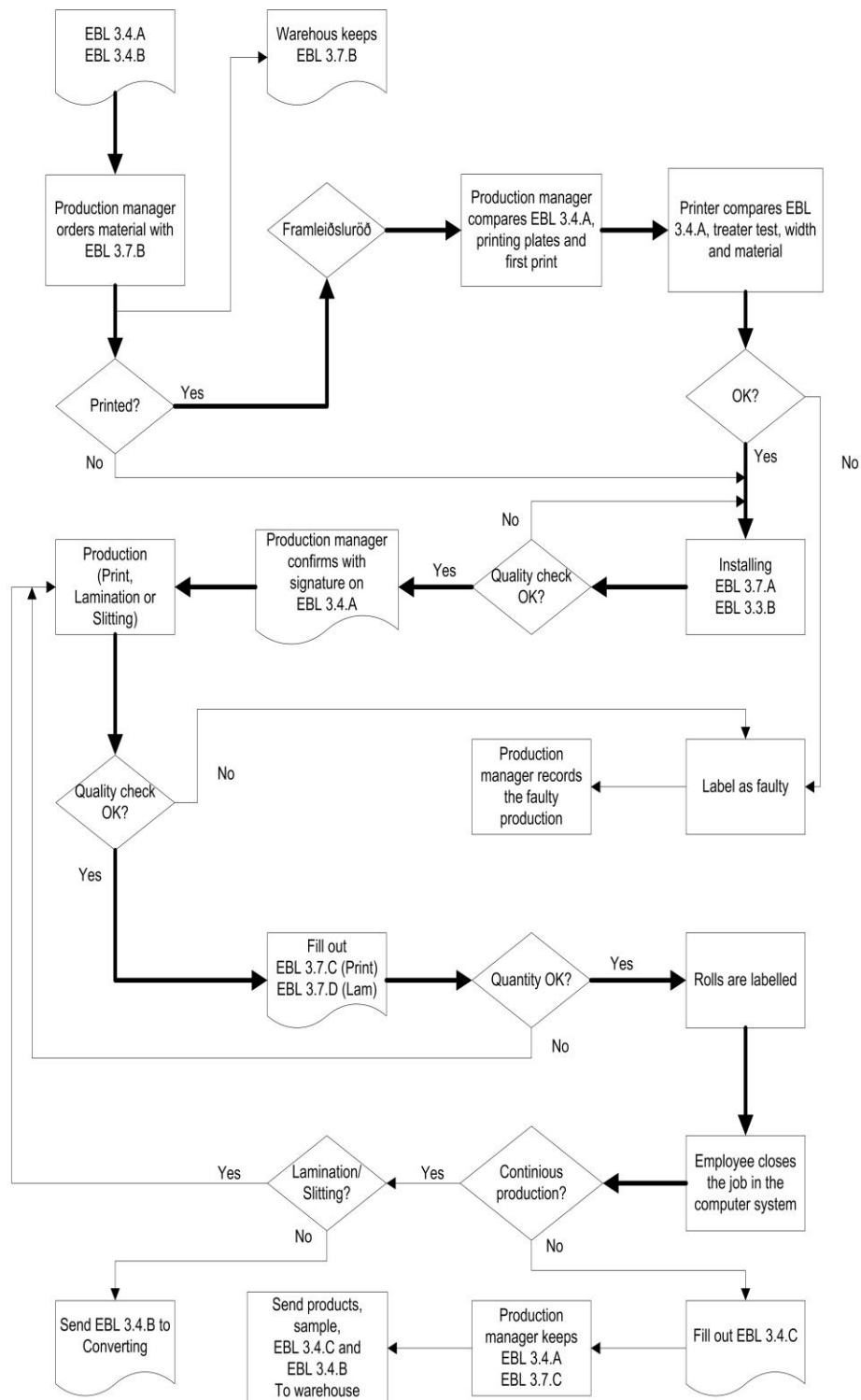


Figure 40 Production process in the printing department

*Table 15 Processed meters in the printing department in weeks 5 to 17 in 2012*

2012	Meters	No. of jobs	Callibration m.	%of callibration m
<b>Printing</b>	4.081.905	335	206.550	5,06%
<b>Cutting</b>	6.093.099	373	12.545	0,21%
<b>Lamination</b>	1.151.000	98	11.510	1,00%
	<b>11.326.004</b>	<b>806</b>	<b>230.605</b>	<b>2,04%</b>

The meters represent all productions, MTO and MTS. In the printing department it is vital to monitor the amount of meters that go into calibration as that can be costly and time consuming. The percentage of calibration is around 2%, which is under the 4% defined by the product recipes. A worrying factor is that in the department they sold a total of 3.333 hours in this period but operating hours were 5.869, which makes the utilization of just around 57%. There has been a decline in projects in this period and that is having an effect. The following tables show the staff utilization and the machinery down time in the same period. 1,3% of the time, a staff member was absent, which is not worrying and is the least in all production departments. The machinery down time was 3,19% in this period, which is low and not a concern. There is a problem with a particular machine; the 210 printing machine, on which the department has a lot of maintenance issues.

*Table 16 Staff utilization in the printing department in weeks 5 to 17 in 2012*

Staff utilization	Hours	%
<b>Working hours</b>	5.869	94,0%
<b>Absence</b>	80	1,3%
<b>Holidays</b>	297	4,8%
<b>Over time</b>	0	0,0%
<b>Total hours</b>	<b>6.246</b>	<b>100%</b>

*Table 17 Machinery down time in the printing department in weeks 5 to 17 in 2012*

Machine	Down time
<b>201</b>	9
<b>204</b>	8
<b>210</b>	114
<b>211</b>	6
<b>212</b>	12
<b>225</b>	38
<b>Total:</b>	<b>187</b>

### 6.3.3 Converting department

The converting department converts the plastic film into bags or other products. The department has 13 converting machines. The department operates with 20 employees, five days a week with two shifts every day, eight hours each.

Production process in the Converting department is described in figure 41. The schematic gives a detailed flow of the product and all involved quality checks and relevant information sheets to be filled out.

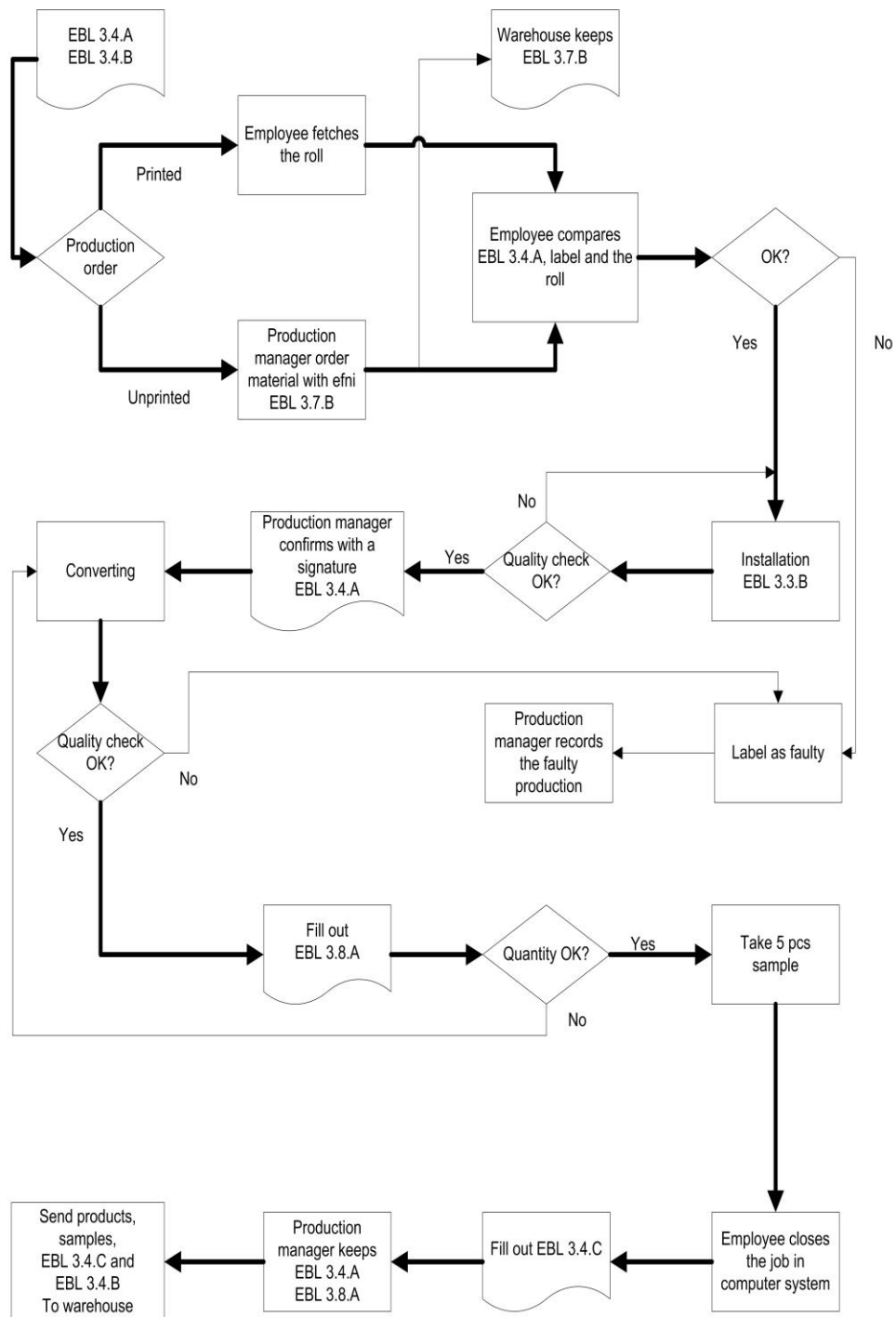


Figure 41 Production process in the converting department

*Table 18 Operating hours of the converting department in weeks 3 to 17 in 2012*

Machine	Total hours	Difference
301	555	141
319B	478	209
305	260	28
306	954	-176
308	423	8
309	394	130
302	193	-7
309C	741	-35
314	342	43
315	340	86
318	1203	-213
322	647	29
320	1626	-461
<b>Total:</b>	<b>8156</b>	<b>-218</b>
<b>Closed projects</b>	<b>445</b>	<b>-2,67%</b>

The hours are all productions, MTO and MTS. The projected hours, versus the actually used hours in the converting department, are more positive, the variation is 218 hours. The production recipes projected 218 hours more in production time than it actually took. This is a positive indication that in some machinery, like in the 320 and 328, the department is managing higher levels of utilization. The following tables show the staff utilization and the machinery down time in the same period. 4,5% of the time, a staff member was absent, which is not worrying and is similar to the extrusion department. It is, however, vital to monitor since there has been quite a high rate of absence with previous experience. The machinery down time was 3,6% in this period, which is low and not a worrying factor like in the extrusion department.

*Table 19 Staff utilization in the converting department in weeks 3 to 17 in 2012*

Staff utilization	Hours	%
<b>Working hours</b>	9.134	89,8%
<b>Absence</b>	457	4,5%
<b>Holidays</b>	423	4,2%
<b>Over time</b>	152	1,5%
<b>Total hours</b>	<b>10.166</b>	<b>100%</b>

*Table 20 Machinery down time in the converting department in weeks 3 to 17 in 2012*

Machine	Down time	Hours	%
301	38	555	6,8%
319B	23	478	4,8%
305	5	260	1,9%
306	52,5	954	5,5%
308	36	423	8,5%
309	23	394	5,8%
302	4	193	2,1%
309C	8	741	1,1%
314	13	342	3,8%
315	23,5	340	6,9%
318	8,5	1203	0,7%
322	14	647	2,2%
320	41,5	1626	2,6%
<b>Total:</b>	<b>290</b>	<b>8156</b>	<b>3,6%</b>

### 6.3.4 Quality

According to literature, quality issues have an effect on the delivery reliability. Faulty productions extend lead time due to re-productions and faults. Plastprent managed to lower their quality cases in the production departments and, therefore, the costs between the years 2010 and 2011. This was achieved in a joint effort in all departments of the company. This effort is continuous and is still an objective of Plastprent in the year 2012. April was the month of quality where members of staff were nominated as quality knights for exceptional progress regarding quality in the production. The awareness of quality in the company is very positive and employees realize the significance of maintaining high quality levels. It is important to maintain this attitude in the company and reduce quality issues as they have an effect on the delivery reliability.

*Table 21 Analysis of quality issues during 2010 and 2011*

Department	Costs 2010	Costs 2011	Difference	Cases 2010	Cases 2011	Difference
Plastics	5.773.826	6.620.641	14,7%	82	56	-31,7%
Printing	8.104.167	2.985.927	-63,2%	81	43	-46,9%
Converting	1.312.836	1.151.503	-12,3%	42	47	11,9%
Sales	2.035.788	1.126.965	-44,6%	19	17	-10,5%
Design	993.359	1.670.768	68,2%	16	8	-50,0%
Purchasing	1.259.899	22.761	-98,2%	20	11	-45,0%
Other	3.437.765	3.094.535	-10,0%	33	25	-24,2%
<b>Total:</b>	<b>22.917.640</b>	<b>16.673.100</b>	<b>-27,2%</b>	<b>293</b>	<b>207</b>	<b>-29,4%</b>

To conclude, there are factors in the making process that are affecting the delivery reliability of Plastprent MTO productions. The highlighted factors in this section are product recipes, staff utilization, down time and quality issues. Possible improvements are introduced in the Improvements chapter hereafter.

## 6.4 DELIVER

The Deliver process describes the activities associated with the creation, maintenance, and fulfilment of customer orders. It includes the receipt, validation, and creation of customer orders; scheduling order delivery; pick, pack, and shipment; and invoicing the customer.

The warehouse is responsible for scheduling orders, delivering orders and invoicing customers. The below schematic is the process for the distribution process.

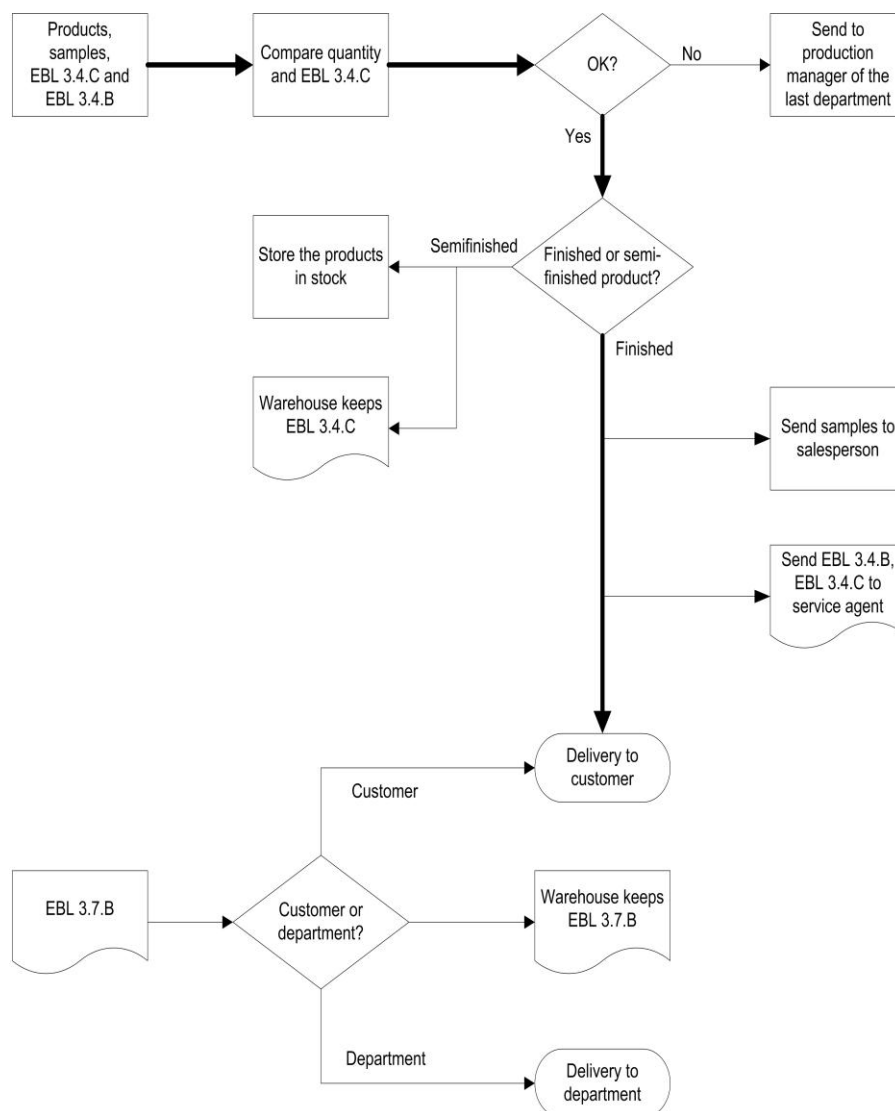


Figure 42 Distribution process



The below schedule is the distribution plan of Plastprent. Some customers choose to pick up their orders themselves. Although the schedule is set up as below it is very flexible and services Plastprent customers well. If orders are received before 11:00 am, they are delivered the same day in the capital area. Most of Plastprent customers are relatively close or in the capital area. Customers, who are outside the capital area, or in the countryside, get their orders shipped daily through an outsourced trucking company.

It is my qualitative opinion that the distribution of Plastprent orders to their customers is not a factor that concerns the delivery reliability. The reason for this is the flexibility of the schedule and the relative short distances orders need to travel to customers.

The only concern is when Plastprent is exporting orders; which need to be ready to leave on Tuesdays when the ship departs for Europe. If they are unable to do so they have to wait a week or use shipping with cargo airplanes, which is more costly. This means that the delivery will be one week late or very costly for Plastprent. However, the company is not a major exporter so this factor is not significant.

*Table 22 Delivery schedule*

<b>Domestic</b>	<b>Monday</b>	<b>Tuesday</b>	<b>Wednesday</b>	<b>Thursday</b>	<b>Friday</b>
Reykjavik	X	X	X	X	X
Kopavogur - East	X	X	X	X	X
Kopavogur - West	X	<i>No delivery</i>	X	<i>No delivery</i>	X
Hafnarfjordur	X	<i>No delivery</i>	X	<i>No delivery</i>	X
Gardabaer	X	<i>No delivery</i>	X	<i>No delivery</i>	X
Mosfellsbaer	<i>No delivery</i>	X	<i>No delivery</i>	X	<i>No delivery</i>
Grandi	<i>No delivery</i>	X	<i>No delivery</i>	X	<i>No delivery</i>
Seltjarnarnes	<i>No delivery</i>	X	<i>No delivery</i>	X	<i>No delivery</i>
<b>Countryside</b>	X	X	X	X	X
<b>International</b>	<i>No delivery</i>	X	<i>No delivery</i>	<i>No delivery</i>	<i>No delivery</i>

To conclude, there are no major factors in the delivering process that are affecting the delivery reliability of Plastprent MTO orders.



## 7 Improvements

The following section focuses on improving the delivery reliability of Plastprent. The section draws upon literature in the field of supply chain management and the supply chain operation reference model. The SCOR models four general supply chain management functions of plan, source, make and deliver will be the focal point of the improvements analysis.

### 7.1 PLAN

A manufacturing company cannot strive to be the best in every manufacturing capability such as flexibility, cost, quality and delivery. The key to the development of an effective manufacturing strategy is to know and develop the capabilities the company is good at.

Customers are demanding and hard to please, and since no company can be the best in every manufacturing capability, careful decisions and policies have to be agreed on by top level management on how to utilize its manufacturing function. Any production system is constrained by the technology it employs, Skinner comments. Decisions on “what to offer” and “how to do it” have to be made. Concepts such as “focused manufacturing” (Skinner, 1974) and the “product-process matrix” (Hayes and Wheelwright, 1979a,b) are based on the basic idea of the existence of trade-offs. Hayes and Wheelwright (1984) explain the potential consequences of trying to pursue excellence along the manufacturing capabilities of flexibility, quality, dependability and price. They write that: “It is difficult (if not impossible), and potentially dangerous, for any company to try to compete by offering superior performance along all of these dimensions simultaneously, since it will probably end up second best on each dimension to some other company”. They add that “... a business must attach clear priorities to each dimension, and these priorities will determine how that business positions itself relative to its competitors” (Hayes and Wheelwright, 1984, p. 41).

Various planning tools are available to manufacturing companies, and in the following figure is a summary that gives a good overview of the many planning tools available at various planning levels. It starts with the strategic plan that is defined by top-level management, where decisions and policies are made on how the company should utilize its manufacturing function. The tactical planning is then introduced, which is performed by middle level managers. There, the supply chain is broken down and various plans are made on various factors, such as demand management, distribution planning, sales and operations planning and resource planning. The last level is the operational planning, which involves the more day to day planning and is performed by the production floor managers in most cases. There, the focus is on execution and control.

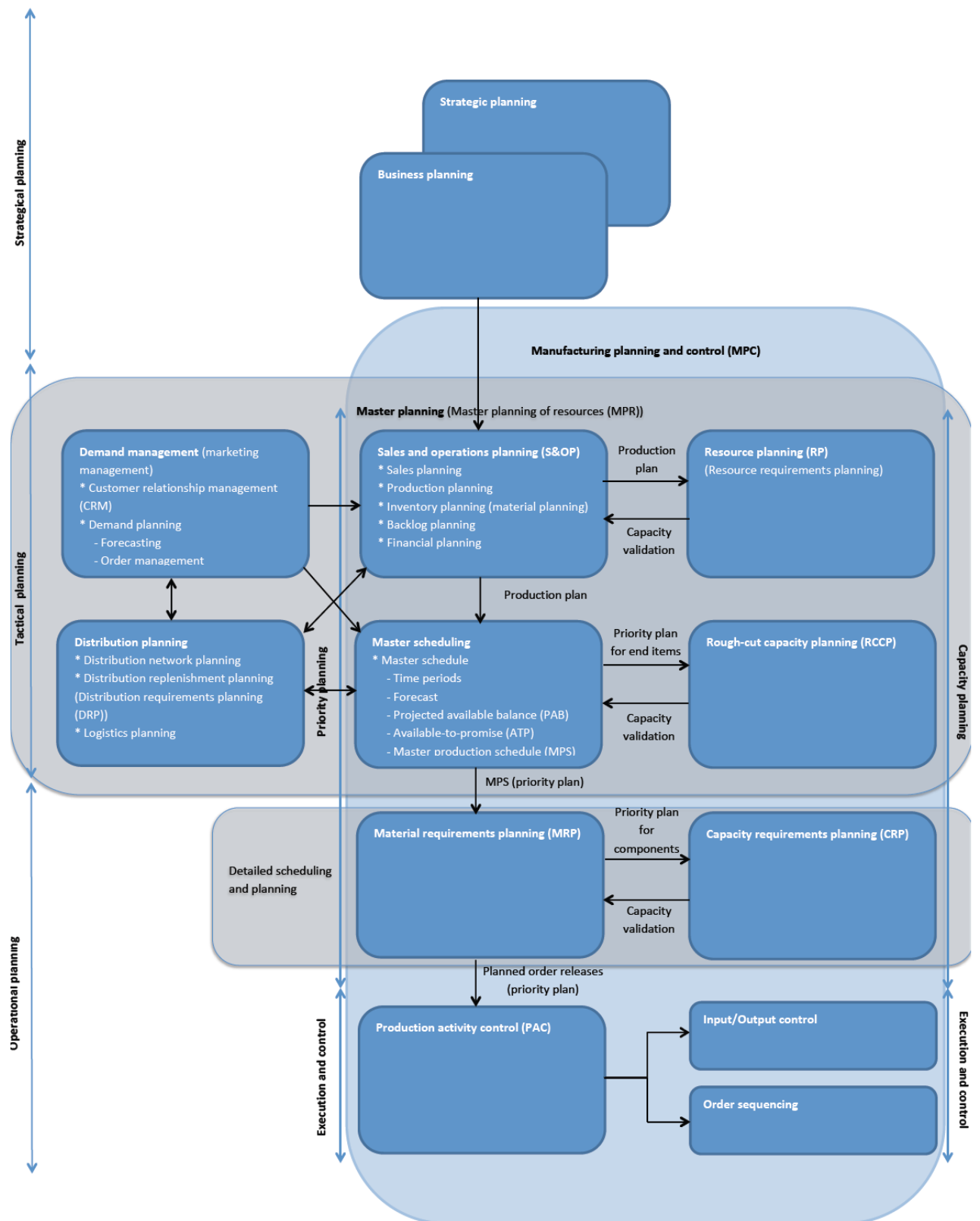


Figure 43 Summary of planning tools

In order to improve its delivery reliability it is vital for Plastprent to plan its production better and all aspects related to the supply chain. The summary picture would help Plastprent in prioritizing their planning techniques and give a structure on how to organize the planning processes. The development of an effective manufacturing planning and control system is vital to a successful operation of the production system. Moreover, truly effective MPC systems coordinates supply chains and utilize them efficiently.

The priority requests need to be organized and customers categorized to define a priority plan. Also collect data on priorities from customers and sales persons. It could be useful to keep track of these requests to have an overview of the quantity and what customers are most frequently requesting shorter delivery times. This information could be used to improve customer relationships and help the production have a better overview. Between 01.01.2012 and 15.03.2012, there were registered 46 priority request, which is quite considerable compared to there were around 260 MTO productions in that time. This is why these priority requests need to be analysed and organized better.

Plastprent could introduce the concept “frozen window”. It refers to freezing the production schedule for a defined time, most often a week or two—no longer. This is done so that the production plan cannot be changed or altered so the production efficiency is maintained.

By having a better plan Plastprent can move on to utilizing the plan by purchasing the right amount of material according to the planned productions and forecasts, to manufacturing what was defined by the planning process to delivering the finished product to customers “on-time”.

*Table 23 Summary of improvements for the SCOR process Plan*

<b>Improvements</b>	<b>Benefits</b>
<b>Define the overall strategic plan &amp; objectives</b>	<ul style="list-style-type: none"> <li>• Makes clear to employees on how the production will take place.</li> <li>• Clear objectives are easier to attain.</li> </ul>
<b>Implement planning tools in summary picture</b>	<ul style="list-style-type: none"> <li>• Better overview and organized way to plan.</li> </ul>
<b>Sales &amp; operations planning (S&amp;OP)</b>	<ul style="list-style-type: none"> <li>• Increased communication between sales &amp; production departments.</li> <li>• Sales and production plan better combined.</li> <li>• Better inventory planning that will help with resource and material planning.</li> </ul>
<b>Manufacturing planning and control (MPC)</b>	<ul style="list-style-type: none"> <li>• Better coordination &amp; utilization of the supply chain.</li> <li>• Manage better the flow of material and equipment.</li> </ul>
<b>Master production schedule (MPS)</b>	<ul style="list-style-type: none"> <li>• Helps forecasts the future production volume, as well as the material requirements to fulfil the production requirements.</li> </ul>
<b>Priority plan</b>	<ul style="list-style-type: none"> <li>• Better overview of priorities.</li> <li>• Clear what companies gets priorities.</li> <li>• Less disruption of production plan.</li> </ul>

## 7.2 SOURCE

The Source process describes the ordering/scheduling of purchased goods. It is important for companies to purchase the right amount of material in the right time. By purchasing in an affective manor, companies can save money in inventory and maintain good service level to customers.

How do companies decide on how much to buy and when? Plans, regarding the projected demand on produced goods, need to be done. An idea of required materials needs to be prepared ahead of time to be able to identify how many employees are needed and the capacity and the effects on the supply chain. Forecasting models are developed to predict the material requirements of companies. The forecast is only an estimate of the demand until actual demand is known. Dependable forecasts are beneficial for companies as it helps it maintain better inventory levels and utilize the capacity better. Plastprent sales department needs to perform a sales plan where they estimate what products they will sell ahead of time. The production department needs this information so they can pinpoint the material requirements so they can plan what has to be purchased. This information needs to be cross-referenced with the use of materials from previous years so an accurate purchasing plan can be completed.

By implementing an effective forecasting model, Plastprent can forecast the demand better and, therefore, purchase its required materials more efficiently and achieve lower inventory levels to save cost and have fewer shortages to improve customer service levels.

Plastprent has a good visibility of inventory, which is positive; it measures every week the amount of raw material available. Work needs to be done in developing supplier relationships and negotiate with suppliers in decreasing the lead time of goods. If Plastprent future objectives are to maintain high levels of delivery reliability they will have to maintain high levels of inventory to maintain high service levels.

*Table 24 Summary of improvements for the SCOR process Source*

Improvements	Benefits
<b>Forecasting &amp; purchasing plan</b>	<ul style="list-style-type: none"><li>• Better indication of what material is needed and when.</li><li>• Saves costs in inventory.</li><li>• Utilizes capacity better.</li><li>• Increases service level to customers, less risk of shortages.</li></ul>
<b>Increase supplier relationships and/or look for new suppliers</b>	<ul style="list-style-type: none"><li>• Possibly better prices and shorter delivery times.</li></ul>

## 7.3 MAKE

The Make process defines the activities connected with the conversion of raw materials to products. It is important for manufacturing companies that these processes are effective so the company is able to compete.

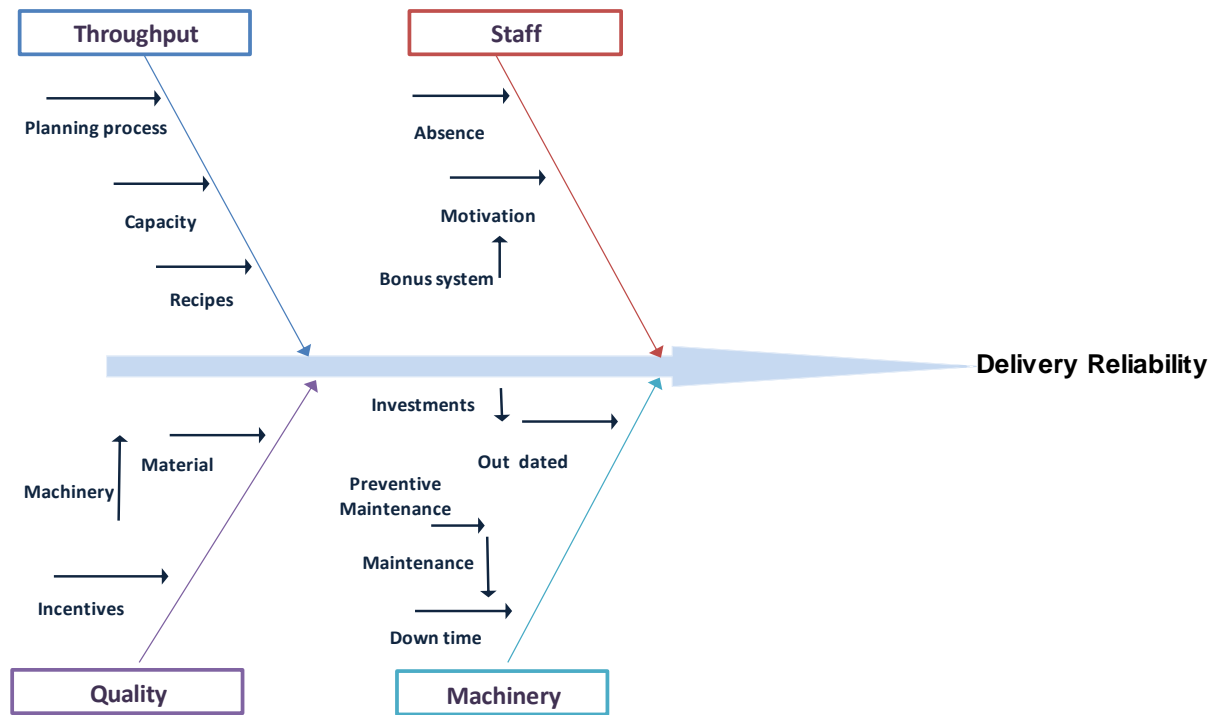


Figure 44 Ishikawa diagram of the cause and effect on the delivery reliability

### 7.3.1 Throughput

The capacity of the production departments is not utilized to its fullest as the machinery is not operated 24/7, there is room for added capacity by increasing work hours but is not necessary. Also the machinery is old and is not at the same capacity as it was when new. Investments should be made in newer more productive machinery which is more automated. Recipes need to be reviewed as the extrusion department is using considerably more hours than projected in producing, which would help in the planning process. The manufacturing process needs to adopt Supply chain management theory and use Manufacturing planning and control system to streamline the production and increase the throughput.

### **7.3.2 Staff**

As previously mentioned, the machines in the production departments are quite old so they are not automated and require staff to operate them at all times. Therefore, the presence of staff is required and is a factor that affects the throughput in the departments and consequently the delivery reliability. Investment in new automated machinery would lower the dependability of staff. Motivation incentives could be introduced in a bonus system for departments or individuals. This could decrease the absence of staff, increase quality and increase satisfaction of employees.

### **7.3.3 Machinery**

Down time in the factory is having an effect on the delivery reliability. The average age of all machinery in the factory is around 20 years. The equipment is old and, therefore, so is the technology it employs. Preventive maintenance should be a bigger factor in the maintenance schedule at Plastprent. Preventive maintenance could save costs in unwanted down time. Investments in new machinery should be a priority, as previously stated. The machinery could be updated, it could cost less.

### **7.3.4 Quality**

It could be debated that a production process with high levels of internal quality can help achieving high delivery reliability. In other words, if a company is due to deliver to a customer, the chances of delivering on schedule increase as the uncertainty of the outcome of the process in terms of lead time and quality reduces. This view is consistent with the network theory of plant performance that Schroeder (1996) and his colleagues proposed. They argue that conformance quality will drive higher levels of on-time deliveries, fast deliveries and lower costs. Wacker (1987, 1996) mathematically demonstrates that a reduction in defect rates can have a positive effect on throughput time and delivery reliability. Consistent with this, some studies have reported a compatibility situation between delivery reliability and variables that relate with throughput time (production cycle time, delivery time, delivery speed, etc.) and internal quality (Schroeder et al., 1996; Vickery et al., 1997; Safizadeh et al., 2000).

Quality standards at Plastprent are high and employees are aware of the importance maintaining high quality standards. It is a continuous improvement and they need to continue their hard work. An issue affecting the quality is the material that is made in the extrusion department. Due to the out dated machinery it is sometimes poor and hard to print on or convert into finished products. This is having an effect on the quality; therefore, the delivery reliability and it should be a factor when considering investments in new machinery. Plastprent could adapt a bonus system for quality and reward departments or individuals for achieving certain goals in regards to quality. Therefore, Plastprent can increase their delivery reliability by decreasing quality issues.

Other factors can improve the making process. The Sand Cone model suggests that, although in the short term it is possible to trade off capabilities one against the other, there is actually a hierarchy amongst the four manufacturing capabilities of quality, cost, flexibility and reliability as explained in the literature review in chapter 4. By implementing the idea behind the sand cone model Plastprent might be able to achieve



higher standards in all the manufacturing capabilities; therefore, increase their delivery reliability.

*Table 25 Summary of improvements for the SCOR process Make*

<b>Improvements</b>	<b>Benefits</b>
<b>Investments in new machinery and/or update old</b>	<ul style="list-style-type: none"> <li>• New machinery = less downtime + better quality products; therefore, less quality issues.</li> <li>• Newer machines are more automated and require less attention from employees.</li> <li>• Updated machinery may increase throughput and quality of material.</li> </ul>
<b>Preventive maintenance</b>	<ul style="list-style-type: none"> <li>• Less unexpected down time.</li> <li>• Saves cost in the long run.</li> </ul>
<b>Review recipes of products</b>	<ul style="list-style-type: none"> <li>• More accurate recipes help in pricing and in planning the production process.</li> </ul>
<b>Manufacturing planning and control system (MPC)</b>	<ul style="list-style-type: none"> <li>• Streamline the production.</li> <li>• Coordinates the supply chain and utilizes it efficiently.</li> </ul>
<b>Incentive system to motivate employees</b>	<ul style="list-style-type: none"> <li>• Decrease absence of staff.</li> <li>• Decrease quality issues.</li> <li>• Increase throughput.</li> <li>• Increase employee satisfaction.</li> </ul>
<b>Quality</b>	<ul style="list-style-type: none"> <li>• Continuous improvements.</li> </ul>

## 7.4 DELIVER

The Deliver process describes the activities associated with the creation, maintenance, and fulfilment of customer orders. These activities need to be in order so the customer receives his orders at the right time and place, in the right quantity and receives the correct information, e.g. invoices.

The delivery schedules of Plastprent MTO orders are very affective. There are no obvious improvements to be made. The size of Iceland and the short distances orders need to travel to customers is a benefitting factor. No improvements will be introduced in the deliver section of this thesis.



## 8 Conclusion

In this thesis the concept delivery reliability has been introduced and analysed with Plastprent make-to-order productions in mind. Factors and processes that influence the delivery reliability have been introduced and discussed with attention on the Supply chain operations reference model. Improvement in the Plan, Source and Make processes of the model were presented.

The three research questions defined at the beginning of the thesis were answered:

*Question 1: What is the delivery reliability of MTO productions at Plastprent?*

In the year 2011 the delivery reliability of Plastprent MTO productions were the following; orders delivered “early” were 47,24%, “on-time” were 33,29% and delivered “late” were 19,46% of orders. The performance level of the delivery reliability was around 81% which is satisfactory.

*Question 2: What Processes and factors have the most influence on the delivery reliability of Plastprents MTO productions?*

The processes and factors were defined with the help of the Supply chain operations reference model processes of Plan, Source, Make and Deliver. In regards to the Plan process the pre-production process, priority requests and the lack of an overall planning process were factors influencing the delivery reliability. Factors in Source process were the lack of resource planning and complicated purchasing requirements. In the Make process quality, down time, staff utilization and throughput were identified as factors that influence the delivery reliability. No factors in the Deliver process were identified as having an influence on Plastprent delivery reliability of MTO productions.

*Question 3: How can Plastprent improve the delivery reliability of its MTO productions?*

The following improvements were presented with the Plan, Source and Make processes of the Supply chain operation reference model in mind:

*Table 26 Improvements to the Plan process*

<b>Improvements</b>	<b>Benefits</b>
<b>Define the overall strategic plan &amp; objectives</b>	<ul style="list-style-type: none"> <li>• Makes clear to employees on how the production will take place.</li> <li>• Clear objectives are easier to attain.</li> </ul>
<b>Implement planning tools in summary picture</b>	<ul style="list-style-type: none"> <li>• Better overview and organized way to plan.</li> </ul>
<b>Sales &amp; operations planning (S&amp;OP)</b>	<ul style="list-style-type: none"> <li>• Increased communication between sales &amp; production departments.</li> <li>• Sales and production plan better combined.</li> <li>• Better inventory planning that will help with resource and material planning.</li> </ul>
<b>Manufacturing planning and control (MPC)</b>	<ul style="list-style-type: none"> <li>• Better coordination &amp; utilization of the supply chain.</li> <li>• Manage better the flow of material and equipment.</li> </ul>
<b>Master production schedule (MPS)</b>	<ul style="list-style-type: none"> <li>• Helps forecasts the future production volume, as well as the material requirements to fulfil the production requirements.</li> </ul>
<b>Priority plan</b>	<ul style="list-style-type: none"> <li>• Better overview of priorities.</li> <li>• Clear what companies gets priorities.</li> <li>• Less disruption of production plan.</li> </ul>

*Table 27 Improvements to the Source process*

<b>Improvements</b>	<b>Benefits</b>
<b>Forecasting &amp; purchasing plan</b>	<ul style="list-style-type: none"> <li>• Better indication of what material is needed and when.</li> <li>• Saves costs in inventory.</li> <li>• Utilizes capacity better.</li> <li>• Increases service level to customers, less risk of shortages.</li> </ul>
<b>Increase supplier relationships and/or look for new suppliers</b>	<ul style="list-style-type: none"> <li>• Possibly better prices and shorter delivery times.</li> </ul>

Table 28 Improvements to the Make process

Improvements	Benefits
<b>Investments in new machinery and/or update old</b>	<ul style="list-style-type: none"> <li>• New machinery = less downtime + better quality products; therefore, less quality issues.</li> <li>• Newer machines are more automated and require less attention from employees.</li> <li>• Updated machinery may increase throughput and quality of material.</li> </ul>
<b>Preventive maintenance</b>	<ul style="list-style-type: none"> <li>• Less unexpected down time.</li> <li>• Saves cost in the long run.</li> </ul>
<b>Review recipes of products</b>	<ul style="list-style-type: none"> <li>• More accurate recipes help in pricing and in planning the production process.</li> </ul>
<b>Manufacturing planning and control system (MPC)</b>	<ul style="list-style-type: none"> <li>• Streamline the production.</li> <li>• Coordinates the supply chain and utilizes it efficiently.</li> </ul>
<b>Incentive system to motivate employees</b>	<ul style="list-style-type: none"> <li>• Decrease absence of staff.</li> <li>• Decrease quality issues.</li> <li>• Increase throughput.</li> <li>• Increase employee satisfaction.</li> </ul>
<b>Quality</b>	<ul style="list-style-type: none"> <li>• Continuous improvements.</li> </ul>

Plastprent delivery reliability was 81% in the 2011 which is satisfactory. “Early” orders were 47% of that which is too high; it is causing additional holding costs. The “early” deliveries need to be limited to improve the reliability to customers and cut cost. “Late” orders need to be reduced. It has been established that high delivery reliability is one of the order winning performance criteria for make-to-order companies. In order for Plastprent to be competitive it has to be able to maintain high delivery reliability.

Next steps for Plastprent:

- Material in the thesis reviewed by the production team and representatives from the sales department and the main conclusions analysed.
- Factors affecting the delivery reliability prioritized and decisions on how to implement the improvement recommendations completed.
- Define overall delivery reliability objectives for MTO productions. For example: *“Plastprent aims to deliver 95% of all orders “on-time” or “early” to customers in the year 2012. “Late” orders must not exceed 5% of productions”*.
- Categorize customers, review sales contracts and define the delivery reliability performance for each category.
- Define a priority plan regarding priority request to establish clear objectives and processes to limit the disruption of these requests.

- Implement the ideology of the Supply chain operations reference models Plan, Source, Make and Deliver processes. Start planning the production with the before mentioned planning tools. Review the purchasing process and use the improvements identified in the Source section. Streamline the production processes with the improvements mentioned in the Make section.

## **9 Discussion**

The discussions chapter includes qualitative analysis of factors that could benefit Plastprent in achieving better delivery reliability and some ideas for further possible improvements.

### **9.1 Define Plastprent delivery reliability to customers**

Who, and what, gets what kind of delivery reliability? A categorization of Plastprents customers in terms of importance and service level needs to be done and sales contracts reviewed to define which customers get three, four or five week delivery time. Some products are more complex in production and need more time in the production process. There needs to be constraints to product types and quantity. Plastprent could define two possible delivery windows, the first half of the year and the second half, as in the first half of the year there are fewer productions than in the second half. The first half could be defined as the months January to July, with 3,5 to 4,5 weeks delivery reliability. The second half could be defined as August to December, with 4,5 to 5,5 weeks delivery reliability. This needs to be agreed upon with the production and sales department and the information shared with customers. Customers need to be better informed on when they should expect their orders. The goal is to achieve higher delivery reliability without sacrificing other aspects, such as quality and additional cost.

Plastprent need to define its delivery reliability objectives. At what cost will they maintain high reliability? With a lot of overtime cost, or with a high amount of inventory?

### **9.2 Key performance indicators (KPI's) in production departments**

The production manager in the Conversion department collects data on throughput, staff utilization and machinery down time and compiles a report. This is valuable information to have to be able to make decisions and to see whether progress is being made. The Extrusion and Printing department are compiling similar reports; however, work needs to be done to standardize these reports. The three departments and the whole production team need to decide upon measures to follow and define objectives or standards in those measures, to make the report more affective.

## **9.3 Information system**

A variety of information systems and technologies have been introduced to manage the movement of information to the right places in the right forms so that the supply chain can be organized, measured and controlled. An information system is the involvement of people, equipment and procedures to gather, sort, analyse, evaluate and then distribute information to the appropriate decision-makers in a timely and accurate manner for making the right decisions (Sadler, 2007). The emphasis and importance of managing information is to ensure the application of direct, immediate and accurate information.

The information system is not utilized well enough in terms of the production. They use Microsoft Dynamics AX. The system could provide additional information and could help organizing the production, it is wise for Plastprent to explore whether the information system could be operated and developed better.

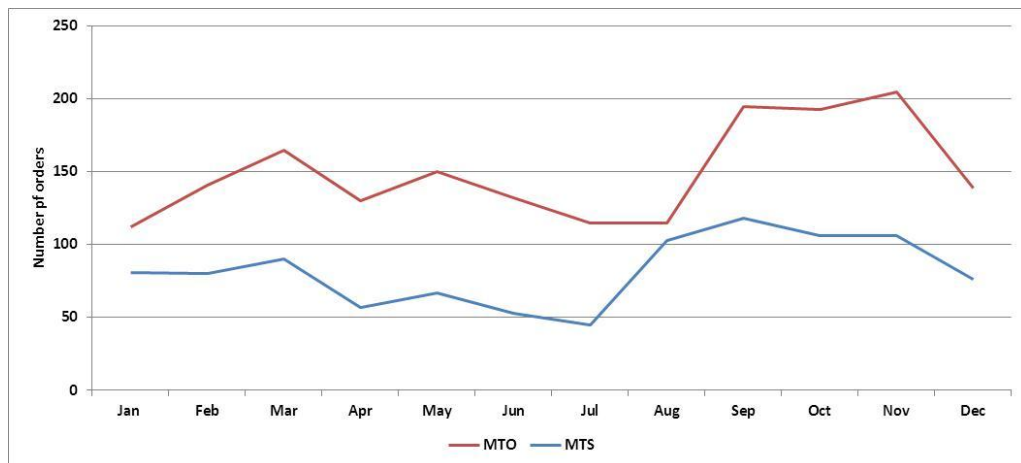
## **9.4 Sales department vs. the production department**

Sometimes, working at Plastprent, it feels like there are two companies are operating: a sales and a production company. It is in my opinion that those departments need to work better together to achieve common goals. They need to implement a better sale and operations plan (S&OP), develop a sales plan so a production plan can be prepared. With an affective sales plan an effective materials plan can be made which can cut costs in excess inventory and improve service levels. With these departments working together, they are more likely to attain their common goals. I think the objective of the departments should be on producing what Plastprent makes money on, not simply producing what they can.

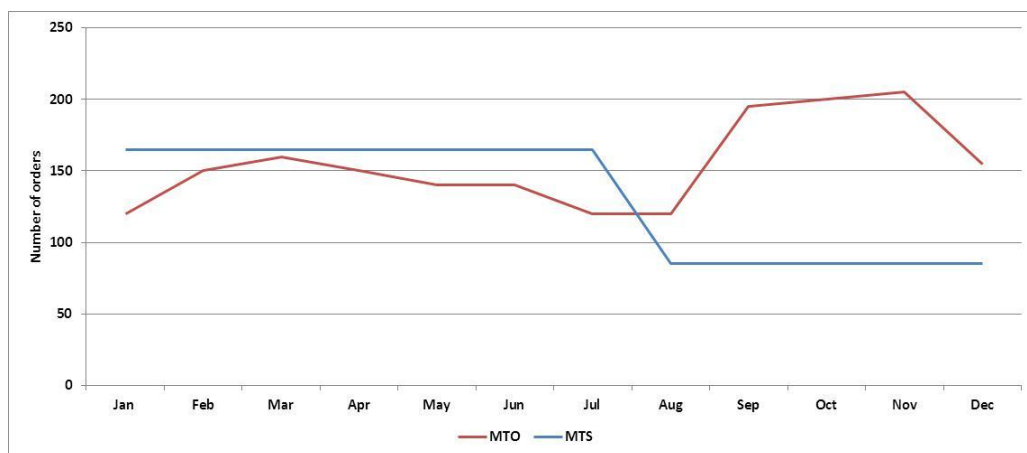
## **9.5 MTS vs. MTO – capacity planning**

The line chart below shows the typical production load of MTO and MTS productions at Plastprent annually. The year starts off slowly; in August the demand rises and the following months are the busiest time for the production departments. Plastprent need to take advantage of this trend and have to dedicate the beginning of the year producing MTS orders, to prevent shortages later in the year when demand rises. By utilizing the production like this, Plastprent could better serve their customers later in the year when demand increases. The second line chart gives an illustrative perspective on how the productions should be planned to better utilize the productions capacity. This means building up inventory, which could be costly; however, in the long run, will increase customer service by increasing the delivery reliability.





*Figure 45 Typical productions of MTO and MTS during the year*



*Figure 46 Proposed utilization of MTO and MTS productions*

## 9.6 Product development

MacDuffy et al. (1996) and Fisher and Ittner (1999) have argued that the strategic decisions of senior management about the variety of products and the product portfolio can negatively affect the performance of a supply chain. Increased product variety increases the challenges in inventory management, which can increase the likelihood of material stock outs, and material handling costs. Product proliferation increases the level of complexity not only for the production system but also for forecasting (Fisher et al., 1997), purchasing (Kotteaku et al., 1995) and production scheduling (Van Donk and Van Dam, 1996). Scheduling the production of several products can be a very difficult task often resulting in several schedule revisions, which in turn hurts delivery performance (Brown and Vastag, 1993).

Plastprent offers a wide range of products to customers and in my opinion, there are too many. Product development needs to be done with the objective of standardizing more products. Plastprent is offering small customers customized bags, that they are only purchasing around 10.000 units of once a year, which is a small amount. Foreign producers do not offer this. They offer small companies standardized bags with basic printing. This

would benefit Plastprent and their customers because they could offer them bags at a lower prices and the production utilized better, bringing lower costs and shorter delivery times.

## 9.7 Production team meetings

On Monday to Thursday mornings, at 9:00 am, the production team, which consists of; production managers, quality manager, technical manager and the CEO, meet up and discuss matters concerning the production for that day and other issues. It is a good way to get information across to the divisions and discuss important matters. The meetings occur too often and it is my opinion that they should reduce the meetings from five a week to three, which would save PP half a million ISK annually. This would not only save money in salaries but it would utilize the production teams time better.

*Table 29 Production team meetings*

	Today	Proposal
<b>9:00-9:20</b>	0,33	0,33
<b>4 days</b>	Mon, tue, wed, thurs	Mon & wed
<b>10:00-11:30</b>	1,5	1,5
<b>1 day</b>	Fri	Fri
<b>Weeks</b>	42	42
<b>Staff</b>	6	6
<b>Average wage</b>	5.400.000	5.400.000
<b>Hours</b>	1.800	1.800
<b>per hour</b>	3.000	3.000
<b>Hours</b>	714	544
<b>Cost of meeting</b>	<b>2.142.000</b>	<b>1.632.960</b>
<b>Saving annually</b>	<b>0</b>	<b>509.040</b>

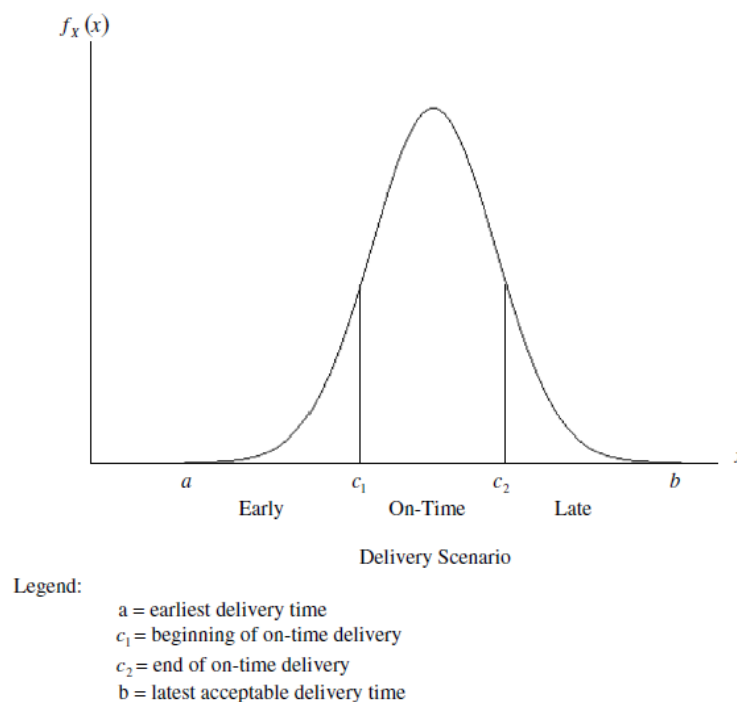
## 9.8 Summer and winter closures in production

Plastprent closes its factory twice a year; during the summer holidays for three weeks in July and in the winter, from the middle of December to the middle of January. This is done to cut costs and allow staff to take their vacation. These breaks need to be better planned and the down time of machinery needs to be utilized better. During this time machine maintenance should be performed and any specific changes completed.

## 10 Definitions – Glossary of terms

### *Delivery window*

The supplier, or customer, gives an earliest allowable delivery date (a) and a latest allowable delivery date (b). A delivery window is defined as the difference between the earliest acceptable delivery date and the latest acceptable delivery date. The customer and the end supplier responsible for product delivery contractually agree that no deliveries will arrive before (a) or after (b), thereby establishing a mutually agreeable framework for managing delivery performance.



*Figure 47 Delivery window*

### *Down time*

Refers to a period of time that a system fails to provide or perform its primary function.

### *Enterprise resource planning (ERP)*

Is a system that integrates internal and external management information across an entire organization, embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc.

### *Lead time*

Definition of lead time in supply chain management is the time from the moment the customer places an order (the moment you learn of the requirement) to the moment it is received by the customer.

### *Make-to-order (MTO)*

A production strategy that typically allows consumers to purchase products that are customized to their specifications. The make to order (MTO) strategy only manufactures the end product once the customer places the order. This creates additional wait time for the consumer to receive the product, but allows for more flexible customization compared to purchasing standardized products.

### *Make-to-stock (MTS)*

A traditional production strategy used to match production with consumer demand forecasts. The MTS method forecasts demand to determine how much stock should be produced. If demand for the product can be accurately forecasted, the MTS strategy can be an efficient choice.

### *Median*

Is the middle value of the given numbers or distribution in their ascending order. Median is the average value of the two middle elements when the size of the distribution is even.

### *Mode*

Is the most frequently occurring value in a distribution.

### *Process*

In a manufacturing environment, a process can be seen as the logical organization of people, materials, equipment and information into work activities designed to produce a required product.

### *Quantity flexibility*

Refers to the flexibility of quantity or the amount the customer can purchase, high quantity flexibility is to offer customers smaller batch sizes. Reduces the customers' investment in purchased goods.

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# Appendix I

## 2010

- 1 ÁTVR
- 2 Byko
- 3 Dögun
- 4 Fisk seafood
- 5 Fispak
- 6 Freyja
- 7 Kartöfluverksmiðjan
- 8 Nóri-Siríus
- 9 Papco
- 10 Saltkaup
- 11 Samhentir
- 12 Samkaup
- 13 SS
- 14 Steinull
- 15 Tandur

## 2011

- 1 ÁTVR
- 2 Byko
- 3 Dögun
- 4 Fispak
- 5 Freyja
- 6 Icelandair
- 7 Iðnmark
- 8 Nóri-Siríus
- 9 Papco
- 10 Saltkaup
- 11 Samhentir
- 12 Samkaup
- 13 SS
- 14 Tandur