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An Optimization of Inbound Logistic Flows at Haldex by Applying Consolidation and Monitoring to a Distribution Network

A Case and Simulation study

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Abstract

Title: An Optimization of Inbound Logistic Flows at Haldex by Applying Consolidation and Monitoring to a Distribution Network.

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Background: Throughout history the same factors have been of major importance regarding the transportation of goods between companies: costs, speed and reliability. Nowadays these factors are even of increased importance as supply chain networks become more and more global and contain more diverse companies and products, the complexity of transportation increases. Although complex, companies still want their transportation to be performed as fast, cheap and reliable as possible. This means that both incoming and outgoing flows need to be well set-up and monitored to ensure that operations are formed in a (close to) optimal way. Still, this is not as easily said as done as different supply chains have different characteristics. Various actions and methods can be required for different supply chains to transfer logistics into a strength instead of a weakness.

Problem description: This research has been performed together with Haldex AB, a disc brake manufacturer. Haldex sees potential cost savings and other improvement opportunities for the way they currently handle their transportation. The cost-savings should, according to Haldex, be reachable by implementing a consolidation strategy to the intercontinental transportation. At the same time, information on future incoming loads is badly shared between departments resulting in unprepared departments and less-than-optimal smoothening of processes. This report aims to tackle these problems by suggesting possible implementations to Haldex's processes and its supply chain.

Research questions: 1. How can a consolidation strategy enable a decrease of costs and environmental impact at the case companies supply chain?

2. How should the case company design its consolidation strategy for its upstream supply chain to maximize cost-savings, reduce environmental impact, and ensure reliability?

3. How can visibility and traceability of inbound flows be improved for the operational performance of a manufacturers receiving process?

Methodology: As very common among case studies, this research will follow a system approach with usage of adductive methods. The project has partly been a single case study with some of the departments of Haldex as the units of analysis and a simulation study. Both quantitative (data from databases) and qualitative (interviews) data has been used as input for the report. The main goal of the case study was to build a good foundation to answer the research questions in need of a simulation study. The simulation study has been performed by usage of a simulation tool called ExtendSim, which enabled comparison of different scenarios. A credibility check has been performed to evaluate the quality of the thesis.

Conclusion: By following the proposed methods in this research, Haldex should be able to further improve the inbounding goods flow by increasing its reliability, transparency and most of all efficiency. This report recommends methods to benefit Haldex on a strategic, tactical and operational level. The major method analyzed is a consolidation policy that groups inbounding loads from Chinese suppliers for combined transportation. A simulation tool has been used to analyze the current scenario and possible future scenarios. As different scenarios come with different costs, the total savings depend on different factors but transportation costs should be reducible with 40 to 50%. It has also been analyzed that future market trends will not affect the feasibility of the consolidation strategies. To reach this cost savings, a new process of purchasing components is proposed to enable the consolidation strategy where four different ports in China are used as consolidation hubs. If the consolidation network gets implemented, Haldex would not only reduce costs on transportation, it would also reduce necessary inventory levels and their emissions, thus benefitting Haldex on multiple levels. A link with consignment stock has shown that consignment stock and consolidation go hand-in-hand if consignment stock is applied to the items with the below average demand.

Other improvements can be made by better monitoring the flows and their arrival times as this will smoothen operations. A monitoring tool is proposed in this report that can be implemented to assist these improvements. The tool would display data on the future incoming loads and therefore assists the receiving staff in their preparations for the upcoming days. Finally, a more optimal arrival scheduling process is suggested to create a more stable workload which smoothens the operations at the unloading area of Haldex.

Keywords: Consolidation, Consolidation strategy, Supply chain management, Case study, Simulation, Consignment stock, Monitoring, Transportation

Table of Contents

List of Tables

Table of Figures

1. Introduction

This introduction deals with a description of the background for this master thesis, describing the problem, concluding in the research questions and purpose, with a few delimitations. At the end, the target audience for and the importance of the following paper will be presented.

1.1. Context of the thesis

Supply chain management faces a very different environment today than merely a few years ago. The continually changing face of the transportation service industry confronts today's companies with a range of challenges and opportunities that contrast dramatically with those of a decade ago. Thus, many companies have failed to fully adapt to the changing environment, resulting in performance shortcomings and lost opportunities (Stank & Goldsby, 2000).

With value creation now taking place in complex production networks instead of individual companies, production planners must include upstream and downstream companies in their decisions to synchronize material flows and to reduce inventory levels. Reducing the total cost of producing and distributing a product in the supply chain increases its competitiveness and generates a cooperation gain that can be distributed among the companies involved (Glock & Kim, 2014). In order to meet ever-increasing expectations, the basic work of transportation has changed from operationally meeting low cost or high service criteria to providing a strategic edge by simultaneously meeting elevated service requirements and increasingly lower costs (Stank & Goldsby, 2000).

1.2. The company

Haldex is a Swedish manufacturer of brake and air suspension systems for heavy vehicles. The company has its roots from 1887 when it was called Halda and produced watches. The Haldex concern was created in 1985 by merging three Swedish companies:Garphyttan, Haldex and Hesselman. At that time the main source of revenue was the spring wire industry, constituting 50 percent of the total sales. Haldex did not start to produce brake adjusters until 1960 and it was not until 1985 that the company got its current name. Today Haldex is listed on Nasdaq Stockholm Exchange (HLDX) and has presence in 19 different countries and around 2100 employees. Haldex produces in USA, Mexico, Brazil, Sweden, Germany, Hungary, India and China and has also distribution centers in Canada, France and South Korea. The head office is located in Landskrona where they have around 270 employees.

The brake adjuster has been a success story for Haldex, after 50 years they are still a global market leader in this category. In 1993, Haldex initiated a project to produce air disc brakes, which lead to the delivery of the first air disc brake (ModulX) in 1999. Since 2011, Haldex has been working only with commercial vehicles, focusing on brake and vehicle control systems using pneumatics and/or electrical control for heavy trucks, trailers, buses and the agriculture segment. Axles and military customers are also included in these applications. A second version of the air disc brake was made in 2011, the ModulT, and it has been the fastest growing product for Haldex. They are currently the second largest producer in Europe in the bus segment and are market leader in the trailer segment.

Haldex have chosen to move the production of the brake adjusters (ABA and S-ABA) from their site in Landskrona to Hungary to solely focus on the air disc brakes in Landskrona. Haldex has around 15-20 article numbers for their air disc brakes. The logistics team at the Landskrona office consists of about 25 people, including material handling. The team has a material planner, a production planner, internal logistics and shipping.

Currently, Haldex has 55 suppliers. Most of the suppliers are from Sweden, Germany, and Asia. Haldex has approximately ten customers in the air disk brakes segment. These customers are some of the largest truck and trailer manufacturers, such as: Daimler, SAF Holland and Volvo. Some of them are bigger in terms of sales volume but Haldex strive to have the same relationship with all of their partners.

Haldex Brake Products AB engages in surface-treatment and painting brake systems for automobiles. The company also produces specialty wire from steel alloys. Haldex Brake Products AB is based in Landskrona, Sweden. The company operates as a subsidiary of Haldex AB (Bloomberg). The biggest owner of Haldex, with 13 percent of the stocks and votes, was previously Investment AB Öresund, (later Creades AB). Since the autumn of 2016 the biggest owners are ZF AG and Knorr-Bremse.

A fundamental task becoming increasingly fierce for Haldex is the competition from low cost suppliers on their products. Therefore Haldex aims to question their cost and cost structure at all times.
Working through strategic suppliers to sustain a sustainable and cost competitive position, is a large part of managing their costs. They identified total cost of ownership and environmental demands as two of the strongest trends in their industry.

1.3. Problem description

Haldex Brake Products is one of the main divisions at Haldex, which is still located at the current headquarters and has gained, according to Haldex, consistent importance over the last years and tends to be one of the future drivers of the that company. Haldex sees untapped cost saving potentials in lean optimization of their physical distribution process. One of those potentials might be the uncoordinated distribution network from China, both the national transportation within China and the intercontinental shipment to the site in Sweden. Therefore, a deeper look into consolidating shipments could unlock tied capacity and reduce transportation costs throughout the upstream supply chain, especially in the context of incoming goods on an international level.

A more efficient utilization of resources throughout the supply chain is key for Haldex. Both the less than truckload transportation (LTL) and the unutilized capacity indicate room of optimization. The fact that

receiving and unloading mainly take place in the first two hours of the day supports the aforementioned aspect.
Additionally, Haldex struggles with the lack of information for trustworthy predictions to schedule and trace goods and transports. They are eager to find a more structured way to monitor when supplies arrive and provides a reliable solution when they should arrive, depending on other arrivals and free time-slots at the docks.

1.4. Purpose and Research questions

The main purpose of this thesis is to decrease costs in the upstream supply chain by assessing opportunities in implementing a consolidation strategy and identifying ways of enhancing visibility and traceability in the inbound supply chain.

To approach the aforementioned purpose, the following research questions will be answered throughout this thesis:

RQ1: How can a consolidation strategy enable a decrease of costs and environmental impact at the case companies supply chain?

RQ2: How should the case company design its consolidation strategy for its upstream supply chain to maximize cost-savings, reduce environmental impact, and ensure reliability?

RQ3: How can visibility and traceability of inbound flows be improved for the operational performance of a manufacturers receiving process?

The research questions are answered by conducting a case study mapping out the inbound supply chain and its consolidation opportunities and the corresponding management process. Furthermore the information requirements in the receiving process and weaknesses in the current solution are examined, concluding in a simulation study testing the consolidation strategy and different implementations of it. The goal is to optimize Haldex's upstream supply transportation network by making it both more cost-efficient and more reliable.

1.5. Project delimitations

The scope of the research is limited to the area of consolidation, supply chain mapping and visualization of transport scheduling. This thesis solely focuses on the Haldex' site in Sweden and their collaboration with their suppliers from China, and the information that is being shared between these two parties. Hence, information that might be shared with other supply chain partners has been disregarded.
Our results are also affected by the limited amount of time given and the status quo at the company during that time period. As a result, the study only focuses on the current pool of suppliers and will not investigate further collaboration with other Haldex sites that are using the same supply chain or even the

same distribution network. Since Haldex is a global company with many facilities it may not be sufficient for a complete picture.

Furthermore, single case study produces usually less appealing results and might be considered less robust compared to a multi-case study. The study was conducted before the implementation of the ERP system was fully executed. Due to that, an impact on the reliability of the derived data must be taken into account. However, it is important to remember that a lot of the information is collected from secondary sources which might, in some cases, give a biased view of the reality. In addition to that, the selected methodology and variables in our study also set a boundary on what our findings can ascertain.

1.6. Target audience

This thesis is mainly aimed to people working or being involved in Haldex upstream distribution network. Those readers are primarily located on an operational and tactical level (receiving, shipping, planning, warehouse staff) within the company. Since there are not only internal forces playing a vital role in a potential implementation of consolidation, this work also addresses external players such as suppliers, forwarders and port authorities. Overall our work is truly driven by providing deeper knowledge for both the research community in the field of supply chain and companies considering to adopt a consolidation strategy.

A further target group is of course our alma mater Lund university, the academic supervisors at the department of Engineering Logistics, as well as students just interested in the subject.

1.7. Importance of the paper

The outcome this research will have a major importance to Haldex as a company and a minor importance to the academic world. As for Haldex this research aims to benefit Haldex on an operational, tactical and strategic level.

On an operational level the benefits can be seen by blue collar workers in the reduction of incoming trucks as the incoming goods will be more consolidated. Additionally, a better monitoring of the inbound supply chain will result in a better overview on when the trucks arrive and a better spreading over the day, thus avoiding the creation of peak-hours and surprises.

On a strategic level this paper aims to suggest a more cost-efficient transportation flow towards Haldex. This will not only save Haldex some money, it will also result in better visibility of the goods as there are less shipments to keep track of.

The strategic level of Haldex benefits by having a consolidation policy for global suppliers that could be used by setting-up new networks in the future. It also helps reducing emissions by suppliers and therefore it assists Haldex in its vision to help create a more sustainable society.

The academic world also profits from this research as it will show how a consolidation strategy can benefit a manufacturing company in Sweden with only a limited amount of suppliers on a global scale. This paper will also involve consignment stock and will show the link on a practical level between the opportunities of consignment stock and the implementation of consolidation.

1.8. Projected outcome

At the end of the research various deliverables will be presented. As in most research projects there will be an actual academic paper, in this project it will have the form of an advisory report to Haldex which answers the research questions. The report should give clearance to Haldex on which strategy would be the most cost-efficient for them to implement. The content of this report should also help outsiders by presenting an analysis on consolidation possibilities in contexts similar to Haldex's. Next to the report, a model will be presented that calculates the optimal way of handling inbound transportation. This model will be developed in such a way that it can be used by Haldex in other scenarios in the future when Haldex wants to focus on different suppliers. Finally, a lay-out for a monitoring tool will be developed which should benefit Haldex with their daily operations by assisting with the monitoring of their incoming goods. This tool should be ready for development as soon as the project finishes to create performance enhancement of the receiving department as soon as possible.

1.9. Project outline

Chapter 2 - Methodology

In this chapter the methodological approach of the thesis is presented. Different research methods and research strategies will be presented from a theoretical perspective. This is done to sketch the reader an overview of the existing methods. Following, it will be stated which methods are selected for this research and why. It is chosen to do an abductive case research with both qualitative and quantitative research methods. In the beginning the project can be described more as a descriptive typical case research when the case gets analyzed in detail to create a foundation for the prescriptive part of the project. In this second part of this research a more prescriptive analytical model will be developed to define the best method to improve the inbound flows.

The different methods of data collection used will be discussed together with the methods used to assure credibility of the project. To sum it all up, a more detailed project plan will be presented in the form of a Gantt-chart and a step by step description of the planned approaches.

Chapter 3 - Frame of references

The theoretical framework describes the consolidation strategy and its implementation throughout a given supply chain and summarizes the status quo of consolidation application transportation. Some examples for consolidation adoption in supply chains are also presented. Secondly, different consolidation policies will be described followed by their impact on the environment and sustainability. Thirdly, factors are discussed to evaluate the success of consolidation as strategy for companies. On top of that, the literature on consignment stock will be discussed also. Finally, we give a short summary that has commonality for the rest of the thesis, and then outline the contributions of this dissertation.

Chapter 4 - Empirical data

This chapter provides an overview of the current state of the case company, i.e. Haldex AB (at the moment of conduction of the study). Data has been collected through interviews, information systems and observations. The data will be presented while using figures and tables to draw a clear picture before the research questions can be approached.

Chapter 5 - Analysis and Findings

This chapter serves to guide the reader through the different parts of analysis. First of all, the full model for applying consolidation on Haldex Chinese distribution network is presented and evaluated. Finally, a comparison of different scenarios and their corresponding costs, concluding in an analysis of the sustainable impact. Further on the reader will be introduced to the study of monitoring supply chain measures at Haldex and the scheduling of supply receiving.

Chapter 6 - Conclusion

The last chapter concludes the results of the on-hand work. Firstly, the purpose and the assigned will be evaluated and answered on all levels. Afterwards the authors refer to the underlying theory and reflect on important aspects. Finally, possible future research fields are discussed, followed by conclusive recommendations.

2. Methodology

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2.1. Different approaches of methodologies

In the world of research, there is a whole forest of methods that can be used to research the objective at hand. Between the different methods there are major differences and the right choice depends on the characteristics of the study area and the view of the researcher on the context of the to be researched phenomenon (Arbnor & Bjerke, 2009). This indicates that the same research question might require different research methods depending on how the context is perceived; this perception is called the scientific approach. Overall, it can be said that there are three different perceptions possible, each with their own characteristics: the analytical, systems and actors approach.

2.1.1. Explaining the different approaches

The analytical approach sees the world as a collection of independent units and facts and tries through statistical calculations and quantitative models to create a quantified solution. A system approach recognizes relations between the factors in the to be researched context and therefore argues that theory might apply differently to this particular research question. A system approach often goes hand in hand with case studies. Lastly, the actors approach is more focused on social constructions and it can be used to see for example how participants of the research behave and react in certain situations (Arbnor & Bjerke, 2009).

2.1.2. The approach in this research

In this research it has been chosen to look mostly through a system approach. As Haldex is selected as the context of the research it cannot be expected that Haldex is a perfect copy of every other company and thus general theory cannot be developed. Looking through a system approach it is possible to see relations at Haldex that can impact the research results and analyze in which way general theory is applicable in the case of Haldex. By spinning analytically developed theory to an applicable variant to Haldex it was hoped that the right outcome would be generated to answer the research questions.

2.2. Characteristics of methods

In this section, first a description off different methods will be presented in the form of theory, subsection 2.2.3. will then show the appropriate methods for the study at hand.

2.2.1. Inductive, Deductive and Abductive

If one looks deeper into the methods that are used to conduct research, they can be categorized in different ways. A main differentiation is made between inductive, deductive and abductive methods. An inductive method has the aim to develop new theory by analyzing a phenomenon that has not been previously studied. By collecting data and analyzing relations a theory is built to be as generic as possible. In contrast with the inductive methods are the deductive approaches. A deductive research builds on previously researched theory and evaluate if the theory is applicable to another context. A deductive approach thus usually involves large amounts of literature review on established theory or generalizations to develop a hypothesis, which is afterwards tested in a specific instance (Hyde, 2000). The last option, the abductive method is close to a combination of deductive and inductive as it unsuccessfully tries to match existing theory with a real-life observation following by a new theory suggestion. Abductive research is commonly used in case research. (Kovács & Spens, 2005)

2.2.2. Qualitative and Quantitative

Another basic differentiation between methods is the categorization of quantitative approaches and qualitative approaches (Kothari, 2004). A qualitative study is typically inductive where a quantitative study usually follows deductive methods (Kotzab, Seuring and Müller, 2005). Qualitative studies have the goal to describe the phenomenon using broad explanations while analyzing it in its natural selection. As quantitative techniques are not used, qualitative studies mainly consist of surveys, observations or interviews. As with inductive approaches it is mainly used to create theory to capture the nature of the phenomenon (Kotzab, Seuring and Müller, 2005). The quantitative methods aim to add knowledge by constructing formal theory that explains theory in a numerical way. Usually a numerical approach is only possible if the phenomenon has been studied in deep before in a qualitative way, hence the connection with deductive research. The conclusions of a quantitative studies are usually testable with real-world data whereas qualitative studies lack this generalizability (Kotzab, Seuring and Müller, 2005).

2.2.3. Chosen methods

As consolidation has been a major subject of research the past decades, many theories have been developed. Many of these theories claim generalizability, but the aim of this study is to reflect if previously constructed theory is applicable to Haldex and evaluate if theory needs to be altered to form a perfect fit for Haldex, so they can benefit from them. This is thus clearly an abductive study. As abductive studies usually come with quantitative methods combined with qualitative methods, a similar approach was planned for this project but with a larger focus on the quantitative aspect. In a quantitative way the theory has been used to come up with calculations that show the potential for improving the inbound flow of Haldex. Qualitative methods as interviews and surveys have been used to see what is possible at Haldex and to test if the theory is perfectly applicable to Haldex. If the research questions are taken into regard it can be said that the first question requires a more qualitative approach as it is a more general question on the concept of consolidation. The second research question asks for a more quantitative approach as the idea is to get a financial result based on formulas.

2.3. Research methods in debt

The previous sections elaborated on the different kinds of research by describing different categories. On a more detailed level there are different ways to conduct the research. Three of the major ones will be discussed in this section: case research, survey research and simulation/mathematical research. An introduction to the methods will be given, while in chapter 2.4. the actual choices for the methods will made.

2.3.1. Case Research

By performing a case study, the researcher tries to analyze a certain phenomenon in its natural setting by making use of both quantitative and qualitative techniques. This allows the investigator to obtain a holistic and real-world perspective (Yin, 2014). Meredith (1998) defines case study as followed: “The use of multiple methods and tools for data collection from a number of entities by a direct observer in a single, natural setting that considers temporal and contextual aspects of the contemporary phenomenon under study, but without experimental controls or manipulations.” From the definition it can be seen that the distinguishable parts of case research are that the study is conducted in its natural setting and the problem is often observed by the researcher himself. Case studies serve as replications, contrasts, and extensions to the emerging theory and are often regarded as both the “most interesting” research (Bartunek, Rynes, & Ireland, 2006) and the best choice to form a bridge between qualitative evidence and deductive research. Other authors claim that case research is ideal for testing theory in their contexts (Eisenhardt &

Graebner, 2007). Unfortunately, there are also some dwonsides to case research as the results are not very generalizable. As case research depends to a large extent on the context, the results are often only reliable for that specific case. To make the research more generalizable one can choose to perform a multiple case research where different cases get analyzed.

A case study is best suited if there is no existing theory that offers a feasible answer or only answers that are likely to be wrong regarding the specific to be researched phenomenon (Eisenhardt & Graebner, 2007). It is often used to answer "how" and "why" questions in research areas that are fairly unexplored (Edmondson & McManus, 2007). Overall it can be said that there are four different kind of purposes of case research: exploration, theory building, theory testing and theory extension Voss et al. (2002). Deeper explained in Table 1.

Table 1 Comparison of different research purposes (Voss et. al, 2002)

Purpose	Research question	Research structure
Exploration Uncover areas for research and theory development	Is there something interesting enough to justify research?	In-depth case studies Unfocused, longitudinal field study
Theory building Identify/describe key variables Identify linkages between variables Identify "why" these relationships exist	What are the key variables? What are the patterns or linkages between variables? Why should these relationships exist?	Few focused case studies In-depth field studies Multi-site case studies Best-in-class case studies
Theory testing Test the theories developed in the previous stages Predict future outcomes	Are the theories we have generated able to survive the test of empirical data? Did we get the behaviour that was predicted by the theory or did we observe another unanticipated behaviour?	Experiment Quasi-experiment Multiple case studies Large-scale sample of population
Theory extension/refinement To better structure the theories in light of the observed results	How generalisable is the theory? Where does the theory apply?	Experiment Quasi-experiment Case studies Large-scale sample of population

The case research in this project would link the closest to theory testing as theory building and exploration are not applicable as there is already plenty of research concerning inbound logistics. However, Jul and Hak (2008) split theory testing further into theory-oriented research and practice-oriented research. The theory-oriented approach still has a final goal to contribute to the existing theory by analyzing for example the generalizability. This could thus also be seen as theory extension in the theory of Voss et al. (2002). Practice-orientated is more appropriate for the research at hand as it tries to contribute to the knowledge of a specific practitioner, in this research Haldex. It analyzes if applying the existing theory would have a positive effect on the case at hand, disregarding the theoretical aspect of the outcome on for example generalizability. The case research in this study can thus be seen as theory testing with a practice oriented approach.

2.3.2. Survey Research

Survey research is a lot different from case research as it involves data gathering from a very large sample instead of observing a single sample for a long-time period. Survey research therefore depends more on rich statistical significant data received from answers on the surveys. There exist three categories of Survey research: exploratory, confirmatory and descriptive. As in other research methods the exploratory variance has the goal to create a start for future research and enables studies in more depth. Confirmatory research cannot be performed before a certain level of knowledge in a field is developed and is used to test theories. Lastly, the descriptive research is mainly created to understand the phenomenon's relevance and the distribution inside a population (Forza, 2002). Overall it can be stated that surveys are often effective when case methods are not fulfilling due to lack of controllability, deductibility, repeatability and generalizability as surveys do cover these aspects (Gable, 1994). A survey thus verifies hypothesis more objectively as it relies on more data sources.

Survey research will not be part of this project as there is no usage of a large pool of data sources. This research will only regard the data sources that are at the moment directly working with Haldex, hence even if a survey would be conducted on the suppliers it would result in an interview round instead of an extensive survey as the number of suppliers related to the project is limited.

2.3.3. Simulation/Mathematical Modelling

Simulation and mathematical modeling are very similar and thus analyzed as one. This method uses a mathematical simplification of reality to create a calculated outcome. The main difference between them and previous methods is that they are a good fit to analyze quickly a change in a real-life situation as the real-life situation does not need to be altered. Besides, it has the benefit that it can analyze the effects of a certain timespan easily without the need to sit out the timespan. It also needs to be mentioned that it enables research on complex systems that might be too difficult to grasp for other kinds of research.

There are some downsides to it as well as a model does not provide accurate results without sufficient data. On top of that, it has to be kept in mind that a model is always a simplification of reality. This brings the issue that if the wrong simplifications are made the results become unreliable; therefore one must be sure that the model correctly represents the real-life situation. As a last comment, it should not be forgotten that it is hard to generalize the results and seeing them as valid for other systems without major adjustments as it is usually only valid in specific contexts.

This method will be used in this project as the effects of consolidation will be analyzed numerically to give a proper and convincing advice.

2.4. Proposal of research methods

2.4.1. Methods

By writing this thesis in cooperation with Haldex, a company has been found to analyze the possibilities of implementing a consolidation and visualization strategy for the incoming goods. As Haldex has been used as a basis for this research, the main methodology is a case research where the environment of Haldex is tested against consolidation and visualization possibilities to solve the research questions. Thus, the incoming goods environment of Haldex has served as the context of research to analyze if according to theory a consolidation strategy would be beneficial for Haldex and how enhanced monitoring of incoming goods could improve Haldex' operations.

As described before, a single theory testing case research has been used for this project. It is theory testing as the goal was not to develop new theory but to test and analyze how well theory applies to Haldex. As we only had Haldex to focus on and time delimited us from researching different cases it turned out into a single case study.

Nevertheless, inside this case research it is possible to use other types of research. Research even states that mixing research methods brings the potential to address more complicated research questions plus opportunities to collect richer and stronger evidence (Yin, 2014). Part of the research conducted was still a simulation research. The simulation research has mainly been conducted to prove numerical what the consequences are to implement a consolidation policy by Haldex. By being the quantitative part of the project, the results of the simulation have been used to present a hard-economical result which will bring direct advice to Haldex and therefore enables Haldex to make decisions based on numbers. The simulation tool used in this report is called ExtendSim. Extendsim is a tool that creates dynamic models from building blocks and uses the relations between these blocks to affect input which will result in specific output. It assists to predict performance of potential systems and shows the user quickly the effect of a change in an existing system. (Extendsim.com, 2018) The simulation will represent the transportation network of Haldex and its costs.

2.4.2. Connection to research questions

If a deeper look will be taken at the research questions, one can see they fit a single case research perfectly as well. Yin (2014) describes case research as the ideal way to answer "how" and "why" questions as case research is ideal for descriptive research. Two of the developed research questions are indeed such questions. A more detailed view can explain the need of case research to fit the research questions even better. The second research question: *How should the case company design its consolidation strategy for* *its upstream supply chain to maximize cost-savings, reduce environmental impact, and ensure reliability?* uses the words specific characteristics. As explained before, one of case research main advantages is that the research is performed in a context with special characteristics. To translate the effects of the consolidation into financial numbers the simulation research is necessary. The third research question: *How can visibility and traceability of inbound flows be improved for the operational performance of a manufacturers receiving process?* is also perfectly fitting for case research as the research needs to be specific to a manufacturer's receiving process. A case study performed at Haldex is thus an ideal method to answer the questions. The first research question does not need a specific case research, but this does not affect the choosing of methodologies as the research question is designed as only a start-up for the project to gather enough information to handle the other two deeper questions.

2.4.3. Taxonomy

Fisher (2007) performed a taxonomy on the different empirical research methods (figure 1). Fisher categorizes on level of structure of the research. In general, it can be said that mathematical studies are usually more structured in contrast to case studies. Another differentiation has been made with descriptive and prescriptive studies. Our study can be seen as a two-phase project. At the start it was more in the less-structured, descriptive quarter. This phase has been the gathering of information on Haldex and creating an understanding where Haldex might differ from existing theory. After this phase the project has moved to the highly-structured, prescriptive phase as this phase has depended mostly on mathematical formulas and simulation.

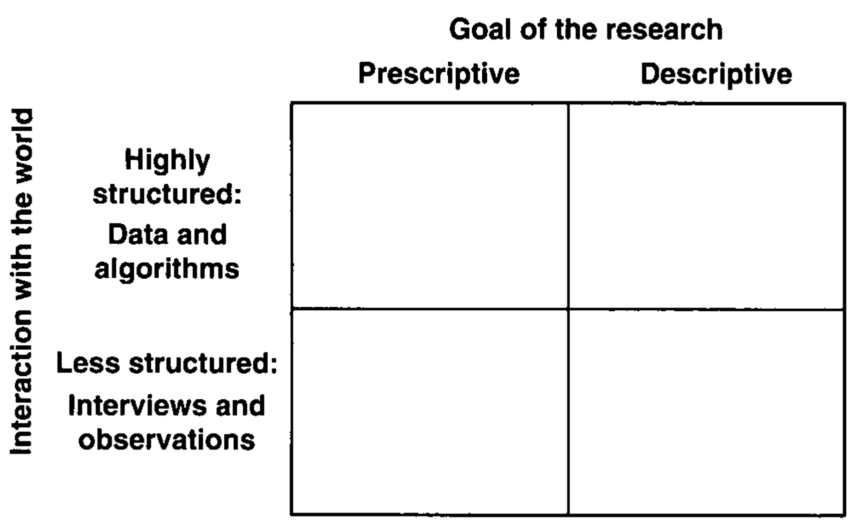


Figure 1 taxonomy of research methods (Fisher, 2007)

2.5. Unit of analysis

The unit of analysis is as defined by Yin (2014) the phenomenon, person or department that will be researched and is relevant to answer the research questions. In this project some departments of Haldex have been part of the unit of analysis. The departments that were included in the scope are first of all the departments that are working with suppliers from China: sourcing, planning, receiving and shipping. The overall warehousing department has been included as the tool that has been developed should be useful for the warehousing staff. On top of that, the logistical department that is responsible for logistical flows at Haldex was connected to the project as well as they have a higher overview as the other departments. A main department at Haldex that does not belong inside the unit of analysis is the production. As the goods stay the same, the quality of products will not differ and therefore the result of this project is less important for production.

Outside of Haldex the unit of analysis can be broaded to the suppliers from China and the carriers that transport the goods to Haldex. They will need to give a green light to strategy changes concerning consolidation as Haldex cannot implement the strategy solely on its own. Therefore, it needs to be researched if the suppliers and transportation companies will not be a limitation to the suggested strategy.

Table 2 gives an overview of the unit of analysis.

Table 2 Unit of analysis

Inside of Haldex	Outside of Haldex
Sourcing	Suppliers from China
Planning	Forwarders
Receiving	
Warehousing	
Logistics	
Shipping	

2.6. Data collection methods

2.6.1. Interviews

Data is the basis of a proper research, without the right data a researcher will find himself/herself lost and unable to solve his/her research questions. Luckily there are various ways to collect the necessary data. Blumberg et al. (2011) describes interviews as the most common way to gather data while doing case research. He argues that these interviews are usually unstructured or semi-structured. The risk is tough that some important informants can jeopardize the research by giving wrong information or even keeping information behind.

This project relied among others on semi-structured interviews with key players inside Haldex. It is believed by the authors that semi-structured interviews are a better way of interviewing as unstructured interviews due to assurance that every topic that needs information will be covered. The interviews are conducted with employees during their working hours and therefore they might have limited time. Semi-structured interviews helped to cover all topics in the available timespan. A list of the employees with whom either interviews have been conducted can be found in table 3. It has been aimed to interview at least one person per group inside the logistical department of Haldex. The specific persons were either selected after recommendation of Pålsson, the supervisor for this work, or they simply were the only ones available at the times the interview got requested.

Table 3 List of interviewees

Name	Position
Anders Pålsson	Manager logistics
E. H.	Logistic developer
J. L.	Planner
T. W.	Planner
M. M.	Shipping
K. M.	Intern
A. A.	Shift leader logistics
J. Ö.	Internal logistics manager
J. A.	Sourcing director
M. L.	Business Systems Analyst
Haldex Responsible	Logistical partner

If necessary, the suppliers were also reached to obtain data on their side to receive their opinion on the consolidation process.

2.6.2. Other sources

More objective and numerical data has been gathered from the ERP system used at Haldex. The ERP system contains data on the suppliers, stock levels and other necessary input needed for the research. The authors had their own Haldex' account to connect to the ERP system. This data has not only been used both for bringing ideas to the table on how to answer the research questions, but also as input for simulation models used to analyze the benefits of the proposed methods.

Another source of data has been a project performed by Haldex just before the start of this research. This project involved frequent checks on the incoming trucks including their goods and utilization. It is believed that this data benefited to this research.

Some data has been extracted in the form of theory from existing literature to assist the analysis and enable a proper formula-based benefit calculation.

A last data source has been the observations done by the authors themselves. As the authors had access to the company during the span of the research, it was possible to control incoming goods by themselves on arrival time, utilization and other factors that could be relevant. Those factors include, for instance, pallet size, pallet weights, quantity delivered, the bill of loading, etc.

2.6.3. Case protocol

Yin (2014) has developed a case protocol that could be used within case preparations to be sure that everything is prepared in the way it should be to obtain optimal results. The case protocol has a large focus on the data collection part of the process. Most parts of the protocol have already been pointed out somewhere else in either this or another chapter, but it has been considered important to highlight a single part of the protocol. Yin (2014) states that researchers should ask themselves questions that they want to obtain from the data collection before actually starting the data collection, this is thus not directly the question you would ask in an interview but the final result you want to obtain from an interview. These questions should be linked with probable sources to find this data. An example of these questions would be: *what would benefit Haldex to know extra about incoming shipments?* This information could be gathered while interviewing the receiving (and possibly the planner) departments. A table with questions has been put in Appendix A. All the questions are linked to interviews and therefore data to be gathered from for example the ERP system has not been taken into account.

2.7. Credibility

As results of this project need to be trustworthy, the credibility has been safeguarded at every step of the process. The credibility can be subdivided into validity and reliability.

2.7.1. Validity

The validity is defined as the quality of the results of the project and they will be ensured by different methods that support validity of the data. The data gathered through interviews has been validated by interviewing multiple people on not only different functions inside the business but also different responsibility levels. This way different insights were combined to gain the correct understanding of Haldex. The literature has also been ranked on their citations together with usage of the 5-year journal impact factor to make sure that the data gathered from literature is reliable. Lastly, the data collected from the ERP system has been checked by Haldex' ERP experts to make sure that the data is correct.

2.7.2. Reliability

The reliability of the project is defined as the change of receiving the same results if the research would be performed again. The reliability is ensured by developing a clear project plan including all the different steps and explanations on how to perform these steps. During the project, sidesteps of the project plan were noted and discussed in the final report to give other researchers the opportunity to perform the research in the exact same way. On top of that, it is discussed why certain steps are taken and why the project is especially applicable to Haldex and could be a less-well fit in other cases.

2.8. Detailed project plan

This last section of the methodology chapter will be a more detailed explanation on the different steps that will be taken to reach the end result. The chart below has been developed to visualize this section.

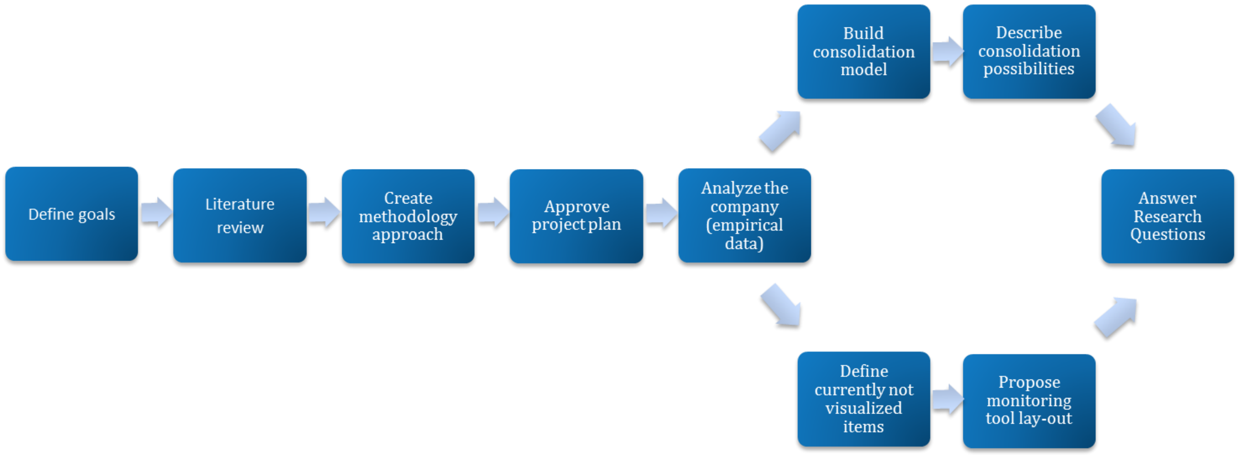


Figure 2 Detailed project plan

The start of the project involved the writing of a goal document which involved the idea of the project in short. The goal document got both approved by Haldex and the university to make sure that everybody is on the same page. Along with the approval of the project a contract got signed with Haldex to ensure the necessary facilities and knowledge was secured to assist with the research.

As usual with research, the first step is a literature review to analyze what the current status is of the research field and where a new research could benefit. Literature has been searched online while using different keywords: consolidation, mapping of supply chain, monitoring, inbound logistics, supply chain modelling, scheduling, supply chain sustainability. As a result, over 60 beneficial articles, books and websites were found which have been used as inspiration to the researchers to define the suggest research methods in this project plan. Various research theories have been analyzed concluding in this proposal of the in the authors eyes best fitting methods to tackle the research question.

To answer the research questions first an understanding was needed of the current situation at Haldex as a proper analysis cannot be performed without full understanding of the case. In this stage, interview rounds have been held between with different employees inside Haldex. These interviews were performed as described in the data collection section. Next to the interviews, the ERP system was analyzed thoroughly to gather enough quantitative data. The focus was on stock levels, order frequencies, turnover-times and everything else that seemed necessary for the research at hand. The documented work, described in the data collection section, which is performed previously at Haldex concerning arrival frequencies of trucks has also been thoroughly analyzed and if seemed relevant expanded by own observations done by the authors. In case of necessity, currently used forwarders were interviewed either face-to-face (as some of them are stationed close by the Haldex facility) or by email to gather more information on consolidation potentials.

The gathered data was afterwards used to see how the existing consolidation theory would suit Haldex and where it should be alternated to serve the companies needs in the best way. The perfect consolidation policy was examined to achieve strategic fit aligning competitive with the overall supply chain strategy.

The underlying goal was to maximize the cost savings with the created set-up. A model was then custom developed to analyze the most cost-efficient strategies for the inbound logistics. Following, the model was implemented in a simulation tool, Extend Sim, to simplify understanding and future usage by Haldex. The modeled simulation represented the different flows inside the supply chain. After conducting a proper analysis of the current supply chain in the case research, the simulation aimed to model the supply chain as close to reality as possible. The simulations goal was to simulate the flow of the goods from China to Sweden, while seeing origins of different ports as different flows, resulting in different models. Costs were attached to the different activities inside the model to sketch a total cost picture after a simulation run. By modifying the models, different scenarios were created that were compared to present an optimal supply chain lay-out with the lowest costs.

On the monitoring problem, the data has been used to create an understanding on where Haldex is currently lacking in their visualization efforts and where this could be improved to increase receiving operations at Haldex.

In the last stages of the project the model results were discussed, and the best strategy was determined and documented in an advisory paper format. Parallel, a lay-out for a monitoring tool was proposed for further development as the actual development seemed to be unfitting for the timespan of this project. In the end an overall concluding paper has been written and defended on the research questions asked in the beginning of this project plan.

2.9. Summary of methods

This section has given an overview on the different research methods and how they can be used to perform research. Different characteristics of ways to conduct research have been presented and it has been chosen which would be most applicable to this project. To start with, the research approach has been described as this is a very high-up view on research methods. Following, a look has been taken if the research should be performed in a conductive, abductive or deductive way while using qualitative or quantitative methods. After it had been defined what kind of research methods would suffice, three main research methods have been discussed: case, survey and mathematical/simulation research. To conclude the section a description of the chosen research method containing the unit of analysis, how credibility will be guaranteed and finally how the data will be collected. Table 4 will show the decisions made.

Table 4 List of choices

Category	Choice
Approach of methodology	System approach: accepting that Haldex is a system on its own and that the relationships between factors are important
Inductive, deductive or abductive	Abductive: alter theory to fit a specific situation
Qualitative or quantitative	Both are used to complete each other's shortcomings
Research method	Case study and simulation study
Unit of analysis	Departments of Haldex concerning suppliers from China and the suppliers themselves
Data collection methods	Interviews, documents and the ERP system
Validity assurance	Interview on different levels, check data and rank literature
Reliability assurance	Describe steps taken clearly

The main conclusion from the methodology decisions would be that this research uses a single case study to describe the consolidation and monitoring opportunities. Following, a more numerical method has been used by using simulation research to come up with quantitative results. To collect the data for these research methods, interviews were held and documents from electronic databases were analyzed besides the observations done by the authors themselves.

3. Frame of references

The theoretical framework describes the consolidation strategy and its implementation throughout a given supply chain and summarizes the status quo of consolidation application transportation. Some examples for consolidation adoption in supply chains are also presented. Secondly, different consolidation policies will be described followed by their impact on the environment and sustainability. Thirdly, factors are discussed to evaluate the success of consolidation as strategy for companies. On top of that, the literature on consignment stock will be discussed also. Finally, we give a short summary that has commonality for the rest of the thesis, and then outline the contributions of this dissertation.

Transportation and physical distribution are assuming an increasingly important role in contemporary extended supply chains. Large international companies are reconfiguring their supply chains to stay competitive as global competition increases while demand for freight increases more and more (Lemoine & Skjoett-Larsen, 2004). Outsourcing and off-shoring of manufacturing to low cost regions/countries (e.g. Far East, Eastern Europe, Latin America) coupled with advancements in information and communication technologies has resulted in global dispersion of production and distribution activities, creating complex multinational supply chains. Clearly, these trends have implications for the design and planning of physical distribution networks that need to strike a balance between customer responsiveness and cost efficiency. Hence, several decisions such as prioritizing performance objectives (e.g. speed of delivery vs. cost efficiency), selecting the right mix of transport modes to minimize costs (but also to account for environmental impact), locating distribution facilities and planning transport routes become crucial in this context. Nevertheless, it can be very challenging for companies to cope with these transitions in the transportation environment. Transportation management was therefore still often seen as the weakest supply chain's elements but includes great opportunity (Stank & Goldsby, 2000).

3.1. Supply chain management

La Londe and Masters (1994) defined Supply chain management (SCM) as follows. According to them it includes at least two or more firms in a supply chain entering into a long-term agreement, the development of trust and commitment to the relationship, the integration of logistics activities involving the sharing of demand and sales data and the potential for a shift in the focus of control of the logistics process. Despite of a wide range of definitions for Supply chain management the latter covers most of the aspects of the author's understanding of SCM. In the on-hand work SCM is therefore seen as a set of management processes and not as management philosophy (Mentzer et. al, 2001).

3.2. Supply chain mapping

A general approach to analyze a given supply chain is to visualize the entire flow between the members as its whole. Mapping the supply chain is a strong tool to identify hidden issues in the set-up or strategic process as well as potential improvements. Many companies or at least individual functions are not totally aware of how their supply chain looks like and how they contribute to its success. Gardner and Cooper (2003) presented ten “compelling reasons to map” a supply chain.

First of all, it is one way to link corporate strategy to supply chain strategy and should enhance the environmental scanning process of strategic planning. In addition, it could be used to distribute key information and alert planners to possible constraints in the system. A strategic supply chain mapping can also offer a basis for supply chain redesign or modification and overlaps and duplication should become more apparent through visualization. The role and power of each supply chain member and their value for the company might also be displayed. Obviously the map serves, moreover, as a communication tool to reach across firms, functions, corporate units and should facilitate the comparison of the descriptive and prescriptive view. Finally, new employees or new integrated members of the supply chain can be quickly educated to their position and role.

3.3. Consolidation as Strategy

In the logistical field, it is a well-known fact that consolidating shipments can create cost reductions. Buffa (1986) already wrote an article on this area over 30 years ago. He states that small shipments from different suppliers are often not consolidated as these possibilities are forgotten during the contract negotiations between supplier and buyer. This is confirmed by another study that shows that about 50 per cent of the companies leave the responsibility of the whole shipment with the supplier instead of optimizing it for the buyer (Bagchi and Davis, 1988). Due to this, most companies deal with multiple small shipments from different suppliers while they could be transported at the same time to increase volume benefits. Nevertheless, companies do start to realize that changing delivery policies throughout the supply chain can bring significant cost savings (Moon et al. 2011).

According to Buffa (1986), Cooper (1984), Jackson (1985), Trent & Monczka (1998), Çetinkaya (2005) and Chopra & Meindl (2007), consolidation is defined as the grouping of several small shipments into one at a designated location and can reduce total logistics cost. If several inbound shipments could be consolidated, then the purchaser could substantially reduce transportation cost and, in turn, unit purchase cost (Buffa, 1986). Nowadays, consolidation becomes more and more attractive for all kind of supply chain systems. Even though the topic appears in literature since the late 50s, it still gained active research attention in recent years enhancing it to a new level. Most of the research in the field of consolidating shipments has been conducted by simulation studies or analytical models (Cooper, 1984; Higginson & Bookbinder, 1994 and Jia et al., 2016). Despite that for the last period, further qualitative research was observed to become a venue in consolidation strategy to research specific consolidation environments or the addition of sustainability impact (Vaillencourt, 2016 and Ülkü 2011). SCL (shipment consolidation) is a logistics strategy that combines two or more orders or shipments so that a larger quantity can be dispatched on the same vehicle. This often results in considerable economies by reducing the transportation cost per unit shipped, and also possibly enhances the quality of transportation service. SCL has enabled some companies to cut transportation costs by half, decrease inventory levels and improve on-time delivery (Ülkü & Bookbinder, 2012; Hall,1987).

There are many successful examples, where a company could achieve substantial cost savings by applying consolidation. Mobil has been using this system for three years, reducing annual transportation costs by about $1 million (US) The system consolidates deliveries automatically or with dispatcher assistance, creating a large set of promising candidate schedules costed for each available truck (Bausch et al., 1995). For over a decade, the Kellogg Company has used its planning system (KPS), a large-scale, multiperiod linear program, to guide production and distribution decisions for its cereal and convenience foods business. A tactical version of KPS, at a monthly level of detail, helps to establish plant budgets and make capacity-expansion and consolidation decisions. Operational KPS reduced production, inventory, by an estimated $4.5 million in 1995. Tactical KPS recently guided a consolidation of production capacity and distribution costs with a projected savings of $35 to $40 million per year. (Brown et al., 2001) General Motors' Delco Electronics unit successfully saves at least 26 per cent of logistics costs annually by using a computer model to manage a mix of direct and consolidated shipping routes. (Wu & Dunn,1995)

The following example (Adapted from Bookbinder and Higginson, 2002) gives a simple indication, how the principle of consolidation works. Suppose that, at the end of each day, 1.500 kilograms of plates is shipped from Cologne to Eindhoven. Assuming a constant production rate, an inventory holding cost of $0,10 per 100 kilograms per day, and a transportation charge of $1.95 per 100 kg, the total transportation and inventory holding cost for this shipment is

$$\begin{aligned} Inventory\ holding\ costs\ &= [1.500\ kg\ \times\ \$1{,}95/100\ kg]\ +\ [(1.500/2)\ kg\ \times\ \$0{,}10/100\ kg] \\ &=\ \$30/day \end{aligned}$$

Then, the total weekly cost is

$$Total\ weekly\ costs\ =\ 5\ working\ days\ \times\ 45/day\ = \$150/week.$$

Now suppose that there is an all-unit discount scheme with volume rate of $1.20/100 kg for the weights of loads larger than 6.000 kg. So, if we decide to consolidate (i.e. combine daily shipments) over a week, the total weekly transportation and inventory holding cost would be

$$Weekly\ inventory\ holding\ costs\ =\ [7500\ kg\ \times\ \$1.20/100\ kg\ +\ (7500\ kg/2)\ \times\ (\$0.10/100\ kg)\ \times\ 5\ days]\ =\ \$108.75/week.$$

Therefore, consolidating and then shipping at the end of the week rather than shipping daily creates a saving of $41,25, which is almost 27,5% better than with daily shipments.

Not with the same frequency, but there are also researchers that tried to survey practical experiences from companies that had adopted or even implemented consolidation as supply chain strategy. Jackson (1985), one of the few researchers conducting a survey to prove the importance of consolidation, stated that the full 100% of his interviewees said freight consolidation was important when it comes to cost. One of the most common problems to face though is the volume of goods that has to be shipped to make consolidation beneficial. According to Robert J. Trent & Robert M. Monczka (1998)'s survey, a continued increase in purchase volume accumulation or consolidation is expected to take place. Furthermore, organizations will increasingly focus their consolidation efforts worldwide rather than across domestic units only. Although consolidation efforts have increased since 1990, respondents say their efforts have resulted in only a moderate level of consolidation, even when opportunities for consolidation exist. Purchase consolidation remains an evolving opportunity at most organizations. Organizations will increasingly concentrate their consolidation efforts across worldwide buying units. Lemoine & Skjoett-Larsen (2004) also conducted a survey to point out general trends that brings attention to consolidation such as centralization and relocation of plants and distribution centers, the consolidation of the carrier base and changes in the demand for freight transport.

3.3.1. Policies

Most existing analysis among research papers in the field of consolidation focuses on evaluating and comparing the performance of two or more consolidation policies and the corresponding development of mathematical models to obtain the optimal parameters for the proposed policies. Nevertheless, authors categorize those policies differently according to their research focus (Chopra & Meindl, 2007; Dror & Hartmann, 2007). Cetinkaya (2005) and Tyan et al. (2003) described different forms of consolidation. One of those is pure consolidation meaning without any coordination. If it is attached to inventory decisions, it becomes an integrated inventory consolidation policy. Fundamental is when vehicles should dispatch to meet service requirements and how much quantity is required to achieve scale economies. Higginson and Bookbinder (1994), Wei et al. (2017), on the other hand, identified three different consolidation policies that are used for combining shipments. Time-based policy sets a pre-determined interval within which orders are accumulated and one shipment is dispatched at the end of the interval (Gupta and Bagchi, 1987). The quantity policy combines shipments until a certain quantity is accumulated (Mutlu and Çetinkaya, 2010; Marklund, 2011). A time and quantity policy does the previous at the same time; whichever constraint (time or quantity) is binding first, determines when a consolidation is released (Mutlu et al., 2010). By simulation and trying different parameters, they draw conclusions in which case which policy performs best (Chen et al., 2017).

The appropriate SCL policy for inbound and/or outbound logistics essentially depends on the operating environment of the customer order characteristics, such as product type and due dates as well as the cost and transportation capabilities of the consolidating party (Ülkü, 2012).

Zhang et al. (2013) proposed a different approach comparing an order coordination policy in which common replenishment epochs or time periods are proposed by a company and the subsidiaries are encouraged to coordinate the timing of their orders based on the common replenishment epochs with an order consolidation policy in which the subsidiaries combine the quantity of their orders and the company places a combined order with the supplier. Verseput (2016) comes to the conclusion that both the tactical and operational planning need to be considered, as consolidation policies are determined on the tactical level and the actual scheduling of shipments is done at the operational level. However, when consolidation gets implemented, numerical studies indicate that it is usually optimal to schedule deliveries in such a way that the buyer receives large shipments at the beginning of the delivery cycle and small shipments at its end. The results also suggest that vendor groups with high (low) production capacities should be scheduled to deliver their shipments towards the end (beginning) of the delivery cycle (Glock & Kim, 2014).

3.3.2. Factors

Among several others Buffa (1988) presented four key factors to evaluate whether or at least to what extent consolidation is applicable for a company: types of inventory ensembles that are arranged into groups for reordering purposes, the shipping distance, transit time statistics and the unit freight rate structure. He also identifies transit-costs and transportation costs as considerable factors. Freight consolidation across time and customers also depends on the use of warehouses and direct LTL distribution systems in place compared on distribution costs and delivery times for selected product characteristics and demand patterns. (Cooper, 1984)

Holguín-Veras & Sánchez-Díaz (2015) identified the important role played by the receivers of supplies in determining when and how deliveries are made. Their paper provides background on consolidation programs and estimates a behavioral model to shed light on the factors explaining receivers' interest in cargo consolidation.

Moreover, Chen et al. (2017) analyzed and discussed, how the profit, the optimal consolidation time and the price are affected by model parameters such as cost and capacity factors. Based upon industry practices, Higginson & Bookbinder (1994) outlined factors when to consolidate shipments. According to their paper the unshipped orders and expected future orders, the product and transportation characteristics, order information, the geographical destination and the linked transportation and inventory holding costs are main drivers of that decision. In addition, quantity discount provides another incentive to consolidate shipments (Zhou & Zhang, 2017). Bookbinder and Higginson (2002) noted additionally that because the cost of operating a vehicle in a private fleet largely depends on distance rather than on load size, the dispatch of a vehicle each week instead of each day could reduce transportation cost by as much as 80%.

Berling & Eng-Larsson (2016) investigated the service provider's pricing and timing problem and the environmental implications of the optimal policy. They compare direct express delivery with immediate dispatch at full cost, or consolidated delivery at a given frequency at a reduced cost. They showed that the optimal policy is largely driven by customer heterogeneity: limited heterogeneity in customers' costs leads to very different optimal policies compared to large heterogeneity.

3.3.3. Trade-offs

Many papers analyzed cost trade-offs for different networks, i.e. for direct shipping, shipping via a freight consolidation terminal, and a combination of these two strategies. Other shipping strategies used in practice are "collecting" and "peddling". These involve either pick-ups from more than one origin per load or deliveries to more than one destination per load. They are analyzed in Bums, Hall, Blumenfeld and Daganzo (1985). Moon et al. followed the same idea but used a different perspective. According to his paper consolidation policy determines how long and/or what quantities of shipments must be accumulated, by considering the trade-offs between the consolidation benefit of lower transportation charges and the consolidation penalties of increased inventory costs, longer customer waiting time, and increased terminal operating and ownership costs (Moon et al., 2011; Szgenda, 1999).
Wei et al. (2017), on the other hand, compared the trade-off between economies of scale and expedited shipping costs. Meaning he discussed the impact of expedited shipment on both shipping policy and order fulfillment policy, as delaying the shipment of some orders can potentially increase total shipping costs due to the need to use more expensive expedited shipping modes. Traditionally the trade-off has also been between lead time and corresponding inventory costs (safety stock) and transportation costs but now emission costs come into the equation (Hoen et al., 2012). Wu & Dunn (1995) identified even an entire group of trade-offs, induced by consolidation strategy: transport cost versus transit time, and customer service versus logistics costs, trade-offs between transport costs and potential freight delays, consolidation savings and information systems investments, and consolidation savings and inventory carrying costs. (Wu & Dunn, 1995)
According to Qiu & Huang (2013) total cost savings resulted from the application of consolidation are highly on the size of the supply chain, the vehicle capacity, and the rates of fixed transportation costs and holding costs of finished products at manufacturers. A certain size of business is indispensable for the application. Most of the literature agrees that setting up a new warehouse, especially the in-transit inventory cost, the intense investment in supplier relationship management have further influence whether a company benefits from consolidation or not (Sheffi, 1986).

3.4. Consignment stock

Consignment stock is a certain way to handle inventory together with the suppliers. The main idea is that the supplier owns the goods even after delivery until the customer actually consumes the goods (Valentini & Zavanella, 2002 and Corbett, 2000). In a well operating consignment operation, the supplier guarantees the customer sufficient goods at the customer as long as the contract holds. The responsibility for the goods stays at the supplier until the customer uses the goods for production or other needs. Due to this, the customer only pays after actual usage instead of after receiving. The part of the holding costs that could be seen as opportunity costs is thus shifted to the supplier (Corbett, 2000). Nevertheless, there are also benefits for the supplier as they do not have to pay for the holding costs as the goods are held at the customer. On top of that, it can be said that it increases collaboration and relations inside the supply chain (Valentini & Zavanella, 2002 and Holweg et al., 2005). As goods are not paid yet until usage, this could be considered beneficial for a consolidation strategy where it usually takes longer for goods to arrive and therefore, they are kept longer on stock. During a deep search in the scientific literature, a proof of this connection could sadly not be found.

3.5. Sustainability

The assumption that the reduction of the environmental impact and optimal supply chain efficiency is still a trade-off is not contemporary (Carter and Rogers, 2008; McKinnon, 2008; Ubeda et al., 2010). Many contributions on this topic can be found in the extant literature, sometimes under the label "Green Supply Chain Management" (GSCM) (Marchet et al., 2013; Hoen et. al, 2012; Ülkü, 2012). Environmental concerns and fluctuating fuel prices drive a growing interest among companies for more sustainable distribution systems (Stenius et al., 2018). Also, the growing environmental regulations and awareness have urged companies to look into carbon emissions and optimization policies (Lagoudis & Shakri, 2015). Berling & Eng-Larsson (2016) claimed that from an environmental perspective, changes in transport costs are of interest to investigate in greater detail, since a regulator can influence these costs directly through taxes, fees or subsidies. The transport sector largely contributes to emissions (GHG) which significantly affects the sustainability performance. The transport sector contributed about 23% of the CO_2 emissions from fuel combustion in 2014 (IEA, 2016b). A fundamental question companies face, is how to leverage the type of intermodal transportation solution to reduce transport emissions while minimizing the total inventory and transportation costs of their distribution systems (Stenius et al., 2018; Lagoudis & Shakri, 2015).

Stenius et al. (2018) and Ülkü (2012) contribute with modeling and exact analysis of capacitated volume dependent shipment costs and transportation emissions, allowing for combinations of transportation modes and evaluation of expected emissions. Hoen et al. (2012) developed a model, in which the transport mode, which causes the minimum, expected total cost, including emission costs, is selected. They concluded, on the other hand, that the emission related values of the parameters needs to be extremely high in order for a decision maker to select a different transport mode. Smokers et al. (2014) and Hoen et al. (2012) explored that if freight volumes grow according to expectations; this requires over 70% less CO_2 emissions per unit of transport. One way to attend to this issue is by reducing the amount of vehicle kilometres, meaning same tonne kilometre or m^3 km (increased load factor, increased vehicle capacity, modal shift, etc.). These innovations include logistics that are more efficient, for example through optimized routing, and changes in the management and design of supply chains. Consolidation is one way to mitigate the effects of increased traffic congestion and pollution (Ülkü, 2012). Consolidating shipments would lead to larger volumes per shipment, hence it not only improves environmental performance but also reduce costs (e.g. Ülkü, 2012).

Optimized distribution networks can reduce the unit costs and unit emission intensity of transport by taking emissions as costs and reducing the speed of delivery, bundling of goods into account.

3.6. Monitoring

Since monitoring is a way of keeping track of and displaying data and measurements, and can thus be seen as applied studies, there has not been too much theoretical research in the supply chain community. Nevertheless, Lau et. al (2002) stated that companies are constantly looking for better ways to monitor ongoing activities in their supply chains. Being able to respond to these events in a timely fashion can be the difference between pulling ahead of, or falling behind, the competition.

Supply Chain Monitoring solutions can add real-time connectivity and business process control on a network level. There is a range of supporting tools on the market, that are able to link orders, shipments, containers and inventory together in an operational data store for end-to-end supply chain visibility (Goel, 2010). This allows to manage also complex scenarios where the company may use multiple host systems and execution systems, and still have the ability to link supply chain data together and control the supply chain with a single point of access.

3.7. Connection to Analysis

The theoretical background is summarized in figure 3. In order to serve as an overview for the remaining chapters, it serves to link theory with the research process (project plan) and the contribution to answer the underlying research questions.

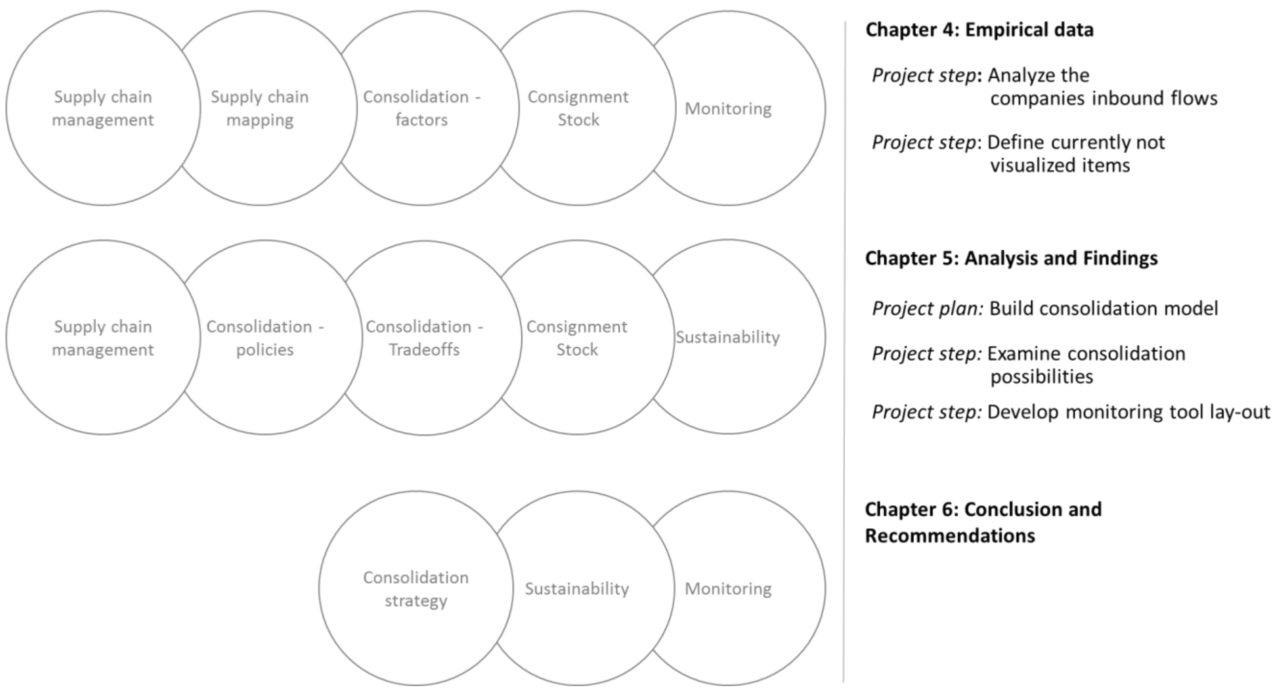


Figure 3 Summary of frame of references

4. Empirical data

This chapter provides an overview of the current state of the case company, i.e. Haldex AB (at the moment of conduction of the study). Data has been collected through interviews, information systems and observations. The data will be presented while using figures and tables to draw a clear picture before the research questions can be approached.

4.1. Haldex and its supply chain

As the scope of this research is solely considering the Landskrona facilities at Haldex, only the suppliers and their goods of Haldex Landskrona will be considered. Although, Haldex has multiple suppliers from all over the world, it has been decided to only focus on the suppliers from China for consolidation opportunities. As for now, an overall consolidation strategy seems too complex and not beneficial enough. China is chosen due to believe that it has the highest impact, as Haldex has multiple Chinese suppliers, thus large consolidation opportunities, plus the shipping distance from China is the largest among Haldex' suppliers. The improved monitoring aspect of the research does consider all suppliers, but as this is more a general way of working and not supplier specific, it has been chosen to only describe the supply chain through China.

Haldex Landskrona is supplied by a large number of suppliers but only ten of them are located in China, they are spread over the country while six of them are in the area around Shanghai, two others are more north near Qingdao and the other ones are near Fuzhou and Guangzhou. The research is thus limited to these ten suppliers. At the moment, the goods are shipped through 4 ports: Shanghai, Qingdao, Fuzhou and Nansha. A geographical picture of the suppliers and the ports can be found in the Appendix B. On top it has to be noted that two suppliers: Supplier1 and Supplier3 are shipping by air. Both suppliers are stationed in the Shanghai area and are therefore using Shanghai Airport.

The reason for shipping products by air in the current scenario is that these products are both much lighter as the products transported by ship and the demand is lower. Thus, decreasing the relative price of transportation. The items using air freight have an average weight of 0.1 kg while the other weigh on average 0.3 kg. Although suppliers are scattered around eastern China, multiple consolidation scenarios will be considered by using optionally less ports and if beneficial the exclusion of air transport.

When the goods are sent to Sweden they are shipped to the port of Helsingborg if it is a full container. If the container is shared with other companies, Göteborg port is the destination. This is done as Göteborg is a larger port thus sharing containers becomes easier. Still Helsingborg is used for full containers due to the strikes that often occur at the port of Göteborg. The planes from Shanghai fly to Malmö airport. After arrival in Sweden, all goods are driven to the factory in Landskrona by trucks. An overview of the supply chain has been presented in figure 4. The lead time is usually 6 weeks till arrival in Sweden and 1 more week till arrival at Haldex Landskrona's front door.

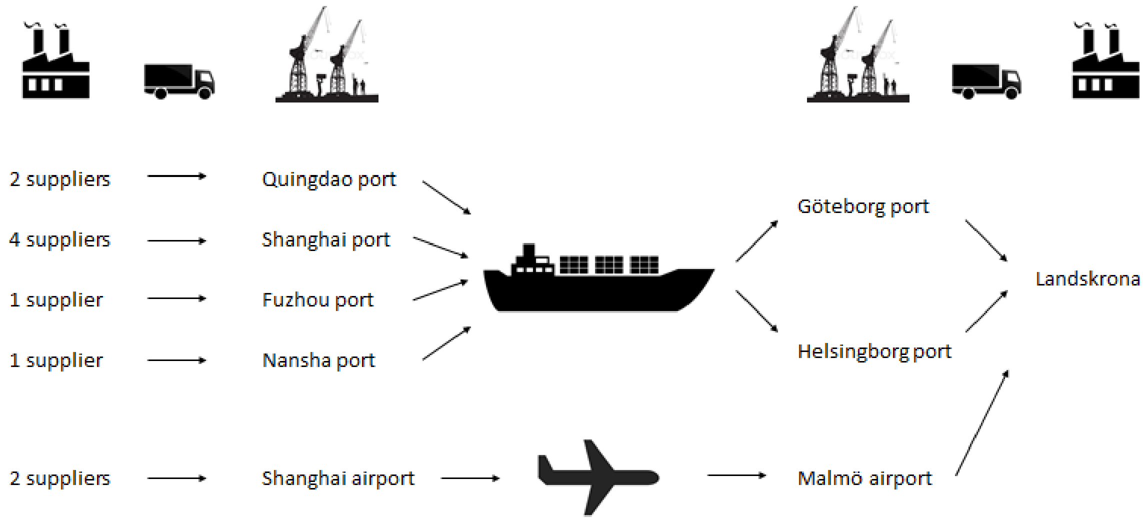


Figure 4 Haldex' supply chain

Haldex uses two logistical partners to set up the transportations. For the European suppliers only one contracted forwarder is mostly in charge of the daily operations while another 3PL (third party logistics) has control of the supplies coming from Asia. The logistical costs for this research are therefore received from this logistics partner (3PL1) first hand as Haldex aims to keep the partnership even after implementation of a consolidation strategy. The logistical costs are thus both in the current and in the future scenario applicable. In the current scenario, 3PL1 consolidates goods for Haldex if they stumble upon an opportunity that is beneficial but this is only in a small percentage of the cases as they do not have a specific policy for it. 3PL1 has stated that they are open for a consignment policy to assist Haldex not only when the opportunity arises but also on a more long term basis.

4.1.1. Transport price structure

As Haldex has outsourced everything related to the transport of supplies from China, most of the communication and information sharing with Chinese suppliers is done externally. 3PL1 is not only responsible for the port to port transportation but also, depending individually on the agreement made with the supplier and Haldex, takes care of the inland transport in Sweden from Helsingborg (FCL) respectively Gothenburg (LCL) to the site in Landskrona. 3PL1 offers both FCL and LCL solutions, meaning shipping items to either one of the aforementioned ports depending the achieved volume. Currently 3PL1 consolidates shipments of items produced by the same supplier at the port of Shanghai, only if the items are ordered at the same time, and preferably ships them together on one ship. Nevertheless, the gathered information from interviews and data collection speaks to some extend a different language. In some cases goods from the same supplier arrive in Landskrona two consecutive days. That might be due to several reasons. First of all, they could have been shipped on different vessels, second of all, there was no truck available to pick up the second container at the port or thirdly, custom procedures just released one of the containers in the first place. The rates for transport are mainly based on volume needed to store the pallets in a container and overall weight of assigned load. Prices also differ from day to day since 3PL1 makes use of several forwarders, which conduct the actual transport. Each forwarder offers a different price though and 3PL1 passes the difference to Haldex causing slight price fluctuation for attached order dates. In addition to that the cost for the required truck fuel (DMT), the terminal handling charge at the port (THC) and a security surcharge also at the port, called ISPS are added (see table 5). When it comes to full containers 3PL1 applies a fixed price per container excluding the environmental extra fee of 3,60 SEK (see table 5), which is multiplied by the number of containers but still almost neglectable. 3PL1 has everything in place to arrange the consolidation in Shanghai, but there is no information about the conditions at other ports, yet.

Table 5 Transport prices

Full container shippment		
Location	**Fee**	**Amount**
Helsingborg	DMT	20,00%
Helsingborg	THC	1.195,00 SEK pr. unit
Helsingborg	Bill of Lading	515,00 SEK
Helsingborg	Port Charge	460,00 SEK pr. unit
Helsingborg	ISPS	10,00 EUR
Helsingborg	Green Service Fee	75,00 SEK
Helsingborg	Handling	485,00 SEK
Helsingborg	Environment al Fee	3,60 SEK pr. tonne, minimum 25,00 SEK

When it comes to long distance transportation incoterms play a key role. Haldex has, in collaboration with 3PL1, negotiated incoterms, which differ along their Chinese suppliers. They range from EX-works (EXW) over FOB till Delivered at place (DAP) and thus covering both extrema (see table 6), full sellers and full buyer's obligation. To manage the consolidation of goods along more than one supplier, responsibility should be preferably on Haldex' respectively 3PL1 side. Hence we are able to erase further parties from the equation.

Table 6 Incoterms

Supplier	Incoterm
Supplier1	EXW
Supplier2	DAP
Supplier3	FCA
Supplier4	FOB
Supplier5	EXW
Supplier6	FOB
Supplier7	FCA
Supplier8	DAP
Supplier9	FOB
Supplier10	FOB

4.2. The material itself

4.2.1. The products sold

The main products that Haldex Landskrona is selling are disc brakes. The components bought from China are thus used in these disc brakes. As Haldex produces disc brakes for multiple kinds of trucks, there are multiple different disc brakes, each with their own product number, usually there are even two different product numbers per truck type as it involves a left and a right disc brake.

In the current situation there are 81 products sold containing components from China. Although a few of these products are directly imported and sold by Haldex, most are the result of a manufacturing process using a large variety of components, including multiple Chinese components. After a study on the demand of these items, performed by the authors, both in the past and in the future it became clear that 40 of these products are not produced or sold in recent times or are planned to. These items can thus be considered old items that have no impact on the consolidation strategy, leaving the count of products with a relevant demand at 41. In this section the inactive items will still be sometimes referred to, but if so this is clearly stated, in following sections the inactive items will be neglected.

Most, but not all, of the disc brakes share similar bill of materials, or at least when the Chinese components are concerned. For consolidation methods, this brings opportunities to the table as the demand for a certain product thus creates identical demand for components.

4.2.2. The components

Haldex actively sources 29 items from Chinese suppliers. A list of the items and the suppliers can be found in Appendix C. As can be seen, some suppliers sell only one component while others sell more, as often one component goes into one disc brake, total demands can differ a lot among suppliers. To see how the different components integrate into the different products and where demand patterns can be found a visual overview based on the bill of materials of the end goods has been made. Figure 5 presents the relations in this overview.

As the picture can be quite chaotic at first glance, an explanation will be provided before presenting the figure. The green items on the bottom present the components from the suppliers with their item numbers used by Haldex. These are thus the items bought by Haldex from China and transported to Landskrona. The different number colors are representing the different suppliers. The three items on the left are directly sold after receiving and thus not involved in any production processes, hence the big blue arrow on the left side of the figure, whereas all the other components are used in production. The orange items are semi-finished products while the blue items are the finished goods and thus the goods sold by Haldex. If a number has been written in red, this products is not sold at the moment at Haldex, as the reasons for this are often unknown it has been decided to keep them in the figure but they are unimportant for the further analysis. The red numbers are hence not important for a quick understanding.

The blue items are mostly the disc brakes, but some items are less important items with often less demand (the actual demands will be presented later). The arrows try to show where the items are used. For total understanding it has to be noted that the bottom green block is divided in different sections by vertical lines, the blue arrows only belong to the section they are originating from. The left blue block does not get divided in sections, the right blue block on the other hand contains three sections with some overlapping blocks.
To illustrate some examples will be given: item 96003, which can be found in the middle of the green block, gets immediately used in all the end-products in the top left blue square as the only arrow connected to that section of the green block points directly at the blue block on top. Item 94655 on the other hand gets first used in the semi-finished goods in the orange block, which later turn into the blue finished goods. The combination of blue arrows on the right side illustrate that these 4 green components are needed in both blue squares. It is thus easily to be seen which component gets created if a sales forecast for a product has been made and that a sale of the blue blog on the left side results in an demand increase for almost all green items. A sales increase in the blue blocks on the right side, will only have an impact on a few components though.

Lastly, if the background of the item box has been made bold, this indicates that two of these items are necessary for production of one product. Components 93918 and 95228 will thus be needed two times as much as the other items in the same segment as every time a disc brake gets produced, two of them are needed in contrast to the other items where only one part is needed.

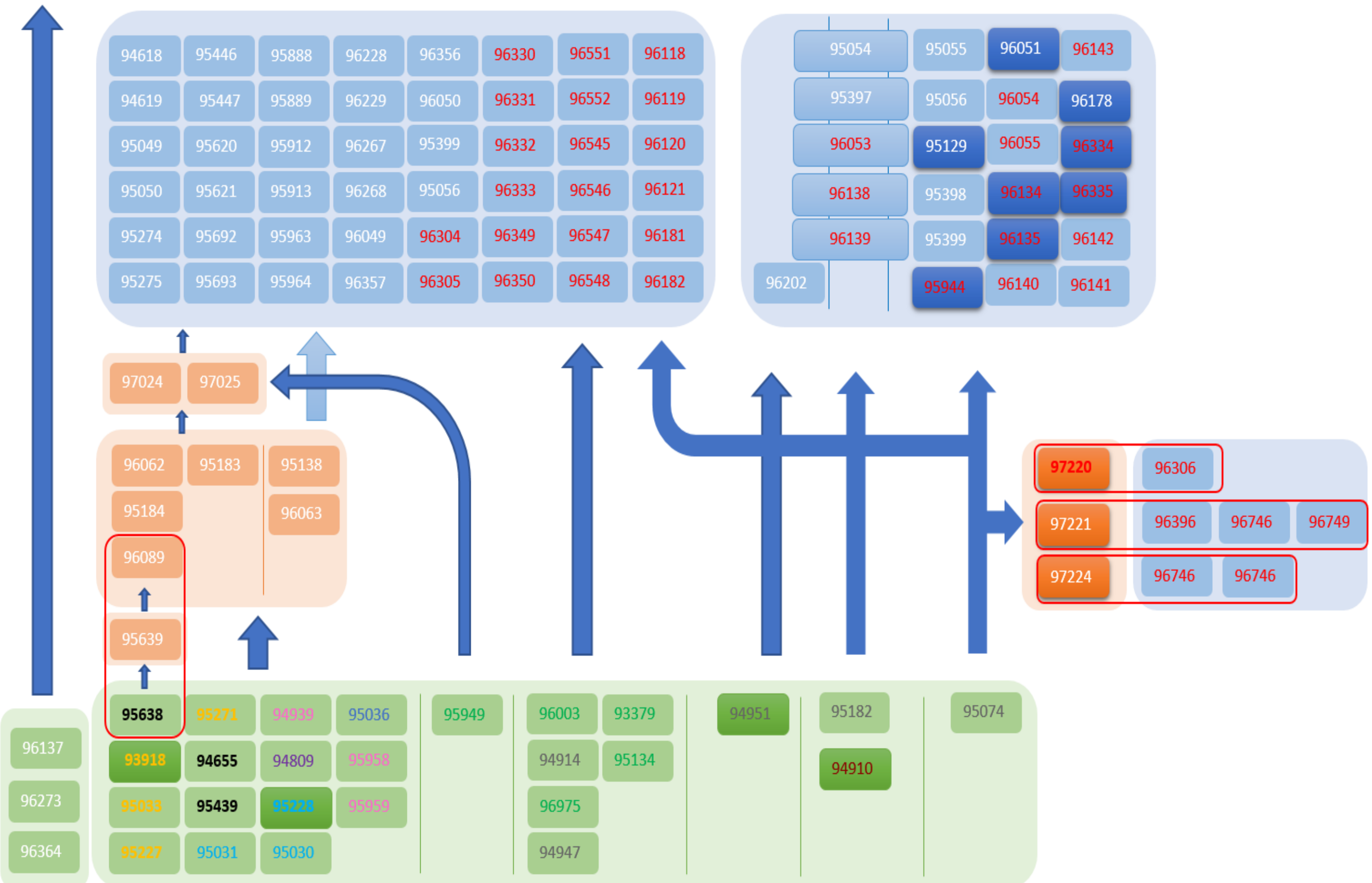


Figure 5 Chinese BOM patterns

= sourced components from China
= semi-finished goods
= finished goods

4.3. The demand patterns

As mentioned in the frame of references, one of the biggest requirements for consolidation is enough demand. Jackson (1985) already named this the largest issue regarding consolidation. If the demand is too small and too far away spread, consolidation becomes less attractive as it will be harder to fully fill up containers. Grouping of incoming orders might in such scenario take a relatively long time compared to the lead time, resulting in too long transit times. The demand of the components needs thus to be analyzed to ensure that a consolidation policy is feasible.

In the current scenario, Haldex' ERP system plans automatically a new purchase order every time the stock level is going to drop below the decided safety stock. The stock level reductions are based on forecasted demands of the finished goods. Haldex aims to have reliable forecasts both on the customer and supplier side for at least one year in advance, but after some discussions it became clear that it would be better to use the demand till the end of the year. For this reason, forecasted demand of the components will be considered till the 31th of December, 2018. Nevertheless, past demand data has been collected as well. A comparison will be performed to see if the results obtained for the future, would have had the same effect in the past as the upcoming 7 months might be an incorrect snapshot of future demand patterns. It has to be mentioned though that the industry has grown overall, resulting in higher demands this year than have been seen in the last years. Resulting, it could be possible that consolidation policies that should be beneficial in the upcoming months, might not have been beneficial in the past. Figure 6 shows the different demands per month. The corresponding numbers can be found in the Appendix D.
The idea of the picture is not to give a detailed picture per component, if that is required by the reader the appendix would solve this issue, the real idea of the picture is to show the total demand development over the months and that different items often have the same demand, confirming the patterns suggested in the figure 5.

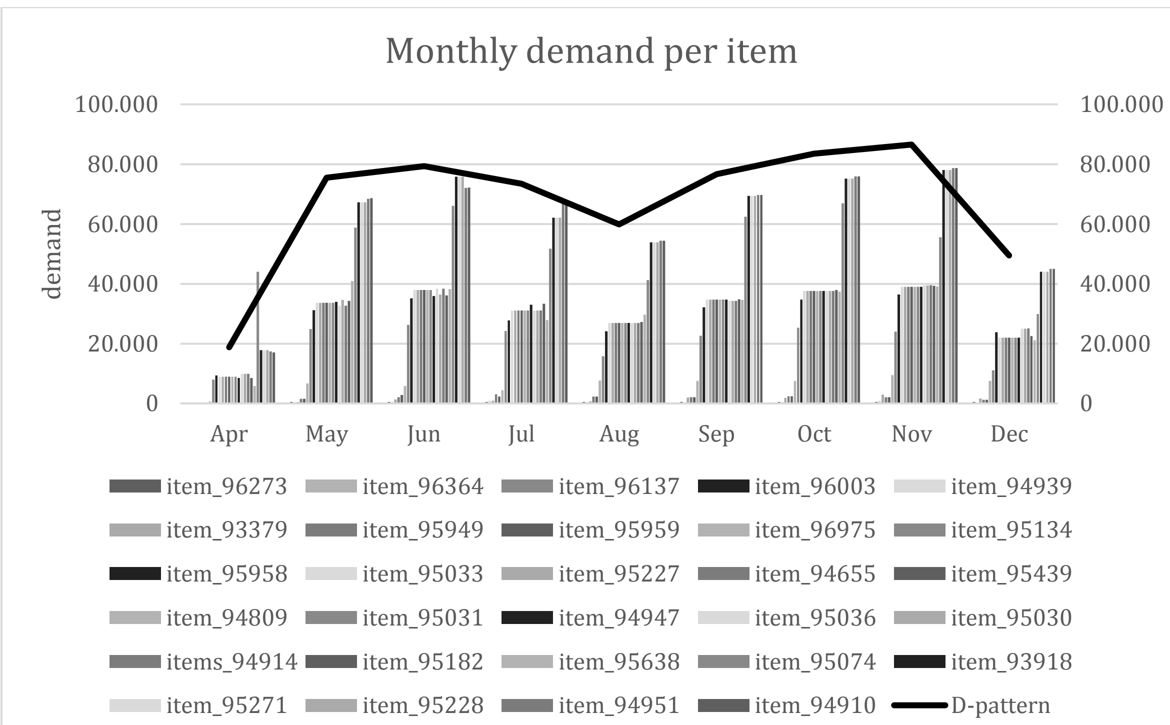


Figure 6 Future demand per item

As can be seen from the chart, most items follow a similar pattern and reach till halfway of the lines, fluctuating around 30.000 pieces. These are the disc brake components that are needed one time inside a disc brake and the disc brake demand is thus equal to the component demand. The tall bars on the left of every month, towering above the others are examples of components that are ordered twice per disc brake. Its demand is thus exactly double as of the majority of the lines. The shorter bars on the left side of the month represent components flown in by air transport. It is thus the case, as was stated before, that the decision for the mode is at least partly based on the demand volume. Still there are small differences between bars that should be identical, this is easily explainable as some products might be produced a couple days earlier than others although they will become part of the same end-product. The demand of one component could thus fall in the previous month, while the other item falls in the next month. On a last note, the month December shows shorter columns than the other months, this could be explained by the holiday season just as in August, or that not all purchase orders are already planned for this months and thus do not appear in the ERP system yet. The month April has even lower demand as the demand was collected half way during the month April, only around 30% of the data could thus be taken into account.

As purchase orders often include multiple items from the same supplier, it becomes interesting to look at the demand on a supplier level. If a supplier has a high demand on its own, it could be feasible to create a full container without consolidation with goods of other suppliers. If the demand per supplier, is not fulfilling the requirements, it might be necessary to involve other parties into a consolidation strategy. Figure 7 shows the demand per supplier over the upcoming months.

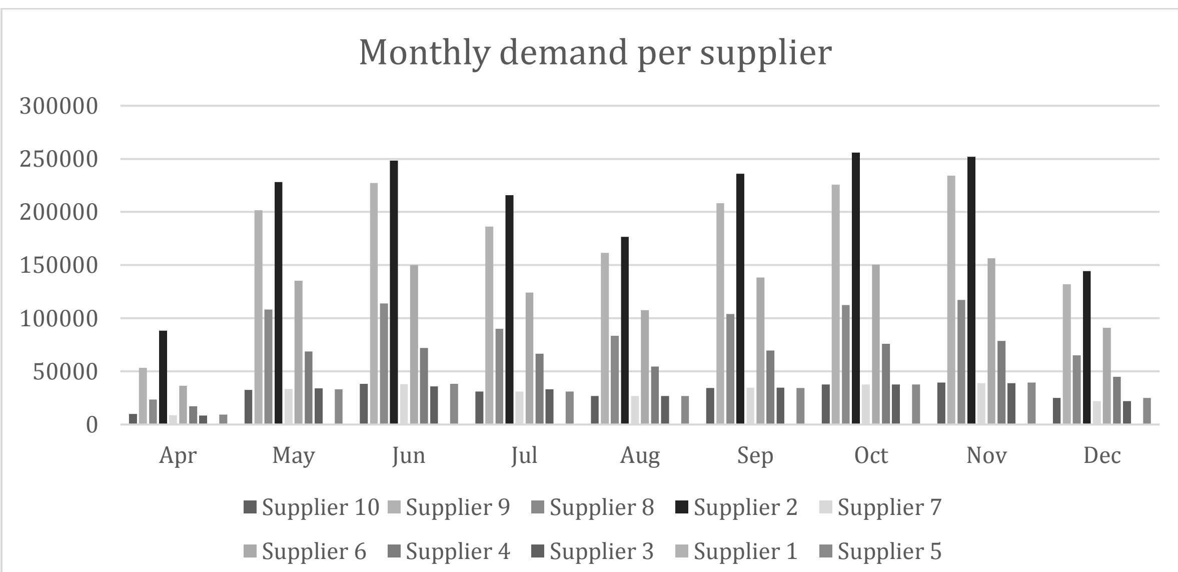


Figure 7 Future demand per supplier

Clearly, there are main differences between the suppliers. Later in this research, an analysis will be performed to see how fast a supplier is able fill up containers with the current demand patterns.

4.3.1. A comparison to past years

Usage of the demand of the past years is necessary to prove that a preferable consolidation strategy is not only a fitting solution for the specific snapshot of the next months, but it can show that consolidation is a more long-term solution. Figure 8 and 9 have been created to present past data per month.

Only the previous two years, 2016 and 2017, were taking into consideration since the sample of data is neither too old to be representative nor too small to leave room for misinterpretation nor contains obsolete items. Both years are basically following the same pattern. The demand has increased from 2016 till 2018 but the behaviour of each item has only slightly changed. In 2017 a new item (96975) was introduced opening up the launch of a new model of disc brake, but did not influence the amount of goods ordered by its supplier. Furthermore the first and last months of the year have been more intense in both cases. The summer tank is mainly driven by the Swedish custom to allow most of the employees to take their holidays in the same period, which reduces the output of the entire plant (see figure 8 and 9). Differences appear only due to new launched items, items belonging to more than the usual bill of material or caused by an additional step in composing those items to the final product. In general, the portfolio of disk brakes did not change too much and more or less the same finished goods were frequently sold, assuming that the products proved successful and the demand stayed stable both over the past years and in future. On the supplier level Haldex is building on long-term relationships. As all figures in that chapter indicate Haldex rather sticks with the well-chosen suppliers and develops new products in collaboration than fall back to multi-sourcing.

However, the demand for the afore-discussed years are very much similar and it can be argued that this pattern will continue in the upcoming periods, always under the assumption of an overall increase (30% over budget for 2018; Anders Pålsson, 2018). It has been chosen not to present the data for figure 8 and 9 in the appendix as again only the big picture is considered to be important: the comparison with the 2017 data.

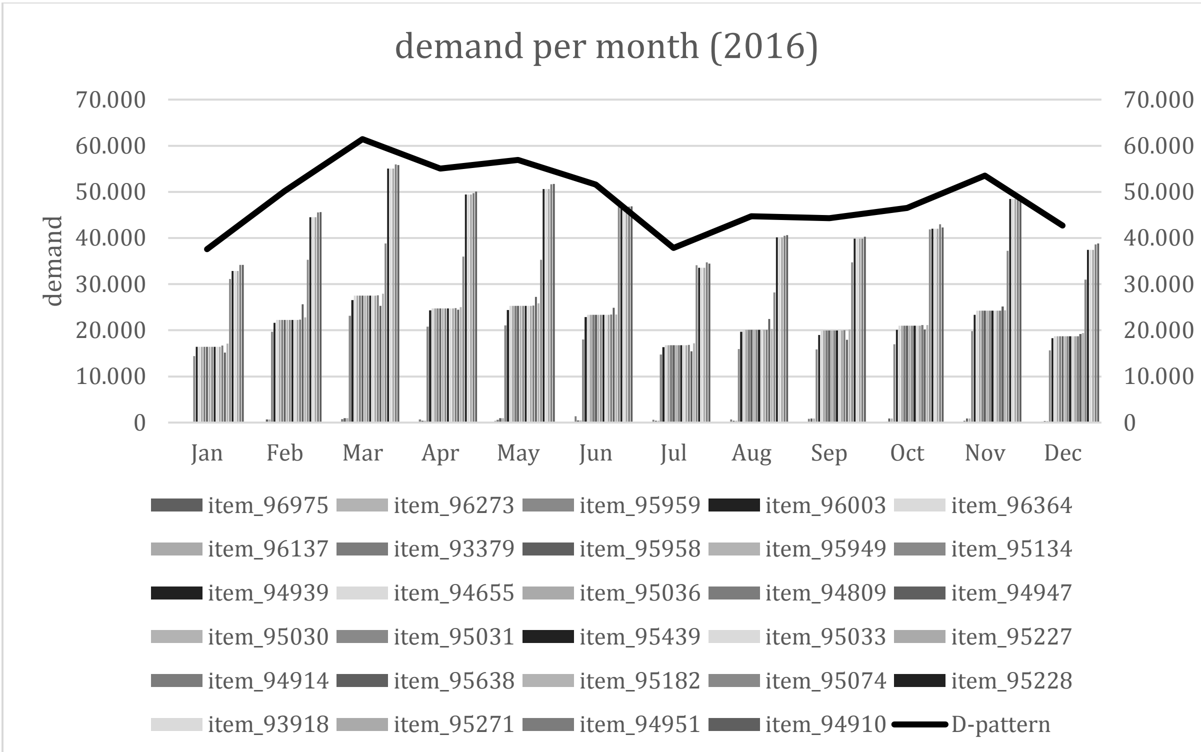


Figure 8 Demand per item in 2016

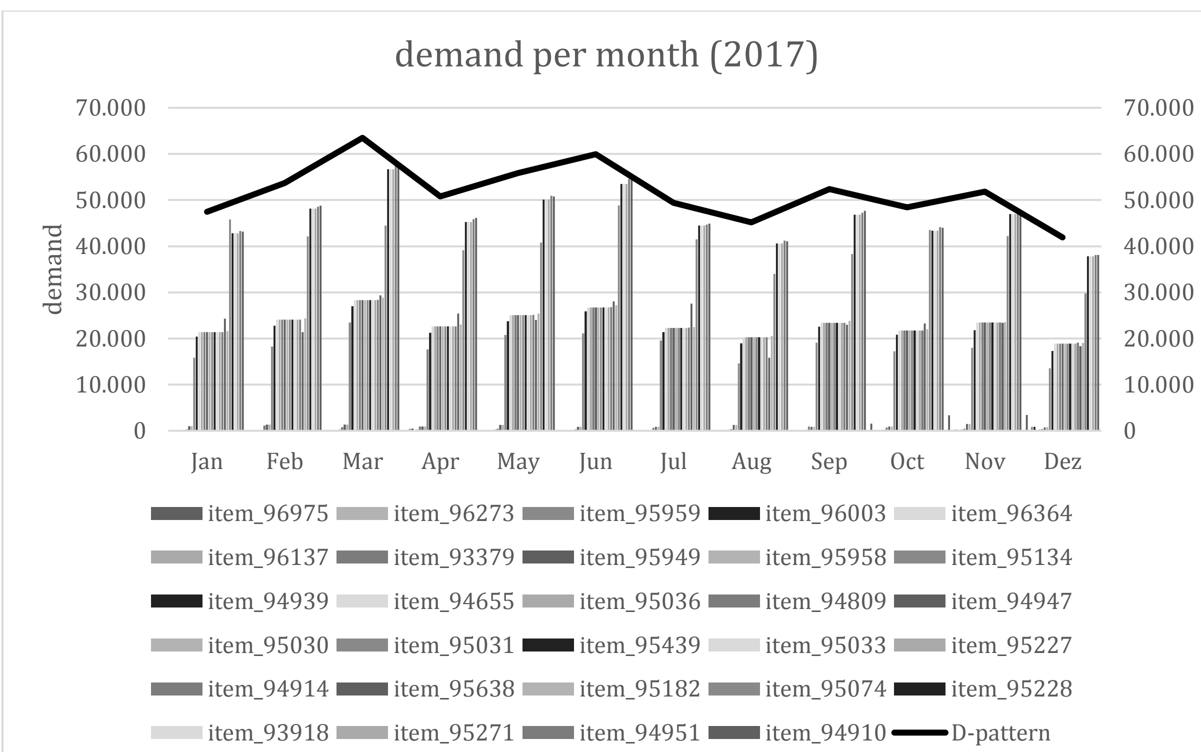


Figure 9 Demand per item in 2017

4.4. Component characteristics

As freight gets transported in containers, the optimal scenario would be that a container is fully utilized to optimize economy of scale. As a container has a certain amount of space that can be utilized, certain characteristics of the components become important. The main characteristics to be considered are the weight and volume of the pallets, as it indicates how many pallets can be placed inside a container. The other important characteristic is the pallet quantity, as it obviously does not make sense to order largely above demand as warehouse space is costly. Haldex also works with a minimum order quantity, this quantity is often set to the amount of one full pallet but in some cases there is chosen for a different minimum order quantity. This is done to not have too many shipments in transit from China as it would make transportation very costly. Nevertheless, this research aims to recalculate the whole transportation cost system from the Chinese suppliers, therefore it has been decided that the minimum order quantities will be set to the amount of one full pallet for all Chinese suppliers to support this research. 3PL1, the logistic service provider of Haldex, uses both 20 feet and 40 feet containers. They are able to store 28 and 25 tons respectively weight wise, and 22 and 36 pallets size wise. The details for the components are listed in Table 7.

Table 7 Pallet dimensions

Item number	pallet quantity	The gross weight pallet (kg)	volume (m3)
95036	1008	458,1	0,58
93918	9800	544,9	0,30
95033	10500	82,5	0,30
95227	19600	174,0	0,45
95271	26310	165,0	0,45
94655	1330	626,8	0,45
95439	1800	600,0	0,45
95638	5000	499,5	0,30
94914	5120	156,0	0,71
94951	4500	103,2	0,70
95074	21600	257,6	0,70
95182	6160	137,6	0,56
94947	14400	136,5	0,41
94809	4500	303,8	0,71
95228	10800	432,8	0,41

Item number	pallet quantity	The gross weight pallet (kg)	volume (m3)
95030	10800	402,8	0,41
95031	18000	282,0	0,41
94910	7776	326,3	0,56
95958	558	581,6	0,73
95959	558	581,6	0,73
94939	558	581,6	0,73
93379	5000	17,6	0,01
95134	5000	17,6	0,01
95949	5000	17,6	0,01
96003	5000	17,6	0,01
96975	5000	17,6	0,01
96137	200	48,0	0,40
96273	125	33,0	0,40
96364	100	22,5	0,26

As Haldex uses a standard pallet, the length and width are always the same. The volume does thus only depend on the amount of pallet collars placed upon the pallet which each add to the volume. The weight on the other hand shows that even the heaviest product, can be fully loaded into a 20 feet container

without reaching the maximum weight. As long as Haldex would only use 20 feet containers, the weight is not a constraint.
Lastly, the pallet quantity appears to differ significantly per product, for all items a graph has been made that sets the average monthly demand of May till November 2018 (it is excluding April and December due to incompleteness of the demand data) next to the pallet quantity. Figure 10 shows the results.

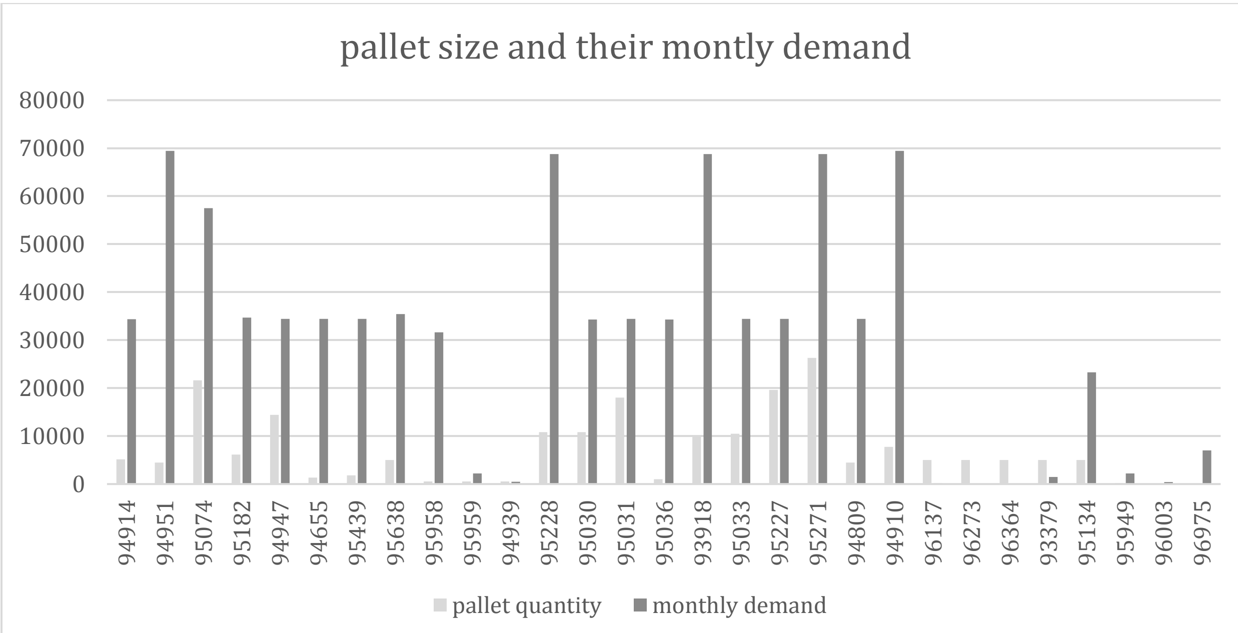


Figure 10 Pallet size vs. monthly demand

As pallet quantities are quite different among the items, the amount of pallets to fulfill the monthly demand is equally differing. Most items will need multiple pallets to cover their demand, but there are some items on the right side of the graph by which a pallet covers the demand of multiple months. These items are all using air-transport (every item from 96137 to the right). To see if items can fill up whole containers on their own or by other suppliers from the same city and to place a first look on possible consolidation solutions, a second graph has been created. This second graph will add the maximum container capacity of a single item plus the average demand of all suppliers connected to a single port. As consolidation is naturally more likely to pay-off if the same port is already used, grouping items might give indications of likely solutions. Figure 11 shows the grouped data.

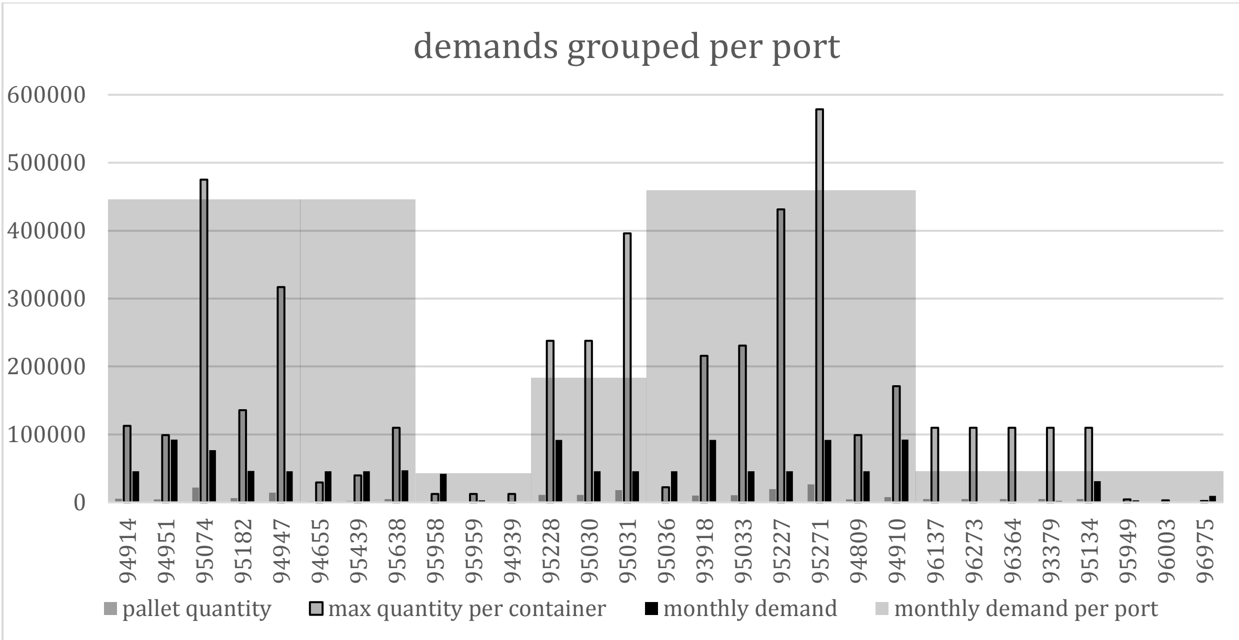


Figure 11 Component demand per port/airport

The tall max quantity per container bars are a multiple of the monthly demand bars by 22, as 22 pallets fit in a 20 feet container. It can be seen that most items are not able to fill up a monthly demand on their own, while a few of them do. The squares on the background of the graph show the average monthly demand per port. The order is Qingdao, Fuzhou, Nansha, Shanghai and Shanghai air. From the graph it can be seen that in the case of Nansha, as all tall bars are higher as the grey square, all components can be send in one container and the monthly demand would be achieved. In Qingdao and Shanghai, where the demand is the highest, thus the most consolidation opportunities might arise, multiple containers will need to be send as only monthly demand could only be placed in a single container if the whole demand was fulfilled by item numbers 95074 and 95271. Overall it can be stated from the graph that consolidation might not be logical with all items but in some cases combining for transportation could surely pay off.

4.5. Consignment stocks

As mentioned in the frame of references consignment stock is a way of controlling stock ownership. With consignment stock, the supplier keeps ownership even after delivery of the goods. The actual selling takes place when the buyer uses the goods and takes them out of stock. As consignment stock benefits mostly if goods are stored at the supplier or in transport for a longer time, Haldex has decided to only use consignment stock for supplies from Haldex. At the moment six out of ten Chinese suppliers are using consignment stock, these are all shipped by sea freight. Due to non-ownerships of the stocks while they are still stationed at Haldex, the storage-time factor becomes less important as Haldex will not have invested money in the stocks during the time that they are on stock. It could thus have an effect on the to be decided consolidation strategy, this will also be analyzed.

4.6. The arrival of goods

4.6.1. Current arrival frequencies and ways of consolidating

As mentioned before, at the moment no consolidation is performed by Haldex or their suppliers/ logistical partners. Only if by luck two orders pass the port at the same time, 3PL1 consolidates the goods. At the moment purchase order schedules are created totally separated per item. Even if the items are sold by the same supplier, Haldex does not consider buying them together as the goods are needed at different times. Nevertheless, it does happen that different items of the same supplier are shipped together if again by luck their required shipping days are the same or at least close to each other. To show how the purchase orders are scheduled in the present day, the tables in figure 12 are created. Only two suppliers are displayed but they are representative for the other suppliers. The other can be found in the Appendix E. It can be seen from the tables that the shipments arrive at Haldex quite irregular. This has indeed been an issue for Haldex in the last years, the main reason for this is fluctuating demand but also inconsistency in order sizes. A pattern was sought on the order sizes and the arrival frequency but it has sadly not been found. Discussions with the planning department of Haldex brought the conclusion that the last years have been more or less without a policy on the order sizes. Minimum order sizes exist though, and a multiple of a certain number was always ordered. Although, for Chinese suppliers a new policy will be used for the shipment frequency. The new aim will be to supply Haldex with average 3 weeks of demands while the planners monitor sudden demand changes in the near future to optimize the order sizes/shipping dates.

Supplier10

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	1	6	3	2	3	2	2	3	1	3	2	1
ChargeableWeight(Kg)	7 700	49 280	23 870	15 400	40 810	23 100	29 260	46 950	7 700	34 650	23 100	15 400
Cost	8 344	51 899	24 528	14 348	31 667	20 926	22 854	37 129	7 325	32 584	23 119	14 465

Supplier9

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	1	2		2	1	3	4	3	3	5	3	1
ChargeableWeight(Kg)	4 305	8 000		7 000	4 000	7 600	9 285	7 000	10 200	13 380	9 779	2 906
Cost	5 998	10 631		7 550	4 096	8 941	12 839	9 485	12 197	19 001	14 117	4 256

Figure 12 Present day shipments for 2017

4.6.2. Process of information sharing

Interviews were held during the data collection process to get a deeper insight into the way information on the arrival of goods get shared. In the process there are two parties involved inside Haldex, on one side there are the planners who gather the information and share the information, on the other side there is receiving, they receive the information and use it to plan and optimize their daily work.

For most suppliers there is a standardized process. The process starts with the placement of a purchase order, this is automatically done when the ERP system receives a signal that the demand will drop below the safety stock. In some cases, mostly with the suppliers from China, this needs to be done manually. The demand has been placed into the ERP system by usage of EDI. The supplier confirms the order and in combination with 3PL1 an expected arrival date gets created. This date is stored in the ERP system and Haldex' planners create a load. A load is a line in the ERP system that shows the items in transit. During the supply process, the planners actively get updated on the transport process and get informed when a transport reaches a port. If the delivery date changes, this date is updated in the ERP in most scenarios. It does happen that the date does not get updated as even updated dates are often considered unreliable or the date is not used anywhere at the moment.

Every morning the planners update the receiving staff in a meeting where is discussed which items will arrive that day and which of them are more critical than others due to small current stocks or even backlogs on production orders. The receiving staff than schedules their work for that day by the knowledge received in that meeting.

A flow chart describing the process has been created and is shown in figure 13.

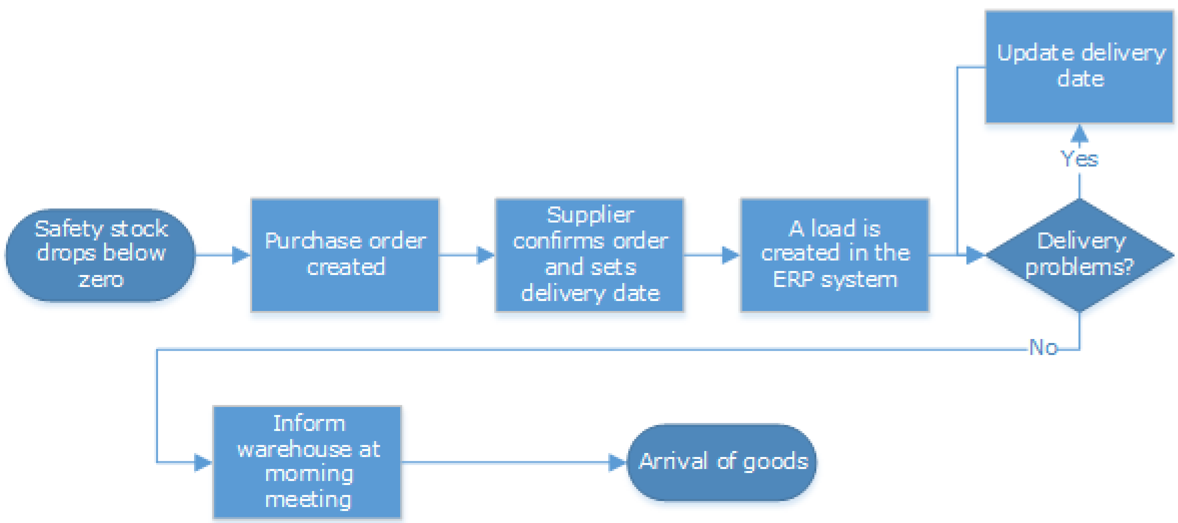


Figure 13 Information flow at incoming goods

4.7. Smooth arrival scheduling

In order to face the smooth arrival scheduling of incoming trucks, interviews with persons involved in the current process were conducted, both internally and externally. The contracted forwarder (3PL2) takes care of all road transport for Haldex. According to 3PL2 and internal sources at Haldex the most frequent used suppliers are from Sweden, Denmark, Germany, Switzerland, Czech Republic and Italy. 3PL2 does not conduct any container transport for Haldex and no shipments involving a different mode of transport. The by far highest amount of transports are going directly to Haldex and do not pass the distribution hub at 3PL2, Landskrona. Only in the case of small parcels the goods are sorted there and shipped individually to Haldex. When Haldex places an order at a supplier it is on the supplier to manage the transport to Haldex. Haldex agreed contractually with their suppliers to exclusively use 3PL2 for all shipments and book the required trucks independently. As soon as the supplier books a truck at 3PL2, Haldex receives a notification per e-mail including the expected arrival date. As a rule of thumb, the loading of the supplies triggers a common process and quite predictable time of delivery. After the goods are placed on the truck, the lead time usually totals up to 2 days (3 days for southern Germany and Italy) till the goods can be received at Haldex. 3PL2 is equipped with a tracking tool based on GPS data, able to locate most of their trucks within a few minutes in case of need. Haldex has only access to that information when a delay is detected or at least expected to occur. 3PL2 is also able to guarantee specific time windows for suppliers and already provides this service to other companies such as Scania. All other interviews held supported the previous information and drew the same process for transportation scheduling.

5. Analysis and Findings

This chapter serves to guide the reader through the different parts of analysis. First of all, the full model for applying consolidation on Haldex Chinese distribution network is presented and evaluated. Finally, a comparison of different scenarios and their corresponding costs, concluding in an analysis of the sustainable impact. Further on the reader will be introduced to the study of monitoring supply chain measures at Haldex and the scheduling of supply receiving.

5.1. Modelling the implementation of consolidation

During the interviews the overall wish to implement a consolidation for long distance transportation was identified. Due to lack of time and loss of know-how through employee fluctuation Haldex put it on the backburner for several years. The first attempts to bring this project back into discussion were developed in close collaboration with 3PL1. Nevertheless, there was neither a final cost-benefit-analysis conducted nor any feasibility check. The on hand work tries to fill up those gaps and deals with a profound analysis taking all factors into account but neglects details, that do not contribute any benefit. The plan was to examine with which suppliers Haldex should consider a consolidation approach and Haldex would benefit the most. The assumption was made that Chinese suppliers might have the highest potential. Collaboration and integration of suppliers in the internal process are currently not fully implemented and create a loss of cost saving potential. How things stand, each supplier is shipping their goods individually and immediately. Even within the same organisation, goods are not delayed for batching them and reducing the amount of shipments. Haldex detected a win-win situation for both sides and was finally willing to tackle this challenge and develop it further. A supportive management is recognized as a key success factor for all processes, but especially if the change affects more than one structure within Haldex.

5.1.1. Assumptions

Below are listed the assumptions used in Chapter 5 to assist the analysis. They are explained in the text once more when called upon and are not used with the intention to create an unrealistic analysis but merely to create the possibility to develop a proper model.

- Haldex only uses 20 feet containers.
- Demand does not change after it has been written in the ERP system.
- All future demand for the months May 2018 till December 2018 are written in the system.
- Cost prices for transportation on a certain random day are representative for shipping on other dates.
- To compare the profitability of one scenario over another, the transportation costs to the ports in China can be excluded, as long as they are excluded in all scenarios.
- Pallets are not stackable inside a container.
- At least one pallet of safety stock is kept per item.

5.1.2. The consolidation model

The goal of this research is to understand how a consolidation strategy can be implemented at Haldex and which effect it would have on the costs, thus indicating if a consolidation strategy would be a lucrative option for Haldex or not. To create an idea of the profits that can be made while using a consolidation strategy a simulation model was build using the ExtendSim application. ExtendSim is a simulation model specialized in discrete event systems and uses blocks with different attributes that are connected with other blocks. "Items", in this case the different goods, are following these connections line from block to block and get affected by the attributes of the blocks.

As a simulation is merely a simplification of reality, a certain amount of assumptions needed to be developed to achieve a useful outcome, these assumptions will be described throughout the text but have been listed at the beginning of this chapter. The main goal of the simulation is to compare how well a certain consolidation strategy would fit for Haldex, this resulted in the development of different scenarios which will be compared and afterwards a final recommendation will be given. First of all, the current way of operating has been simulated including the resulting costs and these will be compared to the results of the consolidation simulation.

5.1.2.1. The input used

Before the simulation model is presented, an overview is given of the data used as input for the model. Different inputs have been used to get a reliable simulation running. The input can be categorized in the following categories: Demand data, component attributes, transport costs.

5.1.2.2. Daily demand

The demand data that is used for the products is the real planned data for 2018 from may till December and thus the data presented in earlier chapters. This is the demand for the components to be actually in need on the production line. The argumentation for using these numbers as the demand is that it is the closest to reality. The planned data is continuously updated. The data has been brought down to daily numbers per component, thus giving the simulation an input signal every day of the simulation run. Due to this, the components will always arrive in time for their production schedule and the transportation strategy will not affect the service levels of the components. The total demand is relatively fixed and will thus not change during the upcoming months but the daily demand might shift for several reasons as for example unavailability of production lines. It is assumed for the simulation that the daily demand will not shift anymore after it has been planned in the ERP system, plus that all the demand from May 2018 till December 2018 is written in the ERP system. As the demand is the real data, the demand will not enter the system according to a distribution but scheduled according to the demand plan. Therefore, the simulation stays not only the closest to reality, but different runs of the simulation will give the same result and thus eliminating the need for approximations and statistics.

The data used of one item, 95036 of Supplier10, is shown in table 8. The time numbers represent different days while 1 equals the 1st of May, 2018. Weekends have been excluded from the day counter as the demand would always be 0.

Table 8 Daily demand input item 95036

time	quantity	time	quantity	time	quantity	time	quantity	time	quantity
3	180	38	450	73	3063	108	75	143	540
4	546	39	0	74	480	109	3423	144	5488
5	720	40	4623	75	75	110	4116	145	100
6	495	41	0	76	4167	111	75	146	4548
7	4104	42	240	77	0	112	3543	147	0
8	1083	43	96	78	2679	113	0	148	540
9	1785	44	1272	79	1752	114	394,5	149	6672
10	4104	45	564	80	480	115	663	150	100
11	558	46	1752	81	2199	116	0	151	4564
12	1230	47	0	82	1752	117	394,5	152	0
13	1560	48	663	83	75	118	1896	153	526
14	960	49	0	84	3543	119	1827	154	5488
15	1035	50	201	85	3636	120	394,5	155	100
16	480	51	183	86	75	121	4044	156	4724
17	960	52	0	87	3783	122	75	157	0
18	4170	53	0	88	480	123	159	158	526
19	75	54	3060	89	315	124	0	159	5488
20	960	55	0	90	3207	125	3120	160	100
21	2244	56	0	91	888	126	4276	161	884
22	2013	57	3540	92	2199	127	1184	162	0
23	1170	58	201	93	2232	128	2932	163	526
24	960	59	4023	94	75	129	2976	164	2528
25	75	60	4428	95	405	130	100	165	2436
26	3585	61	3633	96	1896	131	4884	166	244
27	0	62	615	97	1827	132	0	167	0
28	480	63	0	98	4143	133	540	168	526
29	4344	64	3069	99	0	134	2528	169	5392
30	0	65	3063	100	75	135	2436	170	100
31	480	66	960	101	3663	136	5524	171	212
32	3060	67	3039	102	0	137	0	172	0
33	201	68	12	103	405	138	540	173	0
34	3063	69	1827	104	4116	139	5448	174	2528
35	2580	70	225	105	0	140	100	175	4160
36	201	71	4596	106	405	141	4884		
37	4383	72	75	107	5004	142	0		

5.1.2.3. Component Attributes and transportation costs.

All components virtually transported in the simulation receive a weight, volume and pallet quantity. This is the same data as presented in table 8: pallet quantity, weight and volume. This data is used to decide when a container is full and how much it will cost to transport that specific container to Landskrona. During the year 2017, Haldex only received 20 feet containers. This enables the researchers to state the following assumption: In the future, Haldex will only use 20 feet containers. The maximum container size has been set to 22 pallets as this is as explained previously the maximum capacity of the containers used by Haldex. A maximum weight of 28 tons has been set per container. Research has been performed if pallets could be stackable in the container, thus increasing the pallet capacity. During the major part of the report the simplifying assumption is made that pallets are not stackable as this is very close to the real situation in the present. At the moment Haldex receives containers with stacked pallets in very rarely and if so it is unclear what influenced the decision to stack.

As 3PL1 has provided the researchers with a cost database for the transportation from the different ports in China to Landskrona, the costs retrieved from this database were imported into the simulation. A long cost table has been created that links the different weights and volumes of the total goods inside a container to a certain cost price, the simulation thus looks up every time a ship needs to be send off, what the total weight and volume is of the goods and connects it to a predetermined cost. Some side notes need to be placed though as there are some small flaws to this process of cost calculating. One constraint is that the shipping costs are actually dynamic and change every day. Since this is very unpredictable and the costs can thus either be lower or higher as expected, a certain day has been chosen for all the cost price retrievals in all different scenarios. It is therefore assumed that the cost prices on this day are representative for the prices on other shipping dates. Another constraint is that it excludes the costs of transportation from the factory in China to the closest port used by Haldex (transport costs from the ports in Sweden to Haldex are included). As the main goal of the simulation is to compare different scenarios and in both cases the goods need to be shipped to the ports in China before consolidating at the port, it has been decided that the costs for the transportation to the ports is neglectable. The assumption that justifies this decisions: to compare the profitability of one scenario over another, the transportation costs to the ports in China can be excluded, as long as they are excluded in all scenarios.

5.1.2.4. Parameters

Different parameters as the maximum weight, maximum volume and pallet quantities are used but the input chosen in the current simulation are not advisable to change. There is one parameter existing that could and will be changed in this research to analyze different results, the waiting time of a pallet till it gets shipped off on an less than full container load. To illustrate this it is necessary to refer back to the literature review placed at the beginning of this paper. The literature describes different consolidation policies, one of the papers describing three policies very clearly would be Mutlu et al. (2010). He differs between a time-bases, quantity- based and time-quantity-based policy. In this paper it has been decided to use a time-quantity-based policy. In more detail, this policy operates with two parameters: a maximum load (in this case the maximum weight and the maximum amount of pallets per container), and the maximum waiting time. The latter parameter refers to the time a component ready for shipment is allowed to wait till a container can be filled. If the time-limit gets reached, the component that has been waiting for that specific amount of days will be shipped together with all the items that are waiting at that moment. This way a container will always get filled up as much as possible without the risk that the lead-time of items gets unacceptably long. By reducing the maximum waiting time, loads will be shipped to Sweden more often, reducing the order quantities and thus the average amount of products on stock. Nevertheless, the costs will increase as the containers are not filled up. Increasing the maximum waiting time will allow the consolidation of full containers and thus cheaper transportation costs but will delay deliveries.

Currently a safety stock is in place at Haldex. By keeping this safety stock the consolidation strategy will still ensure that demand will always be covered in time. It might be possible to optimize the safety stock more by connecting it to this new policy, but this research will not go deeper into that. The difference on the amount of stock at hand will be realized by having a different frequency of incoming shipments. Two different graphs, figure 14, are presented showing the effect of increased frequency of shipments. The first graph has lower frequency policy, while the second one orders more frequent. It can be seen from the graphs that the first graph has a higher average stock level while the second graph shows a clear reduction, thus resulting in lower storage plus opportunity costs.

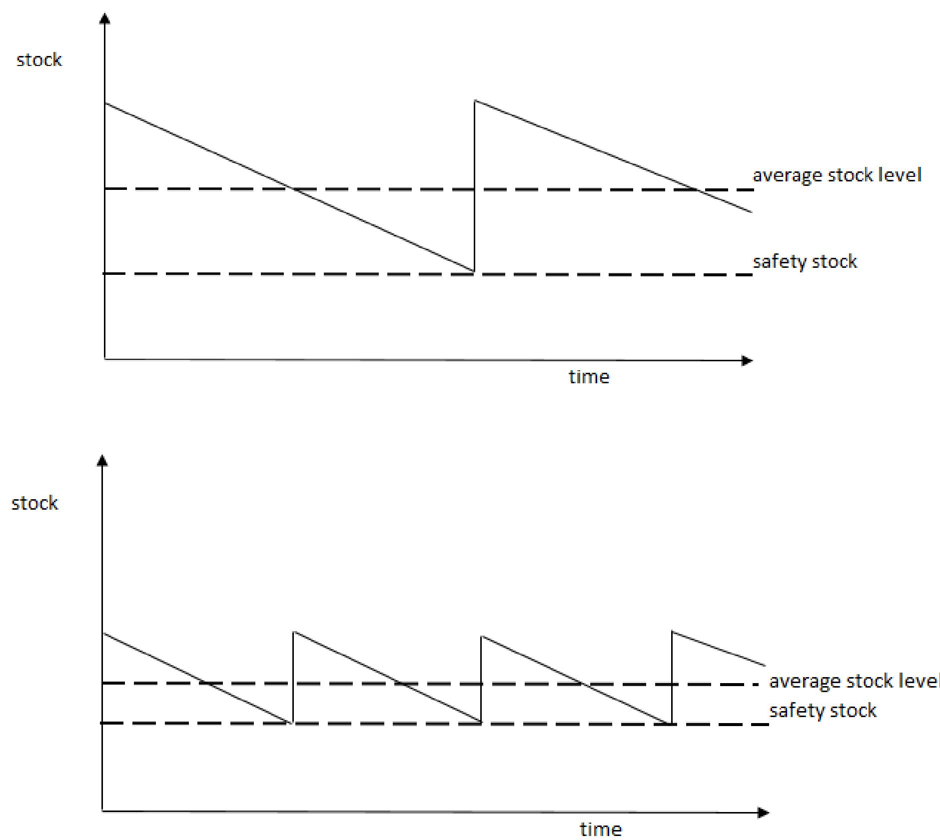


Figure 14 Effect of order frequency

5.1.3. Explanation of the model

Before the model can be explained properly, the idea behind the consolidation model needs to be elaborated on. As previously described, the product demand is based on a schedule of the real data. To enable the model to operate in a reliable way, the demand will be accumulated till a pallet quantity gets reached. Afterwards, the pallet will be send to the port where it will wait for either a full container or it will be shipped with a less than full container as the maximum waiting time will be reached. As both the demand is known around one year in advance and the day a container should be shipped can be retrieved from the simulation, the order process can be adjusted to consolidation. Instead of letting the products wait at the port, which is costly, the purchase orders can be delayed slightly to make them all perfectly align with each other and the to be shipped container, thus excluding for the most part the storage cost at the ports in China. This asks for reliable suppliers as order schedules are very strict. If a supplier misses the shipping date, it could affect the transportation costs as the product might be ready for transport too late for its assigned container space. If demands are high enough though, the next to be consolidated container should depart only a few days later. According to the simulation, the maximum waiting time is the maximum time between placing a purchase order and the shipping of the transports. This is not fully true though as one issue is faced. The simulation groups demands till the quantity of a full pallet is reached, after one full pallet is created the maximum waiting time clock starts ticking. It is thus possible that demand that did not reach a full pallet and has to wait longer as the maximum waiting time. If Haldex wants to use the proposed order system to make sure that all items arrive in time, they will need to order all products at least the maximum waiting time plus the transportation time in advance of the need of the product, and keep one pallet of safety stock for each item. This one pallet of safety stock will ensure that no demand is unmet due to components waiting longer as the waiting time. At the moment Haldex already works with safety stocks for the Chinese suppliers and they are always larger as the pallet quantity. The assumption is therefore set that for every component there is at least one pallet of safety stock.

The basics of the model will be explained in this section, no look will be taken into the characteristics of a simulation program but the focus will be on what characterizes this specific simulation. A short explanation of all the different blocks used can be found in Appendix G. To simplify the understanding, the simulation will be presented by using the part of the simulation that shows the current goods flow from Supplier10, thus without the consolidation policy. Figure 24 shows the total model in this scenario. As there are a lot of blocks and lines in this picture for somebody that has never worked with ExtendSim before, it is very normal to not see the forest through the trees. Therefore, there will be zoomed in on different parts of the model to explain it more detailed after figure 15.

The different parts of the model that will be analyzed more deeply are:

- The arrival process
- The shipping of a full container
- The shipping of a less-than-full container
- The cost calculations

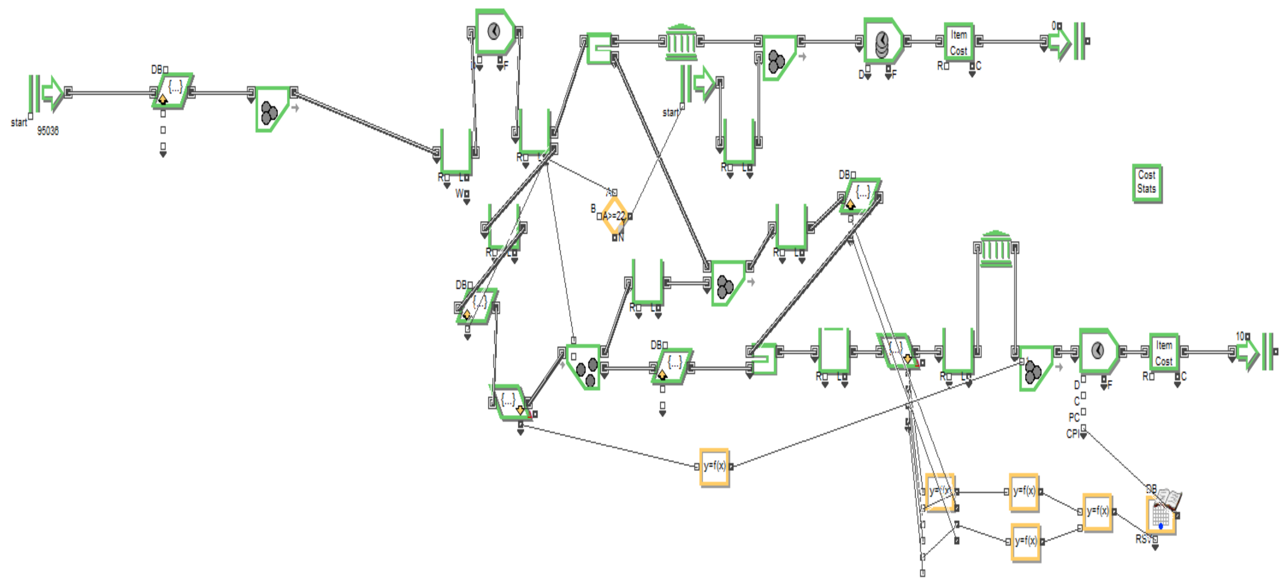


Figure 15 Current situation Supplier10

The first section of the model that will be discussed is the arrival process of the goods and it is presented in figure 16.

5.1.3.1. The arrival process of the model

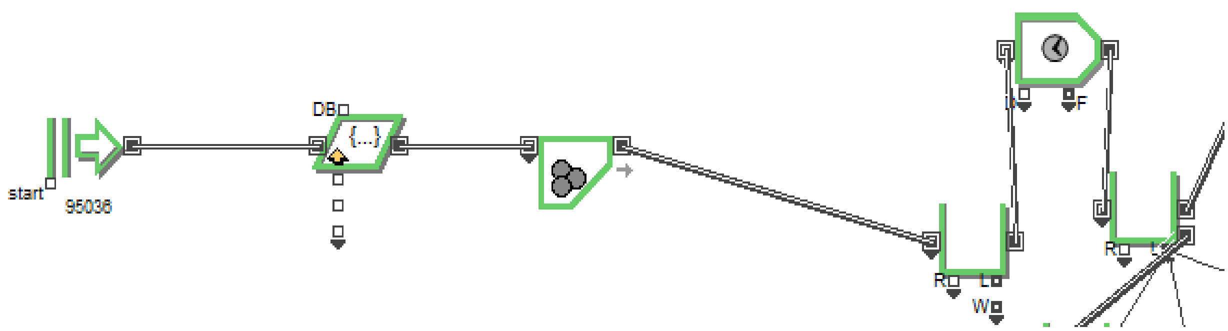


Figure 16 The arrival process

The items are created in the create block on the left of the figure. They are created according to the schedule presented in the input data. After creation, they flow to the second block which assigns them the attributes that are connected to this specific item: weight of a full pallet, volume of a full pallet and item number. The third blocks accumulates demand till a full pallet is reached and ensures that only full pallets are send. The next 3 blocks form the port in China, in this case Shanghai. The last queue block on the right is the actual port where the supplies are waiting till either a full container is reached (a full container is 22 items, if 22 items exist in this block they will be send on a full container). The block also has the waiting time parameter in its settings and recognizes as an item has waited for too long. The other two blocks are there for simulation purposes. The activity block is a fictive activity with a very small duration time and a maximum capacity of one item at a time, this has been done to ensure that items can never enter the second queue at the exact same time. The queue block before that block is only used as a buffer if the activity block has reached its capacity.

5.1.3.2. Shipping a full container

The second part of the model that will be explained is shown in figure 17 and represents the scenario that a full container will be shipped.

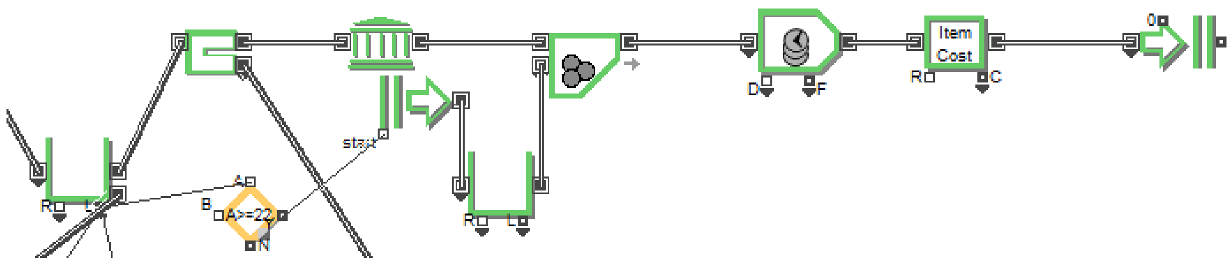


Figure 17 Full container gets shipped

Every time a full container needs to be shipped, the items follow this path. It starts with the port queue on the left, both outputs are blocked till either the maximum amount of pallets or the maximum waiting time is reached. They diamond shaped decision blocks input is connected with the thin line to the queue block, this line visualizes the extraction of the amount of items in the queue. If the length is indeed 22, the block will send a signal to the create block to create an item which will be dropped in the queue block afterwards. The batch block is crucial in blocking the path unless 22 pallets are ready for transport. The block only batches if both 22 pallets and the one item created by the create block are ready, if not it will not accept items to continue the path. The queue on the left has the ability to sense this blockade and blocks the output as long as the batch block is blocked. As a result, items cannot leave the port till either the maximum waiting time is reached or 22 pallets are ready for shipment. The batch block batches the items into a single item which will serve as a container.

The select item out block will be more clearly explained later but the most important for this scenario is that the bottom path is blocked until the maximum waiting time is reached. The history block connected to the select item out block has only been placed for administrative reasons as it writes down the items passing through and its attributes, and is used to show which items are present on the container. The last 3 items are representing the actual shipping. The activity block has a certain cost attached to it. The cost for a full shipment is different per port but inside a port it stays the same. The item cost block lists these costs and at what time they occurred, thus at what time a container was send. The last block lets the containers leave the simulation.

5.1.3.3. Shipping a less-than-full container

After the relatively simple top path a look can be taken at the bottom flow of the simulation. This flow represents what happens if due to extensive waiting time, a less-than-full container load needs to be shipped. Figure 18 represents the flow.

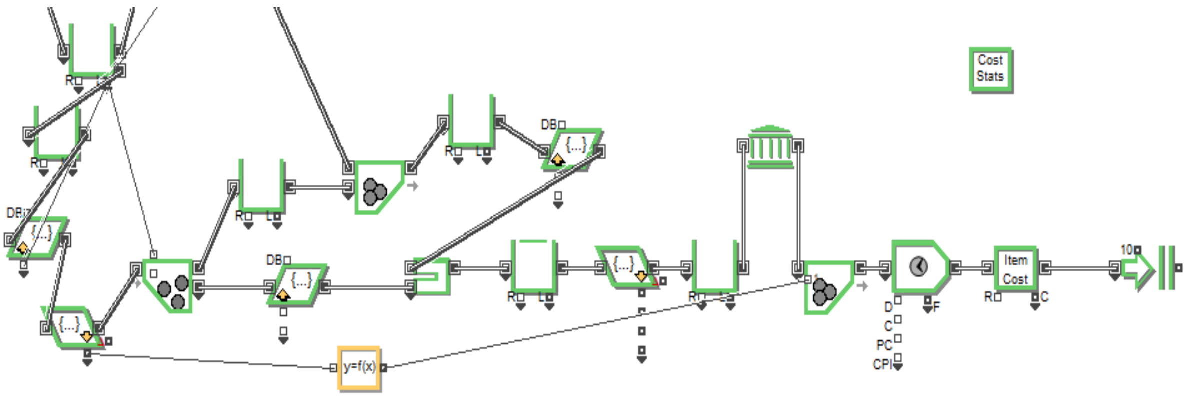


Figure 18 Process of less-than-full container load

As soon as an item waits the full maximum waiting time in the port, it will be send through the bottom output into the second queue. This second queue has no theoretical reasons of existence but it is purely necessary due to some flaws of the program. The set block, gives an attribute, named quantity to the item as it passes through, this quantity is the amount of pallets still in the port after the item has left the port. Following, this attribute is received by the get block and will be used later on. The unbatch block sends one item into the bottom path and uses the amount of pallets still waiting in the port to determine the unbatch quantity in the top part. The queue placed behind the unbatch block is again placed for practical reasons. The batch block in the top flow batches one item from both paths into a single item, as the unbatch block previously created the amount of items that is waiting in the port after one item leaves the port due to reaching the maximum waiting time, the top incoming path will open up for all items left waiting at the port. This method ensures that whenever one item has waited for the set time, all other items waiting at that moment will be shipped with this item to fill up the container as much as possible.
Once again, a queue is placed for practical reasons and a set block is used to set some attributes. These attributes refer to the cost calculation and will be explained later on. The set block between the unbatch block and the select item in block sets two attributes, weightsum and volumesum, and gives them both the value zero. These attributes are also used for the cost calculation. After the select item in block all items follow the same path as they will be put on one container. The path is almost similar as in the scenario that a full container is shipped. The queues in this path are again for practical reasons while the get block is used for the cost calculations and the history blocks main purpose is to list the items on the container. The following batch block is used to batch all the pallets into one container, it gains the batch quantity by usage of the formula block. The formula in this blocks = quantity + 1. As the quantity attribute ignores the one pallet that left the port after waiting for the maximum time. The last blocks are identical to the previous scenario, although this time the activity block is connected to the cost calculations.

5.1.3.4. Cost calculations

The last part of the simulation that requires explanation is the section that calculates the costs for the less-than-full load shipments. The last section of the model has been presented in figure 19.

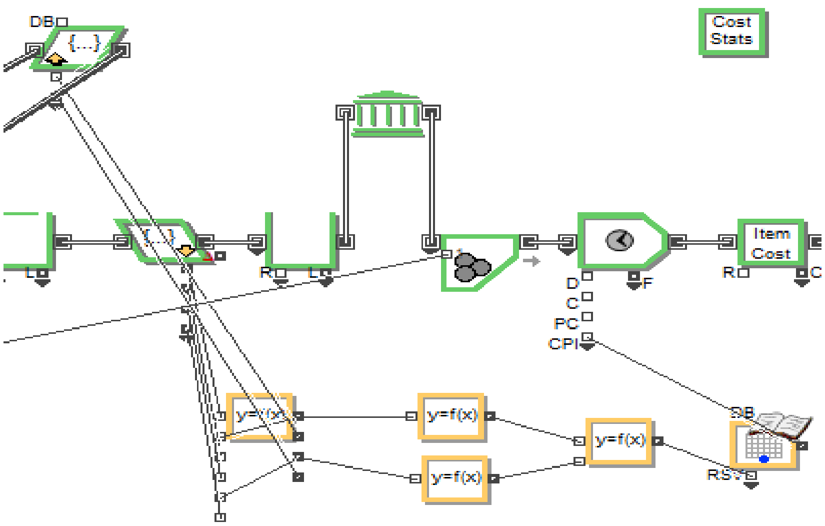


Figure 19 Simulation's cost calculations

The first item that will flow through this path is the item that got its volumesum and weightsum attribute set to zero. It will enter the first get block and therefore sending a signal to the equation block with the following formula:

$$weightsumb = weightsum + weight;$$
$$weightsum = weightsumb;$$
$$volumesumb = volumesum + volume;$$
$$volumesum = volumesumb;$$

The formulas sum up the weight and the volume of the pallet to the value zero received from the first item. This value is set equal to two other attributes: weightsum and volumsum. These values are connected to the set block a few blocks back in the simulation. Every other item that will end up in the same container as this first item will pass through this block and receives the new values. These new values are needed to continue the summation of the weights and volumes till all items past the get block. The second pair equation blocks are used to round up the weightsum and volumesum to integers, this is necessary for the final cost calculation. These formulas are very long but the first rows of the equations will be presented.

Top block:

```
if (weightsum < 100.1)
weightroundup = 100;
else if (weightsum > 100 AND weightsum < 200.1)
weightroundup = 200;
else if (weightsum > 200 AND weightsum < 300.1)
weightroundup = 300;
...
```

Bottom Block:

```
If (volumesum < 0.01001)
volumeroundup = 0.01;
else if (volumesum < 0.02001)
volumeroundup = 0.02;
else if (volumesum < 0.03001)
volumeroundup = 0.03;
...
```

The volumes are placed two numbers behind the comma to make the third equation block possible. The third equation block simply adds up the selected weightsum and volumsum into one number, thus placing the weight in front of the comma and the volume behind the comma but still operating as one value. This is a necessity to enable the last block, the read block, to look up the costs from a database as it can only look up one attribute at a time. The database lists the attribute and the connected costs obtained from 3PL1 for the different ports and the read block reports this cost back to the activity block which will apply the cost after an item, the container, passes the activity block.

5.1.4. Different scenarios

To make the results of our model more reliable and comparable to the current state, additional models are created representing different scenarios. Each of them has their own characteristics and simulates real case scenario handling the same demand patterns. If an additional model differs significantly from the models explained in the previous section, an elaboration will be performed on the differences. Nevertheless, to see the impact of the implementation of a consolidation strategy, the analysis will start with a diving into the current situation and its attached costs.

As every other properly operating company, Haldex records their costs on transportation. It could thus be argued that the costs of the current policy are easily obtainable by taking the past costs. It has been chosen not to go this way as there are multiple flaws with this tactic. First of all, to compare different scenarios correctly the same input should be used. As the past data used different demand data the results would be flawed. Besides using the same input data, it should also not be forgotten that the same assumptions need to be made in both scenarios, hence it is considered optimal to analyze the costs in both scenarios with usage of similar simulations. Lastly, as the events affecting the past data naturally already occurred, the past data includes emergency shipments and other unpredictable correction operations thus increasing the costs. These unforeseen costs are not included in the simulation and should thus be excluded from the current scenario analysis.

5.1.5. Current scenario

Two scenarios have been created to frame the current situation. According to Haldex, suppliers are not actively aiming to consolidate their individual items for Haldex on the same pallet, truck or container. If that still happens it is usually due to coincidences and the logistical partner saw the opportunity at hand to consolidate in this specific instance. To not fully exclude the latter case a worst-case / best-case approach was chosen to cover all possible scenarios. It has still been assumed that the worst case has a higher probability to appear, thus the truth lies somewhere between those two boundaries with a strong tendency for scenario 1.

To approach the most accurate representation of the costs assigned to the current distribution network between China and Sweden two scenarios have been developed. Both scenarios can be seen as the extreme forms of today's status quo. In the first case, the best case scenario, each supplier applies an internal consolidation, i.e. if Haldex orders more than one type of component, both items will be dispatched to the same shipment. This reduces the amount of shipments per supplier. As internal consolidation is performed in this scenario, some adjustments need to be done to the previously explained model. In the new model, the components of a supplier enter the same queue at the port where the waiting time is 15 days. This way, they are placed on the same container. An example for the supplier Supplier9 International Trade Co., LTD. is placed in figure 20.

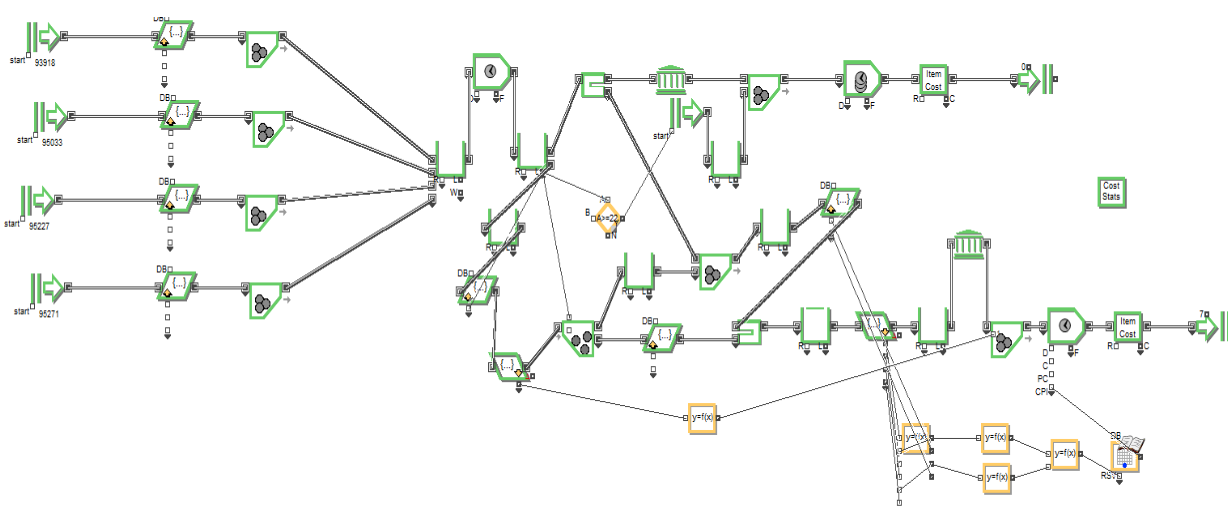


Figure 20 Internal consolidation at Supplier9

On the other hand, a worst case scenario has been designed, representing a pure order-reception/immediate shipping policy. In other words, as soon as the supplier receives the order from Haldex, the items will be sent out immediately without considering any other current or future demand. The simulation will look similar as it has been explained earlier in the report, although it has logically be performed for all the other items as well. As the items are not consolidated in this instance, not even among the same supplier, all items have their own path inside the simulation. This in practice means that the previous showed model for Supplier10 in figure 20 is copied 20 times while every time different component characteristics are added and the costs for the corresponding ports are used. Afterwards the total costs are measured. It has been decided for now to exclude the products that are shipped by air, this has been done as it is unclear if they could join the consolidation policy and therefore they should be excluded as well in the current scenario. A chapter further in this report will be more devoted to the air-shipped products to not fully exclude them.

The two cases serve as a range of possible appearances. To assure comparison between the two cases and the consolidation scenario, input data was defined. The time of delay for the queue, meaning the fixed waiting time at each port, has been set to 15 days. 15 Days has been chosen as the current policy at Haldex for Chinese suppliers, meaning they order 3 weeks of demand every time a purchase order is placed. This grouping of 3 weeks of demand is successfully imitated by setting the maximum waiting time to 15 days. Furthermore, the forecasted demand for the upcoming months was used in both cases. After running the simulation the cost represented in figure 21 arose as a result. As data has been used for May till December, the costs are applicable to an eight month period.

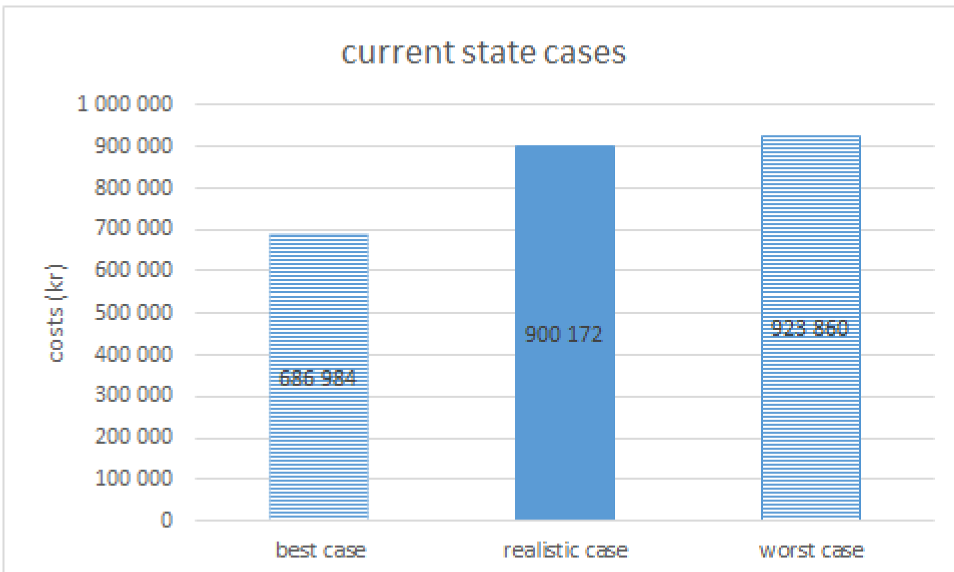


Figure 21 Total cost for the current state

If all goods are delivered instantly, the costs for transportation result in around 923.860 kr. While in the case of internal consolidation the total cost drops down to 686.984 kr. As stated before, it could be assumed that internal consolidation executed by suppliers is currently solely coincidence. Hence, the worst case scenario can be seen as the most probable. Nevertheless, to not fully exclude the internal consolidation effect, it was partly integrated by setting the cost at 90% of the gap between both cases, which concludes in 900.172 kr. for the most feasible case (realistic case). To get a better understanding of the underlying numbers of figure 21, the costs by categorizing the suppliers by port are presents in table 9.

Table 9 Current costs per supplier

	Shanghai	Qingdao	Fuzhou	Nansha
best-case	235457	267377	122417	61734
worst-case	281688	418268	137680	86224
realistic case	277065	403179	136153	83775

From the table it can be seen that the different between worst and bad case is the largest in Qingdao and Shanghai. This means that the savings opportunity are the largest in these ports by just applying internal consolidation. To bring a deeper insight into the costs connected to the previously discussed scenarios, two graphs have been made containing the amount of LCL containers and the average amount of pallets per container. Figures 22 and 23 show these numbers.

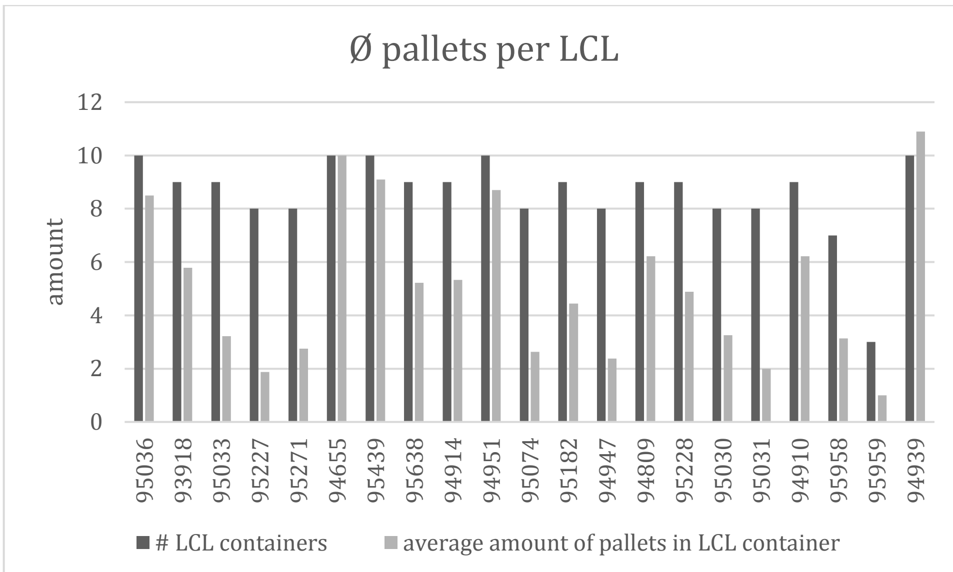


Figure 22 Average pallets per LCL - no internal consolidation

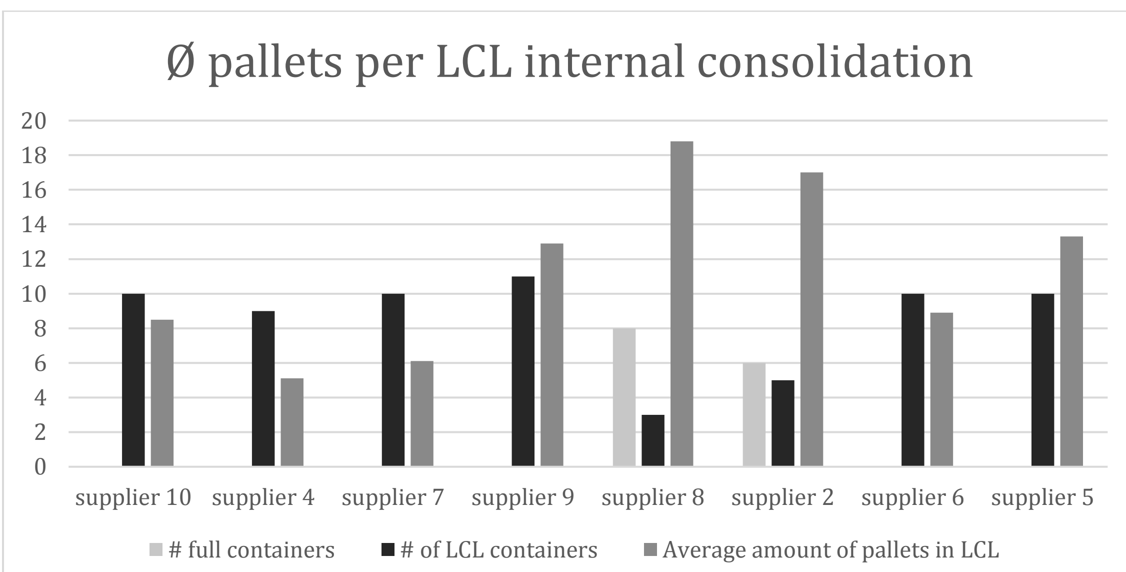


Figure 23 Average pallet per LCL - internal consolidation

From the graphs and the costs, it can be seen what the effect of a first consolidation step would be. If only internal consolidation is applied, costs are 25,6% lower as with no internal consolidation. If the last graphs are compared it can be seen why the other scenario decreases the total cost. On average, the amount of pallets per container becomes a lot higher as with no internal consolidation, and as the demand stays the same, the amount of container shipments drops significantly. Two suppliers, Supplier2 and Supplier8 even manage in some months to create full containers on their own while staying with the three-week demand policy. Nevertheless, it does not have an effect on all suppliers as Haldex only sources a single component from some suppliers. Obviously, internal consolidation will not result in cost savings for these suppliers. To enable cost-savings for these suppliers as well and increase the cost savings for the other suppliers, deeper consolidation scenarios have been developed for the future.

5.2. Consolidation opportunities

5.2.1. Applying consolidation to the current scenario

With the numbers of the current scenario retrieved from the model, the path has been paved to look into extra consolidation opportunities for the future. As described in the beginning of this paper, the suppliers of Haldex are geographically divided along the Chinese coast. At the moment Haldex uses the four aforementioned ports to transport the goods to Sweden. As the suppliers are all closely stationed by one of the four ports, the ports could be used as consolidation hubs. At the moment 3PL1 already has a consolidation warehouse in Shanghai which could be used for these purposes, but as the future demand is known a year in advance, proper scheduling of purchase order should exclude the need for long storing at a warehouse as the goods arrive around the same time. Similar adjustments to the model as with the internal consolidation need to be made, this time all the suppliers that ship through the same port will be connected to the same queue. The simulations for the different ports can be found in Appendix H.

To determine the lucrativeness of consolidation for Haldex, in essence it all comes down to the total cost of the applied distribution network. The on-hand work covers only a fraction of Haldex supply chain, but beside that it still gives an indication and could be generalized for other sites and parts of its network. To decide what the optimal maximum waiting time would be for a consolidation strategy all different options were simulated and the graphs are created per port. The parameters were thus set separately among ports. The graphs 24 to 27 show the results per port. The corresponding tables are presented in Appendix I. On the x-axis of all four graphs the maximum waiting time has been placed, scale of the axis is different though per port as results are totally different. The costs are using the y-axis on the right while the container amounts are using the axis on the left. It has to be mentioned one more time that the maximum waiting time is not the exact amount of time between shipments, but the amount of time between shipments in the most extreme case allowed. Often, the loads will be shipped more frequent.

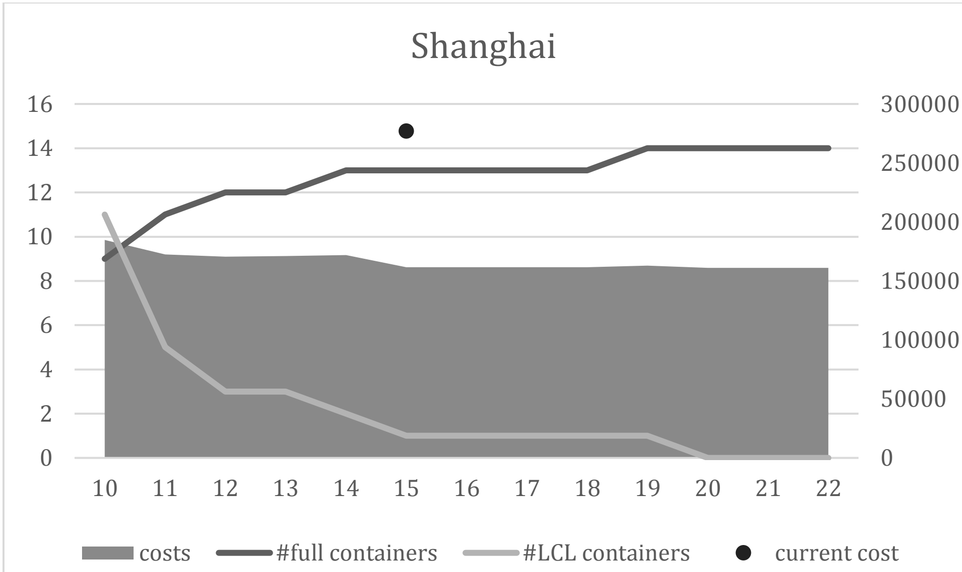


Figure 24 Consolidation results in Shanghai

At the port of Shanghai the optimal transportation cost can be reached when the maximum waiting time is 20 days as with that amount of days only full containers will be shipped to Sweden. 20 Days might seem like a large number of days, but it should be noted that the savings effect compared to setting the maximum waiting time to 15 days is very small. This is due to relatively low demand in one single period, which lets one shipment wait for 20 days till its capacity is reached, while in the other months all ships are send of after maximum 15 waiting days. If thus the lowest possible transportation cost needs to be achieved, it is advisable to set the maximum waiting days to 20, but if it is preferred not to hold items on stock for four weeks, it will not have a large cost effect to set the maximum waiting times to 15 days. If the new costs are compared to the old cost, the costs drop with a bit more than 40%.

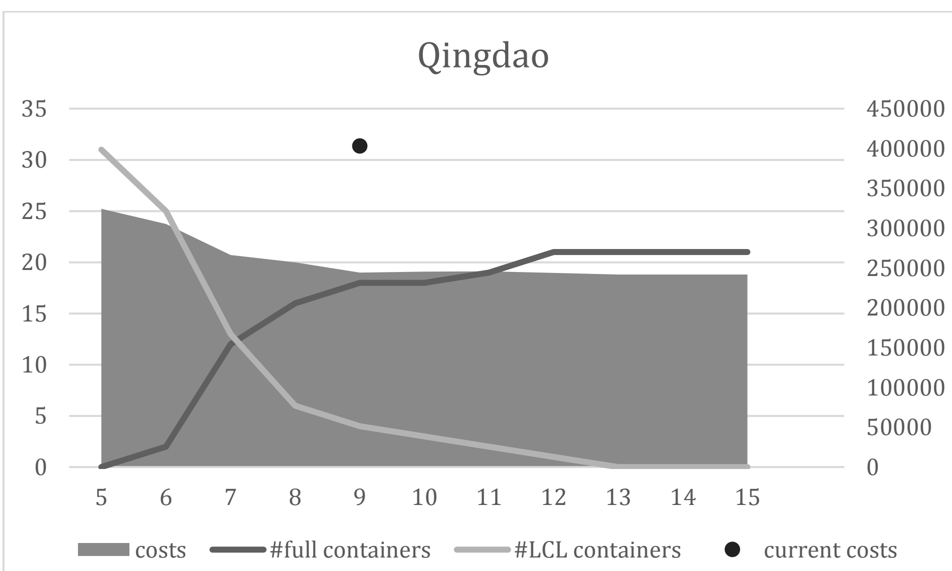


Figure 25 Consolidation results in Qingdao

As Qingdao has the largest current costs due to the large amount of components shipped from Qingdao, the consolidation opportunities are the largest. If only full containers are shipped, the costs drop again with around 40% but in absolute numbers, a consolidation strategy is the most profitable at Qingdao. Due to the large demands, full containers are also already reached at a maximum waiting time of 13 days.

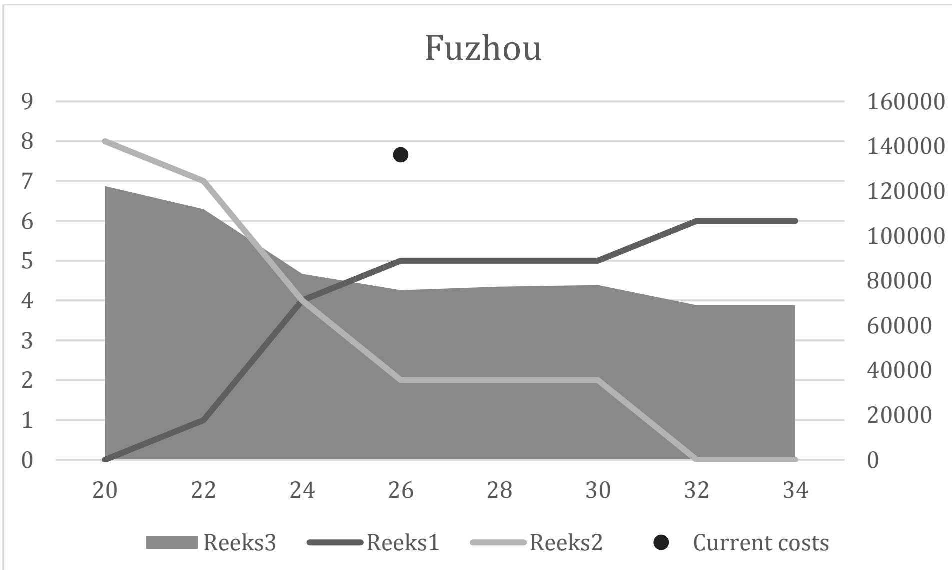


Figure 26 Consolidation results in Fuzhou

At Fuzhou port, cost savings of around 50% can be obtained with a consolidation strategy. As demand is low though, the maximum waiting time has to be set to 32 days or six and half weeks. Due to low current costs, the absolute savings are not as high as at the two previous ports, so it is advised to Haldex to analyze how long they would prefer to have their stock on hand. The supplies from Fuzhou are using consignment stock so it is more a space than a cost concern.

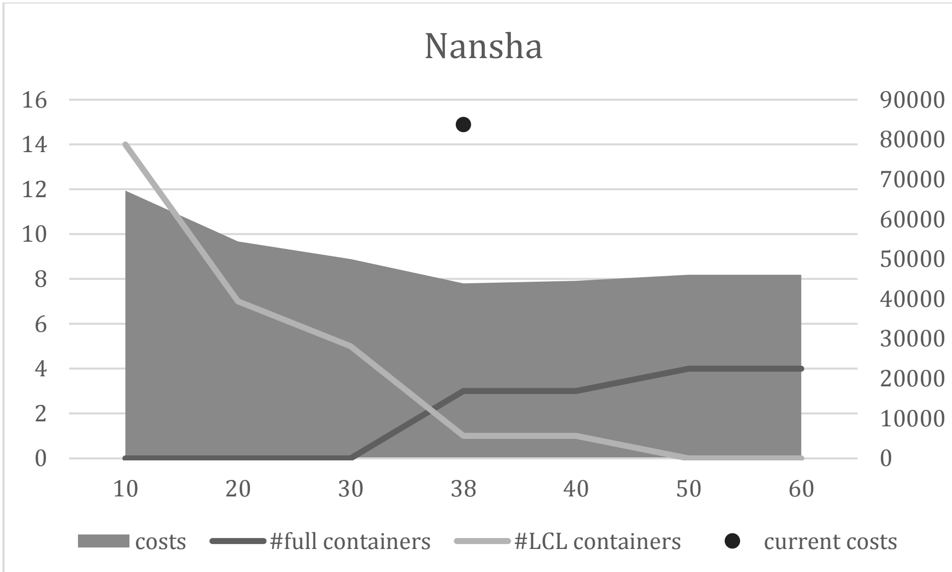


Figure 27 Consolidation results in Nansha

The last port has the lowest current costs and therefore also the lowest cost saving potential. Still costs of around 55% could be saved by implementing a consolidation but the maximum waiting time needs to be set to 38 days. As with 38 days, the one container that is not full only has a small volume, this becomes actually cheaper as having another full container. Due to extremely low demand for Nansha, it takes a lot of time for the containers to be filled to their capacity. The same questions as with the port of Fuzhou should thus be asked, although again the positive note is that these suppliers use consignment stock.

The figure 28, displayed below, illustrates the achieved total costs of the current state (realistic case) and the total costs in case of consolidation. While the current set-up creates overall costs in the amount of 900.172 kr the cost for consolidated distribution come to 515.810 kr. The comparison leads to a delta, i.e. cost savings of 384.361 kr, which implies a cost reduction of around 42.70%.

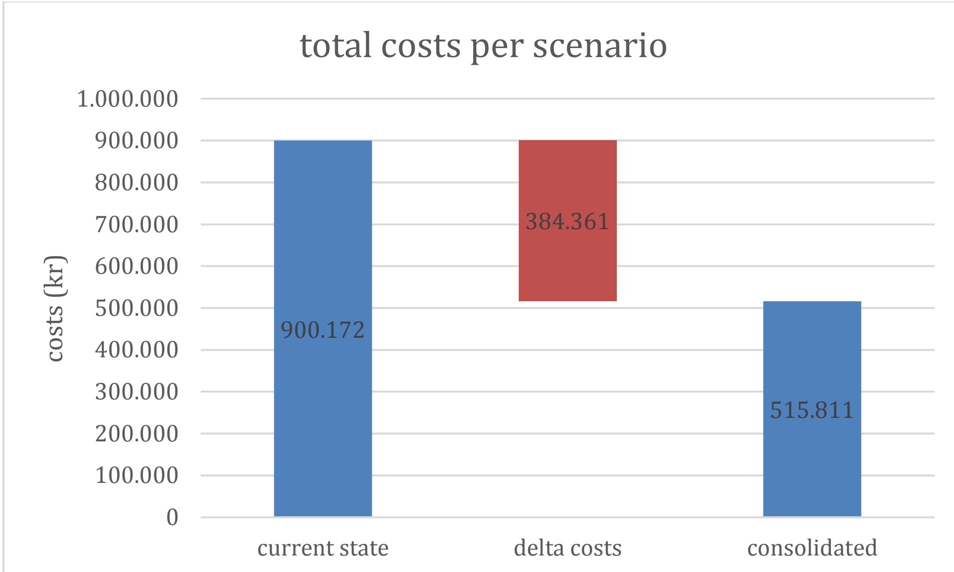


Figure 28 Total cost savings with consolidation

Table 10 gives a deeper view on the cost savings by splitting them up per port. If Haldex prefers to start consolidating only at 1 or 2 ports, the numbers in the table can be used as reference.

Table 10 Cost savings per port

	realistic case	consolidation	savings
Shanghai	277065	161149	115916
Qingdao	403179	241724	161455
Fuzhou	136153	69064	67089
Nansha	83775	43873	39902
total	900172	515811	384361

To realize this exact amount of cost savings, a consolidation proposal is presented in Appendix J. The tables indicate which items needs to be shipped at which moment in time, thus when the components need to be ordered. Every time an item is listed, the meant quantity is a full pallet. As demand is dynamic, the proposed order schedule should be continuously corrected and altered to fit the latest needs of Haldex. It is thus not advised to take this schedule as a strict plan which guarantees the savings, but it gives a good idea of how much to order on average per component per shipment.

5.2.2. The effect on the stock levels

Besides the hard savings on the transportation side, it is interesting to see what is happening on the inventory side. As described before, less inventory is necessary when orders are placed more frequently. As the maximum waiting time is just an indication of how large the time can be between orders, it is not necessarily the average time between shipments after implementing the consolidation strategy. By calculating the times between shipments and comparing it to the current policy of shipping three weeks demand, it can be seen if the total stock could be expected to reduce at Haldex' warehouse. Table 11 shows the shipment times.

Table 11 Shipment times

Qingdao		Shanghai		Fuzhou		Nansha	
Shipment	Time	Shipment	Time	Shipment	Time	Shipment	Time
1	13	1	16	1	26	1	45
2	19	2	26	2	51	2 not full	83
3	27	3	36	3	83	3	116
4	34	4	47	4	104	4	151
5	40	5	61	5	129	Average inbetween	35,33
6	49	6	80	6	159		
7	59	7	90	Average inbetween	26,6		
8	70	8	100				
9	87	9	110				
10	89	10	120				
11	96	11	130				
12	104	12	139				
13	110	13	150				
14	116	14	164				
15	125	Average inbetween	11,38				
16	131						
17	139						
18	146						
19	154						
20	161						
21	174						
Average inbetween	8						

From the table it can be observed that on average shipments will be send more frequent from Shanghai and Qingdao and less frequent for Fuzhou and Nansha. This is in correlation with the demand intensity from these ports. Haldex will thus on average need to have eight days of stock for the components supplied from Qingdao and 11,38 days for the supplies shipped in from Shanghai. As these are most items with the highest demand intensity, this will reduce the amount of necessary stock and thus warehouse space connected to Chinese suppliers intensively. It is true that the results point in the other direction when Fuzhou and Nansha are considered. Luckily, there are only few items shipped from these ports with very low demand. The increase will thus be smaller as the decrease of pallets, resulting in an overall reduction of the pallets in the warehouse at Haldex. The numbers of a performed approximation are displayed in table 12. Besides, if Haldex chooses to not implement consolidation at Fuzhou or Nansha due to low demands and thus low benefit opportunities, the amount of pallets can be reduced with 26.

Table 12 Pallet savings

	Average inbetween	pallets	Average inbetween	pallets	difference	Saving
Qingdao	8,0	22,0	15,0	41,3	19,3	4,0
Shanhai	11,4	22,0	15,0	29,0	7,0	
Fuzhou	26,6	22,0	15,0	12,4	-9,6	
Nansah	35,3	22,0	15,0	9,3	-12,7	

The consignment stock becomes an important factor when stock changing is discussed. If more stock is necessary from a certain supplier, the costs will be lower in case the supplier uses consignment stock. As mentioned in the literature review, this is mainly due to exclusion of opportunity costs, storage costs is still applicable though. This obviously is a two-sided effect, if the pallet amount decreases, more benefits can be made if consignment stock is not in place as consignment stock mostly pays off with high stock quantities. All the supplies shipped from Fuzhou and Nansha are currently using consignment stock and thus the cost effect of increasing the current stock will not be very large. If the focus is placed on the suppliers that are not using consignment stock, all the pallets will be reduced and cash will thus be saved. Overall it can be said that consignment stock can have an impact on the consolidation strategy as in cases of low demand it could negate the benefits of implementing the strategy. If demand is high though, consignment stock becomes less interesting as the stocks do not necessarily increase. Concluding, it can be stated that a decrease of the total amount of shipments due to consolidation of shipments, still reduces the average time between incoming shipments in most cases, thus the necessary amount of pallets on stock to cover for the demand. If demand is really low, pure transportation costs might be saved but holding costs would rise much faster as the cost savings. The low demand products would thus be benefited by consignment stock.

5.2.3. Demand changing effects

In this report it has been mentioned that a changing of demand could affect the consolidation process and as a result the outcome in terms of costs and benefits. As could be seen in the section of this report where the past years demand of products was presented, a further increase of demand for air disc brakes is expected and with that the sales of Haldex are expected to grow as well over the next years. As implementing a consolidation strategy should not be a short term solution but a long term strategy, future feasibility of consolidation should be explored together with potential cost savings with increasing demand. Three different scenarios have been developed: an increase in sales of 10%, an additional increase of 10% in the following year and, since it is just an estimation of the future, the opposite case has also been considered by implementing a decrease of sales of 10%. This has been implemented in the simulation by alternating the demand input with the mentioned percentages. To re-calculate the cost savings, the current case and the consolidation case have been recalculated. The current case costs can be seen in figure 29.

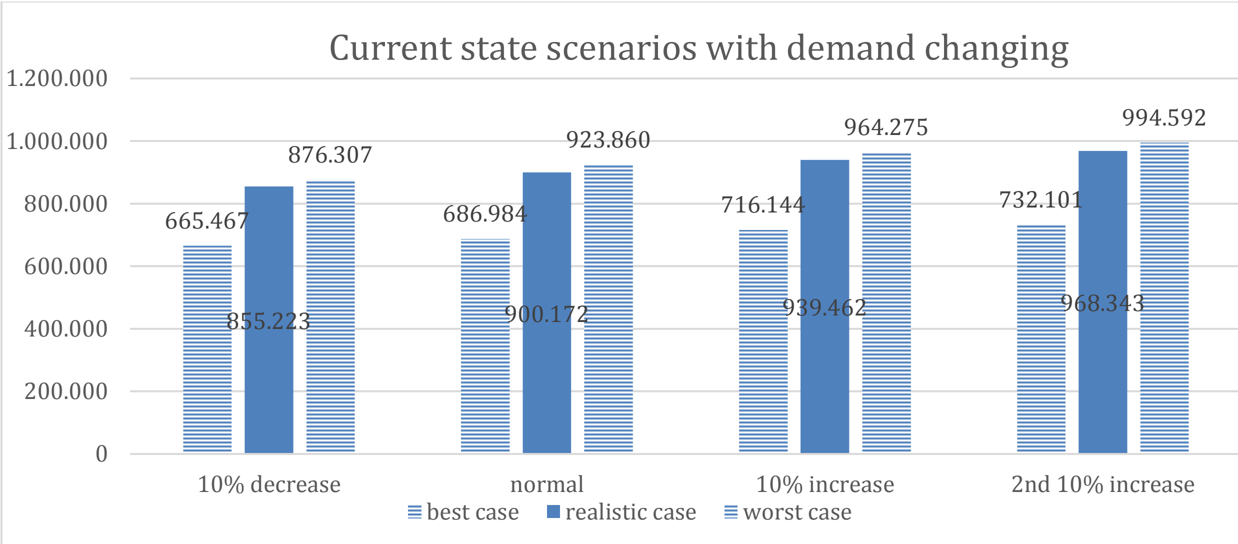


Figure 29 Current state costs when demand changes

As could be expected, the costs increase when the demand increases due to more necessary transports. Unfortunately, the same consolidation strategy cannot be applied in the exact same way as a changing of demand has an effect on the optimal maximum waiting time. Table 13 represents the new optimal waiting times per port.

Table 13 Expected waiting times

	10% decrease	current	10% increase	20% increase
Shanghai	18	20	18	17
Qingdao	17	13	10	14
Nansha	51	38	34	41
Fuzhou	33	32	29	29

From the table it can be seen that the maximum waiting time changes when the demand decreases or increases. The most common pattern is that when the demand increases, the maximum waiting time decreases, this can be explained as more demand for a container means that the container will reach its maximum quicker. Nevertheless, the pattern does not always hold. This phenomenon can be explained as the demand is not constant. As containers are send off earlier when demand increases, new containers will start filling up at different times. This has the effect that containers might start receiving demand at different times, including periods of low demand. To still reach full capacity off all containers and increase in maximum waiting time is thus necessary in extreme cases.
The cost savings of the new consolidation programs have been displayed in the same way as done in the previous scenarios in figure 30.

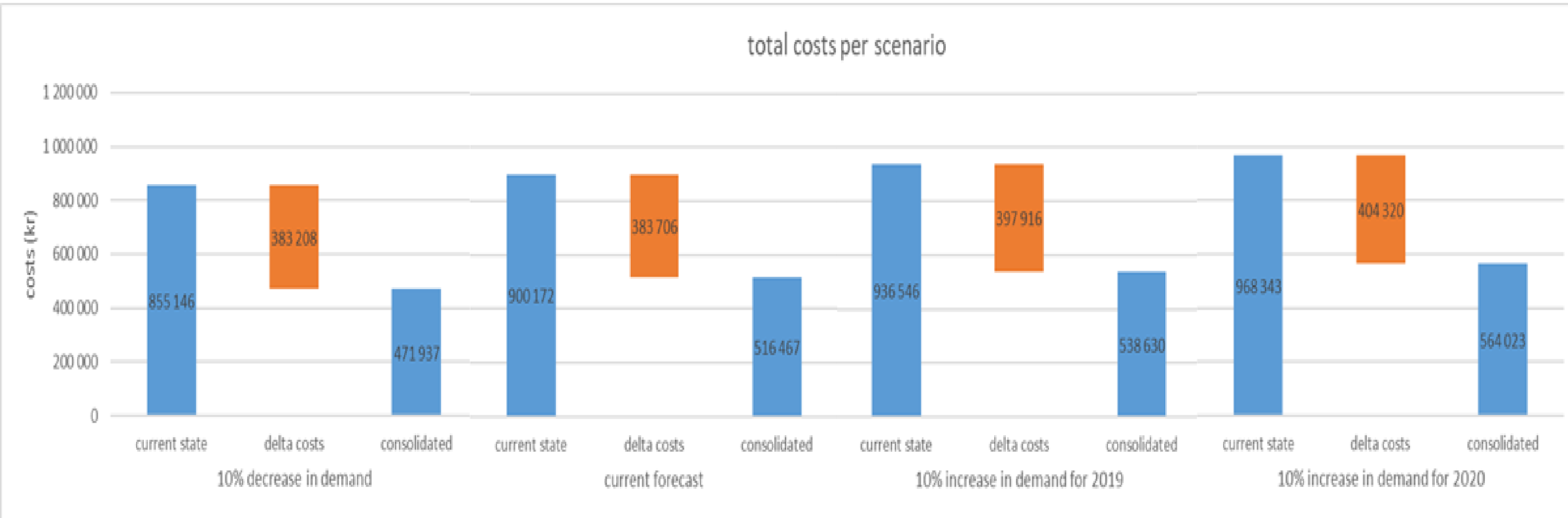


Figure 30 Consolidation saving when demand changes

An increase of demand engenders that the cost saving due to consolidating items comes even more into effect in absolute numbers. Although, percentage wise they drop slightly but not significantly. In the first examined year with demand increase the savings decline from 42,7% to 42,5%. One year later they decline further to almost 41,8%. As the decline is very small, it gives occasion to expect feasibility of consolidation in the future, as long as the demand does not increase in enormous amounts. Still, it is advisable to re-analyze the different maximum waiting times and expected cost savings on a regular basis as the disc-brake market is dynamic when demand is considered.

5.2.4. Air-transport opportunities

In the earlier scenarios the components shipped by air transport were excluded. As written in the empirical data part of this project, interviews with the different departments of Haldex made it clear that the reason why these components are flown to Sweden in the current scenario is that the goods are extremely light which sets the transportation costs low enough to justify air transport. This is not a reason to exclude them from sea transportation, it only justifies the choice for air transport. Throughout the interviews it became clear that no one could give a clear argument against the inclusion of the air products into the sea freight consolidation project. Nevertheless, it needs to be said that it was hard to retrieve information concerning the contracts set-up in the past and the factors that influenced certain transport decision. Hence, it is unclear if there are underlying, more binding reasons why the goods should be transported by air. For this reason, it has been decided to exclude air-transport from the previous discussed scenario's and to give it its own section that Haldex could look into if they decide that it is possible to shift the transportation mode from air to sea.

All suppliers currently using air-transportation are currently based in or near Shanghai and use Shanghai airport as departure hub. The suppliers are thus in the simulation model connected to Shanghai port. 3PL1 has not provided similar cost data to Haldex as with air shipments. They have sent historical data per shipment though including the costs and the chargeable weight per shipment. This data has been used to come up with an average cost of airfreight per weight. It has been decided to only include the flights from Shanghai Supplier3 and Haldex China in the equation and leave out other air transports as for example emergency shipments from different suppliers. The argument for this decision is that the included flights are the closest to the flights in the simulation. 36 Flights over 2017 have in the end been considered and figure 31 presents the results.

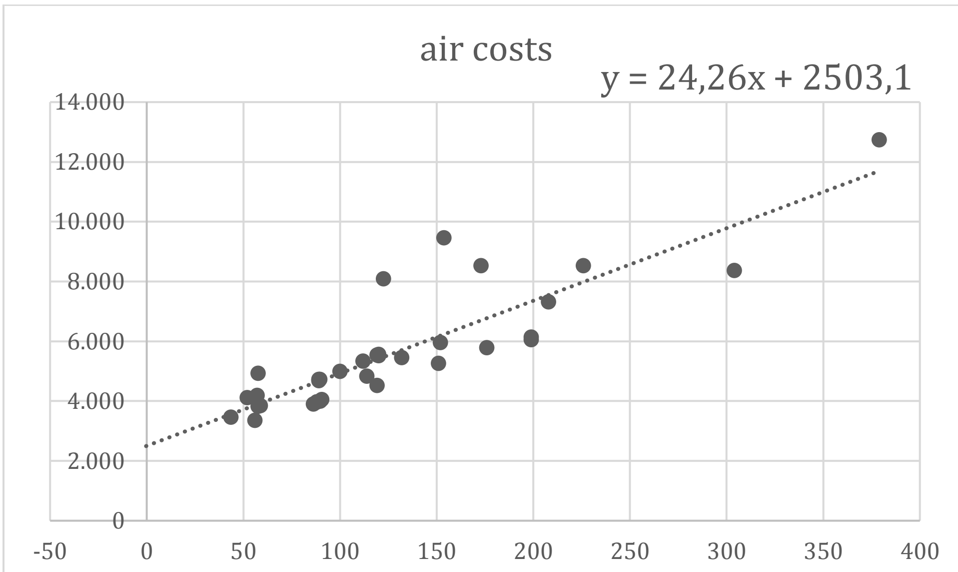


Figure 31 Cost of air-transport on average

As can be seen from the graph, by approximation the costs for air flights can be calculated by using the formula:

$$y = 24,26 * x + 2503,1$$

By replacing the cost formulas in the simulation tool with the formula for air-transport costs, the costs can be easily calculated when it comes to Haldex China. The other supplier, Supplier3, becomes more problematic as it transport small parcels which are placed on a single pallet. Different item numbers, six in total, are placed on the same pallet when an item is ordered by Haldex. In total ten parcels are placed on one pallet and the total pallet quantity it thus ten parcels. Supplier3, therefore already operates in the "best-case" scenario and in contrast to Haldex China a worse-case scenario is thus not existing. The new alterations with Supplier3 do complicate the simulation as multiple product-numbers are placed on a single pallet. Figure 32 shows the new simulation model including the alternations for Supplier3. Haldex

China is not displayed as it works in the same way as the previous model.

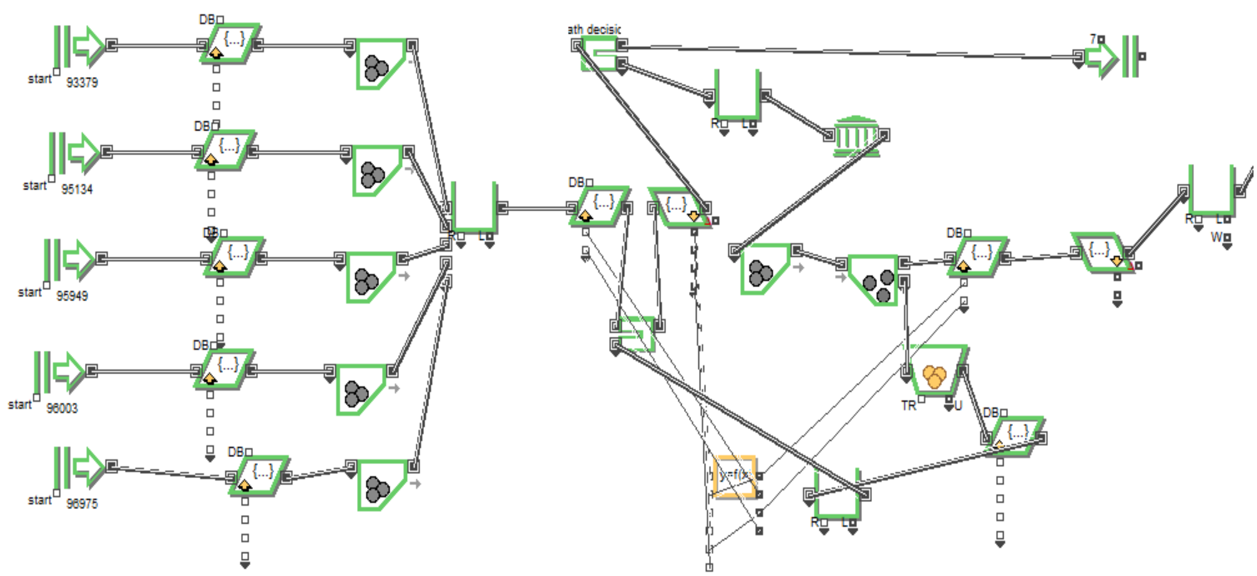


Figure 32 Air transport in simulation

To give an idea of where this model is placed in relation to the previous model, the queue block on the right side of the figure is the same queue block in the normal simulation that represents the port. The first three blocks on the left for each item are still the same as in the normal scenario, afterwards they get placed in the same queue just as with a consolidation policy. The following set block is again used to set the weightsum and volumesum attribute that is needed for the total weight and volume calculations. The next block is used to merge two paths, the other incoming path will be explained soon. When the item passes the get block further in the path, the necessary weight and volume of the items is received from the system and it is summed up in the equation block by help of the same formulas in the cost equations. The select item out block is placed to direct all “real” items into the downward flow and dummy items into the upwards flow where they leave the system straight away in the exit block. The dummy items will be explained further on. In the next spot a queue block is again only used for practical purposes while the history block is needed to list administrative data.

As mentioned before, there is a total of ten parcels per pallets. The items therefore need to be batched into full pallets of ten, this is done in the batch block. Straight after they are unbatched again in one real item and one dummy item. This dummy items follows the downward flow and receives the value zero for all weight and volume attributes to reset the summation of the weight and prepare the system for a new incoming pallet. The recourse block in this “dummy path” of the simulation is used to create one recourse already at the start of the model that sets all attributes to zero before the first demand comes in. The real items that leave the unbatch block receive their total weight and volume of the pallet from the set block and the volumesum and weightsum values get set back to zero at the last set block to not mess up with further calculations.

The current state simulations have been run and the results can be found in figure 33. Again, as data has been used for May till December, the costs are applicable to an eight-month period.

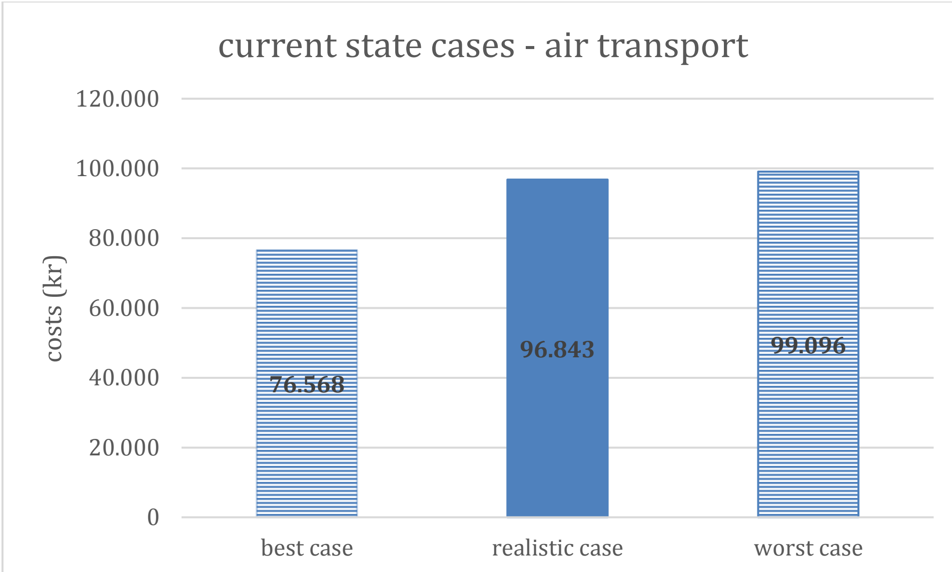


Figure 33 Current state costs for air transport

The cases are relatively close to each other but this is not too important as the real cost effects will appear when the air-transports shift their mode to sea-transports. The main reason for the low difference between the two cases is the low demand and thus the low amount of pallets shipped. A table in Appendix K shows the shipped pallets in case of the best case scenario to give an idea of the amount of pallets that currently use air transport.

Adding the air-transport to the sea freight consolidation is easily done by just adding them to the other suppliers at Shanghai. The new costs are shown in figure 34. The left bar shows the previously proposed consolidation strategy plus the realistic case of current air-transport. The right bar shows the total costs if air transport is included as well.

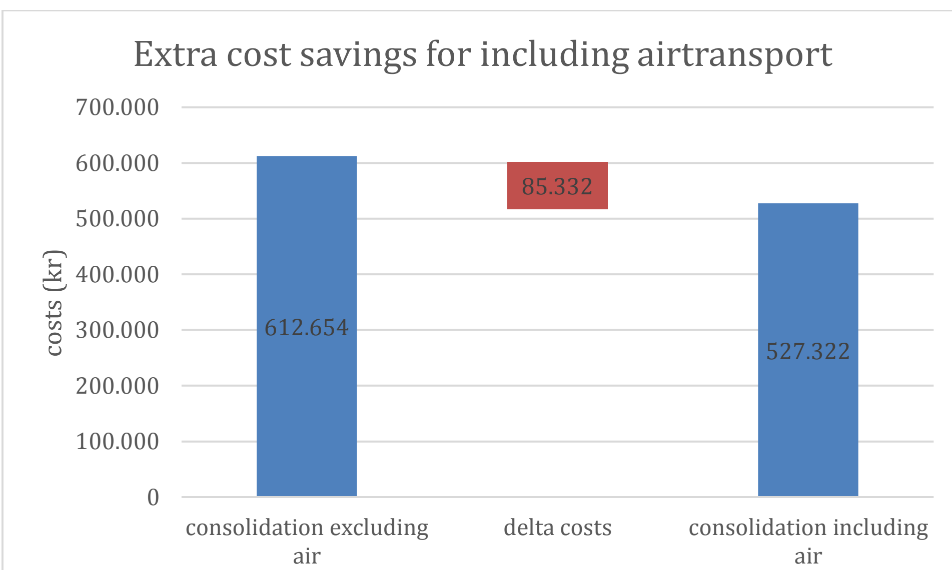


Figure 34 Saving opportunities with air-transport

Although demands are not high when it comes to Supplier1 and Supplier3, the cost saving effect of adding their products to the consolidation strategy is still substantial. The costs are lowered by an extra 85.332 kr. The question now stays if the products are actually suitable for sea-transportation, but the results do prove that more cost savings can be obtained.

5.2.5. Sustainability

Not solely the transportation costs play a key role for Haldex. When it comes to the reflection of distribution processes, the consumption of fuel and the assigned production of pollution becomes also important. Therefore, the authors decided to take the caused CO_2 emissions into account and include them in their analysis. Hence, not only the aforementioned costs but also the amount of shipments for each scenario have been examined and confronted in comparison.
To calculate the amount of CO_2 emissions, few assumptions had been made. First of all, all applied sailing distances (table 15) are based on actual routes in commercial sailing schedules (sea-distances.org). It is assumed that the carrier always chooses the shortest route for shipping by sea, i.e. in this case, through the Suez Canal. In the case of airfreight transportation, the direct connection (shortest distance) is applied. Secondly, Haldex is exclusively responsible for the fraction of weight, they are contributing.
According to ECTA (the European Chemical Transport Association) CO_2 emissions are officially calculated as followed:

$$\begin{aligned}\text{CO2 emissions} = {} & [\text{transport weight} * \text{transport distance} \\ & * \text{CO2 emissions factor per tonnekm}]/\text{transport mode}\end{aligned}$$

Table 14 CO2 emission factor

Container vessels	gCO2/tonne-km
Small container vessel (2500 tonnes)	**13,5**
Larger container vesssel (2000 tonnes)	**11,5**
Average deep-sea container vessel	**8,4**
(assuming mean 11 tonne load per TEU)	
Aircraft	**602**

According to McKinnon for short-sea shipping an average emission factor of 16.0 gCO2/ tonne-km is recommended. For deep-sea shipping Mckinnon is proposing an average of **8.4 gCO2/tonne-km** for container shipping, which is applicable for our purposes. As the mean length of haul for air freight movements in the Cefic survey was 7000 kms, an average of the two long haul emission factors i.e. **602 gCO2 /tonne-km** is proposed by McKinnon.
As an example serves the connection between Shanghai port and the port of Gothenburg. Applying the numbers stated in table 14 CO2 emissions total up as follows.

$$CO2 \text{ emissions} = 1{,}948 \text{ tonnes} * 10.969 \text{ km} * 8{,}4 \text{ g} / 1.000.000 = 179 \text{ kg } CO2 \text{ emission}$$

Throughout the analysis it became obvious that the reduction of shipments itself does not have any impact on the total amount of emission produced by Haldex. The total weight shipped is only sliced into different sizes and distributed over different number of shipments. The amount is only shifted between the two factors of the equation if you multiply the CO2 emissions by the amount of shipments. Either the weight or the number shipments increases, but the relation stays the same and will finally result in the same amount of emissions.

Table 15 CO2 emission savings

Mode	Origin	Destination	Distance (km)	CO2 (kg)
Sea	Shanghai	Gothenburg	10969	179
Sea	Shanghai	Helsingborg	11053	-
Air	Shanghai	Malmö	8256	12 863

While the reduction of shipments achieved through consolidation does not have the desired effect, the shift of transport mode for the two suppliers, currently flying their goods to Sweden, to sea accounts in noticeable emission savings. The table 15 shows the results for both cases. Applying the predicted demand for those items for 2018 the CO2 emissions are reduced from currently 12.863 kg CO2 to 179 kg CO2 i.e. a decrease of 99% emissions for the applied weight.

Although the application of consolidation does not reduce the CO2 emissions directly, the increased amount of full containers still has an impact on sustainability. Not only is the regional transport in Sweden affected, as containers could be picked up directly at the port and delivered to Haldex, but also full containers shipments are guaranteed. The latter ensures fully used container space on the behalf of Haldex but unfortunately data on the current usage of other container space by external companies is unavailable, but even though emission savings cannot always be quantified, a consolidation strategy can only affect emission in a positive matter.

5.3. Monitoring

According to all interviewees, the key information for the following process of receiving is the expected arrival date of goods. That includes the entire portfolio of supplies, not only the goods purchased from Chinese suppliers. This information should be shared along each party being affected at least 24 hours in advance, to ensure to have the right staff in place and divide the workload accordingly. In addition to that, it is crucial to know which items are critical, where awaited supply is currently, when is it expected to arrive and whether there is any action necessary. The required information is mainly motivated by the current morning meeting. All the aforementioned info is currently distributed at this meeting, not unstructured but neither digitally presented. One important downside is that information is only stored for a certain period and can only be seen as snapshot, which might be already past an hour later. Furthermore, the information shared in the current process only covers one specific day and is not meant for anticipating upcoming problems. Although it is accessible for all employees, the receiving staff either do not know how to extract the needed information from the ERP-system or it is not illustrated in a proper way.

To identify the critical parts Haldex employees usually check the current stock-on-hand, the corresponding safety stock and scheduled planned (BOM line) and booked production lines (production line) and the in-transit inventory. If any of these factors indicate an issue for production, the affected items will be discussed in the daily morning meeting. Haldex categorizes them by their criticality i.e. does the stock level, covering in-transit and on-hand-stock, of a specific item reaches a certain point, the item becomes critical. Usually that happens if the level is about to fall below the safety stock quantity (green category), already consumes parts held for the safety stock (yellow category) or affects the planned production schedule (red category). In all cases it might be crucial to share this information in advance to avoid or at least mitigate the risk of urgent deliveries or in worst case scenario interruptions for production.

To complicate things, the application of several filters is needed to find the information related to expected incoming goods (open loads). Sometimes, for instance in the case of the "item arrival date", Haldex has to keep track of the item and even update the data manually. This date is currently not displayed in the initial grid and can only be accessed by calling up that specific order line. Thus, it is not possible to view the ETA (expected time for arrival) for the entire day, week or for any other time unit. At the moment a load and the attached ETA are created simultaneously. The most reliable arrival date is the so called "item arrival date", which is indeed connected to all loads created so far but is found in a complete different section of the ERP system (procurement and sourcing). Another obvious upside is that this field is manually adjustable when a change of the ETA needs to be performed. Unfortunately, this date does not affect any other process within the ERP-system including the process of production scheduling. Due to that planning needs to adjust this information twice to ensure the MRP is updated and is executing the plan based on the right numbers. According to one of the responsible persons for the implementation of the ERP system, the date has also been kept updated to ensure the right arrival date is matched to the right purchase order line (POS). Therefore, the user has to call up each item individually in the "advised item arrivals" window.

To improve the current state of monitoring the aforementioned data, the authors identified information, which should be displayed, preferably as a commonly used real-time report. Haldex uses Atlas to design and generate reports. Since this work is limited to 12 weeks and the process of designing those reports is quite challenging and time consuming, the on-hand thesis provides a guideline for creating the right report with the necessary information, instead. Therefore, a dashboard has been designed. The underlying idea was to give guidance to Atlas designers for implementation. In the end of this section a sample is presented to give the reader an impression of how it could look like after implementation. In the next step, firstly, the data extraction is described to proper extent.

Moreover, in collaboration with the planning department it has been decided to integrate the expected arrival date not only in the required field "item arrival date" but also in the "all loads" grid where filters are applicable and the needed information is easy accessible. Along several other unused dates appearing at that grid the ETA column was selected as the most relevant. In order to do this the grid has to be individualized, since the ETA does not appear in the standard version. Two factors were mainly taken into account. First of all the name implies exactly the expected information and does therefore not lead to further confusion and second of all this field is also manually adjustable with just a few clicks. In addition to that, the field is directly linked to the “advised item arrivals” and could easily be fixed after the initial input of the “item arrival date”.

5.3.1. Information extraction

According to the overall goal: making the information accessible for the entire company; a standard way to extract the data from the ERP system was developed. As aforementioned, one key aspect was the presentation of useful information in one screen. Therefore, a personalized filter was created sorting the data of interest in a clear way. The final version of that filter can be seen in the figure below. The tab “all loads” can be reached through the section “warehouse management”.

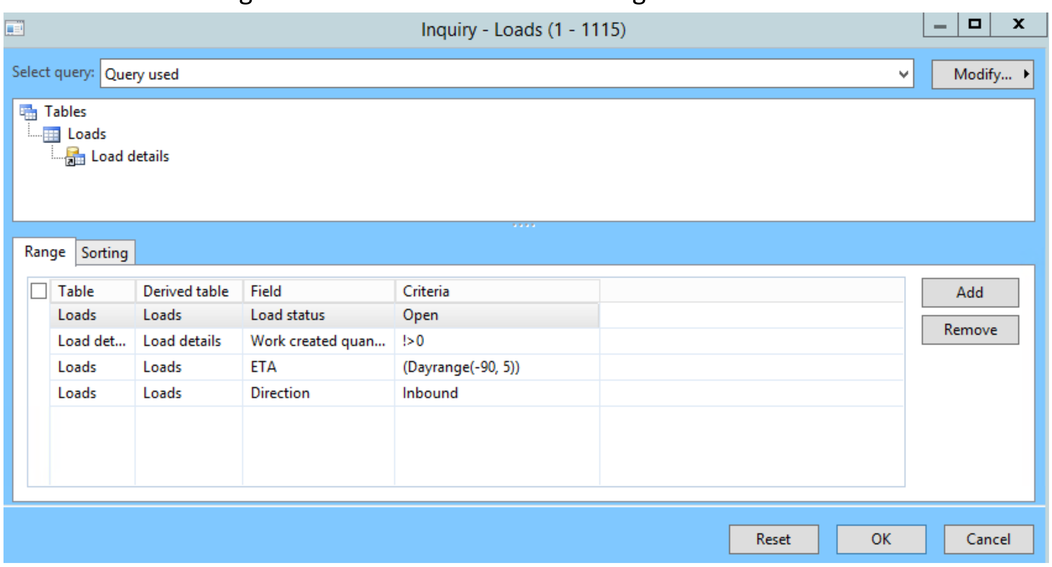


Figure 35 Personalized filter

In order to define a personalized filter (see figure 35) a new query has to be created as follows. When a load is created its first status is always “open”. It changes during its life cycle to “in progress”. In current case only loads, which have not processed yet are relevant. Applying the first line causes a limitation of the display to all loads in the beginning of their cycle. The selection on the “load details” “work created quantity” eliminates any line on which work has been executed. Changing the criteria of that line to “!>0” entails that all other lines are not displayed. The ETA field is updated by the load creation function when the load is actually created. Using the “dayrange” filter enables the user to store a value that will not have to be changed every time the filter is applied. The first argument in the dayrange function is the number of days passed till today and is set as the low bound of the range. The second argument is the corresponding upper bound, defining the amount of upcoming days displayed. The last line reduces the remaining loads on inbound orders.

The application of the personalized filter results in the following table (figure 36). “All loads” are now structured the way described before. In this way the necessary information can finally be seen at a glance.

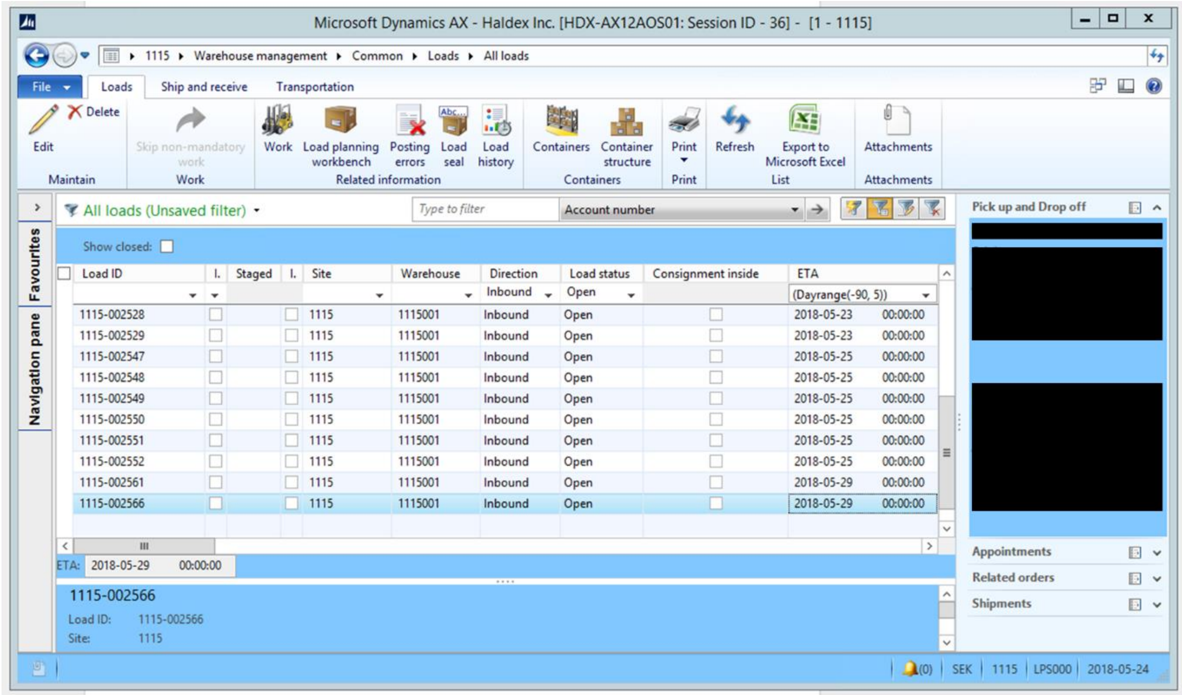


Figure 36 Upcoming deliveries

Taking the “today's” date into consideration a range of 95 days, 90 back in the past and 5 work days, was chosen and should cover all open and active loads. Usually there are no shipments with lead times exceeding 3 months. The last load listed is exactly 5 work days from the day the data was extracted. It is crucial to keep in mind that the date found in column ETA is still the expected time of arrival when the load was initially created and was not updated so far. In future, the ETA field will be constantly adjusted as described in previous paragraphs.

Now the planning department uses the “item arrival date” to set and update a reliable receiving date for purchased items. The item arrival date is attached to “advised item arrival grid” and can be reached through the procurement and sourcing section. The tab “item arrival data” uncovers the actual date (see figure 37).

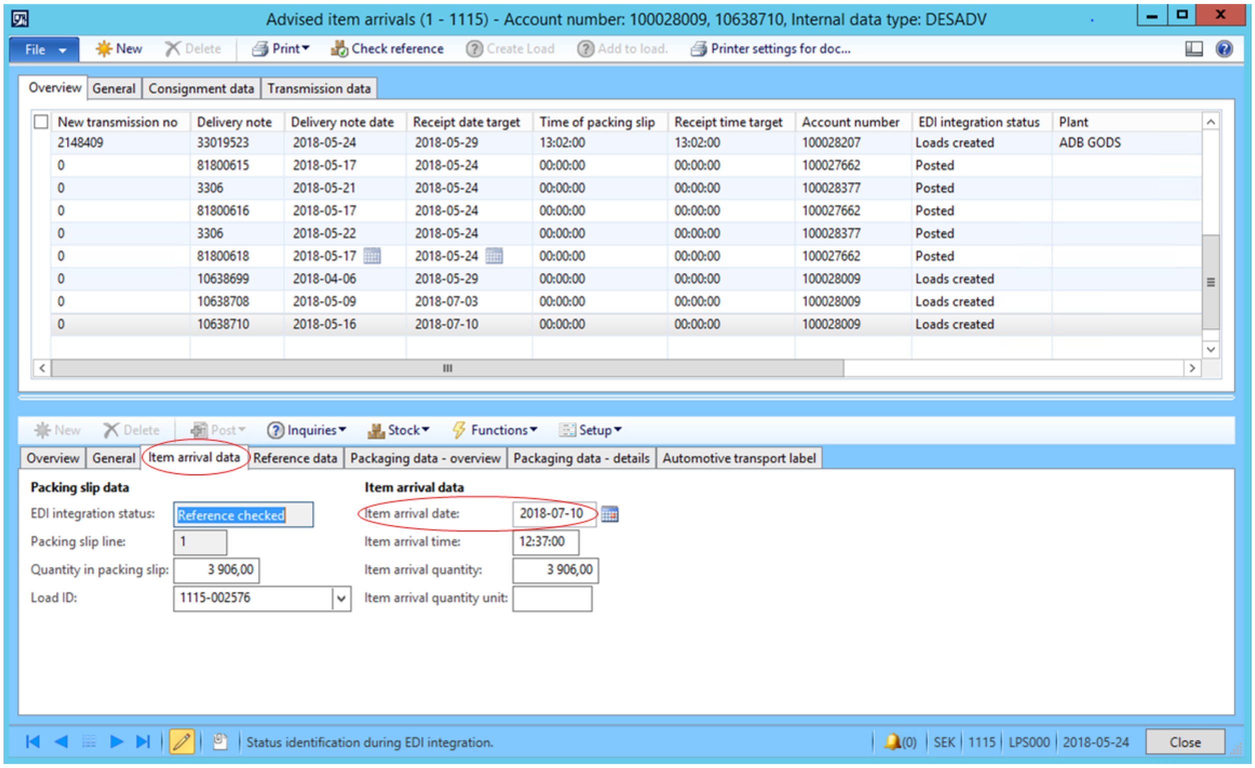


Figure 37 Item arrival date

Although this procedure should be fully replaced by the ETA date, the current state of the ERP implementation process does not allow this rigorous change. The uncertainty of failure occurrence cannot be quantified at the current stage.

Similar as has been performed with the expected arrival time, a process to identify critical items was initiated. To define a critical part, more than one aspect has to be considered. Thus, the information required is threefold. Both the current stock-on-hand, the amount of inventory being in-transit and the expected arrival time of the corresponding shipment. In order to distribute the pending items in the afore-described categories the current physical stock needs to be compared with the assigned safety stock (minimum). Both data can be easily detected in the "stock management" section of the ERP-system. The user could find two of the three info in the display illustrated below (see figure 38). The "available physical stock" delivers the amount of items currently being on site, i.e. the physical stock-on-hand (198.872 items). The goods that have been ordered by Haldex from "external suppliers" according purchase orders and forecasts in the scheduled plan but not received yet are called "ordered in total" and cover the in-transit inventory (79.236 items). The "on order in total" field contains the quantity reserved for customer orders or production orders (8.388 items). All three numbers together yield in the total available stock, i.e. in the presented case 269.720 items.

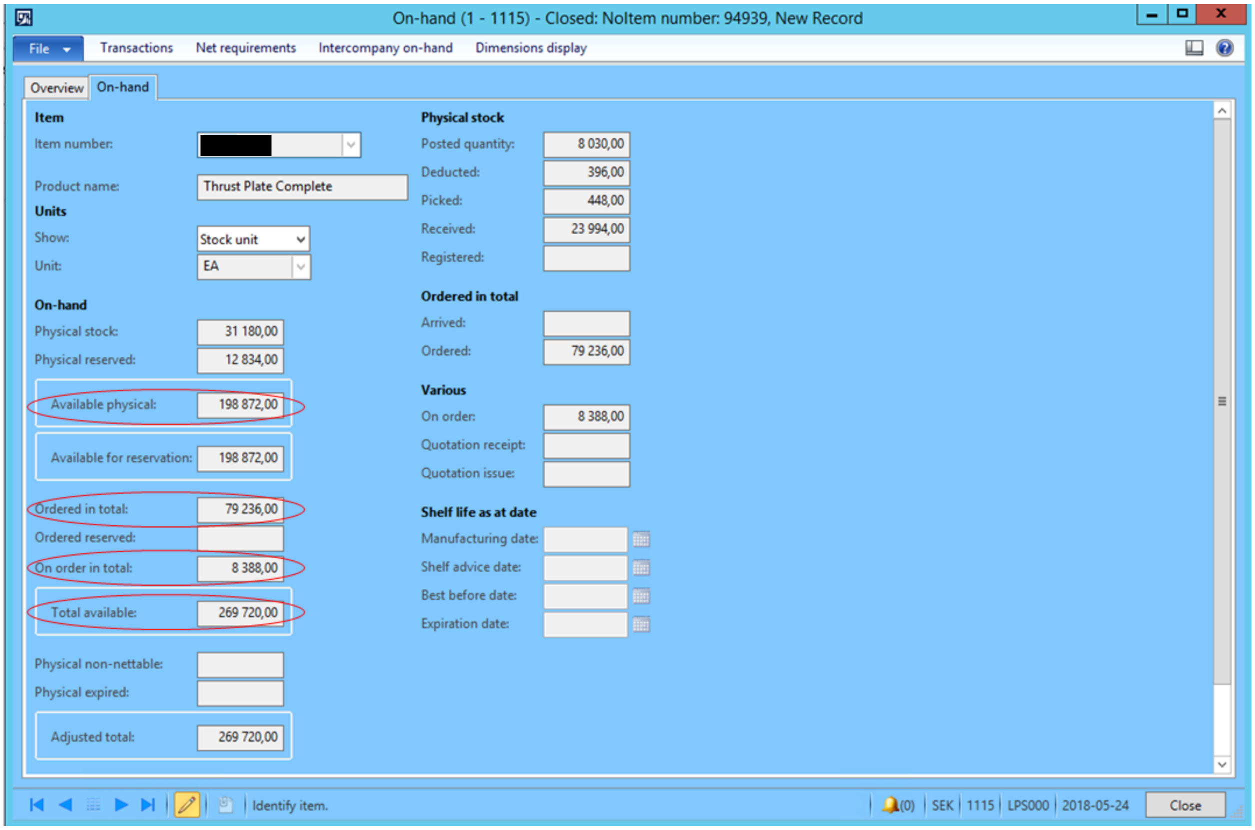


Figure 38 Stock-on-hand

To complete the required information the safety stock quantity needs to be extracted. Hence the “net requirements” of each item are called up. In the “setup” tab the “minimum” defines the safety stock for that specific item. In order to demonstrate the item 94939 was selected as illustrated in the figure below. The safety stock quantity accounts therefore 20.000 items.

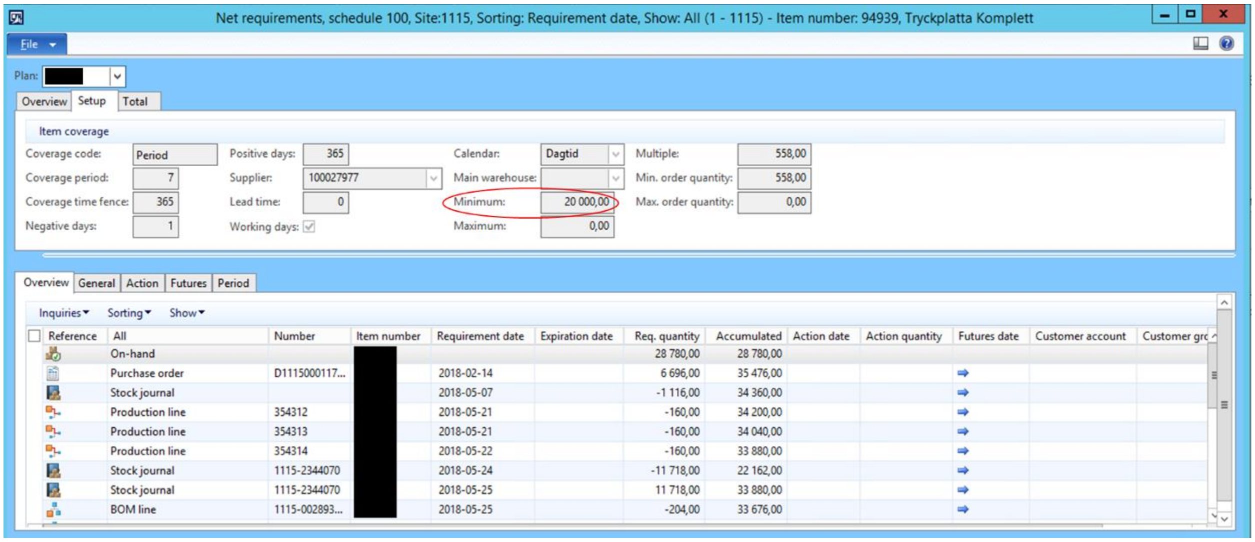
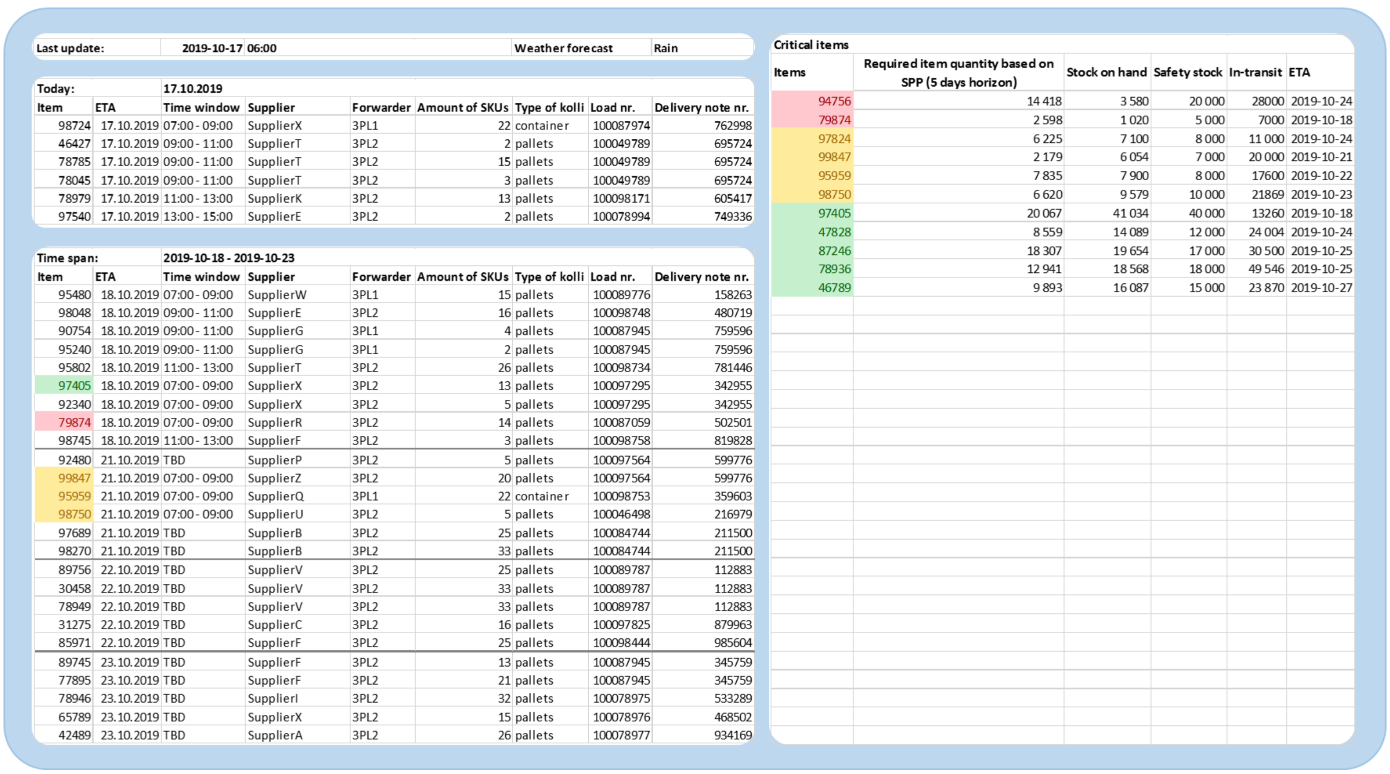


Figure 39 Safety stock quantity

In order to evaluate criticality the on-hand stock needs to be compared to the assigned safety stock quantity. If the available stocks reaches a critical level, the item will appear in the monitoring tool.

5.3.2. The tool



Last update:	2019-10-17 06:00	Weather forecast	Rain

Today:	17.10.2019							
Item	ETA	Time window	Supplier	Forwarder	Amount of SKUs	Type of kolli	Load nr.	Delivery note nr.
98724	17.10.2019	07:00 - 09:00	SupplierX	3PL1	22	container	100087974	762998
46427	17.10.2019	09:00 - 11:00	SupplierT	3PL2	2	pallets	100049789	695724
78785	17.10.2019	09:00 - 11:00	SupplierT	3PL2	15	pallets	100049789	695724
78045	17.10.2019	09:00 - 11:00	SupplierT	3PL2	3	pallets	100049789	695724
78979	17.10.2019	11:00 - 13:00	SupplierK	3PL2	13	pallets	100098171	605417
97540	17.10.2019	13:00 - 15:00	SupplierE	3PL2	2	pallets	100078994	749336

Time span:	2019-10-18 - 2019-10-23							
Item	ETA	Time window	Supplier	Forwarder	Amount of SKUs	Type of kolli	Load nr.	Delivery note nr.
95480	18.10.2019	07:00 - 09:00	SupplierW	3PL1	15	pallets	100089776	158263
98048	18.10.2019	09:00 - 11:00	SupplierE	3PL2	16	pallets	100098748	480719
90754	18.10.2019	09:00 - 11:00	SupplierG	3PL1	4	pallets	100087945	759596
95240	18.10.2019	09:00 - 11:00	SupplierG	3PL1	2	pallets	100087945	759596
95802	18.10.2019	11:00 - 13:00	SupplierT	3PL2	26	pallets	100098734	781446
97405	18.10.2019	07:00 - 09:00	SupplierX	3PL2	13	pallets	100097295	342955
92340	18.10.2019	07:00 - 09:00	SupplierX	3PL2	5	pallets	100097295	342955
79874	18.10.2019	07:00 - 09:00	SupplierR	3PL2	14	pallets	100087059	502501
98745	18.10.2019	11:00 - 13:00	SupplierF	3PL2	3	pallets	100098758	819828
92480	21.10.2019	TBD	SupplierP	3PL2	5	pallets	100097564	599776
99847	21.10.2019	07:00 - 09:00	SupplierZ	3PL2	20	pallets	100097564	599776
95959	21.10.2019	07:00 - 09:00	SupplierQ	3PL1	22	container	100098753	359603
98750	21.10.2019	07:00 - 09:00	SupplierU	3PL2	5	pallets	100046498	216979
97689	21.10.2019	TBD	SupplierB	3PL2	25	pallets	100084744	211500
98270	21.10.2019	TBD	SupplierB	3PL2	33	pallets	100084744	211500
89756	22.10.2019	TBD	SupplierV	3PL2	25	pallets	100089787	112883
30458	22.10.2019	TBD	SupplierV	3PL2	33	pallets	100089787	112883
78949	22.10.2019	TBD	SupplierV	3PL2	33	pallets	100089787	112883
31275	22.10.2019	TBD	SupplierC	3PL2	16	pallets	100097825	879963
85971	22.10.2019	TBD	SupplierF	3PL2	25	pallets	100098444	985604
89745	23.10.2019	TBD	SupplierF	3PL2	13	pallets	100087945	345759
77895	23.10.2019	TBD	SupplierF	3PL2	21	pallets	100087945	345759
78946	23.10.2019	TBD	SupplierI	3PL2	32	pallets	100078975	533289
65789	23.10.2019	TBD	SupplierX	3PL2	15	pallets	100078976	468502
42489	23.10.2019	TBD	SupplierA	3PL2	26	pallets	100078977	934169

Critical items					
Items	Required item quantity based on SPP (5 days horizon)	Stock on hand	Safety stock	In-transit	ETA
94756	14 418	3 580	20 000	28000	2019-10-24
79874	2 598	1 020	5 000	7000	2019-10-18
97824	6 225	7 100	8 000	11 000	2019-10-24
99847	2 179	6 054	7 000	20 000	2019-10-21
95959	7 835	7 900	8 000	17600	2019-10-22
98750	6 620	9 579	10 000	21869	2019-10-23
97405	20 067	41 034	40 000	13260	2019-10-18
47828	8 559	14 089	12 000	24 004	2019-10-24
87246	18 307	19 654	17 000	30 500	2019-10-25
78936	12 941	18 568	18 000	49 546	2019-10-25
46789	9 893	16 087	15 000	23 870	2019-10-27

Figure 40 Monitoring tool

As shown in the figure 40 above, all items arriving within the next five receiving days (excluding weekends) appear in the dashboard. The user could easily see which items are arriving today and if and to what extent they are critical for keeping the production running. In order to give the user additional help to set the arrival time in the right context, further information is displayed. Besides administrative information such as "Delivery note number" and the "Load number" there are the names of supplier and forwarder attached. The "Amount of SKUs" (in the given case, pallets), the "type of kolli, either containers or pallets, and assigned time windows are also covered in this monitor. The latter is referring to the idea of scheduling the arrival of trucks more precisely. Although it is not implemented yet, the authors considered it to be monitored in case of realization

On the upper right side, all critical items are presented, including the ones arriving within the next five receiving days. The different colours indicate the aforementioned categories, reaching from "about to hit the safety stock" (green) over "below safety stock level" (yellow) till "critical for production" (red).

Another key advantage of combining all this information in one screen and updating the information constantly is that there is no need to hand over the current state between shifts anymore. Information can thus not get lost or wrongly interpreted. All required information is saved in this report and can be looked at any time.

Since the framework is meant to be used by employees with different backgrounds and level of education, it is important that the framework is easy to use. This means that the framework should feel intuitive, regardless of the employee's knowledge and experience.

5.4. Arrival scheduling

The discussion of the current situation at receiving brought problems to the surface. An issue mainly discussed was the unpredictable time slot when trucks actually arrive at the site in Landskrona. As mentioned before most deliveries were made in the first hours of a day and tend to be concentrated on the beginning of the week. As shown in figure 41 the inbound area is frequently used between 7 am and 11 am. Over 80 % of the trucks arrive and are unloaded in that specific time window, according to a sample of three weeks. The supplier Heurlins is excluded from those statistics since those transports can be seen as intra logistics and soon become replaced by a new in-house production line.

Time	week 3	week 4	week 5	Total	%
07-09	13	8	11	**32**	39,5%
09-11	12	17	7	**36**	44,4%
11-13	1	3	3	**7**	8,6%
13-15	1	2	1	**4**	4,9%
15-	2	0	0	**2**	2,5%
	29	30	22	**81**	

84%

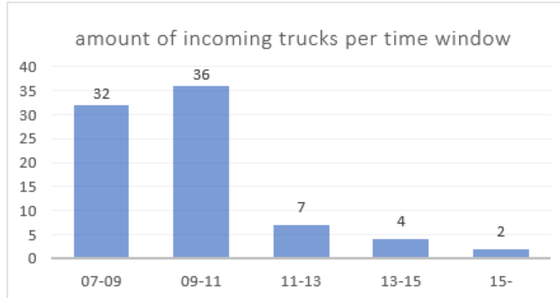


Figure 41 Amount of incoming trucks per time window

When the analysis is moved to the level of pallets received, the number is even more far-fetched (see figure 42). In this case over 90% of the workload is concentrated in the first 4 hours.

Time	week 3	week 4	week 5	Total	%
07-09	269	235	248	**752**	52,7%
09-11	170	277	83	**530**	37,1%
11-13	27	34	25	**86**	6,0%
13-15	26	7	3	**36**	2,5%
15-	24	0	0	**24**	1,7%
	516	553	359	**1428**	

90%

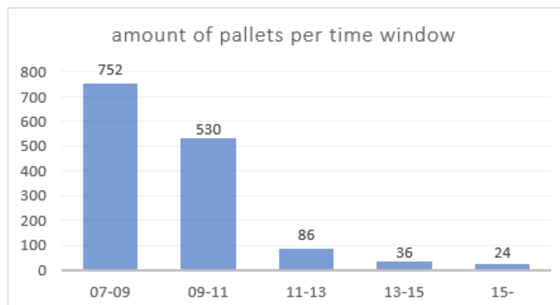


Figure 42 Amount of pallets per time window

When it comes to the pallet throughput there are also differences within the week. The chart below summarizes the data collection of 3 weeks, and can be assumed as significant for all weeks. That was additionally confirmed during the interviews held with employees assigned to the process of registration and unloading of trucks. Especially in the beginning, the middle and slightly at the end of the week most of the goods are coming in (see figure 43).

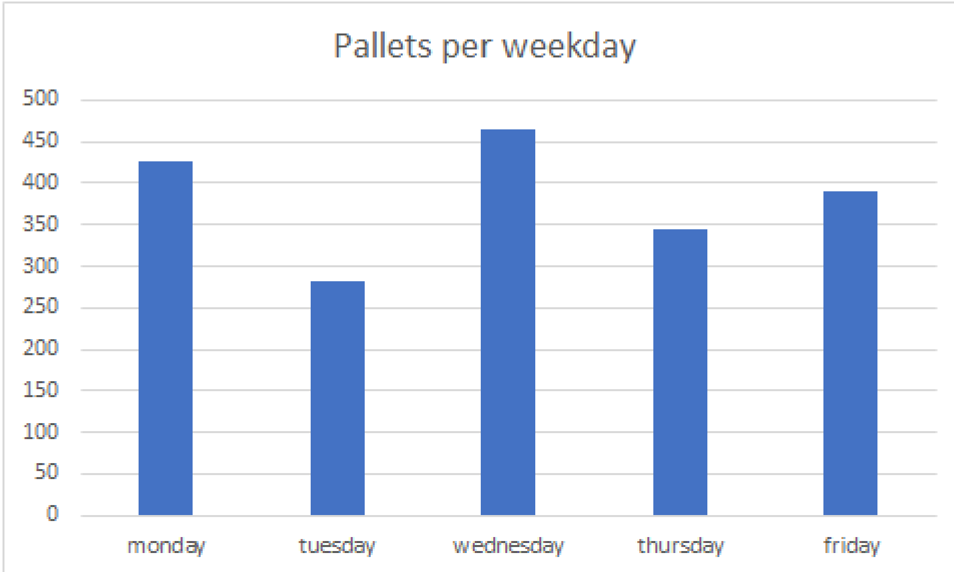


Figure 43 Amount of pallets per weekday

The top ten suppliers (the full table can be seen at Appendix F) since the beginning of 2016 is responsible for around 42% of the shipments arriving at Haldex Landskrona. As shown in figure 44 most of them have a tendency to deliver at the same day of a week. Georg Fischer, for instance, does only deliver urgent supplies on Wednesdays. According to 3PL2 suppliers usually prefer a specific weekday, but the main reason for this phenomena is the order pattern at Haldex. Since Haldex triggers the process of delivery, the day it places the order dictates the day of delivery. Following that argumentation Haldex, in essence, needs to control and manage the placement of orders more precisely.

Supplier	Monday	Tuesday	Wednesday	Thursday	Friday	Grand Total
Supplier A	252	115	89	147	110	**713**
Supplier B	9	115	95	95	117	**431**
Supplier C	78	57	68	65	76	**344**
Supplier D	30	46	88	43	123	**330**
Supplier E	76	62	58	54	46	**296**
Supplier F	60	36	75	43	36	**250**
Supplier G	19	86	37	12	18	**172**
Supplier H	3	3	143	9	4	**162**
Supplier I	16	84	30	12	16	**158**
Supplier J	7	13	11	104	20	**155**
Grand Total	550	617	694	584	566	3011

Figure 44 Arrival weekdays for top 10 suppliers

While the interviewees elaborated on that topic, it became obvious that changes are needed. The amount of trucks within the receiving area are disturbing the process of unloading and labeling the goods. Pallets have to be touched several times and be stored outside without any protection from weather due to a lack of space. Especially for delicate goods, the latter cannot be neglected. Furthermore, the receiving staff, especially the forklift drivers are usually fully stretched during the peak times but not too busy after the first wave faded away. Even the forklift drivers themselves argued for scattering the workload caused by incoming trucks over the entire day, respectively over the entire week.

The overall goal is to smoothen the receiving procedure at Haldex Landskrona. Hence an interview with 3PL2, mostly responsible for the scheduling of arriving trucks, was set up and the several reasons were discussed to the effect to find long term solutions. The main factor influencing the time, when items arrive at Haldex, is the fixed schedule of ferries commuting between Germany and Sweden. That fact leads to crowded arrival during the morning hours. According to 3PL2 suppliers preferably pick the cheapest ferry at around 10 pm. Since trucks are only supposed to enter Haldex site between 7am and 3pm all trails carried on that specific arrive in the morning. 3PL2 urges the suppliers to use the ferries due to the assigned costs. Only during the summer months suppliers are allowed to select a different route easing up the situation at times. Since Haldex aims for a more distributed delivery schedule and 3PL2 covers most of the suppliers and is able to ensure arrivals in assigned time windows (for Scania 3PL2 achieve a frequence of 15 min per truck), the main obstacle to overcome is finding agreement for both parties. This service obviously comes with additional costs, which need to be negotiated. Focusing on key suppliers instead might already change the current state to a better way.

The increasing amount (due to ferry schedules) of trucks coming in at same time can also easily be tackled by shifting the regional suppliers to the afternoon time slots. Thus you could achieve a smoother receiving process. The idea is to designate a specific time window to each truck (or supplier) and transfer that information directly to the truck driver, preferably in advance. When every supplier keeps the same spot both the companies could plan resources and standardize their processes according to that. It might be necessary to exclude the long distance distribution network since most of the lead times are up to 6 weeks and cannot be predicted precisely. Nevertheless, the driver picking up the goods at either Helsingborg or Gothenburg should be informed when the last update of the arrival time is fixed and at what time approximately he is allowed to enter the inbound area. As a conclusion a modification of the inbound process comes along with several benefits and should be seriously considered by Haldex.

5.5. Results of simulation

To finalize this chapter, an overview will be given off all the costs and savings calculated with the simulation. In table 16: all results can be found, including the percentage of the real total costs. As mentioned before, it can be seen that cost savings are between 40% and 45% and a further increase is possible if air-transport is included.

Table 16 Summary of results

Simulation result	Costs (sek)	percentage of real case scenario costs
Current worst case scenario	932.860	103,63%
Current best case scenario	686.984	76,32%
Real case scenario	900.172	100,00%
Costs after implementing consolidation	515.811	57,30%
Savings after implementing consolidation	384.361	42,70%
Reduction of pallets inc. fuzhou nansha/exc. fuzhou nansha	4/26	-
Consolidation 10% decrease savings	383.208	42,57%
Consolidation 10% increase savings	397.916	44,20%
Consolidation 10%*2 increase savings	404.320	44,92%
Extra savings by including air-transport	85.332	9,48%

6. Conclusion

The last chapter concludes the results of the on-hand work. Firstly, the purpose and the assigned will be evaluated and answered on all levels. Afterwards the authors refer to the underlying theory and reflect on important aspects. Finally, possible future research fields are discussed, followed by conclusive recommendations.

The purpose of this research was to analyze how the inbound supply chain of a company with Haldex' characteristics could be made more efficient, transparent and reliable by exploring consolidation strategies, monitoring solutions and schedule optimizations. Considering what Haldex AB wants from this thesis, one of the main issues is to make a framework which can and may possibly be used. It would be easy to just copy one of the calculation methods suggested by the literature as a formula, but this would not fulfill its purpose as theory needs to be adjusted to the practical environment. A more tailored solution has successfully been created in this research, combining theory with personally performed observations and data recovered from the company's database. It has been aimed to design a solution that is ready for implementation immediately and understandable for readers that are not necessarily familiar with supply chain studies and other related theory. This study considers that it has provided Haldex desired results and managed to both identify opportunities to improve business processes and provided solutions that will resolve the problems that have been faced. The study has fully fulfilled its purpose and delivered according to the agreement between Haldex and the project group. It has further upheld the agreed time plan, milestones, and documentation without exceptions.

6.1. Research questions

The original purpose and deliverables have changed slightly during the study but only to become more comprehensive and fitting for the faced issues by Haldex and without undermining the requirements of the agreement. Still, the research questions stayed the same to ensure tackling of the right problems. The problems have been analyzed on a strategic, tactical and operational level. By going through the research questions, a summarized solution for the research is explained.

RQ1: How can a consolidation strategy enable a decrease of costs and environmental impact at the case companies supply chain?

By using ExtendSim as a simulation software, cost savings have been discovered by implementing a consolidation strategy on a strategic level. Currently, Haldex suppliers are located around certain ports, but components are shipped individually. By consolidating shipments together, transport prices per item become lower due to the economies of scale effect. As the transport price of a full container is relatively lower as a less than container load transport, applying a strategy that ensures full capacity usage of a container drops the total cost. First cost savings can already be obtained by applying internal consolidation

per supplier. The simulation shows though that cost savings do not stop after adjusting a suppliers purchase orders in such a way that all components are transported together. Further cost savings can be gained by consolidating goods between suppliers to maximize capacity usage of a container. A policy that defines when goods get consolidated and when they should not needs to be developed by the usage of a time-quantity policy to ensure that products are not delivered too late to meet the demand.
Furthermore, the on-hand analysis has revealed that an application of consolidation strategy does not result in higher inventory levels due to less incoming shipments but also comes with a reduction and thus, decreases necessary warehouse capacity. Especially when items have a high demand, a reduction of inventory on-hand is expected. If a consolidation center, in this case a port, has a low total demand, the components might need a higher stock capacity as in a non-consolidation strategy due to containers slowly reaching their full capacity. A consolidation strategy is thus less fitting for consolidation hubs with low demand as holding costs could overshadow the transportation savings. In this scenario a consignment stock strategy could be the required solution as it mostly negates the effect of high holding costs.
Beside the enormous cost reduction for transportation the developed model spawns also some savings concerning the emission of CO_2. Due to the shift of the mode of transport for some products a company can achieve both cost reduction and the reduction of environmental footprint.

RQ2: How should the case company design its consolidation strategy for its upstream supply chain to maximize cost-savings, reduce environmental impact, and ensure reliability?

The simulation has shown that a company with the same characteristics as Haldex would benefit from applying consolidation in four different ports in China. The suppliers in Shanghai and Qingdao would especially benefit from a consolidation strategy. If only an internal consolidation strategy would be applied at the different suppliers, costs can be reduced by 25,6%. An even more optimal transportation network can be achieved by consolidating the suppliers that are operating around the same port. To reach maximum cost reduction a demand and port specific demand time-quantity policy needs to be applied. The lowest total cost is achieved at a maximum waiting days of 15, 13, 32 and 38 in Shanghai, Qingdao, Fuzhou and Nansha respectively. This drops the total transportation costs to 515.810 kr which is a saving of 384.361 kr or 42.7% of the total transportation costs and an extra saving of on-stock pallets ranging from 4 to 26 pallets depending on the consolidation strategy used.
To enable these cost savings, a company would need to set up such a specific consolidation network by planning their purchase orders ahead by using for example a similar simulation as created for this research. This simplifies the grouping of loads for consolidation by the logistics department/partner of the company. This requires reliable suppliers as the order schedules are strict. Nevertheless, if this network is successfully created, it will be a long term solution as the cost savings are relatively the same, whether demand increases or decreases. A 20% demand increase reduces cost reduction by less than 1%.
Another implementation can be considered to raise the cost savings by shifting the transport of light and small components with low quantities that are normally transported by air to the consolidated sea-transport. Sending these items on their own by sea might not be cheap enough to compensate for the advantages of shipping by air but adding them to the even cheaper consolidation network could change this decision. This would reduce the costs by an extra 85.332 kr resulting in a total cost reduction of 52.9%.

RQ3: How can visibility and traceability of inbound flows be improved for the operational performance of a manufacturers receiving process?

By displaying the information on incoming loads, that is already existing in different places of the databases used by Haldex, in a more structured way, a better overview for all employees can be created. By transferring this information into a dashboard that lists when items arrive, stating the quantity and how critical they are to Haldex, a clear picture of the current status can be seen at any point in time. This dashboard can both be used by planners and managers to assist their tactical planning as well as warehouse employees that handle the goods. A better overview will help with improving the recourse planning to ensure enough workforce and helps prepare the next shifts as vocal information sharing gets substituted by the digital dashboard, thus decreasing the chance that information is forgotten or wrongly interpreted. Besides the previously mentioned advantages, it informs and prepares the employees on where actions should be taken rapidly due to needs at the production lines and therefore smoothening operations.

The arrival time scheduling induced an improved resource planning for all functions related to the receiving process on a more operational level. In the current situation, pallets mostly arrive in the mornings which creates an unevenly distribution of workload for the receiving department. As an effect, pallets must wait outside and get handled multiple times, solely due to lack of space to store them at that exact moment. Ideally, the incoming transport is equally scheduled over the week. Currently, this is at the moment hard to achieve due to ferry timetables. Haldex' logistical supplier does provide time-windows per supplier upon request but compensation is required. To lower costs, Haldex could look into solely applying time-windows to key suppliers or shifting the local suppliers that do not use the ferries.

6.1.1. Returning to the theory

Aligned with the presented theory we considered all three consolidation policies. According to Higginson and Bookbinder (1994), you could either consolidate on time, volume or an individual combination of those two factors. In the given case a hybrid approach was detected to be most feasible. In this policy either a certain quantity is required before dispatching the goods into a single shipment or a maximum waiting time is reached. As soon as the waiting was exceeded the shipped immediately without taking the amount of pallets on-hand into account. Thus, it could be argued the applied hybrid policy is rather time-volume than volume-time focused. This approach was mainly driven by the premises of increasing the cost savings to an optimal solution for the given case data.

6.2. Reflections

As Haldex is a large manufacturing company, with over 2000 employees worldwide and most of them operating at Landskrona and goods entering and leaving the Landskrona facilities on an hourly basis, data can be found in large quantities. Together with the dynamic characteristics of a continuously operating company, it makes searching for relevant data not always an easy operation. The data gathering process

has for example been affected by the recent introduction of a new ERP system, resulting in large losses of data on the previous years. The new ERP system also brought the issue that employees were less familiar with the new ERP system, disabling them from assisting us with the necessary information to utilize the ERP system optimally. Another barrier was the large amount of positions being fulfilled by new people, resulting in knowledge loss. Nevertheless, it has been aimed and in the writer's eyes achieved, to present a relevant status-quo of the case at hand and to find relevant answers to the research questions.
To develop a feasible plan to improve the efficiency, transparency and reliability of the incoming goods assumptions needed to be made. These assumptions have always been made with a close look on the reality to not drift too far away from the real case. Still, without some of the assumptions the results might have been more reliable but the research would have either been impossible to perform or it would simply take too much time till completion. Another challenge that has been faced was to balance the complexity of the methods used and the simulation. Throughout the project the intuitiveness of the solutions and the easiness of usage has been an important aspect but, although not with intention, this might have affected the accurateness of the suggested methods.

6.2.1. Credibility

During the timespan of the research, the pre-developed project plan has been kept in mind. The actions have been performed in the same sequence and it has been tried to write down the different actions performed with as much detail as possible to enable further researchers to obtain the same result if it is deemed necessary to redo the research. The only small difference between the project plan and the actual outcome is that it turned out impossible to develop an actual monitoring tool. Instead, a proposal of a monitoring tool was created, together with its necessary input and output.
One way this work assured extra credibility is the usage of different demands. On one hand, historical demand has been adduced to build the approach not only on estimated data but also demand that actually occurred. Additionally, patterns could be identified and the development of future demands predicted accordingly. On the other hand, we examined the effect of consolidation also on estimated demand for the next two years, taking in consideration both increase and decrease of numbers.
To further ensure right decisions were made during the project, experts as Haldex' logistical partners and the departments of Haldex that worked on a daily basis with the processes of focus were asked for their input regularly. Their input has played a key role to keep the research as close to reality as possible.

6.3. Future research

During the timespan of this research is has been aspired to develop an all-including, watertight report. Due to limited time available for research, this is closely but not fully achieved and room for further research exists.
To obtain the results and costs reductions mentioned in this reports the adaption willingness of the suppliers needs to be analyzed. Reaching out to the suppliers was left out of the scope of this research and therefore their opinion was not used, but should definitely be considered valuable as a consolidation

strategy cannot be fulfilled without the suppliers. Linked to this gap in the research would be a benefit analysis for the suppliers' side. In the current report benefits were mainly linked to Haldex's side, but an overview of the benefits for the suppliers might help in convincing them of the lucrativeness of proposed methods.

To get a better picture of the costs connected to consolidation, it would be helpful to take a deeper look into the practical daily actions needed in China to make consolidation possible. The grouping of demands, storing them till other goods have arrived, and placing of all the goods in a container might be more expansive as in the current situation, thus affecting the cost savings.

6.4. Contribution to research

Our contributions to the body of literature in inbound logistics could be outlined as followed:

1. We are focusing on consolidation, presenting a case of a feasibility analysis at a Swedish company. That includes both the overall benefit of the implementation and the application of consolidation product groups and geographical linked suppliers.
2. We are proposing a new consolidation framework; we study the behavior of optimal dispatch decisions under various factors.
3. We emphasis the impact of sustainability on strategic decisions within upstream transportation
4. The limited amount of work in freight consolidation in combination with consignment stocks suggests the at-hand work to be useful, particularly in the area of international suppliers
5. The study also provides a practical approach for other companies to adopt consolidation by linking the tactical decision with scheduling and smoothing receiving operations

6.5. Contribution to industry

When it comes to industry this thesis could be found useful as well. It is particularly useful for companies that find themselves in the same situation as Haldex during the time of this research. These are companies with an international supply chain with multiple suppliers that do not use any kind of consolidation strategy at the moment. This report would give them an idea on how to see if a consolidation strategy would reduce their costs and how a simulation tool could help them to analyze different scenario's. As the effect of consolidation depends on multiple factors, it would help them in seeing which factors are important in their company and how they are different from Haldex, thus maybe bringing a different result. Although the monitoring and arrival scheduling sections of this report are more specific for Haldex, reading it might give other companies ideas on how they could improve their preparedness for the arrival of goods, thus smoothening their operations.

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	International Journal of Quality & Reliability Management	Suarez-Barraza, M., Miguel-Davila, J. and Vasquez-García, C. (2016). Supply chain value stream mapping: a new tool of operation management. International Journal of Quality & Reliability Management, 33(4), pp.518-534.	Web of Science	No
Sustainability on transportation	Flexible Services and Manufacturing Journal	Hoen, K., Tan, T., Fransoo, J. and van Houtum, G. (2012). Effect of carbon emission regulations on transport mode selection under stochastic demand. Flexible Services and Manufacturing Journal, 26(1-2), pp.170-195.	Web of Science	Yes
	Journal of Manufacturing Technology Management	Marchet G., Melacini M., Perotti S., (2014) "Environmental sustainability in logistics and freight transportation: A literature review and research agenda", Journal of Manufacturing Technology Management, Vol. 25 Issue: 6, pp.775-811.	Emerald Insight	Yes
	Green Logistics: Improving the Environmental Sustainability of Logistics	McKinnon, A. (2010), "Environmental sustainability: a new priority for logistics managers", in McKinnon, A., Cullinane, S., Browne, M. and Whiteing, A. (Eds), Green Logistics: Improving the Environmental Sustainability of Logistics, Kogan Page Limited, London	Web of Science	Yes
	The International Journal of Logistics Management	Rigot-Muller, P., Lalwani, C., Mangan, J., Gregory, O. and Gibbs, D. (2013). Optimising end-to-end maritime supply chains: a carbon footprint perspective. The International Journal of Logistics Management, 24(3), pp.407-425.	Web of Science	No

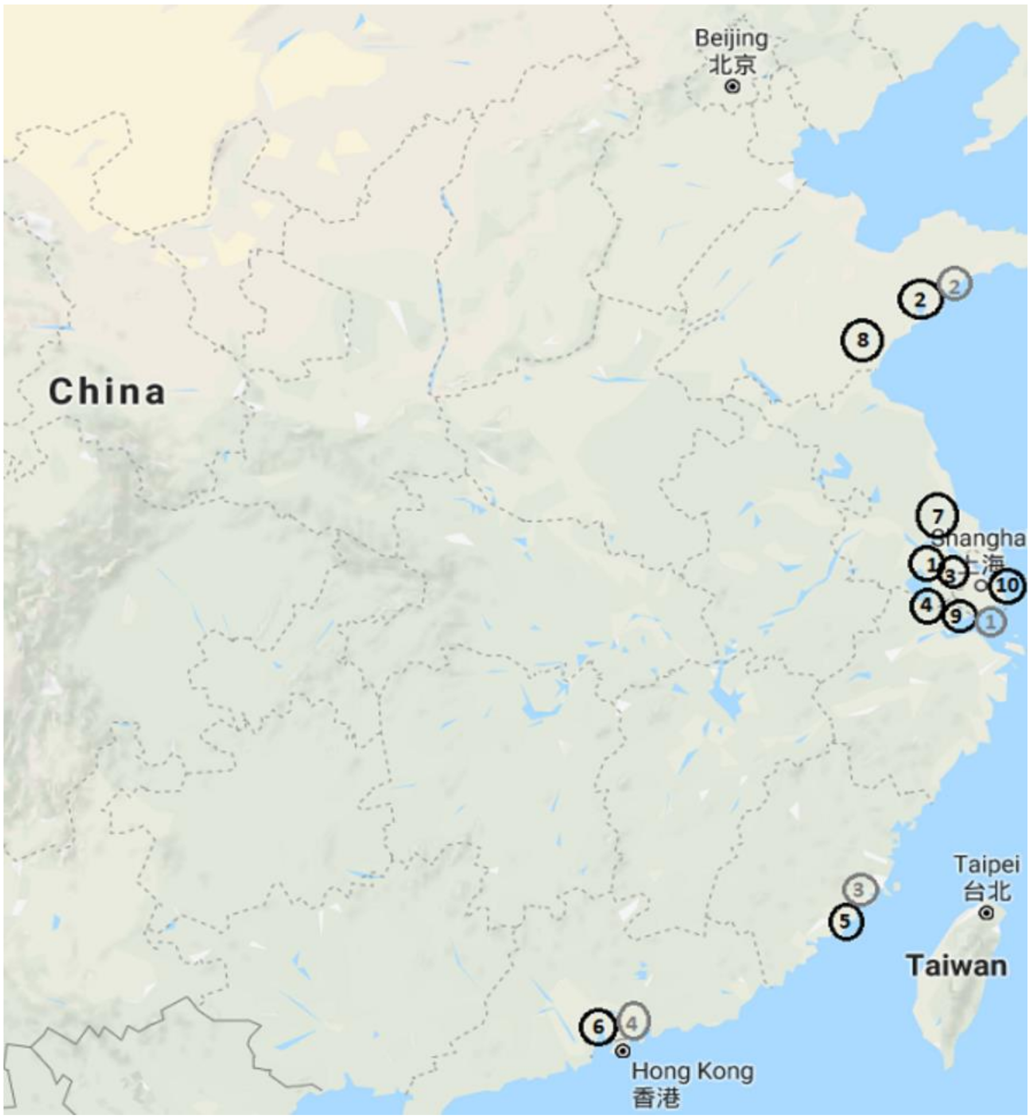
	Sustainable Logistics	Smokers, R., Tavasszy, L., Chen, M., Guis E., "Options for Competitive and Sustainable Logistics" In Sustainable Logistics. Published online: 04 Dec 2014; 1-30.	Web of Science	Yes
	European Journal of Operational Research	Stenius, O., Marklund, J. and Axsäter, S. (2018). Sustainable multi-echelon inventory control with shipment consolidation and volume dependent freight costs. European Journal of Operational Research, 267(3), pp.904-916.	Emerald Insight	Yes
	International Journal of Production Economics	Ubeda, S., Arcelus, F.J. and Faulin, J., 2010. Green logistics at Eroski: a case. International Journal of Production Economics.	Web of Science	Yes
	Journal of Cleaner Production	Zhou, G. and Zhang, Y. (2017). Integration and consolidation in air freight shipment planning: An economic and environmental perspective. Journal of Cleaner Production, 166, pp.1381-1394.	Emerald Insight	No

Appendices

A. List of questions for the protocol

Questions	Recources
What would benefit Haldex to know extra about incoming shipments? *- What is the knowledge of future shipments at the moment?* *- How is information distributed?*	Receiving, shift leader logistics and planner
What is the process of receiving goods? *- Who is responsible?* *- Is there double handling?*	Receiving, shift leader logistics and observations
How is the space in the warehouse utilized? *- Is there space for consolidated goods?* *- Is there space for more consignment stock?*	Internal logistics manager
How are purchase orders scheduled? *- Is the workload of the warehouse taking into account?* *- How detaild are are arrival time agreements?*	Planner
How does the arrival frequency look like? *- Do patterns exist?*	Intern, receiving, observations and documents
How are the logistical flows set up? *- Which suppliers are close to each other?* *- What is the environmental importance to setting up the flows?*	sourcing, manager logistics, logistic developer

B. Geographical location of suppliers



List of suppliers back:
1. Supplier1 (air)
2. Supplier2
3. Supplier3 (air)
4. Supplier4
5. Supplier5
6. Supplier6
7. Supplier7
8. Supplier8
9. Supplier9
10. Supplier10

List of Ports grey:
1. Shanghai port
2. Qingdao port
3. Fuzhou port
4. Nansha port

C. Items per supplier

Supplier	Item number	Mode	Consignment?
SUPPLIER10	95036	Ship	yes
SUPPLIER9	93918	Ship	no
SUPPLIER9	95033	Ship	no
SUPPLIER9	95227	Ship	no
SUPPLIER9	95271	Ship	no
SUPPLIER8	94655	Ship	yes
SUPPLIER8	95439	Ship	yes
SUPPLIER8	95638	Ship	yes
SUPPLIER2	94914	Ship	yes
SUPPLIER2	94951	Ship	yes
SUPPLIER2	95074	Ship	yes
SUPPLIER2	95182	Ship	yes
SUPPLIER2	94947	Ship	yes
SUPPLIER7	94809	Ship	yes
SUPPLIER6	95228	Ship	yes
SUPPLIER6	95030	Ship	yes
SUPPLIER6	95031	Ship	yes
SUPPLIER4	94910	Ship	no
SUPPLIER3	93379	Air	no
SUPPLIER3	95134	Air	no

SUPPLIER3	95949	Air	no
SUPPLIER3	96003	Air	no
SUPPLIER3	96975	Air	no
SUPPLIER1	96137	Air	no
SUPPLIER1	96273	Air	no
SUPPLIER1	96364	Air	no
SUPPLIER5	95958	Ship	yes
SUPPLIER5	95959	Ship	yes
SUPPLIER5	94939	Ship	yes

D. Future item demand per month

	Supplier 10	Supplier 9				Supplier 8		
	item_95036	item_93918	item_95033	item_95227	item_95271	item_94655	item_95439	item_95638
May	32643	67206	33603	33603	67206	33603	33603	40950
Jun	38375	75789	37895	37895	75789	37895	37895	38250
Jul	31032	62124	31062	31062	62124	31062	31062	27900
Aug	26913	53826	26913	26913	53826	26913	26913	29700
Sep	34254	69408	34704	34704	69408	34704	34704	34650
Oct	37602	75204	37602	37602	75204	37602	37602	37350
Nov	39461	78021	39011	39011	78021	39011	39011	39150
Dec	25028	43995	21998	21998	43995	21998	21998	21150
Total	265307	525573	262787	262787	525573	262787	262787	269100

	Supplier 2					Supplier 7
	item_94914	item_94951	item_95074	item_95182	item_94947	item_94809
May	32643	32643	32643	32643	32643	32643
Jun	38390	72081	66006	36059	35927	37895
Jul	31062	66732	51746	33372	33030	31062
Aug	26943	54414	41195	27222	26913	26913
Sep	34284	69660	62414	34836	34704	34704
Oct	37633	75891	66889	37961	37602	37602
Nov	39488	78648	55534	39336	39011	39011
Dec	25096	45012	29873	22500	21998	21998
Total	265538	530901	432400	265580	263153	262787

	Supplier 6			Supplier 4
	item_95228	item_95030	item_95031	item_94910
May	32643	32643	33603	68589
Jun	75789	36455	37895	72117
Jul	62124	31032	31062	66744
Aug	53826	26913	26913	54444
Sep	69408	34254	34704	69672
Oct	75204	37602	37602	75921
Nov	78021	39461	39011	78672
Dec	43995	25028	21998	45000
Total	525573	265307	262787	531159

	Supplier 3				
	item_93379	item_95134	item_95949	item_96003	item_96975
May	438	24840	1527	450	6714
Jun	1352	26280	2055	450	5790
Jul	915	24195	3084	450	4386
Aug	729	15780	2334	450	7620
Sep	1980	22620	2118	450	7536
Oct	1911	25275	2430	450	7536
Nov	2957	24060	2124	450	9420
Dec	1640	11100	1272	450	7536
Total	11921	174150	16944	3600	56538

	Supplier 1			Supplier 5		
	item_96137	item_96273	item_96364	item_95958	item_95959	item_94939
May	300	94	75	31146	1527	450
Jun	150	0	75	35126	2799	450
Jul	150	0	75	27792	2340	900
Aug	150	0	75	24129	2334	450
Sep	150	0	75	32136	2118	0
Oct	150	0	75	34722	2430	450
Nov	150	94	75	36437	2124	900
Dec	150	0	75	23756	1272	0
Total	1350	188	600	245243	16944	3600

E. Present day shipments for 2017

Supplier8

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	2	1	2	2	0	1	1	1	2	1	1	1
ChargeableWeight(Kg)	51 082	24 901	35 683	43 382	0	26 871	19 024	24 798	23 560	19 500	25 500	22 000
Cost	0	0	0	0	0	0	4 422	0	0	0	0	0

Supplier7

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	0	3	1	1	1	1	3	4	1	1	0	0
ChargeableWeight(Kg)	0	13 166	3 762	6 590	5 642	7 523	10 343	16 925	5 642	9 404	0	0
Cost	0	12 898	3 644	4 651	4 876	5 747	10 588	15 657	4 929	7 662	0	0

Supplier5

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	0	1	1	2	0	0	1	1	1	0	0	1
ChargeableWeight(Kg)	0	21 340	971	6 790	0	0	4 850	6 790	10 686	0	0	5 820
Cost	0	19 287	6 221	16 795	0	0	10 805	12 290	17 492	0	0	12 705

Supplier10

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	1	6	3	2	3	2	2	3	1	3	2	1
ChargeableWeight(Kg)	7 700	49 280	23 870	15 400	40 810	23 100	29 260	46 950	7 700	34 650	23 100	15 400
Cost	8 344	51 899	24 528	14 348	31 667	20 926	22 854	37 129	7 325	32 584	23 119	14 465

Supplier4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	0	0	2	1	1	2	1	2	1	2	0	1
ChargeableWeight(Kg)	0	0	6 120	3 700	4 440	8 880	4 440	8 880	4 440	8 880	0	8 140
Cost	0	0	7 397	3 763	3 987	7 438	3 279	8 043	3 983	8 416	0	7 968

Supplier6

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	1	1	1	3	1	1	1	2	1	2	1	1
ChargeableWeight(Kg)	4 023	4 906	2 246	11 266	4 528	4 892	3 437	8 817	5 615	12 840	4 438	6 738
Cost	5 154	6 647	3 558	19 295	5 674	6 120	3 994	10 072	6 641	15 467	5 975	8 616

Supplier9

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	1	2	0	3	1	3	4	3	3	5	3	1
ChargeableWeight(Kg)	4 305	8 000	0	13 600	4 000	7 600	9 285	7 000	10 200	13 380	9 779	2 906
Cost	5 998	10 631	0	16 478	4 096	8 941	12 839	9 485	12 197	19 001	14 117	4 256

Supplier2

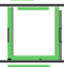
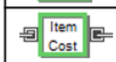
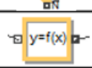
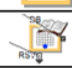
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shipments	0	0	1	5	5	3	4	2	4	1	2	3
ChargeableWeight(Kg)	0	0	333	1 446	2 818	2 591	2 428	1 014	2 783	470	1 048	1 704
Cost	0	0	1 275	2 550	0	0	800	0	0	0	0	0

F. Arrival weekdays for all suppliers 21,19; 15,06

Supplier	Monday	Tuesday	Wednesday	Thursday	Friday	Grand Total
Supplier A	252	115	89	147	110	**713**
Supplier B	9	115	95	95	117	**431**
Supplier C	78	57	68	65	76	**344**
Supplier D	30	46	88	43	123	**330**
Supplier E	76	62	58	54	46	**296**
Supplier F	60	36	75	43	36	**250**
Supplier G	19	86	37	12	18	**172**
Supplier H	3	3	143	9	4	**162**
Supplier I	16	84	30	12	16	**158**
Supplier J	7	13	11	104	20	**155**
Supplier K	11	86	23	14	11	**145**
Supplier L	27	46	28	10	16	**127**
Supplier M	27	21	30	26	19	**123**
Supplier N	54	30	11	12	4	**111**
Supplier O	2	53	33	14	5	**107**
Supplier P	31	18	25	17	11	**102**
Supplier Q	61	19	5	8	8	**101**
Supplier R	2	85	8	5	1	**101**
Supplier S	2	50	30	15	1	**98**
Supplier T	31	19	18	14	14	**96**
Supplier U	6	32	26	9	20	**93**
Supplier V	43	27	4	7	6	**87**
Supplier W	60	3	5	6	5	**79**
Supplier X	8	16	12	12	31	**79**
Supplier Y	6	22	28	17	5	**78**
Supplier Z	15	6	3	2	52	**78**
Supplier AA	26	6	14	17	12	**75**
Supplier AB	14	17	17	17	10	**75**
Supplier AC	14	18	18	12	9	**71**
Supplier AD	9	4	3	40	14	**70**
Supplier AE	11	17	16	14	12	**70**
Supplier AF	3	54	6	2	4	**69**
Supplier AG	14	14	17	12	11	**68**
Supplier AH	16	20	10	11	11	**68**
Supplier AI	12	19	19	11	4	**65**
Supplier AJ	30	16	4	7	6	**63**
Supplier AK	13	14	14	13	9	**63**
Supplier AL	14	10	9	11	12	**56**
Supplier AM	11	7	14	8	15	**55**
Supplier AN	15	25	2	3	8	**53**
Supplier AO	1	1	4	38	4	**48**
Supplier AP	3	26	16	1	1	**47**
Supplier AQ	12	13	5	7	10	**47**
Supplier AR	12	13	9	8	4	**46**
Supplier AS	26	10	4	2	2	**44**
Supplier AT	6	11	5	12	8	**42**
Supplier AU	6	22	6	2	3	**39**
Supplier AV	17	4	0	11	5	**37**
Supplier AW	11	13	4	1	4	**33**

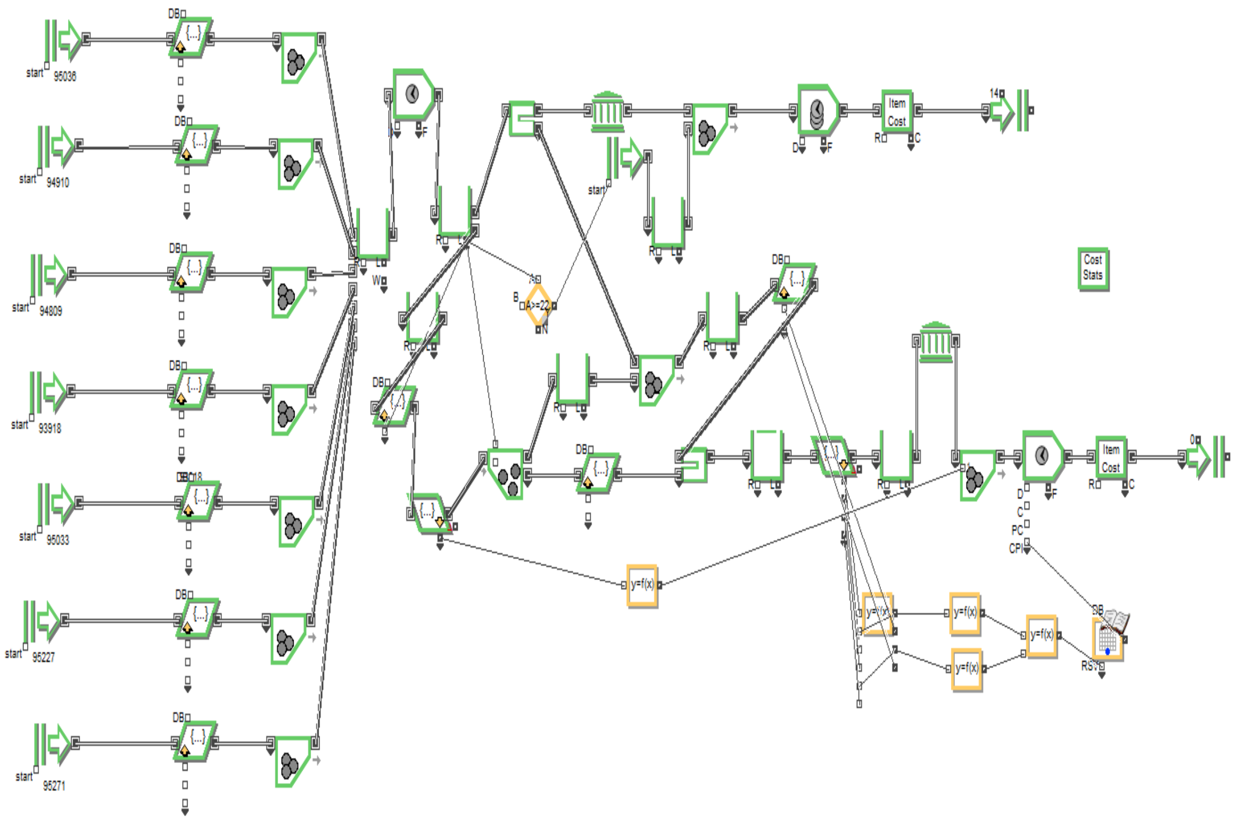
Supplier AX	8	8	3	7	6	**32**
Supplier AY	0	4	5	13	10	**32**
Supplier AZ	7	8	3	7	6	**31**
Supplier BA	7	7	7	4	5	**30**
Supplier BB	6	2	6	10	6	**30**
Supplier BC	9	4	3	7	6	**29**
Supplier BD	11	3	1	4	9	**28**
Supplier BE	3	12	4	2	6	**27**
Supplier BF	7	3	6	2	9	**27**
Supplier BG	3	0	3	17	3	**26**
Supplier BH	5	9	2	9	0	**25**
Supplier BI	7	10	1	3	4	**25**
Supplier BJ	4	4	3	4	8	**23**
Supplier BK	4	7	3	6	3	**23**
Supplier BL	4	7	2	3	3	**19**
Supplier BM	5	3	3	2	6	**19**
Supplier BN	7	2	4	3	3	**19**
Supplier BO	4	1	1	6	5	**17**
Supplier BP	4	2	4	7	0	**17**
Supplier BQ	1	7	3	3	2	**16**
Supplier BR	4	2	3	3	4	**16**
Supplier BS	3	3	5	3	2	**16**
Supplier BT	3	0	6	0	7	**16**
Supplier BU	0	2	3	11	0	**16**
Supplier BV	2	9	2	0	2	**15**
Supplier BW	1	0	9	2	2	**14**
Supplier BX	4	2	3	4	1	**14**
Supplier BY	5	1	1	4	3	**14**
Supplier BZ	2	1	1	1	8	**13**
Supplier CA	2	4	2	3	2	**13**
Supplier CB	3	1	3	5	0	**12**
Supplier CC	0	0	3	5	4	**12**
Supplier CD	3	1	3	2	2	**11**
Supplier CE	1	0	6	2	2	**11**
Supplier CF	1	2	2	1	5	**11**
Grand Total	1372	1635	1318	1197	1097	**6619**

G. Explanation of the blocks in the simulation

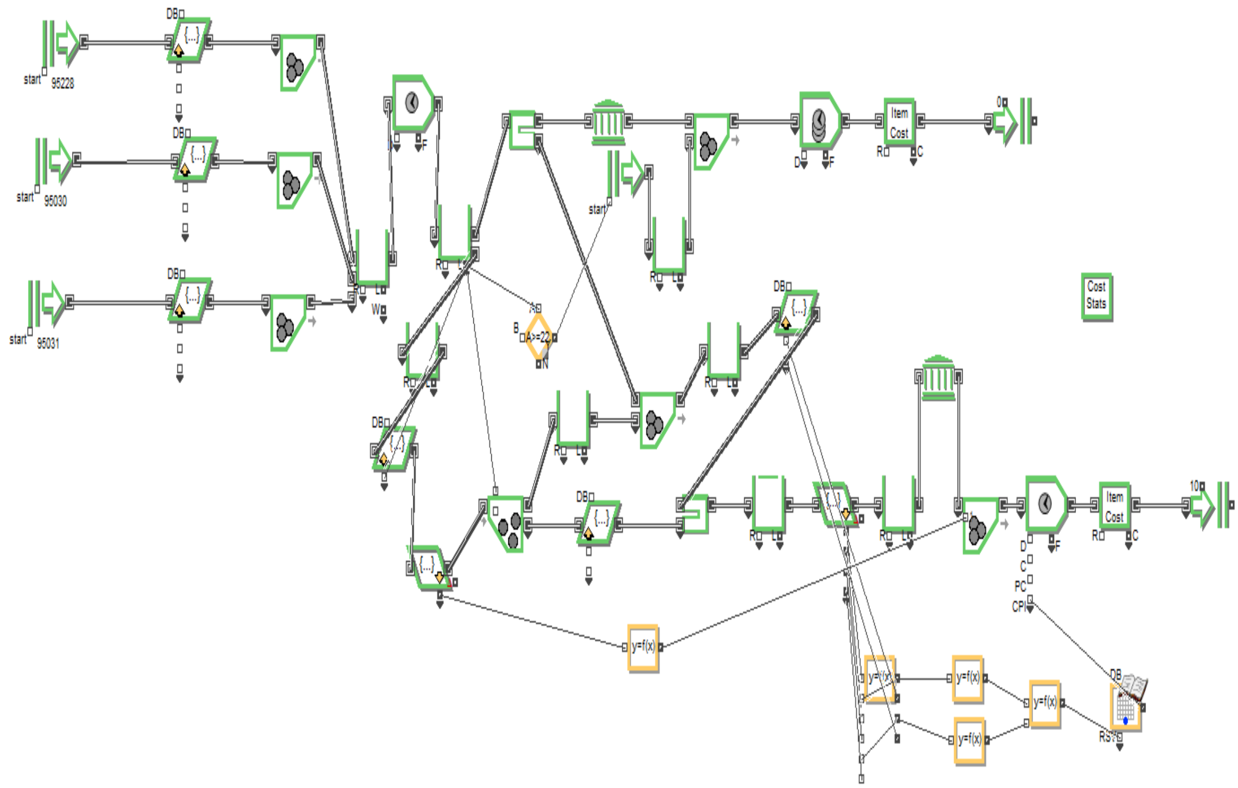
Symbol	Block	Characteristics
	Create	Creates items according to either a distribution or schedule
	Set	Assigns attributes to an item
	Get	Reads the attributes assigned to items for further use
	Batch	Batches a determined amount of items into a single item
	Queue	Buffers item that cannot continue in the simulation yet
	Activity	Holds an item for a certain amount of time and can attach a cost per time the activity is performed
	Select item out	Lets the item choose from 2 different paths
	History	Keeps track and displays the items that have passed this block
	Cost by item	Tracks the costs, that the item has gained throughout the system, of the items that pass this block
	Unbatch	Unbatches a single item into multiple others
	Select item in	Puts 2 different paths together and merges them to one
	Cost stats	Displays the total cost of the simulation run
	Recourse	Holds a certain amount of recourses from the beginning of the simulation, operates same way as items
	Exit	Lets the items leave the system
	Decision	Gives an output if a certain condition is fulfilled
	Equation	Changes value input in a different output according to a developed equation
	Read	Looks up an incoming variable in a data set and outputs the connected value

H. Simulation models for each port

Shanghai port

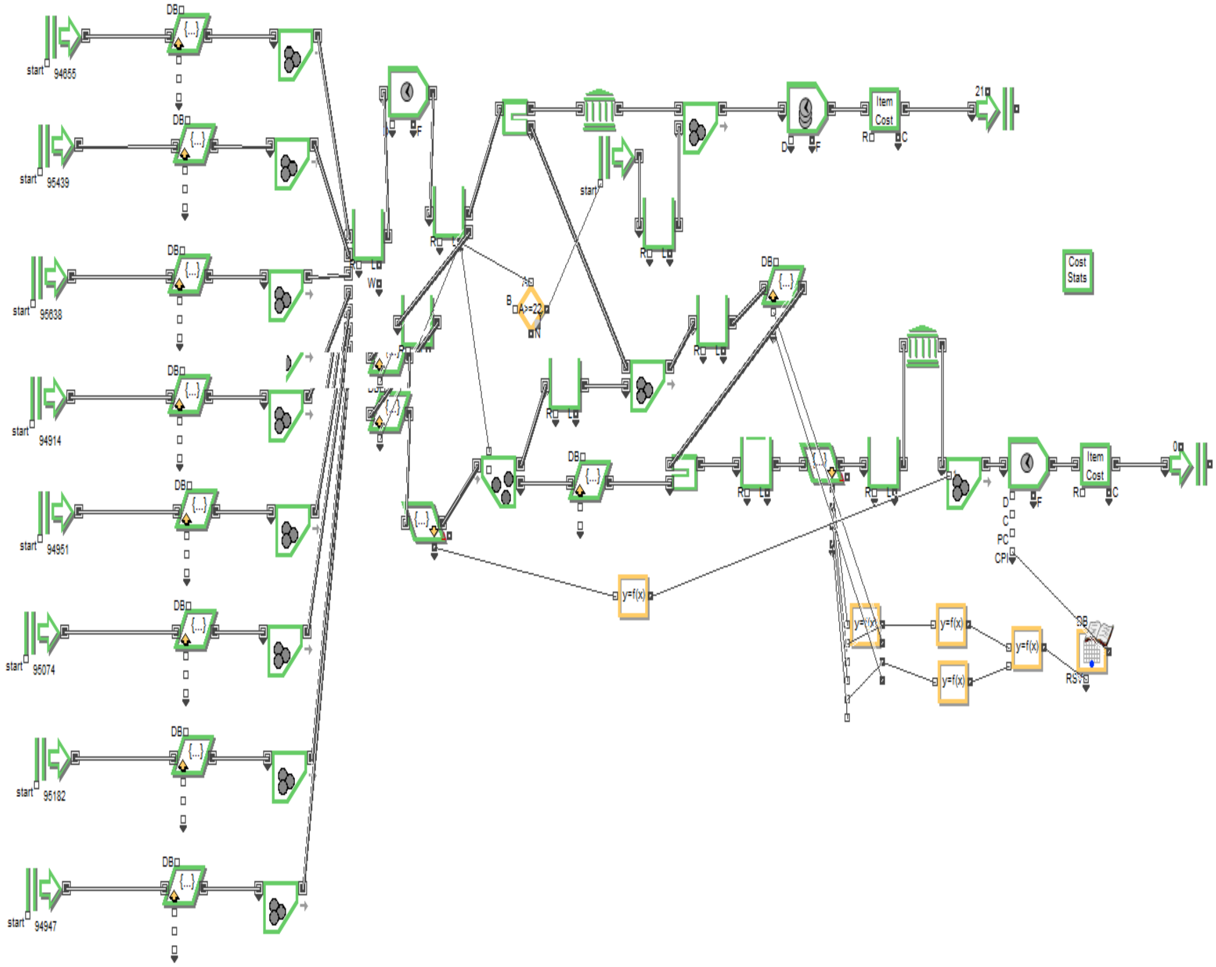


Nansha port

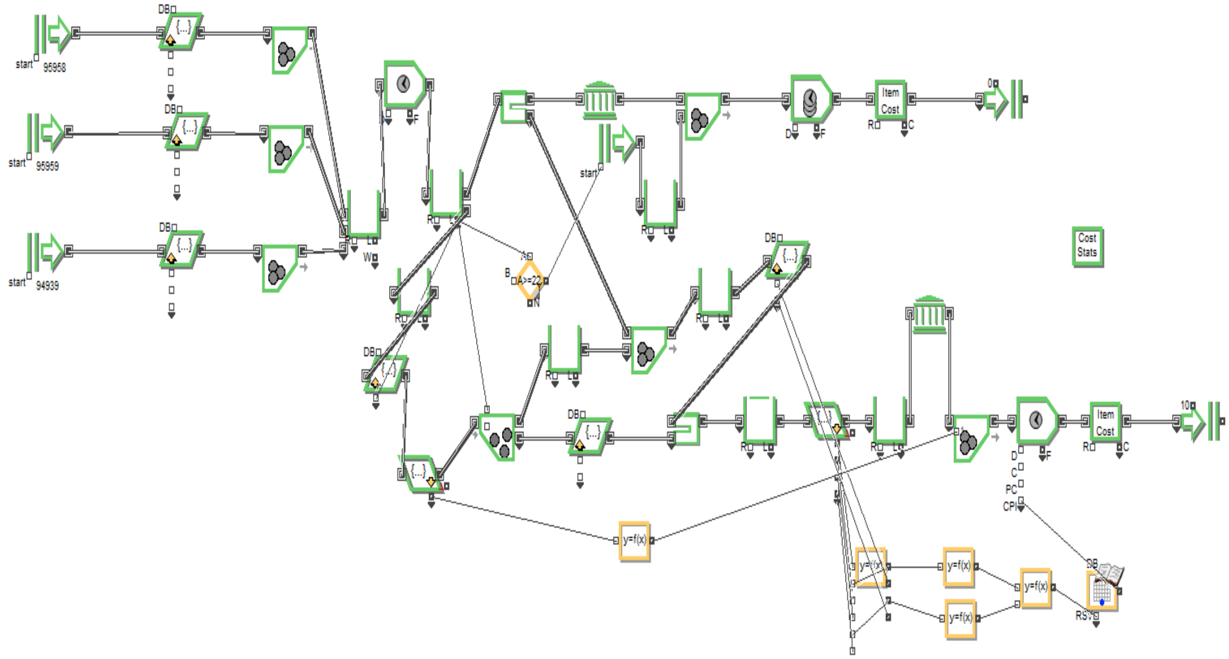


start
95228
start
95030
start
95031
start
Item Cost
Item Cost
Cost Stats
A>=22
y=f(x)

Qingdao port



Fuzhou port



I. Costs after consolidation

Shanghai			
Waiting time	#full containers	#LCL containers	costs
10	9	11	184756,5
11	11	5	172545,1
12	12	3	170497,2
13	12	3	171117,3
14	13	2	171969,5
15	13	1	161760,8
16	13	1	161760,8
17	13	1	161760,8
18	13	1	161760,8
19	14	1	163050,4
20	14	0	161149,4
21	14	0	161149,4
22	14	0	161149,4

Nansha			
waiting time	#full containers	#LCL containers	costs
10	0	14	67189,48
20	0	7	54398,18
30	0	5	50043,2
38	3	1	43873,46
40	3	1	44529,1
50	4	0	46042,68
60	4	0	46042,68

Qingdao			
waiting time	#full containers	#LCL containers	costs
5	0	31	324280,8
6	2	25	305324
7	12	13	266332,4
8	16	6	256966,2
9	18	4	244264,8
10	18	3	245397,7
11	19	2	245974,1
12	21	1	243816,6
13	21	0	241724,1
14	21	0	241724,1
15	21	0	241724,1

Fuzhou			
waiting time	#full containers	#LCL containers	costs
20	0	8	122217,2
22	1	7	111919
24	4	4	83022,84
26	5	2	75702,91
28	5	2	77252,37
30	5	2	78083,41
32	6	0	69064,02
34	6	0	69064,02

J. Exact order times

Shanghai port

16	95036	36	94809	80	94910	110	95227	130	95036	164	95036
16	94910	36	95036	80	94809	110	93918	130	93918	164	93918
16	95036	36	95227	80	95227	110	94809	139	94809	164	95036
16	93918	36	94910	80	93918	110	95271	139	95271	164	93918
16	94809	36	93918	80	95033	110	94910	139	95227	164	94809
16	95036	36	94809	80	95036	110	95036	139	94910	164	94910
16	94910	47	95036	80	95271	110	93918	139	95036	164	95036
16	95033	47	94910	80	94910	110	93918	139	94809	164	95227
16	95036	47	95033	80	94809	110	94809	139	95033		
16	95271	47	93918	80	95036	110	94910	139	93918		
16	95036	47	94809	80	93918	110	95033	139	95036		
16	93918	47	95271	80	94809	110	95036	139	93918		
16	94809	47	95036	90	94910	110	95036	139	94809		
16	94910	47	94910	90	94910	110	94809	139	94910		
16	95036	47	93918	90	95033	110	94910	139	95036		
16	93918	47	94809	90	95036	110	95036	139	94809		
16	94809	47	95036	90	93918	110	93918	139	95271		
16	95036	47	94910	90	94809	110	95271	139	94910		
16	95227	47	95033	90	95271	120	95227	139	95036		
16	94910	47	95036	90	95036	120	94809	139	93918		
16	95033	47	95227	90	95227	120	94910	139	95033		
16	95036	47	93918	90	93918	120	95033	139	94809		
26	93918	47	94809	90	94809	120	95036	139	94910		
26	94809	47	94910	90	94910	120	93918	139	95036		
26	95036	47	95271	90	95036	120	95036	150	93918		
26	95271	47	94910	90	94910	120	95036	150	95227		
26	94910	47	95036	90	95033	120	93918	150	94809		
26	95036	47	93918	90	94809	120	94809	150	94910		
26	93918	61	94809	90	93918	120	94910	150	95033		
26	94809	61	95036	90	95036	120	94809	150	95036		
26	95036	61	95033	90	94809	120	95271	150	93918		
26	94910	61	95036	90	94910	120	94910	150	95271		
26	95033	61	94910	90	95036	120	95033	150	95036		
26	95036	61	93918	90	95271	120	95036	150	93918		
26	94809	61	94809	100	93918	120	93918	150	94809		
26	95036	61	94910	100	94809	120	95036	150	94910		
26	93918	61	95036	100	94910	120	95036	150	94809		
26	94809	61	95271	100	95033	120	93918	150	94910		
26	95271	61	95036	100	95036	120	94809	150	95033		
26	94910	61	93918	100	95036	120	94910	150	95036		
26	95036	61	94809	100	95227	130	95227	150	93918		
26	95227	61	94910	100	94809	130	93918	150	95036		
26	94910	61	95033	100	95036	130	94809	150	93918		
26	95033	61	95227	100	93918	130	94910	150	94809		
36	95036	61	93918	100	94910	130	95033	150	95271		
36	95036	61	94809	100	95036	130	95036	150	94910		
36	93918	61	94910	100	93918	130	95036	164	95227		
36	94809	61	95036	100	94809	130	95271	164	94809		
36	95036	61	95036	100	95271	130	95036	164	94910		
36	94910	61	93918	100	94910	130	93918	164	95033		
36	95036	80	94809	100	95033	130	94809	164	95036		
36	93918	80	95271	100	95036	130	94910	164	93918		
36	94809	80	94910	100	94809	130	94910	164	95036		
36	95036	80	95033	100	94910	130	95036	164	93918		
36	94910	80	95036	100	95036	130	93918	164	94809		
36	95036	80	95036	100	93918	130	94809	164	94910		
36	95271	80	94910	110	94809	130	95033	164	94809		
36	95033	80	93918	110	94910	130	95036	164	95271		
36	95036	80	94809	110	95033	130	95036	164	94910		
36	93918	80	95036	110	95036	130	94910	164	95033		

Qingdao port

13	95439	27	95638	49	94947	82	94951
13	94951	27	95182	49	95439	82	94655
13	94655	27	95439	49	94951	82	94947
13	95638	27	94655	49	94655	82	95638
13	94655	27	95074	49	94914	82	94914
13	94914	27	94951	49	95182	82	95638
13	95638	34	95439	49	95439	82	95439
13	95182	34	94655	49	94951	82	94655
13	95439	34	94947	49	94655	82	95074
13	94951	34	94914	49	95638	82	95182
13	94655	34	95638	49	95439	82	95439
13	95074	34	95439	49	94655	82	94951
13	94951	34	94951	59	95074	82	94655
13	94655	34	94655	59	94951	82	94914
13	95439	34	95182	59	94655	82	95439
13	94951	34	95439	59	94914	82	94951
13	94655	34	94951	59	95182	82	94655
13	95638	34	94655	59	95439	82	95638
13	95182	34	94655	59	94951	89	94914
13	94947	34	94914	59	94655	89	95638
13	94914	34	95638	59	94947	89	95182
13	95439	34	95439	59	95638	89	95439
19	94655	34	94951	59	95439	89	94951
19	94914	34	94655	59	94655	89	94655
19	95638	34	94914	59	94951	89	94947
19	95439	34	95439	59	94655	89	95439
19	94951	34	94951	59	94914	89	94951
19	94655	34	94655	59	95182	89	94655
19	95182	40	95074	59	95439	89	94914
19	95439	40	95638	59	94951	89	95182
19	94951	40	95182	59	94655	89	95439
19	94655	40	95439	59	95074	89	94951
19	95074	40	94951	59	95638	89	94655
19	95638	40	94655	59	94655	89	95638
19	94655	40	94947	70	95439	89	95439
19	95439	40	95439	70	94951	89	94655
19	94951	40	94951	70	94655	89	95074
19	94655	40	94655	70	94947	89	94914
19	94914	40	95638	70	94914	89	95638
19	95638	40	95439	70	95182	89	94951
19	95182	40	94655	70	95439	96	94655
19	95439	40	94914	70	94951	96	95182
19	94951	40	94951	70	94655	96	95439
19	94655	40	94914	70	95074	96	94951
27	94947	40	95182	70	95439	96	94655
27	94914	40	95439	70	94655	96	94947
27	94951	40	94655	70	95439	96	95439
27	95439	40	95074	70	94951	96	94951
27	94655	40	95439	70	94655	96	94655
27	95638	40	94951	70	95638	96	94914
27	95074	49	94655	70	94914	96	95638
27	95182	49	95638	70	95439	96	95439
27	95439	49	95182	70	94655	96	94655
27	94951	49	95439	70	95182	96	95638
27	94655	49	94951	70	95439	96	95182
27	94914	49	94655	70	94951	96	94951
27	95439	49	94914	82	94655	96	94914
27	94951	49	95638	82	95439	96	95439
27	94655	49	95439	82	94655	96	94951
27	94951	49	94655	82	95439	96	94655

Qingdao port (2nd part)

96	95182	116	95439	139	95439	161	94655
96	95439	116	94951	139	94951	161	95439
104	94951	116	94655	139	94655	161	94951
104	94655	116	94914	139	94947	161	94655
104	95074	116	95182	139	94914	161	95182
104	95638	116	95439	139	95182	161	95439
104	94914	116	94951	139	95439	161	94951
104	94947	116	94655	139	94951	161	94655
104	94914	125	95074	139	94655	161	95074
104	95439	125	94914	139	95638	161	95638
104	94951	125	95638	139	94914	161	94914
104	94655	125	95439	139	95439	161	94947
104	95074	125	94951	139	94951	161	94914
104	95182	125	94655	139	94655	161	95439
104	95439	125	95439	146	95182	161	94951
104	94951	125	94951	146	95439	161	94655
104	94655	125	94655	146	94951	161	95439
104	95638	125	94947	146	94655	161	94951
104	95439	125	94914	146	95638	161	94655
104	94951	125	95182	146	95439	161	95182
104	94655	125	95439	146	94951	174	95638
104	94914	125	94951	146	94655	174	94655
104	94914	125	94655	146	95074	174	95439
104	95638	125	95638	146	94914	174	94951
110	95182	125	94914	146	94947	174	94655
110	95439	125	95638	146	94914	174	94914
110	94951	125	95439	146	95638	174	95439
110	94655	125	94951	146	95182	174	94951
110	95439	125	94655	146	95439	174	94655
110	94951	125	95182	146	94951	174	95638
110	94655	131	95439	146	94655	174	95182
110	94947	131	94951	146	95439	174	95074
110	94914	131	94655	146	94951	174	94914
110	95182	131	95074	146	94655	174	95439
110	95439	131	95439	146	95182	174	94951
110	94951	131	94951	146	95439	174	94655
110	94655	131	94655	154	94951	174	94947
110	95638	131	94914	154	94655	174	95439
110	95439	131	95638	154	95638	174	94951
110	94655	131	95439	154	94914	174	94655
110	95074	131	94655	154	94914	174	94951
110	94914	131	94947	154	95439	174	95638
110	95638	131	94914	154	94951		
110	94951	131	95182	154	94655		
110	95182	131	94951	154	95182		
110	95439	131	94655	154	95439		
116	94951	131	95439	154	94951		
116	94655	131	94951	154	94655		
116	95439	131	94655	154	95074		
116	94951	131	95638	154	94947		
116	94655	131	95182	154	95638		
116	95638	131	95439	154	95439		
116	95074	139	94951	154	94951		
116	94914	139	94655	154	94655		
116	95439	139	94914	154	94914		
116	94655	139	95638	154	94914		
116	94947	139	95439	154	95638		
116	95638	139	94951	154	95182		
116	95182	139	94655	161	95439		
116	94951	139	95074	161	94951		

Fuzhou port

26	94939	51	94939	104	94939	159	94939
26	94939	51	94939	104	94939	159	95958
26	94939	51	94939	104	94939	159	94939
26	94939	51	94939	104	94939	159	94939
26	94939	83	94939	104	94939	159	94939
26	94939	83	94939	104	94939	159	95958
26	94939	83	94939	104	94939	159	94939
26	94939	83	95958	104	95958	159	94939
26	94939	83	94939	129	94939	159	94939
26	94939	83	94939	129	94939	159	94939
26	94939	83	95958	129	94939	159	94939
26	94939	83	94939	129	94939	159	95958
26	95958	83	95958	129	94939		
26	94939	83	94939	129	94939		
26	94939	83	94939	129	94939		
26	94939	83	94939	129	95958		
26	94939	83	95958	129	94939		
26	94939	83	94939	129	94939		
26	94939	83	95958	129	94939		
26	94939	83	94939	129	94939		
26	95958	83	94939	129	94939		
26	94939	83	94939	129	94939		
51	94939	83	94939	129	94939		
51	94939	83	95958	129	94939		
51	94939	83	94939	129	95958		
51	95958	83	94939	129	94939		
51	94939	104	94939	129	94939		
51	94939	104	95958	129	95958		
51	94939	104	94939	129	94939		
51	94939	104	94939	129	94939		
51	95958	104	94939	159	94939		
51	94939	104	94939	159	95959		
51	94939	104	94939	159	94939		
51	94939	104	95959	159	94939		
51	95958	104	94939	159	95958		
51	94939	104	94939	159	94939		
51	94939	104	94939	159	94939		
51	94939	104	94939	159	94939		
51	95958	104	95958	159	94939		
51	95959	104	94939	159	94939		

Nansha port

45	95228	116	95030	151	95228
45	95030	116	95228	151	95228
45	95228	116	95031	151	95030
45	95031	116	95228	151	95228
45	95228	116	95030	151	95030
45	95030	116	95228	151	95031
45	95228	116	95030	151	95228
45	95030	116	95228		
45	95031	116	95031		
45	95228	116	95228		
45	95030	116	95030		
45	95228	116	95228		
45	95228	116	95031		
45	95031	116	95030		
45	95030	116	95228		
45	95228	116	95228		
45	95228	116	95030		
45	95030	116	95228		
45	95228	116	95031		
45	95228	116	95228		
45	95031	116	95030		
45	95030	116	95228		
83	95228	151	95228		
83	95228	151	95031		
83	95031	151	95030		
83	95030	151	95228		
83	95228	151	95228		
83	95228	151	95030		
83	95030	151	95228		
83	95228	151	95031		
83	95031	151	95030		
83	95030	151	95228		
83	95228	151	95030		
83	95228	151	95228		
83	95031	151	95228		
83	95030	151	95031		
83	95228	151	95030		

K. Current pallets shipped by air - results from best-case simulation run

Haldex China		Supplier3	
17	96137	51	95134
17	96364	96	95134
17	96137	121	96975
17	96273	153	95134
34	96364		
34	96137		
56	96364		
56	96137		
78	96364		
78	96137		
99	96364		
99	96137		
122	96364		
122	96137		
141	96273		
141	96364		
141	96137		
165	96364		
165	96137		
165	96364		

L. Interview Guide

General questions

- What is your position at Haldex? What are you responsible of? What are your main tasks?
- How would you describe the upstream logistical flow? How does it look like?
- How does Haldex schedule their inbound logistics?
- What are the different physical flows?
- Where does it make sense to consolidate shipments?
- How many different components do you purchase from your suppliers?
- Is purchasing integrated in logistics?
- What BI-system do you use? How do you process the information gathered from your BI-systems (decision making, control function, forecasting)?
- Recommendations? Requirements? What should not be changed?

Logistics

- Where should the consolidation be executed? Should consolidation take place at the factory, on a vehicle, at a warehouse or terminal?
- Who should consolidate? The manufacturer, shipper, customer, carrier, or a third party?
- How should consolidation be carried out? Which specific techniques will be employed?
- Are you already consolidating shipments on a smaller scale?
- How does the national transport in china work so far?
- Do you use distribution terminals or is each shipment individually sent to the port and dispatched to a container?
- How is 3PL1 involved?
- What kind of container does Haldex use?
- Does supplies go through Göteborg or Helsingborg?
- What is the current shipping policy? FCL or LCL?
- What are the usual lead times for goods sourced from China?
- How are transportation costs currently calculated?

Sourcing

- Do you prefer transport with environmental friendly companies?
- Do you include the environmental aspects in your transportation strategy?
- Do you include the environmental aspect in suppliers performance evaluation ? How?
- Do you ask your strategic suppliers to develop their strength in this areas? Do you help them to develop in that area?
- Who are your key suppliers?
- Which suppliers do you have a closer partnership with?
- Does each production facility has its own suppliers? (is it local, regional or global)?
- Why are you constantly reducing the amount of suppliers?
- What kind of information do you share with your suppliers and forwarders (especially forecast information?
- Can suppliers monitor your current inventory levels? And do they react on those independently?
- How many SKUs are purchased from chinese suppliers? Where could we find their dimensions, characters and BOMs?
- Why do you use airfreight?
- Is consolidation feasibil?
- Why did you agree on consignment only with certain suppliers?
- How many suppliers does Haldex frequently use?
- What is Haldex leverage position in comparison with its suppliers?
- How do you categorize your suppliers? Sourcing strategy (dual sourcing, multiple sourcing?
- Who is responsible for the goods during transportation?

- Do we have access to supplier contracts?
- Are we allowed to contact the suppliers?

Planning

- How does the planning process look like?
- How do you monitor the transportation to the site at the moment?
- How are supplier and forwarder involved?
- Do you measure your performance and if so, based on which KPIs?
- Do you have IT systems supporting scheduling, planning?
- What should be consolidated? Which orders, respectively items need to be consolidated and which shipped alone?
- When are orders released? What event(s) will trigger the dispatch of a vehicle containing a consolidated load?
- What is your order policy, order to stock, order to forecast, etc.?
- What would you like to have monitored to make your planning easier/take decisions more efficiently?
- How is your MRP conducted? Do you use DRP, too?
- Is the batch size related to the pallet size?
- What is meant by minimum and min quantity?
- What is the safety stock based on?
- How often does the production plan gets updated?
- BOM line vs. production line?
- What is the frozen time for each supplier?
- What is your position at Haldex? What are you responsible of? What is your task?
- How would you describe the upstream logistical flow? How does it look like?
- How does Haldex schedule their inbound logistics?
- Who are your key suppliers? Who are your suppliers?
- What are the different physical flows?

Forecast

- How do you conduct your forecast at Haldex?
- How often do you update that forecast?
- How is your forecast accuracy?
- What are the lead times of your suppliers?
- What kind of tools do you use for forecasting?
- To which point is forecast reliable?

Internal logistics

- Internal logistical procedure: from receiving till put-away
- Potential information to monitor?

Logistics provider – 3PL2

- What kind of services is 3PL2 executing for Haldex?
- What information is shared between Haldex and 3PL2?
- Which factors influence the time of arrival?
- What obstacles need to be overcome to implement time windows?
- How does the booking procedure of trucks work?
- Does each supplier have a specific or prefered day of delivery?
- When and how do you receive a notification of delay?
- Is 3PL2 using time windows with other companies?