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Applying Lean Six Sigma to Optimise the B2B Order Fulfilment Process of Electronics in Europe.

Adam Burnage

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Abstract

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Author(s)
Adam Burnage

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This project based thesis will assess and optimise the B2B order fulfilment process of electronics in Europe. This study, which is based on the application of Lean Six Sigma process improvement methodologies, focuses on how these ideas and tools can be used to in a real business case. The ideas of Lean Six Sigma, order fulfilment and change management are discussed from a theoretical perspective before moving onto the empirical study.

The focal company Secretive Electronics Producer (whose name is altered for confidentiality reasons), was studied using a mix of exploratory research, qualitative research of customer viewpoints and quantitative data analysis. The chapters of this study were based on the DMAIC project management framework. The outcomes of the project consist of; an analysed database of the current performance that outlines the *root cause,* as well as improvement ideas that were introduced and tested, and recommendations for maintaining and further implementing/improving the proposed solutions.

Keywords
Six Sigma, DMAIC, Lean, Continuous Improvement, Change Management, Process Improvement, Electronics and Order Fulfilment Process

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1 Introduction

This project will assess and optimise the B2B order fulfilment process of electronics in Europe. The focal company Secretive Electronics Producer (SEP) is experiencing challenges in meeting customer expectations of reduced lead times and greater accuracy in delivery time estimates. The Secretive Electronics Producer's (SEP) name has been created for this project to hide the true name of the business being discussed. The outcomes will consist of; an analysed database of the current performance that outlines the *root cause/s* for improvement together with recommendations for maintaining and further implementing/improving proposed solutions.

1.1 Background

This business problem contains is a wide variety of forces. We have multiple businesses all with their strengths, weaknesses and viewpoints. We have customers each with their own unique demands, we have competitors and their alternative offerings, we have manufacturers with their production and sourcing capacities and we have the host company trying to compete, whilst creating value for their stakeholders. In this web, it is difficult to understand how each minor section can operate in a way that not only improves its internal performance but also that of the entire chain. In business problems like this, a holistic viewpoint is important; therefore, a process improvement approach of looking at all the cross-department activities that are present in each stage of a product or service is favourable (Krajewski, Ritzman & Malhotra 2007, 5). This is due to the way departments operate. Typically, they have clear directions and objectives to achieve as well as specialist knowledge on their role and limited knowledge on the roles of others. In the process approach, a cross-departmental team looks to ensure that all relevant departments be heard equally. Another benefit of this process approach is that rather than looking narrowly at a problem in one stage of a production or service it promotes problem solvers to look at the whole process. (Krajewski & al. 2007, 4-9.)

Six Sigma looks at individual processes in depth and builds data on certain defining aspects (or metrics) that measure the process's accuracy and consistency. Six Sigma looks to understand why, when and how often a process creates defects and more importantly *how can they be avoided?* Six Sigma is centred on finding the *root causes* of process defects and in turn reducing and removing them. A root cause can often be hard to identify as the effects of a root cause are more visible. This is the reason that Six Sigma centres on analysing data and aiming to find correlation or in other words, the cause and effects. (Pyzdek & Keller 2014, 3-12.)

For instance, consider a person throwing a dart over twenty metres and hitting the centre of the target. If we say that he is successful in hitting the target three times per every ten opportunities, which is far from achieving Six Sigma or 3.4 defects per million opportunities; then how can we improve this process? Six Sigma projects, look to the data and question what could be effecting the outcome? Does the positioning impact on the result? What effect does the time of day have on this process? Does the weather effect the result? When did the person last eat? What did they eat? Was the dart the same every time? How many darts were thrown? Etc. Even in this simple scenario, there are so many possible reasons for the variation. Next it would be important to collect data on these possible reasons and test them to measure their effect. The data will reveal the probable root cause/s through correlation in the data. So, if there is evidence that the greatest effect on the variation came from when the person ate and what they ate, you can then change each element slightly and measure the responses. Over the course of multiple tests, you can find the point that is accurate and creates the least variation in performance and, therefore, achieve the greatest possible rate of success.

This empirical tool has long been championed in manufacturing industries to control quality in a way that could at the same time improve cost effectiveness. The strategy of defining an optimal range and ensuring that you operate within it has been hugely successful and has driven companies to reduce variation and, therefore, increase quality. Increasingly though, these ideas are adapting to new challenges, in new industries. Anywhere there is a process that can be measured, Six Sigma can be applied. (George 2003, 7-14.)

1.2 Project Objective

The project objective is to implement Six Sigma to optimise the order fulfilment of electronics in Europe. For this project, the DMAIC model will be used (Define, Measure, Analyse, Improve and Control) as a framework and structure. DMAIC works as a step by step process with each step leading into the next as seen in Figure 1. (Pyzdek & Keller 2014, 30.)

Figure 1. DMAIC Model (Pyzdek & Keller 2014, 30).

Excusing the first Project Task (PT) which will focus on the theoretical framework, all tasks will follow the DMAIC model. For an overview of the project tasks see Table 1.

The final outcome will aim to target the root cause problem as well as the implementation and testing of a proposed solution. Additionally, a detailed description of how this project was undertaken and a critical review of the outcomes can be used as a basis to solve similar business problems.

PT1. Theoretical Framework for the project

The aim of this task will be to build a theoretical understanding of Lean Six Sigma methodology and the tools that can be used. Core principles such as gathering the customers' voice and process flow analysis will be discussed. In addition, the order fulfilment process will be studied as this process is the focus of the study. Change management theories shall be looked at as change is a key element of the process improvement process, that Lean Six Sigma looks to achieve. This will provide a theoretical backdrop so that the project can ensure it is in line with current thinking. It will also enable the study to utilise the best possible tools available.

PT2. Define

The *Define stage* is aimed at assessing the need for a project, the risks that could damage the project and focusing the project to target the correct scope. If a project moves on to measuring the metrics but then realises the scope was not sufficiently identified it will lead to wasted time and the need to return to the *Define stage*. Getting this correct the first time can ensure a systematic approach is followed. Important to this phase of the project will be assessing what the process is that will be analysed and what resources or funding will be required in order to conduct the project. All of these details will come together to create a *Project Charter*. (Pyzdek & Keller 2014, 245-269.)

PT3. Measure

With the project clearly defined it is then possible to move on to identifying the exact measurement criteria and collection methods for the data. Questions needed to be answered here include: how much data will be needed? Can the entire population of data be analysed or will we need to use sampling? If sampling is used, how will this be controlled to not affect the reliability, validity and objectivity of the study? How do we ensure that we are using the correct measurement for the aspect that we are measuring? Due to the wide variety of tools and measurement techniques available, this study will focus on the ones needed in order to answer this specific business problem. (Pyzdek & Keller 2014, 271-292.)

PT4. Analyse

The analyse phase is very much the turning point in the project. With the metrics defined and the data collected it is then time to study what the data shows. In the ‘Analyse’ stage the data is assessed to find and prove hypotheses of possible root causes. With this evidence built, ideas begin to emerge on how to fix issues. Is there correlation between certain aspects? This section will include theories and tools that can be used to assess data, find root causes and identify solutions. (Pyzdek & Keller 2014, 427-520.)

PT5. Improve

The improve phase is focused on the implementation and fine tuning of the solution (Pyzdek & Keller 2014, 521.). Based on the historic data and the root cause analysis of previous steps now the task is to experiment with ways to solve the problem. Eventually through testing; the project should hopefully lead to a solution that is optimal, given the constraints. Again, this will be looked at in theory slightly but predominantly the focus will be on solving the problem in practice so not all improvement tools will be discussed, but rather the ones that offered value to this project. (Pyzdek & Keller 2014, 521-583.)

PT6. Control

The final stage of DMAIC and the last project task of this thesis will validate the successes and failures of the project and create a control plan to ensure any gains from the project are maintained. What worked, what didn’t, and why? Could the improvement ideas uncovered in this report be sustained and continuously improved upon? What factors will the company need to bear in mind and how often should it be reviewed? Crucially, given the time restrictions of this thesis improvement data from this project will not be assessed so this project task will look more closely at reviewing the project process than the resulting performance improvements. (Pyzdek & Keller 2014, 585-599.)

Table 1. Overlay matrix

Project Task	Sources of Information	Project Methods	Outcomes	Chapter
PT1 Theoretical framework	Books, journals, articles & case studies	Secondary data	Key theories defined.	2
PT2 Define	Process owner interviews and customer interviews.	Primary data	Project Charter with defined scope and project objectives, top level process map.	3
PT3 Measure	Historical performance data.	Primary data / secondary data	Defined data collection methods/metrics. Detailed process definition.	4
PT4 Analyse	Historical performance data, graphs and charts.	Primary data / secondary data	Gap analyse, identified root causes and prioritised improvement ideas.	5
PT5 Improve	Results from PT4, books, journals and articles.	Primary data / secondary data	Innovate and implement new solutions.	6
PT6 Control	PT1-6	Self-evaluation	Ideas for future activities to maintain and improve the ideas implemented.	7

1.3 Project Scope

In terms of the scope this will be defined by those aspects that are relevant to SEP. With Lean Six Sigma, it is crucial to include the customer viewpoint (referred to as the customers' voice), and to remain open in terms of where the problems lie. The initial scope of this project is very wide, but through the course of a Lean Six Sigma DMAIC project, the scope will narrow down to focus on a specific problem. The data will lead to finding the root cause/s, and one of these root causes will be studied in depth. (Table 2)

Table 2. Project Scope

Case Company	SEP
Focus area	Total Quality Management (TQM), Six Sigma
Location	Europe (customers) and global (supply chain)
Industry	Technology, manufacturing
Research methods	Quantitative and qualitative
Stakeholders	SEP, customers, contract manufacturer, logistics service provider and the author
Products	One specific line of products (emitted due to confidentiality)
Timeframe	Data collection between October and September 2017

The purpose of this study is to reduce the variation of the lead times of electronics to Europe. The reason for the project being based on customers in Europe is due to this being an area where the focal company are currently experiencing challenges with their lead time variation in the order fulfilment process. The product is an important boundary as the supply chains differ between products so one line of products will be assessed.

1.4 International Aspect

Due to the requirements of the degree program of an International Business Degree at Haaga-Helia UAS it is important that this study is of interest on an international scale. SEP are a global company with operations in many countries around the globe. The supply chain is truly global and the focal customers in this study are spread all over Europe.

1.5 Benefits to Stakeholders

The key stakeholder for this project is the focal company: Secretive Electronics Producer (SEP). Lead time variations lead to a lack of customer trust, which can be damaging to SEP's reputation. In addition, it can potentially lead to refunds and cancelled orders if not dealt with. This leads us to the second key stakeholders which are the customers of SEP. Shorter lead times and reliable delivery estimates are of course of great value to customers. SEP have noted that variation in the lead times is more of an issue than the lead time itself. Customers want to be told a delivery time, and that estimate be met. One element of this thesis will be to validate this company view with the customer, and in doing ensure SEP fully understands their customers' needs.

This study will be looking at the order fulfilment process and trying to understand the fundamental reason for variations in lead times. The two key players in this performance are the contract manufacturer who makes the products, and the Logistics Service Providers (LSPs) that transport the products to the customers. They will as a result be key stakeholders.

Finally, this project is quite specific and needs specialist knowledge. In preparation for this the author has undertaken a Lean Six Sigma Black Belt certification with the Averta Business Institute (https://www.sixsigmaonline.org/). Therefore, this project and its success is of great importance to the author and their professional development. Success here can be of major value to the writer and their professional development.

1.6 Key Concepts

Six Sigma or 6σ. Sigma or σ is a Greek letter that is used to represent standard deviation. So, Six Sigma, therefore, refers to six standard deviation. In a process, this requires that the outcomes be so centred around the mean that the range of six standard deviation (plus and minus), from the mean, which includes, 99.999998% of opportunities (in normally distributed data), is acceptable as the product specification from the viewpoint of the customers. A Six Sigma project aims to measure processes and reduce variation, by finding the root causes that are creating the variance and reducing/removing them. To achieve Six Sigma, a process needs to create efficiency levels of ”3.4 problems-per-million opportunities” (Pyzdek & Keller 2014, 3). (Pyzdek & Keller 2014, 3-12.)

Six Sigma terms. Within Six Sigma projects there are many other related terms some of which can be introduced later in the text. Important terms include concepts such as a *Process Owner* which is someone who is in charge of a particular part of the business or a *Process Flow* which is looking at the step by step motions that occur in any given process. (Pyzdek & Keller 2014, 213.)

Root Cause. In a process, the outcome or effect is usually pretty evident. For instance, a man drops a glass of water. What is clear from only one sentence is that a glass of water was dropped. What isn’t clear is why? What was the input that if removed would mean that the glass was not dropped? This is essentially a root cause. Did the man want to drop the glass? Was the glass poorly designed? Were his hands wet? Etc. Another way of looking at it is that, whatever outcome you are trying to create, what input in the process would have the greatest impact on whether that outcome is achieved or not? (Pyzdek & Keller 2014, 149-151.)

Customers’ Voice. In Lean Six Sigma, we are looking to achieve optimal output with minimal variation. This output is defined by the customers’ need. Therefore, the customers’ voice is basically how the customer would define the quality they require (from a product or service). How well defined the customers’ voice is, will determine how well the product or service quality can cater to their needs. (Oakland 2014, 4-16.)

Lean. Often referred to as a philosophy Lean is the pursuit towards doing more with less. The focus is on value mapping and removing wastes from the processes. (Heizer & Render 2011, 676.)

DMAIC. DMAIC is a gated project management framework used in Lean Six Sigma projects. It ensures that key aspects of a project are completed when they should be, before moving on to further steps. Each letter refers to a different part of the process. Define, Measure, Analyse, Improve and Control. (Pyzdek & Keller 2014, 213.)

Inventories. Inventories can be categorised into raw materials, work-in-progress products (in production) and finished goods. Inventories only ever refers to stock that will either be sold or used to make something that will be sold. **"**A stock of materials used to satisfy customer demand or to support the production of services or goods" ((Krajewski & al. 2007, 374).

Lead time. "The elapsed time between the receipt of a customer order and filling it" (Krajewski & al. 2007, 52).

Bottleneck. A bottleneck is a constraint caused by limited capacity in an action within a process that reduces the overall output. Whatever the process is, there will always be a bottleneck otherwise the output would be unlimited. A simple way to visualise it would be to consider a concert hall full of people wanting to leave. Only so many people can fit through the doors at one time, so whilst more people have the ability and desire to leave, they cannot. This in effect slows down the process and limits the number of people who have left the building. (Krajewski & al. 2007, 254).

Change Agent. A change agent in Six Sigma projects is responsible for communicating the mission of the project with all stakeholders. They are good communicators who can manage and promote change effectively throughout an organisation. (Pyzdek & Keller 2014, 14.)

2 Applying Lead Six Sigma to Optimise the Order Fulfilment Process

In this chapter, the topic of Lean Six Sigma will be discussed in detail with attention paid mainly to the aspects important to this project. The history of both Lean and Six Sigma will be briefly discussed and well as an overview of how and when to use the DMAIC project management framework. The various tools needed throughout this project will also be discussed in this chapter. Order fulfilment with also be discussed as the focus process and change management theory that is an important consideration when using Lean Six Sigma to effectively communicate and manage the change process.

2.1 Lean

Lean as a term or system is fairly recent but it describes a way of working that has been around far longer. In terms of trying to improve efficiency and speed up a process we could look even to the initial creation of tools and manufacturing processes that date back to the stone age (Roser 2017, 9-17). In terms of more recent times, however, Henry Ford is often seen as the starting point for the modern production line. The River Rouge production line that build the Model-T Ford car from 1913 to 1926 changed production lead times, capacity expectations and cost of production drastically by using a moving production line (with conveyor belts) and a work force tasked with doing a simple job, constantly (Oakland 2014, 305). Before this process shift towards mass production, cars were made in the so-called *craft* way, typically, by one highly skilled worker; one car at a time (Womack, Jones & Roos 1990, 24-31). One of the key turning points in the addition of the moving production line is that now whoever controls the speed of the conveyor belt, controls the speed at which work is done (Womack & al. 1990, 30). The mind of the worker was no longer needed. The difference between craft and mass production at Ford on production times was unbelievably significant. Building a complete vehicle from the premade components in autumn 1913 took 750 minutes by the following spring 1914 it took only 93 (a reduction of 88%). (Womack & al. 1990, 27.)

This model, however, had its limitations, most famously with its toleration towards customisation, summed up by the Henry Ford quote; “Any customer can have a car painted any color that he wants so long as it is black” (Ford 1922, 71).

This is the basis of the challenge that Toyota looked to solve with the Toyota Production System (TPS) (Krajewski & al. 2007, 347-348). In post war Japan, they found that the desire for customisation in their home market was very high (Pyzdek & Keller 2014, 427). In addition, Japan being an island devastated by war, there was a lack of resources such as land, finance and raw materials (Modig & Ählstöm 2017, 69-70). Eiji Toyoda and Taiichi Ohno (the fathers of the Toyota Production System) identified that this need for customisation coupled with a lack of resources, limited their ability operate with the Ford mass production model, which, required long production runs of the same product (Womack & al.1990, 48-69). With customisable products comes variations in processes. It also creates the need for changeover times in the factory, which in turn, reduce the capacity and increase the lead times. Another consideration for Toyota was in identifying, how this customisation could occur? Creating large inventories of customised products is risky. With a range of products, it becomes increasingly difficult to determine which products will have the greater appeal. These challenges were essentially the starting point of what would lead Eiji Toyoda and Taiichi Ohno towards creating the Toyota Production System from the 1950s onward (Womack & al. 1990, 48-69). The Toyota Production System was later studied in detail by Womack & al. (1990) in the book *The Machine that Change the World.* In explaining these ideas to a western audience without them thinking of this as simply a Japanese way of doing things in the car industry, but rather, a universal idea that can work anywhere, and in any industry, they referred to the techniques as "Lean Production" (Womack & al. 1990, 2). Whether or not the Toyota Production System and Lean are interchangeable terms is a much-debated topic, however, what is clear is that these reclassifications mainly serve to complicate an already complex topic (Modig & Ählstöm 2017, 82-83). When this thesis is discussing the development of Lean through Toyota's viewpoint the Toyota Production System will be used. When referring to Lean more generally then the term Lean shall be used. All of the tools and techniques of the Toyota Production System are used in Lean.

In the words of one of the founders of Lean, Taiichi Ohno "*Just get on with it and do Kaizen"* (Pyzdek & Keller 2014, 428).

2.1.1 From a Push Model to a Pull Model

Where Henry Ford had long production runs of essentially identical cars and *pushed* them onto the market based on forecasted demand; Toyota, with their need for customisation looked to the customer and waited for them to *pull* the products onto the market through the placing of orders. (Krajewski & al. 2007, 347-348.)

The move from a push method to a pull method may seem like a simple detail, but in fact, it is a seismic shift. This move from production based on forecasted demand to production based on real demand led to changes in almost all areas of the business. When a company allows a customer to begin the process of production through placing an order (pull method) two key things change. Firstly, the inventories of finished products are sharply reduced (if not entirely removed); and secondly, the lead times are greatly increased. The reduction of inventories is great news for a company, as until a product is sold, inventories are counted only as a cost, meaning; stock that for whatever reason has no demand, either needs price reductions (lowering profit margins) or it is essentially a very expensive waste. This change, therefore, can increase the profitability, decrease the costs and at the same time release valuable capital back to the company to invest in other areas. The increased lead times, however, are the key challenge to the *pull method*. The moment an order is placed, a countdown begins in terms of delivering an acceptable lead time. With a *push method*, this countdown should be very small as the pre-made products (finished inventories) would be as near to the potential customer as possible. Whereas in a *pull method*, the products are not yet made and may be on the other side of the world. (Krajewski & al. 2007, 462-466.)

Figure 2 shows this idea of the pull and push methods in relation to the so-called, decoupling point. This is the point at which the real demand (or the actual orders placed by customers), takes over from the forecasted demand. In pull methods, we see that the real demand has to meet the forecasted demand, before the final production. In push methods, the products are made, before the real demand is known. *Buy-to-order,* means that the even the materials needed for the production are not present when an order is placed. In some industries, this is taken even further and is referred to as *engineer-to-order,* which would be true in shipbuilding, for instance, or construction when the design/architectural drawings would also, not occur until an order was placed. *Make to order* is when the materials are stocked as per forecasting when orders arrive. *Assemble-to-order,* refers to when, pre-built components of the finished product are in stock, but assembly will only start after orders are placed. On the push side *make-to-stock,* would mean that finished goods are made to create inventories that can be shipped and stored close to customers and *ship-to-stock* would mean that finished goods would be made and shipped directly into a customer's inventories without inward inspections upon delivery which of course requires high levels of trust. (Lysons & Farrington 2012, 142-143.)

The key consideration in deciding where to place the decoupling point is balancing what the customer wants with what the host company wants. The customer wants the shortest lead times possible but they may also require high levels of customisation. The shorter the lead time is the greater the value and competitive advantage are. The host company by contrast, wants to have the lowest possible inventories of finished goods as they cost their profitability for every day they go unsold due to warehousing costs and if unsold, result in wasted investments. Deciding how to compete and at what cost or level of investment in inventories, therefore, is of huge strategic importance for a company. (Swink, Melnyk, Cooper and Hartley 2014, 313)

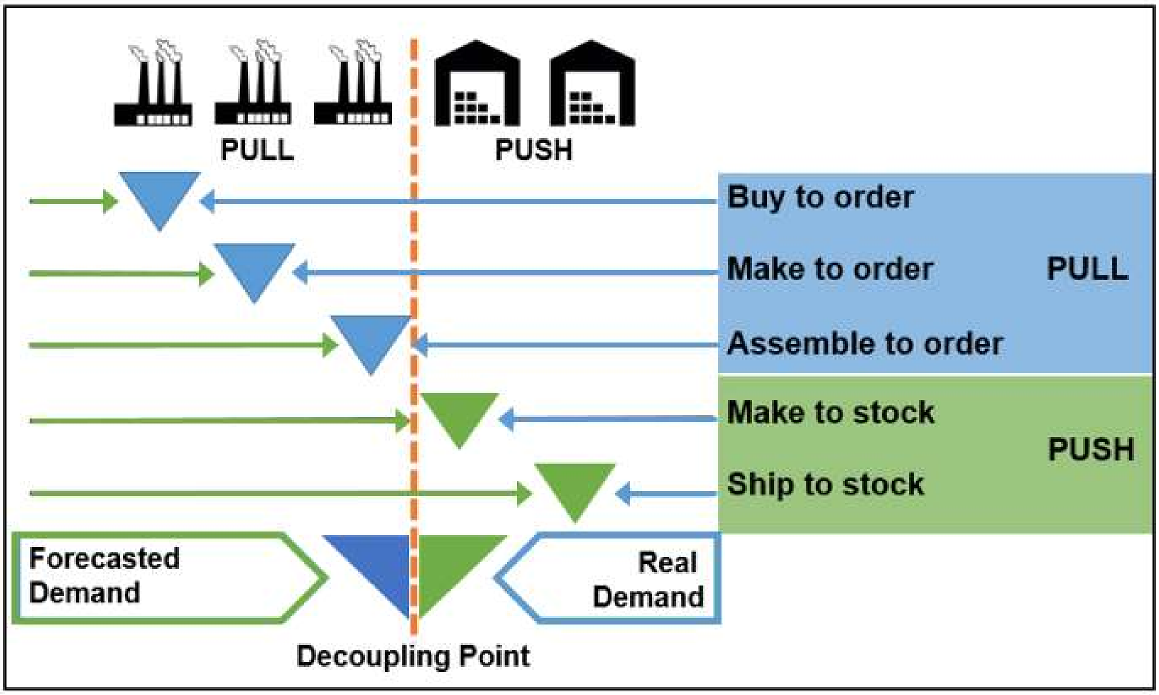

Figure 2. Decoupling Point. (Lysons & Farrington 2012, 142-143.)

So, how can a company like SEP that uses this pull method; ensure they can achieve minimal lead times with variations that are under control so that they can provide reliable delivery estimations to their customers? Essentially, this is what this thesis is looking to answer.

2.1.2 Continuous Improvement

Toyota’s route to success came from truly enabling a continuously improving work force. This means that if a worker finds a better way of doing something (hypothesis), then this idea is tested (using scientific methods). If this hypothesis is proved, then the idea is implemented and the continuous improvement process continues. This move of uniting the entire workforce behind the goal, is believed to be essential to achieving success with Lean (Modig & Åhlstöm 2017, 132-137). Without commitment from the leaders and managers, the message will not be passed onto the workforce initially and the potential changes would be ignored. Without understanding of what continuous improvement is and the critical thinking it requires on a factory level, better ways of working may go unnoticed. One of the key elements that the west didn’t grasp when they looked to develop Lean was this notion that the whole organisation should be able to visualise what is happening, what the goal is and how they can help to achieve it (Modig & Ählstöm 2017, 132-137). This greater vision, understanding and critical thinking led to another development that no defects/error created in one section of a process are not passed on to the next. This method is referred to as *quality at the source* (Krajewski & al. 2007, 350). Its use further improves visibility which aids problem solvers in reducing failure costs. (Krajewski & al. 2007, 347-348.)

2.1.3 Process Flow Chart and Value Stream Mapping

With continuous improvement and scientific methods in place Toyota began looking at their production process in a systematic way. Lean thinking looks to understand a process through creating process maps an example of which is a Process flow chart as can be seen in *Appendix 1. Process Flow Chart*. A process flow chart is used to not only show each action involved in a process but also it shows who is responsible for performing the action. A process map can take many other forms from a simple SIPOC diagram to a more complex Value Stream Map (VSM). Each type of map will have various uses for instance the thought behind the VSM is that it identifies the time in each section of a process that is adding value and the time not spent adding value. The basic SIPOC is helpful is establishing the scope of a project and can quickly visualise what is coming in to a process (and from who) and what is leaving a process (and to who). The SIPOC diagram is a great tool to begin finding the X's (inputs/causes) and their possible effects on the Y's (outputs). Figure 3 shows the basic layout of a SIPOC diagram. (George, Rowlands, Price, & Maxley 2005, 33-55.)

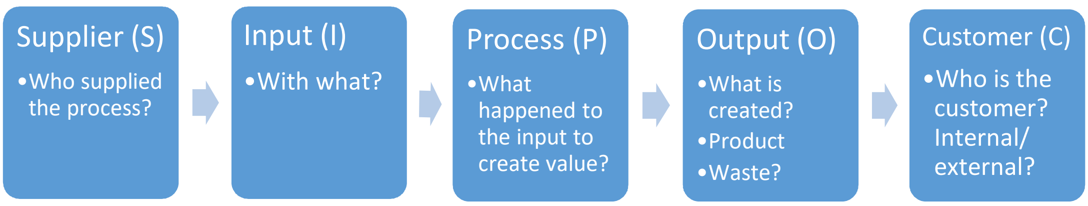

Figure 3. SIPOC diagram. (George & al. 2005, 33-55.)

According to Modig and Åhlstöm (2017, 7-21) there are two types of efficiencies. *Resource Efficiency* where a company looks at a resource and aims to get the most capacity possible from it. For instance, in the production line at Ford the moving production line made the most of their worker's time, therefore, lowered the cost in relation to the capacity. In Lean, however, efficiency isn't seen from the tools used and how well they are utilised but rather from the object passing through. In Lean, the aim is to achieve a *constant* *flow* where the unit (material, component, product or person etc.) passes through the process without stopping in one continuous motion that is continuously adding value. The key focus is on the throughput time and what percentage of that time is spent making value; known as the *Flow Efficiency*. (Modig & Åhlstöm 2017, 7-16)

In VSM each activity that makes up a process is analysed to find how much of the time spent on that activity is creating value. When all the activities have been mapped in this way a processes value creation is visible. What is also visible is the time spent creating no value (non-value-adding activity). Through the VSM a business can now see their *Flow Efficiency*. The flow in Lean is, therefore, critical as if one section of a process is highly efficient but the subsequent section is not, then a bottleneck is created and this additional efficiency in the first section is wasted. (Modig & Åhlstöm 2017, 8-40)

Value can only be determined by the customer. Value, however, is intangible. Person X and Person Y view value as something different and they perceive value in certain goods better than they do in other goods. Take for instance a person obsessed with sailing. They would understand every detail of value and features in a top of the range boat over the lower cost boat. When it came to a hockey stick though, they might not see it. Developing a product for someone who doesn’t notice the subtleties of it is totally different to making a product for an expert. This is just one example of customer segments, but the point is, that in order to define what a product should be, a customer must be defined and preferably consulted. Making a range of different products is one thing, but if they are determined by designers inside the company, still with the idea of making what they think they ought to make, then this isn’t actually capturing a potential customers’ version of value; rather is it creating unneeded variation. (Womack & Jones 2003, 16-19)

2.1.4 Just-in-Time Internal Processes

In order to achieve this constant flow Toyota’s thinking workforce developed the philosophy of *just-in-time (JIT)*. With the shift to a *pull method* the pressure of ensuring timeliness increases drastically as seen in the priority placed on the flows of production (Womack & Jones, 2003, 349). Now that orders begin the process of production, any delay in starting this process increases the lead time, and so; Toyota’s obsession with waste begins to take shape. If they produce even one more car than they need on an order; the lead time of that order and all the orders that follow it, increases by the amount of time it took to make that last car. That production even though it resulted in a product, is therefore, a waste (*overproduction waste*). If the production line takes too long to change, from making one product to another, it results in *waiting* that can be seen as wasting time (which again leads to increased lead times). What Toyota needed, therefore, was to produce just the right amount of a product, at just the right time and they needed to ensure that nothing would jeopardise their ability to do so. (Oakland 2014, 79-80.)

Just-in-time in an internal sense, looks to streamline the production process by removing things that are not needed (wastes). So rather than cluttering a work area with tools or components that are not being used, it ensures that only what is currently needed for that production process, is present. The processes that lead to the creation of the final products, should be assessed, to ensure a constant flow of production with bottlenecks analysed, and their impacts minimised. In addition, much like the pit teams in car racing and the standardised approach to changing from tire to another tire; factories need to change the production, from one product to another product, in as fast, and seamless a way as possible. This requirement to change at speed and only produce just the right amount of a product, led Toyota to develop the *Kanban* system. (Oakland, 79-80)

2.1.5 Kanban

Kanban is a system that is used to *pull* parts or components into the production area. As mentioned previously, this shift in allowing the customers to *pull* products into production has a knock-on effect, that changes the way a business operates. (Oakland 2014, 81.)

In a company using a *push method,* they forecast the demand of a product and then, by using the bill of materials for that product (a list of all the materials or components that go into making a product), they can order the right quantities from suppliers. Then, when the production day of those products arrives the materials are sent, as per the forecast and bill of materials, to the production line. (Oakland 2014, 81.)

Without forecasts, how did Toyota know what they would need to order from suppliers or what materials or components they would need on the production line? Toyota developed a process by which, every material and component is stored in its own box. This box depending on the material, has a defined volume (as small as possible). If a box's volume is lower than it should be, then more materials/components should be brought to replace what has been used. This way, with no time is wasted in someone asking for a particular item, a communication process was made in which the production line essentially ordered this item. In developing *Kanban*, Toyota created a solution to ensuring that just the right amount of materials and components are present at the production line. (Oakland 2014, 81.)

2.1.6 Just-in-Time Supply Chain Approach

Internal changes, however, are only the beginning of this shift towards JIT. This story of the *pull method* and its journey from the customer doesn't stop in the factory. Picture the perfect factory with every process in place to ensure a *constant flow* of production. They have *Kanban* operational; but the neat little boxes are empty. Such a situation would lead to huge amounts of wasted resources and potentially lost orders and customer trust. The final hurdle in this story of Lean is, therefore: *How to ensure the suppliers can follow the same mission*? (Womack & al. 1990, 141-171)

One great way of visualising this journey of how Just-in-time flows through a supply chain can be seen in Figure 4.

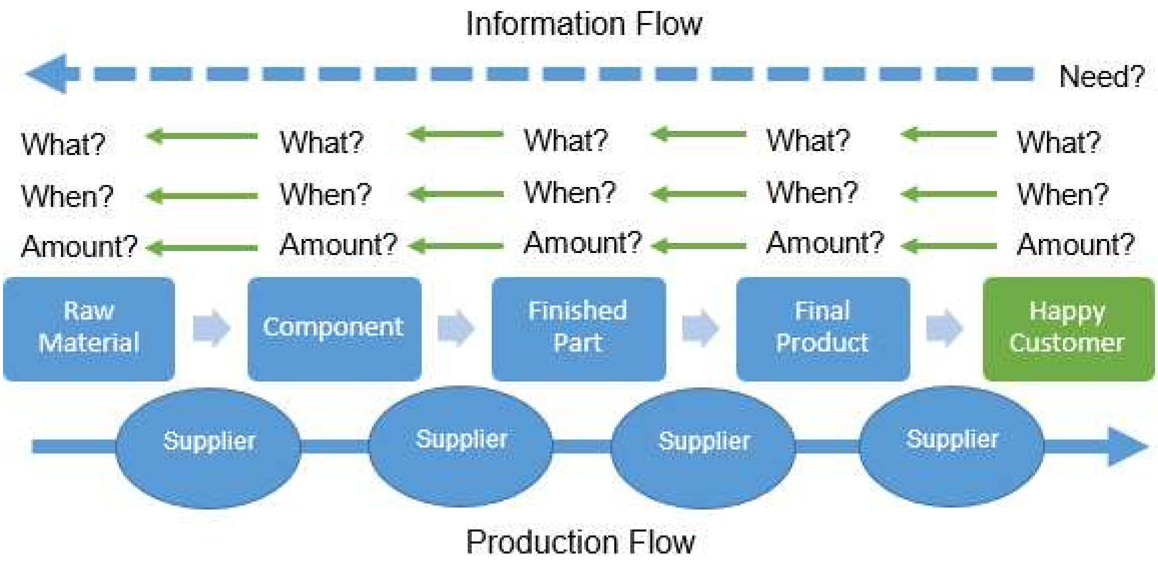

Figure 4. JIT supply chain view (Modig & Åhlstöm 2017, 71).

In *Kanban*, Toyota ensured that the production line could operate with minimal stock that was refreshed, *Just-in-time*. They now needed to ensure that suppliers were both willing and able to replenish their stocks in a similar way. They also needed to ensure that the customers' *Need* was achieved though their JIT strategy. A customer's *Need* is satisfied in the right products (the *What?*), at the right time (the *When?*) and the right quantity (the *Amount?)* (Figure 4). Essentially, in order to meet the *Need* of their customers, Toyota needed suppliers that were more like co-producers (Oakland 2014, 81). In order to build this deep and trusting bond they needed to form long-term relationships and they had to bring suppliers closer so that they could understand the strategy. In order for *JIT* to work efficiently, it requires suppliers to be positioned as close as possible to the production facilities of the buying company. These suppliers need to be able to supply the factory with small orders regularly (often multiple times a day). In addition, anything that can make the process more efficient such as supplying materials or components in the same batch sizes as those of the Kanban system the purchasing company is using are essential improvements. In this way, Toyota could ensure a *constant flow* of production to maximise their capacity whilst putting the customer first. (Oakland 2014, 81-82.)

2.1.7 The 7 Wastes

Already in this study, we have looked at many of the *wastes* that a Lean system looks to consider. It is important though, to mention this concept in more detail as they are central to the Lean approach. There are generally considered to be *7 wastes* (also referred to as *Muda*) in Lean as shown in Figure 5. In these 7 wastes, we can see that some wastes are very familiar such as overproduction which in turn contributes to most of the other wastes (such as inventories, unneeded movement of goods and defects). Waiting wastes are caused by bottlenecks and not ensuring a *constant flow* of work throughout a process. Unnecessary processing refers to products or services that have elements that are superfluous to customer requirements. This means that the added value could be removed without impacting on the customers perceived quality. Unnecessary movement of people refers to any movement of a worker that is not improving their ability to add value. This non-value activity, however minor is a waste of time and, therefore, needlessly reduces the efficiency of their activity.

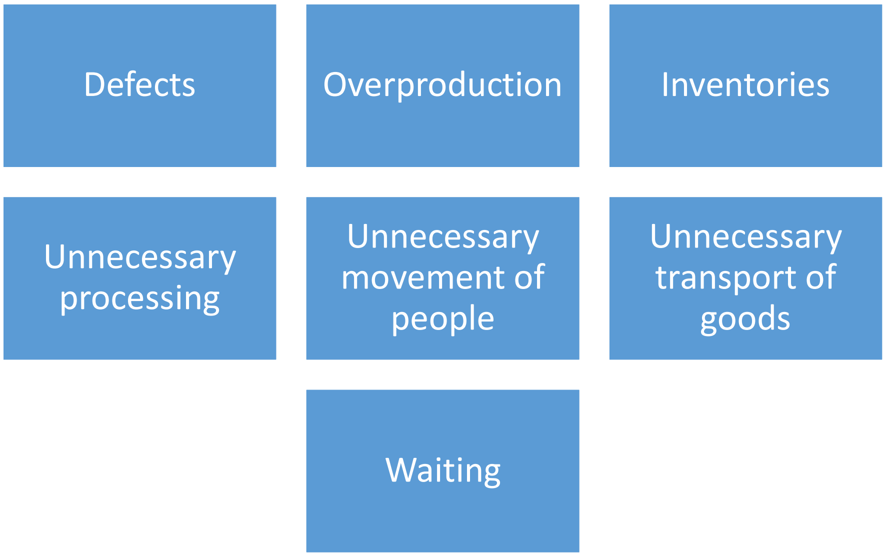

Figure 5. The 7 Wastes of Lean (Pyzdek & Keller 2014, 428)

In 2014, Taiichi Ohno (the father of the Toyota Production System) stated that, in fact, there are not seven wastes and he felt he had been misinterpreted.

> *"There's an old expression: "He without bad habits has seven," meaning if you think you have no waste you will find at least seven types. So I came up with over production, waiting, etc., but that doesn't mean there are only seven types. So don't bother thinking about "what type of waste is this?" Just get on with it and do Kaizen"* (Pyzdek & Keller 2014, 428).

Whether there are seven wastes or eight as Womack and Jones stated (2008, 355), therefore, is not really important. What is important, is this way of thinking that we should open our understanding to what could be considered as waste. Through this view of waste, we get a deeper understanding of the ideas behind Lean.

2.1.8 Kaizen

Kaizen much like a lot of things within the Lean philosophy can refer to a number of things. It means Kai – action towards; and Zen – the better (Oakland 2014, 319). It can be seen as a continuous improvement philosophy in which workers are empowered to implement improvement ideas that lead to the constant improvement of processes (Oakland 2014, 319). It also refers to Kaizen teams or quality circles that are small teams that concentrate on improving specific tasks that they are operational in (Oakland 2014, 348). Finally, it can be used to refer to Kaizen Blitz or Kaizen DMAIC which are short intensive projects undertaken by kaizen teams over a short period of time (typically 3-5 days) to improve a small and well-defined activity (George, Rowlands, Price & Maxey 2005, 20-25). The task is to challenge the current way of performing the activity and trying out new ideas that might improve it. (Oakland 2014, 319.)

Kaizen is the aspect of Lean that western companies often overlooked when they tried to replicate the tools used in the Toyota Production System and tried to bring them into their own organisations. While the concepts of just-in-time and 5S or Kanban were understood the philosophy behind these tools was lost. Kaizen is the continuous improvement idea that unites the organisation from top to bottom in order to improve. (Modig & Åhlström 2017, 128-145)

2.1.9 The Deming Cycle of Continuous Improvement

One framework used for structuring Lean projects in order to promote this continuous improvement focus is the Deming cycle. The Deming Cycle is a problem-solving tool whereby the end of the previous cycle leads to the opening of a new cycle (Krajewski & al.

2007, 212-213). Six Sigma's DMAIC model is based on Deming's original *Plan, Do, Check, Act (PDCA) cycle* and the two models have been compared in Figure 6 (page 22). (Oakland 2014, 296).

The *Plan* stage in the Deming cycle starts with selecting the process which is to be improved and then documents a plan (Krajewski & al. 2007, 212). This fits well with the *Define* stage of a DMAIC project in which a plan is formed and documented in a project charter (George & al. 2005, 4-7). What also occurs in the *Plan* stage is collecting data, analysing it and setting metrics by which the improvements will be compared (Krajewski & al. 2007, 212). This in Six Sigma DMAIC projects would be seen as the *Measure* phase and the *analyse* phase which is trying to pinpoint the root cause and assess if its effect is tied to the project goals (George & al. 2005, 8-14). The *Analyse* phase of Six Sigma takes the project over into the *Do,* of the Deming cycle as this testing of cause and effect further leads towards improvement ideas and validates them with a concrete data driven approach (George & al. 2005, 12-14). The *Do* phase of the Deming cycle is implementing the plan and monitoring the results, improving the ideas if needed (Krajewski & al. 2007, 212). The *Improve* fits very well into this definition of the *Do* phase of the Deming cycle (George & al. 2005, 14-16). It could also still be seen to have elements of the *Plan* phase as there is still the process of evaluating solutions but this is more of a difference in the approach of Six Sigma which is so heavily data-driven (George & al. 2005, 14-16). The *Check* phase is looking to review the data collected over the *Do* and to assess how well the performance fits the goal made in the *Plan* phase (Krajewski & al. 2007, 212). In Six Sigma, this would occur in both the Improve phase (prior to full implementation of the improvement) when small changes are made to optimise the process and the *Control* phase where the process is set and the before and after data is assessed (George & al. 2005, 14-16). Lastly the Act phase of the Deming Cycle the changes made are finalised and become standardised (Krajewski & al. 2007, 212). This is also part of the Control phase of a Six Sigma project where the gains of a project are maintained and plans for future review are made (George & al. 2005, 17-19).

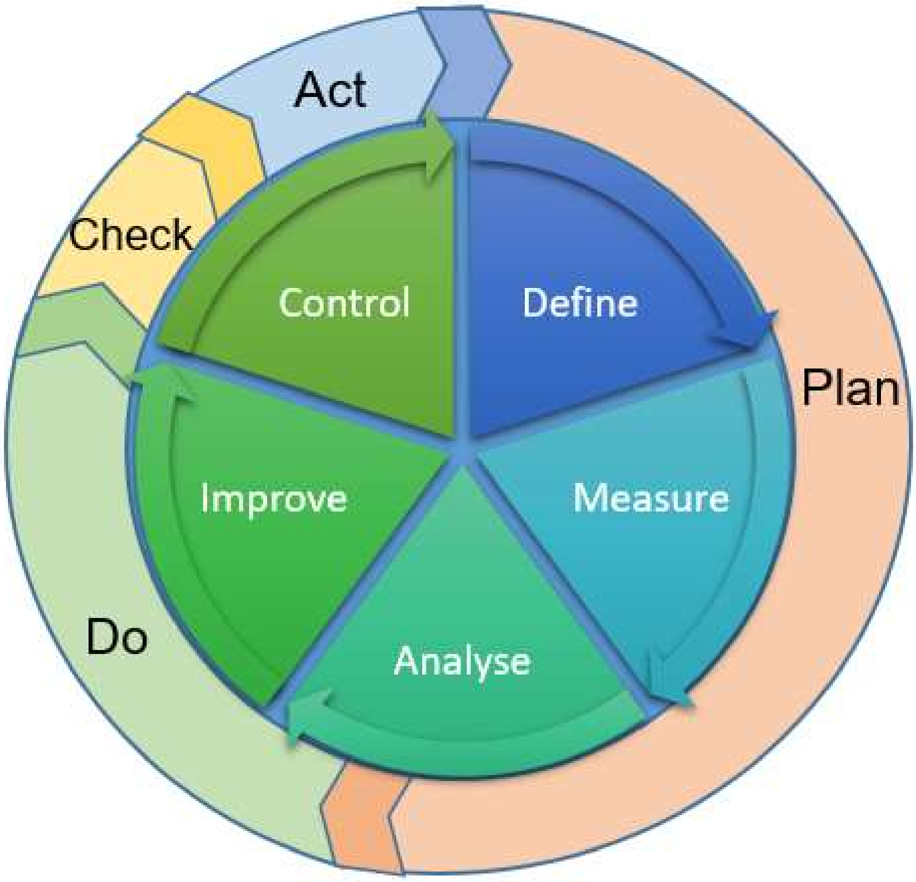

Figure 6. Deming Cycle and DMAIC model overlapped. (Krajewski & al. 2007, 212; George & al. 2005, 17-19.)

2.1.10 Pareto Chart Analysis

Pareto charts are useful to Lean Six Sigma projects as they can be used to identify root causes or to guide projects towards the aspects of most interest to customers. A pareto chart is similar in appearance to a histogram but rather than a continuous scale the pareto chart has categories that are arranged in order of their frequency or level of impact. A percentage line is added to the chart to show a cumulative percentage of the results after each bar of the chart. The idea is that if there is a clear need for prioritisation then roughly 80% of the results will occur in 20% of the available outcomes. This would indicate that there is a so called *clear pareto effect*. (George & al. 2005, 142-144)

2.2 Six Sigma

So why Six Sigma and what is its link to Lean? Both Lean and Six Sigma are looking to improve the performance of a process and both use continuous improvement thinking to achieve this aim. Where they differ, however, is that while Lean looks to remove wastes; Six Sigma looks to assess and reduce variation as seen in Figure 7. (Oakland 2014, 308)

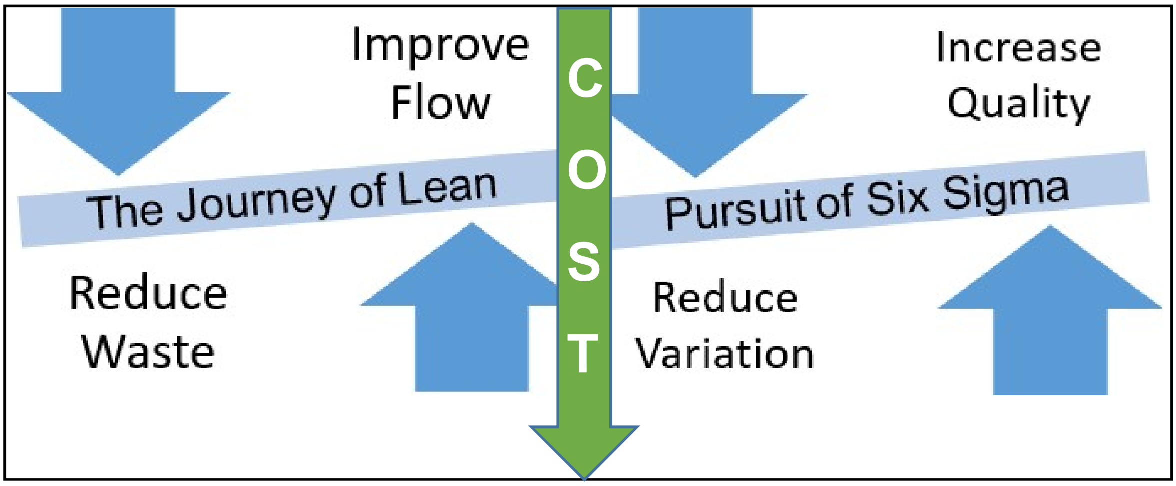

Figure 7. The Relationship of Lean and Six Sigma.

The history of Six Sigma is shorter than that of Lean. In the 1970's a Japanese company purchased a factory from the Motorola company and with the same employees and equipment they managed to cut defects drastically while at the same time reducing costs (Pyzdek & Keller 2014, 4). This was of course an embarrassing moment for Motorola and one that led them by the mid 80's on the pursuit of Six Sigma. (Pyzdek & Keller 2014, 4.)

2.2.1 Six Sigma the Maths

Six Sigma is many things but first, let's deal with the maths. Sigma or σ is a Greek letter that is used to symbolise standard deviation. Standard deviation is the square root of the variance. We establish this variance by calculating the mean of a dataset and assessing each outcomes distance from that mean. (Pyzdek & Keller 2014, 302-303.)

To clarify this idea using an example, imagine a pizza company that are trying to improve customer satisfaction by ensuring customers don't have to wait too long for their pizza. The goal (or specification) is to deliver the pizza in 30 minutes. The pizza company start by tracking their delivery times on a time series plot (run chart). (George & al. 2005, 119-122.)

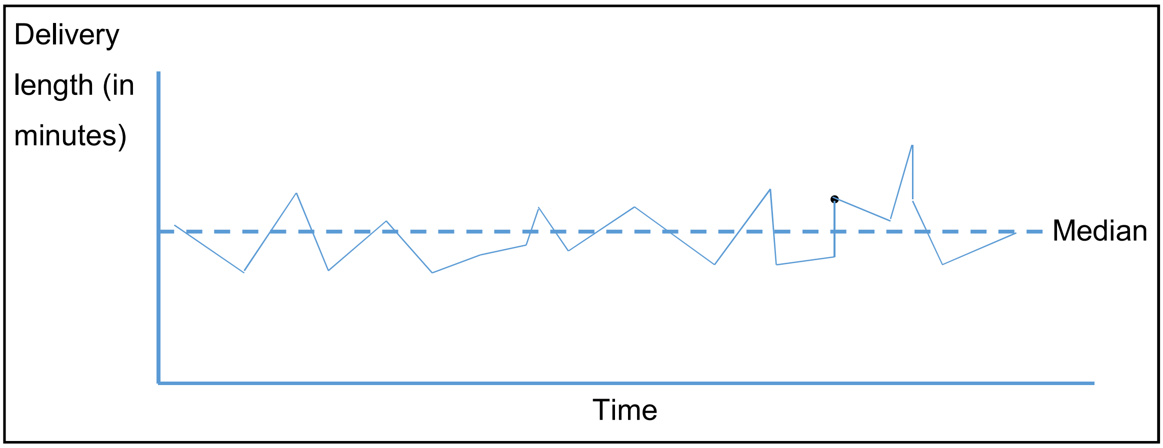

Figure 8. Simplified example of a run chart. (George & al. 2005, 119-122.)

Figure 8 shows a run chart, on which, all of the delivery times were monitored over the course of a day. The dotted line is used to represent the goal that they set to have the deliveries out in 30 minutes.

For simplification purposes, we will say the total deliveries taken was 10 which would be the population of the results. This would mean that we can use standard deviation of a population equation to understand the variance in this process. Standard deviation equation can be seen in Figure 8. (George & al. 2005, 109-110.)

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \mu)^2}{N}}$$

Figure 9. Standard deviation of a population equation. (George & al. 2005,109-110.)

The author has created a breakdown of this equation in to smaller steps can be seen in Figures 10 – 13 starting with calculating the mean (μ).

$$\frac{24 + 35 + 31 + 26 + 34 + 29 + 30 + 24 + 39 + 21}{10} = 29.3$$

Figure 10. Mean calculation of pizza delivery times

Now the average time for delivering the pizzas is known and is slightly lower than the goal. What is not known is how well this process is under control. For instance, the average of 49, 50 and 51 is 50 but so is the average of 0, 100 and 50. The average, therefore, cannot tell us whether the pizza delivery times are close to the target or not. Next the variance is calculated by subtracting the mean from the individual results and squaring them as seen in Figure 11.

$$(X_i - \mu)^2 = 24 - 29.3 = -5.3^2 = 28.09\ etc.$$

Figure 11. Step one in finding the variance. (George & al. 2005,109-110.)

The mean (μ) of these squared numbers gives the variance (28.81) as seen in Figure 12.

$$\frac{28.09 + 32.49 + 2.89 + 10.89 + 22.09 + 0.09 + 0.49 + 28.09 + 94.09 + 68.89}{10} = \frac{288.1}{10} = 28.81$$

Figure 12. Step two in finding the variance.

Finally, the square root of the variance (28.81) gives the standard deviation or sigma (σ) as seen in Figure 13.

$$\sqrt{28.81} = 5.37\ (rounded)$$

Figure 13. Calculating the standard deviation

Now the pizza company knows that each of their delivery times tend to be within 5.37 minutes of their goal of 30 minutes (George & al. 2005,109). By knowing this they can then apply *control limits* either side of the mean (*upper control limit* (UCL) and *lower control limit*) to monitor how in control the process is over time. The upper control limit is placed at +3 standard deviation above the mean. The lower control limit is placed at -3 standard deviation from the mean. They then plot the delivery times again with these control limits in place as shown in Figure 14 (page 26). (George & al. 2005, 122.)

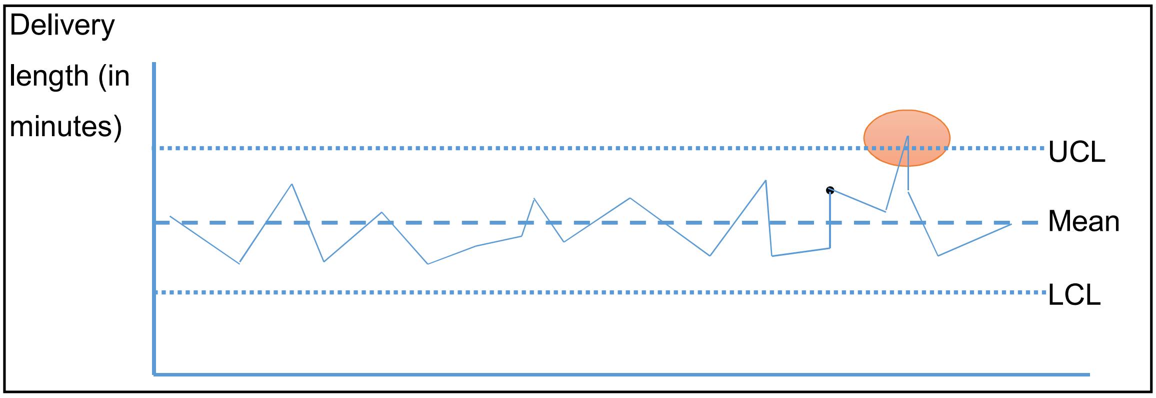

Figure 14. Simplified example of a control chart. (George & al. 2005, 122.)

The process in Figure 14 was overall within the control limits. The highlighted exception is something that is referred to as a *Special Cause.* A *special cause* variation would indicate that the process is out of control and this occurrence would need analysing to find out why it occurred and crucially what could stop it from reoccurring. The variation within the limits is referred to as *Common Cause* variation. While this variation is in control it doesn't mean, it should be accepted. So why wouldn't this variation be accepted? Take for example the result from the data set analysed in Figures 7-13 about the pizza delivery times. If the pizza company took three standard deviation plus and minus from the mean and accepted variation in that field as seen in Figure 15. (George & al. 2005, 118.)

$$Mean\ (\mu) = 29.3$$

$$Standard\ Deviation\ (\sigma) = 5.37$$

$$3\ Sigma\ or\ 3\ Standard\ Deviations\ (3\sigma) = 5.37 \times 3 = 16.11$$

$$Lower\ Control\ Limit = \mu - 3\sigma = 29.3 - 16.11 = 13.19$$

$$Upper\ Control\ Limit = \mu + 3\sigma = 29.3 + 16.11 = 45.41$$

Figure 15. Calculations of the upper and lower control limits. (George & al. 2005, 118.)

If then the pizza company accepted their current variation and made the upper and lower control limits in Figure 15 their specification limits (range of acceptable quality) they would accept variations of 32.22 minutes (upper control limit – lower control limit). This range, however, is created by the process (voice of the process). The crucial question would be: Are their customers willing to accept this? Their customer specification (voice of the customer) might state that only a 10-minute variation is acceptable. (George & al. 2005, 117-135.)

If the upper limit and the lower limit as shown in Figure 15 did become the specification range and they managed to stay in control of it; then the pizza company will have achieved Three Sigma. Three Sigma can be seen on in Figure 16 as the area between -3 and +3 sigma. Under normal distribution as this bell curve is indicating 99.73% of the opportunities would result in a success. Meaning a defect rate of only 0.27%. (Pyzdek & Keller 2014, 8-9.)

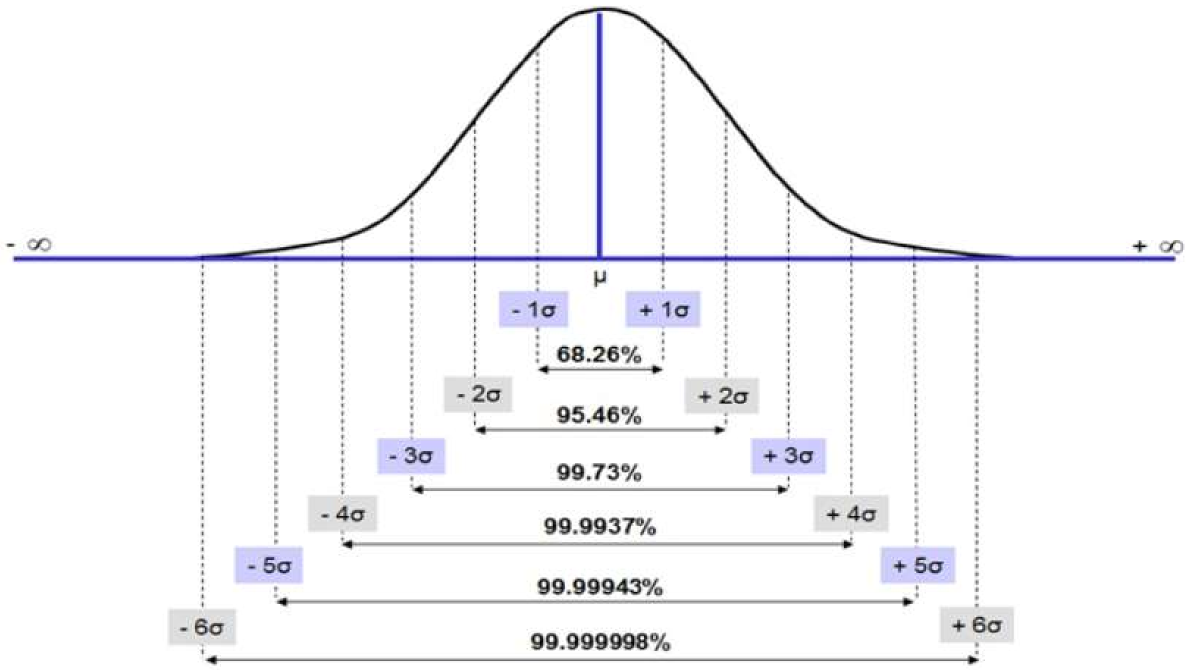

Figure 16. Six Sigma: Normal Distribution. (International Six Sigma Institute 2017)

This example shows the traditional approach to controlling variation in a process, using Three Sigma Performance. In Three Sigma, a process was defined as "capable if the processes natural spread, plus and minus 3 sigma, was less than the engineering tolerance" (Pyzdek & Keller 2014, 8). Engineering tolerance here refers to the range of acceptance. Three Sigma creates a process with very low defect rates of 2700 parts-per-million (PPM). (Pyzdek & Keller 2014, 8-9.)

2.2.2 Six Sigma the Goal

So why the need to push to greater Sigma levels? There are two key reasons for the drive towards Six Sigma efficiency. Firstly, this example shown takes into account a process with one step. In complex processes, however, this is simply not the case. For every additional step the variation of each step would have to be multiplied before the square root of this was taken (that creates the standard deviation). This means that as processes grow in complication Three Sigma standards might no longer meet customer expectations. (Pyzdek & Keller 2014, 3-9)

For example, according to Pyzdek and Keller (2014, 9) Three sigma quality control would lead to "10,800,000 mishandled healthcare claims every year" and practically all modern computers would not function. Achieving Six Sigma requires the variation to be squeezed so close to the mean that the customer/process specification is six standard deviations plus and minus from the mean which would create only "3.4 problems-per-million opportunities" (Pyzdek & Keller 2014, 3).

Six Sigma from this perspective can be seen as a goal to reduce variation to an incredibly low value. While all this math might have people running to the hills in fear; using Six Sigma does not require mathematicians but rather content experts, who are hands-on and driven to see improvements through (Pyzdek & Keller 2014, 31).

So far, we have *Six Sigma the maths* and *Six Sigma the goal* but this is only part of what Six Sigma can offer. Six Sigma views quality differently to the conventional meaning. The traditional thinking would state that quality is how well a good or service conforms to the specification. In Six Sigma, however, the view is more in line with Lean thinking. Quality is "the value added by a productive endeavour" (Pyzdek & Keller 2014, 4). Like with Lean when using VSM uncovered the length of time that was used adding value against the time spent not adding value; Six Sigma looks to identify the total value that can be captured per input and judges that alongside the current value captured per input. This difference between these two is, therefore, wasted potential value. (Pyzdek & Keller 2014, 4-5.)

2.2.3 The Search for Root Causes

One way in which this idea is often represented is in the equation $Y = f(X)$ (George 2003, 21). Y is the output or the effect and X is the input or the cause, while f, is function of X and could be thought of as the process itself. In the real world, a process would usually require more than one input so the equation would look more like this one: $Y = f(X_1, X_2, X_3 \ldots)$. In many processes, there is also likely to be levels of activities within a process (sub-processes and sub-sub-processes). The Y in these equations would be seen as the *Big* Y. In the sub-processes, there would also be so called *Little Y's* that are an intermediate indicator of root cause $X's$. In this sense, it is possible for us to think of the very top level Y to be the company strategy at a senior leadership level. A flow down of this can be seen in Figure 17. (Pyzdek & Keller 2014, 150-153.)

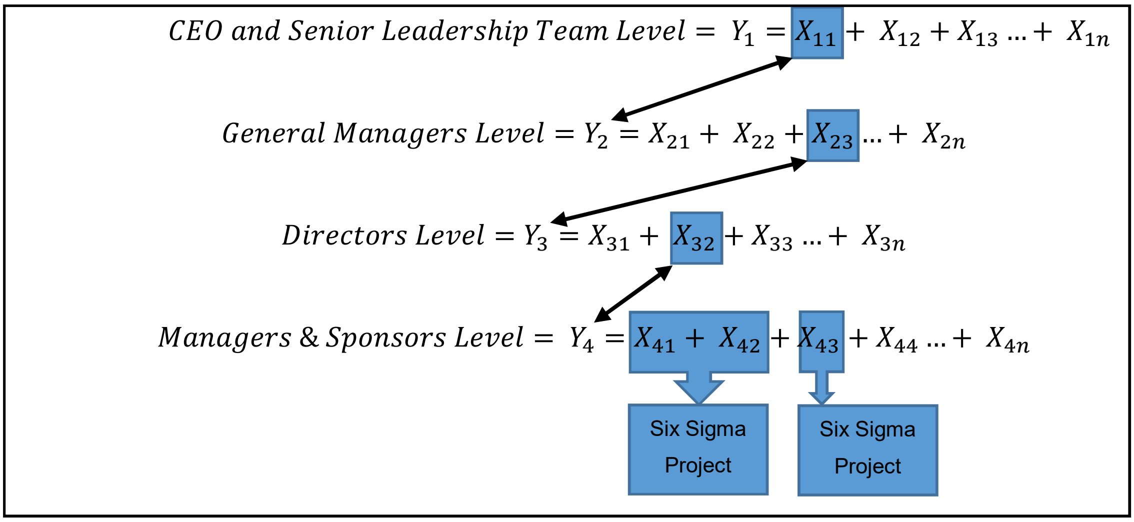

Figure 17. Flow down of Y’s and X’s from Strategy to Six Sigma Projects ((Pyzdek & Keller 2014, 152).

To interpret Figure 17, we might say that the top-level (big) Y would refer to Customer Satisfaction. The X’s would include the product, service, price, reliability etc. Any one of those top-level X’s could then be used as a lower level (little) Y and so on. (Pyzdek & Keller 2014, 148-153.)

Six Sigma is then used to analyse these lower level X’s (root causes). What these root causes will be, depends on the problems being faced in the process and the future definition of the process (based on customer specifications). If the desire is to decrease variation, then the root cause $X's$ would be the inputs (and the associated activities) that have the greatest impact on variation etc. (George 2003, 22)

This idea of identifying root causes through using statistical data requires a systematic approach. In Lean Six Sigma, there are various continuous improvement models available but for the scope of this project the DMAIC process will be used.

2.2.4 DMAIC Process

As mentioned previously the DMAIC model is a well-structured approach, based on the Deming’s Cycle (Oakland 2014, 296). Figure 18 (page 30) highlights each of the DMAIC stages and the different data collections needed in order to proceed with a DMAIC project.

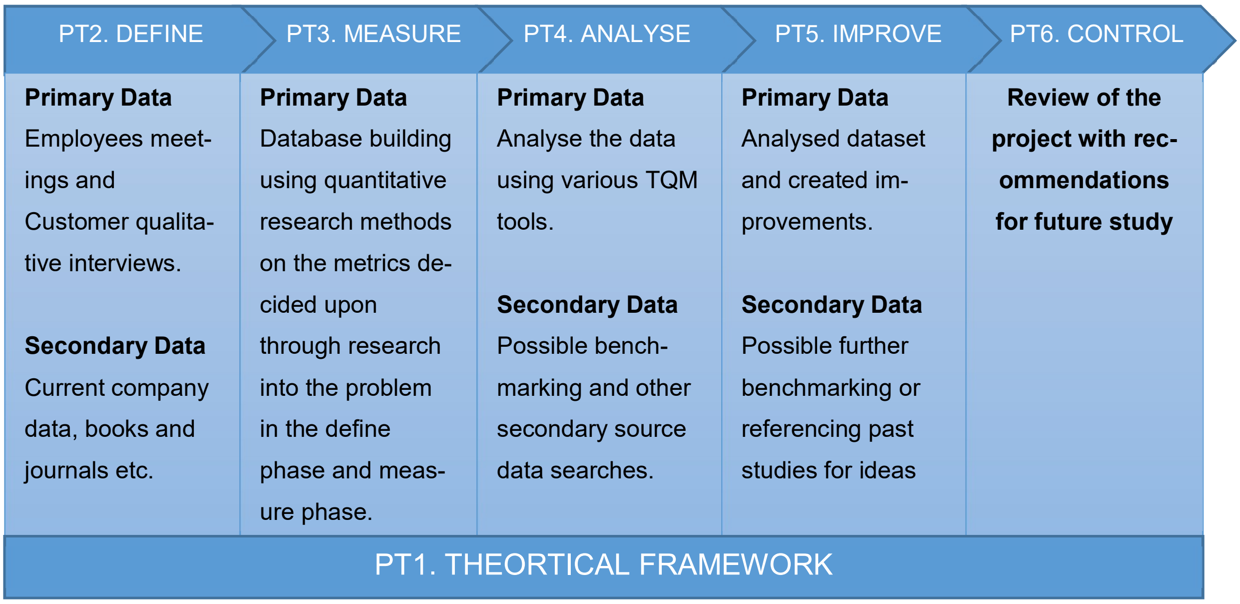

Figure 18. DMAIC process overview including data collection methods

DMAIC is a gated system which means that completion of one phase is needed in order to progress into the subsequent phase. The details of what each section of the process is aiming to achieve will be discussed in the introductions to each phase in Chapter 3. DMAIC has been used for this project as it is considered to be the best way to structure a Lean Six Sigma project that focuses on identifying an unidentified root cause in an operational process. (Pyzdek & Keller 2014, 213.)

2.2.5 Six Sigma Teams

When it comes to the *who* aspect of a project, Six Sigma differs from Lean's approach. In Kaizen projects, the teams were built of workers who have a strong understanding of the activity being developed. In Six Sigma, the team building is quite different here a more hierarchal form is used. The reason being that Six Sigma even more so that in Lean requires support from all levels of an organisation. (Pyzdek & Keller 2014, 21-37.)

Six Sigma projects are based on studying how a company can achieve their strategic goals. Without the project creators aligning with the strategy makers, projects might be created that fail to push the company in the direction that they are trying to move in. This of course leads to huge amounts of wasted resources. Pyzdek & Keller (2014, 23-26) identify twelve levels in the Six Sigma hierarchy but for simplification Table 3 (page 31) shows the core areas.

Table 3. Six Sigma Hierarchy (Pyzdek & Keller 2014, 23-26)

Six Sigma Leadership levels	Creates the strategies, develops the culture and manages the resources and targets.
Master Black Belt	A full-time change agent tasked with overseeing crucial projects and offering support, training and guidance on Six Sigma.
Black Belt	Leads projects that have a high impact or strong change potential.
Green Belt	Brings projects forward for implementation and leads projects at a local level.
Yellow Belt / Six Sigma Improvement Teams	Works on projects to deliver tangible results and identifies candidates for projects

In addition to these levels, there are various roles outside of the projects that look to promote Six Sigma and the changes that are brought about through the projects. Project sponsors, for instance, are crucial. They are the overseer of a particular project and they are ultimately responsible for its outcomes. Typically, they are the owners of the process that is being improved. However, in this project the work will be done solely by the author. (Pyzdek & Keller 2014, 26)

2.3 Order Fulfilment

The order fulfilment process is referred to in many ways, depending on what elements it includes. It can be measured as the *order cycle time* which is more of a general term without a defined start and end point. It can be referred to as the *order-to-cash (OTC) cycle (includes invoicing and payment)* or the *order-to-delivery (OTD) cycle (not including invoicing and payment)* (APICS 2017, 3-48). The reason for these varying terms is due to the vastness of the order fulfilment process. It can contain request for quotations, order placement, order processing, sourcing, manufacturing, warehousing, picking, packing, shipping and in OTC cycles the invoicing and payment processes (APICS 2017, 3-48). The order fulfilment process can be seen in greater detail in Figure 19 (page 32).

Stage 1 Order Transmittal

- Customer sends a requst for quotation and price is quoted

Stage 2 Order Processing

- Customer places an order
- The order is recieved and processed in the system
- Inventory reserved/extra stock sourced
- Inventory reserved for order and production date booked
- Picking of product BOM (Bill of Materials)
- Production
- Storage in post-production, book for delivery
- Orders consolidated for freight and warehouse picking
- Plan and build loads
- Route shipments
- Use routing guide to select carriers and rate shipments

Stage 3 Order Picking and Packing

- Pick reserved finished products
- Load vehicle and create shipping documents

Stage 4 Order Delivery

- Recieve and verify product order at customer site

Figure 19. Order Cycle Stages in the Order Fulfilment Process (APICS 2017, 37).

For the purpose of this thesis, many of these aspects are actually out of scope as they are outsourced. In terms of the host company, aspects of customer service are managed via another company, manufacturing is outsourced and the logistics is handled by a logistics service provider. In this case, we are not then looking at the lower level actions in such great detail but rather we are looking to answer where and to what extent is variation occurring. Stage 1 of Figure 19 is quite crucial; in this starting point the focal company and the customer create the agreements regarding the level of service provided and the expectations related to quality and timely delivery. This sets the standards that this project is looking to measure against. In Stage 2, the customer order is placed with SEP via an ERP system. This order information is shared with the manufacturing company who will arrange sourcing and inventory allocation as well as the booking of the production date and time. The picking of materials for production, production and post-production storage and preparation for outbound delivery is handled by the manufacturing company and they arrange the first section of the journey from the factory, to an international airport located in Asia. They actually outsource this to a local logistics service provider. The manufacturing company inform SEP before the goods leave the factory so that SEP can begin arranging the next leg of the journey, from the international airport located in Asia, through an airport located in Europe, and on to the final customers throughout Europe. A detailed view of this can be seen in Appendix 1 which shows a process flow chart of this described journey.

The order fulfilment process can be thought of as a chain. If we change one link, it will alter the behaviour of the links that follow. Fixing a problem in the beginning of the chain, may pass the problem down the chain; moving the bottleneck to the next activity, that has capacity lower than the volumes passing through it. Therefore, capacities throughout the process must be taken into account. (Pyzdek & Keller 2014, 179-194.)

Another key consideration for order fulfilment is the strategy and the structural set up of a company's supply chain; this was discussed in Chapter 2.1.1 (page 12). The key considerations here are "what are the customers' needs? and "how can the company best service these needs whilst trying to achieve the greatest profits?". Where the decoupling point is placed, is of huge strategic importance to a company as it defines their strategy of how they will get goods to market. The traditional way of thinking about strategic decisions related to supply chains are referred to as *Hard Objectives* (Harrision, Hoek & Skipworth 2014, 18-20). These can be seen as a triangle like in Figure 20.

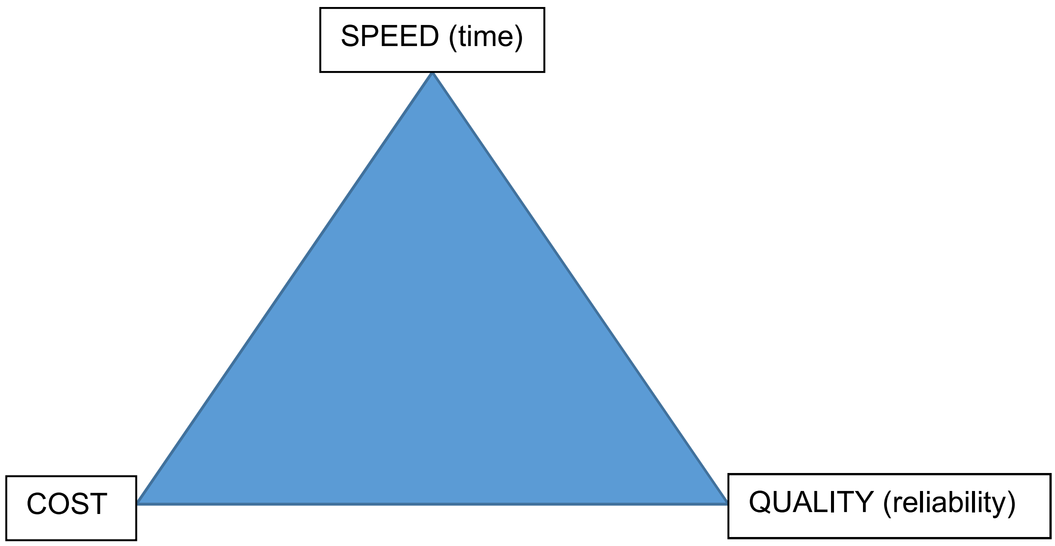

Figure 20. Hard Objectives Triangle. (Harrision & al. 2014, 18-20)

The idea of these three objectives, is that they enable the company to compete through their supply chain set up. This isn't to say that a company that pushes for quality, won't be interested in the cost or speed factors but rather, their key concern is in achieving high quality. For a company wanting to compete on quality, the supply chain performance must be designed in a way that can eliminate defects or errors from occurring. This company is creating value through reliability, and customers who are looking to mitigate the risks of poor quality, defects or delayed goods, will be drawn to such an offering. Supply chains that are designed for speed are looking to minimise lead times. For goods that are available in stores (*make-to-stock* and *ship-to-stock*), the lead time from store to customer should be zero, and so for these types of businesses speed would be a requirement, not an advantage. If we go one step back from the store, however, to the suppliers of these products, then even though they sell the same goods they might gain an advantage by competing on speed. Looking back at Figure 2 (page 14), the decoupling point placement for a company aiming to be fast, should be a far forward as their forecasting accuracy will allow. This, however, is of course reliant on the competitive environment. If the competitors all *make-to-order,* then shifting to *assemble-to-order,* would already be a big step forward in terms of speed. A manufacturer who supplies a supermarket with food products, will be very concerned with the lead times, and competing on this could be a very viable strategy alongside a cost strategy, for instance. In the car manufacturing industry, speed and reliability, could be an essential balance for their supply chains. It could be argued that cost is a key element in all supply chain strategies and, of course this is true, however, if a company prioritises cost over quality and speed their strategy will be very different. Prioritising cost over quality, would mean that company's first concern would be placed on driving down the logistics costs. This type of company might make a decision to not hold inventories removing the costs of warehousing; but increasing the lead times and the risk of variability in the lead times. So, while a company can try to achieve a balanced approach, this might leave them slightly lost, as they wouldn't achieve the cheapest prices or be the most reliable or the quickest. Therefore, traditional thinking here would say that prioritisation is important on these factors. (Harrision & al. 2014 18-20.)

In addition to these hard objectives, are supportive capabilities such as controlling variability so that performance is constant and reliable. This supportive capability is crucial to quality and speed strategies, as nether speed, nor quality, are desirable if they are not also repeatable. If a customer wants speed, they will want it all the time. Another supportive capability, would be agility. How quickly can a supplier respond to changes or difficulties? These changes might require rerouting of logistics to avoid strikes in certain geographical areas, for example, or they could require large and regular fluctuations in demand, that would require very careful planning and quick changes to avoid costly mistakes. Finally, there is the sustainable approach where a supplier's focus on environmental, social and ethical issues are desirable to customers. The sustainable approach is increasingly becoming a requirement. An ever-increasing number of companies are required to publish non-financial reports and, therefore, they require increasing amounts of data on their environmental and social factors. Table 4, shows these supply chain strategies, alongside, some example Key Performance Indicators (KPIs). Key Performance indicators are metrics that are decided to measure crucial aspects that are critical to the success of a company's mission and strategy (Oakland 2014, 53-69). (Harrision & al. 2014, 20-27.)

Table 4. Hard Objectives and Supportive Capabilities KPIs

Hard Objective	**Example KPI**
Speed	Order to Delivery Lead Time
Quality	Pick Accuracy (right goods)
Cost	Logistics cost per unit or cost of goods sold
Supportive Capabilities	**Example KPI**
Reliability (speed) (quality)	Lead time variance (% on time) % defects vs target
Agility	Number of routing options
Sustainability (environmental) (social)	CO2 reduction % (year on year) No bonded labour

Lastly, there are so called *Soft Objectives,* which, unlike *Hard Objectives,* are not so easy to measure. These might include; the business relationships between a buyer and a supplier that generates confidence in one another's ability and desire to perform. For instance, they are quick to answer emails and they do so in a friendly manner. It might also include, how well the supplier or the buyer protects confidential information which in turn builds trust. While things like trust and confidence cannot be measured they can be crucial. (Harrision & al. 2014, 28.)

2.4 Change Management in Lean Six Sigma

A crucial element to both Lean and Six Sigma is *change*. Both Lean and Six Sigma follow a continuous improvement approach. One benefit of this mindset is that it creates a culture that is accustomed to change. The difficult aspect of using tools like Six Sigma and Lean is in ensuring full commitment to the cause and ensuring that the company culture is truly behind the changes that they bring. (Pyzdek & Keller 2014, 12-13.)

So, what is creates this need for change when it can create numerous organisational difficulties and may result in the loss or change of jobs? The *Four Main Causes of Strategic Change* theory states that there are four key categories of change drivers. Firstly, a shift in the environment from external forces, such as changes in the competitive landscape, new legislation or economic pressures (Lynch 2015, 504). These changes can occur slowly; in which case change can be quite fluid, or, they can occur rapidly, in which case there is little time to prepare, and the shock to the organisation is very intense (Lynch 2015, 500). The second reason for change according to the *Four Main Causes of Strategic Change* theory, comes from a change in business relationships. New key suppliers, for example, can bring a change of technology that may alter the value proposition. Outsourcing manufacturing on the other hand, could reduce the size of a company and increase their focus on a smaller area of the value chain. The third reason, was a technology change, which is becoming more and more frequent. Technology changes, have the ability to change entire industries in a matter of years; as they did with the mobile phone industry in the late 2000s (Lynch 2015, 498-500).

In more recent times, the car industry seems to be entering a volatile period. If we look at these first three causes of change, two of them can be seen in the car industry currently. Firstly, new entrants to the market; coincidently these include Google (and is rumored to include Apple) the same Silicon Valley tech giants that disrupted the mobile phone industry in the late 2000s. (Kelleher 2015). Technology (the third reason for change), is ultimately *driving* these tech based companies into the car industry. Two major shifts are occurring currently, automation and driverless cars (from *Smartphones* to *Smartcars*) and electric vehicles (Kelleher 2015). These two market shifts, are opening the market to tech companies that are seeing the benefit of rethinking the traditional car. These shifts bring us to the forth cause for strategic change, people. This relates to changes that need to occur when new people enter an organisation in order to accommodate them, most significantly when this change is in the leadership (Lynch 2015, 504). In May 2017, Ford announced a leadership change with their new CEO Jim Hackett (BBC, 2017). In October

2017, at an investors meeting, Mr. Hackett, announced his radical *vision,* stating that "Fitness is the way you protect your broadsides from disruption" (BBC, 2017). His vision for change is for Ford to move resources away from producing “traditional cars to SUVs and trucks, while investing in electric power and tech services” (BBC, 2017).

It was in 1908, when Henry Ford introduced his industry changing, Model T car, and by 1914, not only had he changed the entire car industry, he had also changed the entire world of manufacturing with his introduction of the moving assembly (Womack & al.1990). The key to all of this, is that it was change that build Ford; now it is change that threatens it and without change, it may find itself in a market that it can no longer compete in. This is why change is essential, the question is how can change be managed?

The 8-step change model is one approach that change agents use to approach organisational change (Pyzdek & Keller 2014, 15). The first step in this model is to create an urgency. In Lean Six Sigma, the combination of the *Define*, *Measure and Analyse* phases offer opportunities for this. Data-driven analysis of the current situation alongside the customer specification and benchmarking are very powerful tools used to identify the need for change. What is crucial with this data-driven approach, is that it is fact based, meaning that the urgency created is difficult for others to object to. (Pyzdek & Keller 2014, 15.)

The second step according to the 8-step change model is to build a team of influencers, who can drive the change. In Lean Six Sigma, Black Belts are required to be good communicators, who are held in high regard and the structured setup of Lean Six Sigma is active at all levels of a company (Pyzdek & Keller 2014, 23-28). Next (3rd step), the new situation that is caused by the change needs to be identified. What will the change look like, and crucially, what will the post-change period improve? In Lean Six Sigma, the change is commonly defined and guided by the customer. Once the vision is clear, the message needs to be clearly communicated with all the stakeholders (4th step). Each stakeholder needs to understand the message in relation to them with a language that is relevant. (Pyzdek & Keller 2014, 23-28.)

One way of looking at this idea of catering the message depending on the stakeholder, is to remember the, *what is in it for me* (WIIFM), response (George 2003, 200). If one message is used to talk to the entire organisation and that message comes from the top, it might sound something like “We need to create a more agile ecosystem”. This isn’t communication at all, if the message isn’t relatable. The related message from this to the sales team would be; “we need a quicker product range rotation to remain competitive and increase sales”. This second message is now talking about making more sales, which a person in the sales team can get behind. This might not be the right way to frame it for the product development team or the sourcing team etc. (George 2003, 200.)

With the organisation coming onboard, the next point (5th step) in the 8-step model, is to empower people to get behind the change. By removing obstacles or relics of the past way of doing things, while at the same time, creating and enabling the new tools or processes. In this way, the road towards change becomes easier to travel. The 6th step in the model, is to prepare for and celebrate the small victories. This becomes more important in bigger changes to ensure that people are reassured that the change is going well, and to maintain motivation. DMAIC's gated approach can help to achieve this, as when each section of the project is completed, there is an outcome or result. The define stage creates the project, the measure stage creates the metrics and defines the critical X's, and so on. As these achievements build, the 7th step comes into play, which is aimed at ensuring these changes are maintained, and that the organisation recognises those who have helped in making the change. This shouldn't be an end goal, however, instead this positivity should be harnessed to promote more desire for change and build the momentum going forward. Finally, the 8th step is to institutionalise the new ways of working. (Pyzdek & Keller 2014, 15-16)

One key step in institutionalising the change, is to assess how this new process should be measured? Whereas a *push method* production process might be measured on its capacity utilisation; in a Lean production process, this could be at odds with the new desired goal of low inventories. Changes to how performance is measured, therefore, is a key concern for change agents implementing Lean Six Sigma. (Krajewski & al. 2007, 364)

2.5 Potential and Limitations of Lean and Six Sigma

So far, the ideas of Lean and Six Sigma have been discussed and a clear idea of what they can offer is beginning to emerge. What might not be so clear though, is when to use Lean or when to use Six Sigma or even, when to not use either?

Just to recap Lean is a philosophy that looks to remove wastes and by doing so shortens the lead times and reduces costs. Six Sigma is concerned with data driven assessments of a process that can identify and reduce variations. Process variation leads to defects (waste). Lean tools are effective on reducing waste, etc. Essentially, Lean Six Sigma sees a link between quality and speed in the pursuit of perfect processes. (George 2003, 6-8)

The greatest challenge of implementing Lean and Six Sigma was discussed in the change management section of this thesis. Organisational changes, require support at all levels of a company. The vision from the leadership is commonly a key starting point and their support of time-consuming change projects (such as Lean and Six Sigma), is crucial. The communication and feedback systems, again, are essential to keep the organisation behind the new system, and also for the Lean/Six Sigma teams to understand the requirements of the stakeholders. (Pyzdek & Keller 2014, 17-22)

Another potential risk with using Lean and Six Sigma, is that these additional activities are well defined, and targeted to solve specific problems in the organisation. If a Lean Six Sigma project is untaken without clear objectives, and realistic scope, then it might well be a waste of resources. It is important to select the right projects, as well as the right number of projects. All these considerations, could help organisations avoid costly and time-consuming activities. (Pyzdek & Keller 2014, 17-22)

Some critics claim that Lean and statistical process control (SPC), used in Six Sigma, can create high levels of stress on the workforce tasked with meeting such tightly defined standards. The effects of reduced inventories can also create more pressure to constantly meet with tight scheduling. The responsibly for process improvement being placed on all levels of the organisation, also creates further pressure on lower level workers; who may not be used to working that way. While this added strain on the workers can be seen as negative; it can also be taken as a positive. Allowing a worker to have input on their work brings their brains into the process. which is often missing in mass production manufacturing. In addition, allowing lower level workers to develop changes in processes can create relationship issues, between managers and their subordinates. (Krajewski & al.2007, 363-364)

2.6 Summary of Theoretical Framework

In Lean Six Sigma, a wide variety of topics are combined throughout the project, including; continuous improvement, statistical analysis techniques, business strategy, project management, change management as well as waste and defect reduction and process improvement. In addition, due to the process being studied in the project, it is crucial to include the theories behind the order fulfilment process and related strategies. Many of these theories are active throughout the project; such as change management or DMAIC whereas others; such as some of the Lean Six Sigma tools, might not be used. This is dependant on the project requirements that will be driven by the data collected. In Figure 21, the theoretical framework of this thesis, has been visualised in a hierarchical chart. DMAIC will be the project management tool used, this will require change management ideas in order to be implemented successfully. Lean Six Sigma tools shall be used throughout the project, and will be identified as and when they are used in each section of this thesis study. The order fulfilment process is the focal process being analysed for improvement in this thesis. The theory of what an order fulfilment process is, will be used in all aspects of the project including; the process strategy, structure and owners. This theory should guide the project, if it is unclear how to prioritise possible improvements.

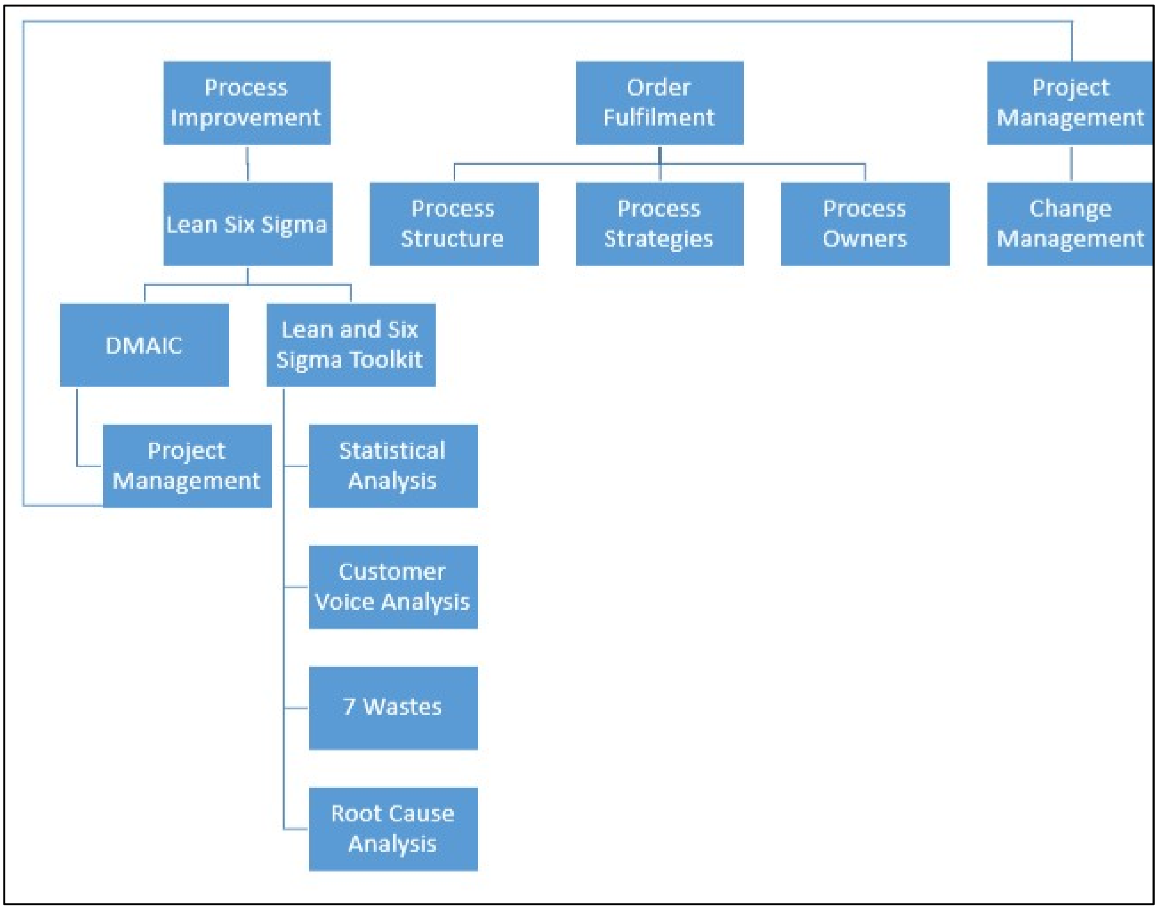

Figure 21. Theoretical Framework Map.

3 Define

Figure 22. DMAIC Model (Pyzdek & Keller 2014, 30).

In this Chapter, the define phase will be discussed from a theoretical viewpoint in Chapter 3.1, and the results of the project will be discussed from Chapter 3.2 to 3.7. The define phase is the first stage of the DMAIC process. In this phase, the scope of the thesis project should be further defined and initial research should lead the project towards prioritisation ideas. (George & al. 2005, 6)

3.1 Introduction to the Define Phase

The outcome of the define phase is to have a clear understanding of the project. A key document used to achieve this is called a *Project Charter* (an example of which can be seen in Appendix 2 – 4). This document is the "why, how, who and when of a project" (Pyzdek & Keller 2014, 245).

The *why* of the project would be covered through a project statement, and the project objective. These look to answer; what the problem that needs to be studied is, and also, what the desired outcome will be. For instance, the problem could be the lead time variation that is impacting on customer satisfaction. The objective, therefore, would be getting the variation under statistical control. Next, the business impact (or need) would look to answer, *who* will benefit from the improvements? The follow-on question would be, *how* will this improvement be measured? This would be the *goal statement*, which looks to establish the Key Performance Indicator (KPI) that the project will be based on. Once these elements are established, perhaps the most difficult aspect to get right, is the scope. If the scope is too narrow in focus, then, the project's ability to assess the real root cause is lost. However, too wide a scope might cause the workload and timeframe needed, to become unmanageable. Within the project charter, there will also be a top-level project plan, highlighting, the key target dates within the project and a list of the team members working on the project. (George & al. 2005, 6)

As well as the project charter, it is important for the Define phase to identify, both the customers' voice (the customers' definition of the process and the challenges), and the Businesses' voice (the business definition of the process and the challenges). How is the process viewed internally, and what are the specifications? How is the process viewed externally, and what are the needs/expectations? Perhaps most crucially, how do these two things differ? (George & al. 2005, 5)

According to Dean Pattrick (15 August 2017) who has over 20 years of experience in the electronics industry; businesses are so comfortable with being on the inside (company viewpoint) looking out (at the market) and trying to build the processes or design products in the way the company thinks they should be; that they struggle to understand the view from the outside (customer viewpoint) and looking in (at the company). What is the customer wanting from our brand? How would they want our products and processes to function and how do they want to be served? Therefore, understanding the customers' voice and using this as a starting point on which to base improvements is an important aspect of Lean Six Sigma. (Pattrick 15 August 2017)

The last element in defining a DMAIC project, is the process map. The process flow chart used and created for this project, can be seen in Appendix 1. The process flow chart, is a way of seeing, who is responsible for conducting an activity. It helps in visualising complex processes like the one in this study, where, many different people in different geographical locations, are working together in order for a process to be completed effectively. Each process map, has its own unique purpose, but ultimately, they are all trying to visualise the given process and enable ideas of problem areas to surface. Additionally, when a process is defined, it is easier to create a future process state, and then, analyse the gaps between what is (currently), and what is wanted (in future). (George & al. 2005, 38-39.)

Once all these elements are in place, the project progresses towards the *measurement phase,* as discussed in Chapter 4. Chapter 3.2, will look at the outcomes of the *define phase* for this project.

3.2 Define Phase Results

For this study, the focal company is an international electronics manufacturer. The focal company (SEP), is wanting to understand how they can reduce variations in their lead times, to ensure the estimated time of delivery is met. To answer this question, we need to analyse the various processes involved. Manufacturing in SEP, is currently outsourced so, for this project manufacturing and purchasing/sourcing will be out of scope.

3.3 Research Methods in Process Flow Analysis

In order to understand the current situation, extensive internal and external meetings were conducted with *process owners,* in each section of the process. The term, *process owner,* refers to the individuals that are responsible for managing a process. For confidentiality reasons, the process owners will not be named, but, their roles are listed in Figure 23. In total 12 process owners were contacted over the course of the project, in various meetings and communications, throughout the project timeframe. The data needed from these project owners, was qualitative, however, the nature of this section of research was required to be unstructured. Scripted questionnaires are not suitable, as in order to build questions, it would require the interviewer to lead the discussion and base it on their limited knowledge of the process. In this Lean Six Sigma project, we are looking to understand the process from the process owners' perspectives, therefore, greater flexibility was required. It was crucial, that these meetings be more free form, and used to gather as much information as possible about a wide range of topics. Some of the meetings were presentations of previous projects, others were brainstorming exercises, and some were quick text based communications, via internal systems. This type of research, is referred to as *exploratory research* (Burns & Bush 2014, 100-103). The key purpose of this form of research, is to gain background information and clarify problems. This research was essential for developing a detailed understanding, and definitions of the process and moving on towards problem identification and prioritisation. (Burns & Bush 2014, 100-103.)

SEP	Chief Operating Officer (COO)
	General Manager
	Logistics Manager
	Order Manager
	Two European Account Managers (east & west)
	Two Local Account Managers
Manufacturer	Order Management
	Factory Planning
Logistics service provider	Account Manager
	Local Account Manager

Figure 23. List of Interviewed Process Owners

From these meetings, it was possible to understand the problems being faced, and the possible relationships between them. A top-level process flow chart was created, and can be seen in Appendix 1. Together this data (process flow and interviews), led towards the creation of the Project Charter (seen in Appendix 2-4). With these in place, a clearer picture of the project aims, scope and challenges took shape. Below, are the key areas of focus for this project, as defined by this *exploratory research* analysis.

Root cause of material flow variance. Is the variation of lead times an issue within the factory, the distribution or both? This will be a key question in understanding the area to prioritise for improvements. If factory variation in production capacity, is creating a situation of extended lead times in distribution, then aiming improvement issues in the distribution processes, would be a waste of time as they would be a result of factory variation. However, if the factory variation, and the distribution lead times, are not linked, then each one can be considered as separate, and so improvements can be targeted towards both sections of the process independently. Correlation must be measured to establish what impact the forecasts of production quantities is having on the LSP's ability to control lead time length and variations. This quantitative study will be important in understanding the material flow aspects of this study.

Strategy. Finally, what is the strategy of the company? How do they compete, and how should the distribution process reflect this? The key to Six Sigma, is finding the project that creates the desired results. It would be pointless, to create a project based on reducing lead time variation, without first establishing, *who wants the lead time reducing and why*? The cost, speed and quality order fulfilment strategy was discussed in Figure 19 (page 32). Customer interviews will be important here for us to understand what they want to see improved.

3.4 Research Methods in the Customers’ Voice Analysis

The customers voice was determined to be crucial to understanding, how the process was viewed from a user’s perspective, and also in understanding, what elements were most in need of improvement? Now, with more of a detailed understanding of process, it was possible to conduct structured interviews for this analysis. The research method used here was qualitative, and the research was conducted through in-depth interviews, using a technique called *Web-TDI* (Burns & Bush 2014, 157-158). *Web-TDI or Web Tele-Depth-Interviews* are conducted over the internet (in this case via Skype for Business), mixing both audio and visual elements. The visuals helped, as they enabled the interviewer to show the questions in text form as well as verbally. With the interviewees, all using English as a secondary language, this was an important element to ensure they understood the questions being asked fully. In-depth interviews, based on qualitative methods enabled the interviewer to also include, so called *probing questions* (Burns & Bush 2014, 158). This meant, that the study was not limited to asking only; “Could you talk me through the current order to fulfillment process for your viewpoint?” (Appendix 5), but also, it could include prompts to help the interviewee. For example, “How and when do you receive delivery estimations and updates?” (Appendix 5). Five key customers were contacted from across Europe, who due to confidentiality, cannot be named. In choosing these customers, it was crucial that they were within the geographical scope of the project (Europe). Due to the limitations of not being able to select the respondents, as well as not knowing the full population of customers due to the confidentiality of this data, a probability sampling method was not possible (Burns & Bush 2014, 238-258). Local account managers were contacted and they selected the customers to be involved. They selected respondents that, they believed, would likely represent the population, which is a nonprobability sampling method, referred to as purposive samples (Burns & Bush 2014, 238-258). This means that, while it is likely the results are true of the population, this selection method is subjective, and is prone to error (Burns & Bush 2014, 238-258). In this study, however, this data is not the basis of the study, but rather, a guiding element. This data is being used to uncover and prioritise issues that the B2B customers are having with the order fulfilment process. In answering this, the population is not as important as we are not looking to state without any doubt, the priority of issues the customers have, rather, we are looking to gather an overview of the issues, in order to conduct further studies. The individual responses are confidential and not relevant to this study, instead, the overall assessment will be shared. The questionnaire can be seen in Appendix 5, and the results are analysed question by question in the subsequent chapters. (Burns & Bush 2014, 157-258.)

The key question in answering the research objective for this study was to answer: *How do customers view the current order fulfilment process and how would they want this process to be improved?* Comparing the customer view (customers' voice), with the current process will help to pinpoint areas for change, so these customer interviews are essential. In addition to the order fulfilment process, customer interviews, will be needed to understand how well the customer is currently informed (information flows) in each stage of the process. This qualitative study, will be crucial in answering, the information flow aspects of this project.

3.5 Customer Viewpoint of Order Fulfilment Process

Question one of the questionnaire was used to gather an overall understanding of customers' view of the process. What they felt was working, and what they felt needed to be improved. This uncovered additional issues, some of which will not be included, due to confidentiality.

Order Book (includes question three analysis. order book vs expectations)**.** The first key issue, was identified in the order book process. This document is sent to customers regularly, and lists their orders alongside the production date, and the proposed delivery date. The issues with this document were: It contained historic data of orders that had been delivered already, 3 out of 5 customers were not using it due to its complexity and due to it being made weekly, it meant that there was still a lack of visibility as to when orders had left the factory. Additionally, if there are variances in factory output then the order book is updated to reflect this, some customers felt this was not a good way to discover changes.

Later discussions with account managers revealed that they were, in fact, creating localised solutions to the order book issues. They were resorting the data to be more user friendly and sending these improved versions over to customers. Looking over the data from this question, then revealed, that there was in fact two distinctly different customers as a result. The customers whose account managers created this user-friendly version of the order book, didn't pay attention to the original copies of the order books, or the delivery estimate emails sent by the LSP. This covered three of the five customers questioned, the other two, relied heavily on the information coming from the LSP and the order book.

Order Numbers. The orders placed with SEP generate an order number, by which, each order can be tracked. Customers systems, however, are not linked and therefore, they need to create their own orders in their system. The problem this creates is that the subsequent communications from SEP, uses the SEP order numbers, rather than those that the customer creates. This means that, for instance, the LSP order updates are not easy to track, as the customer needs to first, uncover which order number relates to their order number. This was included in the order book, to improve visibility, but customers felt they were not well informed on this.

LSP updates (includes question four analysis: delivery updates vs expectations). The customers are informed about where their products are, and when they are due to arrive at two points in the products journey. Once, when the goods are leaving Asia, at which point, they inform the customer when their goods are scheduled to arrive in Europe. Once the goods arrive in Europe the customer is informed of the estimated time of delivery. The first issue with these communications, was that they were not always being sent. This was very troublesome for the customers, mentioned above, that relied so heavily on them. In addition to this, there was reported to be issues with the emails being sent to the wrong people. This issue, is a difficult one as the customers themselves inputted the email addresses of the people who they wanted to receive the updates. One clear issue in this was, that if the office location and the warehousing location, were not nearby; then, the messages might never be received by the warehouse that needed to plan for taking the deliveries. Whilst the recipient of the email was decided by the customer, it is clear, that SEP should review this periodically and ensure the customers are still happy with who is receiving what.

One key problem identified with the updates, is that the first update, does not include an estimated time of arrival. This is due to the estimate that was previously used; being so inaccurate that the variance it created was causing annoyance to the customers. This means that the customer only knows when the goods are scheduled to arrive when they are through customs checking in Europe. For some of the respondents who had lead times of several days from the main arrival airport in Europe were quite happy with the estimates received. However, those who were located closer to the airport in Europe found that at times, they were receiving the estimate on the day of the delivery; in some cases, the estimate came after the delivery had already arrived. Finally, the format of the information coming from the LSP, could have been more customer centric, as it included data that was not relevant to the customers.

Other Challenges. Other challenges were raised and have been passed on for improvements, but, they are not within the scope of this project.

3.6 Prioritisation of Improvements

The second question of the questionnaire was designed to enable the creation of a pareto chart, as seen in Figure 24 (page 48). In a pareto chart, the categories are listed in order of their value; if there is a clear pareto effect, then 20% of the categories, should have more than 80% of the responses. Of course, with this being qualitative research with only five respondents, this is not a fully accurate view of the population. It does give a strong idea though of the areas that the respondents felt needed improvements. The delivery estimate variations in days had over 60% of the responses, and communication and visibility had 40%, making them the clear priorities for this project. (George & al. 2005, 142-144)

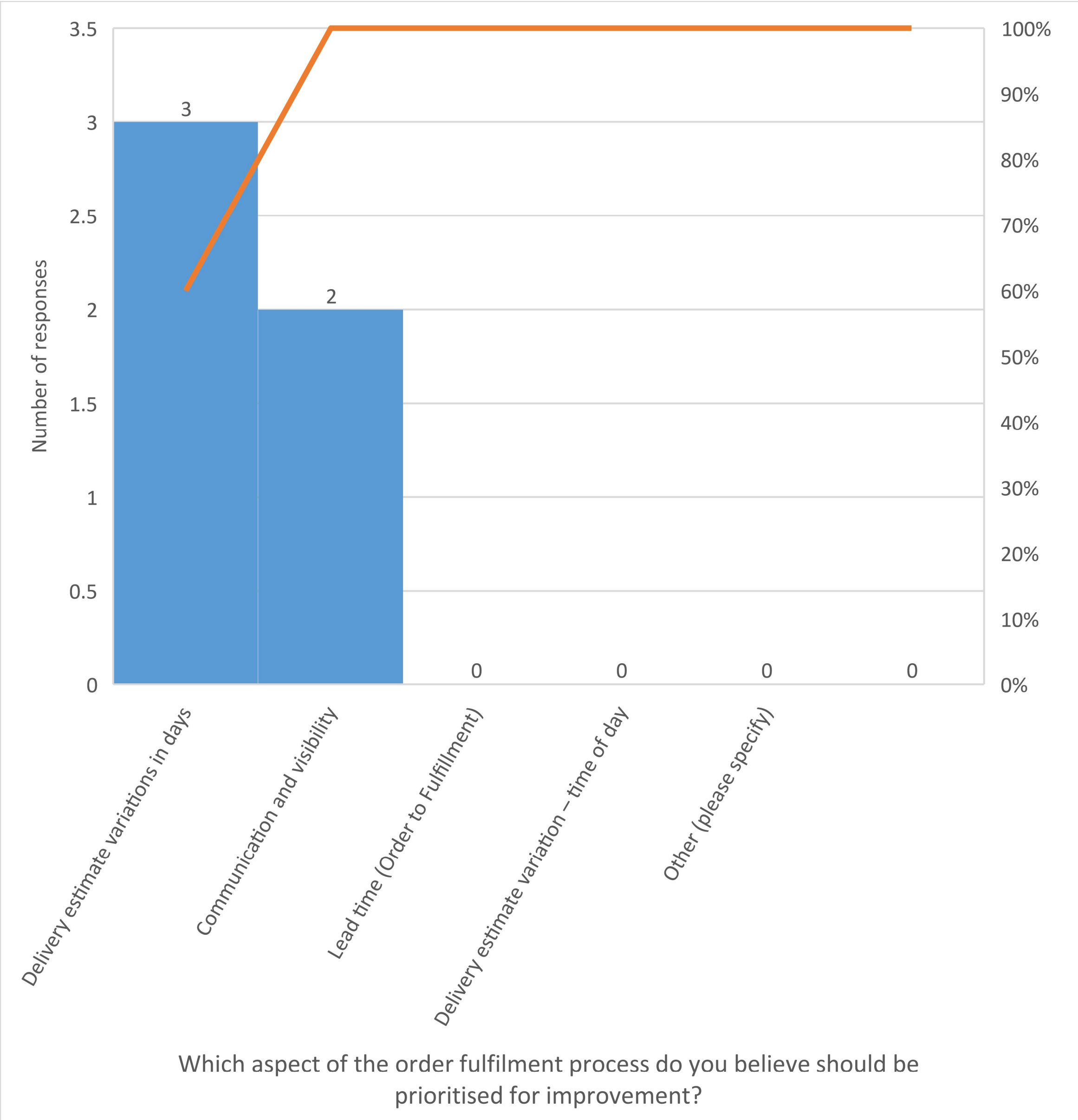

Figure 24. Pareto chart of customers prioritisation of order fulfilment challenges.

Questions 5 and 6, were not analysed further, as they did not create any meaningful outcomes for this project.

3.7 Define Phase Summary

The define phase, was very challenging at times as the process being studied is so vast. Exploratory research was essential to this stage, in order to help understand each aspect of the project in detail. The outcomes of this, enabled the project and problems to be further defined, and led to the creation of the process flow chart and project charter. With this greater internal understanding, it was then possible to conduct qualitative research of key customers, in order to understand the situation from their perspective. The combination of these studies, created focus for the rest of the research project. (Burns & Bush 2014, 101-158.)

The scope, was now focused on answering whether or not the variations in delivery estimates from the LSP, were related to the variance in production quantities, coming from the factory. If they were, then this would mean that reducing the variance in the factory, would lead to improved delivery estimates from the LSP. If they were not linked, then the root cause for delivery variations, would be within the LSPs scope, and so, work would need to be prioritised here. This would need analysis of data, and this would not take into account individual cases, but rather; look at the bigger image. The information flow issues were reported, and are now undergoing investigation and improvements in follow-up projects, so these too leave the scope of this project.

4 Measure

Figure 25. DMAIC Model (Pyzdek & Keller 2014, 30).

The overall aim of the measure phase is to identify the critical inputs and outputs of a process. This includes, identifying the metrics that will be used to measure them. It also requires a plan for data collection and, the act of collecting the data, whilst, ensuring that the quantitative data collection method being used is accurate, repeatable (under the same conditions the same results would occur if the test was repeated) and reproducible (could be conducted by different people and still the outcome would be constant). Additionally, the measure phase is used to understand, in greater detail, the current state of the process being measured. In order to do this, a detailed value stream map is created, in addition, to the previous top level process chart from the define phase. The period of time covered in the data collection is assessed, to ensure that it is enough to uncover at least 80% of the potential variation (George & al. 2005, 137-140). Lastly, the Project Charter may need to be updated after the measure phase is complete, to factor in any major project changes. (George & al. 2005, 8-9.)

4.1 Research Methods defined in the Measure Phase

In terms of this project, the measure phase was quite straight forward. The quantitative data needed to measure the aspects (metrics) being assessed, were already available and, therefore, a collection plan was not required. Data collection methods, would have required sampling sizes to be defined, and decisions on how to ensure the sample was reflective of the true process (Burns & Bush 2014, 238-242). In this project, the data was already being collected, and the full population of the data was available. The population here, refers to “the entire group under study as specified by the objectives of the research project” (Burns & Bush 2014, 238). Therefore, within the timeframe of this project, between the 14th of August, to the 30th of September, every order that left the factory, and travelled through an international airport in Europe, to customers based in Europe, was included. Using the population, is far more difficult in terms of, organising and analysing the data. This is due to the size of the data, however, it is far easier to ensure it is a true and honest reflection of the subject being studied, than in a sample. (Burns & Bush 2014, 238-259)

George & al. (2005, 137) state that it is important for the scope of the data being studied to be big enough to ensure that; at least 80% of the process variation would be covered, within the timeframe. The longer the time period studied; the greater chance there is that, all the variation, has been included. A short period of data collection would be seen as, a day or a week; and a long period would be, months or even years (George & al. 2005, 137). The dataset being used for the analysis, is one thousand and sixty-six lines long, and the timeframe for this project was set, at a seven-week period (week 33 to week 39). The reason eight weeks were not used, was due to fairly major changes to the order fulfilment process prior to week 33 (before the 14th of August 2017), and so, data prior to this, would not represent the current performance of the process. Data from after week 39 (after the 30th of September), included deliveries that had not been made (at the time of organising the data), and therefore, it would be misrepresenting the data to include them (the cut-off date used is confidential). Orders that left the factory on the 1st of October 2017, were out of scope. Another aspect that was quite straightforward was in assessing whether or not, the data was accurate, repeatable and reproducible (George & al. 2005, 87-103). In order to measure these aspects, it would require checks to be taken at all points in the process, and in all the geographical locations, to test to what extent the data created, deviated from the true occurrences. Data, is considered repeatable, when under the exact same circumstances, the same results occur (George & al. 2005, 87-103). It is reproducible, if, under the same circumstances, another person would achieve the same results, and it is accurate, when the data has no variation from the true value (George & al. 2005, 87-103). The size of the variation from the true value, and the recorded value, is called *the bias* (George & al. 2005, 87-103). For the sake of this project, and the limited timeframe, these inspections of the data were not possible. The data assessed, however, was taken from a report created digitally by the LSP directly. The LSP assures SEP, that this data, is as accurate as they can make it. Due to the use of digitalisation, the chance of *nonsampling errors,* such as data gathering errors, or data handling errors, were greatly reduced (Burns & Bush 2014, 292).

The key metrics for this study were decided upon by taking the points raised in the customers' voice analysis, and the project objective, as seen in the project charter (Appendix 2). The effect (Y), that the customers wanted to prioritise for improvement, was the variation in the lead times (based on the estimate made). The causes (X's), of this variation, are not yet known, but, it has to be attributed to either; the contract manufacturer (variance in production), or the LSP (variance in transit). In order to reduce the variance to the customer, the priority would be to reduce the variation in transit. This is due to the customers voice analysis (page 48), stating that, the variation in the lead time from the estimate (created by the LSP) was the priority. Therefore, while the factory variations are causing issues; they are not the primary focus of this study. What is important, however, is that we rule out the possibility that the variations in the production, impact upon, the LSP's ability to control the distribution variance. For instance, if the LSP is told through forecasting that in week X, 600 units will need shipping, but in reality, it ends up being 900; do these additional volumes, cause additional variations in the transit times? This question, will need answering before analysis begins on the LSP performance. If variation in the transit times, has positive correlation with the volumes shipped being over forecast, then, the contract manufacturers performance is, also a factor in reducing the variance of the transit times. If it is not, however, then the focus of this study is solely on analysing the LSP's performance. This performance, will be measured using the variance of the lead times in relation to the estimate.

Value stream mapping, was not used in this project as it would require detailed measurements of each section of the process. This, however, is not of concern to SEP as these actions, are outsourced. The concern here is based on measuring the performance of SEP's business partners, and creating improvement targets and KPIs.

4.2 Creation of forecast variance data

The forecast variance was created using a weekly forecast report, that is created by SEP, based on the schedule of the products planned to be produced in the factory against, the orders that were registered as being dispatched according to the data, in the LSP report. In organising the data, the date of goods issue was used, so that, in the forecast report the planned goods issue date was assessed, alongside, the actual ones registered by the LSP.

4.3 Creation of the lead time data

The daily lead time data, was created using the pickup time that the LSP registered as the time that they took over possession of the goods, and the delivery confirmation time when the goods arrived at the customers door. The orders were organised by the date that they left the factory (goods issue), but, were measured by the day that the LSP took over control of the shipment. This meant, that the data could be assessed alongside the forecast variation data, but, it would still assess the LSP performance fairly. The LSP performance could not be measured from the goods issue date, as they were not in control of the shipments at that time. This lead time data, was used further in creating daily and weekly mean lead times, and also, in assessing the variance from the estimates.

4.4 Creation of the daily lead time variations data

The mean of the daily lead time variations was created by removing the estimate delivery time that the LSP creates, from each of the orders actual lead time.

5 Analyse

Figure 26. DMAIC Model (Pyzdek & Keller 2014, 30).

In this chapter, the analyse phase will be studied from a theoretical viewpoint in chapter 5.1. In chapter 5.2, the research methods will be introduced and the results will be discussed in Chapter 5.3.

5.1 Introduction to the analyse phase

The analyse phase is used to gain concrete understanding of the causes, that effect both the key outputs of the process being studied in relation to the project objective, and the metrics defined in the measure phase (George & al. 2005, 12-14). This phase of the project requires detailed data analysis, that can the identify correlation between the critical X's and the critical Y's. (George & al. 2005, 12-14.)

In a typical Lean Six Sigma project, the value stream should be analysed and gaps in performance should be assessed in the lead towards answering: *how the process can achieve the desired state of improved sigma performance levels* (Pyzdek & Keller 2014, 427-517)? The value stream map at this stage might include the capacities of each process in order to identify the bottlenecks in the process. This analysis, is also looking towards the improvements and trying to understand what wastes are contained in the process. This is a key area where, Lean tools and methods are introduced. Lean tools, such as cause and effect diagrams can be used to visualise and brainstorm the possible causes. Sources of variance should be studied to uncover, what is causing the gap (critical X, otherwise known as the root cause). In addition, benchmarking can be used to uncover the best in class for similar service processes. (Pyzdek & Keller 2014, 427-517.)

5.2 Research Methods in the Analyse Phase.

Statistical analysis tools are used in an effort to validate or disprove hypotheses. The tool used in this thesis is referred to as *correlation analysis* (Pyzdek & Keller 2014, 463-475). In *correlation analysis*, scatter plot charts are used, which; plot the so called *independent variable,* against the *dependant variable* (Pyzdek & Keller 2014, 463). The question to be answered would be: *is the independent variable having an effect on the dependant variable?* (Pyzdek & Keller 2014, 463.)

The aim of the analyse phase is to get to a point where, hypotheses are proved or disproved, and the cause of the variance is known. According to George & al. (2005, 14), it is important at this stage to be critical of the analysis being performed; whenever a tool is used, it should be helping to uncover the problem that is being investigated, not simply analysis for analysis sake. George & al. (2005, 14), refers to this a *"paralysis by analysis".*

5.3 Analyse Phase Results

For this project, the analyse phase was very concentrated around assessing whether or not the forecast variation (which also factored in the production variance coming from Factory X), was causing variance in the distribution process. To answer this, correlation analysis was used, taking the forecast variance as the independent variable, and the lead time variance as the dependant variable. The result of this, is shown in Figure 27.

It needs to be mentioned at this stage, that all of the calculations from Figure 27 onwards have been altered in order to protect the confidentiality of the original data. The results are indicative of the real situation that was studied and the charts show a similar image to the original data. All of the calculations were multiplied by a single undisclosed number.

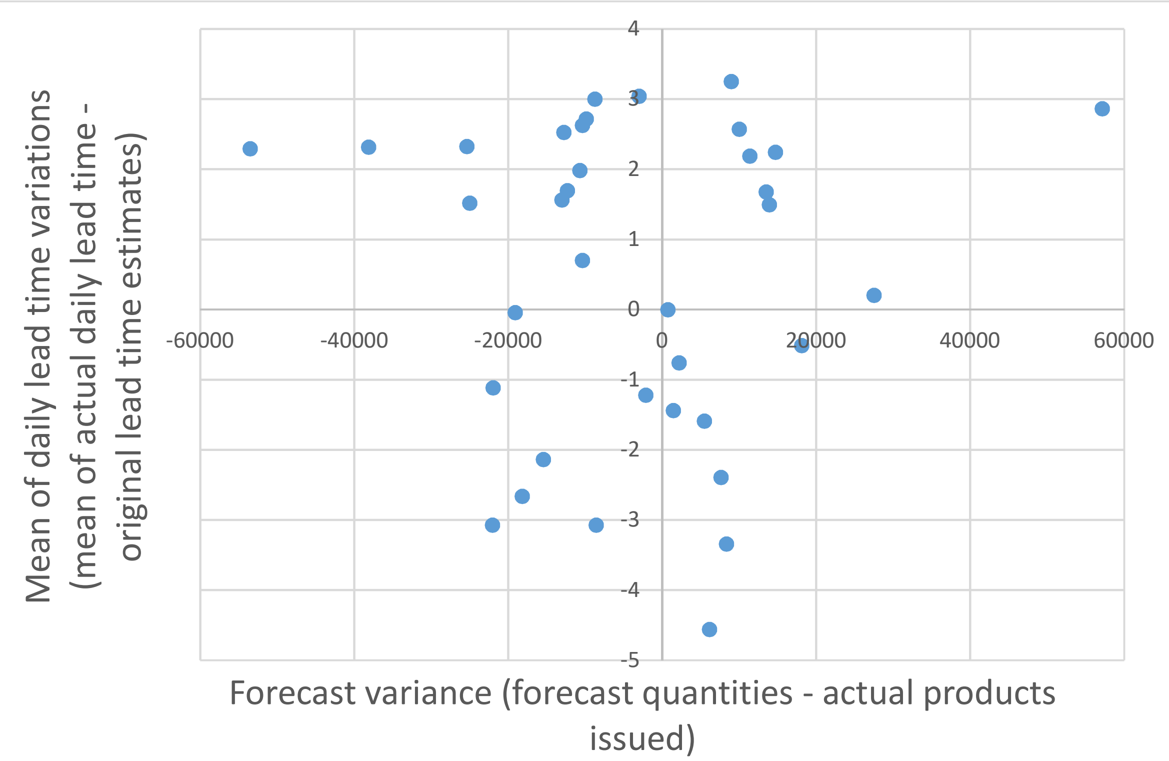

Figure 27. Correlation analysis of forecast variance effect on lead time variance (p = -0.00246).

The chart in Figure 27 (page 55), is not showing correlation meaning that the variance from the forecasts, which includes variation from the factory, is not showing an effect on the mean of daily lead time variations. The actual correlation from the data was -0.00246, which, is far from the 0.7, that is considered to show the positive correlation we were looking for. This means that, it cannot be claimed that the distribution variation is related to the forecast and factory variation. It also means that for the sake of this study, the root cause is not based in the factory or the forecasting, but in the distribution.

In order to further verify this result, Figure 28, is analysing the same relationship as Figure 24 (page 55), but this time; the mean of the daily lead times is used instead of the variance.

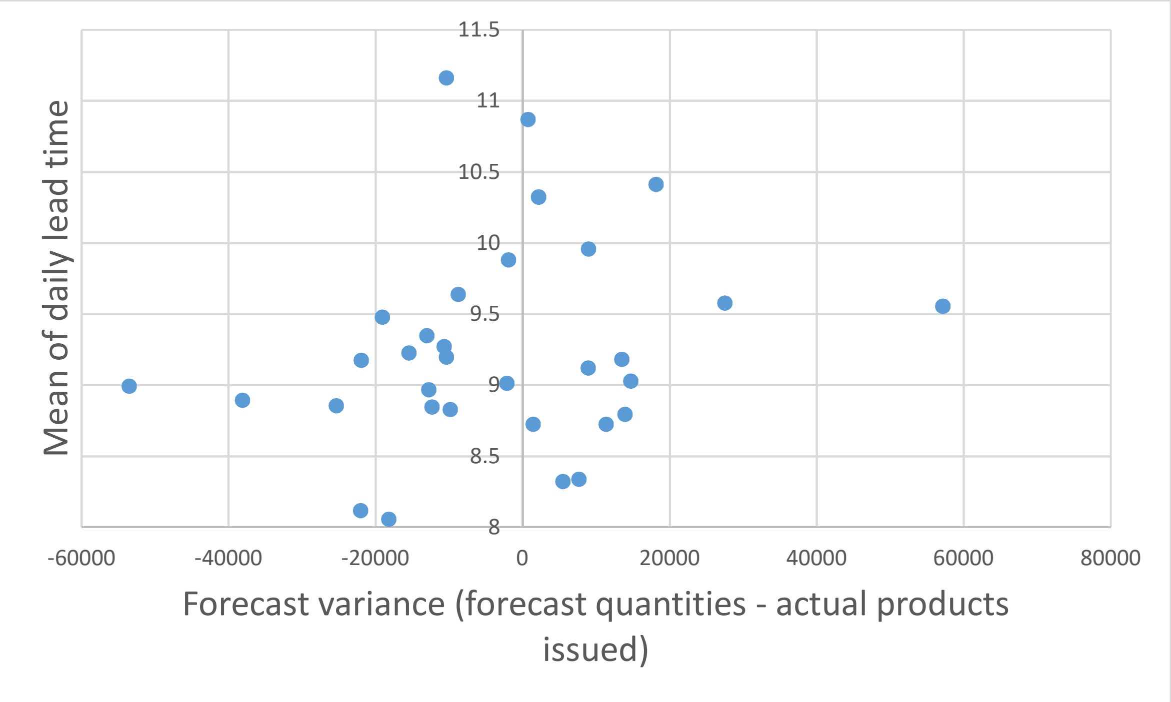

Figure 28. Correlation analysis of forecast variance effect on mean of daily lead time (p= 0.06681)

Figure 28, is telling a similar story that there is no correlation between the mean of the daily lead time, and the forecast variation. With this covered, the question remains *what is the level of variation in the distribution process*? The variation is shown in Figure 29 (page 57).

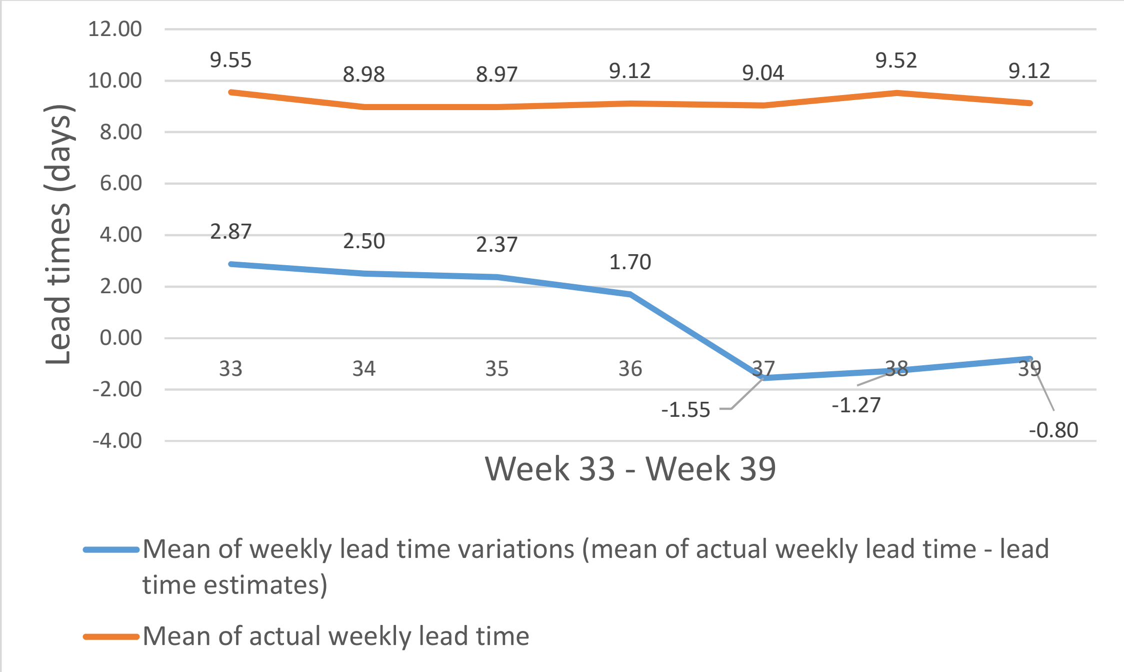

Figure 29. Means of the weekly lead times in orange and weekly lead time variation from the estimates in blue.

From Figure 29, we can see that the mean of the lead time stayed fairly constant throughout the study. At the same time, however, the variation from the estimates changed quite significantly, between week 36 and week 37. This was a very unexpected change and shows that around this time; something must have changed in the way the LSP were creating the estimates. We can see that previously (prior to week 37), the average lead time estimates were slowly improving, but the LSP was still on average, late making the deliveries. From week 37, however, they were overestimating the delivery times, and considering that the lead times did not change over the same period; the estimates must have lengthened.

In order to further assess the performance of the LSP, and to ensure that this analysis is fair, SEP, asked to have delays removed that were attributed to either, the customer refusing an order, or SEP caused delays for whatever reason. This was a simple process as the LSP had registered these issues on their report. Figure 30 (page 58), shows the same information as Figure 29, but, with these orders now removed.

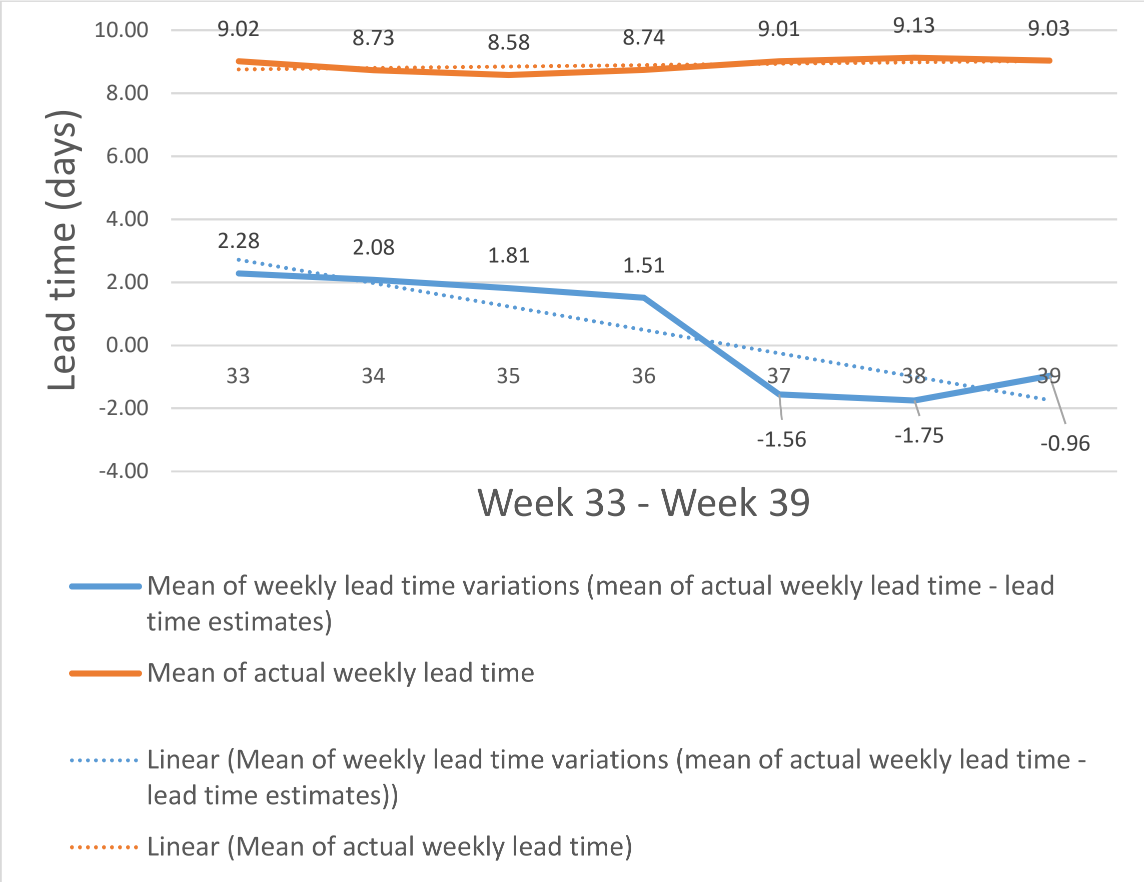

Figure 30. Means of the weekly lead times in orange and weekly lead time variation from the estimates in blue. Customer and SEP caused delays removed.

Figure 30 shows that the removal of SEP and customer caused delays, does slightly decrease on the mean weekly lead times, but, the overall result is the same as in Figure 29 (page 56). The variation in weeks 37, 38 and 39 is, in fact, now slightly worse.

In order to get greater detail on the performance; daily means of the lead time and variation from the estimates, are shown in Figure 31 (page 58).

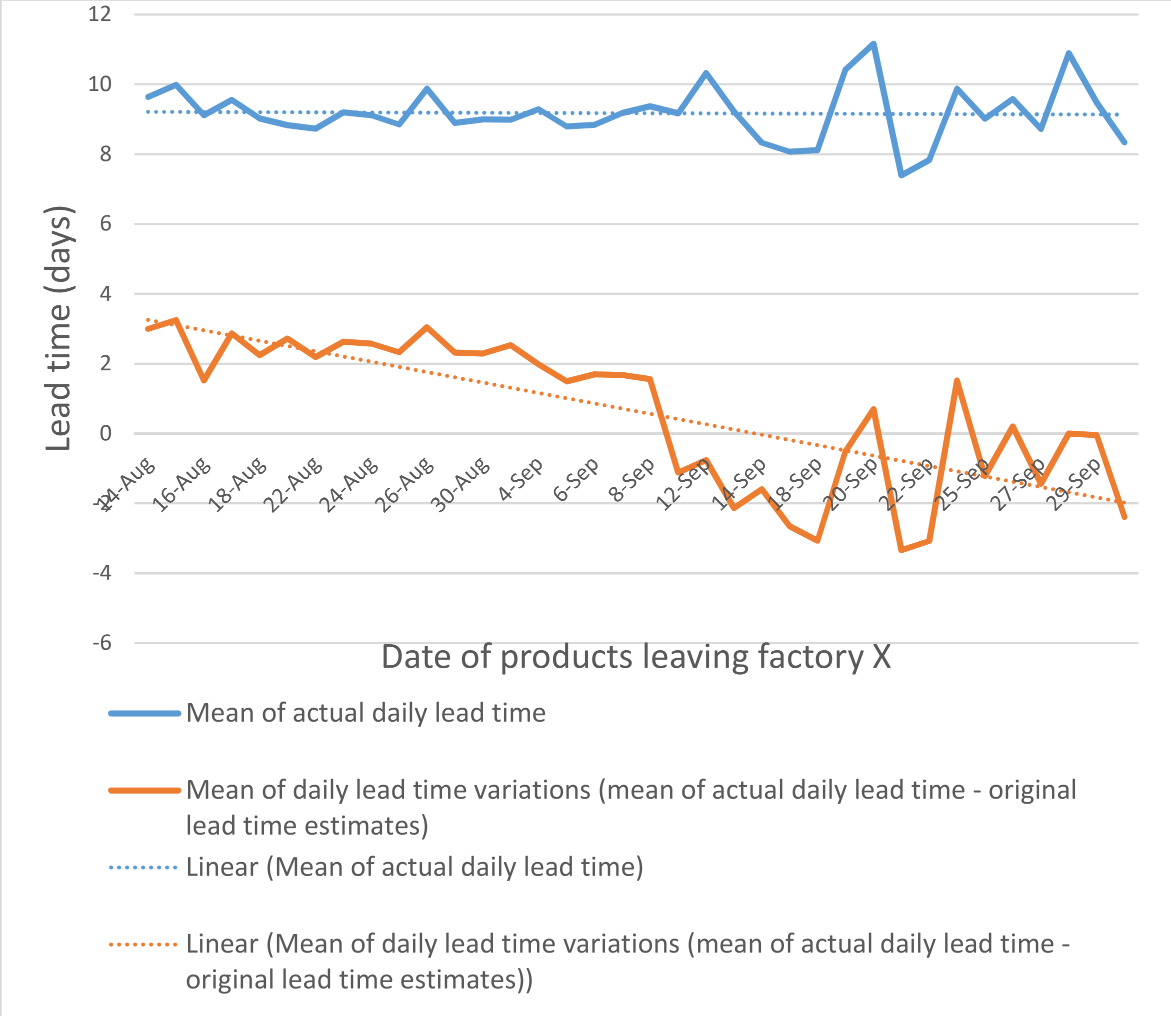

Figure 31. Means of the daily lead times in blue and daily lead time variation from the estimates in orange.

From Figure 31, we can see the daily view of the mean lead times, and the lead time variation from the estimates, pinpoint the shift in estimates to happening around the 8th and 12th of September. Around this time, both the mean of the lead times, and the mean of the variation from the estimates, clearly becomes less stable. What is not clear is; *which element is the cause; and which is the effect*? *Did the LSP, foresee mean time variance issues in this time period, and therefore, as a result, became more flexible in their estimates, or, did a change in the estimations cause changes in performance*? This question needs to be directed towards the LSP as the data available in the reports, does not measure this.

SEP also requested that they could have this analysis conducted at a country by country level. This calculation, was fairly straightforward as the data was already created, so, it was just a case of categorising the data by countries shown in Figure 32 (page 60).

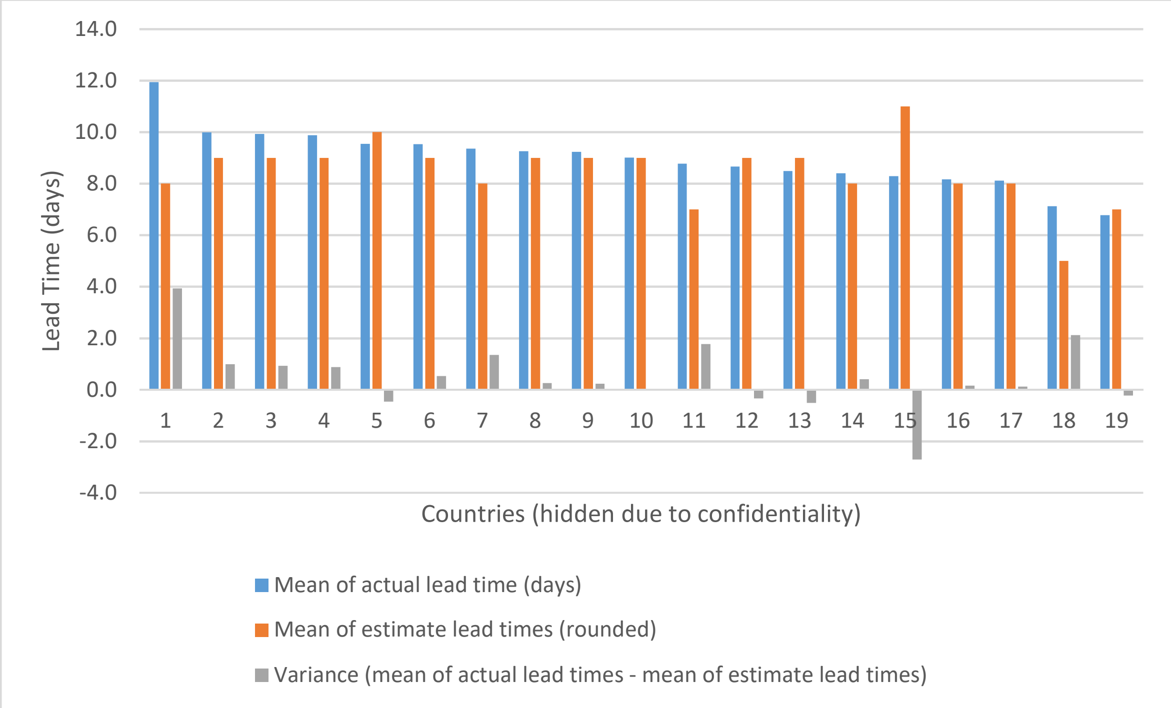

Figure 32. Country by country assessment of the mean of lead times alongside the mean of the estimate lead times and the variance. (countries removed due to confidentiality)

Figure 32, uncovers that the variance between the means of the lead time, and the estimates are not constant from country to country. It is understandable that the lead times would alter, but the estimates, should be more consistent. Country 1, for instance, has a mean variance of four days between the mean of the lead times, and the mean of the estimates. Even country 18, with the second shortest lead time, has a variance of two days on average. Clearly, there are some issues here in the LSP estimates and considering the fact that the customers did not report issues with the length of the lead times, but rather, with the variance between the estimates and the actual lead times, this, would have to be considered the root cause of the problems in this process. Uncovering this, leads us to the next stage of the project.

6 Improve

Figure 33. DMAIC Model (Pyzdek & Keller 2014, 30).

The improve phase of DMAIC, is perhaps, the most straightforward in terms of describing what it is. The task is to implement the improvement idea. In a normal Six Sigma project, this phase would be looking to develop improvement ideas and to evaluate and select the best ones (George & al. 2005, 15). This would then lead on towards creating a new value stream map, that shows what the process will look like after the implementation of the improvements. Finally, the results would be analysed against the old performance to measure the improvement and, once the team was satisfied with the result, a full implementation would begin. (George & al. 2005, 15)

In this study, however, we are studying an outsourced process so it is not SEP's place to look at how to solve the problems. Instead, the information from this study has been made available to the LSP, and with this, they have been asked to create improvements based on the data generated. The LSP then took on the usual actions that would be undertaken in the Improve phase, and returned with their proposed idea for full implementation. These proposals were then studied in relation to the same data used in the analyse phase to see what the situation would have been, if they had used their newly proposed lead time estimates at over this same period. The reason for not using new data to analyse this, is due to the time restrictions of this thesis. It would be unfair to analyse the LSPs performance over the Christmas period in relation to their performance over autumn. In order to get a truly fair idea of the performance improvement, it would need to be take over the same period next year, but, for the purpose of this study, that is not possible. So instead, we will go straight to assessing the improvement proposals that the LSP has made.

The newly proposed lead time estimates from the LSP are confidential information so cannot be shown in raw form. Instead, as with the data shown in the charts from Chapter 5, the estimates have been multiplied by an undefined number (the same number as that used in all other charts in this thesis). Figure 34 (page 61), shows that the mean weekly variance that would be caused by the new estimate lead times that the LSP is proposing, would cause almost no variation, if they had been operational during the weeks analysed in this study. Depending on how well the LSP can maintain their lead time performance in the future, these estimates will be a strong improvement on the old ones, as shown in Figure 34, as the grey line.

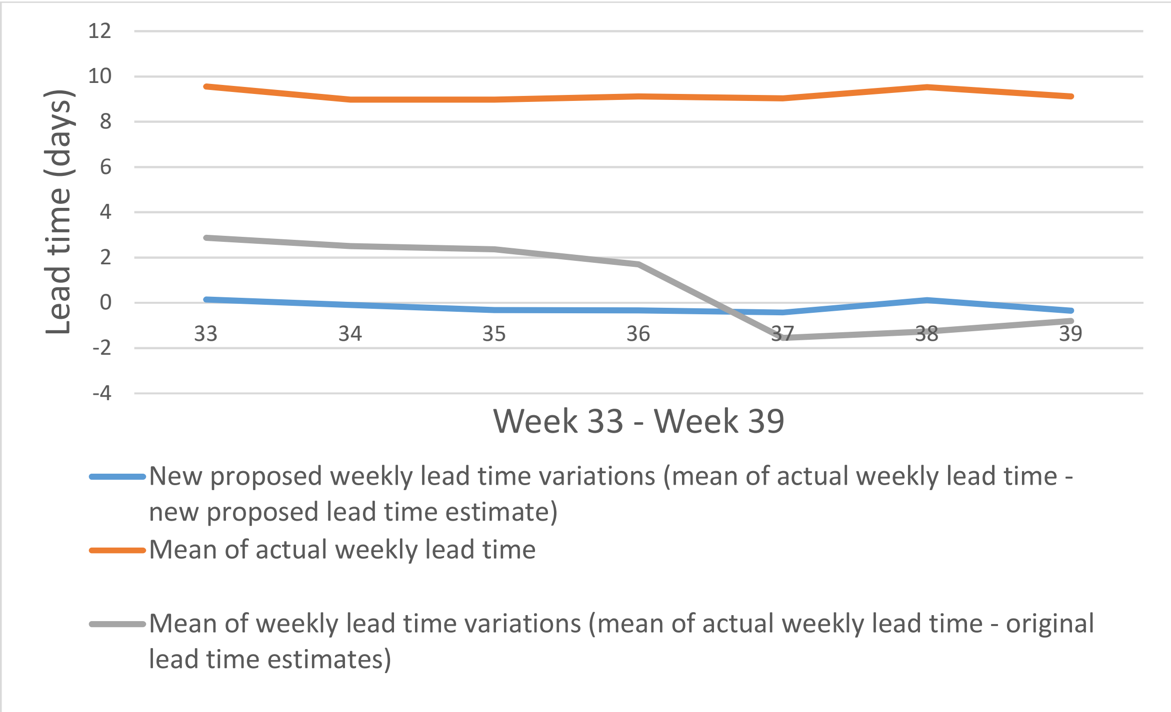

Figure 34. The weekly variation that the LSP proposed lead time estimates would have caused over the data analysed in this study.

Figure 35 (page 63), shows the same timeframe as the Figure 34, but now, the means used are the daily means; rather than the weekly. This gives us a detailed understanding of the variance. We can still see the increased variation in the daily mean lead times is causing the estimates to move off the zero line (which would indicate no variation). This is a logical effect that the mean lead time increasing will cause the variance between the estimate and the lead time to increase; the correlation here of 0.87, signifies a strong positive correlation that agrees with this assessment. The development going forward therefore, will be ensuring that the LSP maintain their lead time performances, and as they begin to improve, these the estimates must steadily reduce with the improvements.

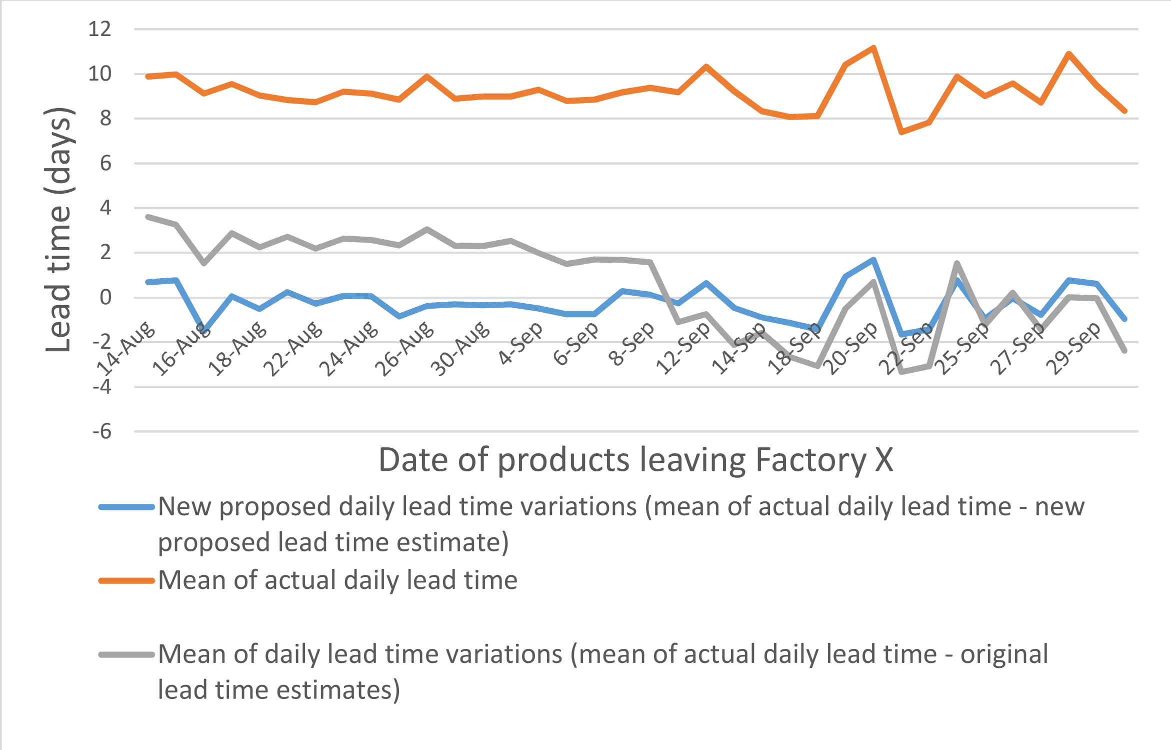

Figure 35. The daily variation that the LSP proposed lead time estimates would have caused over the data analysed in this study.

Figure 36 (page 64), shows the country by country view, through this it is again possible to question lead time estimates, per country. In this chart, we can see that overall the estimates are quite close to the mean of the lead times over the studied period. However, country 6, 10, 14, 16 and 19's estimates are still showing big variances from the actual performance. This analysis, has aided SEP to go back to the LSP, to request further details behind these lead time estimates, as it is not clear if there is valid reasoning behind them.

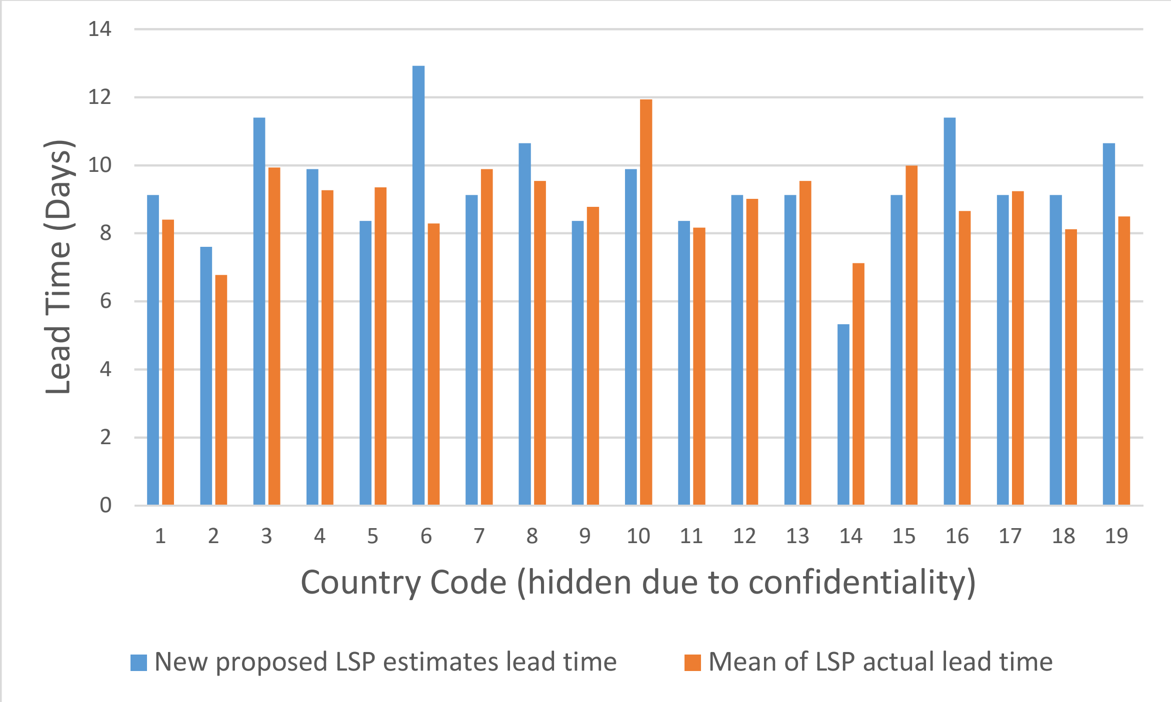

Figure 36. Country by country assessment of the mean of lead times alongside the new proposed estimate lead times. (countries removed due to confidentiality)

As the LSP's control over the lead times was critical to the proposed estimate lead times being reliable in future, it was important to create a control chart of the data assessed in this project. This chart is shown in Figure 37 (page 65).

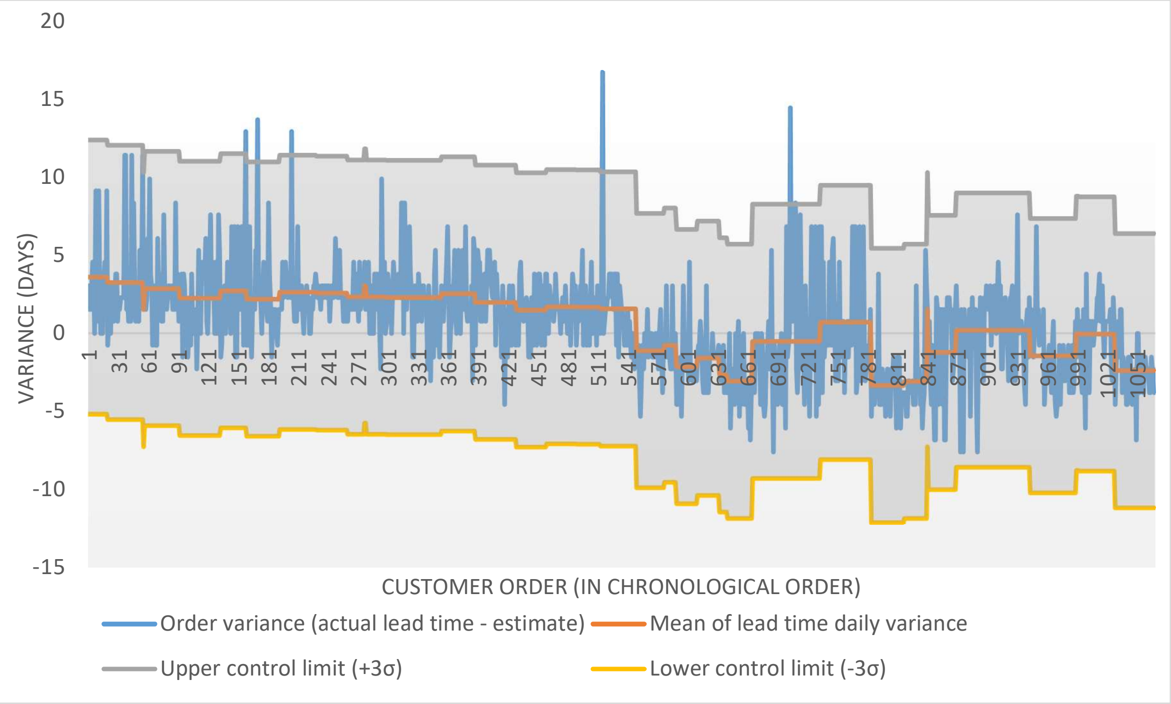

Figure 37. Control chart (u chart) showing every order's lead time variance (actual lead time – the original estimate) in blue alongside the daily mean variance shown in orange, the upper control limit (+3σ) shown in grey and lower control limit (-3σ) shown in yellow. (Pyzdek & Keller 2014, 330-340)

The control chart in Figure 37, allows us to view the distance that every order, studied in this project, is away from the daily mean. This detailed view, allows us to see the variance occurring in each order to see how well they adhere to the mean. The upper and lower control limits are added according to traditional 3 Sigma standards, which dictates that, in a process that is in control; 99.73% opportunities will occur within that range (Pyzdek & Keller 2014, 8-9). As is shown in the chart, the upper and lower limits, move with the mean. Looking at this chart, we can see that the occurrences that are recorded outside of the control limits (referred to as special causes), need to be investigated to determine whatever caused them. This is because whatever did cause them, is not a normally occurring situation in this process. The occurrences within the control range (common causes), can only be improved upon with changes to the process itself, whereas, special causes can be analysed individually. At this stage in the project, however, this is not the reason for including this control chart. This control chart shows how the process shifted over the course of the period studied, to be more centred around the desired outcome (zero). At the start of the process, the control limits were at +12 and -5 (rounded), whereas, at the end they were settling closer to +9 and -9 (rounded). However, the final control limits, shifted down to +6 and -11. You might note that this control area, does not indicate an acceptable specification range as this is determined by the customer (George & al. 2005, 122). It shows, the statistical probability of outcomes occurring within its range. (Pyzdek & Keller 2014, 311-340)

Figure 37 (page 65), is interesting and promising in terms of how we can see the mean shifting towards the desired outcome, but, it is not conclusive. We would need to assess the story going forward, and see how it progressed. Currently, there is far too much variation in this process, and a range of between 17 and 18 days, between the upper and lower control limits, is too high.

At this stage of the project, SEP stated that they were more than happy with the results that were presented and asked that the project ended here. They felt that they had all they needed in order to further improve the lead time estimates.

7 Control

Figure 38. DMAIC Model (Pyzdek & Keller 2014, 30).

Due to the restrictive timeframe of this project, it was not possible to complete all elements of the control phase. In order to implement and measure the improvement, it would not be possible to measure the outcomes until 2018, at the earliest. Instead, this chapter will be used to assess the project outcomes, and look at possible future improvements and developments. Additionally, this chapter will evaluate the project from the perspective of the author.

7.1 Conclusion

At the start of this project, it was crucial to discuss a wide variety of different tools and ideas that can be needed in a Lead Six Sigma project. The reason for this is that no one problem is the same, and the idea behind Six Sigma is that the data should be used to uncover the tools and project tasks that are needed. What is clear, is that this project was very complex in some areas, and in others, it was relatively straight forward.

When it comes to the difficulties the scope was, by far the greatest challenge. Having to look at so many activities occurring in so many locations, in Asia and Europe, as well as the sheer size of the data analysed, the scope was undoubtedly daunting. What balanced out the difficulty of the scope was that the processes being studied, were predominantly outsourced. What this meant for the project, was that, Lean ideas such as the *7 Wastes, Kaizen, Kanban, 5S or 5 whys* were not explored. While this is disappointing, that these elements were not looked at from a practical perspective, it meant that the level of data analysis could be very detailed. It was mentioned in this thesis study, the idea from George & al. (2014, 14), that it is important not to conduct analysis for the sake of analysis. I believe this idea could be taken further to the tools used as well. It is clear from this project, that the idea of a Lean Six Sigma project, is not to show how many tools can be used, but rather, how well can the tools that were used; answer the business problems encountered.

The DMAIC project framework, gave so much guidance to this project. The gated nature, whereby you have to complete a phase before continuing meant, that at any given time, it was clear what tasks were needed to be done, and how far the project had progressed.

The most difficult aspect of this thesis, had to be, the complexity of the statistical analysis that it required. It took days to build the data needed in order to conduct the analysis, but as soon as the charts were created, and they showed the vivid stories that they did, it was all worth it. I believe SEP, were most pleased with the way that this study not only tackled the physical issues and the data analysis, but also, the logistics team now have a good understanding of the customers viewpoint. I think, from my perspective, this is a very critical aspect of the Lean Six Sigma study. The customer interviews at the beginning, led my study throughout the project, and now that I have spoken with them personally, I care far more deeply about getting them results than I would have without their involvement.

One aspect that was not discussed too much in the thesis, but, that was very challenging, was the change management aspects. Whilst there was limited change going on in this project, I did follow a process of ensuring I communicated with all of the relevant stakeholders throughout the project; and the framework of change management helped this a great deal. It was important to understand the needs of the person I was reporting to. It is not a case of reporting the same update, to every stakeholder. For instance, my emails to the management team were far more concise and direct than the discussions I had with the process owners.

7.2 Future Improvements

In terms of future improvements, there are two main categories, the information flow challenges and the material flow challenges. This project, was a very good starting point for analysing the process and for pinpointing areas of improvement from both the information flow aspects and the lead time estimation quality aspects. In terms of the information flow challenges uncovered, I believe SEP have all they need to improve the order book layout, which, needed to have the old orders removed, and also needed some minor simplification in order to improve user friendliness. The messages sent to inform customers of changes needed to be reworked, and this may take more effort and time as it requires more collaboration with external partners. However, they now have a good understanding of how the customers feel, and what they want to see improved; the ground work for this development has now been made.

As for the material flow challenges, I think the story is quite similar. The improvement process is far from over. The data analysed did not change through the course of the study and, therefore, there is no way of knowing what progress was made with the changes implemented. This will be available next year but sadly, for this project, that is out of the scope. What has been achieved, however, is that the company now understand that the lead times are more constant than the estimates and, therefore, in order to improve the customer experience, the key is to first improve on these estimates. Once they are under control, and the process is steadily progressing to higher performance levels, then it will be possible to review the lead time length. Moving the lead time length prior to having the process in control, will create greater variation. I believe that the calculations made in this study, should be continued, and a two-step process of reducing variance and then, looking at reducing lead times, should be taken.

7.3 Key Outcomes

The key outcomes from this project are the analysed data of the customers' voice that can be seen in chapter 3.5 (page 46-48). The root cause analysis of the lead time variation which was uncovered throughout the analyse phase results is shown in chapter 5.3 (page 55-60). Finally, the LSP's new lead time estimations, and their assessment, is seen in the improve phase, chapter 6 (page 61-66). A presentation of this project was delivered to SEP, and this presentation can be seen in Appendix 6. As stated previously, SEP were very pleased with the outcomes of this thesis.

7.4 Reliability and Validity

When a project is so heavily based on primary data, it is important to ensure it data is reliable. In the case of this thesis, ensuring the measure, analyse and improve phases addressed the topics of reliability, validity and objectivity were paramount. The metrics that were decided upon, and how they were measured were the two areas of concern. Data is valid when it actually measures the thing it is setting out to measure (Burns & Bush 2014, 214-215). If a measurement is reliable, it means that if it were remeasured; it would deliver the same result (Pyzdek & Keller 2014, 280).

In terms of this project, the raw data was not created by the author, therefore, it is not possible for me to fully verify the validity or the reliability of the raw data. The raw data was, however, created digitally by the LSP who are responsible for the processes being measured. This reasoning, is strong enough to state that the data included in this study, is reliable and valid.

In addition to the data aspects, the secondary research in this thesis used only reliable sources including, many of the leading theory books of Six Sigma, Lean, Operations management, Supply Chain Management and Business Strategy. Online sources were used very rarely and they kept to reliable news sources such as the BBC (2017) and Time Magazine (2017).

7.1 Evaluation

Overall, I am really pleased with the outcomes of this thesis. That being said, I feel that it is a shame that the timeframe limited my ability to create concrete and proven improvements. Whilst the LSP's projected lead times were clearly showing to be more in line with the real lead time averages, it would have been very interesting to continue the data analysis further into 2018, and beyond. I was preparing to conduct more detailed analysis in this project, however, SEP stated that there was no need. They were more than happy with what I had achieved, and they wanted me to finish my thesis sooner rather than later. Ultimately, I think they were right, and I am immensely grateful to all of the people who helped me on this project. I felt that SEP as a company, took this project very seriously and gave me all the support I could have asked for.

7.1 Self-Assessment

I feel that the project was a very steep learning curve for me as a professional. In trying to understand such a large and complex process as the order fulfilment is with the use of Lean Six Sigma tools, statistical methods as well as project management and change management; it is clear that I learnt a great deal. In addition, understanding how all of these theoretical elements are applied in practice was a really valuable aspect of this project. I began the project officially in September 2017, and completed the project by the middle of November 2017. On presenting the results to SEP, they told me that they were delighted with the results of the project. I have now accepted a permanent contract offer from a company in the same industry taking on similar tasks as performed in this thesis. On the completion of this project, I also passed my qualification as a Certified Lean Six Sigma Black Belt. I am very grateful to everyone at Haaga-Helia UAS for the education I have received and I believe I owe a great deal to the Finnish system in general for allowing me to pursue this level of education for free. I could never have wished to have achieved so much in under three years. I am very proud of the results of this thesis, and I am really happy with my new career prospects going forwards.

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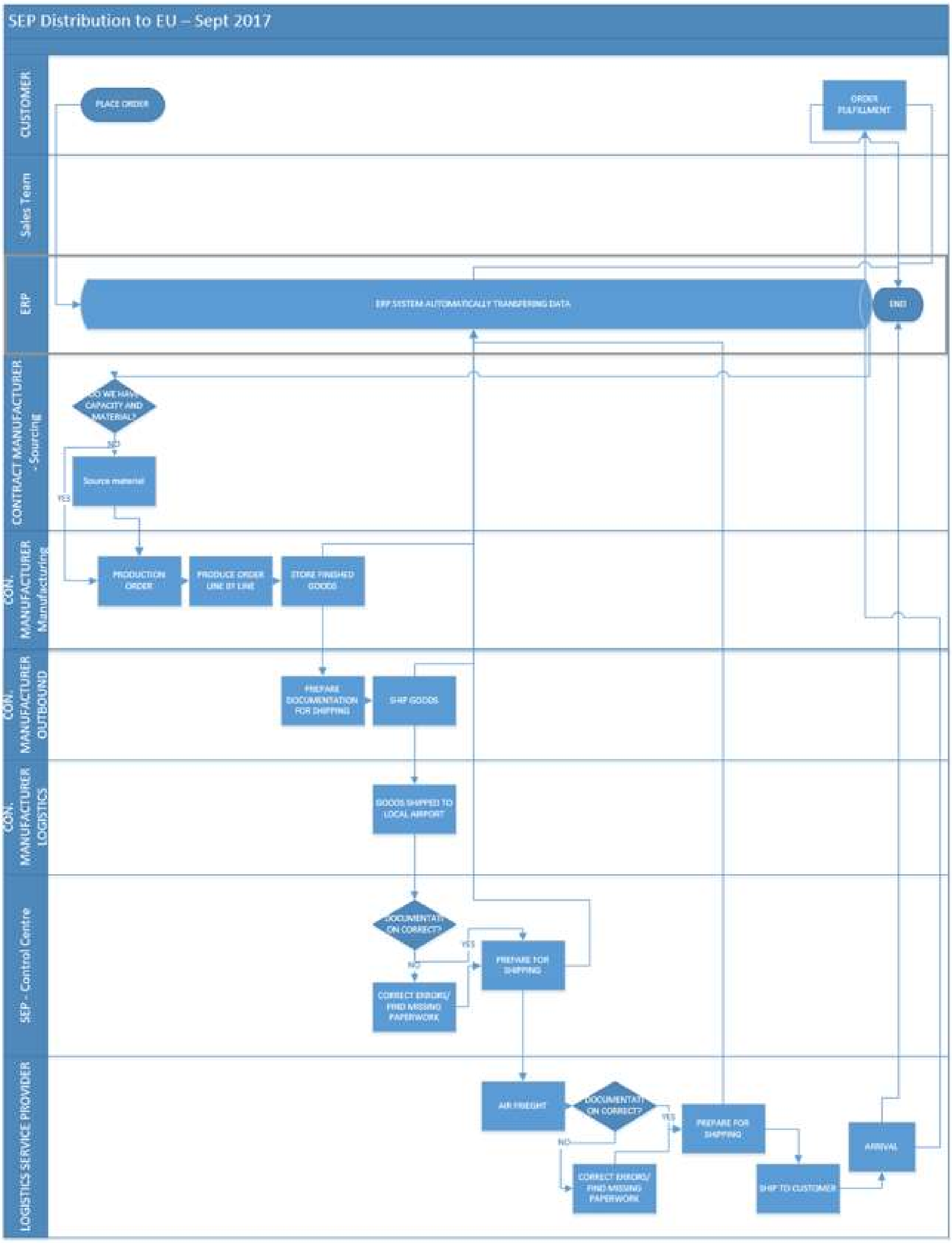
Appendices

Appendix 1. Process Flow Chart



Appendix 2. Project Charter Part 1

Project Charter	
Project Name: Using Six Sigma to optimise the B2B Order Fulfilment of Electronics in Europe.	
Opportunity/Problem Statement: Variability issues in the distribution chain are creating unreliable estimates for customers. The need is to better understand the root cause for these variations and following on from this 1. what can be done to reduce variation and 2. what can be done to create more reliable estimations.	
Business Case/Impact: Customer expectations are not being met currently. Success in this project will have a direct impact on customer trust and satisfaction.	
Team Members: Adam Burnage	Project Owner: Adam Burnage
	Project Sponsor: Confidential Information
	SMEs: Confidential Information
Project Performance Indicator(s): On time Delivery (OTD), Lead times and Forecast variations	Target(s): To reduce variation in lead times and create reliable delivery estimates for customers.
Project Boundary & Scope: Refer only to orders of a determined product from the factory to Europe via a determined port in Europe. Factory purchasing and production processes are out of scope.	

Appendix 3. Project Charter Part 2. Project Schedule (as of 21/09/2017)

Project Schedule

Legend: Planned (white) · Actual (grey) · * indicates tollgate date

Week (2017)	Week 36	Week 37	Week 38	Week 39	Week 40	Week 41	Week 42	Week 43	Week 44	Week 45	Week 46	Week 47	Week 48	Week 49	Week 50	Comments
Define	Problem Statement	Project Charter														
	Top Level Process Flow	Deliverables (critical to schedule)														
Measure			Process Definition	Process Baseline Estimates (current state analysis)												
			Metric Definition (OTD)													
Analyze					Data Analysis (Correlation and Regression)	Further Potential Data Analysis	Potential CTx Study									
							Process Capability									
Improve							Potential Use of Improvement Tools	Potential Use of Improvement Tools	Bench-marking							
									Future Process Flow							
Control										Potential FMEA	Advice for Scalability	Finalising Thesis (plus project buffer)				
										Tools to Maintain Results	Update Documentation					

Schedule of Activities

Appendix 4. Project Charter Part 3. Meeting Schedule (as of 21/09/2017)

Meeting Record

	No.	Date	Time	Att. (+Adam)		No.	Date	Time	Att.		No.	Date	Time	Att.		No.	Date		Notes
Meetings	1	21/08/2017	1 - 2pm																
	2	4/9/2017	1.30-2pm																
	3	12/9/2017	12-1pm																
	4	13/9/2017	2-3pm																
	5	18/09/2017	3-4pm																

Confidential Information

No. - Mtg. # **Date** - of Mtg. **Time** - duration of Mtg. **Att.** - how many in attendance (use Minutes to capture who attended)

Appendix 5. Customers' Voice Questionnaire

Customer Interview regarding the order fulfilment process.

1. Could you talk me through the current order to fulfillment process for your viewpoint? Once we have this defined we can go through this and highlight which sections are not meeting your expectations.
    a) Could you run through your order process?
    b) How well are you made aware of the production process and lead time? How does this information come to you?
    c) How and when do you receive delivery estimations and updates?
    d) Could you run through your view of the final stages, what is occurring, when and why?

2. Which aspect of the current order fulfilment process do you believe should be prioritised for improvement?
    a) Lead time (Order to Fulfillment)
    b) Delivery estimate variations in days
    c) Delivery estimate variation – time of day
    d) Communication and visibility
    e) Other (please specify)

3. Could you discuss the order book? How you receive it and use it currently? Is this current situation good?

4. How and when are you using the delivery updates?

5. How satisfied are you with our current distribution performance?
    1) Not at all satisfied
    2) Unsatisfied
    3) Satisfied
    4) Very satisfied

6. Would you like to add any further comments on these topics?

Appendix 6. Presentation of the project to SEP **1 (7)**

Lean Six Sigma Project Update - 1st November 2017

Adam Burnage

01/11/2017 1

Current Project Status:

Define:
- Project charter – Complete
- Theoretical backdrop – Complete
- Top level process mapping - Complete
- Internal interviews – Complete
- External interviews – Complete (5 interviews)

Measure:
- Metrics defined – Complete
- Data collected – Complete

Analyse:
- Root cause analysis - Complete
- Process flow analysis - Complete

Improve:
- LSP's new estimates - Complete

Control : Out of scope due to time limitations

01/11/2017 2

2 (7)

Customers' Voice Analysis

Information flow challenges:

- What information do customers receive (or have access to) when and why?
- Order book contains too much data for customers to use it (account managers are creating localised solutions)
- We need to consider who receives what information (warehouse or office?)

Material flow challenges:

- Lead time variations (partly related to information flow)
- Quantity variations
- Visibility
- Products sent to the right locations (if a customer has multiple warehouses)

01/11/2017 3

5 Slides were removed from this section due to confidentiality agreements. They covered customer's views on information they recieved during the process and how it could be improved.

01/11/2017 4

3 (7)

Material Flows: Scope and Metrics

Scope:

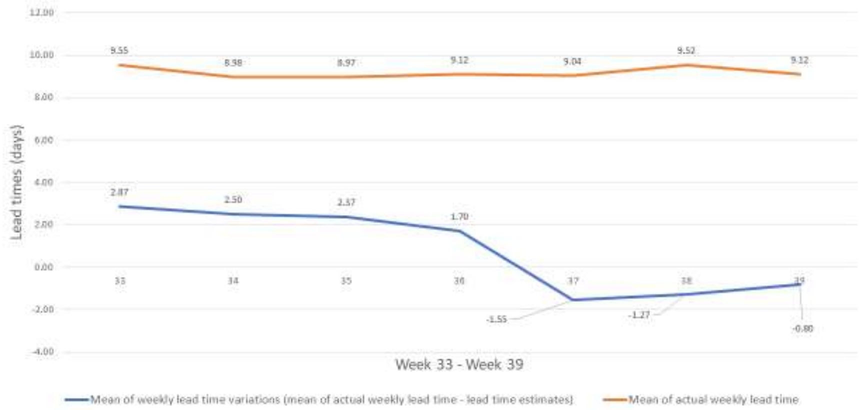
- Data assessment from week 33 – 39
- Includes only product X from Factory X via international port X to customers in Europe

Metrics

- OTD – On time delivery
- Forecast accuracy (factory variation) vs lead times and lead time variance

01/11/2017 10

LSP estimates changed around week 36. Lead times however remained constant.



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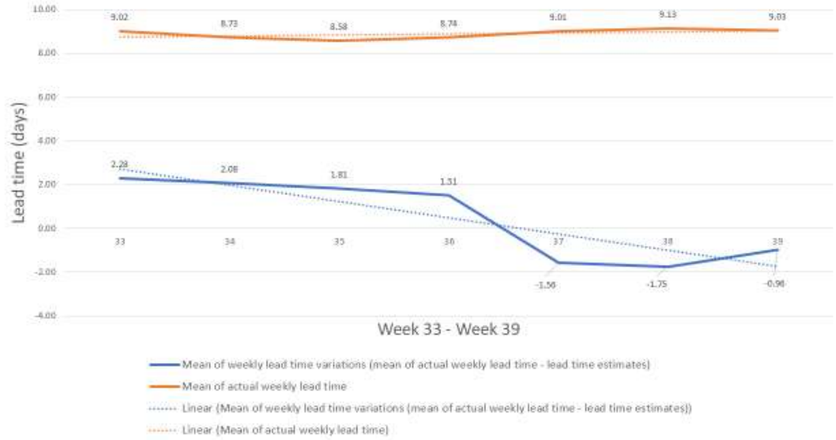
4 (7)

Removing data with delays caused by customers the performance only slightly improves.



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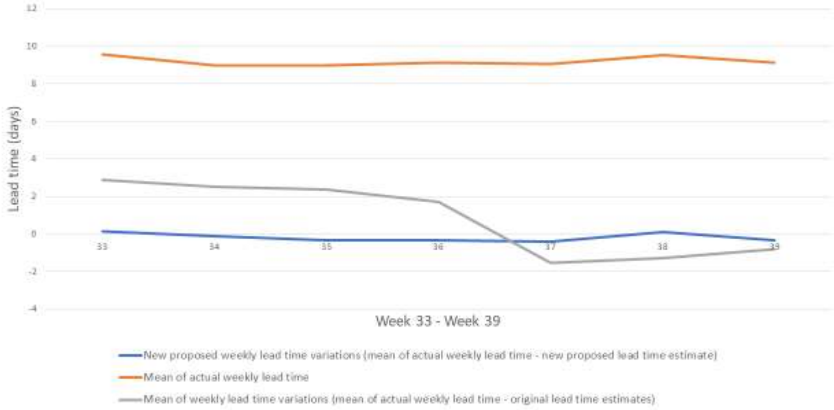
Change in estimates occured around the 8th Sept. Appears to align with increased variation of means.

01/11/2017

13

New LSP estimates would have given better performance over the period analysed.



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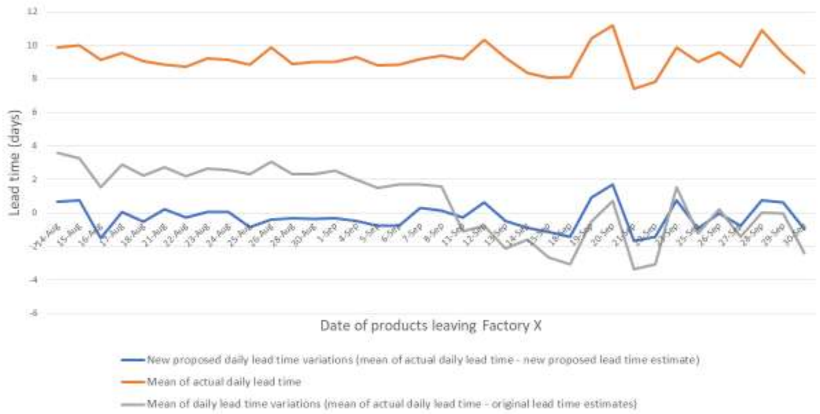
Daily view of the new estimates.



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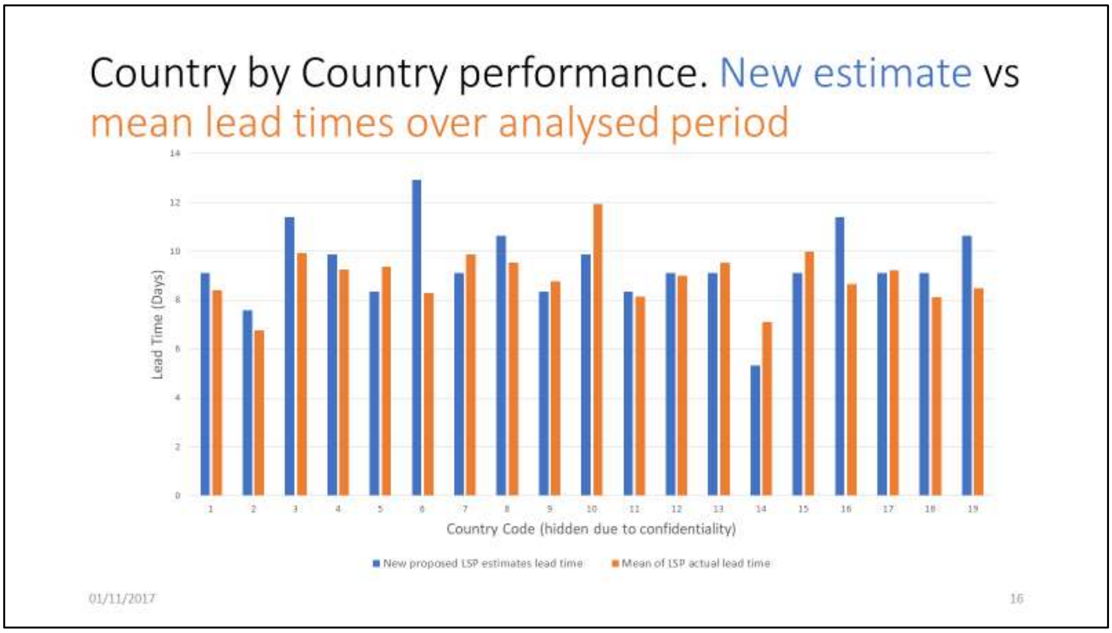
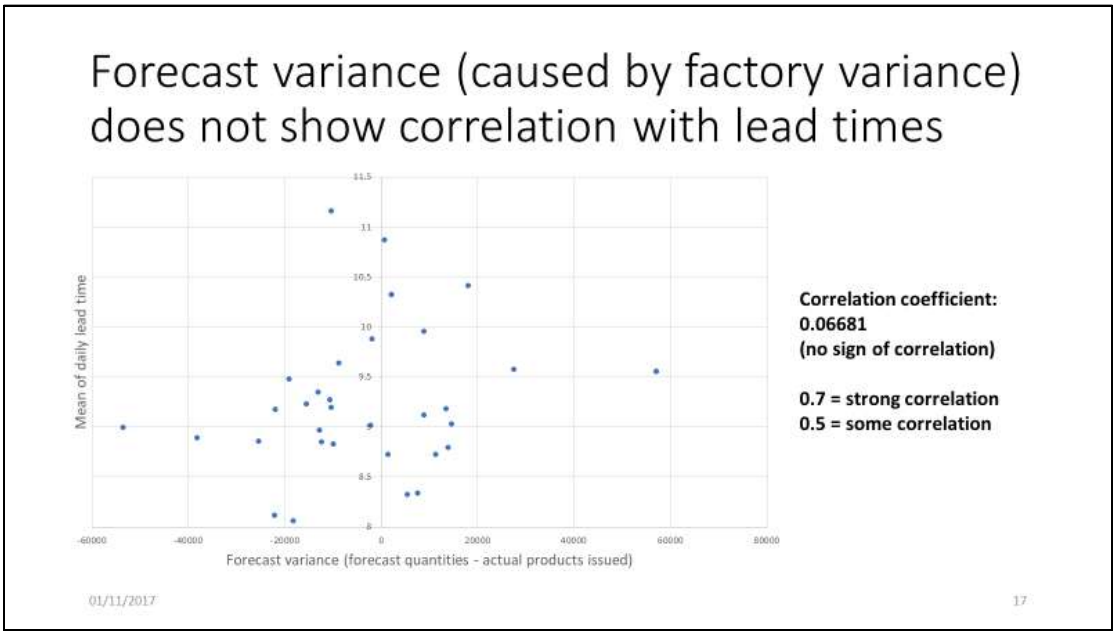

Country by Country performance. New estimate vs mean lead times over analysed period
Lead Time (Days)
Country Code (hidden due to confidentiality)
New proposed LSP estimates lead time
Mean of LSP actual lead time
01/11/2017
16


Forecast variance (caused by factory variance) does not show correlation with lead times
Mean of daily lead time
Forecast variance (forecast quantities - actual products issued)
Correlation coefficient:
0.06681
(no sign of correlation)
0.7 = strong correlation
0.5 = some correlation
01/11/2017
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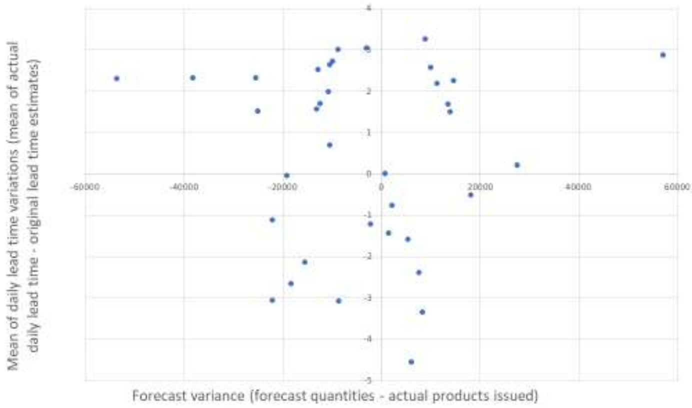
Nor does it show correlation with lead time variations



Correlation coefficient:
-0.00246
(no sign of correlation)

0.7 = strong correlation
0.5 = some correlation

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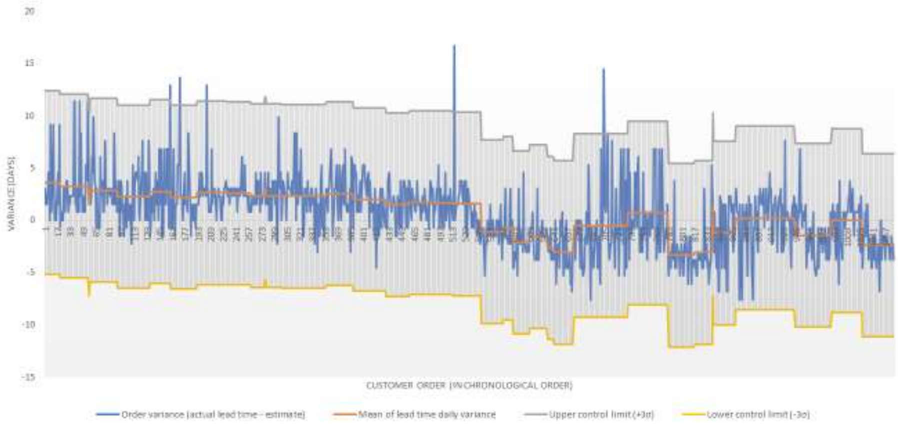
Control chart over same period show process is coming under control.



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