Express distribution of spare parts

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Abstract

This master’s thesis is the final step of the Master’s degree in Supply Chain and Logistics, carried out in the Department of Engineering Logistics of Lund University.

This study deals with how to improve a supply chain side of a part of the Sandvik’s products, which is carried out with the collaboration of the company, in the Sandvik’s base in Svedala.

The study focuses only on a part of their spare parts, the commercial designations spare parts and SRP special components. Both are spare parts of the stationary business unit, which is within the Crushing and Screening product area, and at the same time, is in turn within Sandvik’s business area, Sandvik Minning and Rock Technology.

Likewise, this thesis is in charge of the supply chain from the central European warehouse of these pieces to either the final customer or other smaller stores in Europe. The study has been divided into two parts. In the first one, in order to identify some of the main problems that this supply chain is performed, through interviews and great research, as well as, and through cause-effect relationships, their consequences.

Secondly, to measure what the result would be and effect of Sandvik and the client if these problems in the supply chain disappeared is wanted, trying to explain the value they would have. For this, two variables are measured, the cost related to Sandvik, and the lead time, related to customer service. In order to evaluate these variables, a simulation model in Excel is created that reproduces various situations in which Sandvik would be found. After three simulations, the scenario that would represent the situation in which the problems of the supply chain would be solved arrives and where both Sandvik and its customers would like. Finally, several conclusions are drawn from this study, as well as some challenges in solving these problems and producing the perfect situation for all actors involved in the supply chain. The latter will form part of the proposed further studies.
Acknowledgements

This thesis has been made in the company Sandvik and therefore, in first place, the author wants to thank the company and its workers the great collaborative with her, as well as, all the means offered for the understanding of a wide and complex problem.

Since Sandvik is a big company with a difficult and very large supply chain, the understanding of all of it has not been easy or fast, but it has been possible thanks to the coordinators with whom the student has worked.

Special mention to the coordinators in the company, Miguel Rocha, Jamie Heath and Marie Hallqvist, who have been close and have maintained a daily contact with the student, guiding at all times and offered all the resources and information that have been needed. On the other hand, gratefulness to the University of Lund, since has been a great time in it and also, because was the link of contact with the company Sandvik. Particularly, the supervisor of this thesis, Jan Olhager, for his help and guidance in this work.


Africa Serrano Alvarez.
Acronyms

**QR** Quick response

**CP** Criticality point

**ERP** Enterprise resource program
Contents

3.1.3 Supply chain functional definitions ............................................. 31
3.1.4 Supply chain components ......................................................... 31
3.1.5 Supply chain performance measurements ..................................... 32
3.2 Transportation ................................................................. 33
  3.2.1 Transportation performance characteristics .................................. 33
  3.2.2 Transportation as 3PL ....................................................... 34
  3.2.3 JIT and Quick Response transportation ..................................... 35
3.3 Order management ............................................................. 35
  3.3.1 Managing order cycle time ................................................... 36
3.4 Spare parts ................................................................. 36
  3.4.1 Spare parts’ end user perspective: Inventory ............................... 37
  3.4.2 Spare parts’ manufacturer perspective: Demand ......................... 37
  3.4.3 Spare parts’ manufacturer perspective: Distribution ..................... 38
3.5 6 sigma ................................................................. 40
  3.5.1 Cause and effect diagram ................................................... 40
  3.5.2 Five whys ................................................................. 40
4. Empirical data .............................................................. 41
  4.1 General information concerning Sandvik ...................................... 41
    4.1.1 Sandvik core values ...................................................... 42
    4.1.2 Corporate structure ...................................................... 42
    4.1.3 Sandvik’s spare parts .................................................... 43
      4.1.3.1 Spare parts object of this study .................................. 43
      4.1.3.2 Spare parts’ Europe distribution .................................. 44
  4.2 General information concerning TNT ......................................... 47
    4.2.1 TNT relation with Sandvik ............................................... 47
5. Analysis ................................................................. 49
  5.1 First step ................................................................. 49
    5.1.1 Analysis with five "whys" technique .................................... 50
    5.1.2 Fishbone ................................................................. 53
  5.2 Second step ............................................................... 53
  5.3 Provided data analysis ....................................................... 54
  5.4 Creation of a simulation model ............................................... 62
  5.5 Actual situation. Scenario 0. .................................................. 63
  5.6 Scenario 1 ................................................................. 65
  5.7 Scenario 2 ................................................................. 65
  5.8 Scenario 3 ................................................................. 66
  5.9 Obtained data analysis ....................................................... 67
6. Results and conclusions ....................................................... 77
  6.1 Answers to research questions ............................................... 77
  6.2 Results ................................................................. 78
  6.3 Conclusion ............................................................... 79
  6.4 Further studies and recommendations ...................................... 80
7. Appendix 82
Bibliography 95
1

Introduction

1.1 Background

The management of customer service and the ability of the enterprise to respond quickly to the needs and expectations of today’s customer have become dominant objectives pursued at all levels in the distribution channel. The truth of the matter is that today customers, with their expectations set by "world-class" companies across industries and continents, are demanding more of their suppliers in regard to quick response and the quality and availability of products [Ross, 1996].

In 1990s this operating paradigm has been termed "Quick response"(QR). For the most parts, QR has been associated with the retail side of distribution. Retailers have long been aware of the need to have product on the shelf when needed, minimizing shortages, offer total product quality, and reduce the amount of stocked inventory. However, it is obvious that retailers cannot hope the effectively implement QR principles unless the entire distribution channel that precedes them also is committed to QR principles.

Rather than a narrow philosophy focused on the point-of-sale, the concept of QR should be expanded to embrace the whole supply chain [Ross, 1996]. In the past, international physical distribution has suffered from poor organization, a lack of training, and the absence of interorganizational power and influence. Physical distribution is often seen in a supporting role and not regarded as a key element in the enterprise’s international marketing strategy.[...] resulting in limited opportunities for integrating the two functions and pursuing improvements in cost, efficiency, and productivity. Without effective international distribution organization, the enterprise cannot hope to optimize on global opportunities and deter possible competitive threats [Ross, 1996].

Times have changed, however, with consequent implications for supply chains and especially transportation service providers. Fuel prices have escalated, trans-
port capacity is tighter, labor costs have increased for many global locations, there is more concern about the environment and sustainability, and there are growing infrastructure problems with ports, highways, bridges, terminals, rail right-of-ways, rivers, and canals. The net impact is that transportation can no longer be taken for granted and its importance to efficient and effective supply chain is significant and increasing. This statement may be supported by the figure 1.1:

Figure 1.1 Cost distribution in the supply chain. [U.S. Truck Driver Shortage Elevates Importance of Real Estate in Supply Chain Cost Structures 2014].

"Rising transportation costs, particularly those associated with trucking, are forcing supply chain users, manufacturers, importers, and exporters, to devise blends of warehouses and distribution centers that will most efficiently service the need for port access while enabling quick delivery to end users in densely populated metropolitan areas" said Scott Marshall, Executive Managing Director, Industrial Services, The Americas, CBRE.

Finally, this study is built from an aftermarket perspective, where spare parts are a big part of it. Firms with a well-aligned spare parts logistics strategy can add value for their customers beyond primary product benefits, thus building long term customer loyalty and achieving high profit margins [Johansson and Olhager, 2003].

Spare parts have become ubiquitous in modern societies, and managing their re-
quirements is an important and challenging task with tremendous cost implications for the organizations that are holding relevant inventories. Demand for spare parts arises whenever a component fails or requires replacement, and as such the relevant patterns are different from those associated with typical stock keeping units. Such demand patterns are most often intermittent in nature, meaning that demand arrives infrequently and is interspersed by time periods with no demand at all [Jouni et al., 2011].

1.2 Problem introduction

For every kind of item, Sandvik provides a distribution option from its central warehouse in Europe, located in Eindhoven (Netherland), to a customer or to a local warehouse. The distribution chain is carried out by an external carrier named TNT. When the client or the local warehouse demand an item, they may specify its imperative explaining how fast they need the order. Then, Sandvik may short orders due to their emergency and choose a TNT’s distribution solution that satisfies the specified customers’ requirements. However, this is not being achieved.

On the one hand, even though TNT offers a wide variety of alternatives to Sandvik, all orders are sent using the same solution, which is the fastest and hence, the most expensive one. Thus, Sandvik is not filtering or shorting the orders in the warehouse and, therefore, Sandvik is not sending them in accordance with the shipments’ emergencies. This shipments’ aggregation makes that, replenishment orders for local warehouses are attended in the same way as the most emergency orders, owing to, for instance, a needed piece for a customer with machine down. While these two orders have different requirements, Sandvik realizes there is no point on having the same supply chain configuration.

On the other hand, there are some instants when the central warehouse does not hold all needful items to fulfill the orders and consequently, the clients and local warehouses reply in two ways: firstly, they need to launch the shipments long time in advance to ensure they are going to have the products, which is not in harmony with an express and dynamic distribution, and secondly, they use greater emergencies, which does not answer to real necessities. Besides, while a shipment may include more than one order, customers and warehouses expect to receive the entire shipment in one sitting, however this is not happening either.

1.3 Purpose

The aim of this master’s thesis is to develop a dynamic aftermarket distribution model in Sandvik to supply spare parts for customers or local warehouses in Europe considering customers and warehouses’ requirements. The developed distribu-
Chapter 1. Introduction

tion model shall support quick response to customer’s needs and also reduce costs related to local warehouses, which current amount is not in accordance with the company strategic of the aftermarket distribution.

1.4 Research questions

Before starting this study, some questions have emerged, which will determine the course of this master’s thesis:

RQ1. How is the spare parts’ distribution working?

RQ2. Which dilemmas have the spare parts’ supply chain?

RQ3. Is there agreement between spare parts’ distribution and Sandvik’s strategy?

RQ4. How might spare parts’ distribution be improved from the company’s perspective without depreciating customers’ service level?

1.5 Focus and delimitations

Since Sandvik’s distribution chain is very wide, the biggest found limitation is the time frame to understand, analyze, conclude and write the study. Besides, in order to find a final result for the whole aftermarket distribution problematic, a first approach is needed, ergo this study is bounded by its geographic coverage and product category within aftermarket supply chain.

Geographical limitation. Even though the aftermarket’s distribution is performed for customers and local warehouses around the world, this specific study is delimited to European market. This is due to the fact that, for measuring the greater impact that a change in the aftermarket supply chain would have, choosing the larger market in terms of sales and customers is necessary, which in this case is Europe.

Product area. The Sandvik’s aftermarket is integrated by a wide range of types of spare parts, about which there is more information in section 4. This study is just focused on two types of spare parts, due to the fact that analyzing just these types’ data supposes to lead to more accurate results than handling data from all kind of spare parts and also, simplifies the problem since these distributions are really similar.
1.6 Work flow

This section offers a brief abstract of each report chapter:

**Introduction:** This chapter starts with a selection of commentaries related to different paths this thesis is in contact with. It also advances which are the problems this study tries to solve, explaining the specific purpose and also, the translation of the study to research questions. This chapter ends with an explanation about how and why the project is framed.

**Methodology:** In this master’s thesis part, some theory regarding research methodology is exposed, starting from which type of research this master’s thesis might be and accordingly, how data might be treated, collected and analyzed. Some further information regarding how the thought process of results and solutions should be, since two possibles ways are possible and also, how to build an accurate and a reliable study. Then, a summary about the steps of the project is presented.

**Frame of reference:** The aim of this chapter is to enclose the reader into the paths this study is in related to. In each project execution phase, some information regarding different logistics and supply chain fields is consulted and help to ensure accuracy in the results. Thus, in this chapter this research is presented, and also it is in a chronological way, following the same line the writer does.

**Empirical data:** This section explains some relevant data related to the companies object of study which is completely crucial to understand the whole picture where these enterprises are situated. It briefly explains Sandvik’s supply chain, starting from which kind of company is, which types of services it offers ,etc. Moreover, even thought it is not the focused company, some details related to TNT are clarified, and finally, how these two enterprises are related.

**Analysis:** The analysis, as the entire project, is divided into two stages. In the first one, some techniques are used to understand the supply chain’s situation and to frame the issues and their root. And then, some calculations with Excel is used to develop a better relation between the services TNT may offer and the service level to Sandvik’s customers.

**Conclusions and recommendations:** The final part concludes with the possible answers to the research questions, an explanation about the results that have demonstrated which is the solution that Sandvik might implement in the future. Due to the time restriction and the results of this master’s thesis, some further studies are explained and highly recommended.
Methodology

This chapter is related to the research methodology followed. It explains different research strategies, methods in the data collection and data analysis, several research approaches and, finally, the selection of each for this project. An appointment regarding the credibility of the study is also mentioned, finishing with a deeper explanation regarding to the phases and the process of this project.

2.1 Research strategy

Research strategy is an overall plan for conducting a research study. A research strategy guides a researcher in planning, executing, and monitoring the study. While the research strategy provides useful support on a high level, it needs to be complemented with research methods that can guide the research work on a more detailed level [Johannesson and Perjons, 2014].

As a number of different research strategies exist, a researcher to embark on a study, needs to determine which one of these to choose. The choice depends on the goals and characteristics of the study being undertaken. It is possible to identify three main questions for choosing an appropriate strategy [Johannesson and Perjons, 2014]. A brief summary about the five commonly used research strategies is presented below:

- **Experiment**: an experiment is an empirical study that investigates cause and effect relationships. The purpose of an experiment is to prove or disprove a causal relationship between a factor and an observed outcome. A researcher carrying out an experiment for testing a hypothesis, will manipulate the values of the independent variable and then, observe whether this has any effect on the dependent variables [Johannesson and Perjons, 2014].

- **Survey**: the purpose of a survey as a research strategy aims to map out some path, be it physical or social. A survey usually has a broad coverage and pro-
vides an helicopter view of some area of interest [Johannesson and Perjons, 2014].

- **Archival analysis**: archival research methods include a broad range of activities applied to facilitate the investigation of documents and textual materials produced by and about organizations. In its most classic sense, archival analyses are those that involve the study of historical documents; that is, documents created at some point in the relatively distant past, providing us access that we might not otherwise have to the organizations, individuals, and events of that earlier time [Baum, 2002].

- **History**: it is based on the learning and understanding of the background and growth of a chosen field of study. This might insight into organizational culture, current trends, and future possibilities.

- **Case study**: A case study focuses on one instance of a phenomenon to be investigated, and it offers a rich, in-depth description and insight of that instance. With its focus on depth and context, a case study differs from a survey or a laboratory experiment. While a survey can provide a broad but shallow view of an area, a case study can paint a pregnant and detailed picture of its subject. A laboratory experiment reduces complexity by controlling, even eliminating, factors that can interfere with the experimental results. In contrast, complexity is essential to a successful case study, as it investigates multiple factors, events, and relationships that occur in a real world case [Johannesson and Perjons, 2014].

Nevertheless, the clarification does not imply that the boundaries between the strategies, or the occasions when each is used, are always sharp. Even though each strategy has its distinctive characteristics, there are large overlaps among them. The goal is to avoid gross misfits [Yin, 2003]. That is, when there is a plan for using one strategy while there is another one that fits better.

From [Yin, 2003] perspective there are three conditions to evaluate the appropriate strategy, presented in the Figure 2.1.

The first condition is about the research questions, and is based on the idea that questions may be shorter into five types: "who","what","where","how", and "why". According to [Yin, 2003], if research questions are mainly in the group of "what", either of two possibilities arises. Firstly, some types of "what" are exploratory, this is when a study is undertaken with the objective either to explore an area where little is known or to investigate the possibilities of endeavoring a particular research study [Kumar, 2011]. As an exploratory study, any of the five research strategies can be used and, due to this, does not appear in the Figure 2.1.
Chapter 2. Methodology

<table>
<thead>
<tr>
<th>Method strategy</th>
<th>Form of research question</th>
<th>Requires control of behavioral events?</th>
<th>Focus on contemporary events?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>How, why?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Survey</td>
<td>How, what, where, how many, how much?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Archival analysis</td>
<td>How, what, where, how many, how much?</td>
<td>No</td>
<td>Yes / No</td>
</tr>
<tr>
<td>History</td>
<td>How, why?</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Case study</td>
<td>How, why?</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2.1 Situations to decide which research method to use [Yin, 2003].

The second type of "what" questions is actually a form of "how many" or "how much" line of inquiry [Yin, 2003]. In this cases, the most profitable strategies are a survey, which may enumerate "what" or archival strategies, whereas a case of study would not be an advantageous strategy in this situation. Similarly, "who" and "where" questions, or their derivatives "how much" and "how many", are likely to favor surveys strategies or the analysis of archival records, as in economic research [Yin, 2003]. In general terms, surveys and analysis of archival records are appropriated in the description of an issue, a punctual situation, or even to predict a certain outcome.

Unlike, "how" and "why" questions are more explanatory. In an explanatory study the main emphasis is to clarify why and how there is a relationship between two aspects of a situation or phenomenon [Kumar, 2011]. In this cases [Yin, 2003] suggests to use history strategies or case study. As it is illustrated in the Figure 2.1, just the experiment requires control of the behavior events, as each further step in it is built from a created event and thus, needs control. Finally, all the strategies are focused on contemporary events but history and archival analysis, which may be current or past.

<table>
<thead>
<tr>
<th>Method strategy</th>
<th>Main purpose</th>
<th>Primary data</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>Exploratory</td>
<td>Quantitative</td>
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</tr>
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<td>Survey</td>
<td>Descriptive</td>
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<td>Fix</td>
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<td>Case study</td>
<td>Explanatory</td>
<td>Qualitative</td>
<td>Flexible</td>
</tr>
<tr>
<td>Action research</td>
<td>Problem solving</td>
<td>Qualitative</td>
<td>Flexible</td>
</tr>
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</table>

Table 2.2 Research methods characteristics [Höst et al., 2006].

Even though a strategy might be selected according the Figure 2.1, in order to make a more accurate election, more information regarding the main purpose of the project may guide in the chose. The different purposes can be descriptive, explanatory, exploratory or problem solving. Then, depending on the chosen strategy, qualitative or quantitative methodology should be applied for the collection of the primary data [Höst et al., 2006]. In the figure 2.2 this relation is exposed.
2.1.1 The selected strategy

For this study a case study strategy is selected. This is mainly due to the next exposed reasons:

1. It is a very useful design when exploring an area where little is known or where a holistic understanding of the situation, phenomenon, episode, site, group or community is required. The first step in the project, further exposed in the Part 2.5, corresponds to this description, since a first approach to the entire supply chain is needed. This strategy is of immense relevance when the focus of a study is on extensively exploring and understanding rather, than confirming and quantifying. It provides an overview and in-depth understanding of a case(s), process and interactional dynamics within a unit of study but cannot claim to make any generalizations to a population beyond cases similar to the one studied [Kumar, 2011].

2. The main purpose of this study is also explanatory because, firstly it tries to find "whys" or the causes of the bad performance in the supply chain, and then, "how" the improvement is possible.

2.2 Research methods

Research methods tell the researcher how to collect and analyze data, e.g. through interviews, questionnaires, or statistical methods, and how to research work on a more detailed level.

2.2.1 Data collection methods

A key activity in a research methodology is how to collect information about the path of study. For this purpose, there are several data collection standard procedures. Heedless of the kind of data, there are five types most used: questionnaires, interviews, focus groups, observation studies, and document studies.

Some of these data collection methods have become closely associated with certain research strategies, e.g. surveys typically use questionnaires, and ethnographic studies almost always involve observation. However, in principle, any data collection method can be useful for a given research strategy, and the traditional associations should not restrain a researcher in choosing an appropriate data collection method [Johannesson and Perjons, 2014].

2.2.2 Data analysis methods

Data analysis derives valuable information from data in order to describe or explain some phenomenon under investigation. Raw data does not speak for itself, it needs to be prepared, interpreted, analyzed, and presented before any conclusions
can be drawn from it. Thus, a researcher needs to transform large volumes of data into manageable and meaningful pieces of information [Johannesson and Perjons, 2014].

Two main kinds of data analysis are *quantitative* and *qualitative* analysis. Most methods of data collection can be used in both *qualitative* and *quantitative* research. The distinction is mainly due to the restrictions imposed on flexibility, structure, sequential order, depth, and freedom that a researcher has in their use during the research process. *Quantitative* methods favour these restrictions whereas *qualitative* ones advocate against them [Kumar, 2011].

For example, if an observation is recorded in a narrative or descriptive format, it becomes *qualitative* information, but if it is recorded in categorical form or on a scale, it will be classified as *quantitative* information. Similarly for data collected through interviews. An unstructured interview, recorded in a descriptive or narrative form, becomes a *qualitative* method, but in a structured interview, if the information is recorded in response categories or if the categories are developed and quantified out of descriptive responses, it is a *quantitative* method. Descriptive responses obtained in reply to open-ended questions are all *qualitative* but if the responses are in numerals they will be considered *quantitative*. If categories and quantify the categorisation as a part of the analysis of descriptive responses to an open-ended question is developed, it becomes a *quantitative* analysis. Data generated by focus groups, oral histories, narratives, group interviews is always *quantitative* in nature [Kumar, 2011].

### 2.2.3 The selected methodology

The selected data collection method is a combination of *interviews*, *observation studies*, and *document studies*. During the first step of this project some interviews take place to understand the whole picture. Then, also in this step, some observation studies to some parts of the supply chain as warehouses are performed. Finally, there is a study of some Sandvik’s documents. In the second phase of the project execution, document studies are widely used combined with additional interviews which help in the guide of the study.

Regarding to the data analysis methods, a mix of those two methods is applied, since the information from the interviews is collected in a qualitative way, as it is used to explain the situation, while the data from the documents is mainly quantitative. In the last step is more quantitative rather than qualitative.Although the performance index may be evaluated as qualitative data, such as customer satisfaction, picking efficiency or emergency classification, these values can also be sought through quantitative indicators. For example, customer satisfaction can be assessed qualitatively by surveying, which is mostly qualitative or quantitatively, by measuring whether the product arrives at the time requested by the customer in
2.3 Research approaches. Inductive and deductive

In order to carry out this study, a description of the research approach selected is presented. The research approach is based on the Figure 2.1, where two types of possible research approaches are illustrated.

![Figure 2.1 Inductive and deductive approaches and their relation with quantitative and qualitative.](image)

2.3.1 Inductive

*Inductive* approach begins with specific observations and the conclusions are generalized. In this approach, after selecting a number of observations correctly, one can generalize the conclusion to all groups of similar conditions and situations. These generalizations need to be tested, some of which might be verified and some rejected. Accordingly, all of the principles which are derived based on *inductive* reasoning are theoretically falsifiable.

In the induction process, the researcher as an observer, should honestly, without any prejudgments and biases, and with an impartial mind, register what they observe. Then, these observations form a basis on which theories and laws are constructed, which makes up the scientific knowledge. Inductive researchers also believe that one can logically generalize the observations into general and inclusive rules and the scientific assumptions get verified and ratified [Godfrey et al., 2010].
Chapter 2. Methodology

According to the *inductive* approach, at the end of research and as a result of observations, theories are constructed. The *inductive* approach includes looking for a pattern based on the observations and developing a theory for those patterns through hypotheses [Bernard, 2011]. In this type of research, no theory is applied at the beginning of the research and the researcher enjoys complete freedom in terms of determining the course of research.

Particularly, there is no assumption at the early stages of research and the researcher is not sure about the kind and the nature of findings as research is not finished yet. In inductive reasoning the researcher uses the observations in order to construct an abstract or to describe the circumstances being studied. [Lodico et al., 2006]. The main advantage of the inductive method is that there is no necessity for any pre-fabricated framework or model.

### 2.3.2 Deductive

The *deductive* approach constitutes developing of an assumption based on the existing theories and forming a research plan to test the assumption [Wilson, 2013]. This approach can be explained using the assumption driven from theory. In other words, the *deductive* approach includes deducing the results from the premises. When a *deductive* method is applied for a research project, the author formulates a set of hypotheses that need to be tested and next, using a relevant methodology, tests the hypothesis.

This reasoning has specific characteristics that need be understood. If the premises of *deductive* reasoning are accepted, then, the conclusion must necessarily be accepted. In this reasoning, the contents of the result are implicitly stated in the premises, making such argument a non-ampliative one. If new premises are added to the argument, then the conclusion must still follow. A *deductive* argument is either valid or invalid and there is no degree of validity. There is no choice or decision in applying such argument and no judgment is necessary for getting the result and conclusion [Zalaghi, 2016].

[Kumar, 2011] suggests that the *deductive* research approach studies a certain theory and tests to see if that theory applies under intended circumstances or not. Deductive approach follows the course of logic precisely. Argumentation begins with a theory and leads to a new assumption. This assumption, is tested via comparison with the observations and finally it would be accepted or rejected [Snieder and Larner, 2009]. In addition, deductive argument can be described as a general to specific (top-down) reasoning process [Pellissier, 2008]. While the inductive approach is quite opposite.
2.3.3 The selected approach

For the first step of this master’s thesis an **inductive** approach is selected, according to the next arguments:

- The research questions are not created from a hypothesis and do not will to answer any prove.
- It is mostly built from interviews which collect qualitative data.

Then, the second part of this study might be described as a **deductive** approach, since starts from the hypothesis of a bad performance of the supply chain and wants to prove that there are better transportation ways. Besides, in this part, numerical data from ERP systems are chiefly used which corresponds to the **quantitative** path.

2.4 Credibility and Trustworthiness

Because a research design is supposed to represent a logical set of statements, it might be also possible to judge the quality of any given result in accordance with several logical proofs. Concepts that are offered for these proofs include trustworthiness, credibility, confirmability and data dependability[Yin, 2003]. Thus, four tests are presented and commonly used to establish the quality of a study.

2.4.1 Construct Validity

It is defined by [Johannesson and Perjons, 2014], as establishing correct operational measures for the concept being studied. It is based in two research phases. The first one is in the data collection, where using multiple sources of evidence and also, establishing a chain of evidence would increase the **construct validity** since the data might vary a lot depending on the source and in this manner the facts’ chain. The second one is in the composition phase, and in this part, to have someone with knowledge about the specific subject who may help in the writing phase is important, who would be able to guide if the study is structured in a understandable way from the perspective of a external reader.

In this study, the **Construct Validity** is made due to three sources from each company are interviewed, respecting the different opinions and views of the situation. Besides, an external coordinator is taking into account as a key informant regarding to the composition phase.

2.4.2 Internal Validity

It is a test that measures how accurate the relations between causes and effects are, trying to eliminate the possibility of ending in false conclusion. It is only a concern
for causal (or explanatory) case studies, so is inapplicable to exploratory studies, which are not in touch with making causal chains. The concern about Internal Validity is extended to the broader problem of finding a conclusion from an event that cannot be directly observed, which is known as an interference [Yin, 2003].

The first step of this master’s thesis is the only one with explanatory nature, since it tries to understand the whole cause and effect chain while the second step is a measure to evaluate changes, so it is exploratory. Thus, the internal validity of the first step is performed by using various sources and, also, by making a requirement various facts to demonstrate a particular reality.

2.4.3 External Validity

It is related to the possibility of whether a study might be generalized and extrapolated to other situations. In order to ensure a External Validity, if the study’s results are that the project is generalized to other situations, this might be supported by tests which demonstrate that the same results really occur. Thus, to be able to conclude such results, to demonstrate by making several replications or studying different scenarios is needed, in order to, finally, compare if the results are similar. This is named the replication logic, and it is the one that External Validity has to follow. In the case of single case studies [Yin, 2003] expresses that the possibility of generalization is very low, which is the case of this master’s thesis.

2.4.4 Reliability

It demonstrates that the operations of a study, such as the data collection procedures, can be repeated with the same results [Yin, 2003]. The objective is to be sure that if a later investigator follows the same procedures as described by an earlier investigator, and conducts the same case study all over again, the later investigator should arrive at the same findings and conclusions [Yin, 2003].

In order to ensure the reliability of this study, on one hand, the interviews have followed a systematic performance, where the questions to different sources are the same and in the same conditions. Then, the collection of data is taken from the ERP systems which may not be changed, and, finally, all this steps are supervised by an external actor, the LTH coordinator.

2.5 Project execution

The study is performed in two-step model following in each one the research questions until the farther end point, which is directly related to the time frame the project has.

At the beginning, during the first step, an understanding of the actual Sandvik’s supply chain refereed to this study is accomplished, gauging through various tools
2.5 Project execution

and trying to map the whole picture of the actual scenario. As a result of these tasks, some waste points or improvement areas appear. Afterwards, in the second step, the impact of improving and/or eliminating waste points is made through. In order to do this, the creation of a simulation model is required which, at the same time, needs the collection of more specific data and its analysis. At last, some hypothetical situations are evaluated and how the changes might improve the supply chain. Although a more detailed explanation is rationalized below, the project execution can be abstracted following the next points:

1. Grasp the spare parts Sandvik’s supply chain.
   a) Analyze the data, measure and find waste points.
   b) Summarize cause-effects

2. Develop a dynamic aftermarket from the central warehouse to the end of the supply chain.
   a) Sort data and variables used in the simulation model
   b) Develop a simulation model.
   c) Simulate different situations and choose a possible solution.

2.5.1 Part one

In this part, the information regarding Sandvik and spare parts in Europe is collected, understanding the effect of its performance and also defining issues on it. Once the waste points are comprehended, in order to detect the root or roots of the problems, a more profound research is wanted. From Sandvik’s worker perspective about waste point sources, some studies from Six Sigma and Lean Manufacturing are performed.

Data collection and Empirics

The data collection is totally made by qualitative methods, because it is carried out speaking and understanding in depth and not in exactitude. It is made by several interviews with the coordinators and also, by observations in other Sandvik’s supply chain areas (out of the scope of this study) with well-defined performance indicators.

Literature and Frame of reference

In this part, the literature and frame of reference are divided into two fields. The first one is related to others supply chains and distribution theory, also explaining
the importance of having a company’s strategy aligned to the company’s performance, while the second one is related to Six Sigma and Lean Manufacturing tools, ascertaining methods which may be useful in this task.

Analysis and conclusions

The base of this section is theoretic since it helps to chose a correct tool. Thus, some tools are selected as, 5 whys or Fishbone. Then, they are used and measured in the second part of this section. Finally, a description of the waste point is made explaining the causes and effects.

2.5.2 Part two

In this part the elimination or improvement of the selected waste points is evaluated from the company perspective and also from the customers view.

Data collection and Empirics

The data collection is largely empiric since, it is basically a gathering of specific information from Sandvik’s ERP system, which lets display data in an Excel file and thus, a deeper research on Microsoft Excel is needed. However, as not all the information appears explained, in order to make required calculations, some interviews with TNT and Sandvik are performed, therefore, one can argue that in this step are used both, qualitative and quantitative methods.

Literature and Frame of reference

In this step, research about the impact of the transportation in the supply chain is made. As this step is more specific, to really measure the impact of it, some additional information regarding the aftermarket in general and the distribution of spare parts is performed, such as the specification that these supply chains have and the importance of them for customers.

Analysis and conclusions

In this part, an amount of variables are selected to measure and then, the actual performance is evaluated being the lead time and transportation costs the most important indicators. Since this study’s main idea is to find a better solution, and the evaluation of the variables already selected, it is proceed to create a simulation model. Finally, some alternatives solutions are exposed and one of them is selected.
Frame of reference

The main purpose of this chapter is to give some background and frame concerning logistics and organization of a company. First, the fundamental features of a supply chain are studied, dealing more generally with distribution, particularizing in transport, and without delving much, but mentioning, order management is also defined. Subsequently, and since the work is about them, the chapter also focuses on spare parts, how to manage them and how their management influences in the development of the company. Finally, some data regarding 6 sigma tools and 6 sigma itself is mentioned since are techniques used for the first part.

3.1 Supply chain

In today world, the importance of the supply chain and the challenges it suffers has grown dramatically when it comes to supply and demand decisions. Making optimal inventory replenishment decisions and supply chains configurations has become crucial to supply chain management. There are a multitude of approaches and traditional descriptions regarding the supply chain that to this day have become obsolete because of the environments which it is surrounded from. Current business models need new models that are more flexible and incorporate intelligent technology and tools capable of making reliable predictions, since the existence of all organizations depends on the ability of them to manage the flow of materials, information, money inside, and outside the organization, etc[Stefanovic, 2015].

As an introduction it can be said that supply chain can become very complex, involving many very different organizations while numerous challenges and problems from their operations can arise. These problems can be caused due to too much inventory or too little, differences between expected demand and actual demand, having a low customer satisfaction, low adaptability, etc.
3.1.1 Supply chain concept

The definition of supply chain seems to be common to some authors. Following [Londe and Masters, 1994], when the definition of supply chain is proposed as a set of firms through which the material passes. Normally, many independent firms are involved in the process of taking the material to the end point of the chain, raw material, product assemblers, retailers, warehouses, are all in the supply chain. On the other hand, [Larson and Rogers, 1998] defines the supply chain as the alignment between companies to bring products and services to the market. Supply chain is also defined as the connection between different organizations for the achievement of an end, where various activities and processes are involved.

Finally, the definition of [Mentzer, 2001], which defines a supply chain as a set of many firms, both upstream (i.e., supply) and downstream (i.e., distribution). Following the definition proposed for [Mentzer, 2001], the supply chain is defined as: "a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer".

3.1.2 Supply chain types

[Mentzer, 2001] distinguishes between three different kind of supply chains: basic supply chain, extended supply chain and ultimate supply chain.

![Figure 3.1 Supply chain types](Mentzer, 2001)

A basic supply chain: includes a company, a direct supplier and a direct customer, all connected to one or more lines of information flow, products, finances and services. An extended supply chain: consists of suppliers of the direct supplier and customers of the direct customer which are linked by one or more lines of infor-
3.1 Supply chain

Information flow, products, finances and services. An ultimate supply chain: is composed of all the companies that are involved in the flow line from the initial supplier to the final customer.

Finally, it is also defined what is an alliance or a partnership, which differs from supply chain because it only encompasses dual relationship, i.e., between two companies, regardless of any one company in simultaneous upstream and downstream relation.

In the Figure 3.1, there is a summarize of the different supply chains.

3.1.3 Supply chain functional definitions

According to [Ross, 1996], the functions of logistics within the supply chain, or the functions of the supply chain itself within the enterprise, have traditionally been divided into two parts:

- **Materials management**: this function is traditionally attached to the incoming flow and the information of the material that enters the company. It might be defined as a group of management functions on which the flows of material from the purchase, reception in the internal control of inventory, to plan and to control the added value of the process of finishing goods to the warehouse are based. The activities in this part can be divided into two classes. The first part is associated with the inventory, such as receiving materials, handling, storing, scheduling production and planning, as well as delivering to the carrier.

- **Physical distribution management**: this part is more associated with the part of the execution of marketing management, as far as what concerns to the store and the movement of finish goods to the chain of distribution to gather the demands of the client as far as tempos. The physical distribution is easier to explain studying the activities that includes including the packing, transport, customer order administration product packaging, shipping, etc.

For [Ross, 1996], the differentiation between the two parts is very difficult to establish, and even somehow there are artificial barriers, since they share the same skills, knowledge, management control processes necessary to manage incoming and outgoing inventories, traffic, materials handling and warehousing are identical and are to be found in each area.

3.1.4 Supply chain components

The Figure 3.2 shows the parts in which the supply chain is traditionally divided. The first component of the chain is the **supplier**, which provides raw material to the **manufacturer**, which main objective is the creation and development of products.
Chapter 3. Frame of reference

Although this is true, in some cases, such as wood, coal and grains go directly from the manufacture to the rest of the chain. Then, there are wholesalers who are somewhere between producers and retailers, whose main function is to act as middlemen, providing retailers with different products of different manufacturers. In addition, wholesalers also designs and carries out arrangements between customers and those manufacturers that do not have distribution functions.

![Figure 3.2](image)

**Figure 3.2** Supply chain functional definitions [Ross, 1996].

However, some companies assume the role of assembling and consolidate point managing their own distribution channel, being themselves the wholesaler, sending directly to the retailers. With the development of JustInTime during the 1990s and Quick Response, manufacturers and retailers have expanded their logistics functions, including many of the activities previously undertaken by wholesalers [Ross, 1996].

Finally, the retailer, which is the connection point with the customer, the end point of the supply chain or distribution. They have completely different objectives than the manufacturers and wholesalers, since they must identify the target market and carry out the appropriate operations for offering a diversity of products or services, determining their prices to be competitive. From the point of view [Bowersen and Cooper, 1993], to despise the work of retailers in the supply chain would be very unwise, because, although many retailers are dependent on their suppliers, others such as Montgomery-Wards, Circuit-City or Wal-Mart take a very active part in the development of the supply chain.

### 3.1.5 Supply chain performance measurements

When system is object of being analyzed, qualitative evaluations like "good", "bad", "fair" and "adequate" are often used, and sometimes are difficult to assess. Therefore, quantitative performance measures are usually of major help in this task. When it comes to quantitative measurements that this concept only encompasses numerical values is often believed, which in turn, are usually really visualizers. However, to use numerical values to evaluate how a system works is not always possible [Bea-
mon, 1999]). In addition, the difficulty of evaluating a problem is also very dependent on the scope of the task, since the barriers are not always clear.

Supply chain models were predominantly evaluated using two performance indicators: cost, and the balance between cost and customer service response. Costs may include inventory and operating costs. The customer responsiveness measures includes the lead time, the probability of stock-out, and the fill rate. There are many models that although they have their constraints can be used, such as the Cost and Activity time simulation models, or those of Customer Responsiveness. Other performance measurements are also considered appropriate, however there are currently no models that consider them. These performance measurements can be: customer satisfaction, information flow, supplier performance and risk management, and are difficult to incorporate as they are qualitative [Beamon, 1999].

3.2 Transportation

When dealing with the functions of the distribution chain in general, two parts are mentioned, warehousing and transportation. The warehousing is conceived as the handling of the material and supply cycles, the storage provides value as it satisfies the market needs of materials when it is due. On the other hand the transport is normally associated with the movement of goods, and devalued. However, according to [Ross, 1996], in some cases it may produce 50% of the costs of distribution. Transportation scope can be divided into three parts. First, the more developed the transport system of a company is, the larger its ability to compete. Transport also allows a deeper penetration in new markets far from the point of production. In second place, the wider the product distribution and the greater the demand, the more producers can leverage economies of scale in production and channel transportation costs [Ross, 1996]. Finally, the more efficient the transport, the lower the cost of the same and consequently the lower the price of the product and therefore improving the position in the market of the products.

3.2.1 Transportation performance characteristics

According to [Bowerson and Cooper, 1993] there are some characteristics that need to be checked when choosing a carrier.

- **Speed**: the ability to transport items from one place to another at an appropriate speed, which always, according to [Coyle et al., 2011], should be as fast as possible. It provides the marketing utility of time to distribution and ensures place utility. It is the time required to move the items from where they are, load the products to the vehicle, traverse terminal points, and deliver the product to the end terminal.
• **Completeness**: This ability is related to the use of only one mode of transport to move goods from one site to another. This is critical because the less the product changes one transport mode to another, the lower the cost, the chances of losing material, and in many cases, higher supply speed.

• **Dependability**: It is observed by measuring how carrier provides anticipated demand on time. If a transporter has poor dependability there is a risk that the company have to build excessive inventories because the carrier is not able to move the products that form company’s inventories on time.

• **Capability**: The ability of a transport mode to accommodate a specific load. The characteristics of the product are those that intervene: type of product, weight, dimension, volume, etc. Those are which decide what type of transportation and equipment to move materials are necessary.

• **Frequency**: This variable is the measure of how often a mode of transport can perform the pick up and deliver. Normally the smaller the interval, the greater the flexibility of the carrier to assume new transport challenges. Something important is that if the frequency is high, the amount of inventory needed in the warehouse is lower.

• **Cost**: There are many costs during the transport. The most clear is the tariff paid to the carrier to use its mode of transport. Other indirect costs can be the material handling of loading and unloading products into the mode of transport, if any damage occurs in the material transported, insurance, and in-transit inventories however these are paid by the shipper.

### 3.2.2 Transportation as 3PL

The concept of 3PLs, a third party logistics service provider, encompasses those experts in the organization of flows and freights, leaving the client that contracts them to focus on other parts of your company. Examples of 3PLs companies might be COSCO, FedEx, Maersk or UPS, which provide with a wide range of transportation and logistics services to individuals and businesses all around the world [Coyle et al., 2011].

One of these types of 3PLs are **Transportation based**. These companies have their origins in the movement of goods via truck, train, air or other transport mode. As customers’ wishes have increased, these companies are developed as 3PL and provide organizations that hire them with greater capacity and shipping options. They do not only transport the goods, they also manage the transport operations, operating on many occasions or near the distribution center or even within the company, developing with the contracting organization some logistics solutions, such as packaging or loading and unloading.
3.2.3 JIT and Quick Response transportation

According to [Hutchins, 1999] Just in Time, JIT, is a term used to indicate that a process is capable of instant response to demand without the need for any overstocking, either in expectation of demand being forthcoming or as a result of inefficiencies in the process.

Regarding to Quick Response [Ross, 1996] defines it as the ability to respond to the customer with the right product, quantity, price, and location with the least cost for the organization.

Although JIT methods have traditionally been associated with transporting manufacturing inventories and QR with distribution/retail inventories, the goal is the same as eliminating all the unnecessary steps within the transport by developing techniques that facilitate the frequent shipping, which better predicts the quantities making the supply chain to have the lowest cost.

In order to implement JIT/QR methods, the company must practically redesign the supply chain according to that strategy. Firstly, the transport organization has to be close to distribution and warehousing, as if there is not enough inventory level and enough production to fabric the items which should be in the stock, to supply suitable is impossible. Secondly, the company must reduce the number of carriers to the minimum. This is in order to gain partnership and be closer to the carrier, which will ultimately increases the flexibility offered. The third strategy is to create long-term contracts with carriers, to support the second strategy. Fourthly, an electronic interface with the carriers is necessary to make a calendar, planning and payments easier, and also to check the tracing. Fifthly, if JIT/QR works properly, all products must be collected and sent in their schemes.

3.3 Order management

Taking into account the new class of customers that companies affront, the order management has become indispensable for the companies. How an order is processed is the primary contact between the supplier and the customer. The purpose is to provide how, and when the client specifies and not doing so has an economic and efficiency impact on the firm. Ineffective and inadequate order processing has a cost to the customer, produces excess inventory, results in high costs of transportation and poor quality and performance measurements [Ross, 1996]. It is also possible to extend the limits of order management to the internal orders of replenishment, since it has traditionally been separated.

Despite this traditional order, the idea has grown that not only customers but also inter branch supply, purchase and value-added procession orders could be managed together.
3.3.1 Managing order cycle time

The cycle time may be described as the time between the client identifies and makes known the requirement of a need or service, until the moment in which they receive it. The cycle time is a times’ accumulation. In the same way as the control in production, inventories, etc. attention should also be paid to this part of the supply chain. Distributors generally comment on the error of measuring this cycle only from the moment the order is received until it is sent. However, as it can be seen in the following Figure 3.3, in order to really evaluate how the cycle occurs, all five of these activities have to be evaluated. This is because the time from Invoicing to the time of receipt of the shipments is about 60% of the time.

![Figure 3.3 Steps involved in the order cycle](Ross, 1996)

Ongoing cycle time reduction is one of the benchmarks of service leaders. According to [Ross, 1996] the percentage of all orders sent in one day, will go up from 36% to 41% at the end of the century.

To improve the time cycle two ways might be followed: the implementation of JIT and/or implement better and faster information tools. JIT eliminates unnecessary steps in the entire process of the supply chain from the store until the product meets the customer. Besides, computer tools like EDI, bar code, carton labeling, etc. might reduce cycle time by facilitating speed and accurate information flows.

3.4 Spare parts

Spare parts have become ubiquitous in modern societies and their organization to address their requirements has become a major challenge for organization[Syntetos et al., 2012].

As service business has become increasingly competitive, one of the requirements that has grown has been to guarantee service operation to customers. As the demand for spare parts occurs when a component fails or requires to be replaced in order to function properly, companies have had to put more effort into delivering solution packages that reach customers in the right time[Mo. et al., 2011]. In this
3.4 Spare parts

From the customers’ perspective, it is explained why a very efficient line of spare parts distribution from the manufacturer to the customer is needed, instead of customers having their own stock. Secondly, from the spare parts’ manufacturer how is the prediction of their demand, and in last place, the ways of organizing the process of order and shipment under which the spare parts are usually treated. These kinds of items are called "slow-movers" and although typically the contribution to sales is small, they can account for 60% of the value of the stock. These items are particularly important in the aerospace, automotive, or construction industry where they also have a great index of obsolescence.

3.4.1 Spare parts’ end user perspective: Inventory

End users of spare parts always have a problem to handle them. First, the work-in-process inventories exist to reduce irregularities in the flow of production. These irregularities can be caused by a change in the productive pattern, a breakdown, material handling or other reasons. The inventories of finished products exist to bring the customers the products that they need at the adequate moment maintaining a high customer service. However, the function of having an inventory of spare parts, is to assist the workers keeping the equipment operational. Therefore, the inventory of spare parts should be treated differently, since they are not final products to be sold to a customer. Secondly, the policies governing WIP inventories are different from the spare parts ones. WIP inventories and final products can only grow or decrease by changing production, changing lead times, improving quality, etc. However, the inventory of spare parts changes depending on how the performance of a team is or is being used properly and maintained in a rigorous manner. When maintenance also requires some kind of spare parts, this can be postponed or even avoided, and this choice can have a great impact on the inventories of spare parts [Kennedy et al., 2002].

After a careful research, articles such as [Kennedy et al., 2002], concludes that the best way to handle these inventories, since they are very complicated to predict under statistical and also they are usually Unfinished and erroneous, is having a provider that can assure that if a breakdown of a critical component occurs which is not in the own inventory of the consumed, it may be replaced quickly being sent by the supplier. This is what best reduces the risk of the user to suffer a great delay in the production of their products. For this to happen, [Kennedy et al., 2002] is referring to Internet and provider-client interfaces as a key tool for the information flows.

3.4.2 Spare parts’ manufacturer perspective: Demand

The demand for a spare part comes when a component fails or requires a change. These patterns of demand are very different from those associated with "typical" stock keeping units. This pattern of demand tends to be of an intermediate nature, meaning that demand arrives without stipulated frequency or distribution. Also
when this demand occurs, it is not necessarily for a type of spare parts or a constant size. Then, while Normal distribution are typically accurate for "fast" demand items, this is not the case for spare parts. In [Syntetos et al., 2012], many demand patterns that can be coordinated with the spare parts are described, but only when demand-per-period data is considered, resulting in NBD and Stuttering Poisson give an acceptable results. Finally, [Syntetos et al., 2012] suggests that in order to be able to make a more accurate forecasting demand categorizing the spare parts depending on the frequency they are needed may be a way of being more accurate.

### 3.4.3 Spare parts’ manufacturer perspective: Distribution

The Figure 3.4 shows how a spare parts support operation is, where the biggest challenge is the difference of the type of pieces at the same time as the uncertainty of the number of pieces requested in each period [Mo. et al., 2011].

![Spare parts support operations](image)

**Figure 3.4** Spare parts support operations [Mo. et al., 2011].

The services contracted for this type of pieces, are usually divided into two: a standard service with a guarantee of next-business-day delivery agreement, and a premium service in which the piece reaches the customer the same day, same-day delivery agreement. In this type of operations, the part requested under same-day delivery agreement must be processed immediately and sent, while the others types of parts might be sent under the cut-off time of the day. Apart from the time objective, the service fill rate of a premium service should try to be greater than that of another ordinary service [Mo. et al., 2011].

According to [Mo. et al., 2011] there are also two possibilities to manage the spare parts support operation, which appear in the next Figures.

The objective of reaching different fill rates, from different parts, in different periods trying to maintain a relatively low inventory, is a big challenge in the companies. To optimize both inventories and distribution, [Mo. et al., 2011] proposes to segment the spare parts into different distribution queues which appear in the Fig-
3.4 Spare parts

In [Mo. et al., 2011], two types are proposed, the MIP or multiple inventory pools, and the CIP, consolidated inventory pool. The idea of MIP is to separate the required spare parts units with each type of service, while CIP maintains the same distribution without taking into account the type of service requested.

MIP has the advantage of extending the flexibility of managing different service objectives by controlling distribution and even better tracking inventories. However, CIP’s main advantage is that it has the economies of scale. Moreover, the main disadvantage of CIP is the risk of misunderstanding or not being able to differentiate between different types of orders and to prioritize those that are not urgent. This is a serious problem especially when it comes to very low inventories where the shipping of an order without priority can leave without the required product to a priority order.
Chapter 3. Frame of reference

3.5 6 sigma

Six Sigma is defined by [Pande et al., 2000] as "a comprehensive and flexible system for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data and statistical analyses, and diligent attention to managing, improving and reinventing business processes".

In the definition of Six sigma, three important points can be drawn:

A measure: a statistical definition of how a process can deviate from its ideal.

An objective: to have a maximum of 3.4 defects per million opportunities.

A philosophy: it is a long term part of the strategy of the company, wanting to reduce costs from the reduction of the variability of products and/or processes [George, 2002].

3.5.1 Cause and effect diagram

They are a type of diagrams generated from the brainstorming session. It is the most used and probably one of the most useful of the "Seven Basic Tools". It is based on a process of concatenated questions, to know their answers, and, finally know the root of the problem. To do this through the process of the questions, the causes of the problem are divided into as many as possible, appearing subcauses or branches represented in the diagram. Then, more concatenated questions are made regarding each subcauses, representing them as small branches protruding from the main branches. This process is carried out until the root of the variation of the problem is completely framed [George, 2002]

3.5.2 Five whys

This tool consists on repeatedly asking the question "Why?". It is not necessary to do it five times, this is a general term, and usually a good average too. Thus, it may appeal to the layers of each symptom by leading to the root of the problem. Often the cause for questioning leads to another problem that in turn leads to another problem. This Six Sigma tool does not involve data segmentation, hypothesis testing, regression or other advanced statistical tools, and in many cases can be plotted without a data collection plan, quickly and easily.
4

Empirical data

This section addresses some information regarding the companies this study deals with. Taking into account that it is the company that demands the study and which more contact is had with, the chapter begins by informing about Sandvik, what type of company is, which its market is, how its supply chain is and what part of it this study is focused on. Finally, and in a secondary way, something more regarding TNT is explained, because this company is also involved in the study, however only in a functional way.

4.1 General information concerning Sandvik

Sandvik is a high-tech and global engineering group that provides its clients with:

- Tools and systems for industrial metal cutting.
- Equipment, tools, services and technical solutions for mining and construction companies.
- Advanced stainless steels and special alloys as well as products for industrial heating.

Sandvik is a company founded in 1862 by Göran Fredrik Göransson in Sandviken, Sweden. It has 45,000 employees, operates in 150 countries around the world, although the headquarters are located in Stockholm, Sweden. It has 86 billion SEK of invoiced sales, with 60 R&D centers globally since 3 billion SEK are invested in R&D every year. Finally it also has around 8000 active patents and other IP rights.

In order to situate this company in the supply chain explained in the Part 3.1.4, for some types of products Sandvik is the manufacturer and supplier, as for cemented caribide, while for others it is only the manufacturer. In its distribution chain
there is no figure of the wholesaler, because Sandvik provides, through external carriers, directly to the end-users.

4.1.1 Sandvik core values
The core values pursued and on which the Sandvik’s routine is based are four:

- Customer focus: Sandvik is defined as a company that always tries to exceed the expectations of customers so that they can carry out their own business.

- Innovation: they think of the future by creating new solutions and pioneering solutions, encouraging the worker to be proactive sharing information and experience, and giving him the confidence to think in different ways looking for new perspectives of the product.

- Fair play: Sandvik wants to conduct a business in the most sustainable way possible, acting ethically with the environment and with clients, developing relationships based on honesty respect and trust.

- Passion to win: Sandvik seeks to have the best values of performance and be the company number one of his field.

The vision of the company is "to set the industry standard. It means that we set the benchmark for others to follow" and a strong foundation for continued success as "since Sandvik was established more than 150 years ago, our business concept has been based on innovation, technology leadership and close, long-term customer relationships" [Sandvik official webpage. Vision and strategy].

4.1.2 Corporate structure
Sandvik’s operations are divided into three business areas, segmenting products and services, each area being responsible for that part of production, sales and R&D. These business areas are:

- Sandvik Machining solutions: it is a market-leading manufacturer of tools and tooling systems for advanced industrial metal cutting. The products are manufactured in hard materials and are sold under the brands Sandvik Coromant, Walter, Seco and Dormer Pramet. The focus is on increasing customer productivity by providing them with products, applications and know-how services.

  It has two types of markets, the premise that is highly consolidated and the mid-market that is not fully consolidated, having a low service level and being very price sensitive. In this business area, there are five products areas. In this case Sandvik’s strategy is to focus on the areas of aerospace, advanced
4.1 General information concerning Sandvik

materials, emerging market digital offerings as well as mid-market services. The annual sales of this part were 33 billions and has approximately 18,000, data for 2016 [Sandvik official webpage.Vision and strategy].

• Sandvik Mining and Rock Technology: a world-leading supplier of equipment, tools and technical solutions for the industries of the mining and construction and of services. The fields of application of this business area include: drilling, rock cutting, crushing and screaming, loading and hauling, tunneling and demolition and dismantling. Regarding to the characteristics of the market, the great flow of aftermarket makes the spare parts’ influence in this business area very great as well as of the drilling tools. The growth strategy of this area is to improve aftermarket flow, to automate it, improving computerized productivity, focusing on high-growth regions.

In this business area there are eight product areas and eight business units. The annual sales of this part were of 31 billions and has approximately 14000, data of the 2016 [Sandvik official webpage.Vision and strategy].

• Sandvik Materials Technology: this area offers a great variety of products, ranging from products for induction heating to tube, pipes, cables, strip, and metal powers. A highly selected market where the requirements of the materials, their quality and reliability are the most important. This focused on energy products and solutions for energy efficiency, improving day-to-day materials under the R & D efforts.

In this business area there are three product areas and nine business units. The annual sales of this part were of 13 billions and has approximately 6500, data of 2016 [Sandvik official webpage.Vision and strategy].

Sandvik also has two other areas, not recognized as business areas, but in the future Sandvik wants them to be. These areas are known as "other operations", and involve Sandvik Process Systems, which is a supplier of industrial processes, and Sandvik Hyperion, which supplies hard materials such as cemented caribide and powders, as well as industrial diamond [Sandvik official webpage.Vision and strategy].

4.1.3 Sandvik’s spare parts

4.1.3.1 Spare parts object of this study Due to the fact that Sandvik has many work areas, it also handles a multitude of spare parts from each area, and in turn, from each component. To facilitate the understanding of which are the products this project is centered in, the following Figure 4.1 is created. It can be seen that one of the product areas is Crushing and Screening, and within this product area there are 3 business units, products of Crushing and Screening mobile, stationary and breakers. Inside stationary products, at the same time, there are four types of
spare parts: SRP Sandvik specific components, are the ones that Sandvik has the patent, consumables or ware parts, among which are materials such as manganese, mayor components and finally, comercial spare parts. This project is focused in the distribution of Comercial spare parts and SRP Sandvik’s specific components, which are remarked in the Figure 4.1 in one each orange squares.

Figure 4.1 Sandvik’s Business areas and where the spare parts of this study are localized.

4.1.3.2 Spare parts’ Europe distribution The opinion of Sandvik with respect to the aftermarket in general, and therefore, about the distribution of spare parts is "Our relationship with customers does not end when we deliver a product or solution, rather this marks the beginning of a long partnership. Our service offering has been substantially strengthened over the past few years and has contributed to reducing volatility in our earnings" [Sandvik official webpage.Vision and strategy]. Thus, it can be deduced that one of the major concerns about the nature of their business is to provide a distribution chain to the customers as efficient as possible.
4.1 General information concerning Sandvik

Depending on the type of aftermarket, the distribution changes. If the aftermarket is regarding tools, there would be more major locations, big warehouses (typically 3 to 5 per region) and also local warehouses to ensure fast moving tools, closer to the customer demand, fewer stocking points in the supply chain and lean pull based replenishment. This transportation uses economic transports modes (ship, truck). Nevertheless, for parts the distribution chain is different, having typically one per region, a consolidate assortment hub and then, part satellites, which is a kind of local warehouse. This distribution uses fast transport modes (air, truck). The distribution of spare parts, as they are parts, corresponds to the second mentioned.

Starting with the inbound flow from producers to the central warehouse or hub, spare parts for Crushing and Screening are produced in a high range of manufactures being the ones correspond to 80 % of the total volume sent, Sandvik SRP(Svedala), Sandvik Tamrock and Sandvik mining & construction. Then more than 150 external providers supply the rest of the spare parts. Moreover, they are moved to the central warehouse, hub, in Europe, C1, in Eindhoven, Holland, which is a transaction supported by a partner named CIVA logistics. On the one hand, in the warehouse there is a replenishment policy, based on Reorder point. As explained in the part 3.4.1, Sandvik’s replenishment cycle to the C1 warehouse is very difficult to handle because of the complication of estimating the demand for spare parts properly. On the other hand, about the outbound flows from the warehouse to the customers, there is not an specific replenishment cycle of spare parts to the customers. The shipment of these pieces is carried out when a customer requests the products to the internal system of Sandvik, which is a call center.

![Distribution chain for spare parts](image)

**Figure 4.2** Distribution chain for spare parts

Regarding the Figure 4.2, the red lines are the one that this thesis if focused on.
Hence, by placing the distribution center as a reference, there is a flow of spare parts from various productions areas to the distribution center C1, and a flow coming out from the C1 to the customers or to local warehouses, typically one per country. It is important to remark that right now the rules for the outbound flow are the same wherever the destination is, either local warehouses or customers.

It is important to clarify that from now to the end of this project, the collection of spare parts that a customer asks for to the Sandvik systems is named, "Required shipment" while each of the products that required shipment contains are the orders. For example, one required shipment may contains five orders, which are five products.

When the customer or local warehouses contact Sandvik, they specify the requirements of their requested shipments. Among other technical data, they also assign a criticality point (CP) to the requested shipment. The CP is a way to divide the requested shipments through emergencies as the next Figure explains.

<table>
<thead>
<tr>
<th>Ticket Type</th>
<th>Criticality</th>
<th>Escalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – Unit Down</td>
<td>1</td>
<td>Escalates every 8 hours</td>
</tr>
<tr>
<td>B – Customer Order</td>
<td>2</td>
<td>Escalates every 24 hours (+ Initial 24 time lapse)</td>
</tr>
<tr>
<td>C – Inventory Request</td>
<td>3</td>
<td>Escalates every 48 hours (+ Initial 24 time lapse)</td>
</tr>
<tr>
<td>D – Scheduled Order</td>
<td>4, 5, 6</td>
<td>Escalates every 72 hours (+ Initial 24 time lapse)</td>
</tr>
</tbody>
</table>

**Figure 4.3** How criticalities work, from Sandvik’ ERP.

This technique of dividing orders is mentioned in the Part 3.4.3, denominated MIP, and is used in order to separate different flows in the warehouse according to their urgency and thus, being able to easier satisfy the specific requirements of each requested order.
4.2 General information concerning TNT

TNT is a company that is dedicated to the transport of goods as much from small consumers as from giant companies. It is a carrier that transports goods all around the world, with a focus on time-definite and day-definite delivery.

4.2.1 TNT relation with Sandvik

To carry the spare parts transportation from the C1 to the customer or to a local warehouse, Sandvik contracts TNT like a partnership. It offers transport solutions for Sandvik, which in this case are by air or road.

Instead of dividing the transport options into two, as shown in the Part 3.4.3, TNT offers several transport possibilities to Sandvik which appear in the Figure 4.4

![Figure 4.4 TNT shipment options.](image)

On the one hand, TNT offers a service named in this study General Express. This service is offered throughout Europe and is divided into two, the Express service and the Economy Express service. The Express service is more expensive than the Economy Express but offers around one to two lead time days for the majority of the Europe destinations, instead the Economy Express service offers around three to five days of lead time.

Supplements can be added to the two General Express services, for example, if an Economy Express could be hired, arriving the shipments in that rates lead time but ensuring that it would arrive to the customer before 8.00 am, before 9.00 am, etc. One can argue that according to the Part 3.4.3 these two services would fit in a standard service.

On the other hand, TNT also offers a service for the Nordic countries (Finland, Norway and Sweden) called for this study as Special Service Nordic. For these
countries because some clients were located in remote areas, and through the *General Express* service the lead times are around three to four or even more business day, TNT created a special network, able to reach those points guaranteeing a lead time of next-business-day to X from the locations, the rest of cases being that TNT can only guarantee a lead time of two days. Also in Germany was created a special network called *Special Service Germany*, which in this case it guarantees to all its locations a delivery in next-business-day.

It can therefore be concluded that both the *Special Service Nordic* and the *Special Service Germany*, according to the Part 3.4.3 would fit in a *premium service*.

By TNT collects in the C1 all the requests, collecting once a day and at the same time *General Express, Special Service Germany* and also once a day and only the *Special Service Nordic*. After being collected, the shipments are taken to a consolation point own of TNT and later sent.
5

Analysis

Since the Part 4 already answers RQ1, this chapter is divided into two stages that make a guide to finally answer RQ2, RQ3 and RQ4. The first one is based on the interviews and information received regarding to the main issue, the effects it has and also, some inductive reasoning is made to find the causes. Then, a second step starts with an exposition of which data the author holds and a breakdown of it. Moreover, how a simulation model is built is explained. The simulation model determines the evaluation of the actual scenario performance and also, the visualization and significant variables measurements in new scenarios created by making changes in the transportation mode.

5.1 First step

In this first part, some interviews are made with the three Sandvik’s coordinators collecting all the information regarding the spare parts distribution in general terms, as it is explained in the Part 4 answering the RQ1. Then, more interviews are conducted concerning to the next research question RQ2, actually starting to deal with the case of study.

The spare parts distribution works as order to deliver, which means that each time a customer or local warehouse wants any spare parts, they need to launch the order because, otherwise, no parts will be received. Depending on the CP the orders might be sent by using or Economy Express Express, Special rates Nordics or Special rates Germany depending on the needs, however, that is not happening.

Most of all orders are treated in the same way, which is not aligned with Sandvik’s strategy. As this is a result of a chain of mistakes, to be able to understand every deficiency in the distribution and to really assure where the root of the problem is, two 6Sigma techniques previously explained in the Part 3 are carried out. The first technique applied is the 5 Whys tool, and the second one is Fishbone (Ishikawa) diagram.
5.1.1 Analysis with five "whys" technique

In this case, and as may happen in many cases, six "whys" are necessary for a first approach to the problem. These questions are firstly asked in form of an

Figure 5.1 5 "Whys" application to the case of study.
5.1 First step

The first question asked to the coordinators is *Why is the Spare parts’ distribution not performed well?*. The answer to this comes in two ways. The first is the one related to the orders which a required shipment is form with, or explained in another way, the parts that the required shipment takes. The first indicator of poor performance is that the orders arrive separately, in different boxes, or in different trucks reaching the customer at different times or, even, in different days. This is something the coordinators report the customers are not satisfied. The proof of this reasons is visualized in the next Figure 5.2. Each number of required shipment (first column) is repeated, representing each order in the required shipment, which may be seen as different lines with the same shipment number, same customer and same required date, but different product specifications, being clear that they are treated separately.

**Figure 5.2** Same shipment number repeated, corresponding to each order. Caption from Sandvik’s ERP.

The second "why", also answer by the coordinators is, *Why are the orders of the shipments delivered separately?*. They reply, on the one hand, the management of the central warehouse is a problem, as it does not have a system that classifies the orders of each shipment being able to consolidate them together. On the other hand, in some cases not all the products of the shipments are physically in the central store, so to send as soon as possible, orders are separated and the ones that are already in stock are sent while the rest of the orders are sent when they arrive to the warehouse.

In order to prove this, the first option is to check the stock levels at the time of the required shipments are asked for one by one, which, as it was suggested by the coordinators, is not feasible due to the lack of time. However, following a review of the data, it can be concluded that there are not enough levels of inventory. This conclusion is reached due to several reasons: the first is that customers are requesting Sandvik parts supposedly in a very dynamic and fast distribution, with 6 months in advance, and the second one is the need of small or local warehouses around Europe. This leads to two possible options: either the carrier does not comply with
Chapter 5. Analysis

the transport times, which is easily verifiable in the Figure 5.3 that is not the case, although more details are given in the following sections; or that there are no parts in the central warehouse, and therefore the customer prefers to make an advance demand for the date where it is expected to need the parts.

Taking into account that this is a distribution of spare parts, if the client has to make an anticipated demand, this implies a great effort and, of course, a displeasure with Sandvik’s services which the company does not want to maintain.

Moreover, if the inventory is not enough, the third why which is Why is there not enough inventory? This may be due to either inadequate stock management or to insufficient production. However, and guided by the company, this study is out of the scope of the project.

The first "why", also has a second answer. The spare parts’ distribution is not performed well because the selected transport mode for all orders, in most of cases is, or Express in the case of Europe without counting the Nordic countries and Germany, or in the case of the Nordic countries and Germany Special Service Nordic and Special Service Germany are always used, which are especially high rates. This answer guides to the fourth "why", Why are most of all shipments transport in the same way?

The answer to this questions, since this is not a simple topic, is also divided into two answers. Firstly, the shipments are divided according their emergency with the CP. This system is easily visible that is not working, as appears in the Figure 5.3. There, there are cases in which, for example, local warehouses requests shipments with CP 1, which is impossible because warehouses do not have machinery and CP 1, as explained in the Part 4, may only occur when a machine has stopped working because a requested part is necessary, and therefore, needs to be replaced. This problem is further investigated because of its complexity through discussions with the Sandvik’s workers, making the fivth "why" Why do criticalities not work?, this problem is due to four reasons. The first is that there are several formats where
Sandvik explains the CP differently, and therefore, there are not clear. The author reached this conclusion by asking to Sandvik, where various documents were offered with different explanations related to CP. The second one is some Sandvik’s customers do not trust that the shipment will arrive at the appropriate time and thus, prefer to request with lower CP to ensure that it arrives as soon as possible. The third possibility is that directly customers do not care about wasting resources that Sandvik provides for them while the shipment arrives. And finally, the fourth option is that the necessary or efficient time has not been invested in teaching customers related to how CP work, and how important they are to Sandvik.

On the other hand, the fourth "why" has another reason and this is related to the warehouse. After the interviews with the coordinators of Sandvik, it is informed that, although the criticalities worked well, the orders are not divided by criticalities in the central warehouse, thus, the sixth and last why comes out, Why are not criticalities shorted in the warehouse?. This is due to the general system used in the warehouse which is not enough efficient to make this. Therefore, until this last reason is not solved, there is no point to focus on the work of the CP themselves.

During this study, there is a limitation that has to do with the central store. In each chain of questions, once a point has been reached in which the answer has been "warehouse policy", this path is finished exploring. Therefore, the study is limited to the problems of the supply chain until reaching the warehouse, without addressing why the warehouse manages the goods in that way, as it is beyond the scope of this study. The Figure 5.4 is presented to summarize the information.

5.1.2 Fishbone
Besides, a Fishbone is also created, which appears in the Figure 5.5, where is emphasized that there are three focus of error: the inventories, the warehouse and the criticalities. The figures looks for remark that if inventories are not solved at first, then the problems of the warehouse and finally the criticalities, there will be no positive change in the distribution, leaving out of the scope of the project the root of the problems withing inventory field. Finally, and once the problem is framed, the next phase is to analyze the impact that would have for Sandvik and its clients an adequate operation of the whole chain, which is explained in the second step.

5.2 Second step
Once the problem is framed, the next phase is to analyze the impact that an adequate operation of the whole chain would have for Sandvik and its clients. First, all data that Sandvik and TNT provide is analyzed then, how the simulation model is created is exposed, and finally some simulations are performed.
Chapter 5. Analysis

Figure 5.4  First step process.

5.3  Provided data analysis

From Sandvik’s side, the information regarding 2016 spare parts required shipments from C1 to Europe transported by TNT is used. This information is given in an Excel document, which can be visualized in the next Figures 5.6, 5.7 and 5.8.

In this file, each line is a shipment and each column is a different variable measured by Sandvik.

These variables are:

- **Carrier**: which is previously sorted by TNT.
- **Consignee name**: the entity that has made the request. It may be an specific customer or a Sandvik’s warehouse.
5.3 Provided data analysis

Figure 5.5 Fishbone application to the case of study.

Figure 5.6 Columns from A to H. Capture from Sandvik’s master file.

Figure 5.7 Columns from I to S. Capture from Sandvik’s master file.
Chapter 5. Analysis

Figure 5.8  Columns from T to Z. Capture from Sandvik’s master file.

- **Destination city, Zip Code and country:** which are the data related the Consignee’s localization.
- **Shipper country:** the country where the warehouse that receives the order is localized. As the study is focused on Sandvik’s warehouse C1, in Eindhoven, this column is always Netherlands.
- **Transport mode:** this column is the theoretic transport method that TNT uses. It may be "Land" which means by truck or by "Air" which implies the use of a plane. However, after some interviews with Sandvik’s coordinators and comparing Sandvik’s data with TNT one, the conclusion is that the information of this variable is not accurate. This is due to two sources of error. On the one hand, an error appears when the Sandvik’s ERP detects that a spare parts is ordered in a General express way. In this case, automatically a transportation mode by "Air" always appears. As it is mentioned in the Part 4, TNT has a special service for nordic countries which in some cases may involve a plane, but, again, not always.

On the other hand, when Sandvik’s main data base detected that a spare part is ordered in a S - DNI (Nordic), which is one way to named Special Service Nordic, again a transportation mode by "Air" always appears. As it is mentioned in the Part 4, TNT has an special service for nordic countries which in some cases may involve a plane, but, again, not always.

- **Load closed date:** date when the shipments in C1 are charged in the first mode of transportation.
- **Warehouse:** warehouse where the orders are transport from. In this study is always C1.
- **POD:** the actual delivery date.
- **Lead time:** it might be the date between the realization of a shipment and the date the shipment arrives to the customer as it is explained in the Part 3. It was revealed that Sandvik’s ERP lead time is built as the subtraction between **Load**
5.3 Provided data analysis

*closed date* and *POD* which means that the supposed lead time column is not the lead time as generally known or how it is already defined in the Part 3. This is the transportation time, without taking into account the time between the order arrives and the dispatched time. Besides, as this variable was a simply subtraction, it does not distinguish between working days or weekends, so the variable is not an accurate transportation time. Related to these values, the first thing that may surprise is that there are enormous numbers, for instance, 41 days of lead time, or even some negative numbers which does not make sense in a lead time context.

Although some errors in the writing of the data could be admissible, the observation of the data guided to believe that some kind of additional problem may occur. After some interviews with TNT, they sent the information they have about lead times. A match between Sandvik lead time data and TNT one was needed, and was done by using Excel and the *P.Ist-numbers*. Due to all this mistakes, it was decided to use the data that TNT provided, and also, not to consider this date as lead time anymore and to take into account that they are transportation time.

- **Shipper city**: city where the orders are transport from. In this study, as it is framed to the warehouse C1, is Eindhoven.

- **Carrier product**: is the kind of engagement that is hire with the carrier, in this case, TNT. It is further explained in the Part 4.

- **P.Ist-Number**: is the tracking number. It is the number used to identify the specific shipment.

- **Criticality code**: is the urgency the order has.

- **No of shipments, packages, gross weight and volume**: are characteristics and measurements of each order. For further calculations is better to settle that the gross weight and volume are the total for the entire shipment.

- **Chargeable weight**: for this value, TNT has a fix policy for *Express* and *Economy Express*, which is to choose the maximum between the volume of the shipment multiplied by 250, and its *Gross weight* while for *Special rates Nordic* and *Special rates Germany* the volumetric conversion is 200.

- **Expected cost and total cost all legs**: the first one is the theoretic cost calculated behind TNT’s manners. The *Total cost all legs* is the real cost charged to Sandvik which is a little different in some cases. It could be smaller resulting from an unexpected delay of an special shipment, which are the one with a *Carrier product* that includes a delivery before 8.00, 9.00, etc. For instance, if the *Carrier product* is *9.00 Express*, which would imply a plus in the regular express rate, and the order does not arrive to place before 9.00, TNT does not
charge this extra rate. Other situation that may vary this two columns is the different between the *Fuel surcharge* with is treated more thoroughly at the end of this section.

From TNT side, it has been received some extra information completely crucial to understand how the process works. First of all, the rates, that it may check in the figure 5.9, and how they are calculated.

![TNT Economy Express rates. Capture from TNT’s information file.](image)

TNT has a common procedure for *Economy Express* and *Express* distribution which starts with obtaining *Pay weight* or *Chargable weight*. Then with the variables *Destination country* and specific *Carrier product* there is a basic rate, named *Freight spent*. Besides, there is a *Fuel surcharge*, which is calculated as a percentage of the *Freight Spent* founded. The index based *Fuel surcharge* for each country shipments comes from the monthly average forecourt price of Diesel, as published by the AA and is inclusive of duties and taxes applicable each countries. Due to its monthly possible change, this is why in some cases *Expected cost and total cost all legs*: does not match. TNT makes to sandvik a discount in the fuel surcharge of 75% in the case of Economy Express and Express rates. Finally, there is an insurance, named ESS which is calculated from *Pay weight*.

Related to the *Special service Nordic*, the calculation is a little bit different. The shipments to Finland, Norway and Sweden by using *Special service Nordic* may be done by road or by plane from C1 to a consolidation point in Sweden. It does not matter which type of transportation mode is used because the rate does not depend on that so the lead times are. Then, there are two possibilities which change the rates and the lead times, which is a transportation of last-mile by road or last-mile by domestic airlift. These two possibilities are also, limited to the zip code of the destinations since, to arrive in a competitive express time to some remote areas is

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<th>Holland</th>
<th>Belgium</th>
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only possible to use a plane. Once the rate is selected, then the rest of the calculation is the same as in the other cases being in this cases the discount in the fuel surcharge of 50%.

Finally regarding to the Special service Germany the calculations are the same than for Economy Express and Express adding a german tool MAUT of the 2.5% of the Freight Spent. Next picture clarify how the process is in the Figure 5.10.

![Diagram related to how final cost is calculated.](image)

During some interviews with the coordinators in Sandvik, they said they though that in some cases and for some orders’ weight it is cheaper to send by using Express than using Economy Express. Besides, in the case of the Nordic countries or Germany, they also thought that it was always more expensive to send by special services than by Express or Economy Express. Due to this uncertainty, it is decided to make a graphic for each country and see if there is any break point between rates. These results are gather in the Apendix. It may be observed that in all cases Economy Express rates are cheaper than Express ones.

Related to Nordics, in these cases there is a repeating patter. The cheapest rate is always the Express Economy, then the Special service Nordic by last-mile road, followed by Express rate and, as the most expensive rate, the Special service Nordic last-mile by air uplift. This is important in order to simulate an to choose the most economic rate.

Regarding Germany, the Special service Germany is always the most expensive, then the Express being the cheapest one always the Express Economy.
Chapter 5. Analysis

One important issue before starting with further steps is to realize that in this point the information regarding lead times is not completed, due to the fact that the author just have the transportation time, which might concur or might not with lead time. Also, as mentioned in the Part 5.1, customers commonly place an order with some days or even months in advance, this exactly date an hour is register as Creation time, and can be check in the Figure 5.11.

![Figure 5.11](sandvik ERP)  Shipment "life cycle". Capture from Sandvik’s ERP.

![Figure 5.12](scatter plot)  Scatter plot of Europe’s shipments without Nordics.
5.3 Provided data analysis

As it was described, this is due to the problems with stock in the warehouse. In order to not to take into account the problems in the warehouse while they are out of the scope of this study, it is assumed that in Creation time the inventory levels are enough and also that the customer required the product according to the CP specified and not in the Requested time that appears in the Figure 5.11. Then, TNT sent the transportation schedule they have for C1, depending on the carrier product and the destination country.

So, for Europe (without Nordics) if the shipment enters before 17.00, the TNT system is able to pack, label, etc. and may be in a transportation mode the same day. In this case, the lead time is the same than the transportation time. If the order arrives to Sandvik’s system after that time, it will go in the transportation mode of the next day, being the lead time one day plus the transportation time. For Nordics, this time is 16.30. The next two Figures 5.12 and 5.13 represent the shipments for Europe and Nordics and the cut off time in each case, being clear than most of the shipments might enter in the transportation mode of the same day, specifically 3,68% of Europe shipments and 3,75% of Nordic shipments would be out of the cut off time and will be sent the next day.

It is important to clarify that these times are regarding the actual situation
where customers make orders with time in advance. Moreover, if the stock situation changes, it is possible that the customers make orders just when they need them, thus, this times could suffer big changes.

5.4 Creation of a simulation model

As described in the Part 2, in this study there are two main variables, lead time and costs. They are dependent and inversely proportional while the rate offered by TNT would increase if Sandvik needs a lower lead time. Thus, the aim of building a simulation model is to create a balance that can ensure a good enough service level at a good price. Once all data are analyzed, the next step is to create the model which is able to recalculate the price of the orders with sundry Carrier products and consequently, calculate the lead time associated. After this, the rest of the variables like, number of orders to warehouses, number of shipments which each criticality point etc, are obtained while different models are simulated.

The simplicity has been one of the main point in this study so that, the used formulas and programs has been deeply research and chosen to ensure an easy comprehension and a file of calculations the least heavy and, at the same time, within the reach of the two companies without any additional program. Due to this, and because most of the data were provided by Excel, the first option was using this program for building the simulation model.

While rates do not only depend on the country destination but also depend on the zip code, the destination country column is rebuilt to add the specific name that rates file has for different parts of some countries. This countries are denominated Splitted countries, and are: France, Italy, Sweden, Norway and Finland. For instance, France rates are different for France north which covers some zip codes than for France south thus, the column Destination country needs to be modified. This task is performed by making a new sheet in the excel which includes the specific zip codes with the correspondent country section that may be instead of the general name of the country. That data is positioned in a matrix way and then, the Excel function VLOOKUP is situated in the column Destination country for Splitted countries. The first variable for the function VLOOKUP is the one that has to look up, which is the correspondent destination zip code of the specific order, then the next required variable is the range where Excel needs to search the zip code which is in the new sheet, finally the number of the column where the specific part of the country is.
5.5 Actual situation. Scenario 0.

For evaluating the actual performance of the Express distribution in Sandvik, all variables that this study is focused on must be acquired. Regarding the second main variable, Lead time, TNT provides the Transportation time which is demonstrated in the Figures 5.12 and 5.13 that may considered as lead time.

Related to the first main variable, the cost of each order, a situation appears. While most of the orders have a value in the column Total cost all legs, some of them do not. All these orders have a POD so, the order did not miss. After a deep research with Sandvik and TNT, it was decided to assume that there had been a problem in the system that may explain that. So, it was suggested to, in these cases, use the Expected cost to evaluate the cost those shipments have. However, some shipments did not have Expected cost either.

To carry out it, to identify the specific Carrier product is needed, and then apply all steps described in the Part 5.3 to achieve the final cost.

It would be also needed to apply the recharge for faster delivered, but the orders needed to be calculated does not have this singularity, so it is not taken into account. Likewise, the orders with unknown cost have a Carrier product of Economy Express or Express so the calculation in this step are focused on these two kind of Carrier products leaving apart the Special Service Nordic and Special Service Germany.

Firstly, the file have a column named Carrier product which does not specifically say if the used rate for the order is Express, Economy Express, Special Service Germany or Special Service Nordic and this is a data needed, not only for the recalculation steps but also for further analysis. Therefore, the actual sent orders are shorter into Express, Economy Express, Special Service Nordic, Special Service Germany in a new column named Actual service. These columns are made with the function IF and OR.

In general terms, these two function cluster:

- 48 Hour to Economy Express.

- 9.00 Express, 10.00 Express, 12.00 Express, 15N - Global Express Service (Non docs), D15 - Domestic Express (Non docs) to Express.

- DE Dom Pre9, S - Direct Infeed to Special Service Germany.

- S - DNI (Nordic) to Special Service Nordic.
Secondly, the weight that has to be looked into the rate tables. As it is explained in the 5.3, is not the **Chargeable weight**, but is **Pay weight**, so, **Pay weight** is calculated. Then, a two columns named **Freight spent Economy Express** and **Freight spent Express** where the **Pay weight** and **Destination country** are matched for **Economy Express** and **Express** rates. This procedure has made by restacking the rates’ data and with an Excel function. When the **Freight spent Economy Express** and **Freight spent Express** are calculated, two more columns, **Total Spent Economy Express** and **Total Spent Express** are determined by adding to each **Freight spent** the correspondent **Fuel surcharge** and **ESS**.

![Figure 5.14](image)

**Figure 5.14**  Way of acquiring actual spent.

In order to finally obtain the column **Actual situation. Actual spent.**, a **IF excel function** was used to divide the possibilities into three cases, exposed in the figure 5.14 and 5.15:

1. If there is a value in the **Total cost all legs**, this would be the value that appear.

2. If there is not a value in the **Total cost all legs**, the function checks if there is a value in **Expected cost** and if there is, it would use this.

3. If there are not values either **Total cost all legs** or **Expected cost**, the function would check the column **Actual service** and depending on this is **Economy Express** or **Express** would use the **Total Spent Economy Express** or **Total Spent Express** columns.
5.6 Scenario 1

By doing this procedure, the author ensures the use of the real data provided until the furthest point, and then, data needed is calculated.

5.6 Scenario 1

In the first simulation how a fastest distribution might affect is the object of study, to see how serious the costs and lead times are for Sandvik and customers. In this simulation all shipments are sent either by Express or Special Service Nordic, as they are the two fastest services. In first place the fastest of the two ones is chosen and then, in cases where both are equally fast, the most economic is selected. It is important to note that the Special Service Germany lead time is the same as the Express service in Germany. As can be seen from the breakdown of the tariff prices shown in the Appendix, Special Service Germany is a much higher rate. Therefore, in the cases of Germany it is decided to place an Express fare on all shipments.

5.7 Scenario 2

Due to the results in the break points figures in the Appendix, it is demonstrated that the Economy Express rate is always the cheapest one, therefore, the second scenario is a simulation of all shipments sent by Economy Express. This simulation determines if the service level has worsen too much to consider it or, if the costs are so improved to make decreasing the service level worth. As in the previous simulation, the calculus needed are found in the Part 5.5 while there is already the

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**Figure 5.15** Actual Spent and Total Spent Express and Economy Express.

<table>
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<th>Actual Spent</th>
<th>Actual LT</th>
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<th>Total Spent Economy Express</th>
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</table>
Chapter 5. Analysis

column Total Spent Economy Express and also, the lead times are provided by TNT for each shipment.

5.8 Scenario 3

In the Figure 5.16 appears how this procedure is made.

![Figure 5.16](image)

**Figure 5.16** Way of achieving the simulation 3.

The main point of this study is to really adapt the transportation mode, service level and also the costs to the required needs in each case. This needs are in this simulation model translated into Criticality points. Because of it, it is decided to make a new simulation, Scenario 3, which would have the next characteristics:

1. If the order has not a criticality point of 1 the cost used is Total Spent Economy Express.

2. If the order has a criticality point of 1:
5.9 Obtained data analysis

In this section, the currently used program, Excel, is also used and its results are visualized by using Power BI. Power BI is a suite of business analytics tools to analyze data and share insights. Power BI dashboards provide a 360-degree view for business users with their most important metrics in one place, updated in real time, and available on all of their devices. It combines data from disparate databases, files, and web services with visual tools that help to understand and fix data quality and formatting issues automatically [PowerBI official webpage].

<table>
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</tr>
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</table>

Figure 5.17 Simulation 1 and Simulation 2.

The common procedure in all simulations is to evaluate the variables object to this study which are costs and lead times but also some others like number of ship-
ments to each carrier product, their costs and volume sent by each, as well as the percentage that they mean. Then this calculations are repeated to the specific shipments to warehouse. In the next Figures, 5.17 and 5.18 appear how the simulations look. About the Scenario 0, a deeper research is made, since a good understanding of the actual situation would lead to success simulations. Firstly, the moved orders are analyzed. The total number of General Express orders during 2016 is 7,584, an overall Gross weight of 598,444,91 kg which means a cost for Sandvik of 1,391,541,68 euros.

The Figure 5.19, displays that the 55,19% of the kg which corresponds to 54,37% of all General Express orders are currently send by Special Service Nordic or Special Service Germany, this leads to take an special attention to these countries. Besides, the rest of the kg are mostly send by Express, 32,31 %, and very few by Economy Express, which is one of the questions in this study.

The Figure 5.20 collects the kg sent and their cost depending on the destination country within Europe since, the General Express service has been used for 30 European countries. This figure shows that just 7 countries, Finland, Sweden, France, Germany, UK, Spain and Norway, englobes the 82,44% of the total cost and 87,13% of the total amount of kg sent by General Express and Special Services. Besides, it is notable comparing the bars in the chart the relation between costs and kg is completely different for the different countries. While Spain, UK and Finland have a relation of 2.73, 2.70 and 2.60, Germany, France and Sweden have a relation of 1.38, 1.57, and 1.9. Still, there is a more impressive data regarding Norway, which has got a cost/kg relation of 4.57.

The Figure 5.22 visualizes the cost of the type of service per country, which is
made by counting in the excel file the shipments of each service within each country. The size of each circle is proportional to the amount of kg sent by each country, being the biggest the first 7 countries that before were mentioned. The Figure 5.22 reveals, that the countries with *Special Service Nordic* or *Special Service Germany*, mostly just use the Special Service and then, the rest of the countries, generally use *Express*.

This figure 5.20 in some cases is correlated with 5.22 but in other cases not. It is acceptable that if a country has a possibility of transport by special service and it is generally use it, the cost spend on it is bigger due to the higher cost of the rate. The explanation of why Norway has that enormous cost/kg might be due to it just sends by *Special Service Nordic*. However, that relation cost/kg is much bigger than in Sweden or Finland, and they all are in the same conditions. This is explained, due to the existent differences between the Nordic rates.

**Figure 5.19** Actual Scenario. Total Kg sent and costs.
Concerning Germany also uses most of the times the Special service Germany which in theory is more expensive than the regular rates. However, the cost/kg paid is 1.38 which comparing with a country without special rates as, for instance, France with 1.57, does not imply a comparative higher cost. Concerning Germany, it also uses in most of the times the Special Service Germany which in theory is more expensive than the General Express.

In order to evaluate which shipments are made to warehouses, as it is a part of the supply chain which is not aligned with the company’s strategy of a dynamic distribution for spare parts, data regarding the shipments to the warehouses are needed. Thus, each Consignee name: is study to divide orders between customers and warehouses. Then, a map of the orders that go to the warehouses or to the customers is built a Figure 5.23. As stated in it, Norway, Finland, Sweden, Spain and Germany are the countries that order more General Express to warehouses and also, even more than for customers.

The Figure 5.24 visualizes the amount of orders with each Criticality point per country. As the main problem in this study is the orders sent by General Ex-
5.9 Obtained data analysis

Figure 5.21  Actual Scenario. Cost spent in each type of order to each country.

*press* without emergency, which are all orders with a criticality point bigger than 2, those have heaped. It may observe that the there are some variation between countries, nevertheless, the majority of the shipments have a criticality of 2 or more with the only exception of Holland.

Deepening more in this matter, the Figure 5.25 shows that there are some countries like France, UK, Finland, etc. ordering with a *Criticality Point* of 1 to warehouses, which, as explained in the Part 5.1 might be impossible.

Regarding to the Parts 5.6, 5.7 and 5.8, there is a cost comparative in the Figure 5.26.

If all orders would be sent as the *Scenario 1*, the total cost would increase until 1,464,234,73 euros, since all orders are change to *Express* or to *Special Service Nordic*. *Express* is a rate that is always more expensive than *Economy Express* and also, for some amounts, is more expensive than *Special service Nordic*. However
in this simulations the fastest alternative is selected, which most of the times is the most expensive between these two last options mentioned. This is why the Scenario 1 is even more expensive than the actual situation. If all order would change as Scenario 2 the total cost would decrease until 476,847,307 euros, as Economy Express rate is the cheapest one. About the Scenario 3 the simulation concludes that the total cost would be 612,697,65 euros, reducing the total cost 56% from the Scenario 0.

About the service level impact, the Figure 5.27 remarks the differences between each simulation. While Actual Scenario and Simulation 1 sent by rates which provide a low lead time but the same for all orders, Simulation 2 always sends orders with a very low service level, around 2.4. Finally, Simulation 3 adapts to the necessities being the lead time for CP=1 the same as the one in Simulation 1 but increasing this time for CP greater than 1.
Figure 5.23  Actual Scenario. Orders’ spent cost to warehouses and to customers
Figure 5.24  Actual Scenario. Shipments sent by different CP.
5.9  Obtained data analysis

**Figure 5.25**  Actual Scenario. Shipments sent by CP=1 to warehouses or to customers.

**Figure 5.26**  Actual Scenario, 1, 2, 3. Cost comparative.
Figure 5.27  Lead times depending on the CP and simulation.
6

Results and conclusions

This section includes all the results obtained from the previous analysis, explaining where the problematic object of the study comes from and the proposed answers to the research questions. Besides, some additional and future simulation are suggested and some extra recommendations for Sandvik are presented.

6.1 Answers to research questions

- **RQ1. How is the spare parts distribution working?**
  The spare parts distribution has implications for two companies, Sandvik and the carrier TNT. Spare parts are produced by Sandvik and consolidated in a central warehouse in Europe, named C1. In the case of spare parts, due to its nature, the shipments are delivered when the customer asks for them, which means that there are not a replenishment cycle for them to the customers or to local warehouses. From this warehouse, TNT transports spare parts behind General Express or Special service Nordic or Germany to the final customer or to local warehouses. All of this carrier products are express which means a high cost keeping really low lead times. This question is further explained in the Part 4.

- **RQ2. Which dilemmas have the spare parts supply chain?**
  The two main dilemmas are, on the one hand that the shipments’ orders arrive separately to the customer which creates a problem for them. On the other hand, all shipments are treated in the same way, sending behind the same carrier product, while each one has different needs.

- **RQ3. Is there agreement between spare parts distribution and Sandvik’s strategy?**
  No. Because the Sandvik’s strategy for spare parts distribution means a dynamic supply chain implying a quick response which is not happening, as
there are not enough inventory levels and customers need to make the orders days or month in advance. Also, the existence of local warehouses is not according to the strategy even more when express shipments are made to them, which is a completely waste of resources.

• **RQ4. How might spare parts distribution be improved from the company’s perspective without depreciation customers’ service level?**

Following a temporary scheme of how the changes might happen: firstly, to secure the inventory levels in C1 would be necessary, later, to ensure that there is a system that puts all shipments’ orders together, afterwards, to ensure that customers place the CP correctly, later to ask in the warehouse for a system that orders the shipments depending on their criticalities, and finally, to send them in accordance with their criticalities.

### 6.2 Results

The main result of this study is to evaluate if it would be beneficial to change some parts of the spare parts distribution chain. The results part is divided into the results of the *First step* and the *Second step* aligning with the current methodology. Regarding the *First step*, the roots of the entire bad performance of the supply chain are founded and are:

1. C1 does not group shipments’ orders.
2. Not enough inventory level in C1.
3. CP does not work.
4. Shipments are not sort out by CP in C1.

Regarding to the *Second step*, it is important to clarify that is based in the hypothetical case where all these problem’s roots mentioned are solved. On this occasion a *carrier product* is selected since all steps behind supposed to work well. It is necessary to base the decision on the one that is more aligned with the needs of the client and, at the same time, the least resources implies for Sandvik.

The *Scenario 1* offers a situation where all shipments arrive in an average of 1.12 days, which is very fast, however, all items are treated equally, irrespective of customer requirements, and also, as it uses *Express* or Special Service Nordic is really expensive. So it is not selected.

*Scenario 2* explains a situation where all shipments are sent by *Economy Express*, increasing the average lead time until 2.42 days. In this case, it would not be
6.3 Conclusion

an appropriate option, not only for the same treatment to different shipments needs, also because the shipments needed with CP 1 might not wait so long having another solution. This option is not selected either.

Scenario 3 exposes a case where orders are sent depending on its CP, and thus, according to customers’ requirements being the lead time for CP 1 the fastest one, around 1.15 days growing this number for bigger CP. Also, the prices of this service is of 44% of the actual situation, so, it is much more advantageous for Sandvik. Therefore, the selected strategy or scenario that would be more adequate for Sandvik would be the third one. In this case, the strategy of the supply chain would be aligned with company’s strategy, as each shipment would be sent by each type of carrier product depending on the urgency. This last simulation finally reveals that Special Service Germany is not necessary, as the Express service for Germany has the same lead time resulting also, much cheaper. The next Figure 6.1 shows the cost comparative and the number of shipments by each Carrier product for each simulation.

![Figure 6.1](image-url)  
*Figure 6.1  Actual Scenario, 1, 2, 3.Comparative of type of orders.*

6.3 Conclusion

This study concludes that it is possible to improve the spare parts distribution. First and third causes are related to the warehouse so, in order to change the situation, some changes in the policy related to where the shipments are collocated to the packaging step, and the developing of sorting techniques by CP in the warehouse
would be required. The second and fourth causes are directly in the Sandvik’s path. The inventory levels might be increased, at least for spare parts which would imply a new demand planning is forced to be rebuild.

Then, if this waste points are neglected, the only phase to make is the selection of a Carrier product which would be direct, as all steps behind are corrected, being the translation of this changes in a decreasing of the transportation cost of 56%.

To end, even though in the selected scenario some shipments are sent to local warehouses, it is needed to clarify that no General Express or Special Service shipment should be sent to local warehouses as they use the items for replenishment actions. There is no point on wasting this type of transportation in this task. However, as the neglection of local warehouses is out of the scope of this project, this last point is just mentioned and picked up for further studies.

6.4 Further studies and recommendations

In this case and due to the scope of this study, just the transportation mode has been changed and used to evaluate the effects if the root problems disappear. However, as the cost of the supply chain does not just remain in the transportation, this would not be the only effect that would appear from this change in the supply chain. Thereby, it is recommended to Sandvik to study all effects that an aligned supply chain might have in the existence of the local warehouses, since if the performance in C1 is adequate local warehouses would not be necessary anymore, regarding to spare parts. This would save the costs of local storage, logistics, as well as transport from local warehouses to final customers. Then, to evaluate a new scenario, Scenario 4 would be needed, which evaluates this new change.

Moreover, it is suggested to study the plausibility of a better performance of C1, since, as it is mentioned, Sandvik is not its owner, so, the possibilities of accepting the mentioned Sandvik’s new requirements are limitated.

Also, as the boundaries of this project are in the warehouse, to really answer to the question of why the inventory levels are too low is not possible, which might be either a bad demand planning or a low production, which, meanwhile, would be the effects of another problem. A deeper research in this field would be needed as this is a root of the main issue.

Finally, some recommendation are made regarding to customer relation. One concerns the way customers have to order shipments. Call center has limitated schedule, since it does not work at night. Many companies have all day shifts which means that a break-down might appear during the night and then it is impossible to notify Sandvik. Due to this, it would be recommended to study the possibility
6.4 Further studies and recommendations

def of developing an interface customer-Sandvik. From this idea, it would be easier to have
more information regarding to the customer such as, the information they have
about CP, or Sandvik in general, and also, try to avoid current situations of mistrust
or lack of sentiment of being part of the chain in order to improve how they select CP.
Figure 7.1  Comparative between Economy Express rates (EE) and Express rates (E) for Austria.
Figure 7.2  Comparative between Economy Express rates (EE) and Express rates (E) for Belgium.

Figure 7.3  Comparative between Economy Express rates (EE) and Express rates (E) for Bulgaria.
Chapter 7. Appendix

Figure 7.4 Comparative between Economy Express rates (EE) and Express rates (E) for C.R.

Figure 7.5 Comparative between Economy Express rates (EE) and Express rates (E) for Denmark.
Figure 7.6  Comparative between Economy Express rates (EE) and Express rates (E) for Estonia.

Figure 7.7  Comparative between Economy Express rates (EE), Express rates (E), Special service by road and by air uplift, for Finland.
**Figure 7.8** Comparative between Economy Express rates (EE) and Express rates (E) for France north.

**Figure 7.9** Comparative between Economy Express rates (EE) and Express rates (E) for France south.
Figure 7.10  Comparative between Economy Express rates (EE), Express rates (E) and Special Service (SS) for Germany.

Figure 7.11  Comparative between Economy Express rates (EE) and Express rates (E) for Hungary.
Figure 7.12  Comparative between Economy Express rates (EE) and Express rates (E) for Iceland.

Figure 7.13  Comparative between Economy Express rates (EE) and Express rates (E) for Italy north.
Figure 7.14  Comparative between Economy Express rates (EE) and Express rates (E) for Italy south.

Figure 7.15  Comparative between Economy Express rates (EE) and Express rates (E) for Ireland.
Chapter 7. Appendix

Figure 7.16  Comparative between Economy Express rates (EE) and Express rates (E) for Luxembourg.

Figure 7.17  Comparative between Economy Express rates (EE), Express rates (E), Special service by road and by air uplift, for Norway.
Chapter 7. Appendix

Figure 7.18 Comparative between Economy Express rates (EE) and Express rates (E) for Poland.

Figure 7.19 Comparative between Economy Express rates (EE) and Express rates (E) for Portugal.
Figure 7.20  Comparative between Economy Express rates (EE) and Express rates (E) for Slovakia.

Figure 7.21  Comparative between Economy Express rates (EE) and Express rates (E) for Slovenia.
Figure 7.22  Comparative between Economy Express rates (EE) and Express rates (E) for Spain.

Figure 7.23  Comparative between Economy Express rates (EE), Express rates (E), Special service by road and by air uplift, for Sweden.
Figure 7.24  Comparative between Economy Express rates (EE) and Express rates (E) for UK.
Bibliography


