Norwegian University of
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Comparison of an Enterprise Resource Planning System and a Cloud based Enterprise Resource Planning System in an Aluminium Supply Chain

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Summary

In this master thesis, an investigation has been carried out on whether or not a cloud based enterprise resource planning system (CERP) is better suited for an aluminium supply chain (ASC), than the traditional enterprise resource planning system (ERP). The main objective of the thesis was to increase the performance of the aluminium supply chain trough information sharing.

First, an investigation in the form of literature study, on the ASC was conducted to discover the characteristic of the supply chain. It was found that an ASC could be both a MTS and a MTO SC, depending on which aluminium smelter you were looking at. It was also found that the ASC is a global SC, it produces in high volumes with a low variety of products, there are few customer segments and that it is driven by efficiency.

Secondly, the CERP and the ERP systems were set up against each other, to discover the different pros and cons with implementing each one in the ASC. The pros for the ERP is that it is well-known as well as well-developed, so the companies know what they are buying. The main cons are that the ERP is not very flexible, it may prove difficult to implement, and the implementation demands enormous time and cost resources. The pros for the CERP is that it is the fastest way to the market, cheaper in the short term as well as for small businesses, it is more flexible and easier to access. The main cons of a CERP is security and the fact that it becomes expensive to a large company, since every participant have to pay a fee to get connected to the system.

Thirdly, there were made some reflections on the future of the ASC, and the possibilities of how the CERP can evolve together with the emerging technology of smart factory. It was found that if smart factory was implemented through the ASC, enabled by technologies like auto-id and internet of things, the performance would increase immensely. At the same time, it was found that having such an integrated system is still some years away.

This study found that setting up an ERP like a CERP in an aluminium supply chain, will do the information flow and the material flow more precise, which in turn will increase the performance of the aluminium supply chain. This means that the ERP system is located on a server in the main office, and is perceived as a CERP system for the other actors in the ASC. This implementation of an ERP system that operate like an CERP in the ASC will decrease the need for inventory, mitigate the bullwhip effect, utilize the production, optimize the customer interaction process, as well as make information easier obtainable.

Sammendrag

I denne masteroppgaven er det utført en studie på hvorvidt en Cloud based enterprse resourse planning system (CERP) er bedre for en aluminium forsyningskjede (ASC), enn den tradisjonelle enterprise resource planning systemet (ERP). Hovedmålet med masteroppgaven var å øke ytelsen til forsyningskjeden til aluminium gjennom informasjonsdeling.

Først ble det gjort et litteraturstudie på ASC, for å finne de karakteristiske egenskapene til forsyningskjeden. Det ble funnet ut at en ASC kan være både en MTS og MTO SC, det kommer an på hvilket aluminiums smelteverk du ser på. Det ble også funnet at forsyningskjeden til aluminium er en global forsyningskjede, den produserer i store volum men lav variasjon på produkter, det er få kundesegmenter og den drives av effektivitet.

Deretter ble CERP og ERP systemene satt opp mot hverandre, for å finne fordelene og ulempene ved å implementere hver av de i en ASC. Fordelene med ERP er at det er godt kjent og høyt utviklet, så bedriftene som kjøper det vet hva de får. Hoved ulempene med ERP er at det ikke er særlig fleksibelt, det kan være vanskelig å implementere, og implementeringen er enormt tid og kostnadskrevende. Fordelene med CERP er at det er raskete måte å komme på markedet, det er billigere både på kortsikt og for mindre bedrifter, og det er mer fleksibelt og lettere å få tilgang til. Hoved ulempene med CERP er sikkerhetshensyn og det faktum at det kan bli dyrt for en stor bedrift på grunn av at hver bruker må betale en avgift for å få tilgang til systemet.

Avslutningsvis ble det gjort noen refleksjoner på fremtiden til forsyningskjeden til aluminium, og på mulighetene for utvikling av CERP sammen med konseptet smart fabrikk. Det ble observert at om smart fabrikk blir implementert i ASC, ved hjel av teknologier som auto-id og internet of things, så vil ytelsen øke betydelig. Men det ble også funnet at et slikt integrert system fortsatt er noen år unna.

Denne masteroppgaven kom frem til at å sette opp ERP som en CERP i forsyningskjeden til aluminium, vil gjøre informasjonsflyten og materialflyten mer presis, som igjen vil øke ytelsen til forsyningskjeden. Dette betyr at ERP systemet ligger på en server på hovedkontoret, og blir derfor oppfattet som et CERP system for de andre aktørene i forsyningskjeden. Implementeringen av et ERP system som operer som et CERP system i aluminiums forsyningskjede vil redusere behovet for inventar, minske bullwhip-effekten, utnytte produksjonen, optimalisere kundeinteraksjonsprosessen, samt gjøre informasjonen lettere tilgjengelig.

Preface

In the last semester of the Master of Science in Engineering program at the Norwegian University of Science and Technology (NTNU), the students are required to write a master thesis in the course TPK4930 – Production Management.

This master thesis was carried out in the spring semester of 2017 by Thomas Dørum Øverseth at the department of Mechanical and Industrial Engineering, as part of a two-year master program in Global Manufacturing Management.

I would like to acknowledge my main supervisor Jan Ola Strandhagen for the assistants in choosing topic as well as brainstorming through the semester. I would also like to thank both my girlfriend and my fellow students for moral support through the semester.

Trondheim, June 2017

Thomas Dørum Øverseth

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List of abbreviations

SC	Supply Chain
ASC	Aluminium supply chain
ERP	Enterprise resource planning
CERP	Cloud based enterprise resource planning
MES	Manufacturing execution system
MTS	Make-to-stock
ATO	Assemble-to-order
MTO	Make-to-order
ETO	Engineer-to-order
CODP	Customer order decoupling point
IoT	Internet of things
RFID	Radio frequency identification

Chapter 1 - Introduction

1.1 Background

The aluminium market is very tough; there are a lot of competition for the same business and the market is very sensitive to the rest of the global economy. Every time the global economy have had a recession, the aluminium market have had a recession as well. Even though the demand have had a steady increase of 5-7% annually, the price of aluminium is very fluctuating. During the real estate bubble in 2008, the price of aluminium was at an all-time high, but as it cracked the price dropped almost 3 times in just a year (Olson, 2015). The price of aluminium has recovered in some degree, but many of the less profitable facilities have been closed.

To survive in this competitive market and to protect a company from price drops like the one in 2008, there is a need to produce aluminium better than the competition. Increasing the performance of an aluminium supply chain can be done several ways; one way is to investigate the coordination between the actors in the supply chain. By aligning goals and getting the actors in the supply chain to coordinate, the whole supply chain can go in surplus. If the actors just focus on themselves, it can lead to unnecessary inventory building up in the supply chain, the increase of bullwhip effect and the decrease of general trust between actors (Chopra and Meindl, 2016). The bullwhip effect describes the phenomenon of demand misrepresentation, where there is an increase in demand variation upward in the supply chain. In other words, there tends to be a higher variance in orders to the supplier then sales to the buyer, and this misrepresentation is amplified upstream in the supply chain (Lee et al., 2004).

To coordinate a supply chain there is a need for trust and commitment among the actors of the supply chain (Mentzer et al., 2001), they need to understand that everybody are working towards the best for the supply chain. Further, to coordinate a SC, the need to share information with the other actors are essential, also defining a structure for the information flow is important (Thompson, 1967). Enterprise resource planning (ERP) is such a system that can share information, as well as it provides a structure for information sharing (Chopra and Meindl, 2016). ERP can be defined as “a framework for organize, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage” (Arnold et al., 2012). What this means is the ERP uses the company’s internal knowledge of its capabilities, to get an advantage in the external market.

There are many interesting technologies that are emerging these days; among them are the cloud technology (Hofmann and Woods, 2010). Cloud based solution is a web-based application that are stored on remote servers and accessed via internet by a standard web browsers (Helo et al., 2014). This technology creates some interesting opportunities, as bringing an ERP system unto a cloud solution. Cloud based enterprise resource planning (CERP) will bring a different level of accessibility to the system, like being able to connect with the system anywhere.

ERP systems have proven difficult for implementing for some companies; it was made for fitting one type of industry (Akkermans et al., 2003) and the flexibility of ERP is limited in regards of supporting multiple facilities (Helo et al., 2014), the CERP system presents possibilities in both this regards. Further, CERP systems presents a completely new degree of control, surveillance, transparency and efficiency in the production process (Hofmann and Rüsch, 2017).

Therefore, this thesis is an investigation to find out if a Cloud based enterprise resource planning system (CERP) is better suited for an aluminium supply chain (ASC), than the traditional enterprise resource planning (ERP) system. First, there will be done an investigation on the ASC to discover its characteristics and how the ASC operates. Secondly, the CERP and the ERP systems are going to be set up against each other, to discover the different pros and cons with implementing each one in the ASC. Thirdly, there are going to be done some reflections of the future of the ASC, and the possibilities of how the CERP can evolve together with the emerging technology of smart factory.

1.2 Research scope

This thesis will conduct an investigation on a Cloud based enterprise resource planning system (CERP) in an aluminium supply chain (ASC) and compare it with a traditionally enterprise resource planning system (ERP). The investigation will only look at the CERP and ERP from an overall view, which means that the investigation will only consider the possibilities within the systems, rather than investigating different applications of the systems.

Further, there are two main types of aluminium production, primary and secondary, which illustrated in Figure 1. Primary production is the production from raw material, while the secondary production is when the aluminium is recycled. This thesis will only consider the primary aluminium production in its investigation. The primary aluminium supply chain consists of bauxite mines, alumina refineries, aluminium smelters and forming facilities. The forming facilities can be multiple different actors such as re-casting facility, rolling facility and extruding facility, but in this study, they are gathered into one actor, namely forming facilities.

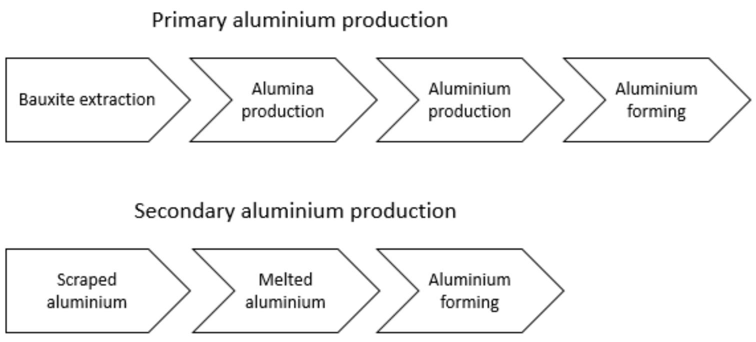

Figure 1 Primary and Secondary aluminium production

1.3 Objectives and Research questions

The primary objective for this thesis is to investigate whether or not a cloud based enterprise resource planning system (CERP) will increase the performance of an ASC better than a traditionally enterprise resource planning system (ERP). To accomplish this main objective some sub-objectives have been made:

- To study the Aluminium supply chains characteristics.
- To identify the pros and cons between the CERP and the ERP in an ASC.
- To reflect on the future of an ASC, when implementing a smart factory together with the CERP

Based on these objectives, the following research questions have be formulated:

RQ1: What are the characteristics of an aluminium supply chain?

To be able to increase the performance in an ASC with either a CERP or an ERP, there need to be a fundamental understand of the ASC. To get an understanding of an ASC an analysis will be performed and the characteristics will be pointed out.

RQ2: What are the pros and cons of implementing a CERP against an ERP in an ASC?

To increase the performance of an ASC, implementing an information sharing system is essential. In this thesis, CERP and ERP have been chosen for that investigation. These systems are going to be put up against each other and the pros and cons are going to be discussed and disclosed.

RQ3: What is the future for a CERP in an ASC, when adopting the concepts of a smart factory?

There are new technologies that are coming that can increasing the performance of an ASC. The concept of smart factory are very interesting and that together with a CERP system are going to be reflected upon to see if there are some potential in regards of increasing the performance of an ASC.

1.4 Thesis structure

The remaining of this thesis is structured as following:

Table 1 Thesis structure

Content	**Description**
Chapter 2 Methodology	The research methods used to gather data is represented along with description of the work.
Chapter 3 Literature study	Provides an overview of relevant literature for this thesis. The chapter start with supply chain, followed by aluminium supply chain, information sharing, cloud based enterprise resource planning, and smart factory.
Chapter 4 Analysis	The analysis of an aluminium supply chain is presented and what type of SC it is, then there is an analysis of how a CERP would work in an ASC, based on a control model methodology and there is a flowchart of customer interactions with the CERP.
Chapter 5 Discussion	The main topics of this thesis will be discussed and the research questions will be answered in relation to theory and assumptions.
Chapter 6 Conclusion	Shows how the objectives have been fulfilled, as well as presenting the limitation with the research.

Chapter 2 - Methodology

Research methodology is related to solving problems systematically using research methods procedures. Research methods are helpful to gather data, samples, analysis that may give answer to a problem. There are two types of research methods, quantitative or qualitative. Quantitative methods handle numerical data which is not descriptive, and the method is conclusive in decision making in regards of what, where and when questions. Qualitative methods are contrarily about non-numerical and descriptive data, that deals with why and how questions in an exploratory manner (Rajasekar et al., 2006).

A literature review was conducted in the early stages of this research. The aim for this research was to develop a better understanding of the aluminium market. As this search went on, it become obvious that the aluminium market is very competitive and the price of aluminium was very fluctuating. When this was discovered, the question of how to thrive in such a market needed to be asked. There are multiple ways of increasing the performance, but the choice fell on information sharing or more precisely on the information technology ERP. As the search went on there was a discovery that there are some limitations with the ERP in regard of involving multiple facilities, but as the realization that a cloud based ERP (CERP) offers some flexibility in that aspect, the thesis was made. The thesis is about comparing the ERP and the CERP in an ASC with the goal of increasing the performance of the ASC. Further, when the search for CERP information went on, several provident articles that described how the future might be when using emerging technologies was found. Based on this, the idea to reflect on how the concept of smart factory might look in an ASC was formulated.

In Figure 2, the thesis structure is shown. First, there was an investigation on the aluminium market, and then there is a literature study on ERP, CERP and smart factory. In the analysis, first there is analysis on the ASC to determine what type of SC it is, second there is an analysis on the material and information flow in an ASC, when a CERP is implemented. In the discussion, the results will be discussed as well as the research question will be answered. While in the conclusion, the answers for this thesis will be disclosed, as well as limitation with the study and recommendation for future work.

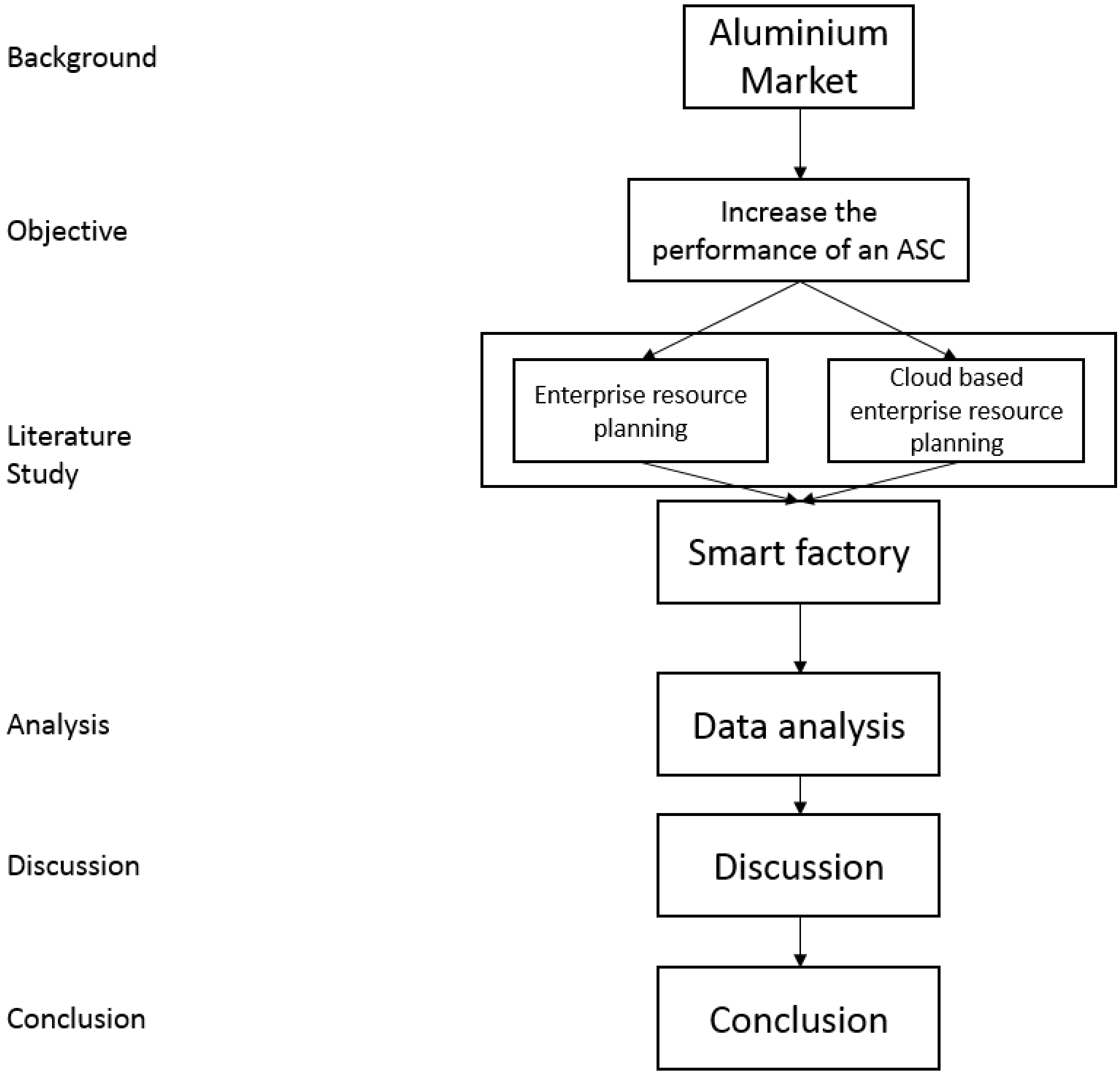

Figure 2 Thesis structure

2.1 Literature study

Literature study of existing literature in the field of interest is a crucial part of academic research. It helps in determining the research ability of the topic and define the possible contribution and scope (Karlsson, 2010). In this thesis, there are three main topics of interest, namely ERP, CERP and Smart factory. To identify relevant information from these topics there have been used three forms of search strategies: Random search, it was uses to get insight into the different topics. Building blocks search, it was used to get a wider perspective of the topics. Sited reference search, it was used to get an overview of the different topics (Croom, 2010).

The literature was targeted to answer the research questions, the topics where identified and searched through databases like, ProQuest, ScienceDirect, Scopus, Google Scholar and Oria. The search result was sorted by highest cited, then the articles were segregated by their title, keywords and abstract. If the article was of sufficient interest, it was thoroughly read. After it was read, the reference was checked to find more material that is relevant on the topics.

2.2 Data analysis

According to Yin (2003), data analysis includes different tasks of examining, categorizing, testing or combining qualitative and quantitative evidence to address the propositions of the study. In this thesis, it was relied on information from articles, books as well as some web-pages. When siting a web-page, there is a need to be extra careful, that is why all web-page references have been cross-checked with other references to check if the same information appears multiple times. When referencing articles and books there have been more of a common sense approach, when checking this information. Further, there have been used control model methodology and flowchart to analyse data. The control model was used to demonstrate the material and information flow in an aluminium supply chain. The flowchart was used to describe possible interaction between a customer and a CERP system.

2.2.1 Control model

A control model is a portrayal of the supply chain, that illustrates the relationship between the supply chain and its actors. It also shows how the suply chain operate and how the operations are controlled. With control model, both the current state of an organisation, with an AS-IS map, and future state with a TO-BE map, can be illustrated in a highly effective way. In control model methodology, material and informational flow is illustraded by firgures, tables and text (Alfnes and Strandhagen, 2000). The control model in this thesis is not totally in line with the control model methology. The purpose with the control model in this thesis is to visiulize how the flow of material and information should go between actors in the ASC.

2.2.2 Flowchart

A flowchart is used to give a graphic representation of an algorithm, workflow or process, where the steps are illustrated by boxes in different shapes and the sequence of the steps is shown by connecting the boxes with arrows. Flowcharts are helpful to get an understanding of what is going on by visualization the process, and it may illustrate a solution model to a given problem. In addition, the flowchart may detect flaws, bottlenecks and other features in the process. Flowcharts are frequently used in different fields to analyse, design, document and manage a process (SEVOCAB).

There are many flowcharts types, which differs when it comes to layout and boxes. The flowchart used in this master thesis is a so-called cross-functional type. This type divides the page in different columns, that each represent different organizational units. This technique visualizes that a step in the process, illustrated by a box, is under the control of the organization unit of the column that the box is within. The responsibility of the different steps in a process is therefore easily located in the flowchart, which may be important in decision-making.

Chapter 3 - Literature study

A literature study has been conducted on the topic of this thesis and the relevant information has been included in the following chapter. The main subjects consist of supply chain, aluminium supply chain, information sharing, cloud based enterprise resource planning and smart factory. In Figure 3, an overview is provided to understand the structure of the thesis, as well as understanding how the literature is related to research question. Chapter 3.1 and 3.2 is to understand what is a supply chain, as well as providing the knowledge to answer research question one. Chapter 3.3 is provided to get the understanding that information sharing is an important part of improving the performance of a SC. Chapter 3.4 is where both ERP and CERP are described and where the information to solve research question 2 is found. Chapter 3.5 is where the information to solve research question 3 is located.

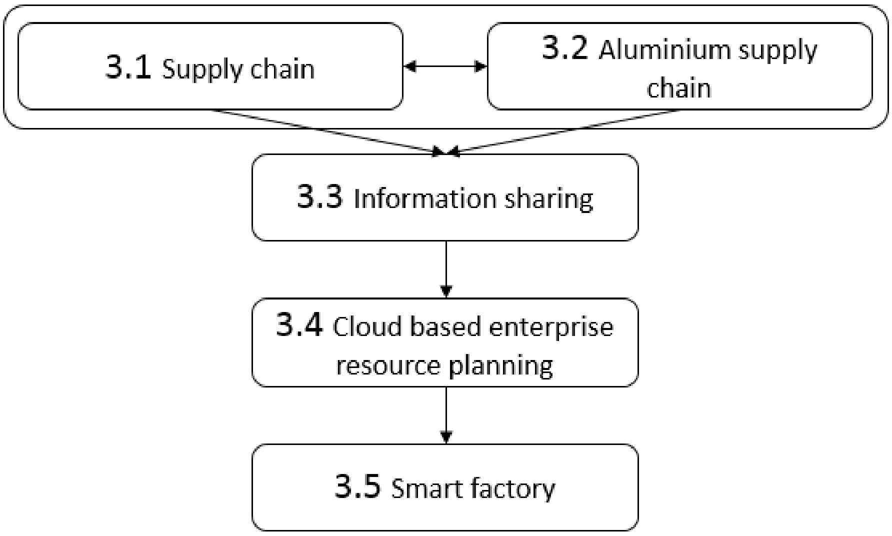

Figure 3 Overview of theory chapter

3.1 Supply chain

The following chapter starts by providing a description of supply chains, the final objective and the importance of collaboration and management in a supply chain. This is followed by a characterization of the four supply chain types. The final section is about factors that can enhance a successful coordination in a supply chain.

Chopra and Meindl (2016) presented the following definition of a supply chain (SC) "*A supply chain consist of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also* *transports, warehouses, retailers, and even customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functions in receiving and filling a customer request".* In other words, a supply chain is a set of suppliers and customers. It involves all the processes and information flows from the end-consumer to the extractions of raw materials, either directly or in-directly. In a supply chain a customer buys from its supplier and then sells to its customer, hence companies are part of a supply chain where they are both suppliers and customers.

The supply chains final objective is to create and maximize value generated by all the actors of the SC. The profitability of the SC depends on the overall ability to create customers value, minus the SC cost. Since customers are the source of revenue for a SC, managing the process efficiently further up the SC is of outmost importance. The performance of a SC can increase if the actors collaborate. Further, more value can be added for the customer as well as for the actors of the SC, if the actors collaborate (Chopra and Meindl, 2016). Lambert et al. (1998) defined it like this:

"*The integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders".*

Further, within a SC, there are several replenishment processes going on. The replenishment process describes the process of restocking inventory between an upstream supplier and a downstream actor. An order is sent from the downstream actor upstream to the supplier; the order is confirmed and sent to retailers via a form of distribution (Chopra and Meindl, 2016). It is important that a company has an effective management of their inventory, which is enabled by keeping accurate records of the inventory and making orders of correct quantity at the right time. The order is determined by finding cycle stock and safety stock. Cycle stock refers to the likely demand of the product and safety stock acts as a buffer for demand variations (Graves et al., 2000).

3.1.1 Types of supply chains

There are several types of supply chains and the customer order decoupling point (CODP) is a way of classifying them. The CODP is a comprehensible way to understand how customers are supplied with products. The concept basically consists of separating what happens before and after a customer order. The upwards activities are forecast driven, while the downwards activities are demand driven based on orders; this is shown in the Figure 4. The more downwards from the CODP, the more the pressure on efficiency, while more upwards from the CODP, there is a higher need to be flexible. The position of CODP enables to differentiate four types of supply chains: make-to-stock (MTS), assemble-to-order (ATO), make-to-order (MTO), and engineer-to-order (ETO) (Stavrulaki and Davis, 2010, Olhager, 2003).

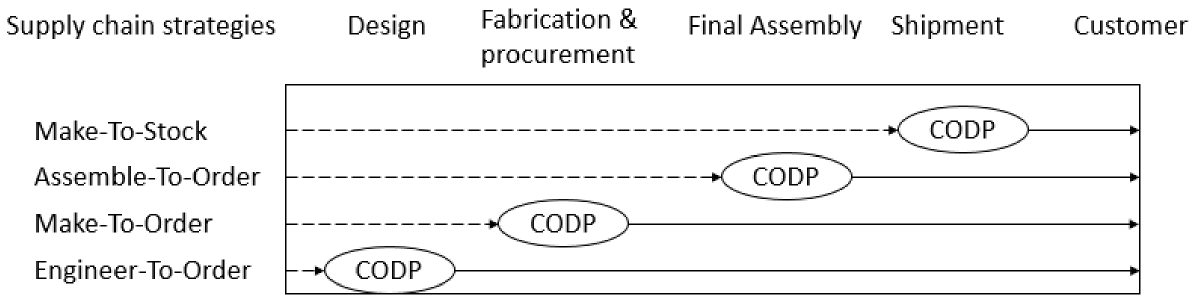

Figure 4 Supply chain strategies. Retrieved from (Olhager, 2003).

The processes in a supply chain can be divided into two categories; push and pull. Pull is the process that is done in response to a customer order, while push is the process that are initiated in anticipation of a customer order (Chopra and Meindl, 2016). By using Figure 4 to explain, push is the processes that is done before the CODP; the product is "pushed" down the SC by the companies. While pull are the processes after the CODP; the customer pulls the product towards them.

3.1.1.1 Make-to-stock

This type of supply chain focuses on satisfying customer needs immediately. The products this supply chain makes is highly standardized and is produced in high volumes. Typical companies working in this type of supply chain produce electronics, food and clothes. The demand for such products are relatively known, although seasonal demand can be hard to handle. Historical data give a relatively accurate demand image with low degree of error. The major challenge in managing this supply chain is cutting cost. Reducing inventory levels and optimizing distribution channels can result in significant cost savings in addition collaboration is an essential capability in a MTS supply chain.

3.1.1.2 Assemble-to-order

This type of supply chain focuses on satisfying a customer need relatively quickly with some degree of customization. Their products are standardized, but do not go through the final assembly before a customer order have been placed. This way a customer can add some degree of customization and a typical product in this type of supply chain is furniture. For example, a customer buying a couch might buy a specific model and choose the colour of the couch. The couch comes in a standardized model, but the cover is not put on. The cover is put on when the customer has decided on a colour. This is how an ATO supply chain operates, standardized products with some variants. Efficient manufacturing and logistics processes are necessary to support an ATO supply chain, in order to balance the pressure of achieving low cost and fast delivery.

3.1.1.3 Make-to-order

This type of supply chain offers highly customized products in low volume. The products are previously design, but often get some customization in the manufacturing phase. This way the customer gets the features they want, but they have to be willing to wait for it to be produced. A combination of modular and customized components provides a flexibility to meet individual customer requirements. The production does not start before an order is received. MTO supply chains only have raw material inventory, as each order is for a specific customer with its own requirement, it is impossible to have a finished inventory.

3.1.1.4 Engineer-to-order

This type of supply chain focuses on fulfilling all of its customer’s needs. Such products have very low volume and forecasting the demand is impossible, as each customer require some degree of design work. Inventory of finished goods does not exist in ETO supply chain, as each product is an adaption of an existing design or a completely new product. ETO supply chains need to be highly flexible to produce completely customized products. Typically such high levels of flexibility results in long lead times. To ensure rapid response to specific customer needs under uncertain supply conditions, the ETO supply chain needs to develop agile capabilities.

In principle, any type of supply chain can fulfil a customer need. However, one type may be more appropriate than another. Taking into account, the existing demand and characteristics of products there are different processes that fit better than another. Already in 1979, Hayes and Wheelwright discussed the importance of having the right manufacturing strategy with the right supply chain strategy. As shown in Figure 5, Hayes and Wheelwright (1979) have made a framework for connecting the manufacturing process and type of supply chain. The framework shows that when there are high volume and low variety of products, the production process should be repetitive flow or continuous flow. On the other hand, if there is low volume and high variety there should be either a project or a job shop strategy. If we implement Olhager (2003) and Stavrulaki and Davis (2010) characteristics of supply chain types into the framework, then it becomes evident what kind of manufacturing process fit with different supply chains.

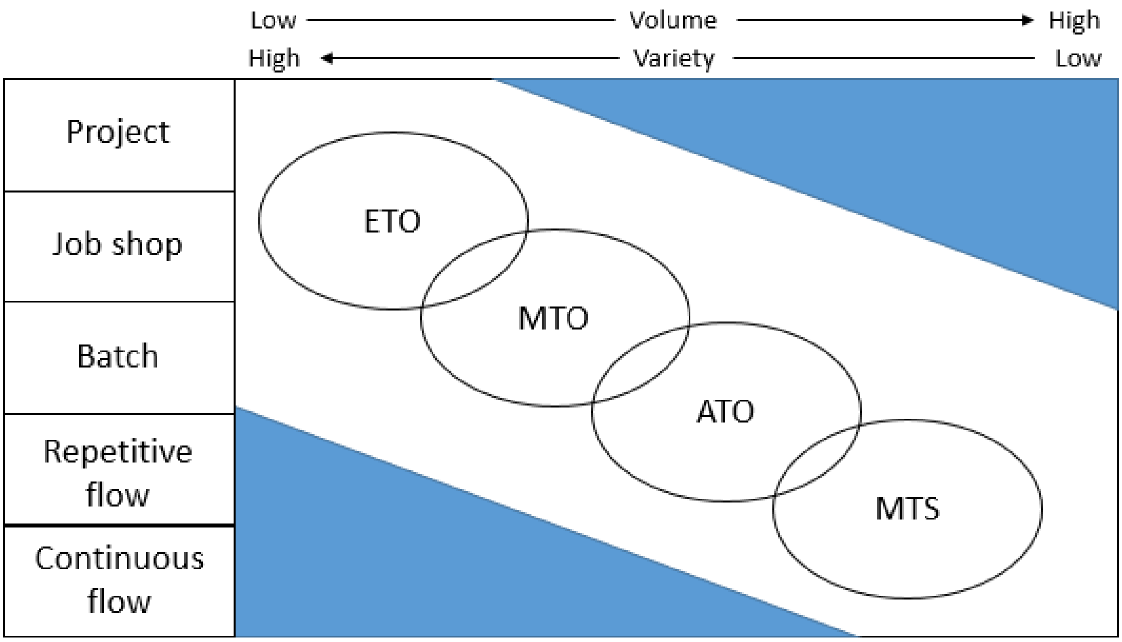

Figure 5 Product/process matrix based on work from (Hayes and Wheelwright, 1979, Olhager, 2003)

Each type of supply chain needs undeniably different management focus, which depends on their strength and weaknesses. Stavrulaki and Davis (2010) states that high volume and low variety correlates with a lean supply chain, meaning that the SC should have focus on efficiency. Conversely, low volume and high variety are more acceptable for an agile supply chain, with focus on the flexibility of the processes. Between these two extremes, the SC should incorporate both types. Increase the efficiency by standardizing some processes, but remain sufficiently flexible.

In Table 2, Stavrulaki and Davis (2010) have identified and characterized some key characteristics of the different SC types. The first one is market orientation; this is how much the customer can customize the product. As shown in Table 2, in a MTS SC there are little customization of products, while in the ETO there are a large degree of customization. The demand management in a MTS SC is driven by historical data, while in an ETO where there are higher uncertainty in future demand; it is driven by the experience of the people working in the company. Order fulfilment in an MTS SC is driven by cost, making the same product multiple times and selling it in big volumes, immediately. In an ETO SC, the order fulfilment is driven by time, making the product with the customization as fast as possible. The manufacturing focus in a MTS is on efficiency, making each product at a low cost. While in the ETO, the manufacturing focus is on flexibility, being able to perform different jobs. The supplier relationship in a MTS SC is collaborative; the demand is quite constant so the supplier can plan how much they are going to deliver at an early stage. In an ETO, the supplier relationship is much more about getting fast deliveries, so an ETO company can form partnership with key suppliers for fast delivery, when they know what they need. These characteristics also apply for ATO and MTO, but they are somewhere in between the MTS and the ETO SC.

Table 2 Characteristics of supply chains. (Stavrulaki and Davis, 2010)

	MTS	ATO MTO	ETO
Market Orientation	Smaller number of customer segments	←——→	Large number of customer segment
Demand Management	Quantitative and data driven (low demand uncertainty)	←——→	Experience and people driven (high demand uncertainty)
Order fulfilment	Cost driven (high volume)	←——→	Time driven (low volume)
Product development	Technology driven: slow development cycle	←——→	Customer driven: fast development cycle
Manufacturing focus	Efficiency (low variety)	←——→	Flexibility (high variety)
Supplier relationship	Regular demand High volume of transaction (potential for collaboration)	←——→	Irregular demand Low volume of transactions (opportunist collaboration)
Main strategic focus	Lean	←——→	Agility

3.1.2 Coordination

Coordinating a SC can involve multiple actors that performs various interdependent activities. The objective for companies when coordinating is to ensure that each actor manage their activities to optimize the performance of the entire SC, rather than just focusing on their individual performance. In essence, coordination consist in defining the structure, policies and goals of the entire system (Thompson, 1967). The existence of a common goal is an important part of coordination. By establishing a pattern of decisions, communication and interaction between supply chain actors, coordination tries to avoid sub-optimal solutions (Romano, 2003).

Coordinate a SC is not easy, but it is doable. Mentzer et al. (2001) found some factors that will enhance the chance for successful coordination, which are described in Table 3. The two most crucial factors when coordinating a SC are trust and commitment. If neither of these factors are in place, coordinating a SC is impossible. There needs to be trust between the actors, trusting that the other actors do what they can do to improve the SC, on the same terms as themselves. If the actors think that one of the other actors are doing something that only benefits them, trust is lost and coordination becomes hard. Commitment is also essential to coordinate a SC. If one of the actors do not think that another actor is fully committed to the coordination, trust is lost and coordination becomes difficult. The other factors in Table 3 build upon these two factors and further improve the chance for a successful coordination.

Table 3 Factors for coordination. (Mentzer et al., 2001)

Factors	**Description**
1. Trust	There needs to be trust between partners as this is essential to collaborate and to overcome mutual difficulties such as power, conflict and lower profitability.
2. Commitment	Commitment is essential to establish a long-term successful relationship. Both trust and commitment are direct factors leading to cooperative behaviour.
3. Interdependence	Interdependence is a motivation to negotiate functional transfer, share key information and participate in joint operational planning.
4. Organizational compatibility	It is defined as complementary goals and objectives, as well as similarity in operating philosophies and corporate cultures. It has a strong positive impact on effectiveness of the relationship.
5. Vision	The creation and communication of a market-winning competitive supply chain vision shared by the whole supply chain provides specific goals and strategies to accomplish the opportunities in the marketplace.
6. Key Processes	The focus of every process is on meeting the customers requirement and that the firm is organized around these processes
7. Leader	Leadership capable of stimulating cooperative behaviour between participating companies. It plays a role in coordinating and overseeing the whole supply chain.
8. Top management support	It has a critical role in shaping an organizations values, orientation, and direction and has substantial impact on organizational performance. The lack of top management support is a barrier in supply chain management.

3.2 Aluminium supply chain

This chapter begins with an overview of the aluminium industry and description of the market that aluminium is traded in today. Followed by an description of the different actors in the primary aluminium supply chain

3.2.1 Aluminium industry overview

The aluminium history starts in the late 1800s, when the Hall-Heroult-process was developed. The Hall-Heroult-process made it possible to industrialize the aluminium production and produce aluminium in big quantities (Olson, 2015). Before the Hall-Heroult-process, making aluminium was very difficult and aluminium was as expensive as gold. After the introduction of the Hall-Heroult-process, aluminium made its way into all kinds of industries such as car, military and aircraft. Aluminium main attribute is its strength compared to its weight. Different alloys do that aluminium have a number of different uses with different attributes, such as anticorrosion (Steinrücke, 2011).

The price of aluminium was quite stabile until the mid-1970s, after that the price have been fluctuating (Olson, 2015), as shown in Figure 6. The reason for the fluctuating price in the mid-1970s is the creation of the International Bauxite Association (IBA). The IBA was established as a result of what the bauxite producing nation saw as unfair accounting and pricing by the producing companies, the IBA become like a cartel and started to control the price (Olson, 2015). Today, the price of aluminium and the global economy is closely linked; one of the reasons is the material exchange. At the material exchange, aluminium is exchanged like a stock. Therefore, there are brokers that speculate if the price goes up and down, they create a fictive demand, this way the demand varies as well as the availability (UC RUSUL, 2015).

Another reason for the fluctuating price is the increasing aluminium production in China. In the last two decades, China have heavily increased their production of aluminium. China stands for one quarter of the yearly aluminium production and almost half of the world’s primary aluminium production (Olson, 2015). Even though most of the aluminium produced there is also consumed in China, more and more is exported and this creates higher competition in the world market. The Chinese companies do not compete on the same basis as the rest of the world’s companies. While the rest of the world’s companies have to consider getting the highest profit margin for their company, the Chinese companies are more concerned about guaranteeing workplaces and maintaining high rates of economic development (UC RUSUL, 2015). This way, the Chinese companies can pressure the price of aluminium down, without considering what it will do to its own profitability.

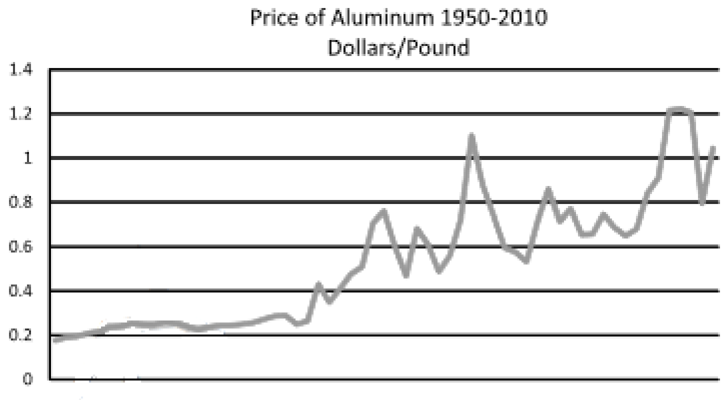

Figure 6 Long-range price of Aluminium 1950-2010. Retrieved from (Olson, 2015)

The aluminium supply chain is a global supply chain, in Figure 7 the location of the different actors of Alcoa's SC are disclosed. According to UC RUSUL (2015), Alcoa was the fifth biggest aluminium producer in 2014, this together with Figure 7 substantiates that the aluminium supply chain is a global SC. Further, in 2008, bauxite was minded in 29 countries, alumina was produced in 28 countries and there were more than 200 aluminium smelters in 46 countries (Steinrücke, 2011). What this means is that there is enormous pressure on the logistics in the ASC.

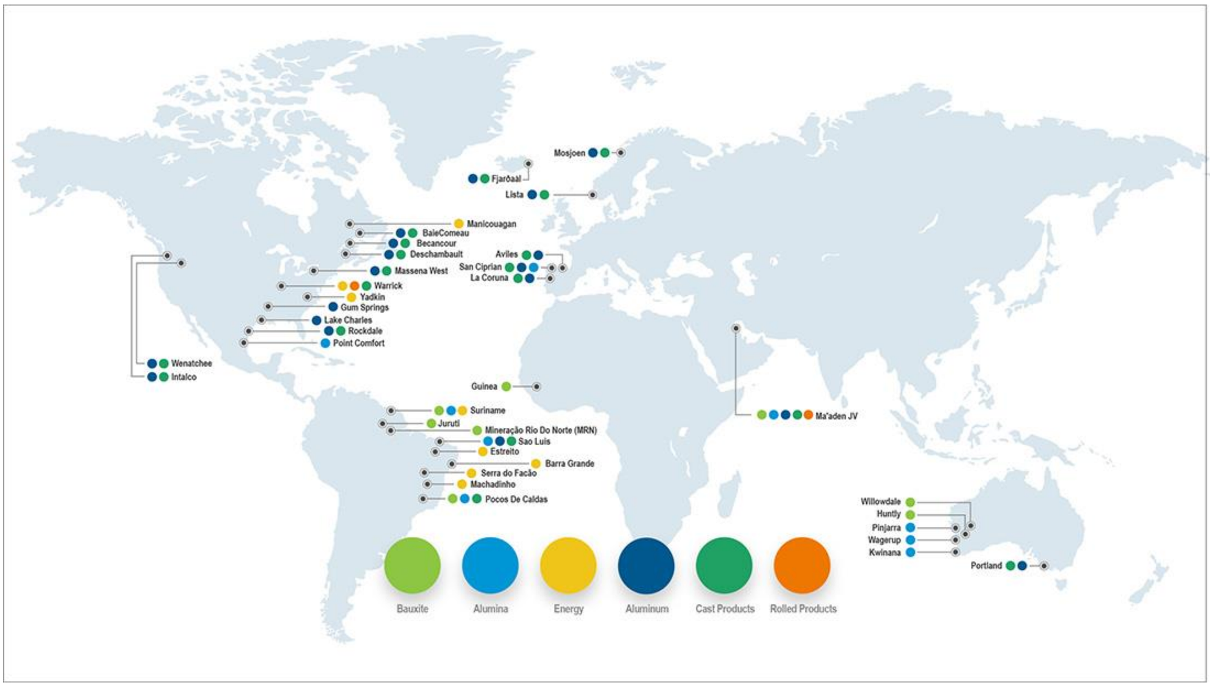

Figure 7 Global supply chain. Extracted from (Alcoa, 2017).

3.2.2 Aluminium supply chain actors

The primary aluminium supply chain has four main actors, which is illustrated in Figure 8. First, the bauxite is mined and then it is transported to the alumina refineries where the white powder alumina is produced. The alumina is turned into liquid aluminium in the aluminium smelter, which is then put in casts. From there it is transported to the final costumer in the supply chain, the forming facilities.

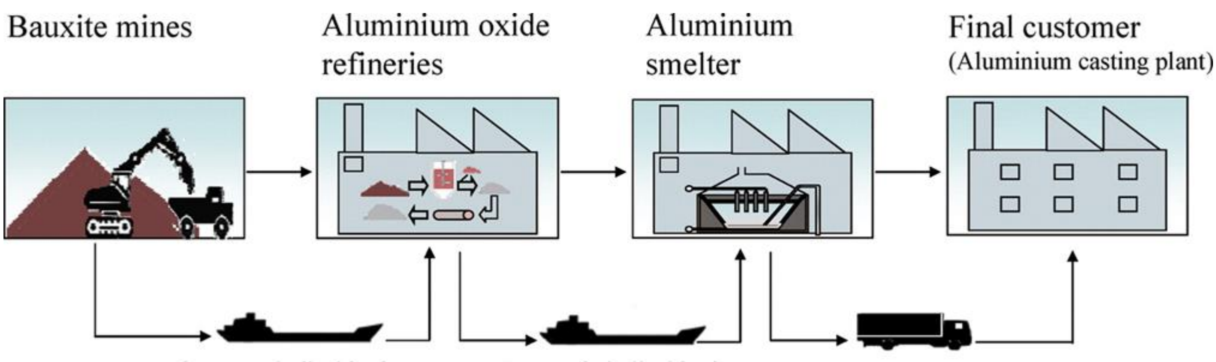

Figure 8 Aluminium supply chain. Retrieved from Steinrücke (2011)

3.2.2.1 Bauxite mining

Bauxite is a red clay that is found for the most part around the equator, but also exists other places. Mining can be conducted both above and below the surface, but in most cases, it is executed above the surface. There are big bauxite mines around the world, such as in Australia, China, Guinea, Jamaica, and Guyana. One of the most important factors when considering a bauxite mine is the purity of the bauxite, the purity of bauxite equals the level of aluminium in the bauxite (Hydro, 2016b, Olson, 2015). The purity of bauxite has big impact on the supply chain and it can differ much on different locations. To make one ton of alumina (aluminium oxide) it takes 2-3 tons of bauxite, the reason for the inaccurate number is the difference in purity among the different bauxite mines (Steinrücke, 2011, Olson, 2015). When considering this industry work in big quantities the importance of purity become clear, transport much more for the same amount of alumina is not economic favourable.

3.2.2.2 Alumina Refineries

After the Bauxite is mined, it is transported to an alumina refinery. The bauxite is then exposed to the Bayer process. The first step in the process is the washing and grinding of the bauxite, before it is filtered. After the filtering process, the solution is exposed to a chemical crystallization process, which is adding a combination of caustic soda and lime to the solution. The solution is then put through a rotary kiln, which dries the solution and the white powder alumina is what is left. Alumina refineries have historically placed their facility close to the bauxite mine, but as the mines closes or the ore is expended, the transport to the refineries gets longer(Steinrücke, 2011, Hydro, 2016a). The building of new refineries is very capital intensive, so new are not established that often (Olson, 2015).

3.2.2.3 Aluminium smelter

The third step in the aluminium supply chain is the aluminium manufacturing; this takes place in an aluminium smelter. Alumina is turned into aluminium by applying the Hall-Heroult-process. The alumina is placed in a furnace and is heated to 1000°C, when the solution is liquid; a direct current is put on the solution. Both the anode and the cathode are made from carbon, which is important since the alumina reacts with carbon in the anode. The carbon in the anode is consumed as the process goes on, the carbon in the anode and the oxygen in the alumina forms carbon dioxide that is extracted from the solution. The liquid aluminium is then extracted from the furnace and transported to the casthouse, where it is casted into different casts depending on what it is going to be used for. This process is very energy intensive, roughly 14 kilowatt hours of electricity are required to produce 1 kilogram of aluminium (Hydro, 2016c, Steinrücke, 2011). When considering that aluminium smelters work in tons, the understanding of energy intensive becomes very clear. Aluminium smelters are located in countries that have low energy prices, which enables the smelter to be competitive. There are more than 200 aluminium smelters in 46 countries (Steinrücke, 2011).

3.2.2.4 Aluminium forming

The fourth step of the aluminium supply chain is all the different forming facilities. The different forming facilities form the aluminium by casting, rolling or extruding. The casthouse at the aluminium smelter cast the aluminium in different forms, such as rods, billets, slabs and even powder. The form from the casthouse at the smelter is determined from what aluminium smelter it comes from and where it is going. The different uses of aluminium has almost no boundaries, as it is easily machined and easily formed, as well as it is stiff. The rolled products can be anything from aluminium foil to aluminium plates on boats. The extruded products can be all sorts of pipes, with any dimension and with any shape. The cast products comes from both the casthouse at the aluminium smelter or from a different forming-casthouse, where they re-melt an aluminium bar. The cast products can be anything, part in a car, part in airplane or a house structure, as well as an aluminium wire rod that is used in electrical cables (Hydro, 2016d).

3.3 Information sharing

Information sharing is an important element in a well functioning supply chain. It is crucial that the information is accurate, available, up-to date and to understand that not all information adds value to the supply chain. Information is described by quality, type and utilization in the following chapter.

The concept of information sharing has been discussed extensively, and there is to a large extend an agreement that information sharing between actors in a supply chain benefits the supply chain. Information sharing can increase the performance of any supply chain. Information flow can be categorized in two ways, downstream and upstream information. Downstream actors are the actors below you, the ones that you are the supplier for, while upstream actors is your suppliers, this can be transferred through the SC. If an upstream actor provides an uncertain image of their output, it can properly raise capacity shortage, or quality problems. In the end, these problems will transform into the retailers. If downstream information has not been accurately transferred into the upstream actors, there is a risk of an increased bullwhip effect. There are many benefits with sharing information in the supply chain, it can increase an organisations flexibility, reduces supply chain uncertainty and mitigate the bullwhip effect. By creating an environment that better utilize the resources through information sharing, there is less need for inventory in the supply chain, this way information sharing can cut cost in the operation of a supply chain (Chopra and Meindl, 2016, Lee et al., 2004).

3.3.1 Information quality

Information on its own has no value; the value is created by the adjustment in decision behaviour derived by the information minus the expenses of bringing forth the same information. Some believe that the information is better if received earlier, with higher accuracy and being more up to date, but this is only true if the information improves the resulting decision. If it does not, the information has no value, and there was still costs in producing the information (Lucey, 2005).

Information can be shared both internally within a firm and externally with other firms. Ruppel (2004) states that a firm’s ability to share information internally, directly affects its ability to share information to other actors in a supply chain. It is important that the information that is sheared in a supply chain has the right quality, because it is used to make decisions (Chopra and Meindl, 2016). If the quality of the information is insufficient, it can lead to an increase of cost in the supply chain, and a mismatch between supply and demand (Omar et al., 2010). Many different researchers operate with different information qualities, but some common dimensions are related to accuracy, timeliness, correctness and ease of use (Chopra and Meindl, 2016).

3.3.2 Information type

One of the most important aspects when it comes to information sharing is the question “what needs to be shared with the other actors of the supply chain?” In this context, there is a need to understand that there are different types of information and that they have different usage areas. The different usage areas can range from organizational need to product specifications, it can vary greatly and is dependent on the needs of the firm (Omar et al., 2010). Lee and Whang (2000) divides types of information into six different groups; inventory, sales data, order statues, sales forecast, production/delivery schedule and others. Lee and Whang (2000) types of information is described in the Table 4. Huang et al. (2003) have a similar definition where types of information is grouped into product, process, resources, inventory order, and planning information.

Inventory levels is a common shared type of data in any SC and alongside sales data the most important type of data to be shared. If there is not any sharing of inventory levels, there will be safety stock with every actor in the SC, which in turn will increase the holding cost in the SC. With the knowledge of knowing when and what to produce at an early stage, the company can improve the service level with less inventory (Lee and Whang, 2000). Inventory information can include current on-hand level, but also backlog and work-in-process (WIP) (Huang et al., 2003).

Sales date generally include orders, in addition it may include order quantities, batch volume and expected due dates (Huang et al., 2003). By solely depending on orders and not actual sales data from downstream actors of the SC; the bullwhip effect becomes evident (Lee et al., 2004). The downstream actors may order in large batches, which means the upstream actors do not receive orders very often and planning their production becomes more difficult (Huang et al., 2003). In addition, as orders are conjecture from the buyer, it may not represent the true dynamic of the market. As the actual demand becomes more and more blurry upwards in the SC, the bullwhip effect will be greater as the orders go up the SC. Ultimately the bullwhip effect hurts the SC, and there will be unnecessarily costs in the SC. Some of the problems can be excess raw material inventories, unplanned purchases of supplies, additional manufacturing expenses created by excess capacity, inefficient utilization and overtime, excess warehousing expenses, premium shipping costs, and poor customer service level. Sharing sales information enables suppliers to be better prepared for a volatile market and differentiate real demand and phantom demand (Lee and Whang, 2000).

Downstream actors may share sales forecast with upstream actors. This will allow the upstream actors to better plan there production, as it reduces the need for multiple forecasts (Lee and Whang, 2000). Sharing this type of information in the SC will enable the actors to work together to reduce the amount of inventory at each level. The excess inventory can be avoided, as all the actors are basing their forecast on each other, there will not be multiple forecasts with conjecture (Huang et al., 2003).

Table 4 Information type. Gathered from (Lee and Whang, 2000)

Information type:	**Description:**
Inventory level	Sharing inventory levels between actors in the SC will enable the actors upstream to plan their production better and deliver products just when it is needed.
Sales data	Sharing sales data together with inventory levels will mitigate the bullwhip effect upwards in the SC. Sales data can be: Point-of-sale(POS), Forecasts, batch volume, etc.
Order status for tracking/tracing	Sharing information on where in the process a product is will increase the customer satisfaction, as well as assisting the downstream actor to better plan their production.
Sales forecast	Sales forecast is a company's prediction on how much they are going to sell. The supplier and buyer should make the Sales forecast together, as both of them have some distinguished market knowledge and trends. By collaborating on the sales forecast both of them know what to expect and the bullwhip effect will decrease.
Product/delivery schedule	A manufacturer could make use of its supplier's production or delivery schedule to improve its own production schedule. It can assist the manufacturer to expand the planning horizon.
Other information sharing	This block consist of performance metrics and capacity. Performance metrics include product quality data, lead time, queuing delays, ETC. Sharing this type of information can assist in identifying bottlenecks in the SC.

3.3.3 Information Utilization

Information sharing can increase competitive advantage, but not necessarily. Firms must be able to capture, store and analyse information (Porter and Millar, 1985). If a firm do not use the information to better plan their production, the information will demand cost and have a negative effect on the SC (Lucey, 2005). The degree of quality of information a firm is able to utilize as well as the amount of information available, are important for effective balancing supply and demand (Omar et al., 2010).

Information technology assist in terms of communication and utilization of information in a supply chain. Information technology have increased the performance and efficiency of transferring information and limiting errors. Real-time information is now achievable due to speed of transaction and the enabler internet (Zentes et al., 2012). More and more information is therefore available to firms, but firms must be able to use the information (Porter and Millar 1985). Information technology may improve the processes of gathering, processing and communicating data to other companies and reduce related cost (Porter and Millar, 1985).

3.4 Cloud based Enterprise resource planning

This chapter begins with defining enterprise resource planning, and describing the characteristics and the pros and cons of this system. This is followed by a sub-chapter on cloud based enterprise resource planning, that include description on the different types, and the pros and cons of this system. The last sub-chapter explains Manufacturing Execution Systems, and describes the challenges and possibilities with bringing this system to a cloud.

3.4.1 Enterprise resource planning

As stated already in the background chapter, enterprise resource planning (ERP) can be defined as "a framework for organize, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage" (Arnold et al., 2012). This is a very general definition that only gives the knowledge of what an ERP systems goal is. Kumar and Hillegersberg (2000) provides a slightly more technical definition "ERP systems are configurable information system packages that integrate information and information-based processes within and across functional areas in an organization". In other words, an ERP system is a single repository of data that are designed to integrate business functions and allow information sharing both internally in the company and with other actors in the supply chain.

ERP systems main goal is to keep track of information and give the right people the right information to enhance the business processes (Chopra and Meindl, 2016). Another goal for the ERP system is to unite the various departments across an enterprise through one system application package (Tarn et al., 2002). Further, ERP systems provide global visibility of information both within a company and through a supply chain (Chopra and Meindl, 2016). What this means is that whatever department a person work at, accessing and relaying on the information within the system to make a more effective decision should be possible. The ERP system consist of several modules, such as accounting, distribution, marketing and sales, manufacturing, and human resources (Tarn et al., 2002). All these modules are intertwined with each other, and the ERP system keeps each module updated, when there is a change in one, the system will automatically update the other modules. The ERP system even reports back, when there is something that needs attention e.g. when the inventory needs some new merchandise. The ERP system do not focus on one module of the system, its focus is on the entire system (Tarn et al., 2002).

Even though the ERP systems revolutionized the industry in the 1990s, there are some limitations to it. The ERP systems was developed to fit a specific type of industry. This type of industry have little flexibility and do not fit all companies. Even though there have been efforts to increase the flexibility in an ERP system, this has just been partly successful. Implementing a ERP system for some companies have even had a negative effect on the competitive advantage (Akkermans et al., 2003). Current ERP-solutions lacks the ability to support multiple facilities, multiple suppliers and lacks functions as inventory control, management planning and production order processing (Helo et al., 2014). Another problem with the ERP systems today is to implement them; the implementation demands enormous time and cost resources. The implementation of ERP systems is a complex operation due to cross-module integration, data standardization, adoption of underlying business model, compressed implementation schedule, and the involvement of a large number of stakeholders. To emphasize that the implementation is a big investment both in time and in cost, the average implementation time is 23 months and the average total cost of ownership is 15 million dollars (Tarn et al., 2002).

3.4.2 Cloud based ERP

Cloud based solutions have different meanings for IT developers, IT managers and end users. The general description is that a cloud based solution is a web-based application that is stored on remote servers and accessed via internet by standard web browsers (Helo et al., 2014). For others a cloud based solution is a style of computing where massively scalable IT-related capabilities are provided “as a service” across the internet to multiple external customers (Lenart, 2011). In this study, a cloud based system means a system that is located another place than the facility and can be accessed through the internet. The main benefit with a system like this, is that the system is easily accessible and there is little requirement to IT investment. Cloud based systems are also the fastest way to the market, as much of the hardware already is in place (Lenart, 2011).

Cloud based ERP (CERP) system is basically an ERP system with the server placed in another location. The CERP is accessed through the internet with a normal computer. ERP is a core business system for many companies and is often tailor made for the company’s need. While normal ERP demand heavy investment in both hardware and software, cloud based ERP only need software that is tailor made and a good internet connection.

There are different types of CERP, the difference between them is how much a company want to do themselves and how much they want to outsource. Figure 9 illustrates the difference between them. The cloud infrastructure refers to the most basic solution, where you just rent a server. The renter handles the installation and maintenance of the ERP system themselves. The cloud platform is when the renter installs and maintain the ERP programing and the vendor provides the server and operating systems. This way a renter just need to concentrate on the ERP system and not worry about the operating environment. The cloud application is when a vendor provides the whole solution and the customer just accessing it through the internet, often through a web-browser (Lenart, 2011) (Johnson, 2010).

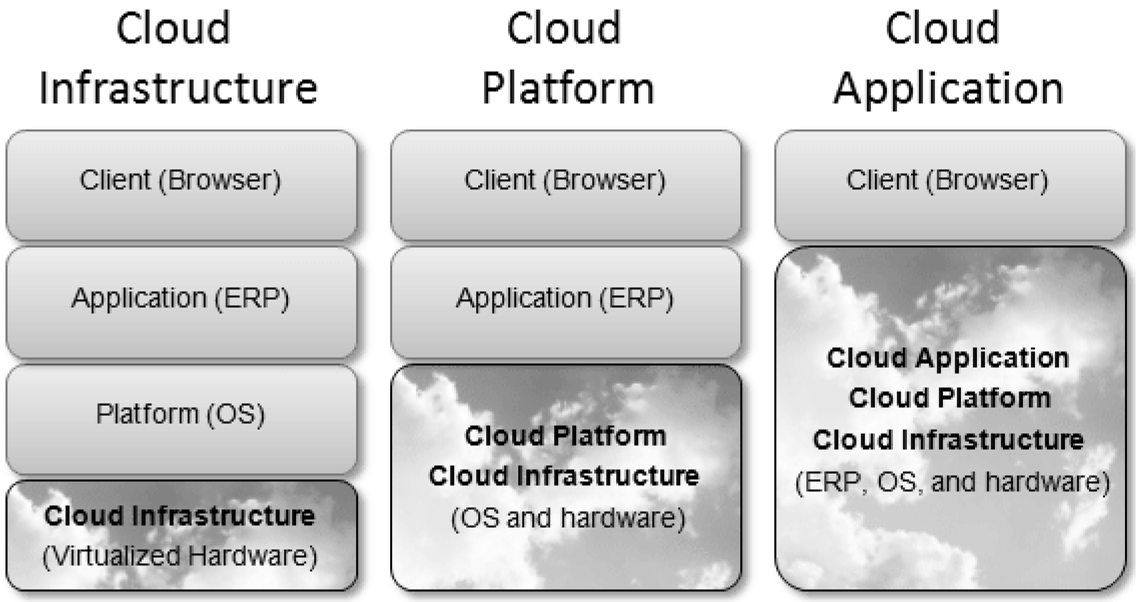

Figure 9 Types of Cloud ERP. Retrieved from (Johnson, 2010)

The main reason for implementing a CERP system to a company is the same as for an ERP system, which is getting the right information to the right people to enhance the decision process. The biggest different between the CERP and ERP, is when choosing a cloud based ERP there is little need for local IT investment (Helo et al., 2014, Lenart, 2011). Therefore, CERP cut much of the investment in hardware as well as operational cost. It also enables the IT department to focus on strategic projects instead of operational activities, such as maintaining the servers (Helo et al., 2014, Mangiuc, 2011). Another benefit with a CERP system is the flexibility that such a cloud provides, the company can meet peak demand without investing considerably in in-house resources. Expanding capacity on a CERP can be done by calling the provider and paying a little fee (Helo et al., 2014). Scalability is relatively easy and cheap for the CERP. When opening a new branch, accessing the CERP only requires a new user, paying a fee and the CERP is up and running (Mangiuc, 2011). Further, CERP presents a completely new degree of control, surveillance, transparency and efficiency in the production process. (Hofmann and Rüsch, 2017). This can be said since there is always possible to check the system, if there is something that needs attention, it can be done immediately. Institute of Management Accountants did a survey where they asked, “What are the key benefit of CERP?” around 800 responded and the result is shown in Figure 10. The key benefits of CERP are lower total cost of ownership (30%), data access anytime and anywhere (28%), streamlines business process (21%), easy upgrades (9%), lower capacity requirement (7%) and speed of development (5%) (Lenart, 2011).

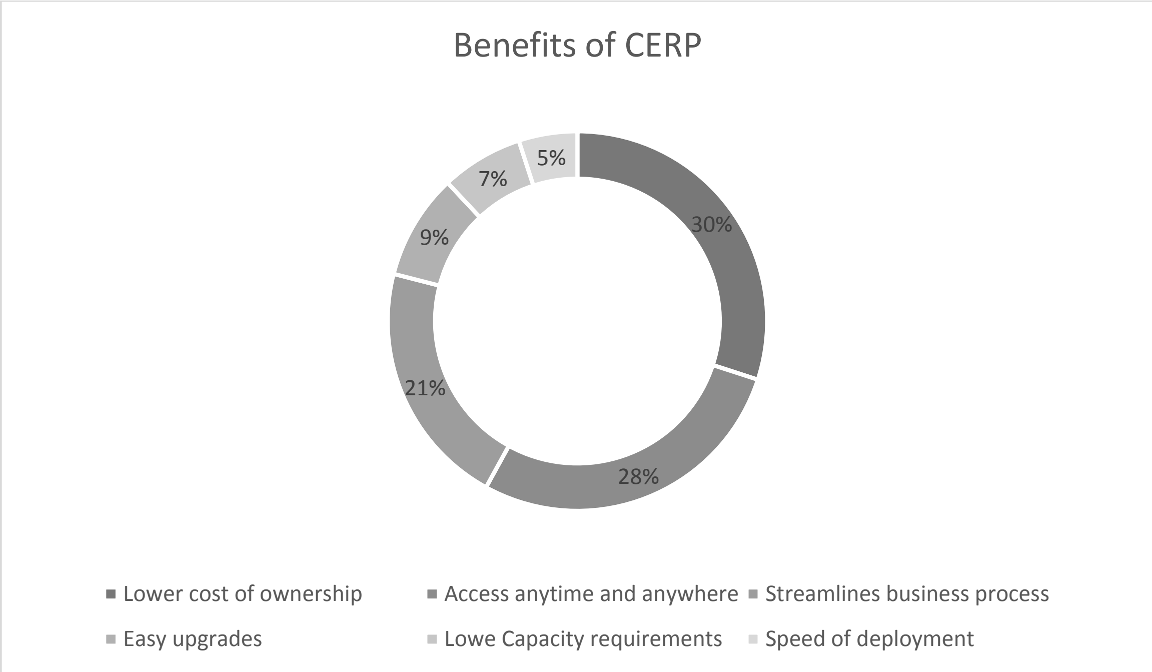

Figure 10 Benefits with CERP

Even though there are some great opportunities with CERP, there are also some concerns. Most of the concerns are different kinds of security concerns. The security concern rots down to the fact that the vendor will have quite sensitive data for the company stored on their server. Further, other security risk are concerns due to the migration from one business model to another (Helo et al., 2014, Mangiuc, 2011). Data protection is another concern that many CERP-customers have, they do not know how well their data is protected (Mangiuc, 2011). Further, a CERP system do not fit for large corporations, as there is a pay-per-use function with the system (Mangiuc, 2011). As discussed in the previous section, Institute of Management Accountants did a survey where they asked, “What are the key benefit of CERP?” In the same survey, they asked, “What was the main worry they had with CERP?” The result of this question is shown in Figure 11 and are security (35%), customization (18%), reliability versus an in-house (14%), ownership of data (12%), no substantial concerns (9%), maturity versus on-premise (8%) and ownership of application (4%) (Lenart, 2011).

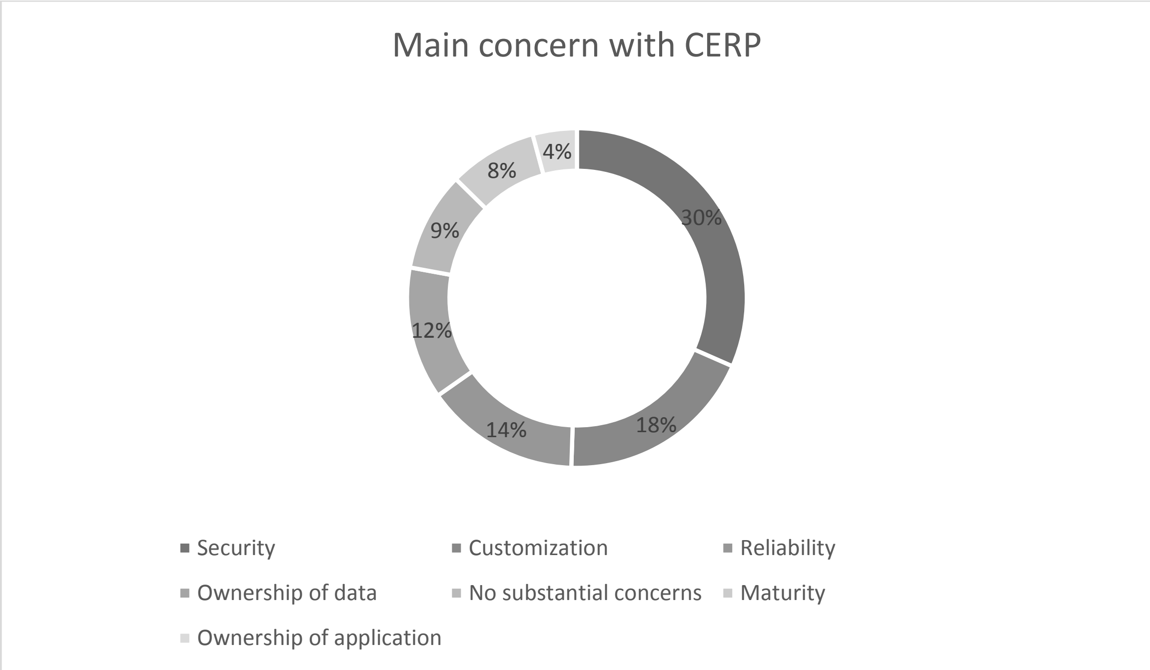

Figure 11 Main concern with CERP

3.4.3 Manufacturing execution system

Manufacturing Execution Systems (MES) are process-oriented software systems, which represent the interface between the automation layer and ERP systems (Witsch and Vogel-Heuser, 2012). In other words, MES is an information bridge between planning systems and manufacturing shop-floor control systems. MES links the production lines with the business level to a cost-effective and more efficient production (Witsch and Vogel-Heuser, 2012). Using MES provides benefits in supporting different types of production and processes. It reduces manufacturing cycle time and data entry time; it optimizes the inventory and warehouse; it improves product quality and empowers the plant operation people; it improves customer services and quickly responds to unanticipated events (Helo et al., 2014).

Bringing a MES system successfully to a cloud solution will be challenging. MES systems are dependent on real-time information from the shop floor. Enabling a good connection is absolutely possible, but if there is even the smallest problem with the connection, it will cause major problems for the MES system. Further, MES systems tend to be highly industry and process-specific, which mean it is highly customized for a specific process running at a specific factory. A MES system needs to be able to quickly change when a process changes. There are some concerns that a cloud-based MES system will not be as secure, available, customizable, and agile as a system running locally in the facility (Moad, 2011, Helo et al., 2014).

Even though there are some problems with bringing a MES system to a cloud, there are some interesting possibilities that this creates. In global supply chains, cloud-based MES solution will allow standardization of manufacturing sub-processes across multiple countries. This way the global supply chains will be able to seek for best practices internally within their entire organisation (Halse, 2011, Helo et al., 2014). Further, within the MES system there are some processes that it is not significantly constrained by latency in the information flow. In fact, service providers that can simplify standard commodity business processes, such as work order processing, or reporting and make these applications available to the customer through the cloud (Halse, 2011).

3.5 Smart factory

In this chapter, smart factory is presented. The chapter starts with explaining that a smart factory is a concept within industry 4.0. Then there will be sub-chapters about two enablers of smart factory, which are auto-id and internet of things.

The fourth industrial revolution, or Industry 4.0, was first launched in Germany in 2011, and is basically the idea of an integrated industry. Hofmann and Rüsch (2017) defined the industry 4.0 as a change in the manufacturing logic, fronting a more decentralised and self-regulating approach to the value creation process enabled by upcoming technology. There has been a rapid progress in technology in the recent years giving basis to trends like digitalization, internet of things (IoT) internet of services (IoS) and cyber-physical systems (CPS). This is some of the core concepts in the industry 4.0 and have enabled the so-called smart factories (Hofmann and Rüsch, 2017).

Smart factories are intelligent factories that have the ability to organise and control themselves in an autonomous manner, based on a decentralised production system. Products moves independently trough the different processes of a production, and it is continuously possible to identify and locate the product. A smart factory pursues an individualised mass production that is both highly flexible and cost-efficient (Hofmann and Rüsch, 2017). The smart factory concept still needs to develop before reaching its practical function in an industrial set up (Radziwon et al., 2014).

A cyber-physical system connects the physical and virtual world through integrations of computations with physical processes that are monitored by embedded computers and networks. Computations are usually affected by the physical processes and conversely the processes get affected by the computations through feedback loops (Hofmann and Rüsch, 2017).

Industrial products and systems have more and more software and embedded intelligence, and new predictive technologies can be used to predict the degradation performance of a product and autonomously control and optimize product service needs. This could make regular machines self-aware and self-learning, ergo improve overall performance and maintenance management, but self-learning machines are still far off being implemented in current industries (Lee et al., 2014).

3.5.1 Auto-ID technology

Automated identification system is a system that transfer information automatically to a supervisory system, which controls and tracks the products through the facility (McFarlane et al., 2003). These systems have been developed to easily identify an item and transfer product related information to enhance different processes in the SC, such as production, distribution and inventories (McFarlane et al., 2003). In today's manufacturing, typically the identification proses is manual, this process is done by manually inspections or by manually scanning the barcode. The location process is then done by proximity data and last known location, which is not very precise and increases the uncertainty in the SC (McFarlane et al., 2003).

There are different types of auto-id, but they have one thing in common, which is that they automatically transfer information when they pass by a sensor. The auto-id technologies are global positioning system (GPS), radio-frequency identification (RFID) , and mobile devices (Chen et al., 2014). Of these auto-id technologies, RFID is the one that show most promise for a SC. An RFID tag can easily be placed on any product and it can intelligently identify, locate, track, monitor, and manage a network, as well as it can be sensed in real-time. Also an RFID can carry specific information about the product on the tag and the tag can be reformatted to fit another product (Chen et al., 2014). One of the drawbacks with RFID is that it cost more than for example barcodes, which causes that industry to hold back on this development (McFarlane et al., 2003).

The possibilities with such auto-id technology is significant, they improve product tracking, enables automated inventory management, more accurate replenishment, as well as providing the control system with real-time information (McFarlane et al., 2003). These systems can in the future become the enabler for self-managed production, distribution and inventory systems, that will lead to a paradigm shift in the manufacturing industry (McFarlane et al., 2003).

3.5.2 Internet of things

The term internet of tings (IoT) became popular in the first decade of the 21st century and can be considered an initiator of industry 4.0 (Kagermann et al., 2013). The Internet of Things is a concept where physical objects can become “smart” by introducing small computers that are connected to the internet. Gubbi et al. (2013) defined IoT like this:

“*Things are active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention*.”

In other words, IoT will create a completely new world where everything is connected and in a manufacturing concept, the production will go seamlessly. “Smart” devices provides a growing volume of opportunities in regards of new functionality, higher reliability, greater product utilization and features that exceeds conventional product limitations (Hofmann and Rüsch, 2017). This new challenge of invisible embedding information and communication in our surroundings may be solved by radio frequency identification (RFID) and sensor network technologies. This bring about the generation of huge amounts of data which needs to be stored, processed and presented efficiently in a interpretable manner (Gubbi et al., 2013).

Chapter 4 - Analysis

The following chapter is divided in to main parts. First off, there have been performed an analysis on the aluminium supply chain to determine the type of supply chain. Secondly, there have been an analysis on how the CERP can assist in improving the material and information flow in the ASC.

4.1 Aluminium supply chain type

To analyse any supply chain there is a need to know what type the supply chain is, Hayes and Wheelwright (1979) and Olhager (2003) framework, shown in Figure 12 and Figure 13, proposes a way to define the type of a supply chain, this was explained in chapter 3.1.1. By applying this framework on the aluminium supply chain, the type of supply chain should be presented. Since the ASC is a network of supply chains, the first step is determining what type of SC each actor in the ASC is.

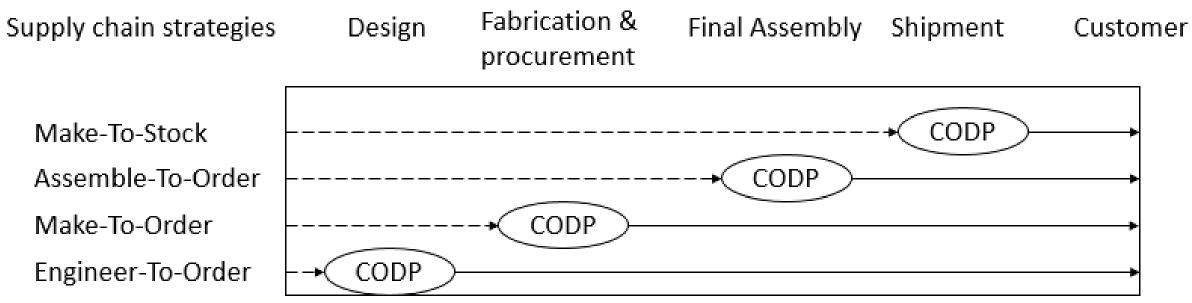

Figure 12 Supply chain types (Olhager, 2003)

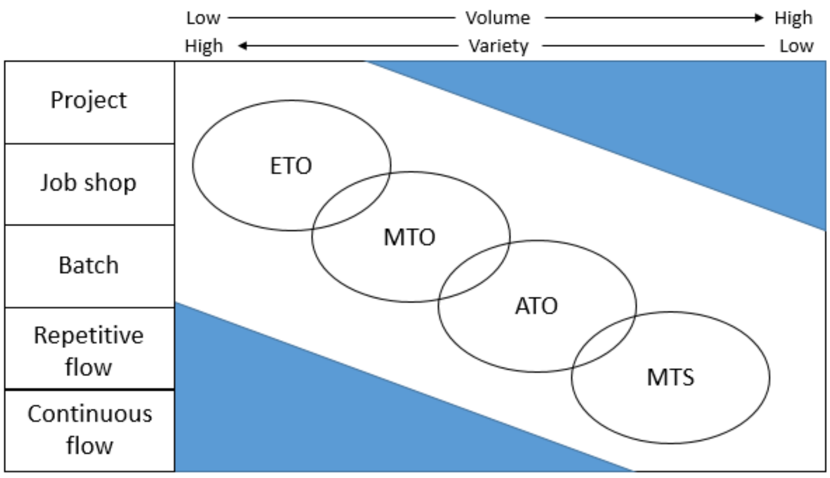

Figure 13 Product/process matrix with Supply chain types (Hayes and Wheelwright, 1979)

4.1.1 Bauxite mine

The first actor is Bauxite mine. This is a typical MTS company. This can be said because of the nature of the operation. The operation they perform is extracting bauxite out of the mine, the operation happens in a constant flow. The variety of their products are low (one product) and the volume is high (they produce in tons). Therefore, if we put High volume and Low variety, with a continuous flow into Hayes and Wheelwright (1979) figure. It becomes clear that the bauxite mine works in a MTS SC, shown in Figure 14.

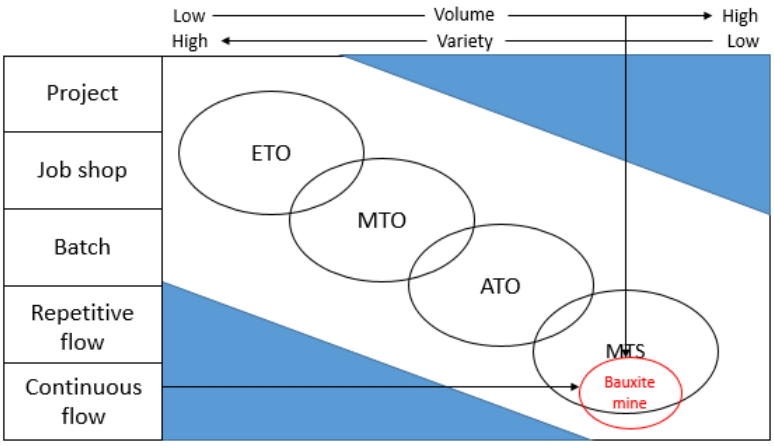

Figure 14 Placing Bauxite mine in Product/process matrix

4.1.2 Alumina refinery

The next actor is the alumina refinery. The production of alumina have a continuous flow, the facility only makes alumina. The variety is low (one product) and the volume is high. With this information it is possible to place the alumina refinery in the Hayes and Wheelwright (1979) framework and decide the type of SC, shown in Figure 15. In Figure 15, we can see that the alumina refinery is a MTS SC.

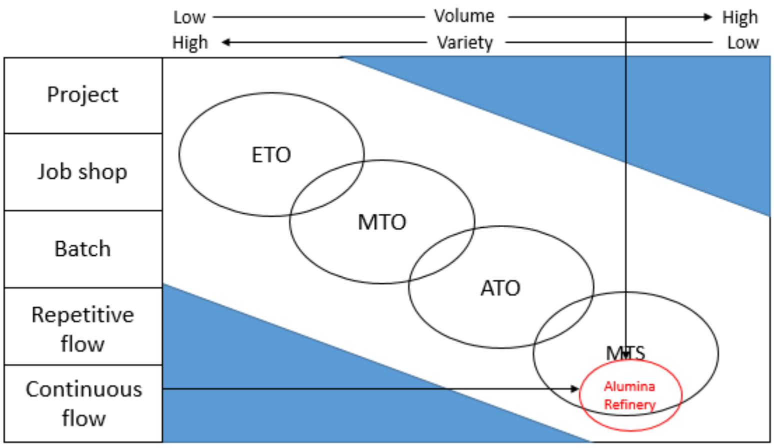

Figure 15 Placing Alumina Refinery in product/process matrix

4.1.3 Aluminium smelter

The third actor is the aluminium smelter, this actor is harder to classify. In the aluminium smelter, the production process can be divided into two; aluminium production and aluminium casting. The aluminium production is a repetitive process with the same product each time, which is liquid aluminium. This production process should be a continuous flow. The aluminium casting is the production process where the aluminium is cast into different moulds. It is here the classification problem arise, this cast can be for a specific customer, which then correspond with a MTO company. However, the cast can also be a standard component, which is shipped for further work, then the company correspond to a MTS.

The production process in the aluminium smelter are different for companies that customize products and for the companies that only make standard products. For companies that produce standard products, the production should be in repetitive flow, to accomplish an effective production in a high volume. When the aluminium smelter produce customized products, the production should be batch; this will enable the variation of product at the aluminium smelter as well as the volume.

Therefore, when the aluminium smelter produce standard products, it produces in big volume and with some variety. Putting this information as well as repetitive flow into Hayes and Wheelwright (1979) framework, shown in Figure 16. Now we can see that, when an aluminium smelter produce standard products it corresponds with a MTS SC.

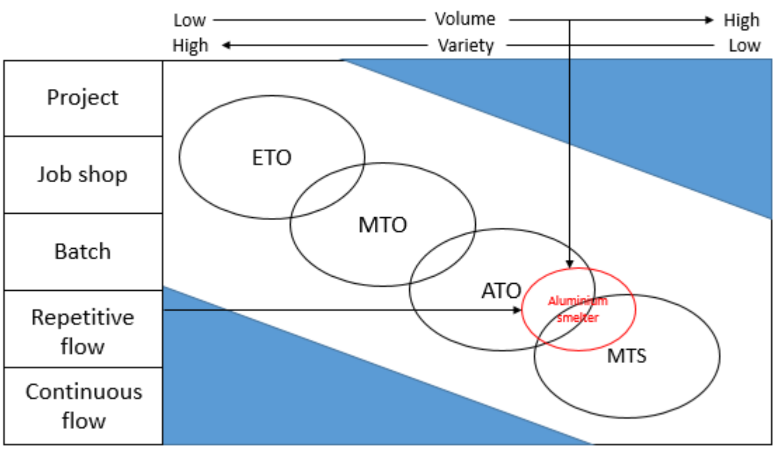

Figure 16 Placing aluminium smelter in product/process matrix, standard products

When the aluminium smelter produce customized products, it still produces in quite a big volume. The variety of products they offer, increases, so the variety is at a medium. Putting this information into the framework of Hayes and Wheelwright (1979) correspond with an MTO SC, shown in Figure 17.

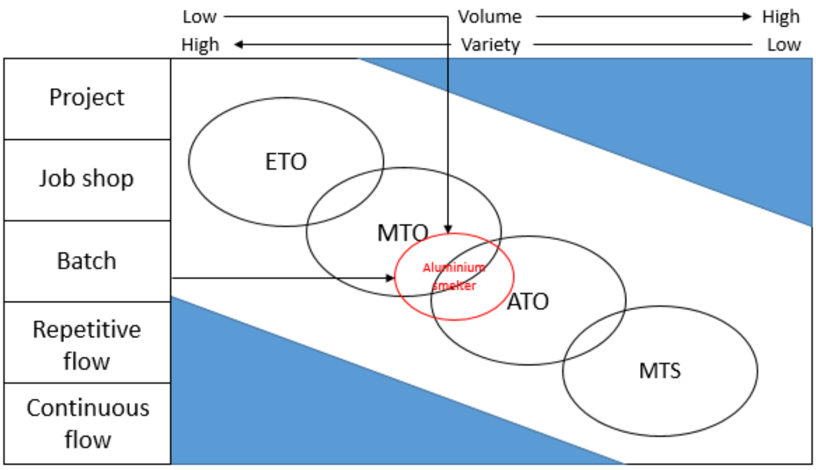

Figure 17 Placing aluminium smelter in product/process matrix, customized products

Further, classifying the different forming facilities as a whole is impossible, as there are so many types and business strategies among the forming facilities. If we are going to classify them, we need to investigate each one of them, which is unnecessary in this thesis. It is possible to determine the ASC, without knowing what type of SC the forming facilities are.

4.1.4 Defining the ASC

Now that we know what type each actor is in the ASC, it is possible to define the entire SC and place the CODP. The material flow between the actors in the ASC is high, they work in big quantities and until the aluminium smelter, there is just one product that is transacted. The aluminium smelter classifies the entire supply chain in this case and since that one is split, the CODP can be placed two places. Figure 18 show the CODP when the aluminium smelter produce standard products, then the CODP is located at the finished inventory at the facility. Figure 19 show when the aluminium smelter produces customized products, now the CODP is located just before the casthouse. The liquid aluminium does not go to a specific customer before it is poured into a specific cast, now the aluminium is for a specific customer.

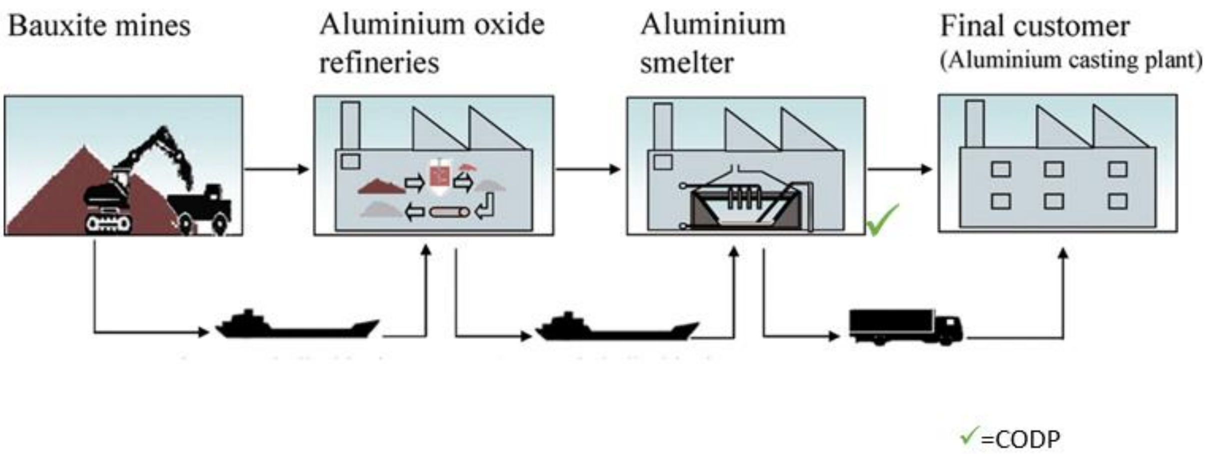

Figure 18 CODP placement, MTS

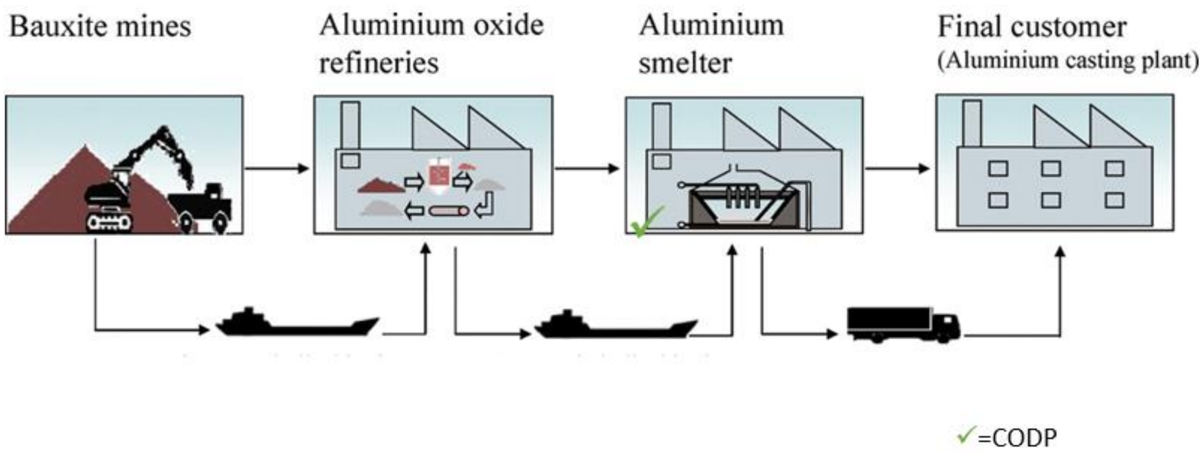

Figure 19 CODP placement, MTO

Further, since we now know the locations of CODP, it is possible to determine the type of supply chain an ASC is. When the CODP is located at the finished inventory, the only operation left is transport it to the customer, which correspond with an MTS SC. Figure 20 describe just this, the products are made and put in inventory, then the customer buys the product and it is shipped. Further, when the CODP is located at the work-in-process inventory, the MTO supply chain is the best fit. Shown in Figure 21, the production of a product is hold off until there is an actual customer order.

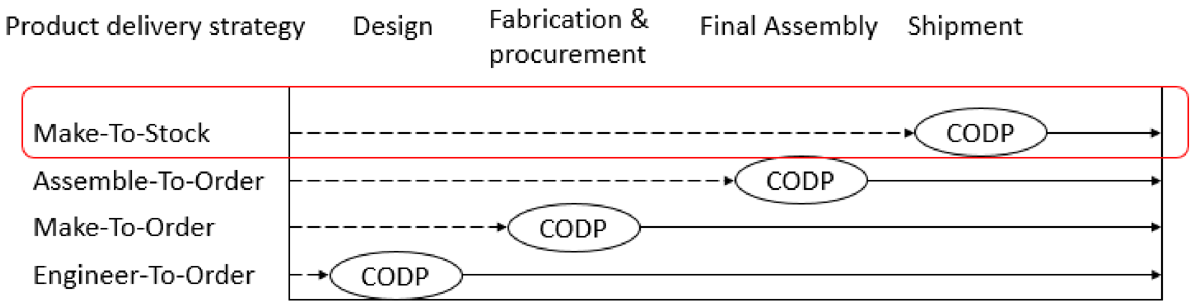

Figure 20 MTS

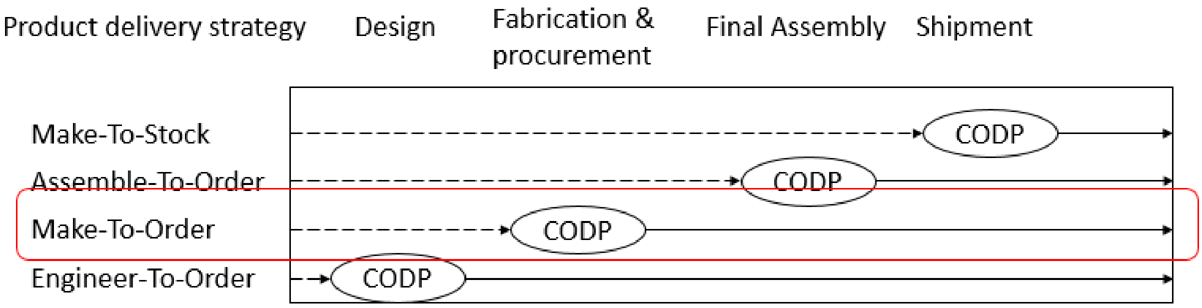

Figure 21 MTO

Another noteworthy observation in the aluminium smelter is that many of them has adopted the LEAN principle Just-In-Time (JIT). JIT is based on the idea that every component should be at the right place at the right time in the production process. JIT creates a pull-environment in the production line, which correspond with a MTO, rather than MTS.

4.2 CERP in ASC

Figure 22 represent a fictive ASC; it is based on principles from the control model methodology. Even though the Figure 22 do not have all the concepts from the control model methodology, it provides a good understanding of the material and information flow of the ASC. The goal for Figure 22 is to get a visual understanding of the ASC with a CERP that controls it.

Figure 22 describes how intricate the ASC can be. The CODP is located at different actors depending on what their processes and business model looks like. When the CODP is located at the backend of the aluminium smelter or in other words, at the finished inventory at the aluminium smelter, these facilities correspond with a MTS supply chain. When the CODP are located at the frontend of the aluminium smelter or at the raw material inventory, then the facility is in a MTO SC. The CODP is also located at the forming facilities in some cases. This is when the aluminium smelter produce standard products and serve the forming facilities before the forming facilities have gotten a customer order. In these cases, the SC is a MTO, with the CODP at the forming facility.

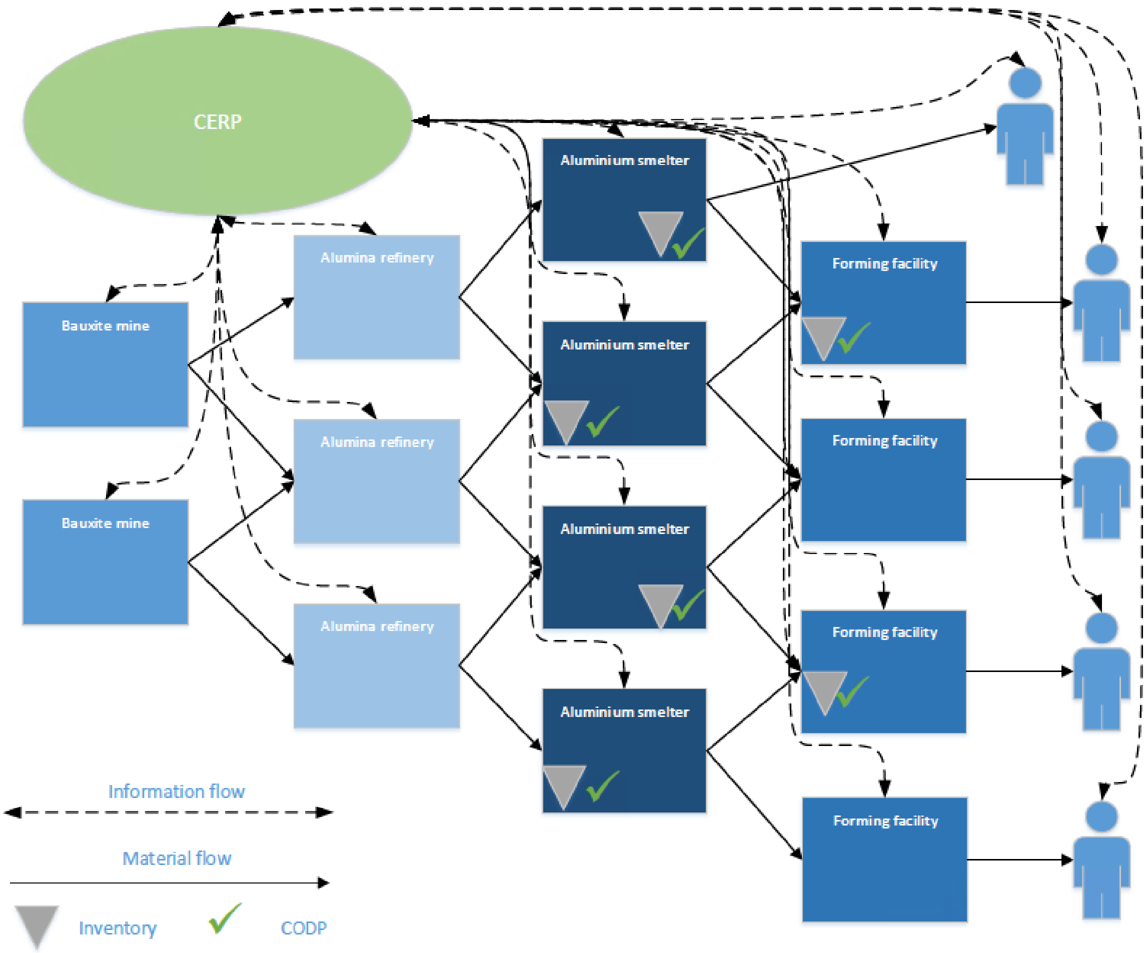

Figure 22 Control model of an ASC with CERP

The information flow described in Figure 22 represent how the information should be shared between the actors of the ASC, all information should go through the CERP. The CERP works as a single repository of information, it works as an information base for the entire ASC. When one of the actors need some information about one of the other actors or even its own company, all they have to do is connect with the CERP and it will have the information. One of the main benefits with a CERP is that it is easily accessible, all that is needed is a standard web-browser and the connection is immediate. When one of the actors in the ASC logs in to the CERP, the front-page is personalized for that actor. All the information that are immediate for that actor are on the front-page and the rest of the information is available systematically in the CERP system, so the information is easily obtained and ready to be used.

The CERP system have inventory level, sales data, sales forecast, product/delivery schedule and more for all the actors in the ASC. If an upstream actor considers this information from the downstream actor when planning its own production, the upstream actor knows when the downstream actor is going to need products. Therefore, planning the production to deliver when the downstream actor is going to send an order are achievable. With that in mind, the bullwhip effect should not become evident and by sharing and using the information shared, the production in the ASC will become seamless and the need for inventory almost become obsolete.

When the ASC is set up like in Figure 22 with the CERP, there are a pull system through the SC. The CERP controls the material flow and pulls the materials through the ASC. When the CERP pulls the material through the SC, the need for inventory is minimal; this is visualized in Figure 22 by not illustrating the small inventories at each actor. This is of course an exaggeration as every actor have some kind of inventory, but as the CERP controls the entire SC and knows when an actor will require more products, the CERP replenishes thereafter. Therefore, the need for inventory is minimal. In Figure 22, the only inventory that is visualized is the ones that are before the CODP, this is done because of the importance of this inventory. This is the inventory where a product is assigned to a specific customer. The smaller inventories at the actors are a necessity to utilize the transport cost; it is to fill up a trailer before shipping it, sending a half full trailer is not economical viable.

The bullwhip effect that can disturb the view for upstream actors. When the view over the big picture of the SC gets unclear, coordinating the SC becomes harder and expensive actions need to be considered. One of the first actions that are made by the actors is increasing the safety stock, which enables the actors to be more flexible to upcoming orders. The increasing safety stock do not only lock capital in inventory, it also requires holding cost. Mitigating the bullwhip effect, to any extent, is important for the SC and the CERP system can assist in this process.

Another important point when implementing a CERP to any SC including ASC, is the point of information traceability and transparency. In a CERP, all information is traceable; this is convenient when an error occurs. In that case, when an error occurs, it is important to find out where it generates from, as well as preventing it for occurring again. Another point for traceability is in the planning process. Being able to make good decisions is important and the biggest contributor to good decisions is good information. Knowing where the information comes from, as well as the quality of information is important for the decision process. Transparency of information within an SC assist the collaboration between the actors, the CERP enables this transparency. Every actor can access the CERP and gather the necessary information they require, this way getting an overview of the SC is achievable. When all the actors have the same information, collaborate to get the best outcome is the goal and the general trust between them will increase. Trust between partners is an important factor when collaborating and enabling them all to solve problems together rather than alone, which will increase the performance for the entire SC.

First, let us look at the material flow between the bauxite mines, alumina refinery and the aluminium smelter. The reason for looking at these together are that the replenishment process between them are similar. As shown in Figure 22, the CERP controls the orders and replenishment between these actors, all information comes through the CERP system. The CERP system recognize when one of the downstream actors need replenishment by looking at inventory levels, production capacity, upcoming sales and lead-time for delivery of all actors, and based on this information, the CERP can generate production orders for replenishment. This replenishment process happens semi-automatic, what this means is that the CERP recognize when an actor needs replenishment and sends a notification to that actor, that actor either approves it or rejects it if he thinks they have enough inventory. The replenishment order goes upstream to the actor that are closest and have available capacity.

In Figure 22, when the CODP is located at the frontend of the aluminium smelter the SC is a MTO. What this means is that the products are pulled towards the aluminium smelter. In other words, the alumina refineries just replenishes the raw material inventory of the aluminium smelter, based on the production of the smelter. This type of aluminium smelter can produce customize products, as well as standard products. This flexibility is this aluminium smelters competitive advantage. Even though this type of aluminium smelter do not have the ability to immediately fulfil a customer order, they can make highly customized products for the forming facilities as well as for a final customer.

The other type of aluminium smelter shown in Figure 22, is the on that have the CODP at the finished inventory of the aluminium smelter, which correspond with a MTS SC. The CERP push the material through the ASC until the finished inventory of this aluminium smelter, the product stays at this inventory until there are a customer order. This allows the smelter to fulfil a customer order immediately. The ability to fulfilling a customer order immediately as well as produce products in a high volume are this aluminium smelters competitive advantage. This aluminium smelter only makes standard products, which allows them to produce in high volume at a low cost. Their production is driven by historical demand, when they look back; they get a quite accurate forecast of future production.

In Figure 22, the forming facilities sometimes have the CODP located at their raw material inventory. In those cases, there are a semi-automatic replenishment process happening between the aluminium smelter and the forming facility as the one described before in this chapter. The forming facility order standard products from the smelter, typically an aluminium-bar that the forming facility are going to remelt and form in the desired form.

As described in Figure 22, the customer interaction with the ASC goes through the CERP. The order is conducted in the web-portal of the CERP and then sent to the actor who have the right capabilities, available capacity and the right proximity to the customer, this interaction is described in Figure 23. When the customer goes straight to the CERP system, the need for someone at the sales department to draft up the order in the system becomes obsolete. In addition, the CERP system can provide an estimated delivery time immediately; the CERP system knows the condition of the ASC, and what is available at the different facilities.

In Figure 23, the interaction between the CERP and the customer is described. When a customer wants to order, he or she logs on to the CERP and then opens the menu of standard products. If the customer wants a standard product, the order is placed through the menu at the front page. The order goes to the aluminium smelter that have the product in stock, within an appropriate distance to the customer. If the distance is too long, the order goes to the closest facility that have the capabilities to make the product. If the product is going to be customized, the front page of the CERP has a link to a separate customization page. At this page, the customer must choose some basic properties for the product, like main shape, alloy, quantity and so on. Then the CERP will send the contact information of the facility that have the capabilities, capacity and the proximity to make the product to the customer. The customer can then contact that facility and add further details to the customized product. When all the details are added, a person at the facility lays the product in the CERP for future reference.

What the Figure 23 tells us and illustrates, is that the CERP works as a single repository of data and can optimize the customer interaction in the ASC. The CERP system connects the right actors with the customer, and prevent much of the unnecessary interaction with the customer. The only direct contact between the actor and the customer is the detailed description in the customized product stage; every other interaction goes through the CERP system. The CERP system performs the procedure of customer interaction and frees up time for the sales department to get new customers.

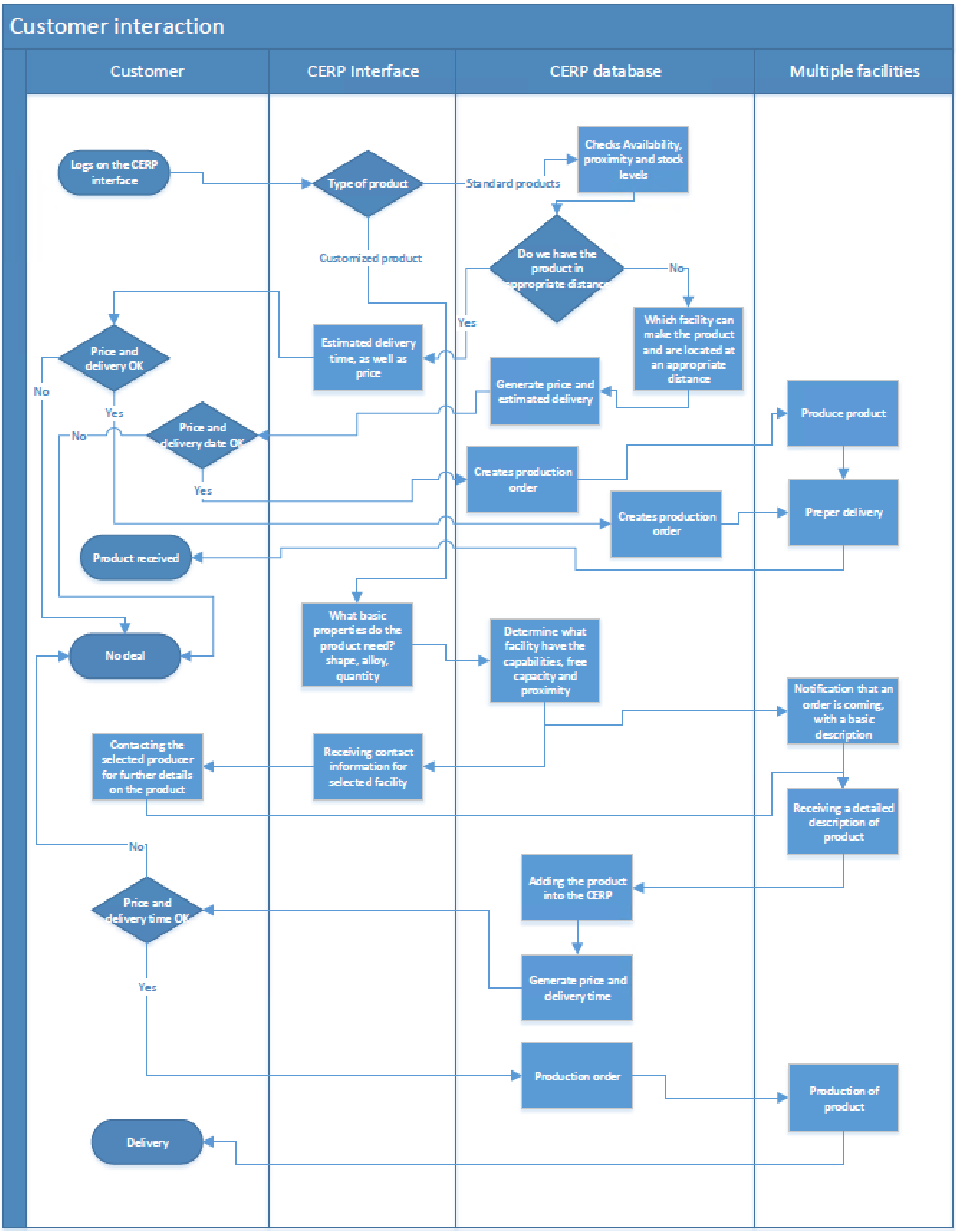

Figure 23 Flowchart of customer interaction with CERP

Chapter 5 - Discussion

The following chapter is divided in three main parts. First off, the characteristics of an aluminium supply chain have been discussed in comparison to a make-to-stock supply chain. Secondly, the challenges and opportunities of CERP and ERP have been discussed and compared with each other. Finally, there have been a discussion on the future of CERP in an ASC, that deals with adapting the concept of smart factory. These three sub-chapters are all written based on the three research questions given in chapter one, and at the end of each chapter, an answer to the research question is formulated.

5.1 Characteristics of aluminium supply chain

From the analyses of the aluminium supply chain, we found out that an ASC correspond with a MTS and a MTO SC. In this chapter, we are going to compare the characteristics of an MTS SC with the ASC; the MTS characteristics are shown in Table 5 and are extracted from Table 2. After these characteristics are discussed, they are going to be summed up into an answer for research question one.

Table 5 MTS characteristics, extracted from Table 2

MTS	
Market Orientation	Few customer segments
Demand Management	Quantitative and data driven (Low demand uncertainty)
Order fulfilment	Cost driven (High volume)
Product development	Technology driven: slow development cycle
Manufacturing focus	Efficiency (Low variety)
Supplier relationship	Regular demand High volume of transaction (Potential for collaboration)
Main strategic focus	Lean

According to Table 5 the market orientation of an MTS SC have little to none customer interactions on the product. What this means is that the customer do not have any input on the product, so there is no customization of the product. For an ASC this is partly true. For the first to actors of the ASC, this is true, as they produce standard products, but for the aluminium smelter and the different aluminium forming facilities, this is not true. The aluminium smelter operates both with making standard products as well as customize them, which means that the statement is both true and not true. For the different forming facilities, this statement also can be true and not. Some of the facilities do customization, where the customer interaction is a vital part of the process. Others only do standard production where the customer buys a finished product.

The demand management statement for an MTS SC is that forecast is made for historical data and the uncertainty is relatively low. This corresponds with the ASC to a large degree. The two first actors of the ASC have at least the possibility to make forecast out of historical data, with low uncertainty of error. The aluminium smelter and the different forming facilities depend what type of business they are, if they are a typical MTS, making forecast based on historical data is a good idea, but if they are a more MTO business, making forecast on historical data alone will generate some errors. MTO businesses should look at historical data, but they need to revise it using experience and common sense. Consequences of having a faulty forecast are the loss of opportunities. What this means is that instead of looking for ways to improve the business, the company has to compensate for either overestimating or underestimating the sale. Another consequence of errors in the forecast is the loss of trust between the actors, not fulfilling a customer order to agreed time do not create trust and goodwill. The bullwhip effect will also make the working environment in the SC harder if the forecast have many errors, the real demand becomes more and more unclear as there are many errors in the forecast upstream in the ASC. Making a forecast with as few errors as possible is important for any SC, also for the actors in the ASC.

Order fulfilment statement for an MTS SC is that it is cost driven, what this means is that in the MTS fulfilling orders is done by focusing on price and their surplus comes from selling in big volumes. For an ASC the order fulfilling process is cost driven. All the actors of an ASC operates in big volumes, where a goal is to make the cost for each product as low as possible. The bauxite mine and the alumina refinery just produce one product and making the process as effective as possible is of great importance. The aluminium smelter and the forming facilities produces in big volumes, but with some variances, still their order fulfilment is cost driven rather than time driven. Even though some of their products are time driven, the focus for the facility is cost. The time driven products are customized and not produced in big volumes, so making them fast rather than focus on cost is the competitive edge there. In general, the facilities are cost driven, so the statement for MTS about order fulfilment fits for the ASC.

The product development cycles according to the statement for an MTS are slow and are technology driven. This is both true and not for an ASC. For the bauxite mine and the alumina refinery, their products are set and cannot evolve, the only thing that can evolve for these actors are the process that make the product, which is technology driven and slow. The aluminium smelter and the forming facilities have a shorter development cycle, but this cycle is also slow. The forming facilities have the shortest development cycle, as they can make new products, but this cycle is relatively slow as well.

According to the statement about suppliers relationship, in an MTS there is a high number of transactions and it is possible for them to collaborate. For an ASC this statement is true. Through the entire SC, there is a high number of transactions and there should be collaborations between the actors. Since there are so much transaction between them, making the actors becoming partners and working together should be a goal and the benefits are many.

In Table 6, the different characteristics are summarized for each actor of the ASC, while in Table 7 some general characteristics for the entire ASC are highlighted. These tables are the answer for the first research question in this paper, which are “what are the characteristics of an aluminium supply chain?” These answers were developed through the analyses done on the ASC, as well as the discussion in this chapter.

Table 6 Characteristics of actors in ASC

Type of characteristic	Bauxite mine	Alumina Refinery	Aluminium smelter		Forming facilities	
Type of SC	MTS	MTS	MTS	MTO	MTS	MTO
Customer segment	None	None	None	Some	Some	Large
Demand management	Data driven	Data driven	Data driven	Data driven with revision	Data driven	Experienc e driven
Order fulfilment	Cost driven	Cost driven	Cost driven	Cost driven	Cost driven	Time driven
Manufacturing focus	Efficie ncy	Efficiency	Efficiency	Efficiency	Efficiency	Flexibility
Supplier relationship	Collabo rative	Collaborat ive	Collaborat ive	Collaborat ive	Collaborat ive	Collaborat ive
Strategic focus	Lean	Lean	Lean	Lean	Lean	Agile

Table 7 General characteristics of ASC

General characteristics	**Aluminium Supply Chain**
Size of SC	Global
Volume	High
Variety	Low
Customer segments	Few
Demand management	Data driven with revision
Order fulfilment	Cost driven
Manufacturing focus	Efficiency for the most part
Supplier relationship	Collaborative
Strategic focus	Lean

5.2 CERP vs. ERP

Implementing a CERP system instead of the traditional ERP system in the ASC is a question on what do the different systems provide and what do the ASC need. The main difference between an ERP system and a CERP system is that the CERP is a cloud-based system. What this means is that the servers that the CERP operates from is located at a different location than the production facility. The ERP and CERP systems are basically the same thing, but there are some challenges and opportunities with both of them.

The ERP system is a well-known, thoroughly studied and well implemented in the market, while a CERP system is relatively new, not as studied and not as implemented in the market. The ERP is highly capital and time consuming; the general implementation time is 23 months. The CERP is the cheaper alternative and less time is needed for implementation. It is cheaper in the form that there is no need for investing in hardware, since the hardware is rented instead. Therefore, the CERP is cheaper in the short term, but not necessarily in the long-term. Further, the CERP system is the fastest alternative to market. The reason for that is that the CERP do not have to go through the implementation phase of hardware that the ERP needs to go through; it can jump straight to the programing phase.

The flexibility of the ERP system is more limited than the CERP system when it comes to processing power. When there is a peak demand and the processing capacity of the ERP system is maxed out, enabling extra processing capacity for the ERP is expensive. In the CERP system, excessing extra processing capacity is not a big issue, just contact the hardware provider and ask for extra capacity for a small fee. The ERP system often have very poor performance when it comes to utilizing the processing power. The ERP have a set capacity, which is the same even though the demand is fluctuating. In that context, when the demand is low and there is not much happening in the ERP system, the processing power of the system is still high and much of the power stands still. The other way around, when there is a high demand, there may not be enough processing power. The CERP system is much more flexible to these changes in demand. By contacting the provider, the processing power can be turned up and down. Therefore, the processing power in the CERP is exactly what you paid for, while in the ERP the processing power is constantly higher to stay flexible, therefore you must pay for more then you need.

There have been some concerns regarding security in the CERP system, as previously show by the survey in Figure 11. One of these security concerns about CERP are protection of data, these concerns are exaggerated. The provider of CERP servers may have multiple companies CERP on their servers, so the loss of data will crush their reputation as a CERP provider. Therefore, the CERP provider work constantly to maintain their protection of data. The ERP system is often protected by its own IT department, while they work on maintaining everything else in the system. Therefore, a company that work constantly on protection, like the CERP provider, are better suited for protecting data rather than a small IT department that work on different ERP issues. Further, another security concern is the loss of governance. The CERP provider will have control over some sensitive information for the company and the loss of them will have negative consequences for the company. This is of course not a problem within the ERP system as they control all their own data, but if the company choose a serious CERP provider, it should not be a problem for them neither.

One of the most important points when discussing the CERP is the point of easy access to the system, which is one of the main benefits with the CERP system and is substantiated by the survey shown in Figure 10; the only thing that is needed is having a good internet connection and a computer to access the CERP system. One drawback with this easy access in the CERP system is that the company needs to pay a fee for each actor attached to the system, which for a big SC will be expensive. Making this easy access in the ERP system can also be done just as easy, but the IT department needs to enable this for it to be possible, which require an investment both in time and in money. Since accessing the CERP system through the internet is how it is designed, there is no need to implement this, as it is for the ERP system. Being able to easily connect with the system will enable some flexibility to people working with it. When there are something that need attention in the system, being able to quickly resolve it will enhance the performance of the SC, as well as enhance the decision process in the SC when the system is constantly up to date.

Further, one big difference between the companies that use CERP and ERP are the size and focus of their IT department. In an ERP company, the IT department needs to be relatively big, to accomplish to evolve the ERP as well as maintaining the ERP. For companies that use the CERP, the IT department do not need to be as big, since they do not need to maintain the hardware. Also in the CERP, since they do not need to maintain the hardware, they can focus their efforts towards the programing of the CERP and constantly making an effort to enhance the program. So when comparing the two systems, the ERP need a bigger department than the CERP just to have the same improvements of the program.

Implementing a MES system with the ERP is done countless times and are a way to increase the performance of the ASC with the ERP. While in the CERP system the implementation of MES, have some issues, but also some opportunities for the ASC. The MES system work as an information bridge between the shop floor and the CERP or ERP. The connection between these programs need to be constant, which creates some problems for the CERP. Having the MES up in the cloud with the CERP and rely on that the connection is stable and constant is a possibility. Another alternative is having the MES system at each facility, but this is a bit counterproductive with the CERP. The point with the CERP rather than the ERP is the point of not having servers at each facility, and then having a server for the MES is contradictory. One of the opportunities with bringing the MES to the cloud together with the CERP is the possibility of standardizing the MES for multiple facilities. Think of having the same standardized MES at each aluminium smelter across the globe; it will decrease the implementation time of the system. As well as allowing best practice for all the smelters and making certain application available for the customer through the cloud. The implementation of MES can be done to all the actors of the ASC, but there need to be some moderations with each actor. This author thinks, at least in the developed part of the world, that bringing the MES to the cloud is possible. Anywhere we go in the developed world, there is the possibility to go online, so having a constant and reliable connection with the MES should not be a problem.

Table 8 ERP vs. CERP

	ERP	CERP
Maturity	Well-studied and well establish	Relatively new
Implementation time	Long, general 23 months	Shortest way to market
Cost of implementing	Expensive	Short-term: cheapest alternative Long-term: Depends
Cost of use	Maintenance cost	Pay-per-actor: • Small company – not significant cost • Large company - expensive
Flexibility of computer power Utilization of computer power	Set capacity Bad	Flexible capacity good
Size of IT department Focus of IT department	Big Mixed focus	Medium Software focus
Implementing MES	Easy	Relying on constant connection

In Table 8 the main points of discussing an ERP vs a CERP are disclosed. Which system should the ASC implement through their SC? In chapter 4.2, we saw how a CERP could improve both the information flow and the material flow, but the CERP system could have been an ERP system and gotten all the same results, as long as the ERP system was set up in the same manner as the CERP. As stated multiple times, there is not too big a difference between an ERP system and a CERP system. Anything that the CERP can do, the ERP can do with some investments and work from the IT department. The reasons for choosing one or the other rots down to price for implementation, as well as the price of using the application. In Table 8, it is shown that implementing an ERP system is expensive, while implementing a CERP is cheaper in the short-term, but in the long term, it depends on the server needs and the number of actors that are going to use it. In the ASC, there are large companies with facilities all around the world. There are many actors that are depending on the system and the system needs to be able to comprehend this kind of activity.

Therefore, the ASC should establish an ERP system that operates like a CERP system with its server at the main office of the company. This way the ERP system will feel like a CERP system for every other actor in the ASC. The system will be more expensive in the short run, but with the number of actors that are going to use it as well as the general activity on the system, an ERP system is the best option for an ASC. In a CERP system, the company will have to pay by the number of actors that are using it, which is a big drawback for the ASC companies, as they have many actors. Even though there is no numbers available on the fee per user, there are so many actors and in the long term, this constant expense is anticipated to be enormous. Another important point is with an ERP system the aluminium company will have total control over their data, which will be appreciated for the aluminium company. Further, the multinational aluminium companies have big IT departments, so maintaining and improving such a system is achievable. The aluminium companies can make the ERP system cloud like, with many of the advantages that the CERP provides. Implementing a MES system for better production control is also easier with an ERP system, compared to a CERP system. Therefore, the aluminium companies should choose an ERP system that operate like a cloud system for their ASC.

5.3 The Future for a CERP in a ASC

The last chapter ended with the conclusion that aluminium companies should choose an ERP system that operates like a cloud system for their ASC. The ASC will then still have the advantages that the CERP provides, consequently the future of CERP in an ASC is highly relevant. To chapter aims to answer research question three, “What is the future for a CERP in an ASC when adapting the concepts of a smart factory?” The chapter start with a discussion on the possibilities of auto-id and internet of things when they are combined with CERP in an ASC, and how these technologies may increase the performance of an ASC. The last section describes an implementation of smart factory in all the actors of the ASC, and how this concept together with CERP, could create a seamless and fully integrated system, enabled by internet of things and auto-id.

5.3.1 Auto-id technology in ASC

Auto-id technology and CERP are two technologies that work well together. Auto-id technology are technology that automatically identifies an object and can communicate with the CERP system, to let the system know where the object are located. Auto-id technologies can be RFID, sensors and GPS. Auto-id technologies are excellent to use together with the CERP, as the auto-id gives the CERP system real-time information. Real-time information generates precise information on how the status is right now, which is an important feature when there is going to be done a decision in the CERP system.

Another important feature with auto-id technologies, are the possibility for automatic counting. For example RFID, when counting the inventory with RFID, all you have to do is go around the facility with a RFID receiver and the counting is done in a couple of minutes. In contrast to other technologies where counting inventory take hours and are manually done. The CERP system only estimate how much inventory there are in stock and are relying on that nothing breaks and there are no mistakes in the factory. Implementing an auto-id system together with the CERP, will allow the CERP to get real information from the inventory.

Auto-id technologies will also assist the CERP with gathering true information through the SC. Most information in a CERP system is estimated and as long as the estimation is good, there are no problems. If the estimation is bad or there is a breakdown, it requires a lot of extra work on the CERP system. The auto-id technology generates real-time information as well as quantities and location. By using this information, the CERP can calculate actual through put time of the facility and the CERP can calculate more precisely when there is time to reorder products. The CERP can also calculate more precisely delivery time.

Further, another interesting feature with auto-id technology is the possibility of calculating transport time. GPS generate the knowledge of always knowing where something is, by using the location information together with maps applications, estimating arrival times is achievable. By knowing how long a transport takes, planning further production down the SC is accomplishable. Further, if there are multiple arrivals of aluminium at an aluminium forming facility the same day, as well as there are many deliveries the same day. Planning the sequence that they unload and load becomes important and then knowing when a truck arrives are essential for that planning.

Using these aspects in the ASC will increase the performance of the entire SC. The CERP system will be provided with more correct and real-time information, which will make the planning of the material flow more reliable. The CERP will know exactly what is going on, from the bauxite mine to the forming facility.

5.3.2 Internet of things

Internet of things (IoT) is the concept that anything can become a smart thing, this alongside a CERP system create some great opportunities.

Utilization is an important point when discussing IoT. When any machine is “smart”, it can request more jobs; therefor the utilization of the machines will increase. When a machine can “think” and is connected with a CERP, the CERP system can know and utilize that machine by knowing what is going on there. When connecting every machine to the CERP, a full picture of the condition of the facility is painted for the CERP system. The CERP system now know the constant condition of the facility and know if there are somewhere in the facility that need assistants and can react thereafter. In an aluminium smelter, there are many furnaces that are making aluminium at the same time, and then getting a complete picture over the facility is hard. IoT will assist in getting this complete picture, the IoT will provide the knowledge of which furnace is about to be done, it will pull the production in a more effective manner as well as utilize the production. Another interesting point when discussing IoT, the machines knows when they need maintenance. The machine can “feel” if there is something that is not as it should be, and it can send out a maintenance order.

Implementing IoT to an ASC is very interesting. If the implementation is successful, the CERP system will have a complete picture and have the possibility to control the entire SC. The CERP will have the true information of through put time of every machine as well as for entire facilities, and then planning further steps in ASC will be effortless. The production of every facility will increase as the IoT will optimize the production and make it more efficient.

5.3.3 Smart factory

Smart factories are intelligent factories that have the ability to organise and control themselves in an autonomous manner, based on a decentralised production system. Products moves independently trough the different processes of a production, and it is continuously possible to identify and locate the product. Smart factories use the IoT and auto-id technologies to accomplices this seamless production.

Let us say that we make an aluminium smelter a smart factory. The production within the smelter will be seamless. Everything from filling the furnaces with alumina to the casting of products will be automatic and people will only work as monitors. A goal for smart factories is to have as few human interactions as possible, human errors are one of the biggest reasons for mistake at the aluminium smelter and by removing them, many mistakes will be gone. The flexibility and the delivery time of the aluminium smelter will increase when it is a smart factory, the smart factory is in constant connection with the CERP that controls the ASC. Immediately after an order is placed, the smelter starts production of the product, it will be in seconds. Therefore, the need for a MTS production will almost be obsolete; all products will be made as soon as they are ordered. The flexibility and the reliability of the smelter will increase dramatically.

Further, let us say that every actor in the ASC are smart factories and to control the system there are an automatically system that utilize the entire system in an effectively manner. The production of aluminium will almost not have any cost in operating and the output of materials and value in the ASC will be extremely high. When ordering in such a system, the only thing that is needed is implementing a 3D model to the system, to let the system know how the product is going to look. Then the system takes over. The system generates the way the product is about to be build, order parts automatically from suppliers, organize the routing through the SC as well as making a production order. When it is time to build the product, the system controls this as well. The system automatically generates delivery time to the customer; it knows exactly how much time that is needed to produce the product, including transport time. Having such a system controlling the entire SC with all its actors will generate a flawless production and utilize every aspect of the SC.

Having such an integrated system is still some years away, but part of this concept is absolutely within our reach with today's technology. Internet of things and auto-id technologies are technologies that exist today, and implementing them together with the CERP is possible.

Implementing IoT and auto-id with CERP will generate enormous control over the ASC. Both IoT and auto-id generate immensely much information for the CERP system, so the CERP system needs to be able to process this data, but if it is able, the control over the production will increase. With the information these systems provide, the CERP system will have total control over the SC; it will be able to calculate through put time for the entire SC; from the bauxite is minded to the delivery to the final customer. The CERP will be able to create a SC without any inventory, except the inventory that are needed before the next batch of product is arriving. The IoT will generate the knowledge of production and capabilities of all the facilities, while the auto-id will assist the CERP in the control of material flow.

The bauxite mine will have better control on how much they produce, when the machines are automatically counting what they dig. The bauxite is tagged and shipped to the alumina refinery. When the shipment arrives at the refinery no paperwork is needed, it is automatically in their system. The production control through the refinery are high, as each step of the Bayer process have automatically counting and through put control. When the alumina is finished, it is packed up, labelled and shipped to the aluminium smelter. When it arrives at the aluminium smelter, it is the same as for the alumina refinery, no paperwork needed. The alumina is poured into the furnaces and the Hall-Heroult-process is introduced, after some time the aluminium can be extracted. Every step is automatic and controlled by the CERP. Once the aluminium has been extracted, the liquid aluminium is transported to the casthouse of the facility; here the aluminium is put in different casts, the CERP system have decided which product are going to be made. When the aluminium has hardened and cooled down, it is labelled, categorized and shipped to their different destinations. The forming facility have the same automatic counting and no paper work, if they remelt the aluminium or rolls it, it do not mater, the IoT know the through put time and the CERP system knows where each product are heading.

As described in the previous section, the CERP controls the entire ASC. By having enablers like auto-id and IoT that provides real-time information, the different processes become more precise and the SC is easier to plan. When the information flow is so constant and informative, the material flow becomes precise. The consequent of having a precise material flow is that all material have a destination and there are little to none errors in the SC. The CERP system have a plan for every product from bauxite mine to the forming facility, which almost mean that the CODP can be place in the bauxite mine. This is not the case as the bauxite mine do not make aluminium products for a specific customer, but it visualize the point that the CERP system controls the ASC in an effective and highly utilized way when using auto-id and IoT as enablers.

Chapter 6 - Conclusion

This chapter concludes the thesis work. It starts with key finding of the thesis. Then the research questions are answered. Lastly, the limitations with the work are presented, as well as recommendations for future work.

6.1 Key findings

The aluminium market is a very competitive market, the challenges to thrive in such a market is demanding, that is way the need to increase the performance for the aluminium companies become crucial, to get a competitive edge. This study found that setting up an ERP at the main office, that operates like a CERP, will be perceived as a CERP for the other actor in an aluminium supply chain (ASC) and will do the information flow and the material flow more precise, which in turn will increase the performance of the aluminium supply chain.

Through this study, it has been shown that a CERP is much more flexible and easier to access, but there is a fee for every actor that accesses it, as well as some security concerns. That is way in the ASC where there are large multinational companies with multiple actors, there should be established an ERP system at the main office that is perceived as a CERP system for the other actors in the ASC. Further, the implementation of an ERP system that operate like an CERP in the ASC will decrease the need for inventory, mitigate the bullwhip effect, utilize the production, optimize the customer interaction process, as well as make information easier obtainable.

6.2 Research questions

RQ1: What are the characteristics of an aluminium supply chain?

The first research question was constructed to get a better understanding of the aluminium supply chain and how it operates. It was answered by a literature search on different search engines as well as visiting different aluminium companies' websites to gather information on how they operate. It was found that an ASC could be both a MTS and a MTO SC, depending on which aluminium smelter you were looking at. Further, the general characteristics of an ASC is that it is a global SC, it produces in high volumes with a low variety of products, there are few customer segments and it is driven by efficiency.

RQ2: What are the pros and cons of implementing a CERP against an ERP in an ASC?

The second research question was developed to examine an ERP and a CERP, and discover which one is best suited for an ASC. It was answered through a literature study on both of them, where there pros and cons where discovered. The pros for the ERP is that it is well-known as well as well-developed, so the companies know what they are buying. The pros for the CERP is that it is the fastest way to the market, cheaper in the short term as well as for small businesses, and it is more flexible. The main cons with the ERP system, is that it is not very flexible, it may prove difficult to implement, and the implementation demands enormous time and cost resources. The main cons of a CERP is security related and the fact that it becomes expensive to a large company, since every participant have to pay a fee to get connected to the system.

RQ3: What is the future for a CERP in an ASC, when adopting the concepts of a smart factory?

The third question was developed to discover what the future might hold for an ASC. The concepts of smart factory was included in this reflection. Smart factory was studied, before it was discussed being placed in an ASC. It was found that if smart factory was implemented through the ASC, the performance would increase immensely, but as automatic as in this predicted ASC will not be possible with current technology. Further, it was found that technologies as auto-id and internet of things will increase the performance of the ASC.

6.3 Research limitation and further work

The choice of research method indirectly determined the research limitation. In this study, it have only been a literature search, which implies that there have not been any contact with a company and research on a real market situation. All information gather in this study have been found in articles, books and on the internet. What this means is that all information is second hand information and the author have to trust on other authors work. The limitation to this study is largely related to that it is literature study.

Further work should consider involving a case or multiple case studies to verify assumptions made in the thesis. With case studies, a more in-depth evaluation could be performed to discover if a CERP is more expensive than an ERP when there are multiple actors using it. Further, a thoroughly analysis could be performed on a case company to discover if the material flow in fact is more precise and the need for inventory decreases with the assistants of an CERP.

Chapter 7 - References

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