Analysing distribution operations using the methods of Lean Six Sigma for Company X

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Abstract

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In today's highly competitive market, logistics companies must strive to achieve excellence in distribution services to win a market share. This requires logistics companies to boost their service quality and cut costs by improving performance through process optimization, loss elimination and waste reduction. Lean and Lean Six Sigma methods have proved to be effective in helping companies achieve these goals.

This Thesis is based on the author's Lean Six Sigma (LSS) Black Belt project commissioned by Company X. The scope of the project was limited to Company X's distribution operations, particularly van loading and delivery processes, in the Helsinki metropolitan area from Terminal Y for four months period, from September to December 2016. This project aimed to provide improvement opportunities for Company X to reduce additional deliveries of the same package using Lean Six Sigma analytical methods.

The theoretical framework consists of three aspects: describing distribution processes of Company X, and discovering a LSS project management approach known as Define-Measure-Analyse-Improve-Control (DMAIC) and LSS tools for data analysis to draw conclusions. The literature review built a theoretical foundation for process analysis, while observations and interviews with workers were made to obtain reliable and valid practical information on process work in Terminal Y. Data analysis on failed deliveries and van loading efficiency was conducted using Exploratory Data Analysis (EDA). In particular the following tools were used: I-Charts, Probability Chart, Process Capability Analysis, Analysis of Variance ANOVA and Pareto chart.

Improvement opportunities were identified and validated in three operational areas: inbound flow, terminal handling, van loading and outbound delivery routing to customers. Other recommendations were made regarding planned improvements to Company X's distribution infrastructure and software, planned for near term capital investment.

Keywords

Distribution, Shipment delivery, Van loading, Lean Six Sigma, Exploratory Data Analysis

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1 Introduction

This chapter presents background information on the thesis topic and describes the case company that was studied. The objective of the study, the project tasks and key theoretical concepts are also discussed in this chapter.

1.1 Background

Rapid development of international trade as stimulated by e-commerce has made logistics a highly competitive business. This requires logistics companies to boost their service quality and cut costs by improving performance through process optimization, loss elimination and waste reduction. The “Lean” approach that originated in Toyota production is now applied to all business areas and industries, including service industries, and its goal is to identify how time is spent across the flow of business activities to eliminate waste, losses and inefficiencies from this flow of work (Myerson 2012, 2). To meet growing customer expectations for on-time delivery and achieve top quality service transactions at the lowest cost for the end customer, logistics companies strive to minimize throughput time and synchronize performance to meet customer requirements using lean-related analysis methods and techniques.

These conditions motivated the case company to look for innovative solutions to deal with productivity issues and commission this research project. The company was interested in applying the Lean Six Sigma (LSS) approach which was successfully used by Amazon (Simchi-Levi 2013, 31). The project commissioned by Company X is the subject of this thesis. The research was completed by the author during her LSS training as a Black Belt between September 2016 and March 2017. The outcome of the project was a thorough report in the form of a Power Point presentation consisting of process analysis, observation comments, deployment diagrams, risk and failure analysis, data files and improvement recommendations.

1.2 Case company

Due to the highly competitive nature of this business and proprietary nature of the performance results in its key performance indicators (KPIs) the case company requested that nominal values be used in the thesis and its identity remain anonymous. Therefore, this thesis refers to the case company as “Company X” and absolute values for performance indicators are not provided.

Company X is an international logistics company that provides distribution, logistics, e-commerce and communication services. The company has an extensive service point network in Finland with more than 20 terminals, warehouses and an extensive truck fleet available to meet the needs of its customers and service the entire logistics chain.

To meet growing customers' needs for faster and more reliable package delivery at a competitive price, Company X decided to improve end-to-end process throughput time, transaction efficiency, timely and accurate external and internal information flow and effectiveness of transportation management.

The case company had reported productivity issues related to its delivery performance. Specifically, from the beginning of 2016 a daily average of X% of shipments was returned to Terminal Y, which is located within the Helsinki capital region of Company X operations. This high return rate created extra process steps for resending packages which, in turn, increased costs and thereby negatively influenced customer satisfaction regarding late delivery. The commissioning company desired to identify potential causes of shipment return rate problems and to focus on organisational improvement that would have enabled consistently effective performance results for package delivery to customers.

1.3 Project objective and tasks

Project objective: to analyse distribution operations (loading and delivery) of Company X in the metropolitan area and identify improvement opportunities to reduce additional deliveries of the same package using Lean Six Sigma analytical methods.

Project objective is divided into project tasks (PT) as follows:
PT1. Designing a theoretical framework for the project
PT2. Creating a research method framework for the project
PT3. Analysing shipment return rate at Terminal Y
PT4. Analysing loading efficiency at Terminal Y
PT5. Concluding and recommending actions based on analysis
PT6. Project evaluation.

Table 1 below presents the theoretical framework, project management methods and outcomes for each project task.

Table 1. Overlay matrix

Project tasks	Theoretical framework	PM method	Outcome
PT1. Designing a theoretical framework for the project. Literature overview on LSS methodology.	Theories and key concepts explaining distribution and LSS methods that will be applied in the project	Literature review Interview with a company representative and Lean Six Sigma expert	Theoretical framework for the project
PT2. Creating research method framework for the project	Theories explaining research methods	Literature review	Research method framework for the project
PT3. Analysing shipment return rate at Terminal Y	Theory described in Chapter 2, operational definitions in Chapter 4	Implementation of Lean Six Sigma Define Measure Analyse (DMA) project management method	Identification of the current state of the process and determination of opportunities for process improvement
PT4. Analysing loading efficiency at Terminal Y	Theory described in Chapter 2, Operational definitions in Chapter 5	Implementation of Lean Six Sigma DMA project management method	Identification of the current state of the process and determination of opportunities for process improvement
PT5. Concluding and recommending actions based on analysis	Theory described in Chapter 2. Analysis described in Chapters 4 and 5.	Decision action meeting	Specific recommendations to management for process changes
PT6. Evaluating the project	Obtaining feedback from Company X regarding the utility of the analysis and expectation of benefits	Written and oral feedback from the company.	Project evaluation from the viewpoint of concept and usability

1.4 Project scope

The scope of the project was limited by Company X to shipment loading and delivery activities at Terminal Y for the Helsinki metropolitan area (cities of Espoo, Helsinki, and Vantaa) during the period from September to December 2016.

1.5 International aspect

In today's global economy it is essential to move goods across national borders from the original manufacturer to the recipient who consumes these goods. The logistics chain that handles shipments include process elements related to sales ordering, transportation, material handling, planning and coordination, and warehouse operations. This thesis focuses on a core element of international trade – logistics, with a specific emphasis on the delivery of shipped packages from the final terminal to the end customer. This delivery process becomes increasingly more complex as the international origin of the shipments means that there are varying standards and methods used for the specification of the shipment order at the source of origin. This variability places a strain upon the customer delivery as the number of returned packages at the final terminal increases greatly as the source of the shipments extends beyond domestic borders. The uncertainty that occurs due to the international origin of the shipments, places a great strain on package delivery performance in the company's operations.

1.6 Benefits

The stakeholders for this project included the commissioning company, the clients of the commissioning company (both shipper and recipient), as well as the author.

The key benefits for Company X were:

- obtained an end-to-end perspective of the flow of its operations based on an analytical treatment of its work process for delivering packages
- identified reasons for high shipment return rate in the final portion of its distribution chain
- understood weaknesses in its data collection and analysis processes for tracking packages and executing the distribution function
- developed a baseline analytical methodology that it may use as a foundation for future efficiency-improvement projects
- increased profit and reduced costs thorough reduction of redundant delivery attempts for packages (e.g., by eliminating additional delivery attempts which are not included in the shipment fee paid by the shipper)
- increased customer satisfaction in both the shipper and recipient customer segments.

The key benefits for the clients of the case company (both shippers and recipients included:

- increased confidence in the shipment process through more complete information which was available for notification of the progress in the package shipment
- increased successful rate for first-time package delivery
- improved overall service level.

The author benefited from both opportunities to enlarge her theoretical knowledge of distribution management and LSS methods and by obtaining practical experience in Project Management. In addition, the author learned how to apply the LSS analysis methods for analysing shipment and distribution processes. In parallel with conducting this internship, the author participated in the Lean Six Sigma training program sponsored by Laatukeskus Excellence Finland Oy and had an opportunity to become certified as a Lean Six Sigma Black Belt.

1.7 Risks

There were several risks involved in the project process. First, team members' commitment to the project could not have been sufficient to assist a part-time thesis researcher in the conduct of the study. This analysis project involved a cross-functional team consisting of terminal manager, quality specialist, dispatchers, and customer service representatives which required time allocated by each member. Considering that the author was from outside the company and had no experience in leading projects, team members could have been reluctant to commit to the project tasks and deadlines. A second risk was the anticipated access to the company's data and information. Data access restrictions could have hindered data collection and the analysis process, which would have extended project deadlines by causing unexpected delays. One significant risk in this area could have been the quality of the company's data and the timeliness of access to its records. Data quality included suitability of the existing process measurement system (points for data capture as well as the set of measures that the system captures) for terminal operations management, planning and decision making. Low quality data would have hindered data analysis and would have required additional data collection and data cleaning to eliminate confusion and redundancy. Collectively, these risks could have adversely influenced the achievement of project objectives and deadlines.

1.8 Key concepts

Third-party logistics provider (TPL) – a company which provides logistics services to its customers, such as materials management and product distribution (Simchi-Levi, Kaminsky & Simchi-Levi 2004, 116).

Cross docking – a distribution system in which products are not warehoused after unloading but instead are recombined according to customer needs and dispatched the same day (Hugos 2011, 12).

Shipment return – is the return of a package from a customer for a variety of reasons, such as incorrect goods, unwanted goods, damaged goods, and recalled goods (Rushton, Croucher & Baker 2017, 373). For this project the author modified the definition of "return" taking into consideration the specifics of services provided by the case company. Under this modified definition, a return was defined as "a non-delivered package to a customer for a variety of reasons such as consignee not present, lack of time, van space for delivery, incorrect or missing address or other consignee information so the driver cannot reach a customer."

Lean Six Sigma (LSS)– is an operating philosophy and methodology that combines two improvement methods making work much better (using Six Sigma methods) while simultaneously also making work faster (using Lean methods) with the objective of identifying and eliminating waste and quality problems throughout a company (Watson 2016a, 5).

DMAIC – is a project-management approach for structured problem-solving that is used in Lean Six Sigma and consists of five steps: Define, Measure, Analyse, Improve and Control. A DMAIC project focuses on improving both the efficiency and effectiveness of work processes. (Watson 2016a, 6).

Exploratory Data Analysis (EDA) – is an approach to data analysis that evaluates the baseline condition of the process performance, to identify special causes of variation and understand the performance capability of the process. Key methods of EDA are: Individual Control Charts (I-Charts), Process Capability Analysis, Pareto Charts, Probability Analysis, Analysis of Variance (ANOVA) and Yamazumi Diagrams. (Watson 2016b, 64.)

These methods are discussed in detail in Chapter 2.

2 Using Lean Six Sigma to evaluate supply chain performance

This chapter reveals the theories and key concepts which create the theoretical basis for the project. Figure 1 depicts the framework for the thesis. This framework was constrained due to the project scope which emphasized shipment return rate reduction. The theory behind the analysis for this thesis is described below, as applied to EDA for both package loading and delivery.

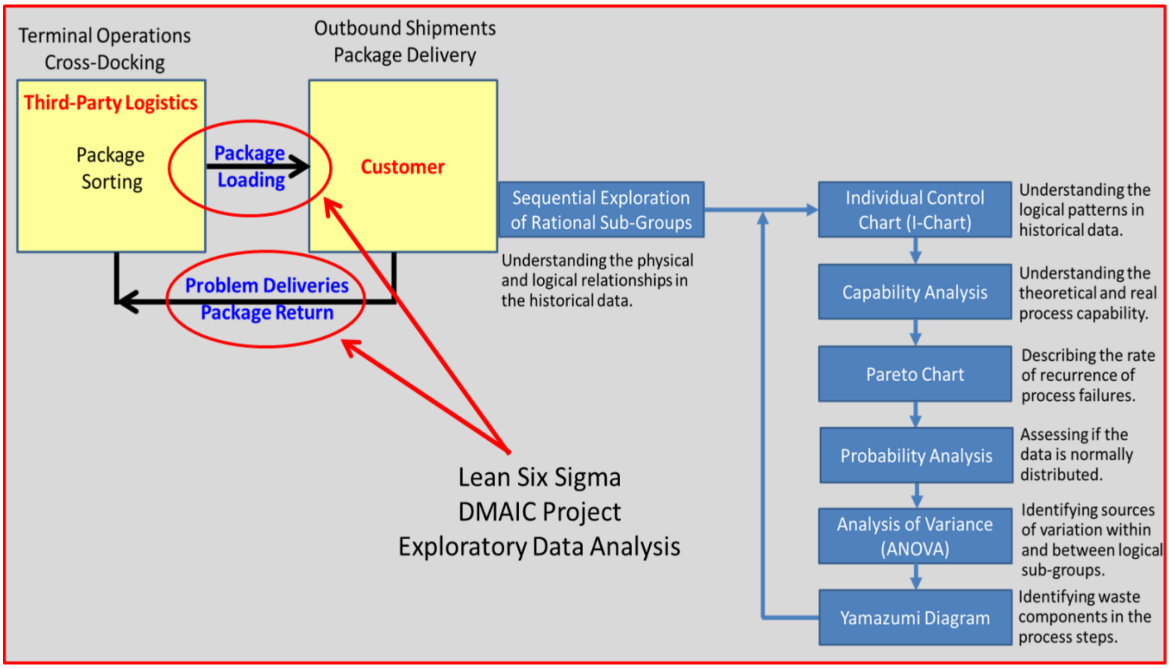

Figure 1. Theoretical framework for the project

2.1 Definitions

Several important terms are used in literature to describe the delivery of goods to customers in international commerce: logistics, distribution management, and supply chain management. The distinctions between these terms establish a context for this thesis.

“Logistics” is the overall term that describes management systems related to the support of operational activities. It is defined by the Council of Supply Chain Management Professionals (2016, 117) as a part of supply chain management that plans, implements and controls the efficient, effective, forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customers’ requirements. This broad use of the term focuses on the planning of the activity rather than execution of the plan and therefore does not focus sufficiently to address the specific application in this thesis.

“Distribution management” pertains to both the planning function and the execution function that satisfies the plan. It is defined as storage and flows from the final production point through to the customer or end user. (Rushton & al. 2017, 4.)

However, this definition also fails to represent the focus of this thesis as it does not concentrate on the delivery of the sales package across international borders to the final consumer.

“Supply Chain Management” is another term that is often used to describe the way that the logistics function operates in an international setting as an end-to-end. It has been defined by Council of Supply Chain Management Professionals (2016, 187) as follows:

> Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence supply chain management integrates supply and demand management within and across companies.

This definition is more inclusive and it adequately positions this thesis. The emphasis of the analysis in this thesis is on the global distribution function in its terminal application as the transported item nears its destination for delivery to the customer (first party). Typically, this activity is not completed by the originating shipper (second party) but it is achieved by a service provider who is also referred to as a “Third-Party Logistics” (TPL) provider. The key feature of this business is that the TPL service provider has customers on both ends of the supply chain. The shipping customer begins the sequence of operations while the receiving customer completes this chain of events. The author designed Figure 2 to visualise the description of TPL role in such a supply chain.

Figure 2. TPL in a supply chain

TPL delivers value in a distribution chain through the efficient, effective and economic completion of the shipment transaction for performance in delivery to the receiving customer. In this project effectiveness is achieved through a low return rate of packages from distribution routes with a concurrent high on-time package delivery performance. Process efficiency is achieved by a rapid throughput across the work processes of the TPL service provider. Economic performance is achieved when work is performed at the lowest total cost of delivery per package.

2.2 Logistics processes

This subchapter provides a brief literature review on core logistics processes representing the case company business model that was analysed during the project.

Design of appropriate processes is the core element of any business, especially for logistics companies considering its dynamic. Smooth processes ensure efficient and effective operations and allow a company to achieve its main goals. Rushton (2017, 117) mentions that every organisation should aim to streamline operations across its various functional boundaries. This implies that processes should be cross-functional and customer-oriented to deliver maximum value to the customer. Thus, TPL companies shall take into consideration the Voice of the Customer (VOC) on both ends of the supply chain delivering to the specification of the shipping customer and sensitive to the particular requirements of the receiving customer (Martin 2014, 4).

Often logistics processes will be assigned to the responsibility of one function while their execution requires coordination across boundaries of several different ones, which creates a challenge in planning and operations. This affects the TPL's performance adding additional costs with delays in lead time and increasing rework, which in combination will decrease the level of customer service. (Rushton & al. 2017, 117.)

Logistics has many processes; some are common to many businesses while others vary depending on industry and organization. The author has described only processes related to the scope of the project within the case company's business area.

"Order Fulfilment" is a traditional component within the overall logistics process. The goal of order fulfilment is to ensure that a customer's order is received, checked and delivered according to customer needs (Simchi-Levi & al. 2004, 50). For Company X this process was described as the ability to turn the requirements of the client company (or the shipping customer) into delivered orders to an end-customer (the receiving customer) in both the Business-to-Business (B2B) and Business-to-Customer (B2C) distribution chains.

Figure 3 describes the order fulfilment process within Company X. The process starts when an end customer makes an order, for example at a web-store, the seller confirms the order and sends an acknowledgement to the buyer, as well as package information and recipient details to the case company. After that, the seller sends the package for distribution to Company X under contract terms. When a package arrives at Terminal Y it is sorted and dispatched for delivery according to the end-customer requirements. When a customer receives a package and signs necessary documents, "Proof of delivery" is generated in the case company system, which is sent to the package sender to initiate payment for distribution and delivery services. Cycle time or the time from the beginning until the end of the order fulfilment process usually takes from 2 to 3-4 days, depending on sender and recipient location (domestic or international) (Voehl, Harrington, Mignosa & Charron 2014, 215).

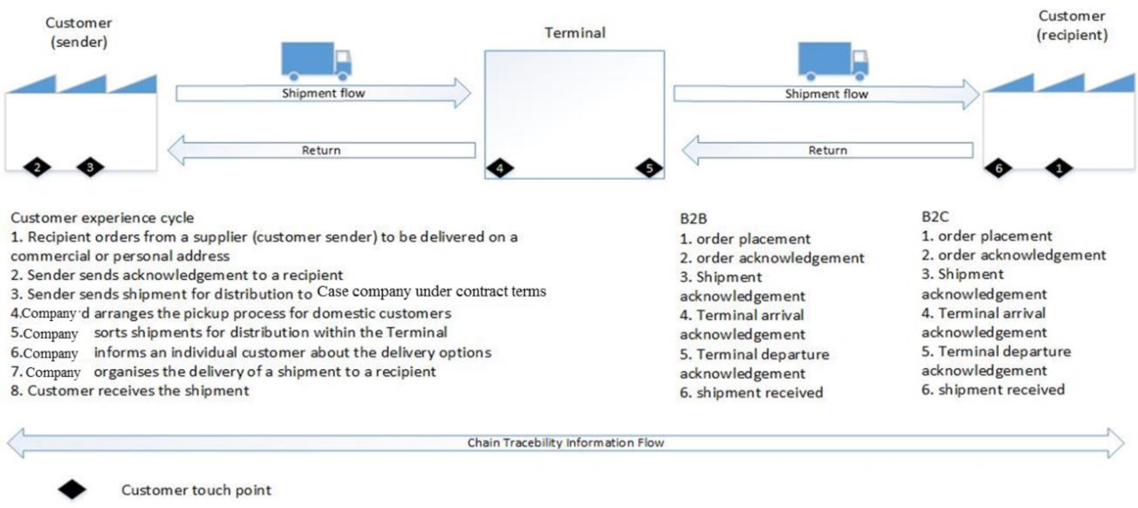

Figure 3. Order fulfilment process in Company X

A Supplier-Input-Process-Output-Customer (SIPOC) map portrays the high-level or abstract conceptual detail of the sequence of all relevant elements in the End-to-End (E2E) process (Voehl & al. 2014, 363). The SIPOC methodology is used to visualise how process inputs are transformed into outputs through a sequence of activities (e.g., sub-processes) and identify the stakeholders involved (suppliers of the process inputs and customers or recipients of the process outputs).

To clarify the core process that this project was focused upon and to identify the activities within that process, a SIPOC diagram of Company X was developed (Figure 4) in collaboration with a team of the company’s employees from the various units across its operating departments.

Package processing by Company X starts when a delivery truck arrives at Terminal Y, after that the package is unloaded and scanned as “Inbound” and is transferred for sorting. At the sorting conveyer packages are sorted according to the following criteria:

- Business packages (B2B) and Private packages (B2C)
- date and time of delivery
- postal code of recipient.

After sorting, some packages are moved to the warehouse at Terminal Y until delivery arrangements are established with the recipient. The remainder of the packages are placed into designated holding areas awaiting pick-up and delivery to the ultimate receiving customer.

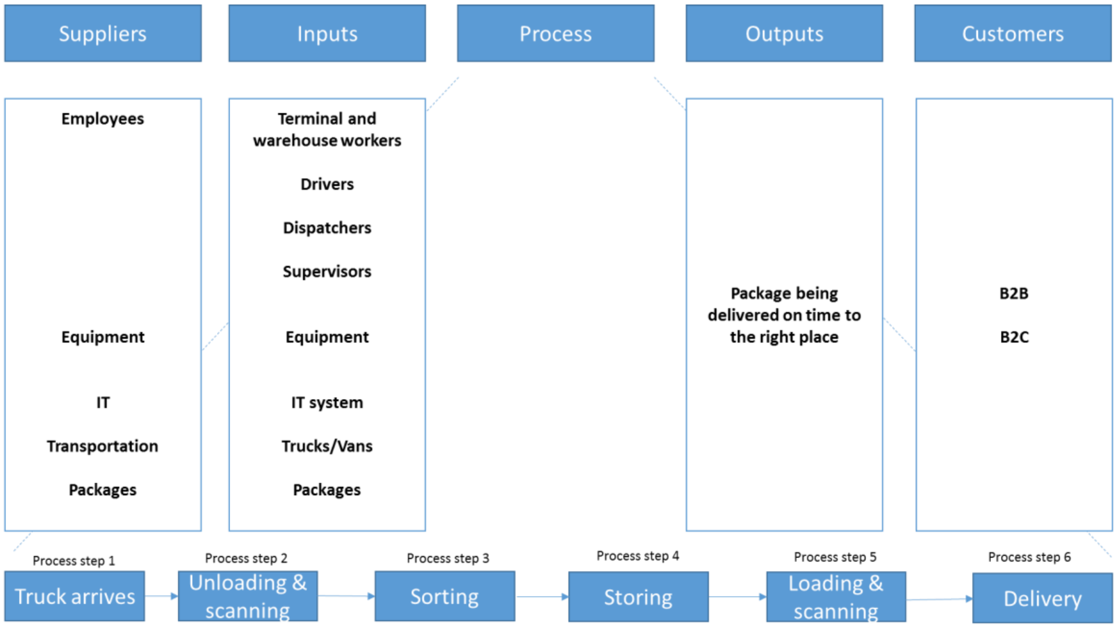

Figure 4. SIPOC diagram for Company X

A more detailed visualisation of this flow is provided by a breakdown of the SIPOC level of detail into more detailed sub-process flows. These flows become evident by examining how the process participants act collaboratively to achieve the overall result. The Deployment Diagram (Appendix 1) illustrates the cross-functional relationship between all the involved parties in the E2E process (where each party is identified as a unique row in the graphical diagram). The sequence of activities in the deployment diagram maps the E2E flow of work from the point of origin (the order placed by the receiving customer to the shipping customer) and the physical and information handling steps required to transport the package through the logistics system to the point of delivery.

Within Company X, package processing at Terminal Y is structured across functions and includes the details regarding which of its functional departments own each of its distribution processes. The Deployment Diagram also illustrates the key process handover points where work is transferred between the participating functions within this E2E process (Brook 2014, 99). The Deployment Diagram may be supplemented by adding a value stream that classifies process work in each step as either value adding or non-value adding. This use of the diagram permits standardization of the process flow and identification of activities within the overall E2E process that contribute to waste in the processing time that occurs at each step in this E2E process. (Watson 2016b, 33.)

2.3 Project management methodology

LSS combines three methodologies for structured problem-solving of issues that arise in the daily management systems of organizations (Watson 2016a, 25):

1. A project management approach for conducting the inquiry into the nature of the problem and for pursuing its resolution called DMAIC. DMAIC is an acronym that identifies the sequence of project management steps of Define, Measure, Analyse, Improve and Control.
2. A set of analytical methods (including both graphical and statistical techniques) used within and across the five DMAIC steps to focus the problem-solving process and pursue its resolution.
3. A set of Japanese work management methods that are collectively referred to as “lean management” and used for eliminating waste, loss, and inefficiency in work processes by streamlining the tasks and creating definitions of standard work.

DMAIC uses a sequence of guiding questions to develop profound knowledge about the way a process performs. DMAIC uses statistics to develop objective understanding of process results and interaction among the performance of the various process elements. It also investigates performance within the context of the E2E process starting with the quality of the deliverable to the ultimate customer. Finally, DMAIC applies lean principles to increase efficiency and eliminate wastes and losses so that process stability can be achieved in the daily work and predictable results occur based on the process inputs. (Watson 2016a, 14.)

Each of the five DMAIC steps represents a stage in the project management approach as applied in Lean Six Sigma improvement projects. DMAIC is summarized below in terms of the definition of each of the five stages and the accompanying analytical questions that guide an inquiry into the specific problem (Watson 2016a, 15-18):

- Define: specifies the problem to be pursued by the team. It begins with a business issue, concern or problem and ends with a project charter. The questions that are addressed during this step include:
  - What is the issue or concern?
  - How big is the business problem?
  - Where is the problem occurring?
  - How does it affect our customers?
  - What people should address it?

- Measure: determines the magnitude of a problem and evaluates the goodness of the measurement system. It begins with a project charter and ends by estimating the performance gap to be closed. The questions that are addressed during this step include:
  - Where do the problems occur?
  - How well is the process doing?
  - How well could it be doing?
  - Can the process detect problems?
  - How can the process fail?

- What are potential causes of the problem?
- Does the history show any trend?
- Is anyone doing this work better?
- What is the cost of poor quality?
- How can the process be simplified?

- Analyse: determines the factors that contribute the most variation and waste to a specific problem situation. It begins by formulating a process performance baseline and ends with a working hypothesis about likely causes that have created unwanted variance in performance. The questions that are addressed during this step include:
  - Which factors most affect variation?
  - Where does the process waste time?
  - Why does the process cost too much?
  - How much variation is explained?
  - What are the potential causal factors?
  - Are there any 'missing' variables?
  - How to define a process experiment?

- Improve: conducts experiments or pilot tests to find the best operational envelope for the process. It begins with a hypothesis of a set of likely causes and it ends in an improvement plan. The questions that are addressed during this step include:
  - Which factors affect performance?
  - What factors manage the variation?
  - What factors shift the average?
  - What is their operating envelope?
  - What happens outside this range?
  - How are these factors controlled?
  - How may the process be managed?
  - How does it work in the real world?

- Control: specifies all work processes to be used to implement team recommendations. It begins with a recommended improvement plan and ends with the definition of standard work. The questions that are addressed during this step include:
  - What standard work must be done?
  - Which factors must be managed?
  - What is their tolerance range?
  - How is the process maintained?
  - What training do operators need?
  - How to prevent errors in the work?
  - What action plan to implement?
  - How to extend these actions?
  - How to capture the benefits?

Often the first three steps in the LSS project management approach: Define, Measure, and Analyse (DMA) is conducted to present detailed analysis to support management decision (Watson 2016a, 20). As the objective of the project was to develop a set of recommendations based on analysis, it was decided to apply this DMA approach. The analytical mechanics of these three steps is provided in the following section.

2.4 Lean Six Sigma Analysis approach to the problem

This subchapter describes statistical and non-statistical Lean Six Sigma tools that were used for analysis of the loading and delivery processes at Company X. Figure 5 created by the author presents an overview of the DMA method including analytic objective and tools used.

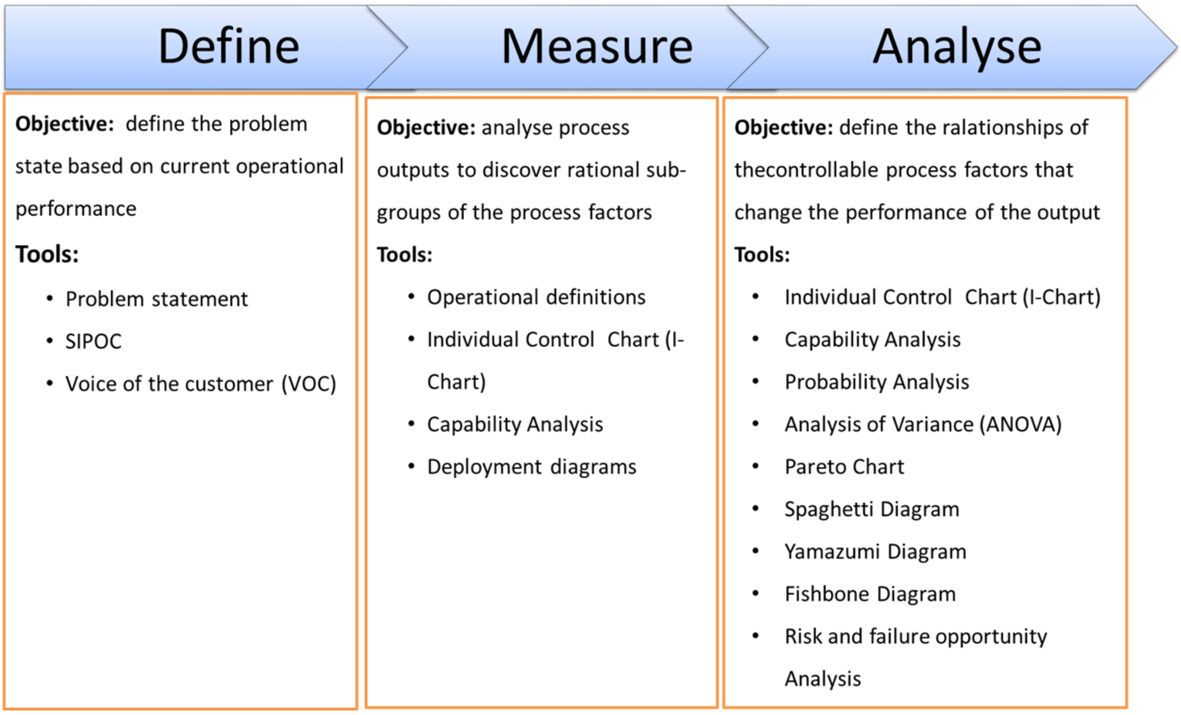

Figure 5. DMA tools used in the project

2.4.1 Causal analysis approach to performance issues

Causal analysis is the process of identifying different causes either creating or affecting a specific problem or issue and discovering the real reasons that created this condition. By studying various factors or combinations of factors that influence process performance, eventually the drivers of performance variation can be reduced to a critical few variables or even a single factor that creates the majority of undesired results. This will greatly simplify and accelerate the problem diagnostic process and reduce the time invested in data collection and analysis. (Voehl & al. 2014, 353.)

The general approach to causal analysis begins with the situation that was first noticed and then observed in more detail: this is the presenting symptom. It must be diagnosed to determine the actions that caused this outcome to exist. Many potential contributory causes may have had a role in the situation, so it is important to breakdown the probable causes into logical sub-groups that fully specify its operating functionality. (Watson 2016b, 10.)

One method to do this is the so-called Fishbone Diagram. This diagram is a form of a basic tree diagram that is used to decompose an issue into categories which could potentially influence the recorded outcome. In a classical Fishbone Diagram, originally created by Kaoru Ishikawa and called by many an Ishikawa Diagram (Watson 2016b, 14), the branches of this tree diagram have been pre-classified using the 6 M structure (e.g., Method, Measurement, Material, Machinery, Manpower, and Mother Earth). Each of these fixed-labelled branches is populated with those factors logically related to the labelled branch and considered pertinent to contribution of variation for the issue that is defined as the presenting problem.

Another tool that may be applied in the initial search to locate potential causes of problems is the Spaghetti Map. This diagram helps to visualise actual flow from the point of origin to its ultimate destination by following the pathway that it takes as it moves across the complete work environment (Voehl & al. 2014, 341). In Japanese tradition seven flows may be traced in an organization using this method: physical flow (parts or products), asset flow (inventory or investments), logical flow (information or data), human flow (competence), financial flow (revenue or expenses), conceptual flow (design flow or service flow), and authoritative flow (decision making) (Watson 2016b, 70).

2.4.2 Risk and failure opportunity analysis

The tree diagram is also used to breakdown the system of potential risks, causes, and failure opportunities that may influence a particular problem or issue. In an international standard on Risk Management, ISO31000:2009, risk was redefined as “the effect of uncertainty on objectives.” (ISO31000:2009 2009, 1). This definition includes both positive and negative consequences of a failure to meet the objectives that have been set for an organization. When risk and failure opportunity analysis is described as a tree diagram the branches represent the different distinct categories of risk, where the final branch can describe the probability of its occurrence and the severity that realization of that mode of risk would induce on the entire system. When a comprehensive tree diagram is mapped, then the final state of each branch represents either a desired state, which the organization should seek to attain or an undesired state, which the organization should seek to avoid. (Watson 2016b, 81.)

2.4.3 Exploratory data analysis

The core set of analytical methods used in DMAIC for defining the problem and focusing the investigation are referred to as an Exploratory Data Analysis (EDA). The concept of EDA was introduced as “graphical detective work” by Princeton Professor John W. Tukey

(1977, 2) as a systematic means to graphically identify rational sub-groups within processes. This identification and categorization of distinct problem components initiated the conduct of a subsequent in-depth data analyses as a means to isolate and characterize potential causes of problems. However, at the time of the introduction of this methodology there were only limited numbers of personal computers available for analysis and most of the calculations were routinely conducted manually.

At that time, manual calculations were done by engineers to understand mechanical equipment in what was called a “machine capability study.” These studies characterized the behaviour of production equipment to understand their limits of performance and to establish proper operating boundaries for running them during production. (Watson & DeYong 2010, 65.) Subsequent advances in this systematic approach were proposed by consulting engineer Dorian Shainin (Steiner 2008, 8) in his “progressive search” approach to find the “Red X” or missing factor that explains the source of variation in a process.

Mikel J. Harry proposed a sequence of “logic filters” for statistical decision making in 1981. The Motorola Six Sigma Research Institute transformed these “logical filters” to formulate the DMAIC project management approach. This approach evolved in stages over a decade and DMAIC became a settled model in 1997. (Harry & Schroeder 2000, 129.)

Management consultant and Lean Six Sigma instructor Gregory H. Watson revised and consolidated these methods for EDA by introducing a sequence of analytical methods. These methods can be used for investigation of the productivity data of any business process deliverable (e.g., product or service output) and segment this performance data into rational sub-groups of data to determine where the sources of performance variation have originated within the process (Watson 2016b, 61).

While the analytical framework of Watson’s approach to EDA was presented in Part 1 of this chapter, a more detailed description of the key analytical methods and their application is presented in the following paragraphs.

Watson refers to his application of EDA as “statistical storytelling” and cites the following set of objectives for this analysis (Watson 2016b, 65):

- uncover underlying structure in data distributions
- extract important variables from data sets
- detect patterns, outliers and anomalies in the data
- test underlying assumptions for data relationships
- develop data models that characterize results and
- determine appropriate boundary conditions for performance of the key factors.

EDA conducts a preliminary graphical analysis of the process to determine how the flow is routed in the organization and what components of the system infrastructure are engaged in supporting the flow. The methods used in this graphical visualization are a functional breakdown of the process elements using either a tree diagram or a Mind Map and a detailed process flow presented as a Value Stream Map (VSM), which indicates the time and quality performance factors across the process E2E flow. Once physical and logical flows have become understood and the rational sub-groups that comprise the process elements are identified (e.g., people, products or services, tasks or methods, equipment, locations, etc.), then the method of EDA statistical story telling can begin. (Watson 2016b, 66.) These graphical methods are used in preliminary analyses to the actual EDA and are therefore considered out of the scope of the current, selective analysis of the core statistical data.

Statistical storytelling asks the questions: "what kind of story can your data tell? How do you get it to confess to its past misdeeds and uncover the real motivation for the way that things turned out?". This approach is contrasted with what Watson has described as a "Theory O" or "Theory Opinion" approach to explaining the current state of organizational performance. Theory O is based on a subjective assessment of events and the assignment of a "personal probability" for performance expectations. It is not based on any scientifically based analysis of performance and it consists mostly of brainstorming and groupthink without reliance on any scientifically valid performance data. This contrasts with the desired outcome of conducting EDA, which is to identify the real sources of unwanted variation that are the origin of waste, loss and inefficiency in a process. In EDA statistical analyses are formulated using two approaches in an integrated manner: enumerative or analytical. (Watson 2000, 20.)

Enumerative analysis combines all of the data collected into a summary statistic, which can be used to estimate overall probability of success, compliance with customer required performance levels, and risk of non-performance within desired boundary levels. When coupled with three basic logical rules about desired performance of a measurement, an enumerative approach can provide an estimate of the long-term stability of a process. The three rules are (Watson 2016b, 71):

- bigger is better (e.g., higher values of the metric represent the desired state of the performance – revenue, productivity, profitability, and line-item fill rate all have this same desired outcome)
- smaller is better (e.g., lower values of the metric represent the desired state of the performance – cost, cycle time, defects, waste, and returned packages all possess this same desired outcome)
- nominal is best (e.g., desired performance occurs when the metric is stabilized at the average of its performance – on-time delivery follows this performance rule).

On the other hand, an analytic analysis evaluates the performance data as it occurs in a time series and can be used to identify recurring patterns in the data, which are related to actual operational events in process activities and therefore can expose the causal structure of the process performance. Statistical Storytelling blends these two approaches to provide a comprehensive understanding of performance data. (Watson 2016b, 72.) A comprehensive inquiry into the sources and nature of variation may be conducted using both of these perspectives as this creates two distinct opportunities for learning about process performance.

EDA employs six analytical methods for conducting this type of blended statistical storytelling inquiry: I-Chart, Capability Study, Probability Plot, Pareto Chart, ANOVA, and the Yamazumi Diagram. These methods are described in the following sub-section where their contribution to discovery of process performance drivers is identified.

An I-Chart plot (Figure 6) provides an analytic perspective of the time series history for a performance measure in its sequential order of occurrence. Two additional analyses are performed on the plotted data: (1) pattern recognition testing identifies patterns that occur across the time series such as: excessive variation, trends, shifts and oscillations; and (2) the boundary conditions for probability of performance (a statistical confidence band that is roughly equivalent to a 95% confidence interval) around the historical central tendency (the mean of the enumerative sum of the observations). Another modified use of the chart is to separate the time series into intervals, which are representative of homogeneous conditions (e.g., data coming from a single shift or using material from a single source) so that changes in performance can be tracked to changes in that factor (e.g., change in performance by shift or by supplier). This results in the production of a series of stages where within each stage; the results are expected to be more homogenous than between the stages. (Watson 2016b, 68; Brook 2014, 247.)

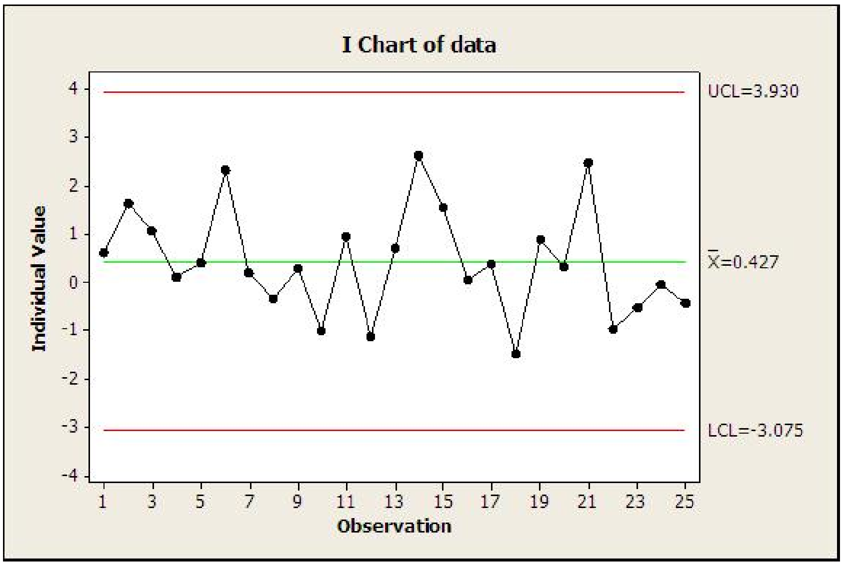

Figure 6. Example of I-Chart (Smart Solutions 2017)

A Probability Plot converts the data observations into a distribution, illustrating the probability of occurrence of the numerical values observed. The shape of the distribution indicates the behaviour of the data that can be expected over time (e.g., uniform distribution, bell-shaped distribution, or a distribution with long-tails). This plot indicates the likelihood of the occurrence of a specific value of the performance indicator based upon the historical observations. It can also be used to compare performance among various operating models or conditions to determine if they have the same likelihood function. (Watson 2016a, 134; Brook 2014, 125.) An example of the probability plot is provided in Figure 7.

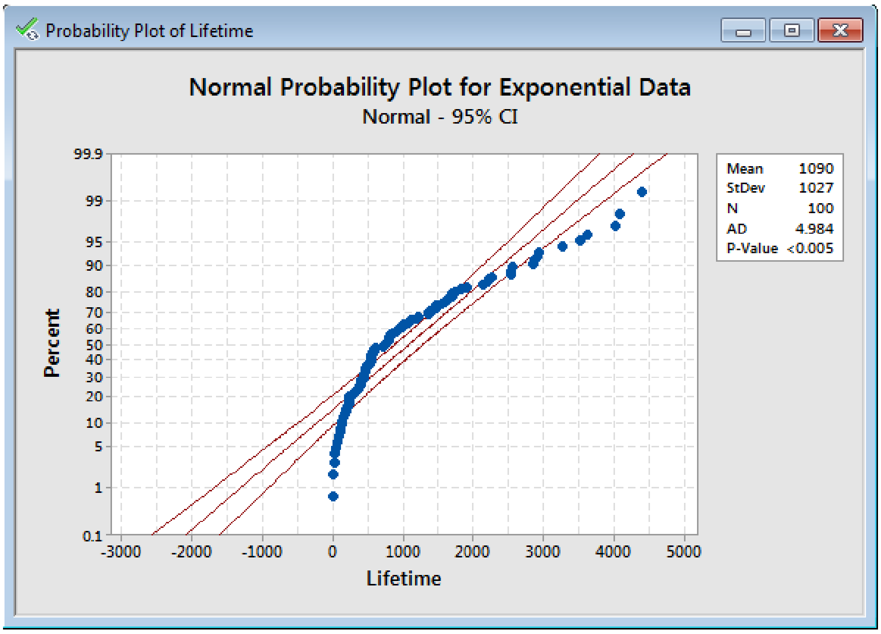

Figure 7. Example of probability plot (ENGI 2010)

A Capability Study (Figure 8) provides an enumerative analysis of the sum of all performance, observations as compared to the upper and lower boundaries of the customer requirement for performance. Statistics are calculated to describe the actual observed performance based on the total distribution function for all of the data observations as well as the ideal performance when comparing only the distribution of the shifts in performance between sequential observations. The ideal performance ratio is called a “Cp” process capability index. The actual or observed performance ratio is called a “Cpk” process capability index, which has been biased according the relationship of the data distribution and the mean data, as compared to the desired customer limits. On the other hand, the Cp index is not related to the mean and provides a theoretical interpretation of the potential level of process performance. (Watson 2016a, 153; Brook 2014, 84.)

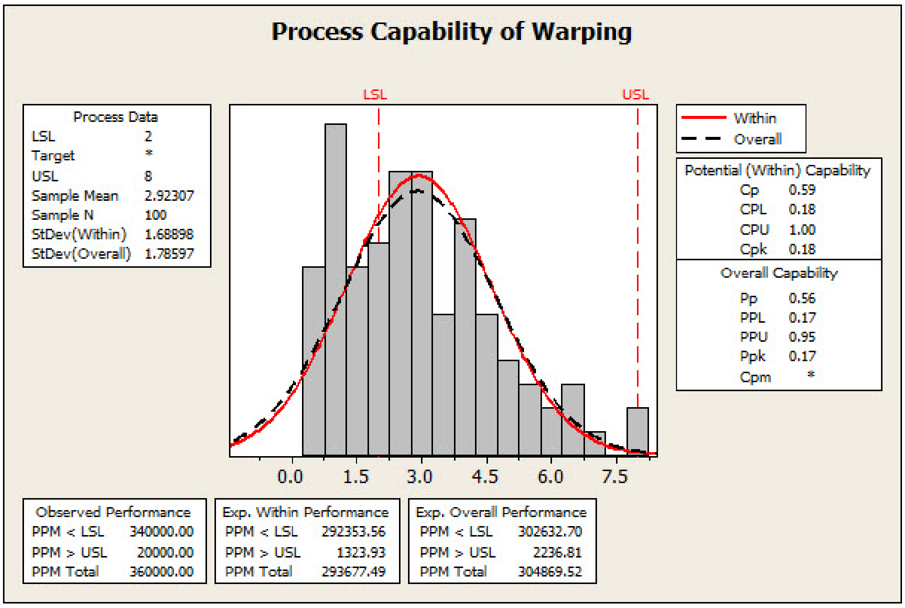

Figure 8. Example of capability study chart (Martz 18 November 2011)

A Pareto Chart (Figure 9) shows the relative frequency of occurrence for the observation of different rational sub-groups of data (e.g., amount of failures that are observed for various failure mechanisms). The chart often has a cumulative distribution across the bar charts of the frequency distribution, that indicates the observation for 100% of the data (mathematically this cumulative frequency curve is called an ogive). (Watson 2016b, 93; Brook 2014, 132.)

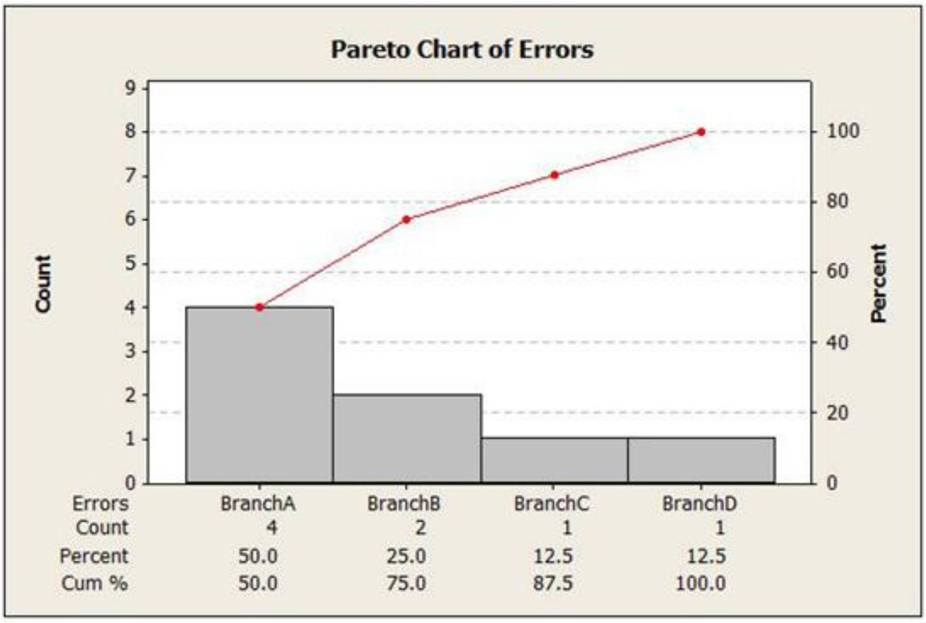

Figure 9. Example of Pareto chart (Minitab 2017)

An ANOVA (Figure 10, page 21) can be used to combine the enumerative and analytic methods by illustrating the distribution function for performance of a common indicator (i.e., cycle time) as a unit flows through a sequence of ordered operations (i.e., the steps in a process) and illustrate the summary of performance values for each of the steps as a box plot (a graph which depicts the quartiles of performance for the distribution of data within the process sub-group). ANOVA illustrates where a process has bottlenecks or exceptional unusual performance compared to the E2E flow of the process across the data. (Watson 2016c, 62; Brook 2014, 165.)

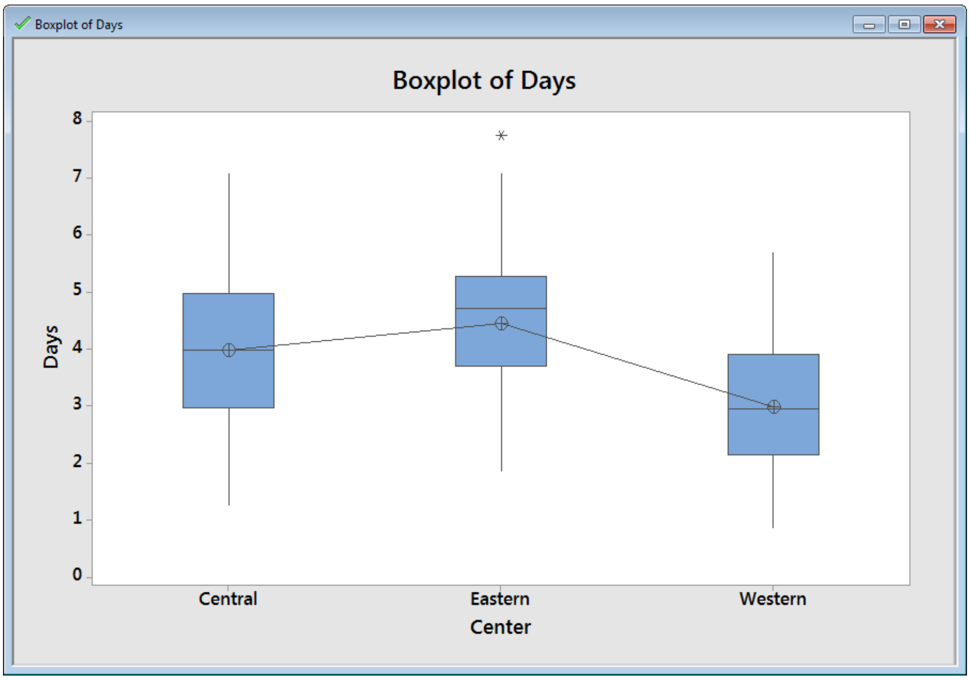

Figure 10. Example of ANOVA chart (Minitab 2017)

A Yamazumi Diagram (Figure 11) is a stacked bar chart where each of the bars represents a Pareto Chart of the relative frequency of occurrence of value-adding time, non-value-adding time and required time that occur within each of the particular sub-process steps. (Watson 2016c, 39.)

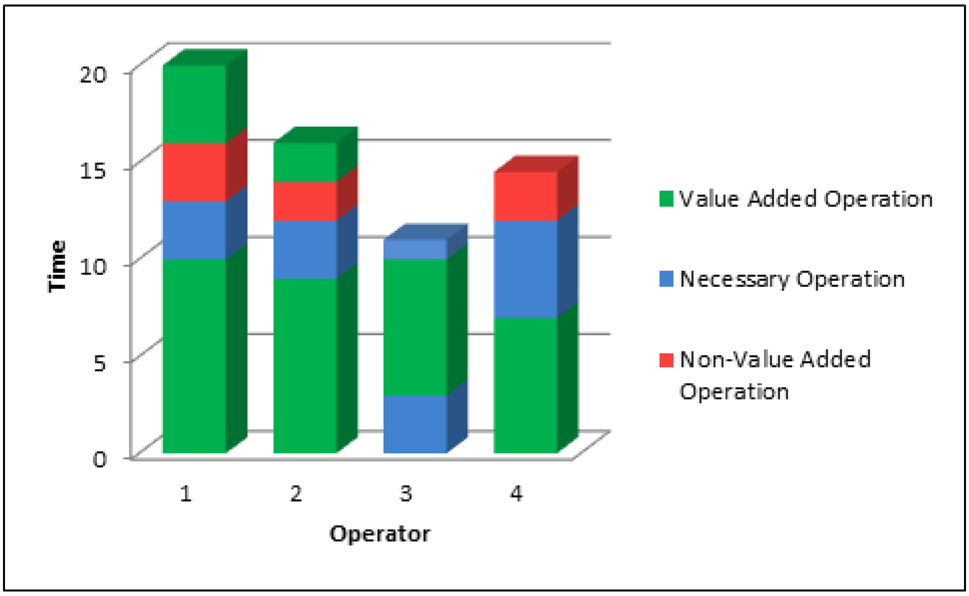

Figure 11. Example of Yamazumi diagram (Lean Manufacturing pdf 2017)

All concepts described in this chapter guided the project research by describing the context of the study (TPL), determining things to be measured (package delivery and loading processes) and methodology applied for analysis of process variables (Lean Six Sigma DMAIC and EDA). Chapter 3 of this thesis covers research approach and data collection process for the project research. Chapter 4 and Chapter 5 analyse the loading efficiency at Terminal Y and the return rate of packages that have not been distributed on the first delivery attempt.

3 Plan of the project research

This chapter describes the research approach and data collection process that were used to conduct analysis of shipment return rate and package loading.

3.1 Project design

As mentioned in chapter one the objective of this project was to identify opportunities for improvement of package distribution performance in Company X. It was a study that investigated various factors that affect shipment last-mile delivery to the customer, particularly the van loading process. The author used a combined qualitative-quantitative approach for process work analysis. The study investigated operational data captured by the company's information systems in combination with qualitative analysis of worker observations and descriptions of their daily activities, to formulate constructive improvement recommendations for Company X management. The research findings are described in chapters 4 and 5 of this thesis. The research question was:

"What can be done to improve the flow of packages in the distribution system of Company X to reduce its rate of returned packages?"

This project applied appropriate LSS methodologies to investigate the research question and discover the drivers of the performance inefficiencies and loss of effectiveness. LSS defines its own project management methodology for conducting this type of analysis. Specifically, this project used the first three steps of this methodology (Define, Measure and Analyse) to formulate recommendations for improvement to the case company's management.

The project was implemented between October 25, 2016 and February 25, 2017 as part of Lean Six Sigma Black Belt studies of the author at Laatukeskus Excellence Finland Oy. As a requirement for this course the author was a project manager at the case company with the following team members:

- Terminal manager
- Quality manager
- Data analyst
- Operations supervisor
- Dispatchers
- Customer service specialist.

The supervisor for the project from Company X was vice present of operations and Gregory H. Watson supervised the technical analytics as a Lean Six Sigma instructor. The project report was submitted to the case company as a Power Point presentation including all calculations, graphts, diagrams and tables. The next sub-chapter define project design and research methods used for data collection.

3.2 Project research methods

Figure 12 presents the research methodology used for conducting this analysis based on the initial steps of the LSS DMAIC process which combines qualitative and quantitative techniques to address process performance issues.

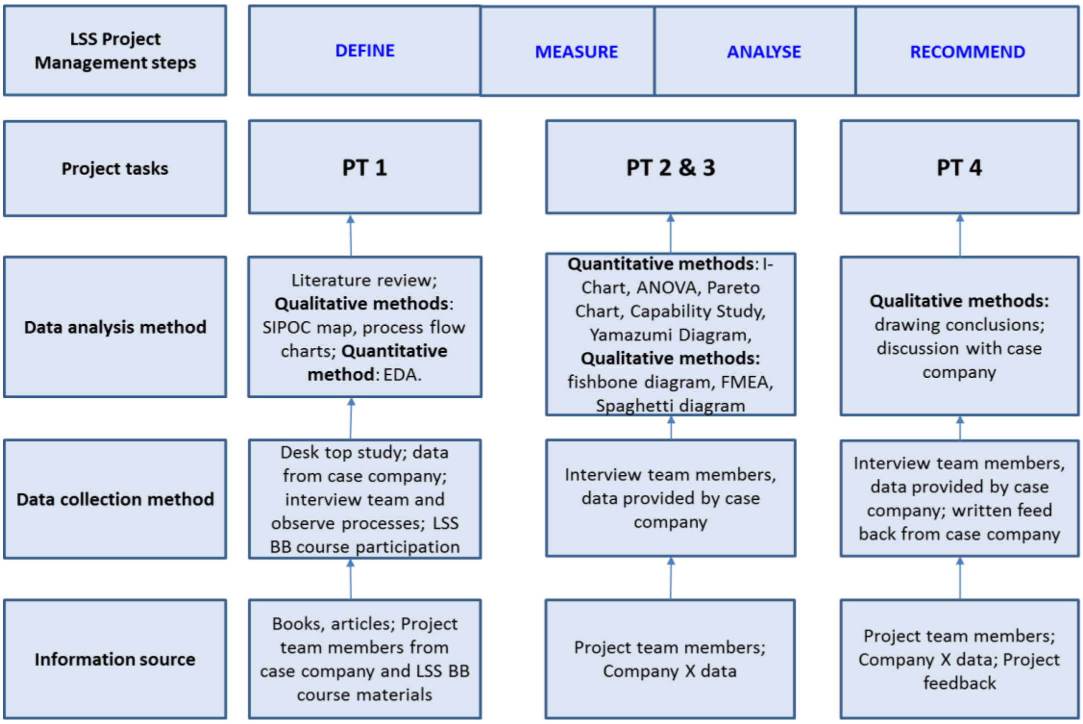

Figure 12. Project research matrix

A desktop study was completed to prepare a theoretical framework for the project. The literature review on the topics of TPL, logistics processes, distribution, Lean Six Sigma methodology and its tools helped to frame this project and to understand the main concepts involved in the research. In addition to books and articles available on the topic the author used materials provided at Lean Six Sigma Black Belt course.

Since the qualitative research aims to understand the phenomena within a specific context (Ghauri and Gronhaug 2005, 202), the author applied this method to get a broad understanding of the distribution processes and end-to-end package flow as she had not had previous experience in this area of logistics. Qualitative data was collected by process observations at Terminal Y and semi-structered interviews with project team members and other workers of Company X.

Observations as a type of data collection method help to obtain first-hand information in a natural setting (Ghauri and Gronhaug 2005, 120). Observing actual processes of package handling and van loading at Terminal Y was crucial for this project as the author could understand the situation more accurately and capture the dynamics of the process. The author made non-participant observations. According to Ghauri and Gronhaug (2005, 121) non-participant observations imply that the observer is not part of the situation when observing a natural setting.

A semi-structured type of interview was chosen for several reasons. Firstly, this interview type is suitable for determined topics and respondents (Ghauri and Gronhaug 2005, 132), which was the case in the project: respondents were project team members and the topic was the project objective. Secondly, sub-questions in these type of interviews are not predetermined (Ghauri and Gronhaug 2005, 133), which gave the author the freedom to modify questions if new or unknown information was revealed by respondents. All the interviews weere completed during project review sessions, one in every two weeks or by scheduled appointment with the author. These methods helped the author to collect necessary information to get insight on the distribution processes, its participants and potential causes of the problem.

The author also organied two workshops with project team members to develop the Fishbone diagram and Voice of the Customer Tree Diagram (VOC). These workshops were conducted in the form of a facilitated brainstorming session with the author as a facilitator.

All quantitative data such as throughput volumes, delivery and return volumes, return reasons, delivery and loading time was provided by the case company. It was decided to use four months data (September-December 2016) for analysis, as this sample size was sufficient to uncover the inherent patterns in the process data at the daily level (Watson 2016c, 102). All information about each package is encoded into a bar code label and these labels are scanned as a package transitions across Terminal Y work process as well as by the truck drivers who make deliveries. This information is captured in a central data system of Company X which is maintained by the IT group and monitored for performance by the Quality Management Team. The software used to capture data in Company X is called X-celerate.

Minitab 14 was used for statistical analysis. This software was provided as a part of the training material for the LSS Black Belt course. To visualise data analysis results, various graphs and diagrams were used: I-Charts, Box Plots, Bar charts, Pareto chart. The deployment diagram and SIPOC map were utilised to illustrate processes flows at teminal Y.

All information given by the case company, team members as well as information collected by the author herself at the terminal cannot be revealed in this Thesis by request of the company due to confidentiality reasons. Hence, no references to company employees were made in the thesis, all numbers on graphs were modified.

3.3 Reliability and validity of the project research

Reliability of a research implies that if the study is done again, the same findings would be obtained (Matthew & Ross 2010, 479). Since the project team consisted of Company X workers who have great experience in the area and have actual involvement in the processes at Terminal Y, the information provided by them is considered to be reliabile to draw clear conclusions about the process. Process data analysed during the project was provided by Company X and verified by the quality specialist involved in the project, which guaranteed the accuracy of the findings. The project was guided by the vice president on operations with regular project reviews, where project work, tools applied and findings were reviewed.

Validity refers to the credibility of a research, meaning that the data analysed represents this aspect of the reality being studied (Matthew & Ross 2010, 480). During the project, validity of findings and process descriptions were checked by workers of Company X. When the project was completed Company X utilised all process diagrams in daily work as a standard document for operations. As for the data provided by the case company for analysis of the shipment return rate and loading density analysis, the author identified some issues related to it. If delivery scan or non-delivery scan was missing, the judgement on package delivery completion was impossible. This problem could be caused by several reasons. Firstly, the driver forgot to scan the label on the package at the moment of delivery or loading, meaning that no information was recorded in the system at that time. Secondly, technical issue with the scanner could also affect the data collection in the system. If the scan was missing from the system record on the package, we did not know what happened to this package at that point in time. This creates a problem with data validity by increasing the variablity in the observations; however, on average the results remain representative of overall performance. For this reason, four months data was used for analysis to identify sources of common cause variation and hence to ensure credibility of findings. In general, validity of data analysis was reasonable as the results were assessed against well-documented time stamps on each package in Company X's system and the physical delivery of an actual package to the customer.

The next two chapters describe the analysis conducted during the project and the research findings.

4 Analysing shipment return rate at Terminal Y

This chapter defines the delivery process in terms of performance measures, potential causes of “defects” which created shipment returns instead of shipment deliveries with the related data analysis. The LSS tools described in Chapter 2 were used to analyse the data.

4.1 Process measures and operational definitions

Process improvement requires measurements that reflect its performance. Key Performance Indicators (KPIs) are system-wide parameters used to measure a process and set performance standards and improvement goals (Voehl & al. 2014, 518). KPIs characterize process results so that the success or failure may be judged by the company and serve as a starting point for more detailed diagnostics of the causal system to identify failure mechanisms for performance issues.

In the parcel delivery process the main KPIs are “delivery on time” or “delivery to promise”. These KPIs monitor the capability of the company to deliver packages according to the targeted schedule agreed with the receiving customer. Any deviation from a scheduled delivery should be considered a process failure and be reflected in these KPIs.

Figure 13 created by the author summarizes Company X’s definitions of “On time delivery” and “Late delivery”.

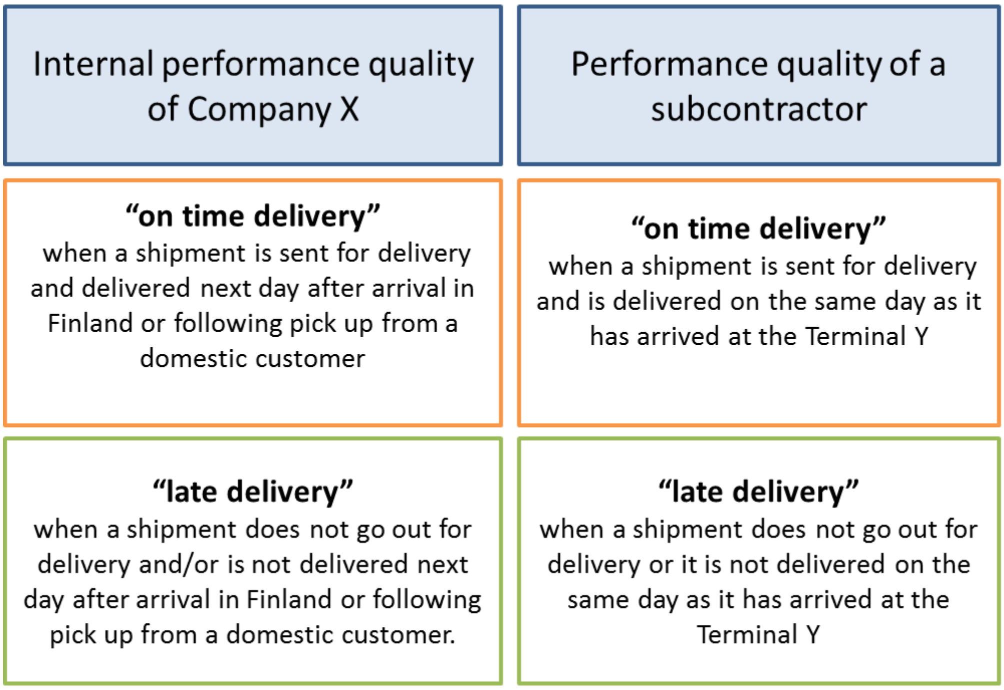

Figure 13. Definitions of “on time” and “late” deliveries according to Company X

Internal performance quality of the case company was measured in hours as the time elapsed between “HUB” or ”Pick up” scan and “Delivered”/ ”Not delivered” scan. At the same time the quality of subcontractor performance was also measured in hours, but as the time difference between “Inbound” scan and “Delivered”/”Not delivered” scan. Figure 14 describes these measures graphically.

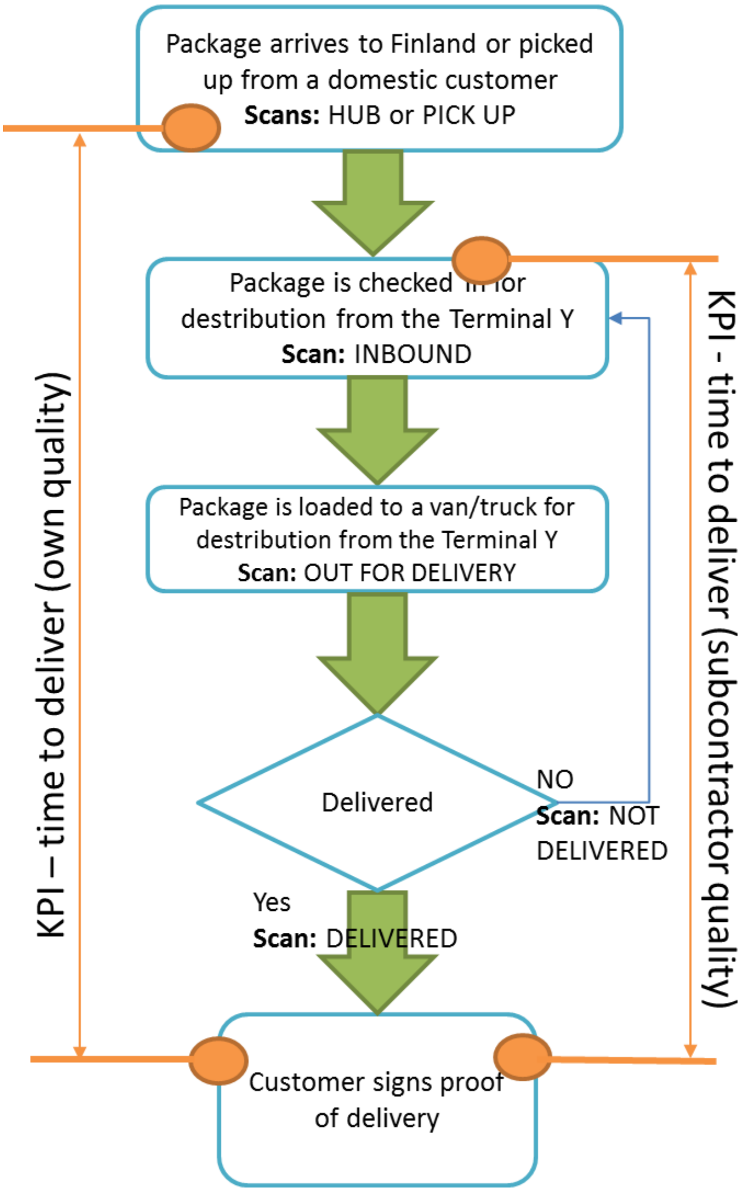

Figure 14. Company X’s KPIs for delivery

Further investigation of operational definitions revealed that Company X considered “delivery attempt” to be a delivery, which meant that it was counted as “on time delivery” even packages that were not delivered. Basically, failure of the process or “late delivery” occurred only if a package did not go for delivery next day (own quality) or same day (subcontractor quality).

In the author’s opinion this definition of “on time delivery” did not reflect critical to quality specifications for delivery from the customer perspective, as it only measured “attempt to deliver", but not actual delivery first time as promised to the customer. To clarify customers' expectations and requirements for the delivery process, a critical to quality (CTQ) tree was developed by the project team. This tool has been described in Chapter 2, method of data collection has been clarified in Chapter 3. From CTQ tree (Figure 15) it was clear that to the customers, packages delivered on the agreed day, at the scheduled time, and in a good shape were the three most crucial ingredients of quality for package delivery.

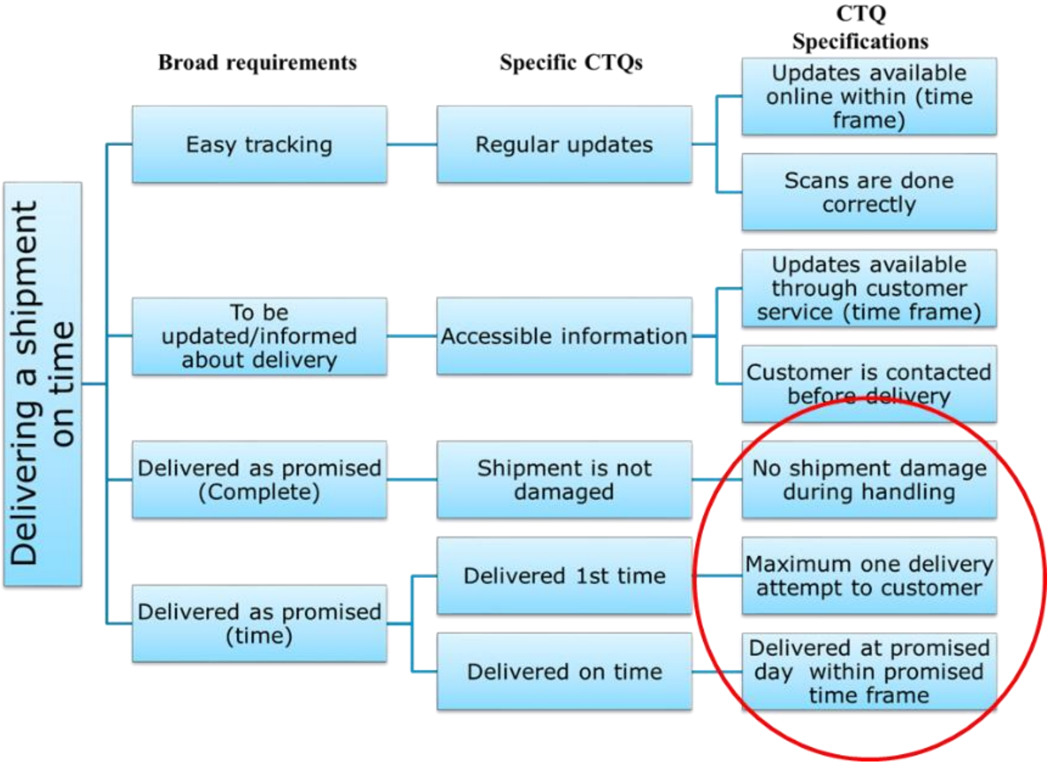

Figure 15. Critical to quality tree

It was found that current delivery KPI's used by the case company did not reflect the actual performance of the process. This made it unsuitable for analysis of delivery performance, which aimed to identify the percentage of successful first-time deliveries (an indicator of good performance) and the percentage of failed deliveries, which equates shipments returned to Terminal Y (an indicator of bad performance). The author selected another measure for the process which is presented in Figure 16, page 30.

According to Figure 16 the "Delivered first time" measure represents the percentage of packages that were delivered on the first attempt. The "package return" measure represents the percentage of packages that were not delivered the first time, regardless of the reason and it was calculated as the number of packages returned, divided by the total volume that went out for delivery on that particular route.

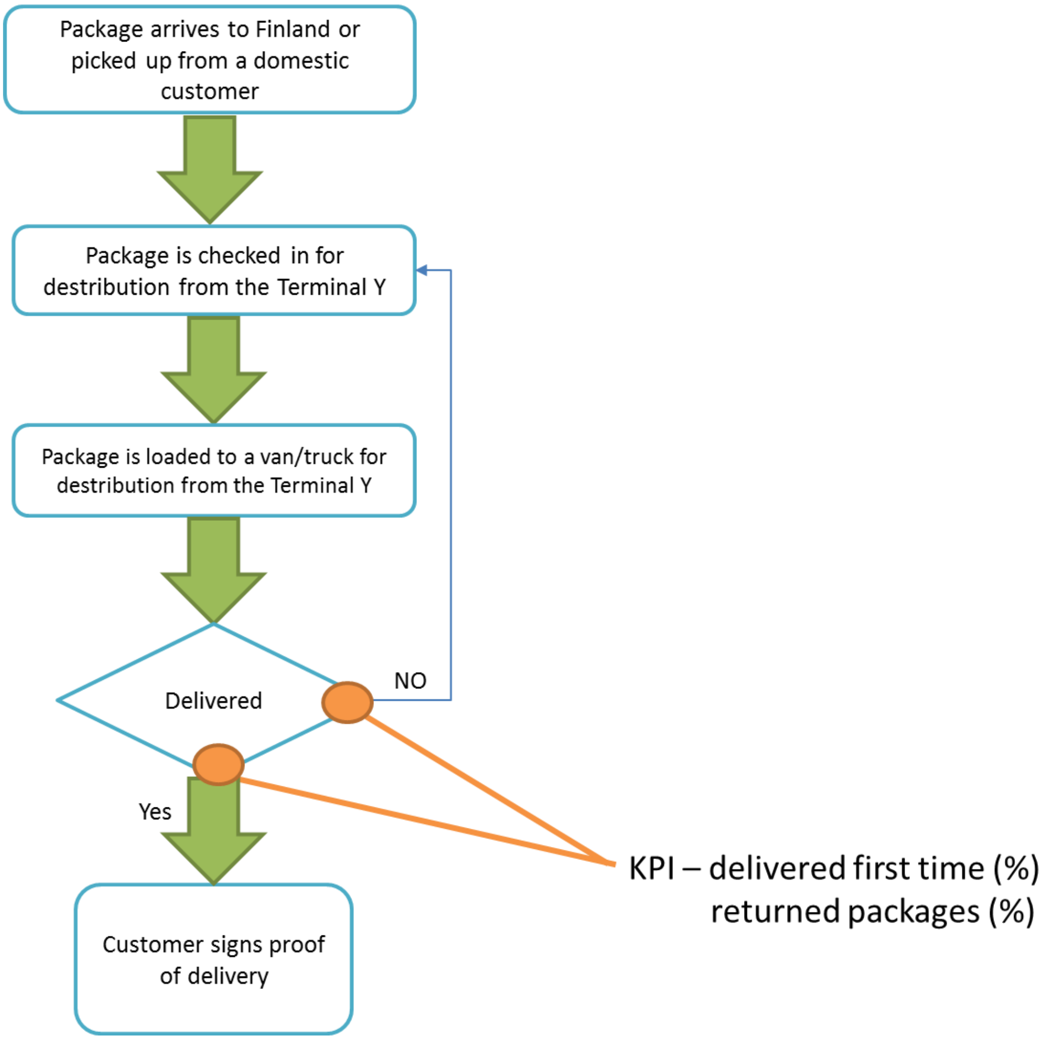

Figure 16. KPI for delivery process performance analysis (during the project)

The next step for the project was to look at the data to understand the baseline performance for delivery, and how many packages were returned to the terminal (%) for a four months period (September-December 2016).

4.2 Delivery performance baseline analysis

To understand the nature of the behaviour of delivery performance, an EDA was performed on the historical data that was provided by the case company to establish a performance baseline. This data covered shipments to all distribution routes within the Helsinki metropolitan area as described in the study scope. This data was collected during the four months period from September to December 2016.

The I-chart (Figure 17) provides insight into the historical behaviour for delivery process variation over this period as compared to the overall performance in the same period. During this period a daily average of 11% of shipments were not delivered to customers but were returned to Terminal Y. There was a lot of variability in the process and predictable return rate ranges up to 33% daily. This process was not stable and the red dots on the I-chart in Figure 17 demonstrate unpredictable or special cause variation in return rates. The blue box in Figure 17 indicates the region of process control under this predictable return rate, while the red box indicates performance variation that is random and unpredictable.

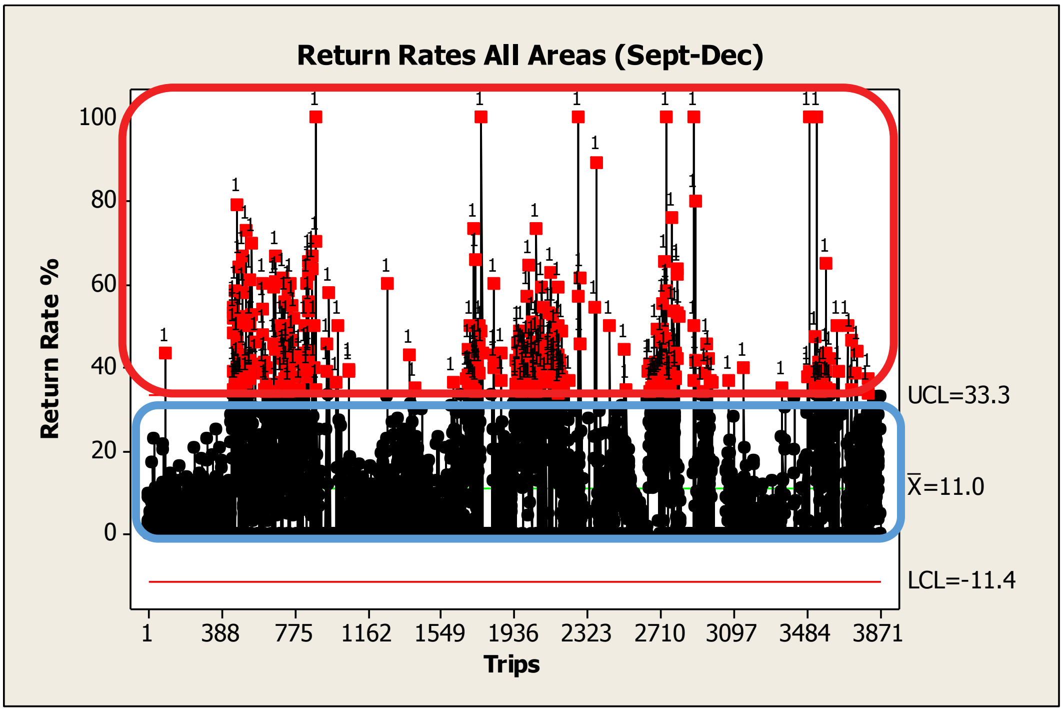

Figure 17. I-Chart for return rate September-December (Minitab 14)

The second component of EDA is the capability analysis. The case company had set the targeted range of shipment return from zero to six per cent of total shipments. Next step was to conduct process capability analysis with desired specifications. Figure 18 on page 32 shows the results of the process capability study: the process was potentially capable of performing within the desired range of return rate less than 6%, as indicated by the data in the blue histogram; however, the actual performance was not very predictable and was far from the target as shown by the red histograms. The Cp indicator of 0,13 defines a process that is able to meet the specification less than 30% of the time by design. The negative Cpk metric describes a process whose performance is outside the specification limits and incapable.

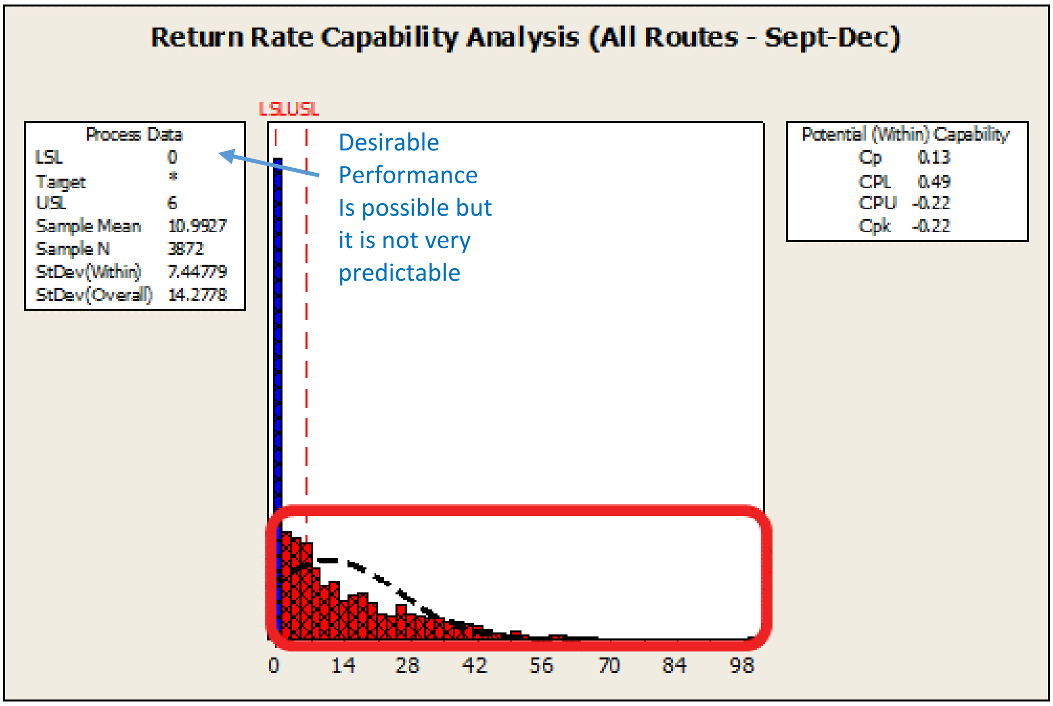

Figure 18. Capability chart for return rate September-December (Minitab 14)

A third component of EDA is the ANOVA (Figures 19 and 20). Figure 19 depicts the four major delivery areas within the Helsinki Metropolitan region. Using these four rational sub-groups that are established by natural geography, the consistency of the delivery problem across the entire region can be observed. The Espoo area is coloured red as it was the focus for subsequent analysis.

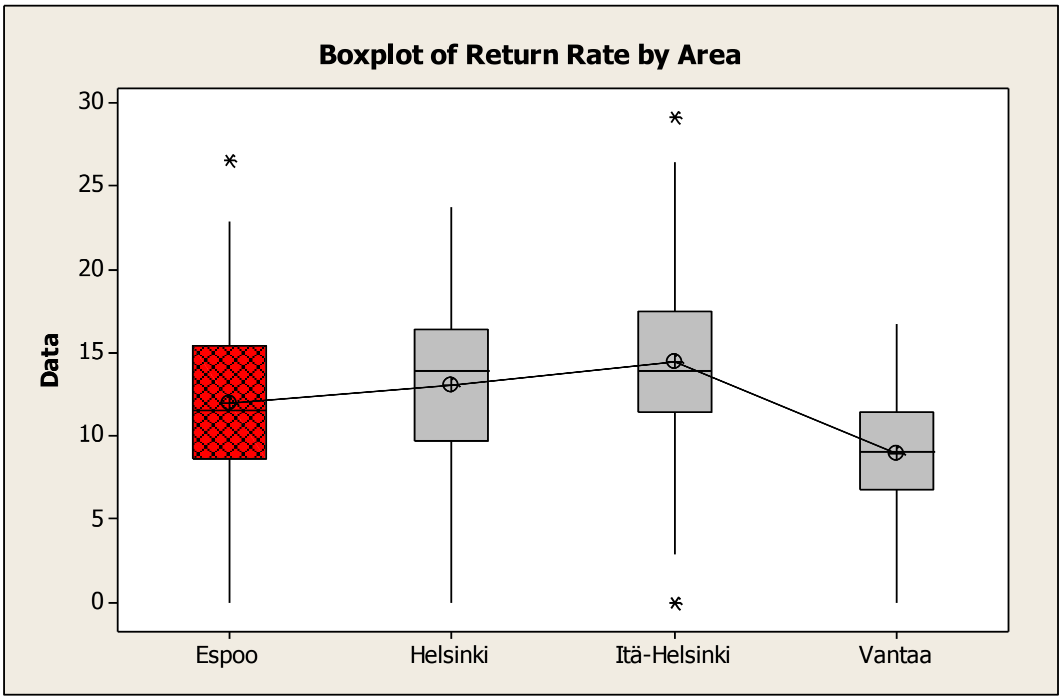

Figure 19. ANOVA by delivery area (Minitab 14)

In Figure 20 (page 33) the total delivery performance for all routes across the four months period is illustrated as a box plot. When observing the summary performance by route for return rate it is evident that there were many routes where return rate was excessive (included within the red box). This graph was used to identify the problematic routes (worst case) and also to focus the next phase of the study on specific routes that require urgent improvement.

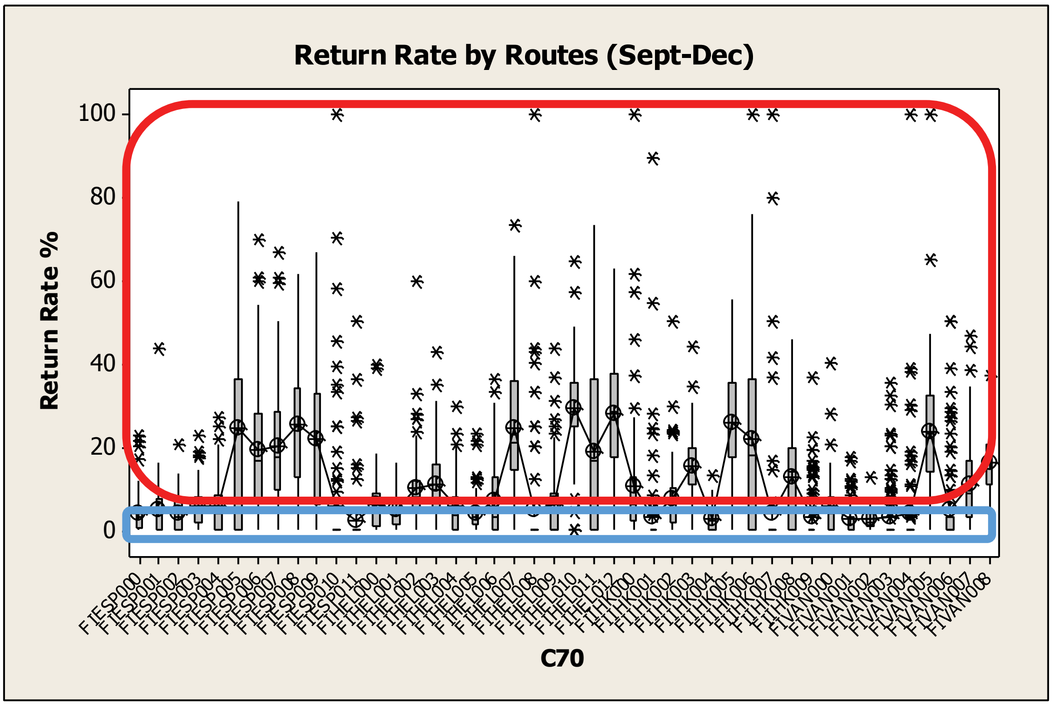

Figure 20. ANOVA of return rate by delivery route (Minitab 14)

From this preliminary EDA we verified the magnitude of the problem and its scope across the distribution areas of interest. The next step was to gain an understanding of the reason for the shipment returns.

4.3 Breakdown of potential reasons for shipment returns

The first step in understanding reasons for poor performance was to categorise all possible logical combinations (rational subgroups) that exsisted within the scope of the problem. The Ishikawa diagram (Figure 21, page 34) was used to decribe these relationships. This diagram was built during a workshop organised by the author with participation of all project team members and the project champion.

In this diagram the six major categories were broken down into sub categories of reasons for risk of non-delivery performance and thus creating shipment returns. Each of these sub-categories were identified with the ability of Company X to control the variable. When variable was labelled with “C” (standing for control) there was some internal mechanism within Company X to control the factor. When the variable was labelled with “N” (standing for noise) Company X had not yet determined how it could be controlled. The strategy for improvement should be to constrain all noise factors so they do not reduce performance and to manage the way the controllable variables operate. It was clear that there were many factors that could affect delivery success. Delayed departures of drives from the Terminal Y were chosen by management as the initial area for focus and further analysis (see Chapter 4).

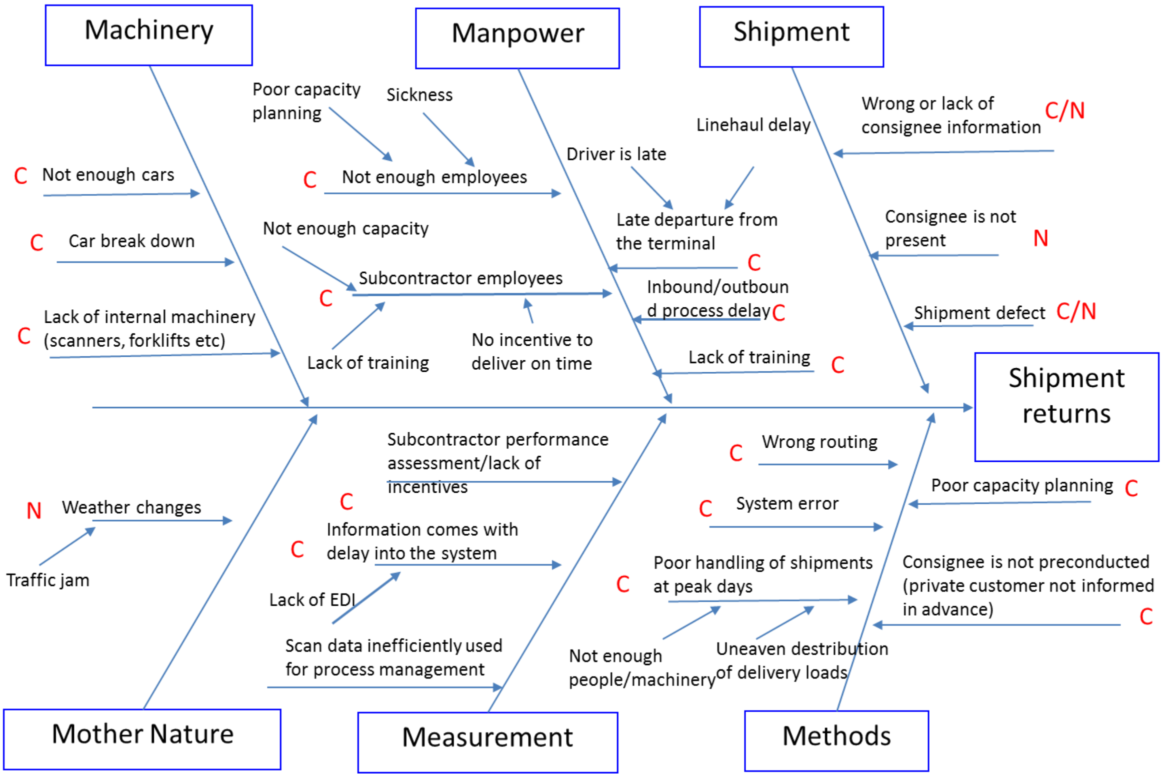

Figure 21. Ishikawa diagram of logical components contributing to shipment returns

When rational subgroups were identified using the Fishbone analysis, the next step was to determine the categories of risk that each of these potential failure opportunities could inflict on the delivery process. A failure opportunity analysis can highlight the risks that are inherent in a process.

4.4 Failure opportunity analysis – what can go wrong and why?

The process of shipment delivery has many opportunities for failure that create a series of risks for creating a high rate of returned packages. Appendix 2 presents the tabular data for the risk and failure opportunity analysis. Based upon this assessment, the most critical failure mechanisms that should have been anticipated in the problem of returned packages from shipments were:

- wrong shipment data (e.g., address, telephone number, etc.)
- package stored in wrong location within terminal
- late departure of delivery van from the terminal
- package assigned to the wrong route
- human process error (e.g., dispatcher mistake, driver mistake, etc.)
- traffic conditions (e.g., due weather or congestion, etc.)

- truck breakdown
- package recipient not present to receive the package
- door code for building access not provided
- lack of time for driver to make delivery.

These potential failure mechanisms were used to identify rational subgroups within the data for analysis using EDA methods. Reason codes for missed delivery were related to these potential failure mechanisms.

4.5 EDA of shipment returns

In order to understand which of the potential failure mechanisms were active in the baseline returned package data it was necessary to investigate the data in more detail. The next step taken was to conduct an EDA on the shipment return statistics for a selected rational sub-group to understand the causal conditions which are prevalent in the process. In Figure 22 an I-Chart of the return rate for Espoo shows a history of exceptionally high return rate (typically well above the 6% target). This overall performance for the Espoo routes combined the B2B and B2C deliveries. When this data was separated into two data sets, then a different observation was made (Figure 23 & Figure 24, page 35).

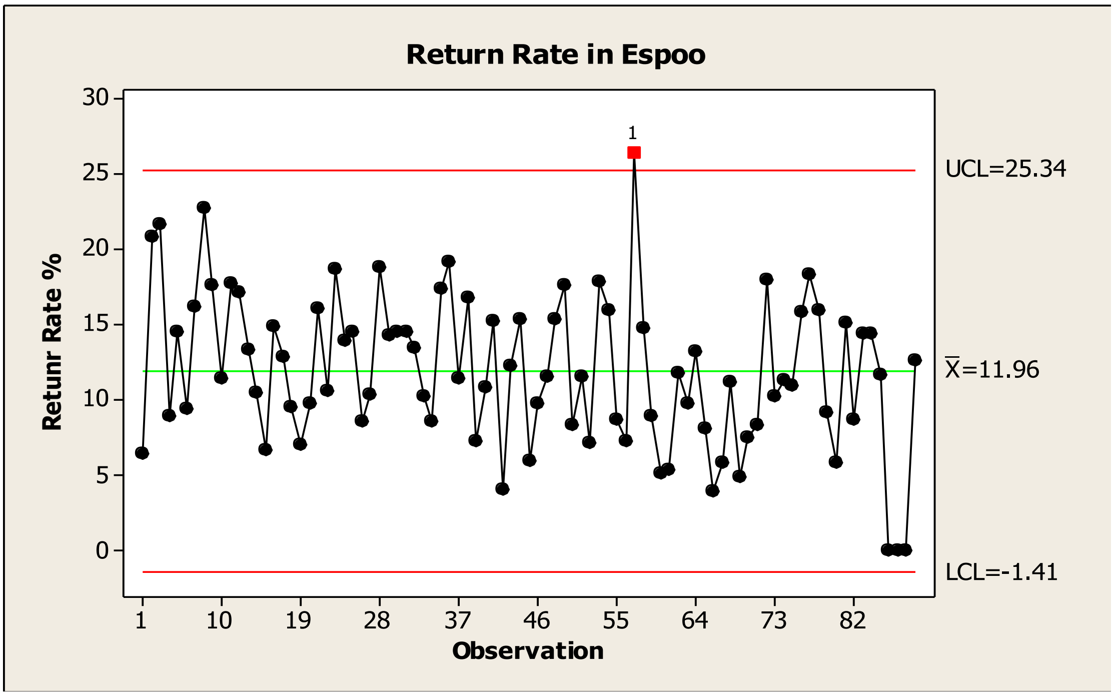

Figure 22. I-Chart of combined B2B and B2C package return rate in Espoo area during September-December (Minitab 14)

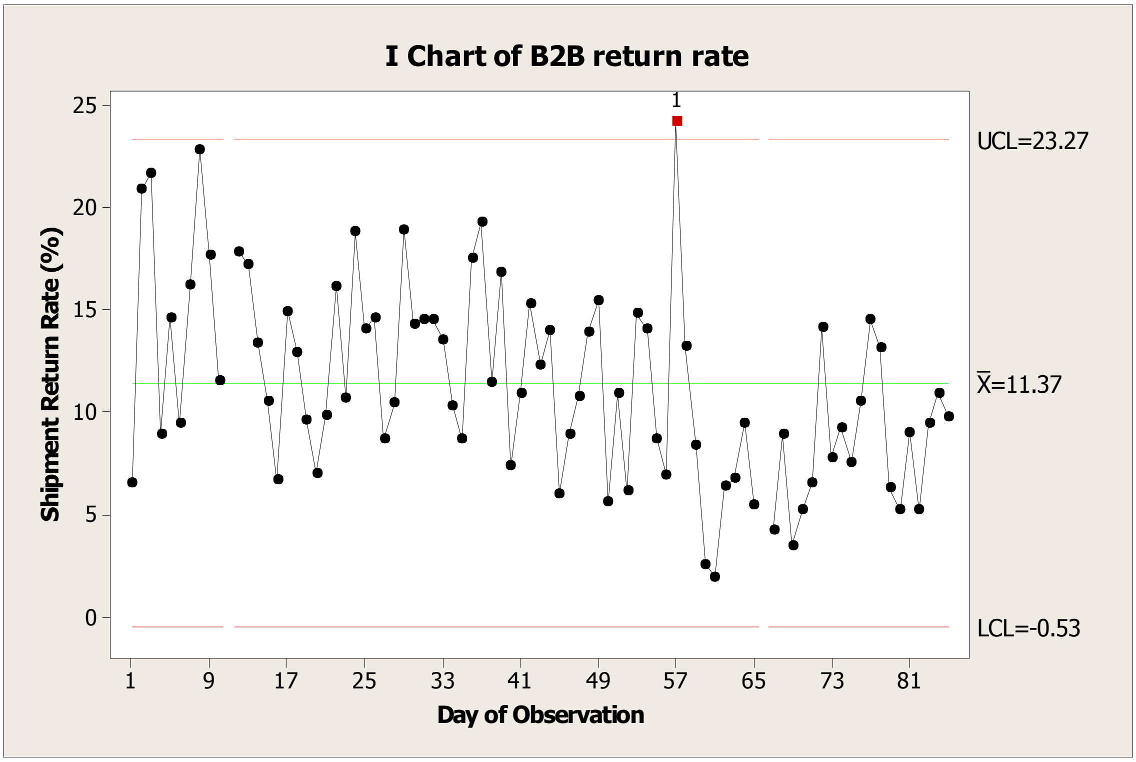

Figure 23. I-Chart of the B2B return rate in Espoo area during September-December (Minitab 14)

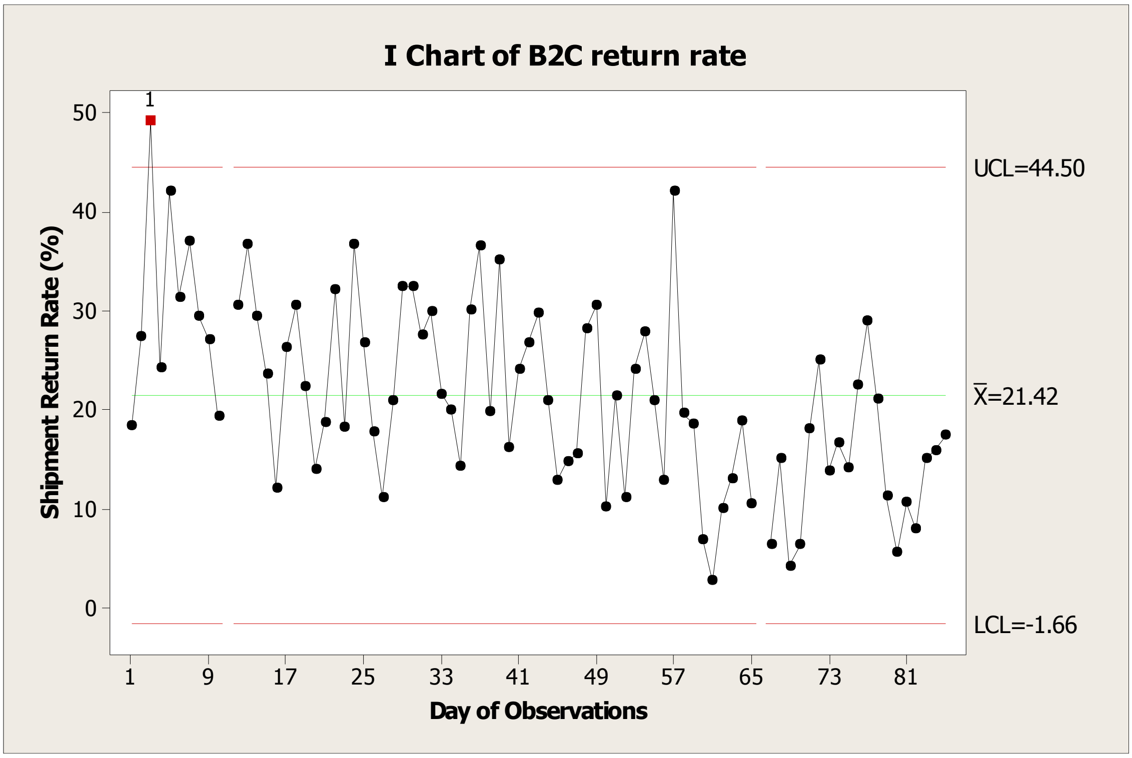

Figure 24. I-Chart of the B2C return rate in Espoo area during September-December (Minitab 14)

The combined performance of B2B and B2C packages hid the overall effect of failure to deliver the B2C packages on time as the majority of the packages delivered occur in the B2B service which has a superior, although also unacceptable, level of service. The level of service for B2B and B2C in the Espoo area for this period of time was compared in Figure 25 (page 37).

The B2C average return rate was higher than the upper control limit of the combined rate of return for B2B and B2C which was evident in Figure 24, but was hidden in Figure 22. This occurred because the volume of package shipments was lower for B2C (as evident from the gap in shipped packages between these services shown in Figure 23) so the influence of the poorer performance was dampened by the better performance for the B2B deliveries.

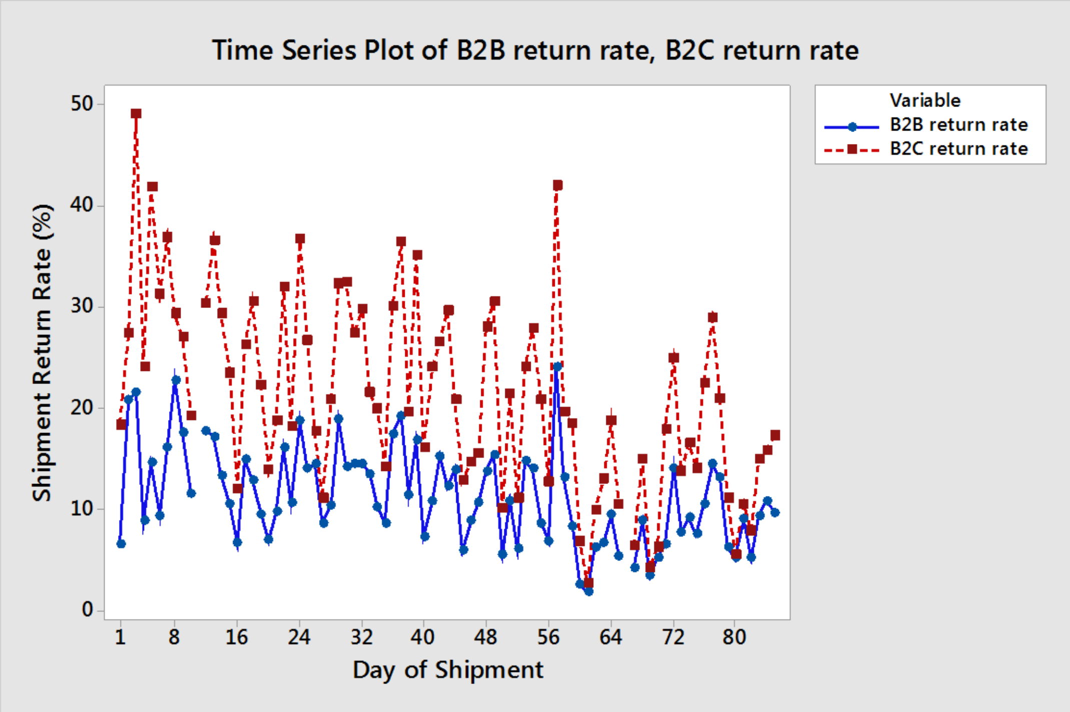

Figure 25. Trend chart of B2B and B2C returns for the Espoo area during September-December (Minitab 17)

From these tables it was clear that the most issues with delivery quality came from the B2C service as the performance was significantly worse than for the B2B service.

The disparity between these two delivery methods in terms of return rate performance is clearer in Figure 26 (page 38) where the return rate was presented as a probability plot and it was clear that the B2C packages have a much higher probability of return than the B2B packages.

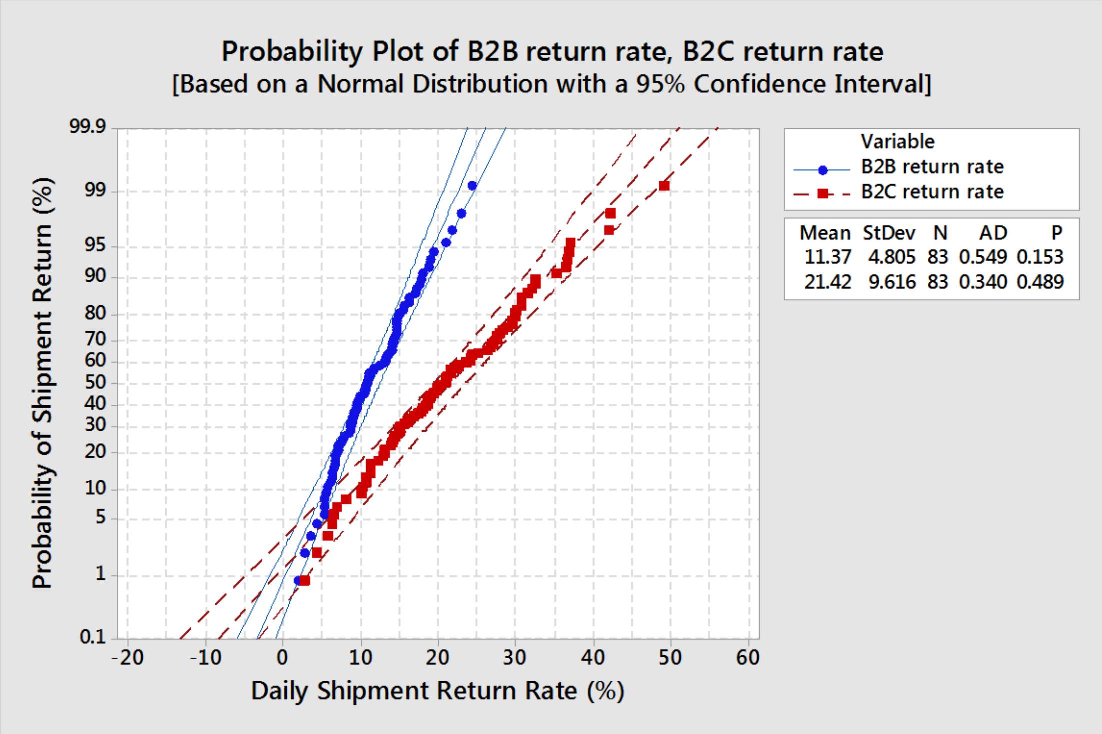

Figure 26. Comparative performance of B2B and B2C depicted as a probability plot for the Espoo area during September-December (Minitab 17)

Capability analysis of the B2B and B2C service methods demonstrated that there was a very different capability when the data was divided into the two rational subgroups, further reinforcing this observation. When the data was divided into these two subgroups of B2B and B2C deliveries then it was clear that the B2C process had approximately twice the variation as the B2B process. Figure 27 (page 39) illustrates the capability analysis of the B2C shipment process while Figure 28 (page 39) demonstrates the superior B2B shipment capability.

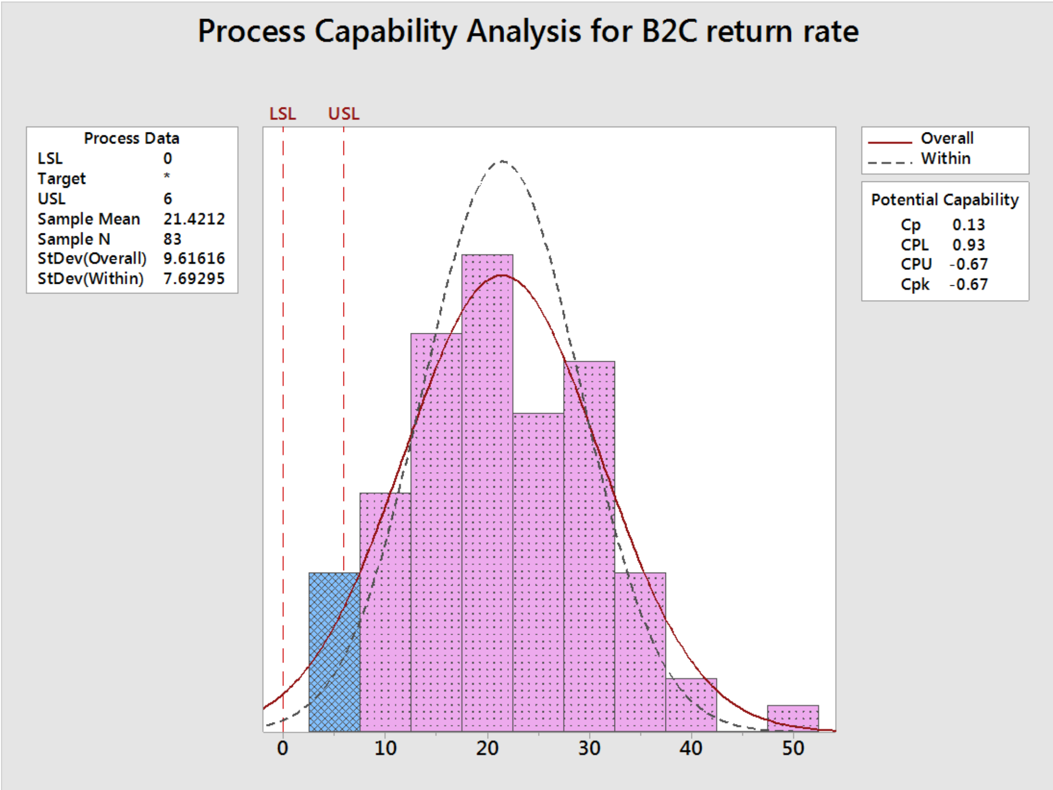

Figure 27. Capability plot of return rate for B2C service delivery for Espoo area during September-December (Minitab 17)

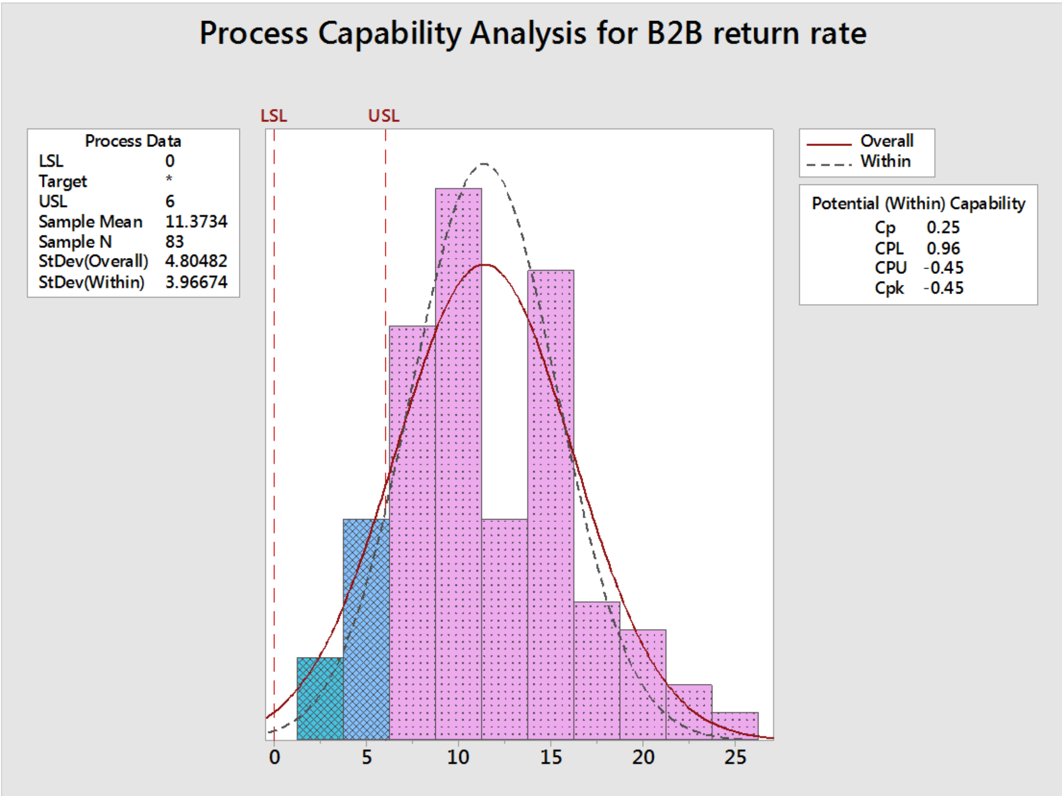

Figure 28. Capability plot of return rate for B2B service delivery for Espoo area during September-December (Minitab 17)

To understand the distinctions between the B2B and B2C service delivery performance, it was necessary to describe the reported reasons for the failure of deliveries to be made within the desired limits of the targeted return rate failure (0-6%). A breakdown of return rate reasons was shown in the Pareto chart below (Figure 29) for the Espoo route system as reported by the van drivers.

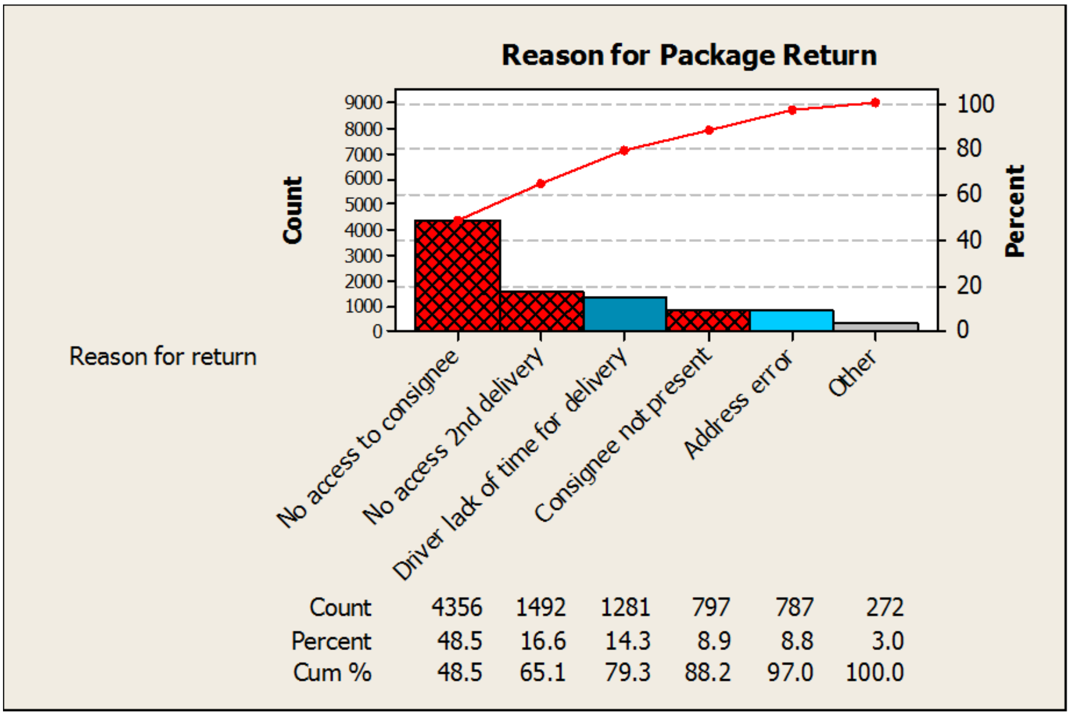

Figure 29. Pareto chart of reasons for package return in Espoo area during September-December (Minitab 14)

Even more importantly, a disparity in delivery return rate for the Espoo routes was seen when the returns were displayed for the daily sequence of routes (Figure 30) which clearly indicated that the morning routes have delivery failures that were much more stable than those of the afternoon and evening. The majority of the morning shipments were B2B packages.

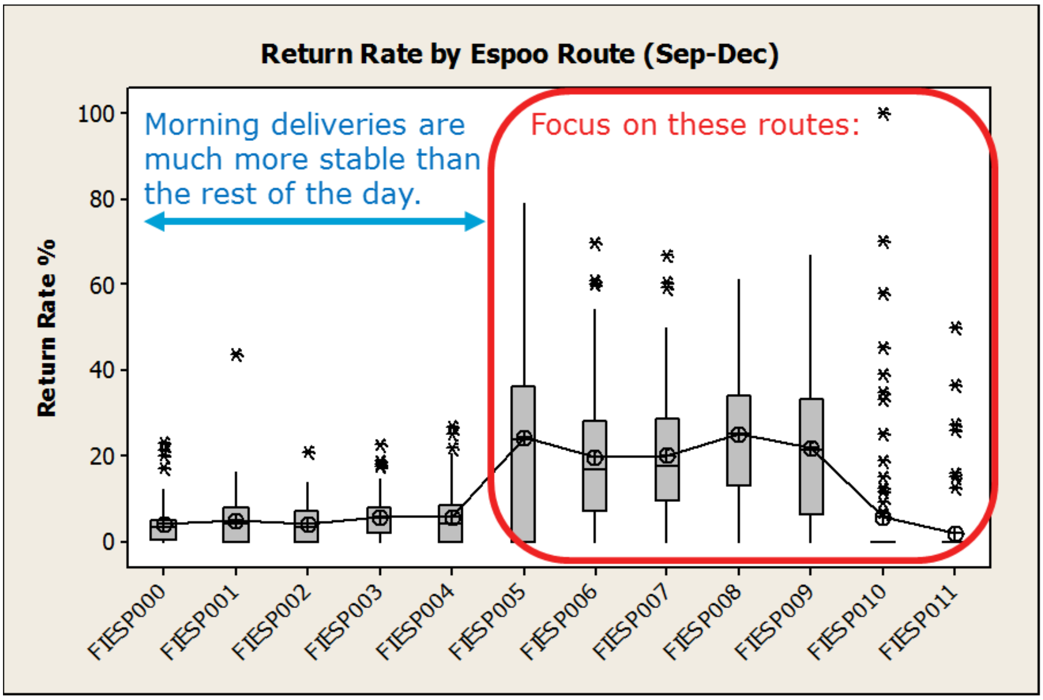

Figure 30. ANOVA of delivery performance by routes in daily delivery sequence for Espoo area during September-December (Minitab 14)

This disparity was even more pronounced when the volume of packages was considered as compared to the return rate for packages. Figure 31 compares the return rate (line chart) for the Espoo delivery routes with the package volume of shipments sent on those routes. The red boxes in Figure 31 indicates the problem areas for delivery performance. Within this box delivery return rate averaged between 20-35% higher than the morning routes, while the volume of packages shipped was about half the volume.

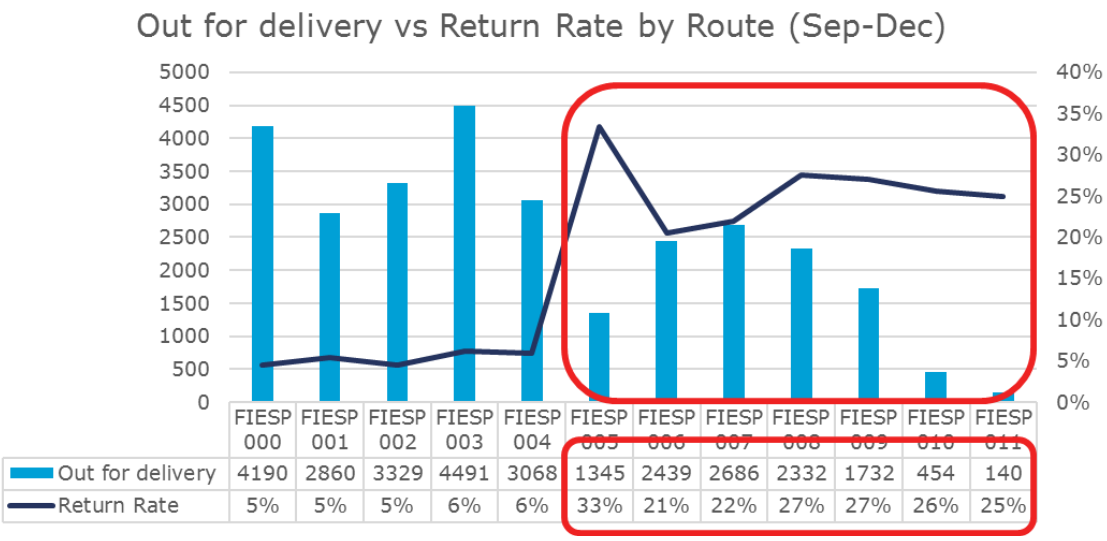

Figure 31. Comparison of shipment volume and return rate for Espoo daily routes during September-December (Excel)

Obviously, such high package return rate was not acceptable to customers as it was about four times higher than the targeted performance by Company X. The first decision in the analysis was to investigate the Espoo route as it had a high package return rate and also sufficient volume to provide valuable data for analysis. A second conclusion was also made with respect to the type of service. Morning deliveries were mostly B2B deliveries, while also providing package pick-up service. Afternoon routes were a mixture of B2B and B2C deliveries. B2B deliveries had lower return rate performance on package deliveries than B2C deliveries, while having a higher package loading density for shipments. The characteristics of B2B and B2C delivery services were compared in Table 2.

Table 2. Summary of Distinctions in Quality Characteristics of B2B and B2C Service

Quality Characteristic	**B2B Service**	**B2C Service**
Shipment/Package Density	High	Low
Routing Stability	Regular	Random
Delivery Location	Regular	Random
Van Loading Density	High	Low
Package Return Rate	Low	High

Therefore, further analysis focused on the shipment loading density of B2C routes in Espoo to understand the source of the problem for the high return rate. Two hypotheses were formed regarding the next focus area of this analysis:

- Ho 1: There is no difference in loading density between vans on Espoo routes
- Ho 2: There is no difference in the delivery performance among the Espoo routes.

Chapter 5 describes findings on loading density for vans that delivered shipments to the Espoo area.

5 Analysing loading efficiency at Terminal Y

This chapter discusses the analysis of loading efficiency as represented by loading density at Terminal Y for vans that deliver shipments to the Espoo area.

5.1 Van loading process

According to Company X's operating procedure, loading of vans was performed by drivers within the loading time period starting from 11 am under supervision of dispatchers. Packages were sorted in advance by Terminal Y workers according to delivery routes and were waiting to be picked up by drivers in a designated place. Each driver had the set delivery area and knew which packages to take for distribution. Upon arrival to Terminal Y drivers picked up scanners and forklifts and started loading. Each package was scanned as "out for delivery" when loaded. With this scan the ERP system recorded data on date and time when the package was loaded for delivery, and was a crucial time stamp from which "on time" delivery KPI is calculated. It also sent information to the track and trace system, allowing recipients to see packages as being out for delivery. Loading process was described in detail in the deployment diagram (Appendix 3).

5.2 Operational definitions and process measures

Loading time and density were defined by the author for the project needs as follows:

Loading time – is the elapsed time between driver's arrival time at Terminal Y and departure time from Terminal Y and is measured in minutes.

Loading density – is the number of packages loaded or scanned by a driver in the elapsed loading time recorded per trip. Loading density is measured as the total number of packages, divided by total scan time.

Example for interpretation:

- Driver loads 50 packages in 10 min: loading density is 5 packages per minute.
- Driver loads 50 packages in 1 min: loading density is 50 packages per minute.

The initial idea to measure loading efficiency was by dividing total amount of packages loaded by total loading time. However, during the project, the author found out that actual loading time or time spent by drivers at Terminal Y had not been recorded in any reports, so drivers' arrival and departure time were unknown.

In the absence of this crucial data the author decided to use time stamps recorded by "out for delivery" scans to measure loading efficiency. Hence only scanning time was taken into consideration, excluding other steps of the process like picking up scanners, checking in/out at the dispatchers' desk and, moving pallets to the loading dock. The data series used for analysis covered the same period of time as the data used for return rate analysis – September-December. Figure 32 developed by the author describes the loading performance measurement approach.

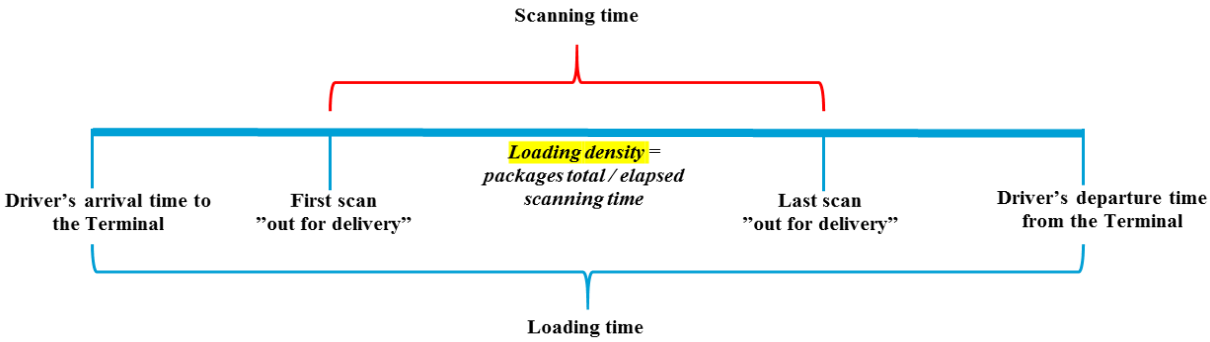

Figure 32. Loading process performance measurement

The efficiency of the process was judged by the rule "the more the better", meaning that the more packages a driver scanned and loaded in one minute, the more efficient was his work performance. The goal of efficient loading was to minimize the amount of time that drivers spent at the terminal for loading which increased the time available for delivery and should have therefore increased the success rate for on-time delivery.

Desirable range for loading efficiency was set by the company as follows:

- desirable range: Efficiency over 5 packages per minute
- undesirable range: Efficiency under 5 packages per minute.

5.3 EDA of the loading process

In order to apply EDA to loading performance the analysis began with an investigation of the time series data to determine if there were any patterns in the behaviour of the loading process as a function of time. To simplify this analysis a single route was chosen based on the volume of packages delivered within the route with the worst performance for package delivery statistics (e.g., package return rate). The result of this initial time series analysis using an I-Chart is illustrated in Figure 33 (page 45). Interpretation of this chart shows desirable performance as a high percentage of packages loaded per minute (e.g., over 5 packages per minute). However, the graph indicates that the current average loading density for this period was two packages per minute with an upper control limit of 7 packages per minute and only in four instances during this month were loads made within the desired range of loading performance. Blue reference lines on the graph indicate the range of desired loading performance over 5 packages per minute.

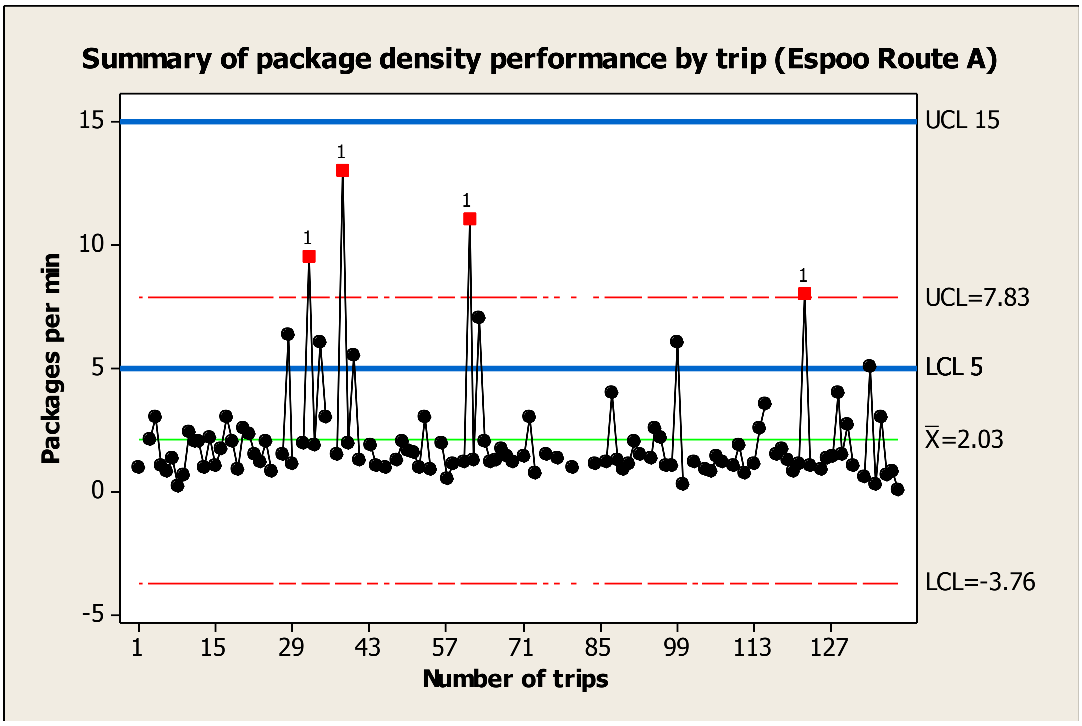

Figure 33. I-Chart for package loading density for Espoo route A (Minitab 14)

This same data may be analysed using a Probability Plot to illustrate the likelihood function or predicted performance based on this observed data set. Figure 34 indicates the outcome of this analysis.

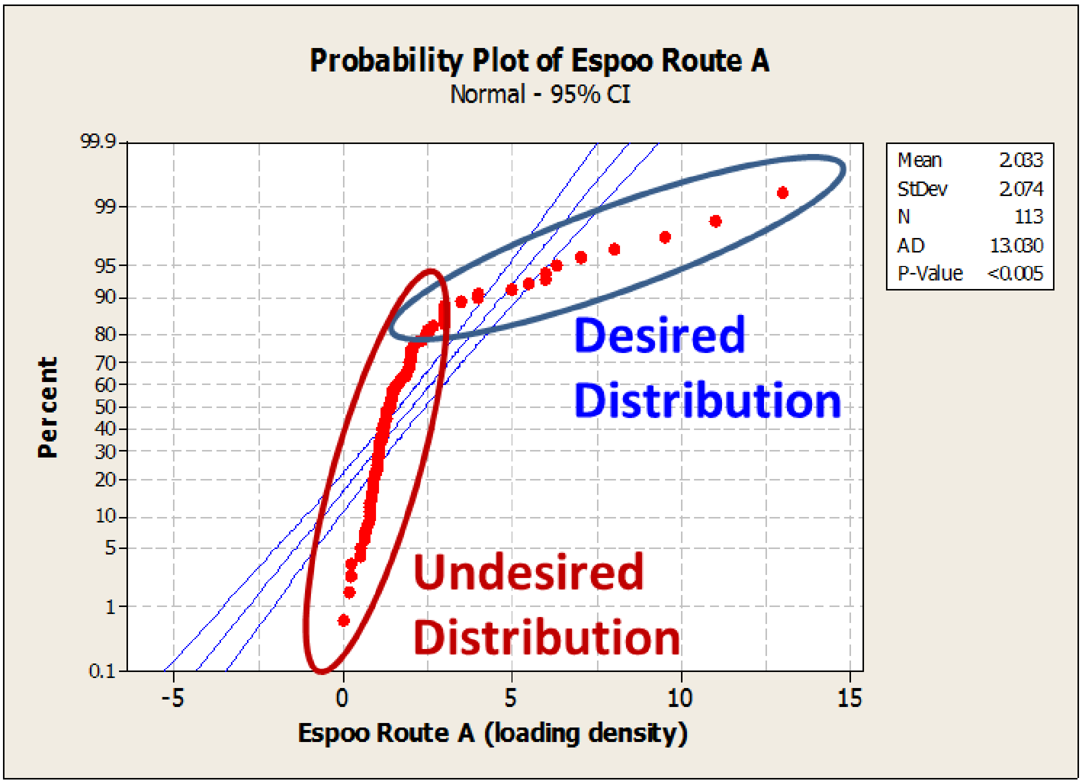

Figure 34. Probability Plot of Loading Density for Espoo route A (Minitab 14)

Figure 35 (page 46) shows that only rarely during this period was the desired range of performance achieved (less than 10% of the time) and that predicted consistent performance (at a 95% probability) would have been a loading density of 2 packages a minute, with standard deviation of 2,07 packages a minute which was well below the desirable range. This data was further interpreted using the enumerative method to estimate the impact of this probability of performance on expectations of customers using the process capability analysis.

When we look at the capability performance of the loading process on the left-hand side graph of Figure 35, we observe the current density range between -3 and 7 packages, both capability indices indicated that the process operated well within the set range (Cp – 0.95 and Cpk – 0.87). This means that the process was designed to achieve current performance expectations. However, this range of loading density was unacceptable for the new specifications of the loading process, which were to improve successful delivery rate by maximizing drivers' time spent on the road for delivery and minimizing time spent in Terminal Y for loading.

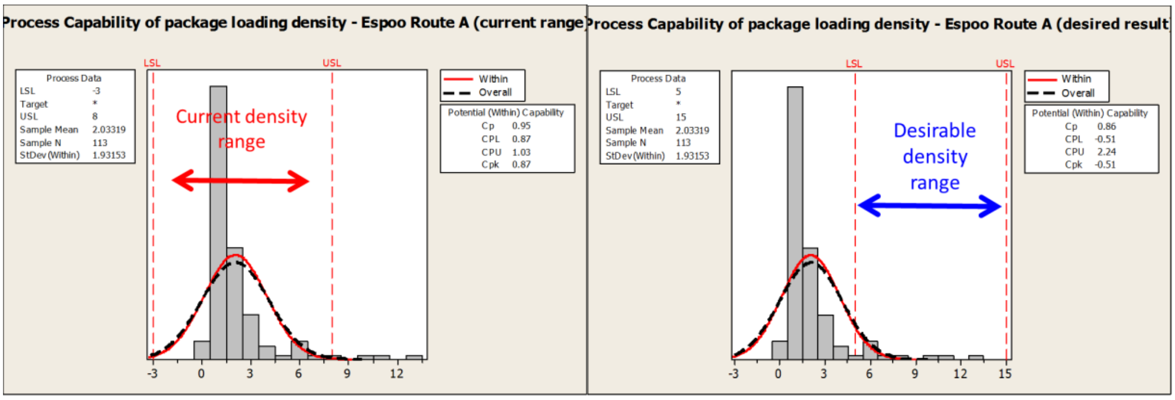

Figure 35. Capability plot for loading density (Espoo route A) current vs. desired range (Minitab 14)

On the right-hand side graph of Figure 35 the desired capability range was set between 5 and 15 packages per minute. We could see the lack of performance capability was clear in an assessment of the Cp and Cpk indices. In this case the Cp index was 0.86 which indicated that the process should have been able to reasonably perform within the range of desired outcomes – this was the designed capability of the process. However, the actual, observed performance as demonstrated by the Cpk index (which is representative of the probability of performance to the desired range of outcomes as set by the customer's requirements or expectations) was a negative value of -0.52. This meant that the process was not inherently capable of operating within the desired range of performance and must be redesigned to meet that level of performance reliably.

The next analysis step should have been to look at the problems in the loading process with the use of a Pareto Chart. However, the Pareto Chart for loading density was not analysed directly during the project as there was no information captured or observations recorded about the functionality of the process. In interviews with the operators (drivers and supervisors) the following reasons were at the top of their recollection:

- Missing fork-lifts/insufficient number of fork-lifts
- Problems with scanners
- Layout of package storage is not convenient for drivers to pick up shipments (amount of locations and distance from the loading dock)
- Lack of supervision
- No clear process description coupled with insufficient training of drivers.

ANOVA chart and analysis of variance (Figure 36) were used to see the relative efficiency or inefficiency in each Espoo route. From this Figure it is clear that loading performance in all routes was below the specified desired loading density range with more than 5 packages per minute. Route A, which was analysed previously was representative of the other Espoo routes in terms of loading density. There was not much variance in loading performance among the routes meaning that the loading process had some chronic issues and required redesigning to improve efficiency. Sample size of routes 11 and 12 was not statistically sufficient to draw reliable conclusions. Sample size (amount of trips per route) is described in the Table 3.

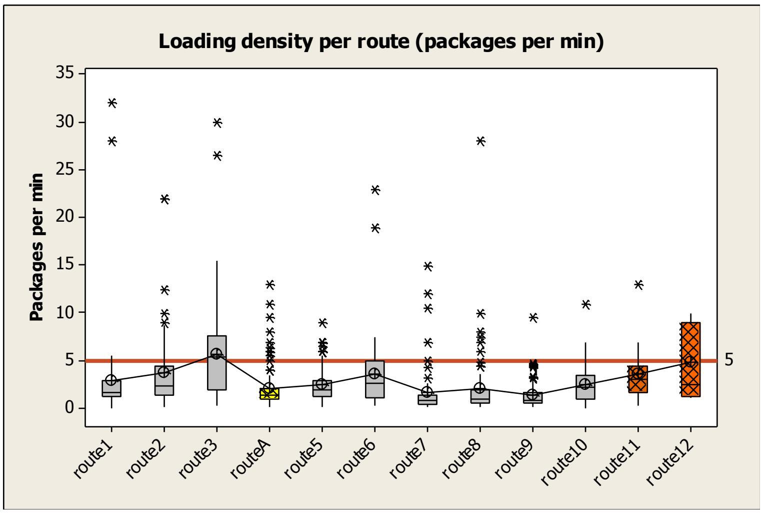

Figure 36. ANOVA loading density per route Espoo area (Minitab 14)

Table 3.Sample size.
* small sample size

Route	Sample size
Route 1	73
Route 2	68
Route 3	104
Route A	**113**
Route 5	131
Route 6	54
Route 7	69
Route 8	70
Route 9	68
Route 10	61
Route 11	23*
Route 12	7*

The final component of an EDA is a Yamazumi Diagram which also requires observational data regarding the causes of defects, so assignment as value-adding or waste may be made for the process data. However, despite the fact that this data was not recorded it could be observed that there was a strong propensity for the loading process to produce waste as observed in the operator assessments that occurred in attempting to create the Pareto Chart.

Indicative of the waste in the process was the excessive randomness of drivers' movement during the loading process. A Spaghetti Diagram (Figure 37) was used to trace movements of drivers from the loading dock to package pick up locations and back. This diagram was designed by the author based on observations of loading processes for two weeks at Terminal Y. It is clear from the diagram that there was lack of consolidated storage location within Terminal Y, which resulted in excess distance a driver must walk to complete the pick-ups of packages.

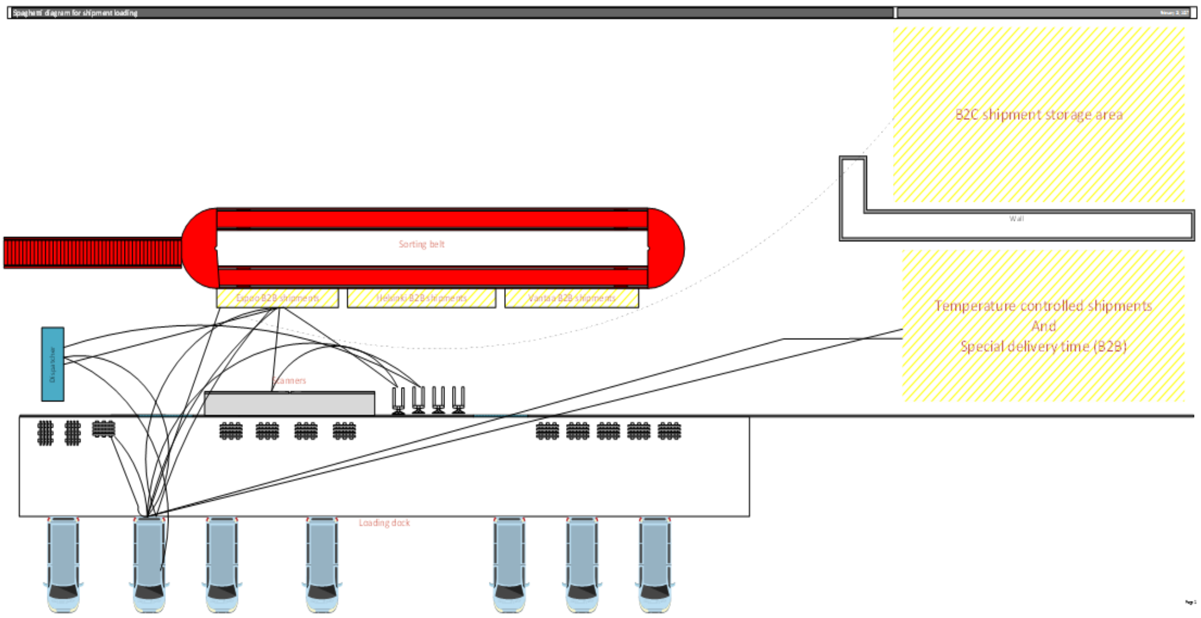

Figure 37. Spaghetti diagram of loading process

5.4 Observations and conclusions of the loading density study

Statistical data analysis revealed that the average loading density was 2,03 packages per minute for the selected distribution route. This loading process was operating in a state of statistical control between the performance capability limits of -3,76 to 7,83 packages per minute. This observed performance was well below the desired state which would have consistently delivered a loading density above 5 packages a minute, which was the requirement for meeting the company's target for delivery performance improvement.

Reasons revealed for the inefficiencies that have produced this degraded state of performance were:

- lack of integrity due to missing data and inaccurate scanning
- lack of standard loading processes and procedures for drivers to use
- lack of control over drivers' performance during their loading processes

- excess movement in the loading process that is a result of poor physical layout of the terminal infrastructure, which causes excess movement of the packages throughout the loading process
- insufficient equipment to support the loading process (e.g., scanners, cages, fork-lifts, etc.).

To improve the efficiency of loading, a set of coordinated actions should be taken to redesign the process to meet new specifications. Author's recommendations on process improvements are described in Chapter 6.

6 Conclusions

This chapter describes the conclusions from this thesis study in four perspectives: the recommendations made to the case company, reflections on the theory and method of Lean Six Sigma as applied in this project, personal lessons learned by the author during the thesis project and project assessment by Company X's CEO and Lean Six Sigma Black Belt course instructor Gregory H. Watson.

6.1 Recommendations to Company X

This study raised several issues as recommendations for management attention. The final study was presented to the management team of Company X on February 28th, 2017. Recommendations included several improvement opportunities in three major distribution process areas: inbound, terminal, and outbound as well as some systemic recommendations for improvement. In author's opinion the issue of failed first-time deliveries could be solved more successfully only when Company X applied a systematic approach dealing with this issue on all process steps and levels.

One of the biggest issues identified during the project was missing delivery information in Company X's system on some packages, like recipient addresses, door codes, and contact information. Without contact information the recipient could not be notified about delivery date and time. If delivery address was absent in the IT system, it was also absent on the delivery list printed for the driver after loading. This created trouble for a driver as to find the address he needed to check each package for delivery, which took a lot of time during loading. Additionally, the author discovered that the case company did not have a forecasting tool for inbound and outbound volumes to be able to plan van capacity more efficiently.

Based on these findings the following recommendations were made regarding shipment inbound process flow:

- enhance the quality of sales data for customer critical information (e.g., phone number of receiving customer, door code to enter apartment building, etc.)
- improve inbound scheduling information quality (e.g., decrease the delivery window for expected arrival time of inbound shipments)
- improve the transfer of information about delays of incoming shipments (e.g., the real-time status of linehauls).

Next, three challenges were discovered in the package handling process at Terminal Y. Firstly, package traceability in Terminal Y. Among reasons for this problem were missing or wrong scans and delays in data registration in the system. Secondly, Company X did not record time on drivers' arrival to and departure time from Terminal Y, which meant that it did not monitor drivers' performance and had no control over it. Thirdly, as was identified in the Spaghetti diagram and by the author's observations the terminal layout was not optimal and drivers had to walk during the loading, which took a lot of time.

After the study the author made the following Terminal Y process improvement suggestions to the case company:

- introduce new scan types and locations of timestamps to improve the traceability of the terminal package throughput
- create an "auto-alert" function within the scans to eliminate shipping errors due to missing or incomplete data fields
- rationalize the terminal layout to improve the flow of shipments and decrease the number of intermediate holding locations and make it more optimal an easy and fast loading
- streamline the organization of the loading dock to reduce the cycle time of drivers while loading trucks
- develop clear instructions for drivers on the loading process
- introduce control over drivers' performance at Terminal Y by creating drivers' reports and by collecting information on drivers' arrival and departure time from Terminal Y.

The author also found out several issues related to the actual shipment delivery process. Drivers did not have any routes planned for B2C deliveries and considering that some addresses were absent from the delivery list, they had to check missing addresses and then build routes themselves. Clearly it took some time from the actual delivery time and created a lot of extra work for the driver. Another challenge was that not all drivers were calling customers before delivery because it was not compulsory and was not stated in the contract. Also, it was identified that sometimes drivers were using the wrong codes for reasons for non-deliveries, as the list of codes in the scanner was too long and not organised by rational subgroups. This resulted in incorrect information generated in the system and raised the question of data reliability. The same issue is related to missing "delivery" or "non-delivery" scans.

The author's delivery process recommendations were built on the previously described observations and included the following ideas:

- improve the efficiency of standard routes by examining historical patterns for delivery and seasonal demand using linear programming
- consider utilizing route planning software for building routes for B2C deliveries
- improve the quality of delivery lists
- introduce real-time monitoring of truck progress while making delivery routes
- develop standard instructions for drivers
- create standard codes to categorize the reasons for package delivery returns.

In addition to process recommendations the author made systemic suggestions on overall delivery quality improvement. Firstly, the internal and subcontractor delivery performance measurement system should be revised to provide improved traceability of actual performance. Current approach which considered only delivery attempt not the actual delivery, in author's opinion, did not reflect the actual process and the rate of successful first-time deliveries. Secondly, revise contract terms and conditions with subcontractor companies so that the assessment of their performance was based only upon shipment delivery and not on the number of driver stops, for example, implement a "pay-for-performance" scheme. Thirdly, design a new layout for Terminal Y and supporting data collection, analysis, and reporting systems to streamline operations across the end-to-end process of shipment handling so that infrastructure supports the process, rather than having the process accommodate a fixed infrastructure.

6.2 Additional recommendations to the case company

The prior set of recommendations was defined to address proposed changes to the system of distribution for Company X. The recommendations listed below were created to address human issues that support the system flow.

Company X personnel recommendations:

- streamline the organization to consolidate data collection, analysis, and process improvement activities into a single unit that works across the end-to-end process
- develop training for terminal workers and supporting organizations in the use of "lean methods" for distribution management
- develop a core group of business analysts who are capable of applying advanced statistical and analytical methods (e.g., LSS methods, cluster analysis, and linear programming) for optimizing the end-to-end distribution system.

Subcontractor personnel recommendations:

- develop training procedures and standard work instructions for terminal package handling workers to guarantee that the inbound handling and sorting processes
- develop truck loading and route management procedures for drivers to assure that packages are delivered on-time the first time and that routes are served at the highest level of delivery effectiveness and efficiency
- develop employee measurement systems that are aligned with the Company X work process requirements and assure that "pay-for-performance" recognition is implemented at the worker level.

6.3 Reflections on the theory and tools

This project focused on the first three steps of the Lean Six Sigma DMAIC process as the author is not employed by the organization and was not able to transition the project into the Improve and Control phases. In many cases a DMA-only study is done instead of the full DMAIC process when the desire is to present recommendations to management for improvement opportunities. The improvements identified in the prior paragraph came because of this approach; however, taking this project to its logical conclusion would have also required an additional 2-3 months of work and the author was not able to exercise the authority necessary to enter these phases.

The methods of DMA that proved most useful in the project were the SIPOC Map, I-Chart, Probability Plot, ANOVA, and Capability Study. These tools were selected from among the 60+ methods and tools that are taught in the Lean Six Sigma Black Belt training. Applying these methods in a structured approach provided a logical disclosure of the underlying problems. The iterative use of these tools helped to drill down from the higher-level causes to uncover the true root cause. This was demonstrated in the investigation of the shipment return rate which firstly was broken down into two rational subgroups of B2C and B2B deliveries and then subsequently unveiled issues related to the geographic routing, truck loading, terminal processing and inbound information quality. Such a comprehensive understanding of the problem was possible because the drill down methodology was unbiased in its pursuit of sources of variation and relied on the sequence of methods for decomposing the problem into the leading causes of observed variation.

The most helpful non-statistical methods were the Spaghetti Diagram, Fishbone Diagram, Process Mapping, and Pareto Chart. These methods identified process flow and the categories of rational subgroups that should be investigated. They also were most helpful in stimulating discussion with terminal workers and drivers. The Spaghetti Diagram helped to uncover how the loading process really operated, rather than the idealized view of this work of management who did not realize how much extra work was involved.

Tools that could not be used were the Yamazumi Diagram and the extension of the Process Map into a Value Stream Map. Both would require a more detailed analysis of categories of waste in the process and the time loss that was observed in detailed process steps was sufficient to identify the areas of inefficiency.

6.4 Project evaluation

In the end the project achieved set goals and objectives in five months, from October 2016 to end of February 2017. Final project presentation to Company X's management was conducted on February 28th, 2017. After the presentation the management gave feedback to the author. Among other comments Company X emphasized the practicality of tools used for analysis and criticality of project findings. Sub-products of this project, deployment diagrams and Potential Risk and Failure chart, were implemented in production at Terminal Y by the end of the project. Deployment diagrams captured how loading and delivery process actually works and were the first step to documenting standard work in Company X. After the project Company X described all processes in production and other business units with the use of deployment diagrams. These diagrams also created the basis for the development of standard operating procedures (SOPs) and work instructions for workers at Terminal Y. The case company also benefited through gaining strategic insight into its business model through a renewed emphasis on creating increased responsiveness within its customer delivery experience and from the insights gained into risk management. Potential Risk and Failure chart clarified and systematized potential risk that might occur during the distribution process at Terminal Y. This tool also provided preventive and contingent actions for listed risks. Execution of this tool helped Company X to improve safety levels at Terminal Y and reduce process risk by being proactive.

This project also raised the necessity for expanding Lean knowledge in Company X. For this reason, the second LSS Black Belt project was conducted by one of the case company employees. The author was invited to develop a "Lean processes" training for Company X workers.

Feedback from Company X's CEO sent by e-mail (13 November 2017):

> Ekaterina Spiridonova has delivered pragmatic advice to our management team and made extremely significant contributions to our understanding of the way our operating processes may be improved. Project outcomes went far beyond our expectations for contributions by an undergraduate student to the operations of a mature business.

The project that laid the basis for this thesis also was the author's study for the Lean Six Sigma Black Belt course. The presentation of project findings for this course occurred on March 13th, 2017 and was followed by the author's successful graduation and obtaining Certification as Lean Six Sigma Black Belt. Written feedback from the course instructor, Gregory H. Watson, was collected by e-mail. Below is an abstract from his comments about this project and the author:

> Ekaterina Spiridonova was an exceptional student in the Lean Six Sigma training – one of the best I have had in over 25 years of teaching this subject. She has a natural curiosity which is supported by an outstanding analytical mind. Her project in logistics system improvement demonstrated her knowledge of the subject and highlighted her skills in statistical analysis. The high level of competence that Ekaterina demonstrated on her project work led to both a job offer as a consulting business analyst and selection for a scholarship to attend a Master Black Belt training which she has almost completed. It is exceptionally unusual for an early career individual to be qualified for this training as the typical student is a mid-career technical specialist in the 40-50 year range. (Watson 13 November 2017.)

6.5 Personal lessons learned

Personal development of the author was significant on this project. This learning can be categorized into six areas: distribution theory and application, analytical methods and application, teamwork and project facilitation methods, practical insights into leading an improvement project, and personal discoveries in the dynamics of daily work and practical problem-solving.

Specific areas of learning included:

- Distribution Processes: while the author gained an excellent foundation into the theory of distribution and supply chain management from courses in Haaga-Helia University of Applied Sciences, the exposure to the practicality of their application proved to be enlightening as the academic theory is not often evident in the real-world application.
- Lean Six Sigma Methods and Tools: this project convinced the author of the practicality of combining visualization methods and statistical methods for investigating complex business process problems. This experience proved the merit of many of the advanced tools for seeking out the causal systems underlying a problem. This methodology should be an important part of the personal toolkit of a business process analyst.
- Teamwork and Project Facilitation: Gaining the participation and cooperation of the process workers required rapport-building and confidence development. An ability to communicate across working levels should also be a core competence of a successful business process analyst.
- The Job of a Business Process Analyst: The job of a Business Process Analyst is a subset of the job of a Business Analyst. The additional emphasis for the Business Analyst is the linkage to financial performance and strategic business direction. Working as a Business Process Analyst is a first step toward expanding a career to become a Business Analyst.

Finally, the pursuit of this thesis research was of significant personal value to the author. Practical benefits to the author included the completion of the Lean Six Sigma Black Belt certification from the Laatukeskus Excellence Finland Oy. This internship also led to the acceptance of the author into a training program for Master Black Belt. An additional benefit of this project was that it led to the offer of employment for the author as a consulting Business Process Analyst in distribution on assignment to Company X.

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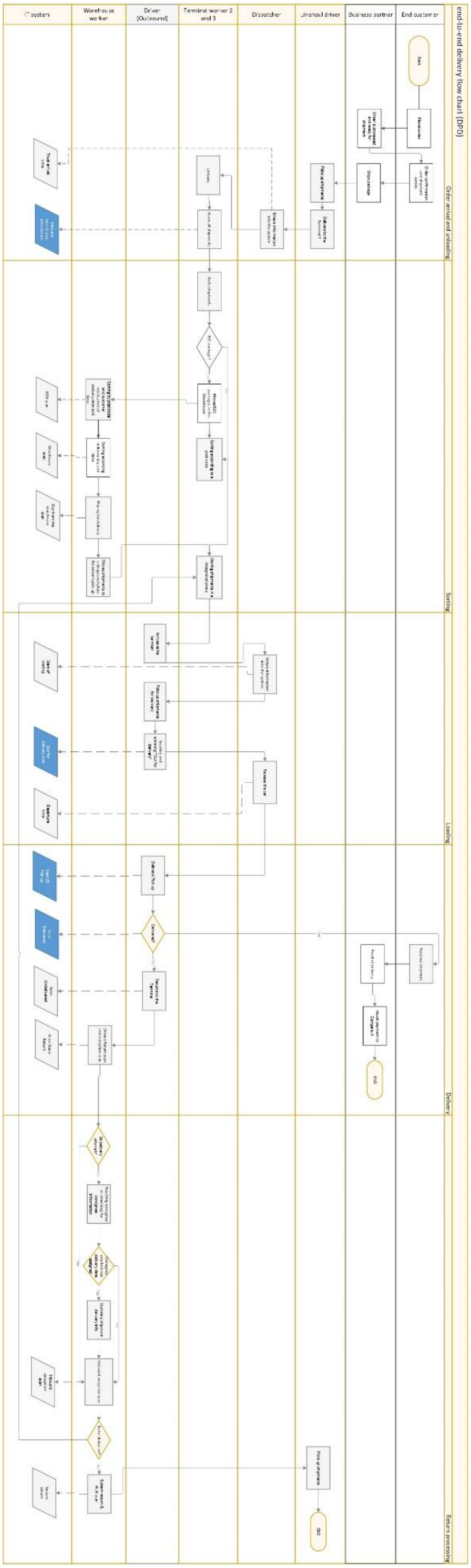
Appendices

Appendix 1. Deployment diagram of the Company X end-to-end distribution process



Appendix 2. Risk and Potential Failure Analysis

Risk and Potential Failure Analysis										
Process step	**Potential failure**	**Effects of failure**	**Severity of effect**	**Probability of failure**	**Criticality Index**	**Likely causes**	**Preventive actions**	**Triggers for continge**	**Contingent actio**	**Control mechanism**
Linehaul truck arrives	Truck arrives late	Delay in the following process steps	7	TBD	7,TBD	Ferry is late Late departure from Turku Terminal Road Traffic Vehicle break down Accidents Driver's route	Ferry schedule delay's ale Implementing schedule control mechanism Route planning Vehicle maintanence Employee training Check delivery times with a subcontractor	Alert that truck is late No truck on time	Adapting capacity to new schedule	
	Trucks queue at the Termi	Delay in the following process steps	7	TBD	7,TBD	Delay in unloading Truck break down at the gate Lack of workers System failure	Proper capacity planning; process agility - to allocate more workers to unloading if needed SLA agreement - subcontractor liability for vehicle maintanence Proper planning Scheduled maintanence	Unloading of the first truck takes more time than planned	Allocating more employees for unloading	
	Truck does not arrive					Vehicle break down Accidents	Vehicle maintanence Employee training			
Unloading	Telescopic belt conveyer b	Unloading manually	7	TBD	7,TBD	Inadequite maintenanc Human mistake Smth stuck in the belt Accidents	Scheduled maintanence Increase maintanence budget Train employees Check the belt	Broken conveyer	Breakdown maint	Peroadic inspection and preventive maintanence schedule
	Lack of workers	Unloading takes more time	7	TBD	7,TBD	Sickness Strikes Poor planning Accidents	Proper planning; Agile employee policy with subcontractor	Unloading of a truck takes more time than planned	Allocating more employees for unloading	
	Shipment damage		5	TBD	5,TBD	Improper handling	Employee training	Broken package	Customer notification??	

Scanning	System failure	Delay in the following process steps	7	TBD	7,TBD	No internet, Server brea	Scheduled maintanence	System is not respond	Notifying IT department	
	Lack of scanner	Delay in the following process steps	7	TBD	7,TBD	Scanner broken, not en	Proper supply of scanner	No scanner		Peroadic inspection and preventive maintanence schedule
	No scan	No data in the system	9	TBD	9,TBD	Human error	Employee training System alert	shipment is missing a	Entering info manually into the system	Make complete training plan, implement personnel training
	Wrong scan	Wrong data in the system	9	TBD	9,TBD	Human error	Employee training	Shipment has a wrong	??	Make complete training plan, implement personnel training
Sorting	Sorting belt broken	Delay in the following process steps	7	TBD	7,TBD	Inadequite maintanence	Scheduled maintanence	Sorting belt broken	Breakdown maint	Preventive maintane
	Wrong sorted parcels	Missed delivery/Shipment return to the Terminal	8	TBD	8,TBD	Human error	Employee training Automated sorting system	Shipment is not delivered ?? Driver noticed a shipment is in wrong post code area	Resorting	Make complete training plan, implement personnel training; strengthen sorting control
	Wrong shipment data (ZIP	Missed delivery	8	TBD	8,TBD					
	Lack of workers	Delay in the following process steps	7	TBD TBD	7,TBD	Sickness, Poor planning	Proper planning; Agile employee policy with subcontractor	Sorting takes more tim	Allocating more employees for sorting	
Storing	Wrong place	Missed delivery/Shipment return to the Terminal	8	TBD	8,TBD	Human error	Training	Shipment is not delivered ?? Driver noticed a shipment is in wrong post code area	Resorting	Make complete training plan, implement personnel training
	Shipments are mixed	Delay in departure from the terminal	7	TBD	7,TBD	Human error	Employee training Improved Terminal layout	Shipment is not delivered ?? Driver noticed a shipment is in wrong post code area	Resorting	Make complete training plan, implement personnel training
		Delay in the following process steps	7	TBD	7,TBD	Accidents	Employee training			

Warehousing	Wrong place	Hard to locate a shipment	6	TBD	6,TBD	Human error	Training	Shipment is not delivered ?? Driver noticed a shipment is in wrong post code area	Resorting	Make complete training plan, implement personnel training
Delivery	Missed delivery	Shipment return	8	TBD	8,TBD	Late departure from the Terminal	Loading process improvement	Shipment not delivere	Contact the customer	B2C - delivery notification to a customer
		Shipment return	8	TBD	8,TBD	Wrong consignee information	Consignee address/info checked prior to delivery			B2B -
						Consignee not present	Inform consignee about delivery			
						Lack of time	Improving subcontractor SLA agreement by introducing better performance measurement mechanism			
						Human error/wrong route				
						Not enough vehicles				
						Vehicle break down				
Pick up	Late pick up		7	TBD	7,TBD	Late system pick up notification	Employee training	Shipment not picked u	Contact the customer	
	No pick up					Dispatcher mistake	Check time with a customer			
						Driver is unable to make a pick up				
						Customer not present				

Appendix 3. Deployment diagram of a van loading process