1918 TALLINNA TEHNIKAÜLIKOOL

FACULTY OF MECHANICAL ENGINEERING
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LEAN APPROACH IN MANUFACTURING AND SERVICE SECTORS

M.SC. IN INDUSTRIAL ENGINEERING AND MANAGEMENT

MASTER'S THESIS – MET70LT

TALLINN 2014

Author's Declaration

I have written the Master's thesis independently.

All works and major viewpoints of the other authors, data from other sources of literature and elsewhere used for writing this paper have been referenced.

Master's thesis is completed under the supervision of

Kristo Karjust (Tallinn University of Technology, Estonia)
Janerik Lundquist (Linkoping University, Sweden)

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Master's thesis is in accordance with terms and requirements "....."....201….

Supervisor …..... signature

Accepted for defence

..... chairman of defence commission

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..... Signature

TUT Faculty of Mechanical Engineering

Master's thesis task

2013 /2014 academic year 4th semester

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Master's thesis topic (Estonian and English languages):

Lean Approach in Manufacturing and Service Sectors
……

……

Tasks and timeframe for their completion:

Nr	Task description	Completion date
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2	Literature search and reading	03-03-2014
3	Case studies and lean analysis	05-05-2014
4	Comparison and conclusion	19-05-2014
5	Final reporting	26-05-2014

Engineering and economic problems to be solved:

The process performance is increased of manufacturing case company as there is reduction in inventory levels and cost by implementing lean production approach. While the process yield and profit of service case company is also improved by practicing lean six sigma techniques.

Defence application submitted to deanery not later than ….…. Deadline …….....

Student ……. /signature/ ……..……. date ….....……

Supervisor…… /signature/ …….……. date ….....……

Phone …… E-mail: ……

OBJECTIVE OF MASTER'S THESIS

The master thesis has the following objectives:

- To understand Lean Tools and Techniques applicable in manufacturing and service sectors

- To compare successful practices of Lean Implementation in both sectors and to understand how lean concept can be applied as continuous improvement process

- To identify challenges that companies face during lean implementation

- To recommend appropriate Lean tools and techniques applicable to manufacturing and service sector in order to simplify and standardize the work processes

- To improve case companies' financial position by eliminating waste and focusing on what customers value

- The lack of comparative studies done related to Lean implementation in service and manufacturing sectors; therefore, this study aim to enhance Lean applicability in both sectors

ACKNOWLEDGEMENT

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1. INTRODUCTION

Lean approach is widely used to eliminate wastes from the systems both in manufacturing and service areas; lean concept is well-known for its profound improvements and on the other hand it is not easy to implement. In order to achieve impressive results in cost, quality and time, lean principles and tools need to be applied to enhance the process performance. These principles enabling a company to differentiate value from waste and facilitate to maximize customer value while minimize waste. This thesis studies provide the application of lean principles in manufacturing and service sectors, and to create awareness of how lean can fetch important changes in the improvement of certain process, but what must be done to implement it. Several literatures were reviewed to get the knowledge of lean and its implementation in different areas of business. A case study is selected from each sector for better understanding and research point of view; in both cases the problems are identified first and then solved with the help of lean approach. The results of case studies have shown improvement in the process of application of respective companies and their goals to achieve certain outcomes. It also reveal that lean is a philosophy and a way of thinking not just the different production tools, implementation of lean is long term approach and in order to see big improvements, companies need to put efforts continuously but it also depends on the nature of process that is under consideration.

The study also highlights the comparison of lean principles and seven types of lean waste not only in manufacturing segments but also in service areas and their effectiveness to improve quality, reduce cost and on time delivery through elimination of wastes.

This chapter will provide the different aspects such as background and objectives of the study, the research tactic, as well as research ideas aimed to achieve this study. It follows definitions of the main concepts and the significance of the study. Furthermore, a structure of the literature review is created in order to organize the literature review process and highlighted the research questions.

1.1 Background of Study

In today's advance world the companies are striving to get better and better, the competiveness in the world market has always existed and is a key element for improvements, because it forces people and companies to drive themselves in order to bring up new tools or methods and take stance in front of innovative gadget. Nowadays, people have to innovative and continuously make efforts for better customer's satisfaction.

As organizations are struggling to meet increasing competitive pressures and to remain competitive, many of them are embracing Lean, as a tool to improve their position. Lean is the process of optimizing systems to reduce costs and improve efficiency by eliminating product and process waste. The emphasis of lean is to eliminating non-value-added activities and the goal has been a goal of industrial engineering i.e., to improve the efficiency of all processes. In the article "The Leap to Lean" states that creating a lean organization comprises the delivery of goods and services using less of everything: less waste, less human effort, less

working space, less investment in tools, less inventory, and less process time to develop a new product, and less motion, for instance (Juran, 2010).

In the beginning of 20th century, Henry Ford developed a new way of manufacturing, mass production, which has been a major evolution. It has been first applied to the automotive industry, and then its philosophy has been applied in every kind of production plants. A second major evolution, which is nowadays considered as the best of way manufacturing has been developed by Toyota, during the second half of the 20th century, Lean manufacturing (Liker, 2004), describes this way of thinking and manufacturing in different books, which go in the opposite way of mass production, where quality is preferred to quantity.

Although lean concepts began in manufacturing operations and sector, it has been successfully applied in many service industries such as hospital patient care, insurances companies, financial services (banks) and more in order to improve cycle time, flow, improve workplace department performance and of course reduce waste. Lean principles can be applied in most processes because mostly contain waste that a customer is not willing to pay for, neither is the business keen to accept higher cost because of them. One reason that Lean has not been applied to a great extent in service industry is because there is organizational traditional thinking that it is related with production, as it was developed firstly for manufacturing purposes. However, nowadays, lean is considered a major tool that can be applicable for all sectors. Therefore when companies look for improvements they deliberately look in the direction of lean and its philosophy.

1.2 Research Approach

The problem or challenge of this thesis work is to study the implementation of lean methods and tools not only in manufacturing but also in service sector. Most of the academic research on lean is centered on manufacturing and its impact on company's performance and improvement, however, less focus has been given on the lean implementation in service sector. Hence, the following research is focused on the role of Lean tools and techniques in process improvement and what are the challenges and benefits of Lean implementation in service as compare to manufacturing sector.

1.3 Definitions of Key Concepts

It is important to describe some of the key concept that are using during this literature and they are as follows:

- **Lean Production**

This concept was born from the success of Toyota Motor Corporation (Womack, 2003), with the focus to reduce waste and use fewer resources compared to mass production system. Moreover, (Emiliani 1998) agrees that Lean production objective is to reduce resources by eliminating non-value added activities. Lean production was expanded from the shop floor techniques to all manufacturing functions by involving the whole organization (Kollberg, Dahlgaard & Brehmer, 2006).

- **Lean Thinking**

It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less equipment, less time and less space – while coming closer and closer to providing customers with exactly what they want (Womack, 2003). To develop Lean thinking, organization should communicate the successes that could be received from its implementation. Also, they should continuously try to identify waste, monitor the flow and focus on customers' satisfaction (Melton, 2005).

- **Lean Services**

It is about eliminating waste from service processes in order to speed efficiency. Even though in services the waste can be tangible and intangible, the key challenge is to manage the intangibility of waste because of its difficulty to identify. Lean service has generated positive results also in retail, airline, hospital and finance (Piercy & Rich, 2009). After top management takes an action to implement Lean in service by changing behaviors and attitudes of employees, they should also empower and give more authority to them over decision making for process improvement within their responsible job areas.

- **Waste**

It includes any activity that does not add value beside the minimum equipment, parts and employees, which are needed for the business (Slack, Chambers & Johnston, 2007). Similarly, waste as anything that is not valuable for customers, for which is spent time, money and work. Waste occurs due to the way of operation of processes in organizations. Moreover, the search of waste in organizations does not have an end point.

- **Value added activities**

Value added activities are those activities that add value from customers' perspective, for which they are willing to pay. These activities are those that customers cannot perform themselves or cannot perform without substantial time and money Value added activities can be defined only by customers (Maleyeff, 2006).

- **Non-value added activities**

These activities are the work which does not add value to the customers, for which they are not willing to pay; therefore, should be eliminated. These activities exist because of the current structure of the system in organizations, and are considered wasteful (Maleyeff, 2006).

1.4 Significance of Study

Following are the points for the consequence of this study:

- The increasing importance of Lean from past few years, where companies with the help of Lean philosophy are trying to improve by generating higher profit and reduce cost

- To improve companies' financial position by eliminating waste and focusing on what customers value

- To enhance companies' knowledge and efficiency by changing the behavior and attitude of all employees as a result of Lean thinking

- The lack of comparative studies done related to Lean implementation in service and manufacturing sectors; therefore, this study aim to enhance Lean applicability in both sectors

1.5 Composition of Studies

The thesis comprises of five chapters. The first is the introduction that consists of background, objective, research questions and significance of the study. The second chapter is the literature review that explores the idea about the history of lean, lean principles, types of waste and implementation of lean in both sectors. The cases of manufacturing and service sectors can be seen in the chapter 3 and 4 respectively while the comparison of cases is set up in chapter 5. The last chapter 6 is about conclusion and discussion. The diagrammatic view of the structure is shown below in figure 1:

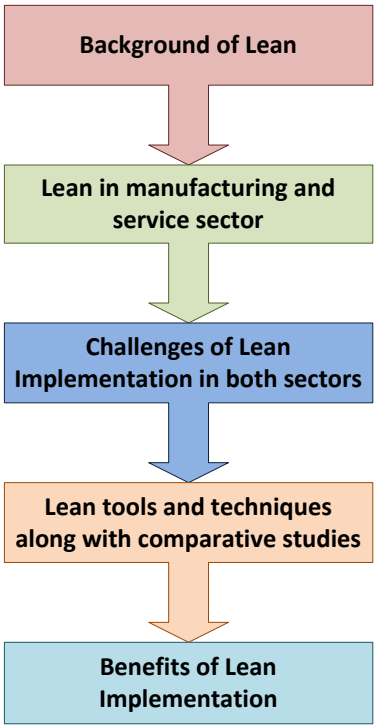


Figure 1: Literature Review Structure (source: create by author)

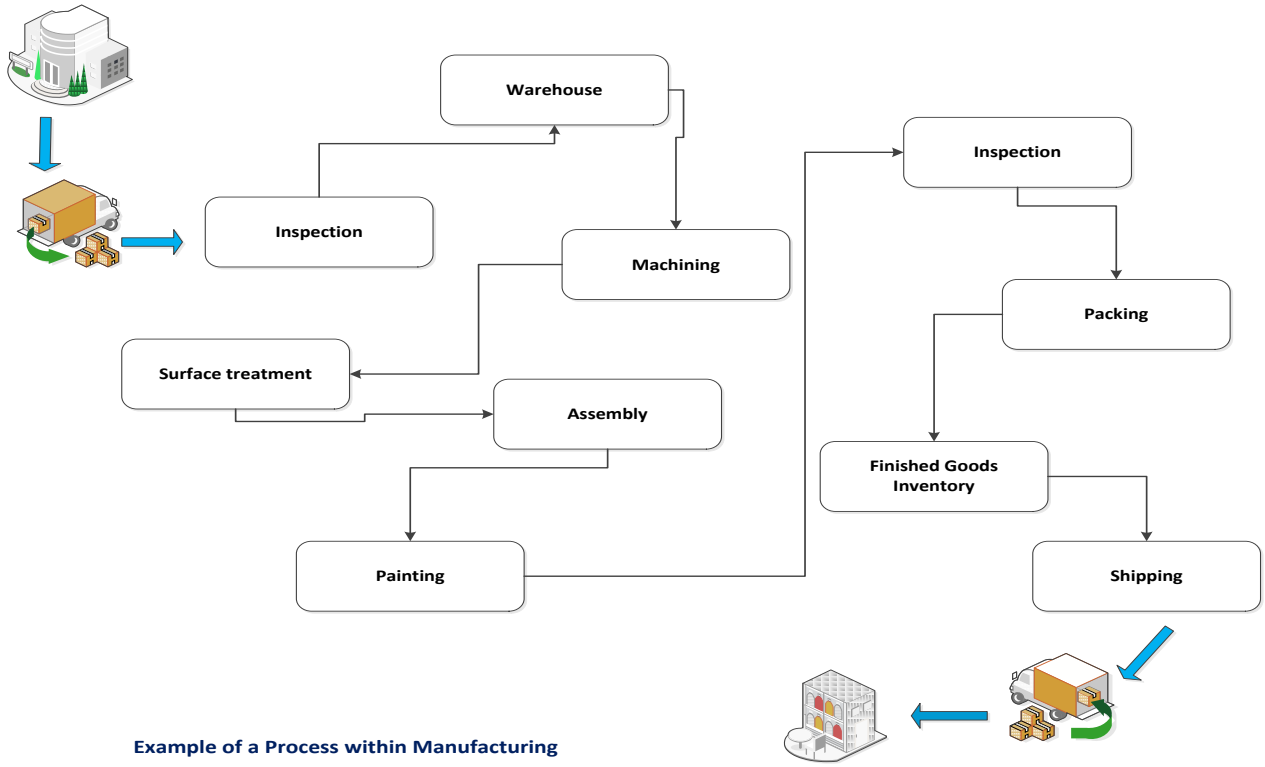


Figure 2: A manufacturing process (Peterson et al. 2010)

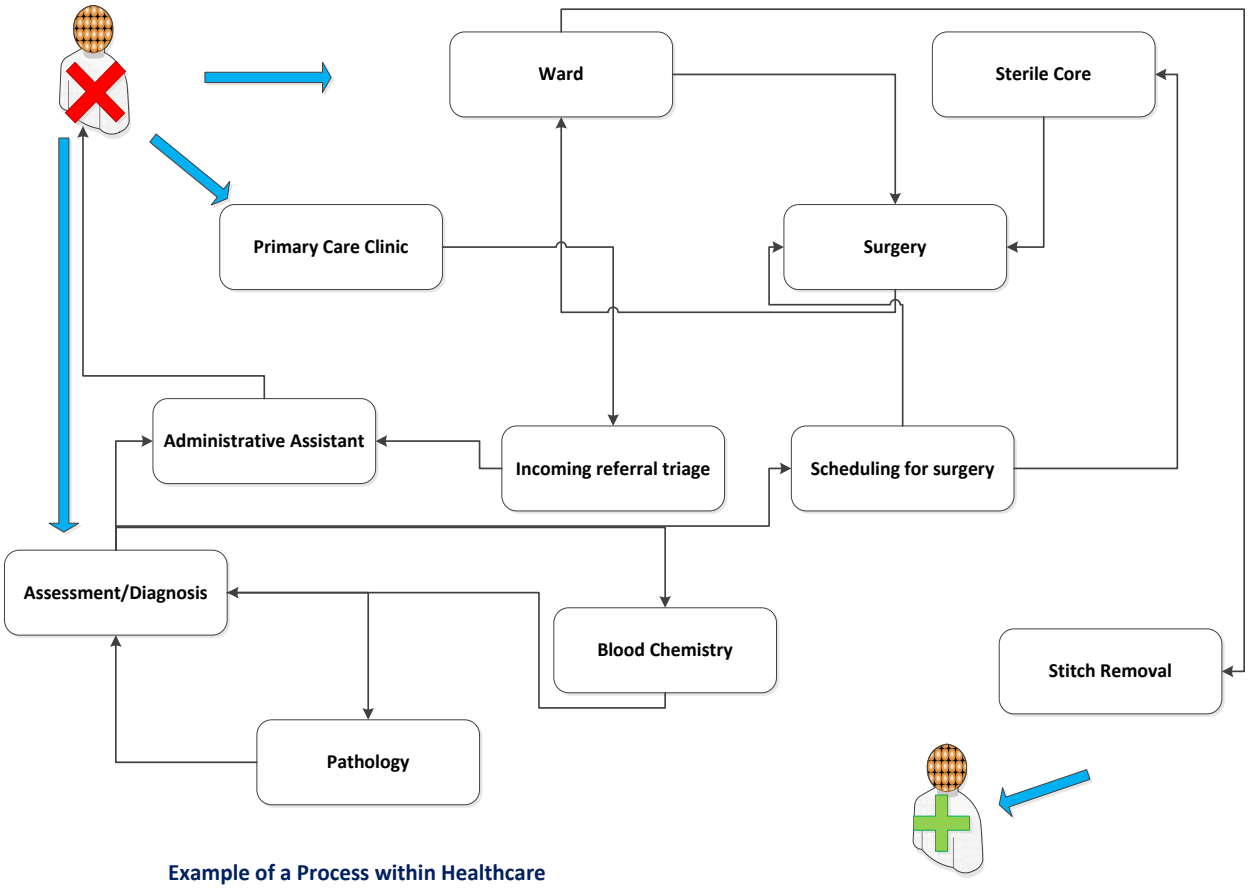


Figure 3: A service process (Peterson et al. 2010)

2. LITERATURE REVIEW

The literature review is more precise overview about lean methodology. This section starts with a history of lean and its corresponding principles, then move on with some explanation of lean in manufacturing as well as in service sector. Further, seven types of waste will be taken into the account. Moreover, it provides the challenges of lean implementation along with success factors, followed by lean tools and techniques. Lastly, it includes comparative study of lean in manufacturing and service areas, benefits of lean and lean criticism would summarize this section.

2.1 Brief History of Lean

The approach of lean was first initiated by Toyota, lean production directly followed from and is normally used as a substitute for Toyota Production System (TPS). Nevertheless, the concept was first introduced in a book named *The Machine that Changed the World* (Womack et al., 1991); which primarily focused Japanese production methods as compared to traditional mass production systems. The follow-on book, Lean Thinking: Banish Waste and Create Wealth in Your Organization (2003), was also a milestone contribution in the history of lean as it summarizes the lean principles and coined the phrase "lean production". The term "lean" means a series of activities or solutions to minimize waste and Non-Value Added (NVA) activities/tasks, and improve the value added (VA) process. This VA and NVA concept was derived from the Japanese style production, especially the TPS.

The term "lean process" in the literature has many definitions. As lean is generally derived from TPS and the basic idea in TPS is to produce the kind of units needed, at the time needed and in the quantities such that unnecessary intermediate (work in process) and finished product inventories can be eliminated. Three sub-goals to achieve the primary goal of cost reduction (waste elimination) are quality control, quality assurance, and respect for humanity. These can be achieved through four main concepts: JIT, autonomation (automation with human touch), flexible workforce, and capitalizing on worker suggestion and eight additional systems (Pettersen, 2009).

The basis of TPS is the absolute elimination of waste; two pillars needed to support the TPS are *JIT* and *autonomation (Jidoka)*. TPS can be described as an effort to make goods as much as possible in a continuous flow (Pettersen, 2009).

Lean production uses half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. It requires keeping half the needed inventory, results in many fewer defects, and produces a greater and ever growing variety of products (Womack et al., 1990).

Hopp and Spearman (2004) defined lean as the production of goods or services that minimizes buffering costs associated with excess lead times, inventories, or capacity.

Shah and Ward (2007) defined lean process as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability".

The lean model that is more close to the original TPS temple is defined below in the figure 4. This lean model only contains the vision, the main principles, and the principles within TPS.

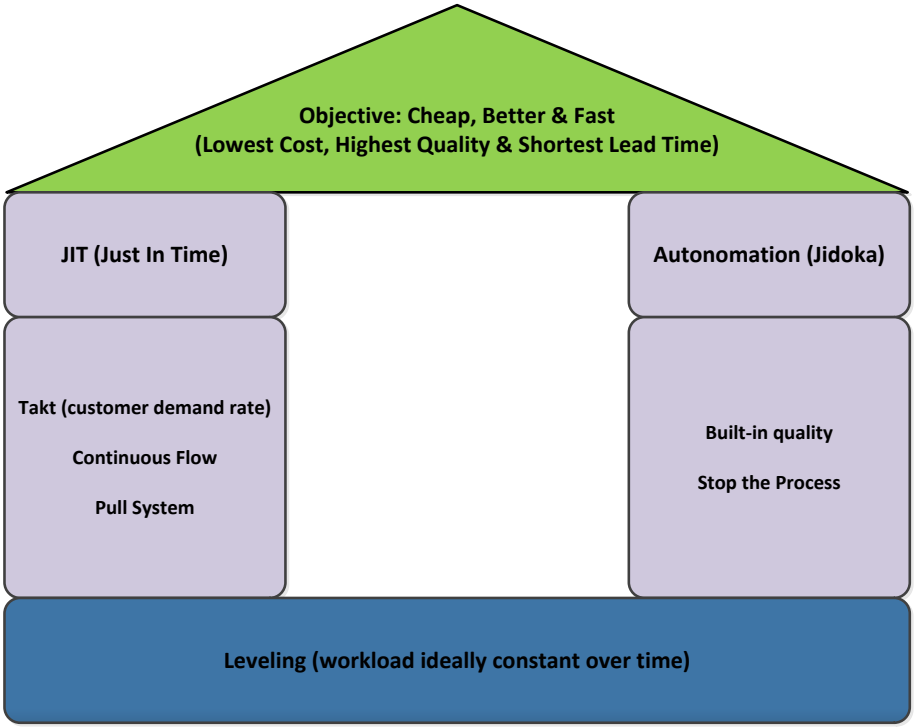


Figure 4: TPS House (Peterson et al. 2010)

The Lean mission is to have the following throughput the entire supply chain to win the marketplace: (Juran and De Feo, 2010).

- Shortest possible lead time
- Optimum level of strategic inventory
- Highest practical customer service levels
- Highest possible quality (low defect rate)
- Lowest possible waste (low cost of poor quality)

This is accomplished by synchronizing the flow of work - both internal and external to the organization, to the rhythm of the customer's requirements. All kinds of waste are driven out – time, material, labor, space and motion, the overall intent is to reduce variation and drive out waste by letting customers pull value through the entire value stream (or supply chain). The history of manufacturing and the introduction of Lean are summarized in figure 5.

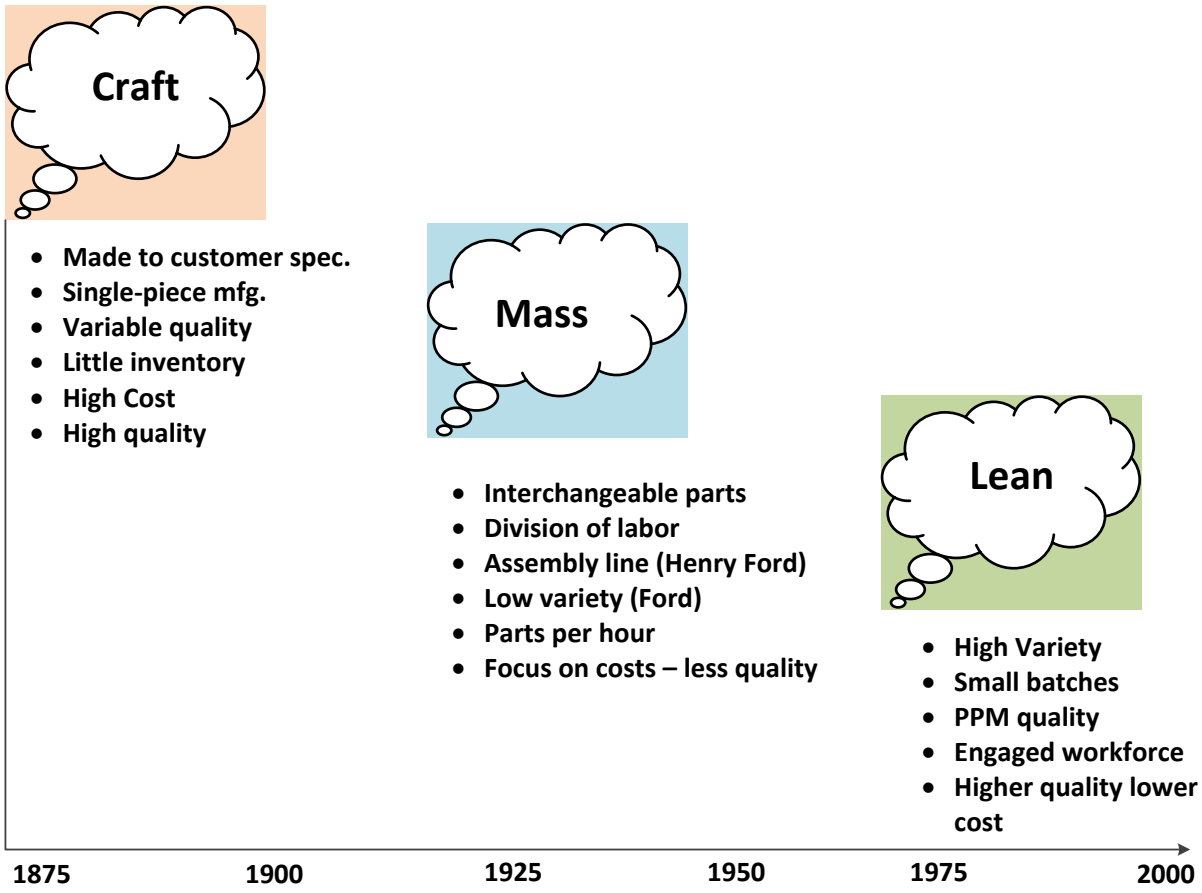


Figure 5: History of Production (Juran, 2010)

By adapting similar practices of lean, manufacturing companies started to implement such practices in service departments within the organization because of positive results from Lean. According to Juran (2010) lean methods are now used in service sector (hospitals, insurance companies, and financial services) in order to increase performance and reduce waste also discussed above. In the article "The current state of Lean implementation in health care" by Poksinska (2010) describes that lean is mostly used in health care (hospitals) as a process improvement approach and value stream mapping is the most frequently applied lean tool in health care. Calborg et al., (2013) suggests in their study of "A lean approach for service productivity improvements" that standardizing services and increasing reliability in service processes through lean principles can increase efficiency. Further, Lean principles can be beneficial in order to improve productivity in services with an appropriate approach in which customer satisfaction must be considered, otherwise the positive long term effects of a lean approach in services will be absent.

2.2 Lean Principles

Lean is focus on steady striving to eliminate waste. It is achieved through continuous exercise to visualize and resolve the deviations in an operation. A deviation is something that deviates from what is normal and can be perceived as defined and specific waste. Perhaps every organization agrees that waste should be eliminated, but the question is how. Here Lean principles have an important task in providing guidance. In order to be successful in Lean effort it is necessary for an organization that its values are aligned with the Lean principles.

2.2.1 Five Lean Principles

The five lean principles are explained by Womeck & Jones (2003) in *Lean Thinking* and focused on more how to add value in any manufacturing or service company not just to reduce waste. Principles are as follows also shown in figure 6:

1. Identify value from customer point of view: This means that the customer buys results, not products, and that any company needs to identify and begin product design and manufacture by focusing on what their customers need and want. It is as simple as the old expression "give the customer what they want" and not what is convenient for the manufactures.

2. Value Stream Mapping: Value Stream techniques focus on one object or product in the company not the viewpoint or the department of process step. The principle is to focus on the whole supply chain, from customers' orders, to the planning department, orders of raw material from different suppliers and then the value adding steps for the product, emphasizing economics of time rather than economics of scale. Value is added to a product while someone is working on the piece, non value adding steps are when the product is waiting in batches or stocks, which is waste.

3. Flow: This principle tries to describe that it is important to make the product move through one value adding step to the next one and keep the product in constant one-piece flow. Companies should avoid batches and queues, or at least continuously reduce them and never delay a value adding step by a non value adding step.

4. Pull: Pull means meeting consumer's rates of demand with production but not over producing. Most organizations will have to push to a certain point and response to a final costumer from that point. The idea with Lean is to push this point as long upstream in the product making process as possible, wait for a demand and then make the product fast and with high quality. So if the delivered products have any defect, only a small batch of products will have been affected.

5. Perfection: The last principle seems more possible after the other four principles.
Perfections does not only mean quality, it also means producing exactly what the customer wants, exactly when they want it, to a fair price and with minimum waste.

Figure 6: Five Lean Principles (Womeck et al, 2003)

2.2.2 Toyotas 14 Principles

There are some companies focusing on five principles of Lean and try to adopt these principles in a quick way with no real deeper philosophy behind the implementation. Hence, they feel the result for the short-term that is not sustainable. The Toyota Way principles give the opportunity to the organizations to make sustainable by truly practicing full set of 14 principles and eventually organization has competitive advantage. Following are *The Toyota Way* Principles describes by Liker (2004).

1. Base Your Management Decisions on a long-Term Philosophy, Even at the Expense of Short-Term Financial Goals – This is the foundation for all other principles. All decisions should be taken to generating value to the company, its employees, the customers and the society as a whole. This principle should be the starting point, not just for product/service design efforts, but for every function in the company. All managers must all take responsibility, the job should be a mission greater then earning a pay check.

2. Create Continuous Process Flow to Bring Problems to the Surface – Flow means reducing all time a product or item is waiting for someone to work on it. Reduce all the none-value added time and make one-piece flow. Benefit of one-piece flow: Builds in quality, Creates real flexibility, Creates higher productivity, Frees up floor space, Improves safety, Improves Morale, Reduce cost of inventory. Flow is one of the keys to true continuous improvement process and to developing people. Everyone is forced to solve the problem so team members have to think and through thinking team members grow and become better people.

3. Use "Pull" System to Avoid Overproduction – The principle means that the customer pull and company replenishment. Receive items only when you demand and the retailer receives product based on actual customer demand but, try to flow where you can, pull where you must. Stock relatively small amounts of each product and restock the supermarket shelf frequently, based on what the customer actually takes away. Small laminated kanban cards could be used to say when an operation should be trigged.

4. Level Out the Workload – Work like the tortoise, not the hare. Eliminating muda (waste) is only one third of achieving flow; eliminating muri (overburden) and smoothing mura (unevenness) are equally important. The only way to realistically create a continuous flow is to have some stability in the workload. Toyota works to find many clever ways to level the workload, spikes and peaks are handled through flexible workforces brought in from contracting companies and suppliers. Look for a smaller number of part number and that are big in demand and perhaps even seasonal, build those when you have few real orders and then keep those in inventory, goes against principle 3.

5. Build a Culture of Stopping to Fix Problems, to Get Quality Right the First Time – When there is a problem, do not just keep going with the intention of fixing it later. Stop and fix the problem now. Productivity may suffer now, but in the long run productivity will be enhanced as problems are found and countermeasures put in place. It is necessary to stop the line if companies want to continually improve the process. The closer you are to one-piece-flow, the quicker quality problems will surface to be addressed. The employees feel the responsibility – they feel the power – they know they count. Keep quality control simple and involve team members.

6. Standardized Tasks Are the Foundation for Continuous Improvement – Toyota has found that standards actually can help people control their own work. Standardization is often confused with inflexibility but for Toyota it is the best practice methods. If the worker had followed the standard list and a problem occur, then the standards need to be modified design and improved upon. Capturing knowledge is not difficult, the hard part is getting people to use the standards and contribute to improving it.

7. Use Visual Control So No Problems Are Hidden – Clean the work place, make every part or item visual. Use 5S (sort, straighten, shine, standardize, sustain) to obtain reduced cycle times, increased floor space, improved working conditions, better work team performance etc. People are visual creatures. They need to be able to look at their work, look at the parts rack, look at the supermarket of parts, and easily see whether they are in a standard condition or a deviation from the standard. People looking at well-designed charts on a wall can have very effective discussions.

8. Use only Reliable, Thoroughly Tested Technology That Serves Your People and Processes – Toyota has had experiences with pushing the latest and greatest technology, and now avoids repeating this mistake. Adoption of a new technology must support your people, process, and values. But Toyota is always interested in being current in their technology and encourages their people to "think outside the box" when considering new approaches to work. Personal contact makes a difference and improving the process is the only way you can control inventory.

9. Grow Leaders Who Thoroughly Understand the Work, Live the Philosophy, and Teach It to Others – Toyota are growing their leaders rather than purchasing them. Because changing the culture each time a new leader comes into office necessarily means jerking the company about superficially, without developing any real depth of loyalty from the employees. It is the basic way of thinking that goes back to principle 1. Lean Productions is only effective with the right management and the right philosophy.

10. Develop Exceptional People and Teams Who Follow your Company's Philosophy – People drive continuous improvements; invest in people and in return get committed associates who show up to work every day, on time and are continually improving their operation. Toyota has a strong internal culture that they often refer to as their DNA. Toyota is very conscious of the importance of maintaining this DNA in all their associates and works hard to continually reinforce the culture. But do not implement work teams before you do the hard work of implementing the system and culture to support them. After that it is all about challenging them to do better and respecting employees at the same time.

11. Respect Your Extended Network of Partners and Suppliers by Challenging Them and Helping Them Improve – The power of supply chain is far more than Information Technology, it is the power of ingenuity and relationship. Find solid partners and grow together to mutual benefit in the long term. Have high expectations for your suppliers and treat them fairly and teach them the definition of respect.

12. Go and See for Yourself to Thoroughly Understand the Situation – Go to where it happens, Gemba, observe the production floor without preconceptions and with a blank mind, repeat why five times to every matter do get deeper down to the problem. There is a basic belief in Toyota that people solving problems and making decisions need to have a deep

understanding that can only come from personally verified data: seeing for yourself, even high-level managers and executives should go and see for themselves as much as possible.

13. Make Decisions Slowly by Consensus, Thoroughly Considering All Options; Implement Decisions Rapidly – A thoroughly considered technology that has been carefully investigated and proven through trials will be implemented quickly and very effectively. Nothing is assumed in a project, everything is verified. Thorough consideration in decisions making includes five major elements; 1. Finding out what is really going on (Gemba). 2. Understanding underlying causes that explain surface appearance – asking why 5 times. 3. Broadly considering alternative solutions and developing a detailed rational for the preferred solution. 4. Building consensus within the team including Toyota employees and outside partners. 5. Using very efficient communications vehicles to do one through four, preferably A4 report.

14. Become a Learning Organization, Through Relentless Reflections and Continuous Improvement – A learning organization does not only adopt and develop new business or technical skills; they plan how to learn new skills, knowledge and capabilities. View errors as opportunities for learning rather than blaming individuals. Standardization and learning goes hand in hand and are the basic for continuous improvement.

2.3 Lean in Manufacturing Sector

Basically Lean starts from Manufacturing as discussed in the history of Lean. The word "lean" refers to lean manufacturing or lean production as it uses less of everything, compared to mass production. Based on the research conducted by Bayou and Korvin (2008), manufacturing leanness is a strategy to earn less input to better achieve the organization's goals through producing better output, where ''input'' refers to the physical quantity of resources used and their costs, and ''output'' refers to the quality and quantity of the products sold and the corresponding customer services. Essentially, the core idea of lean manufacturing is to maximize customer value while minimizing waste. The ultimate goal of implementing lean production in an operation is to increase productivity, enhance quality, shorten lead times, and reduce cost and so on. As Lean approach is first introduced by Japanese - Toyota Motor Company. Therefore, the introduction of lean has significantly changed the market and the strategy during its first emergence in the development of the automotive industry that was pioneered by Toyota Production System (TPS). The success of TPS shows and proves that lean techniques are powerful and significant. The vast set-up has led other companies from different industries such as electric and electronics, auto and machinery, wood, ceramic, machine tool industry and so on to implement lean in their manufacturing. However, most of the companies have implemented lean and have assessed lean practice in their own unique way. The reason for this scenario lies in their internal issues such as lack of knowledge and their understanding of lean, culture, skills and so on. Other factors such as age and size of the company also contribute to the degree of adoption of lean tools or techniques in one's company. Some of the companies have also given up continuing practicing lean due to the mentioned factors. There are also some non-human resistance in changes towards lean (Langstrand and Elg, 2012). But Ward & Shah (2007) have defined a lean production conceptual model during their research that is in the figure 7.

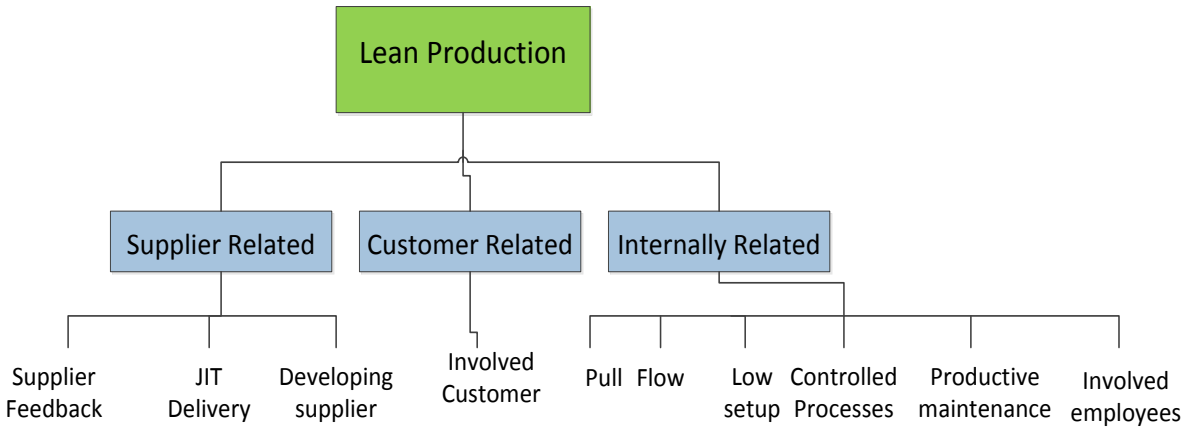


Figure 7: Lean conceptual model (Shah et al, 2007)

2.4 Lean in Service Sector

Lean concept is a way to identify where the value is in the process, eliminate the waste within the process and create value to the customer. This concept shows that Lean is applicable in any organization, since the goal of organization is to create value to end customer. To keep customers satisfied, companies are trying to increase the service quality by integrating Lean principle in order to reduce costs and increase profitability. Lean in service is applicable to organizations that have limited information and face interruption on task performance. The services encounter high costs with slow processes because of non value added activities, which lead to poor quality and low customer satisfaction. There is service complexity, which occur in Work in Progress (WIP) and cause delays. Examples of WIP are reports necessary to complete, unchecked e-mails, necessary phone calls to make and sales orders. This slow process is due to the 20% of activities that cause delay of 80% (George, 2003).

Also, Lean service has shown great success in healthcare system. Healthcare system has adopted Lean by analyzing the flow of activities and making improvement through process mapping techniques, as well as identification and reduction of waste (Radnor, 2011). There are several characteristics of Lean service proposed by different researchers. Some of them involve reducing the performance tradeoffs between the objectives of organization and customers; reducing set-up time and applying JIT; increasing customer involvement and offering training to employees and customers; as well as investing on people because they can make a difference in the business. Therefore, by focusing on Lean service, organizations give greater attention to the investment of people, rather than equipments. (Bowen & Youngdahl, 1998)

Lean in service sector is essential to add value to customers by providing services with higher quality and speed the process by using fewer, but right resources. There is a need to analyze the non value added activities to reduce the cost and complexity. Employees should identify the waste and hidden costs caused in different steps of processes, which might involve reorganization of companies by less capacity, material and people to perform the work more efficiently. Bowen & Youngdahl, 1998 defined lean service characteristics in their research of case studies that is shown in the table 1 below:

Table 8: Lean Service Characteristics (Source: Youngdahl et al, 1998)

Reduction of Performance tradeoffs • Operations goals of both internally-focused efficiency and customer-defined flexibility
Flow Production and JIT pull • Minimize set-up time allowing for smoother flow • JIT levels of both input and output
Value-chain orientation • Apply service blueprinting and value analysis to eliminate non-value added activities
Increased customer focus and training • Involve the customer in the design of the service package • Train employees in customer service skills and behaviors • Train customers in how to contribute to quality service
Employee empowerment • Invest significantly in employees (skills, teambuilding and participation) • Empower employees to leverage customers' value equation (benefits divided by price and other costs)

2.5 Seven Forms of Waste

The key point for Lean theory is the elimination of all the waste within the processes. To achieve excellent efficiency in a process it is needed that it is designed in such a way that waste may easily be detected. This means that there are opportunities to eliminate, or at least reduce, waste. Waste includes activities which do not add value to customers and organizations. For them, waste is a cost that they are not willing to pay. It is important to increase the awareness of employees on the concept of waste, as well as on the ways to identify and reduce waste. Seven forms of waste, and sometimes an extra eighth, are defined with Lean approach:

1. Overproduction
2. Waiting
3. Transportation
4. Over-processing
5. Inventory
6. Motion
7. Defects
8. Untapped Competence

These kinds of waste taken as an initial point would make the identification of waste easier. Following are the description of waste with respect to manufacturing and service perspective along with some examples in the table 2.

Table 9: Seven Forms of Wastes (Pertersson et al, 2010)

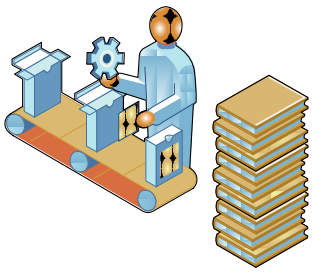
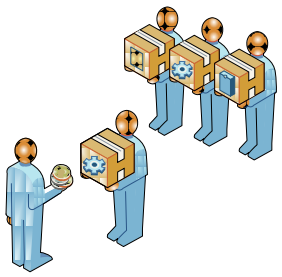
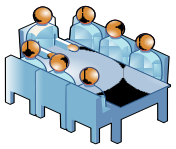
1. Overproduction		
Manufacturing Perspective: It means producing more than the customer wants, producing faster or earlier that what is required by the next process and producing overlarge batches.	*Example:* Producing customer order of 500 units at the beginning of the month and later customer makes changes to the order. Further, producing too early occupied unnecessary space.	
Service Perspective: It means the excess production of service outputs. This happens because organizations produce more services than customers want.	*Example:* Entering unnecessary information for organization. In healthcare, patients are admitted to the hospital and they wait because there is no time to give them service until later.	
2. Waiting		
Manufacturing Perspective: It is considered an enemy of flow, because materials and components do not move as a result of waste. Means time not used in production properly and leads to idle time. It can be due to a lack of material or information needed for next task	*Example:* Operators or employees waiting for something (material or/and information); materials waiting in a queue; and late delivery.	
Service Perspective: It involves a delay in one activity, which causes a delay in the following activity. The value stream mapping technique is useful to identify process delays.	*Example:* Waiting in the meeting for people who show up late, which lead to irritation and loss of time in which work could be performed. In healthcare, patients waiting in various queues.	
3. Transportation		
Manufacturing Perspective: It is the movement of materials which is not needed, because their chance to get damaged and deteriorated increases. Transport adds no value except the one in which product is delivered to customer and it is paid. Internal transports are purely waste.	*Example:* The movement of materials on and off site without a need; and movement of intermediate product in the site. This waste can be originated by wrong layout of the facility.	

Table 2 – continue

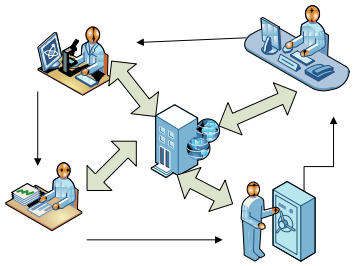
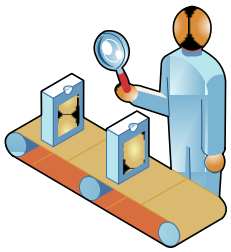
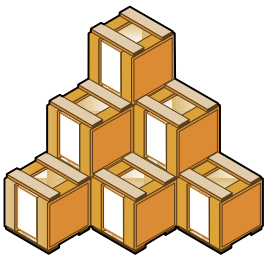
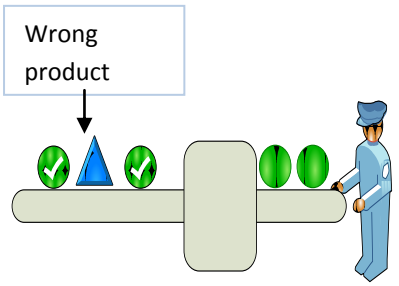
Service Perspective: It means the movement of materials and information, which should be reduced for activities that do not add value, or are related to occurrence of waiting time and queues that dissatisfy customers.	*Example:* In banks, many people face the problem of transportation because they have to collect materials and information by asking different people until they reach the right person. In healthcare, it can be the distance of transport of test samples because of the centralized resources in organizations.	
4. Over-processing		
Manufacturing Perspective: It means performing more work on a product than the customer is willing to pay for. Producing higher quality product than the customer asked, or carrying out unnecessary tasks.	*Example:* Over machining on a part due to initial large blank, can be avoided by buying a smaller blank. Other unnecessary tasks are test and inspections as they are considered to be waste.	
Service Perspective: It includes excess costs with attempt to add more value to service than is needed to satisfy customers.	*Example:* If a store wraps clothing item in a layer of tissue, this might work in boutique that target high income people, but not in retail stores where people want to pay as less as possible. In healthcare, acquiring numerous test samples from patients, which are unnecessary.	
5. Inventory		
Manufacturing Perspective: It involves the over existence of raw materials, WIP and finished goods in organizations. This is considered waste because of the excess of cost spend on them.	*Example:* Large warehouse occupied with inventory in the site. Inventories direct to prolong lead times, hide quality problems if customer makes changes in demand.	
Service Perspective: It means using excess inventory instead of what is actually required to provide service to customers. This should be avoided because it does not add value to customers and involves higher cost of waiting.	*Example:* When employees are unable to provide services according to customer's requirements due to lack of supplies. Providing substitute of products or services, not what was asked by customers.	

Table 2 – continue

<table>
<tr><td colspan="3">6. Motion</td></tr>
<tr><td>Manufacturing Perspective:
It happens when there are unnecessary movement of people and machines.
Unnecessary motions may also be harmful from en ergonomics point of view.</td><td>Example:
Walking to get tools and materials.
The placement of tools is inappropriate and operator has to bend and stretch to reach them.</td><td rowspan="2"> 
Fetching of material
 
Searching for apparatus</td></tr>
<tr><td>Service Perspective:
Motion does not add value to services, because it only takes additional time and cost related to unnecessary movement of employees. The motion is very hard to measure in service.</td><td>Example:
People have to go from one computer to another to complete a task.
Searching for apparatus and equipments which are placed within long distance.</td></tr>
<tr><td colspan="3">7. Defects</td></tr>
<tr><td>Manufacturing Perspective:
It involves any waste which involves costs related to delay, warranty and repairs. Produce defective products results in waste because wrong product has made and need to be corrected, mostly customer are not willing to pay for this.</td><td>Example:
Rework, customers’ complaints, or even lose of customers.
Input incomplete order information of product.
Errors or mistakes in producing a product that end-up with a wrong product.</td><td>  </td></tr>
<tr><td>Service Perspective:
It happens when services are not performed within specification of customers.
Some of the services are not costly to correct mistakes, but organizations should consider that they might
also lose customers</td><td>Example:
A lack of information or inaccurate process of documentation can cause delays which dissatisfy customers.
In healthcare, infections that patients get due to lack of hygiene and poor treatment.</td><td>  </td></tr>
<tr><td colspan="3">8. Untapped Competence</td></tr>
<tr><td>This is an additional type of waste and happens when organization do not use the competence of workforce and their creativity. (both perspectives)</td><td>Example:
The loss of skilled employees that could contribute for organizational improvement.
Not using the creativity of people; not paying attention to ideas of employees, but only managers.</td><td>  </td></tr>
</table>

2.6 Lean Implementation

The concept of lean plays an important role in organization's success because it involves vast understanding, strong commitment and thorough analysis of problems. Moreover, organizations are implementing lean in long term basis to improve quality, reduce cost, fast delivery and efficient queue time along with increased flexibility. Management commitment and support should be there in the accomplishment of lean implementation. Also, external support can be consider to get new way of thinking and transfer knowledge to organizations by recommending the areas that Lean application is necessary about lean. Possibly external support could be helpful for the short term to enhance the knowledge of lean in organizations. On the other hand, organizations should not be totally rely on them as lean is a continuous program that last long and it cannot be implemented overnight. It is needed to work continuously to reduce waste and increase dedication by searching opportunities and limitations. Toyota is an example that they start implemented lean in 1950 and still continuous to reduce waste (Petersson et al, 2010).

2.6.1 Critical Success Factor of Lean Implementation

There are eleven critical success factors recommended by Anvari et al. (2010), for effective implementation of lean approach, i.e., management and leadership, organization cultures, goals and objective, problem solving, skills, continuous improvement, financial capabilities, performance measure, change, education and plan. They proposed three implementation stages (preparation, design and implementation) but failed to establish a systematic methodology by which firms could identify wastes; evaluate existing performance; remove those wastes; recalculate the performance and use sustainable lean tool for continuous improvements.

Langstrand and Elg (2012), highlighted the non-human resistance in order to implementation of lean, according to them there are four different types of non-human protection in change towards the lean in their case study, three lean tools/methods *kanban*, *5S* and *visual mangement* are analyzed. The ground realities that make a hindrance towards lean are *pre-exisiting anti-programs*, *inherent anti-program* such practices that are followed from very begining and change may have a negative impact, *unintentional creation of anti-program* like frequent audits during the processing time and divert the time from main activities, *ineffective non-humans*. To get rid from these resistance can be a critical factor to accomplished lean.

Poksinska (2010) pointed out some challenges and success factors in health care service towards lean implementation. The staff understanding to get involved in this process is quite crucial along with that experience and experts consultants those have their roots in health care sector and can be able to support by giving practical examples from lean healthcare. Because there is deficit of skills in lean health care consultants and usually they hired from manufacturing sector, hence there is lack of synchronization between health care staff and consultants. Moreover, understanding of customer is also a critical factor in health care and it's sometimes not easy to identify who is the customer. The hierarchy in health care is kind that not matching with lean team building and open communication as physician are consider to be high ranked. So, everyone from higher level to bottom should be on same page for lean implementation. Last, but not the least the health care system is not simple which means that it's difficult to improve the entire value stream.

2.6.2 Lean Implementation Challenges

Lean approach has a hype and shown grand success in different organizations. But still there are some challenges that have been facing during the implementation of lean as it's not a short term process and to mold into lean organization takes time. Some challenges are highlighted in the below table 3.

Table 3: Lean Implementation Challenges

Author	Industry	Challenages
Worley and Doolen (2006)	Manufacturing	Resistance to change, Difficulty for supplier to apply JIT concept, when acquiring small amounts of parts
Sarkar (2009)	Service	Processes are not visible; Processes are large and complex; Processes are people Intensive; Processes are technology dependent; Very little books of knowledge for service Lean; Concept of pull and flow; Processes cut through vendors
Grove et al. (2010)	Service (Healthcare)	Process variability; Understanding of Lean; Limited communication and leadership; Target focused; Defining waste; who is the customer and what do they value

2.6.3 Lean Tools and Techniques

There are several different lean tools and techniques that are used in manufacturing industries and same tools can also be applied in service sector although not all of them, but in service lean tools and techniques are developed from the adaption of manufacturing sector. Following are the lean tools that have been discussed in different literatures.

5S – For better housekeeping and arrangement of work (Sort, Set in Order, Shine, Standardize and Sustain

Andon (visual display) – It's a visual response on the production shop floor for status and alerts

Just-in-Time (JIT) – Produce and Fetch the material when it is needed by customer

Jidoka (Autonomation) – Automation of process for better quality, cut-down labor cost and fast process

Heijunka (level Scheduling) – A kind of production time plan and sequence in order to make product/parts in smaller batches

Kaizen (Continuous Improvement) – To get the improvement ideas and suggestions from every level of an organization for continuously improving the process in order to eliminate wastes

Kanban (Pull System) – A card signal system that specify when and where more material is needed for sake of better flow internally and externally both

Poka-Yoke (Error Proofing) – Identify the errors and avoidance of defects in a process from the beginning

Single Minute Exchange of Die (SMED) – Techniques used to reduce setup and changeover time

Standardized Work – Good practices to make documented procedures

Takt time – The rate of customer demand to produce goods and services

Total Productive Maintenance (TPM) – It's a proactive approach to maintain the equipment and trained the operators to fix the problem in the equipment to utilize time well

Value Stream Mapping (VSM) – It's a map of process flow for better visualization

Root Cause Analysis (5- Whys) – A method to deeply figured out the problems in the process along with their causes and ask why 5 times in order to reach the root of a problem

PDCA (Plan, Do, Check, Act) – A continuous improvement approach that describes as

Plan: What to do and how?

Do: Do what was planned;

Check: Did things happen according to the plan (Measure);

Act: How to improve next time

The implementation of lean requires some principles to follow and principles need some tools and practices to adopt in order to execute lean. The following table 4 indicates the lean principles with corresponding practices and tools (Langstrand et al., 2012).

Table 4: Lean principles with corresponding practices and tools (source: Langstrand et al., 2012)

Principles	Practices	Techniques
Specify value from the end customer view	• Source information on customer need • Value chain analysis and end customer focus	• Customer involvement • Value Stream Mapping (VSM)
Map value to expose and eliminate waste	• Value chain analysis • Waste reduction	• VSM • JIT, TPM, small lot size, 5S, SMED
Establish flow	• System organization • Strong and effective relationship • Waste reduction	• 5S, Cellular manufacturing • Supplier integration • JIT, TPM, small lot size, 5S, SMED
Let the customer pull the products	• Production of exact customer needs only when needed • Strong and effective relationship	• JIT, Pull/Kanban system • Supplier integration
Strive for perfection	• Problem search • Problem solving	• VSM, 5Whys, employee involvement • Training,5Whys, employee involvement

2.6.4 Comparative Study of Lean in Manufacturing Area

Based on literature review research following table 5 summarized the comparative study for lean implementation in manufacturing areas.

Table 5: Comparative study of lean in manufacturing area (Brannmark et al. 2012)

Name and Authors	Measures taken as Lean practices	Benefits
A Swedish national Lean Program	Since Swedish industry is lacking behind in competitiveness against low cost manufacturing countries, hence lean is adopted as a solution with some tools like 5S, VSM, standardization, methods for set-up time reduction. Lean documents.	Improvement in terms of cost and productivity. Create a broad commitment of Lean through Lean Lego Games in the company as simulation practice and training.
A large Swedish manufacturing company	Company started to practice lean with focus on standards, continuous improvement, team work, leveled workload, and takted production flow. Implementing 5S, visual management and Kanban.	Reducing lead time. Reduction in production cost within the unit. Educated management about lean.
A medium size manufacturing companies	They started with 5S and bottlenecks removal in production, continuous improvement and flexibility. Followed by some other lean tools as the second wave of lean approach in production.	Shorter lead times. Skilled employees to support changed readiness.

2.6.5 Comparative Study of Lean in Service Health Care Area

Based on literature research following table 6 summarized the comparative study for Lean healthcare implementation in the hospitals. Although, the implementation process in service is complicated, in healthcare, there are several process improvements that can be achieved with Lean, such as waiting time reductions, separating, patient pathways in interactive value streams (De Souza, 2009, Poksinska, 2012). With the successful implementation, the benefits that will be generated to the hospital and patients are quite valuable and significant.

Table 6: Comparative Study for Lean Healthcare Implementation

Name and Authors	Measures taken as Lean practices	Benefits
Shouldice Hospital, USA (Bowen & Youngdahl, 1998)	Patients' involvement starting from the application and selection. Patients shave them self for operation. After surgery patient walk with the help from the doctor and walk to wheelchair. Emphasize on two way communication.	Faster recovery rates for patients. Lower cost with patient being Involved. Patient helping themselves help nurses and doctors to work on more important task which is counseling and surgery.
Flinders Medical Centre Adelaide, Australia (Jones & Mitchell, 2006)	Emergency department divided in two value streams. Patients who can be treated and discharged more or less immediately. Patients who need to be admitted into a ward for further treatment	Average emergency department waiting times fell by 25 % Patients' number leaving the department without seeing a doctor fell by 41 % Less pressure to staff.
Virginia Mason Medical center (Black & Miller, 2008)	Applied several lean tools and techniques such as 3P, Standard work, Value stream, Takt Time, mistake-proofing and load Leveling. Load leveling was to create flow of patients from one after another.	Reduce the patients waiting time by 14% Increase in treated patient's number by 57% Reduce walking for staff to complete the job by 61%

2.7 Research Methodology

The research strategy adopted in this study is a case study research method. The method involves a detailed analysis within a case. It may be used within the office settings with emphasis on the thorough analysis of the given work. There are two kinds of case studies. The first kind is described as limited number of cases to come up with general conclusions. The second one is focus on a single case, obtaining specific conclusions (Gummesson, 2000). This study is based on the second kind as it involves a single case from each sector.

3. CASE STUDY – MANUFACTURING INDUSTRY

The company investigates with respect to manufacturing terms is a metal industry in Sweden, LT Copper. They are producing copper strips by casting process followed by slitting and rolling mill, more precisely the company produces copper strips for automotive and electrical applications. But due to some downsizing in automobile manufacturing business along with higher competition in the market have direct concerns to the LT production facility and this economic recession leads to higher metal price, consequently company face new challenges. Moreover, demand of good quality products from customers also on upper levels and results metal manufacturer to look into new solutions.

By that time LT had some internal challenges describe in problem statement which makes the management to initiate the lean production improvement operation with the focus to increase the production efficiency and to minimize wastes within the processes, to concentrate on quality and reduce costs.

3.1 Production Department Chart

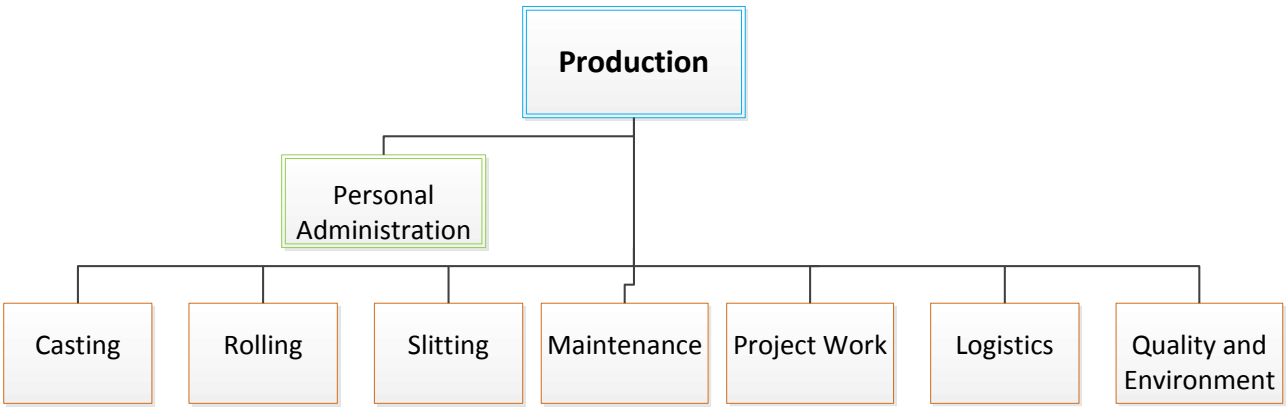


Figure 8: LT Copper Production Hierarchy

As shown in the figure 8, the head of the production is the chief of foundry, who is responsible for the production process and results. The PA – personnel administration is the in-charge of human resource management activities, employees' recruitment, training and development, organization's different policies and unions. The heads of department of casting, rolling, slitting and maintenance are reported to foundry chief (production head) while project work team depends in which area the project is going on so they are accountable to respective department head. Logistics and quality are the production support departments.

3.2 Problem statement

LT Copper AB facing some problems as customer's complaints is raised to get the product delivery on time and consequently losing customers, on the other hand there is some increase in copper price in the metal market. They had significant internal problems of lengthy transportation, low quality, a lot of scrap and excessive stock as well as high work-in-progress, and long manufacturing and delivery lead times and the stoppage times.

3.3 Goal Statement

The aim of the company to keep and restore the customers with focusing on timely delivery to the customer and the goal is to increase on time in full deliveries (OTIF) by 10%. Along with this also focusing on to the cost reduction and aiming for reduce the inventory level by 20%.

Also the vision of lean production approach is to empowering the competent employees to performing well in order to reduce waste continuously, further continuous improvement, waste elimination, Right from me, respect for the individual are some other aspects of this campaign.

3.4 Scope and Boundaries

The work will be conducted according to lean principles which means first will be the study to current performance as it now and then analyzes the performance level after implementation of lean methods with focus on VSM, Kanban and Dedicated flow. In the end there will be suggestions to LT Copper with how to improve the company and the current performance level, localization of the root problems that are causes to the delays and high inventories but also other problems that found and suggesting improvements to those problems, set up measurement and control process. Another aspect is to see how lean approach affects QTC (Quality-Time-Cost), where if used correctly it can give higher quality, shorter lead time, lower costs and flexibility in the process.

The boundaries of this case study are time frame and limited information (data) as the time is limited to implement the lean approach on the other hand lean is not a short term program it's a long and continuous approach to improve the processes. Some information is confidential that cannot be used in this thesis work. The figure 9 below describes the working steps:

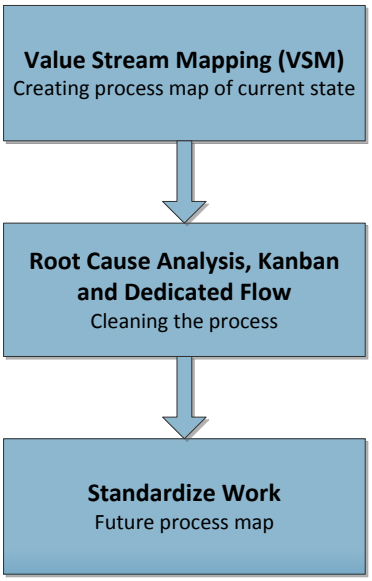


Figure 9: Working Steps

The first step is to create overall current production flow, next step is to clean the process by implementing lean tools – Kanban and dedicated flow to reduce inventory levels and lead times. Third is to standardize the improved process by creating standard operating procedures with better developed process map.

3.5 Current State of Process

The overall process flow of producing copper strips at LT Copper is defined as:

- Foundry that consists of Melting, Casting and Rolling Coils.
- Rolling mill for pressing the coils into desired thickness
- Slitting mill for cutting of coils into strips of desired customer sizes
- Packaging of copper strips

The flow of material and information as described below in figure 10 is monitored and control by production planning and control department. The order of raw material to supplier is placed on weekly basis while weekly schedule of producing products is also provided to production line except for melting as they have their daily schedule consist of different alloy and quantity.

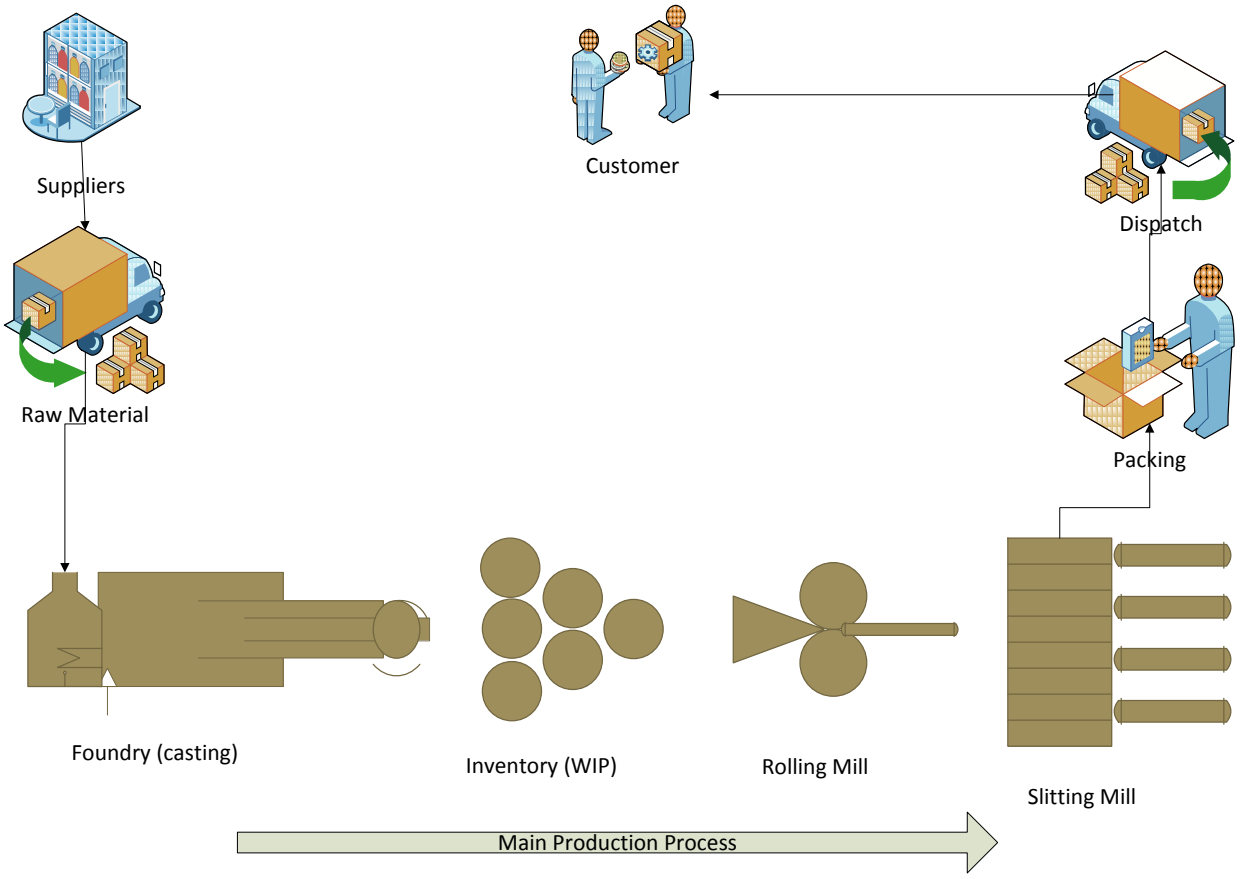


Figure 10: Production Flow

In the figure 11 we can see the production layout along with the respective problems facing by the each department. During the initial mapping of process we came across certain drawbacks and mishaps that are happened frequently in main production process while the way of thinking of worker and respective department manager is also noticeable. Like in casting department the perception of produced more and more is consider to be their goal compare to less focus on quality hence, lot of scrap in the end and on the other hand they are casting the rolls without any proper coordination to their customer (i.e., Rolling mill) about how much quantity they want and when. The result in higher inventory level between casting and rolling as shown in figure 11 with the name supermarket, this work-in-process (WIP) inventory causes of hiding quality problems, incurred holding cost and increases downtime of casting process. The rolling department has been involving in a complex process that is somehow unpredictable in the sense of getting precise constant thickness of copper roll which also leads to uncertainty and high variation in process time. The slitting process has long changeover time issues that also create fluctuation in lead times and inventory levels. In the end the whole process of production has been evolved with high inventories levels of raw material, WIP and finish goods along with downtime during the process and results in buffers within production line.

3.5.1 Production Layout

The process layout is of production facility is shown below that also highlights the problems in each process steps and thinking of people that execute these steps.

The main problems in the production flow are:

- Prefer quantity over quality
- High WIP Inventory
- Unpredictable process and time
- Long changeover time

The layout is a typical product layout (flow-line layout) with continuous process but we have figured out the flow is not smooth due the problems that are discussed above. Next we organized a workshop with production employees to draw a current process map in which material and information flow would be visualized.

The figure 11 that is shown below reflected the whole production area of LT copper. The production consists of the following processes and components:

- Melting Furnaces (melting of copper metal)
- Holding Furnace (Holds the melted metal)
- Strip casting (process to mold the metal into the desired thickness)
- Milling (Shaping process of metal strips)
- Cold break-down (cooling process)
- Cutting (Slicing process of metal strips)
- Rolling (Winding process of metal)
- Intermediate rolling
- Annealing (heat treatment process to remove internal stress and make it more workable)
- Roll to finish
- Slitting (Cutting process of metal into customized sizes with the help of slitting machines)
- Auto-pack (Packing process of finish goods)

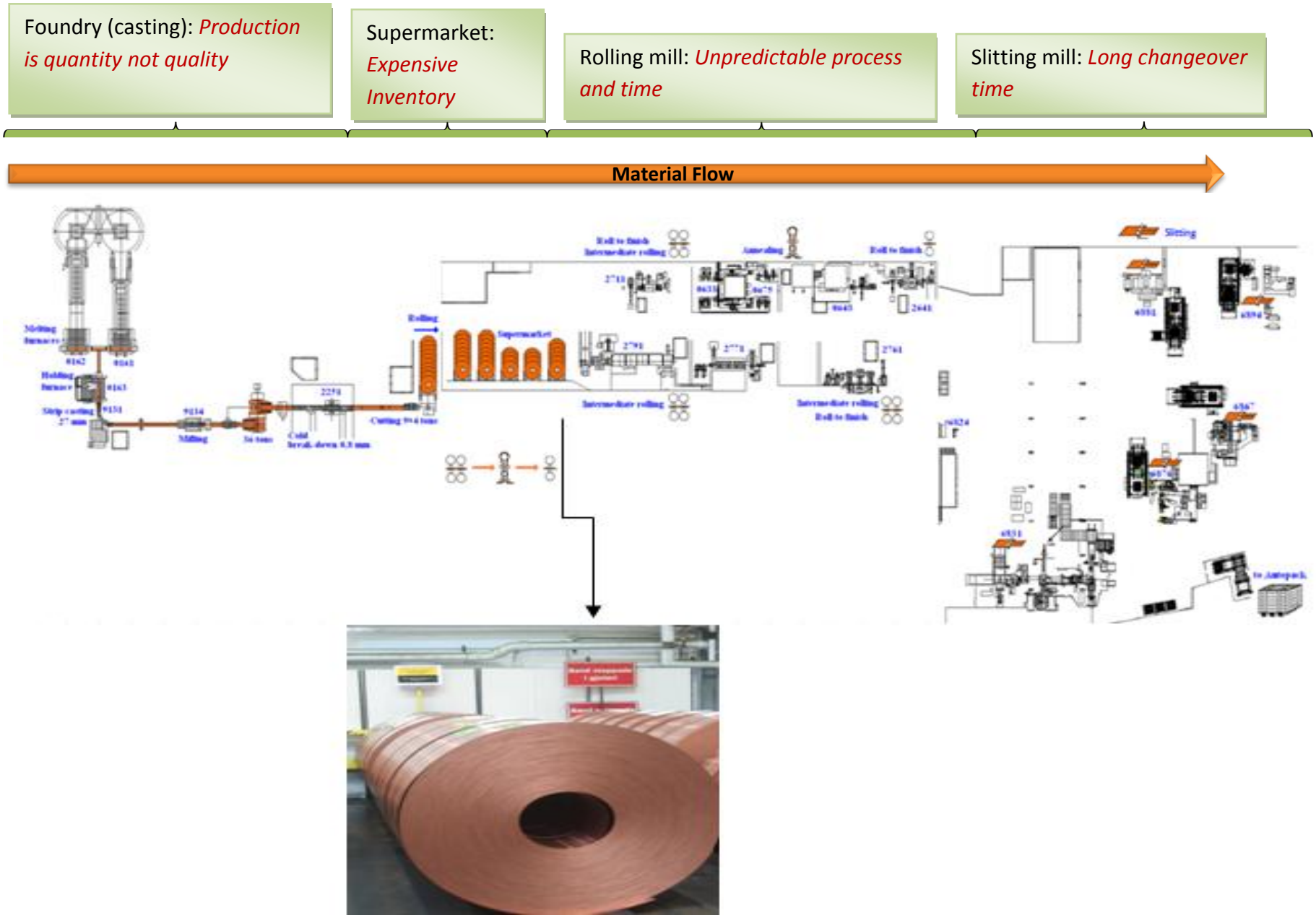


Figure 11: Production Layout

3.5.2 Workshop on Current Process Map

Employees (work force) are one of the key players in Lean implementation process, for better understanding and proper involvement of worker who practicing lean, a seminar on process mapping has conducted and ask them to draw the process flow according to their respective perception. It took some time and workshop was ended in few days but good thing is that we got the idea and perhaps the better one about how process is carried out in LT copper production as worker faced reality on production floor on regular basis.

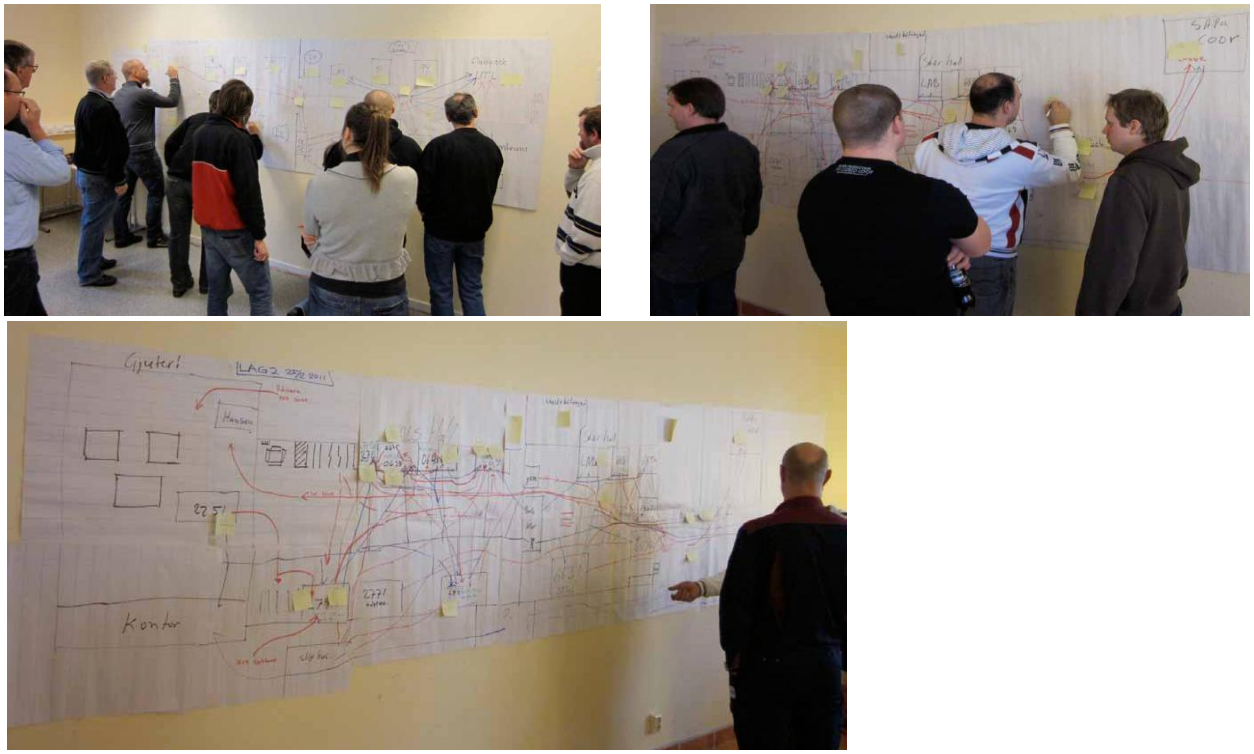


Figure 12: Workshop on VSM

As we can see in figure 12 there are quite unclear views sketched by participants of the workshop with some short comments about the way individual is thinking and performing the specific task. The workshop ended up with some productive results as we found out certain kinds of waste during the process flow and some awkward finding about the flow according to participants, also surprised for management of LT but at least it was appreciated that some misunderstandings are identified and rectified by creating true awareness so as proper implementation of standard operating procedures (SOPs).

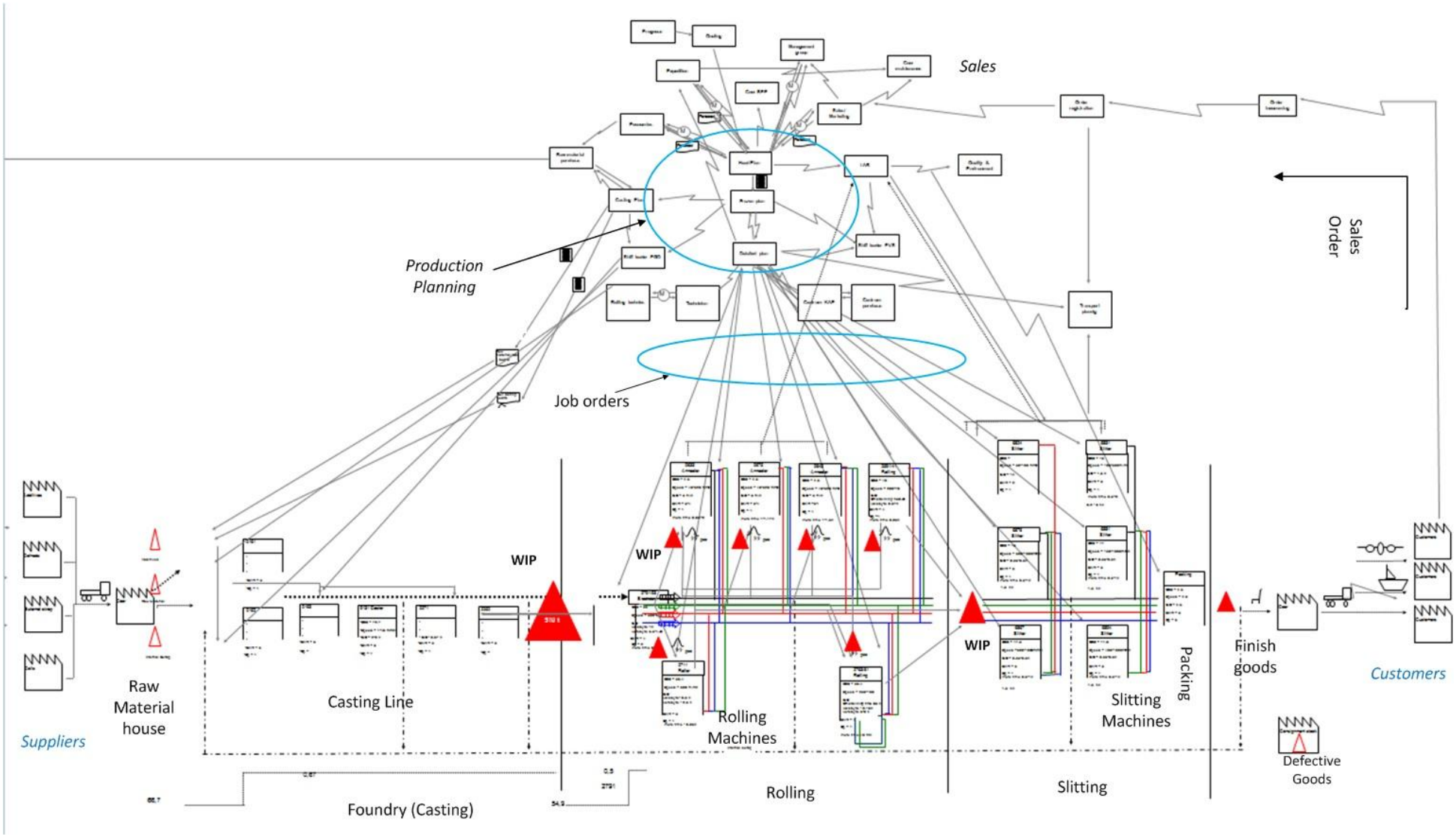


Figure 13: Current Stream Map

3.5.3 Current State of Value Stream Mapping

The above figure 13 represents the current state of stream map from fetching of raw material to dispatch of finish goods. The current state looks a mess and creates chaos due to bad handling of information and lack of communication with some wrong practices. The red triangles correspond to inventory.

The problems and wastes identified during the current value stream mapping after successful workshop are given below and shown in figure 14:

- **INVENTORY ISSUES (CASTING & ROLLING)** – As there is imbalance between casting and rolling processes with respect to production speed, a great amount of WIP inventory (supermarket) is present that creating queues and occupying extra space on the production floor.

- **QUALITY ISSUES (CASTING)** – Since the casting method more depend on different alloy combinations and casting parameters of different alloys vary the production follows. The main focus on quality, to get the right alloy from qualitative point of view from the start would make the smooth process flow to the next stations (processes).

- **PLANNING ISSUES –** The complexity of technical process from casting to slitting more depends on process parameters with great monitoring which sometimes demand to change in planning (re-planning) for long run production as they (casting department) perceived quantity is more important. On the other hand ordering system of raw material is also not enough flexible, since it is not possible to postpone or speed up the delivery of raw material when required and for safety point of view the raw material is stored at the company at least one week before utilization. Hence, if there is any change in customer demand (from sales department) – planning cannot encounter the changes because of different stocks.

- **PULL ISSUES** – First-in-first-out (FIFO) mechanism is not working in rolling and slitting machines because there is no such marking or lanes for such system.

- **LOADING ISSUES** – the work load on rolling and slitting machines is uneven that also creates buffer in terms of inventory and time. It is because of variation in product mix and which is not handled properly, moreover, no grouping of product and dedicated flow of product with respect to machines.

- **SEQUENCING ISSUES** – Due to inflexibility in demands and sales orders, frequent re-sequencing of plan orders is happened that also leads to optimization problems of machines.

- **DELIVERY ISSUES** – Since there are some drawbacks in the whole process – unpredictable process that directly affect the delivery of finish goods to customer and rescheduling of planned dispatch is often faced by logistics department.

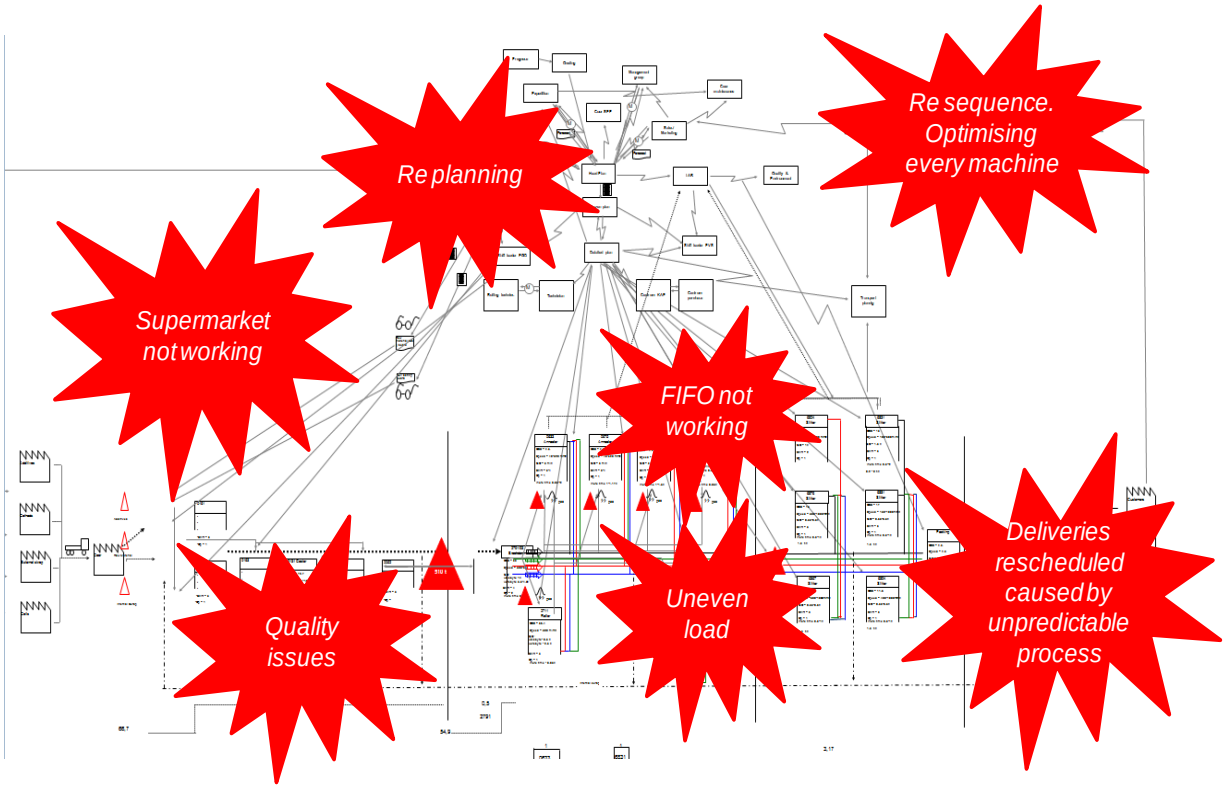


Figure 14: Current VSM with problems highlighted

3.5.4 Types of Waste

Following are the wastes have been identified during the process mapping activities that are shown in the table 7 below:

Table 7: Waste in production area

Identified Waste	Foundry (Casting)	Rolling Mill	Slitting Mill
Overproduction	×	×	×
Inventory	×	×	×
Motion	×	×	×
Waiting			
Over-processing			
Transport	×	×	×
Correction/Rework	×		

3.5.5 Current Inventory Levels

The current inventory levels of all kinds of inventory are shown below in the table 8:

Table 8: Current levels of inventory

Inventory type	Quantity (ton)	Time (days)
Raw Material	349	4.8
Work-In-Process (WIP)	1026	14.3
Finish Goods (FG)	470	6.6
Total	**1845**	**25.8**

3.5.6 Some Theoretical Concepts

- **TRANSFORMATION PROCESS (FLOW)** – It's a dynamic of a process as inputs enter the process, proceed through various activities performed, and finally exit the process as outputs and its shown in figure 15.

- **FLOW UNIT** – A unit which passes through the process, for example, materials, a patient, a project, a bank transaction, etc.

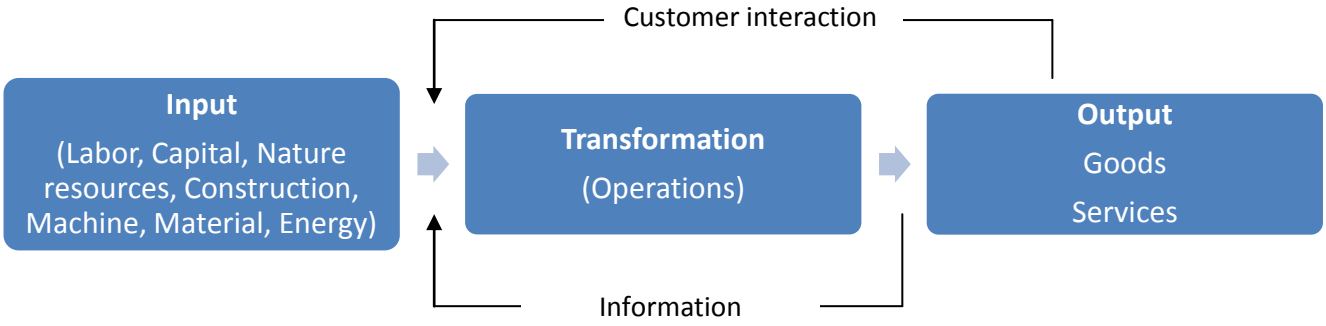


Figure 15: Transformation process

- **FLOW RATE** – It's a number of flow units that flow through a specific point of the process per unit time. Similar concept: production rate, R = average rate.

- **FLOW TIME** – The time that a flow unit enters the process until it exits. Similar concepts: lead time and throughput time, T = average flow time.

- **INVENTORY** - The number of flow units within process boundaries at a particular time, that is, the flow units have entered the process but not yet reached the exit point, I(t) = Inventory at time t.

- **INVENTORY TURNS (TURNOVER RATIO)** – It indicates how many times the inventory sold and replaced during the specific period.

- **RELATIONS BETWEEN RATE, TIME, INVENTORY**

The relation between rate, time and inventory is shown in the figure 16.

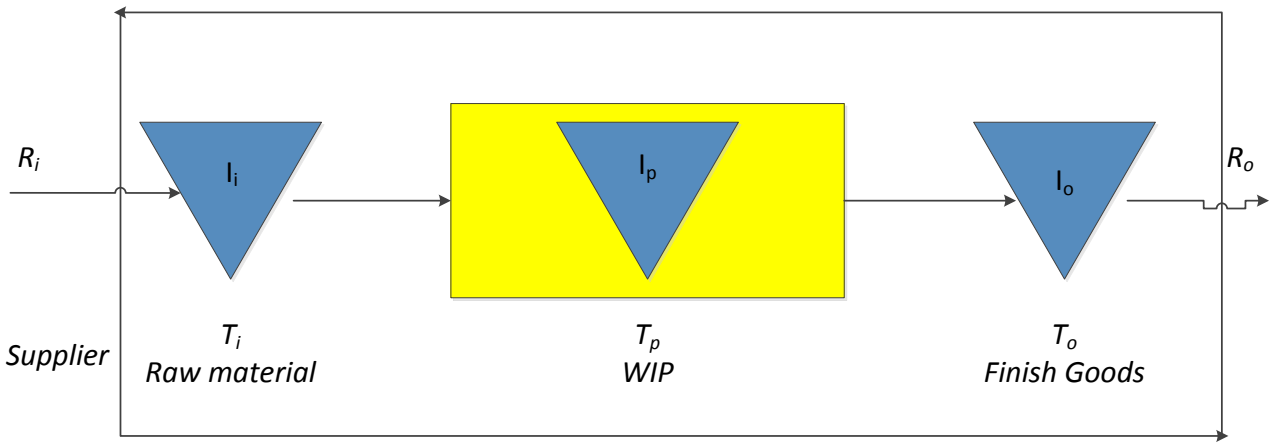


Figure16: Rate, time, inventory relation (Anupindi et al., 2012)

According to little's law:

$$I = R \times T \qquad (1.1)$$

i.e., Inventory = Rate x Time

Inventory Turns or Turnover Ratio (ITR) = R / I or 1 / T (1.2)

3.5.7 Current process performance and Inventory Turnover

The following calculation are made with the help of equation 1.1 and 1.2

Raw material inventory conversion rate:	R_i = 349 / 4.8	= 72.7 tons/day
Raw material inventory turnover:	ITR_i = 1 / 4.8	= 0.21 per day = 6 per month
WIP inventory turnover conversion rate:	R_p = 1026 / 14.3	= 71.7 tons/day
WIP inventory turnover:	ITR_p = 1 / 14.3	= 0.070 per day = 2 per month
Finish Good inventory conversion rate:	R_o = 470 / 6.6	= 71.2 tons/day
Finish Good inventory turnover:	ITR_o = 1 / 6.6	= 0.15 per day = 4 per month
Overall Inventory conversion rate:	R = 1845 / 25.8	= 71.5 tons/day
Overall Inventory turnover:	ITR = 1 / 25.8	= 0.04 per day = 1 per month

Cost of copper (raw material):		€5900/ton
Processing cost is 5% of copper:		€295/ton
Total cost of a product:		€6195/ton
Total overall inventory cost:	6195 x 1845 =	€11429775 = €11.4 M

3.5.8 Root Cause Analysis

Since the major problems have occurred due to high inventory levels and especially high work-in-process inventory therefore, cause and effect diagram (Ishikawa diagram) for this problem is formed to find the root causes. The Ishikawa diagram (figure 17) is divided in 5M's: Man, Machine, Material, Method and Measurement correspond to the major factors to examine the situation of high WIP in production area of LT copper as these factors have more influence and closely related to this issue. The texts in circles are the more prominent root causes of High inventory.

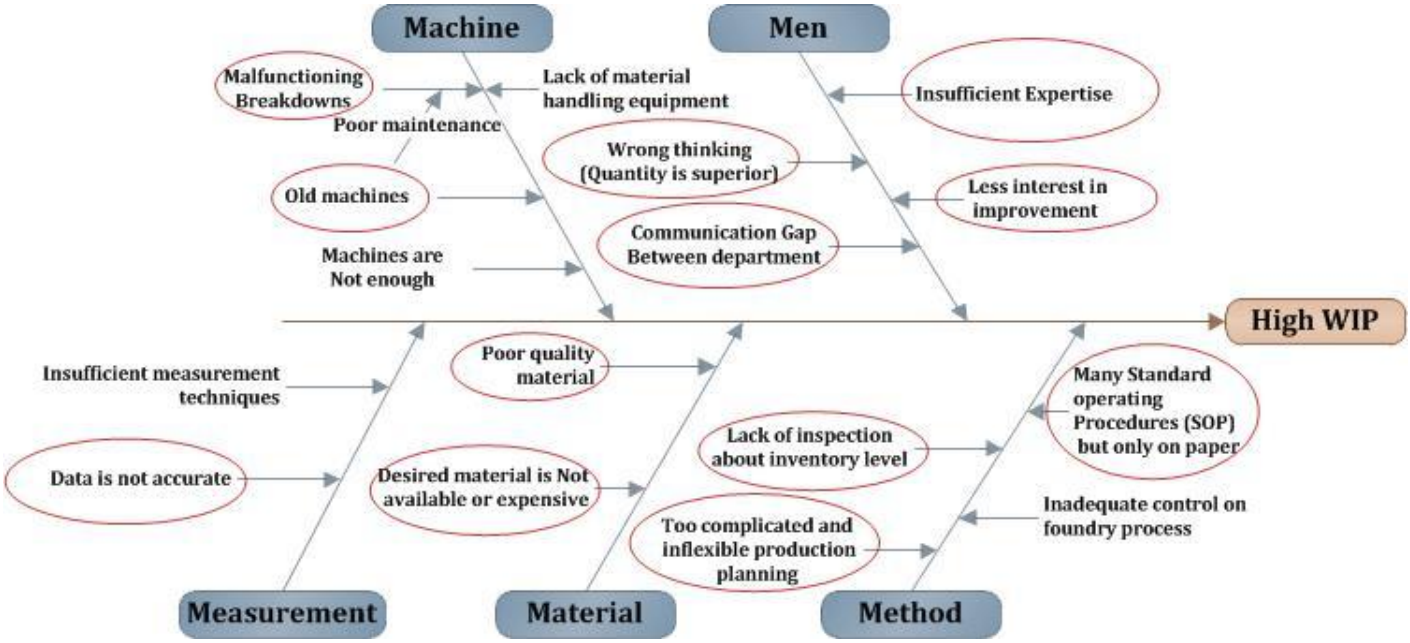


Figure 17: Cause and Effect for High WIP

3.6 Future State of Process

In this section the process of LT copper is described after lean implementation as an improved process. Root Cause Analysis, Kanban and Dedicated flow methods are used to this process improvement. First, future value stream map is under consideration that followed by lean tools and further, future inventory levels are highlighted.

3.6.1 Future Value Stream Mapping

The following figure 18 represents the future process map as an improved values stream map where the information flow is clearly identified and described along with material/product flow and documented process steps as a standard operating procedure (SOP). The awareness of employees about this suggested improved process map also created.

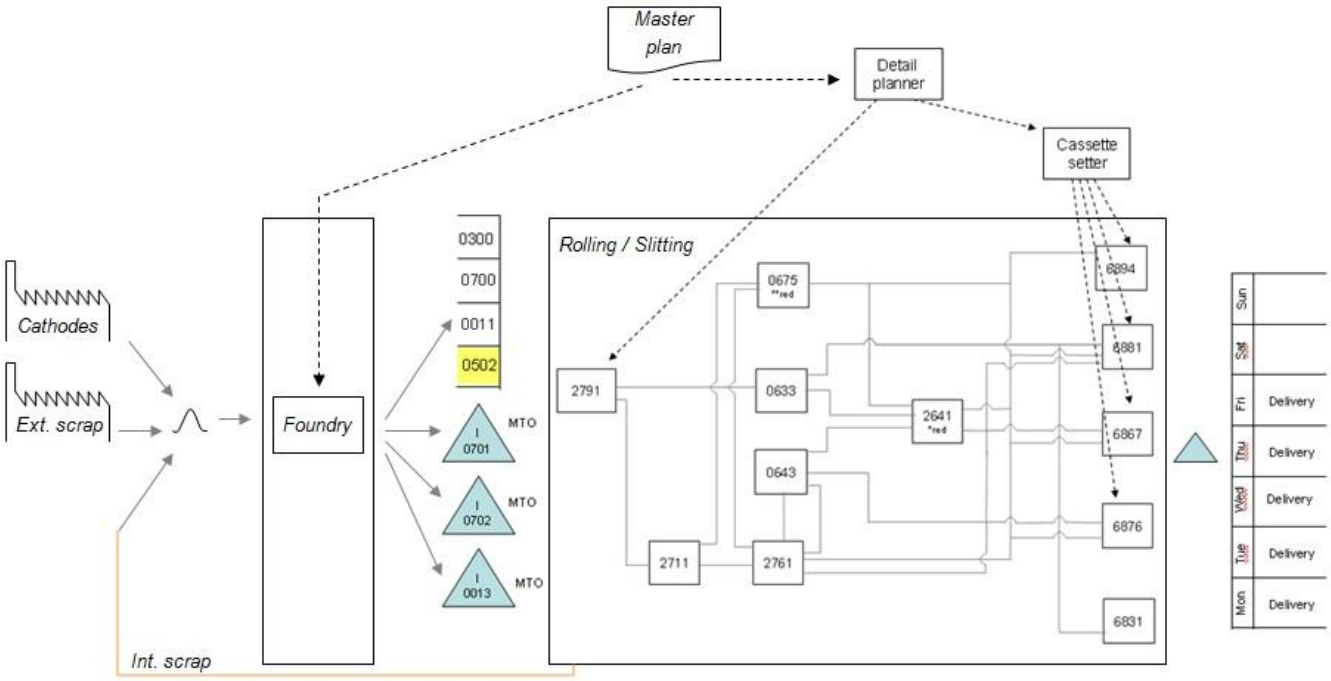


Figure 18: Future Stream Map

The lean approach solutions and control measures of different problems that are mentioned during the current VSM are described below and can be seen in the figure 19:

- **PULL SYSTEM** – The kanban is introduced in a high WIP area known as supermarket to control and mitigate this undesired buffer caused by production disturbance. The kanban simply gives the signals to the upstream about the demand when it needed.

- **BETTER SEQUENCING** – A new alloy combination is suggested to avoid certain quality issues and to cope up with scrap problem especially in foundry process. Supplier evaluation is also recommended with keep an eye on the effect of new combination (product mix) on customer demand through sales department.

- **IMPROVED FLOW DESIGN** – A dedicated flow is implemented in rolling and slitting areas that means rolling and slitting machines are designated for particular product for better clarify flow and optimal planning of these production machines.

- **GROUPING OF PRODUCT (LEVEL SCHEDULING)** – A new grouping of products is suggested, products with similar characteristics would move in a particular path as a flow group to filter the complexity of the previous flow in rolling and slitting areas. Flow group of products also leads to avoid waiting time and extra transportation along with

equal distribution of workload, while the concept of freezing window for product groups is taken into the account to minimize re-planning issues.

- **SYSTEM OPTIMIZATION** – Optimization of slitting machines is under consideration in order to enhance the utilization of these machines by better planning and sequencing, to avoid unnecessary changeovers and to reduce set-up times. The SMED (single-digit Minute Exchange of die) method is also suggested to reduce change-over times.

- **UPDATED FIFO** – First-in-first-out method that was not working previously by introducing new (future) value stream mapping, bound the system to keep FIFO alive in a right and proper way.

- **EXTRA DELIVERY DAY** – In order to avoid and mitigate the problems (delaying in finish goods deliveries) that occurred due to unpredictable process, extra delivery day is taken into consideration to fulfill the commitment of customer and to abstain rescheduling deliveries.

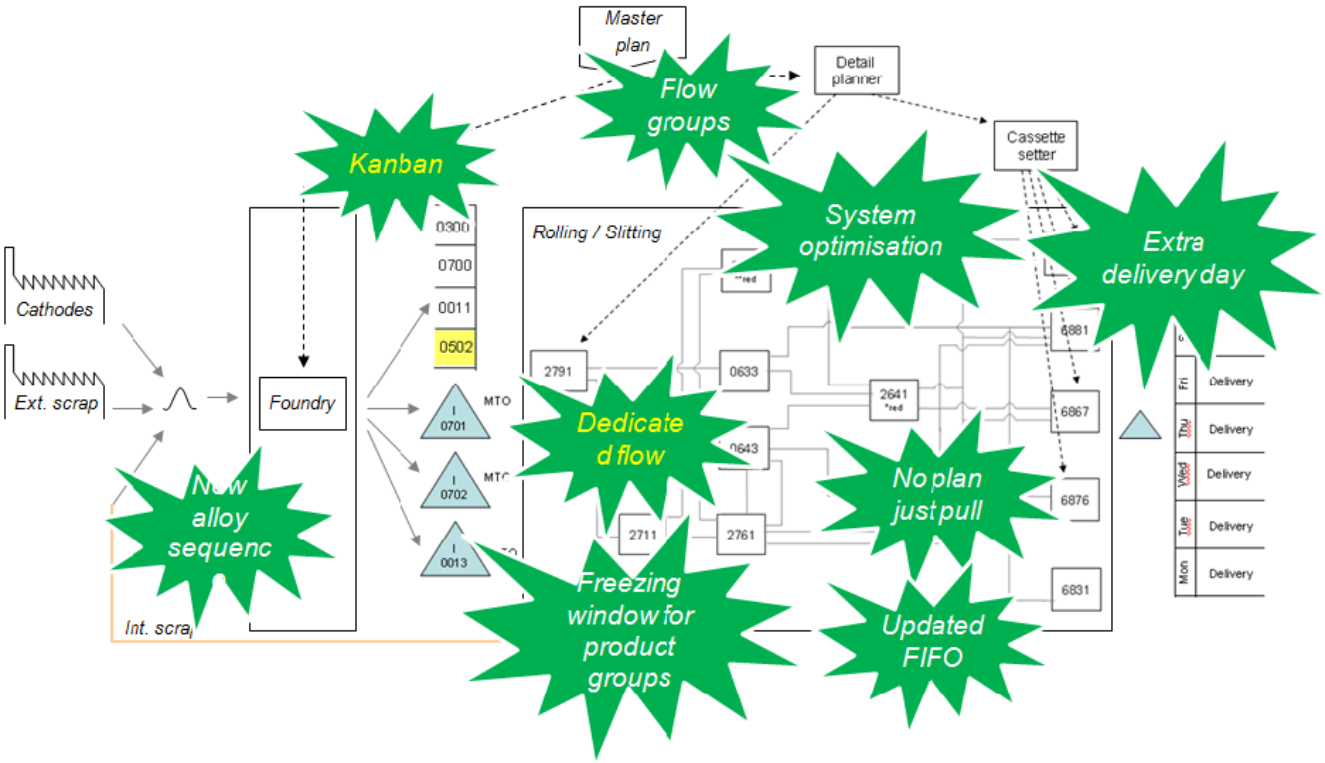


Figure 19: VSM with lean solution highlighted

3.6.2 Implementation of Kanban and Dedicated flow

Kanban – The Kanban replenishment system is successfully implemented that reduced the WIP remarkably and enhance the process performance. A kanban sticker/card is introduced that contains a product information – when, where and how much is needed to produce for the subsequent process as the signal from upstream has triggered. This means information flow and the material flow run parallel, this kanban (pull system) effectively control the buffer between casting mill and rolling mill processes.

The kanban method start from production machine in rolling area that generate a signal by means of card (contains information what they required), this card goes to the planner who plans casting production accordingly, casting produced that specific product (replenishment) and in the end demanding machine get the desired product (withdrawal). The process is shown in the figure 20 below.

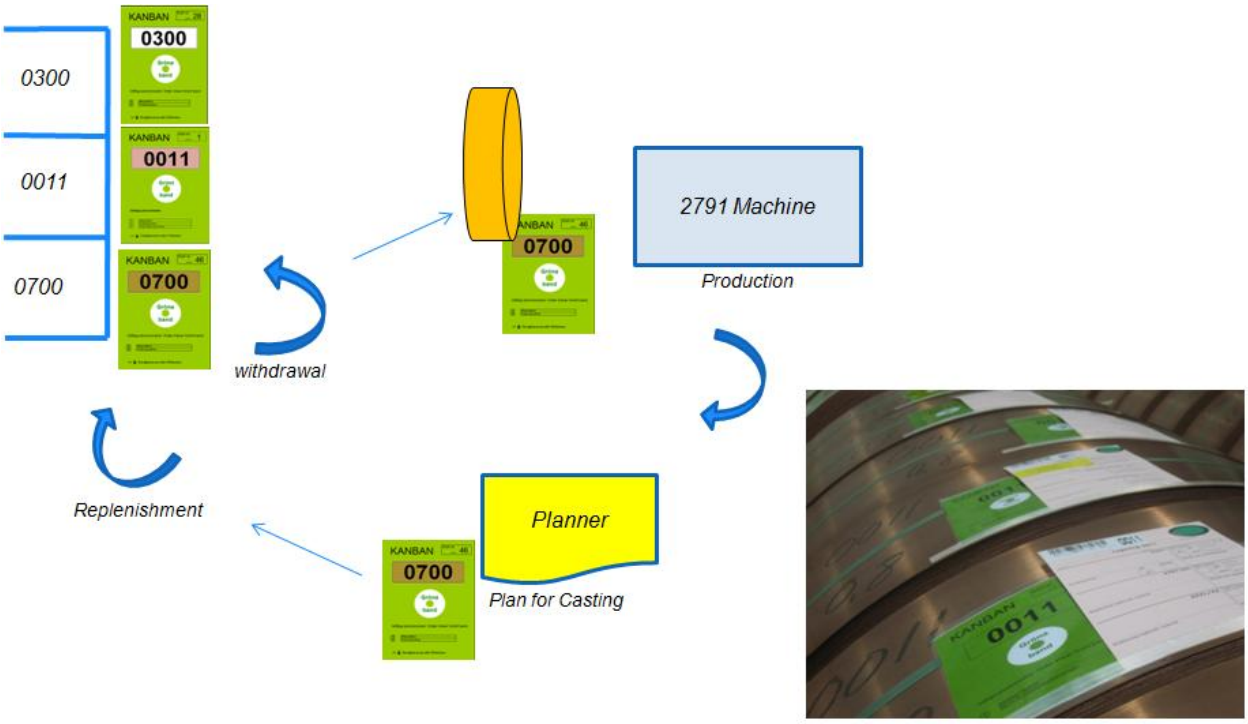


Figure 20: Kanban replenishment system

Although, there were some challenges to keep this system work properly and understand by everyone in the production area. This kanban approach is postponed twice during the transformation to lean implementation due to some issues in foundry management. But in the end this system start working and the WIP level has reduced from 1026 tons to 800 tons.

Dedicated flows – In order to keep the flow continuous that leads to reduction in buffer time, a dedicated flow has been implemented – in this a group of similar products would be process through their designated machines. This result in clear and smooth flow along with waiting time (buffer) gets smaller and hence, transportation has also optimized with better utilization of machines.

The products are divided into different families according to the processes that would be performed on them. Product family A belongs to those products that have annealing point greater than 100 my and thick in dimension, likewise the products passes through annealing between 70 to less than 100 my with single pre-rolling correspond to family B and family C products are those that have annealing point less than 70 with double pre-rolling. The process can be seen in the figure 21 below.

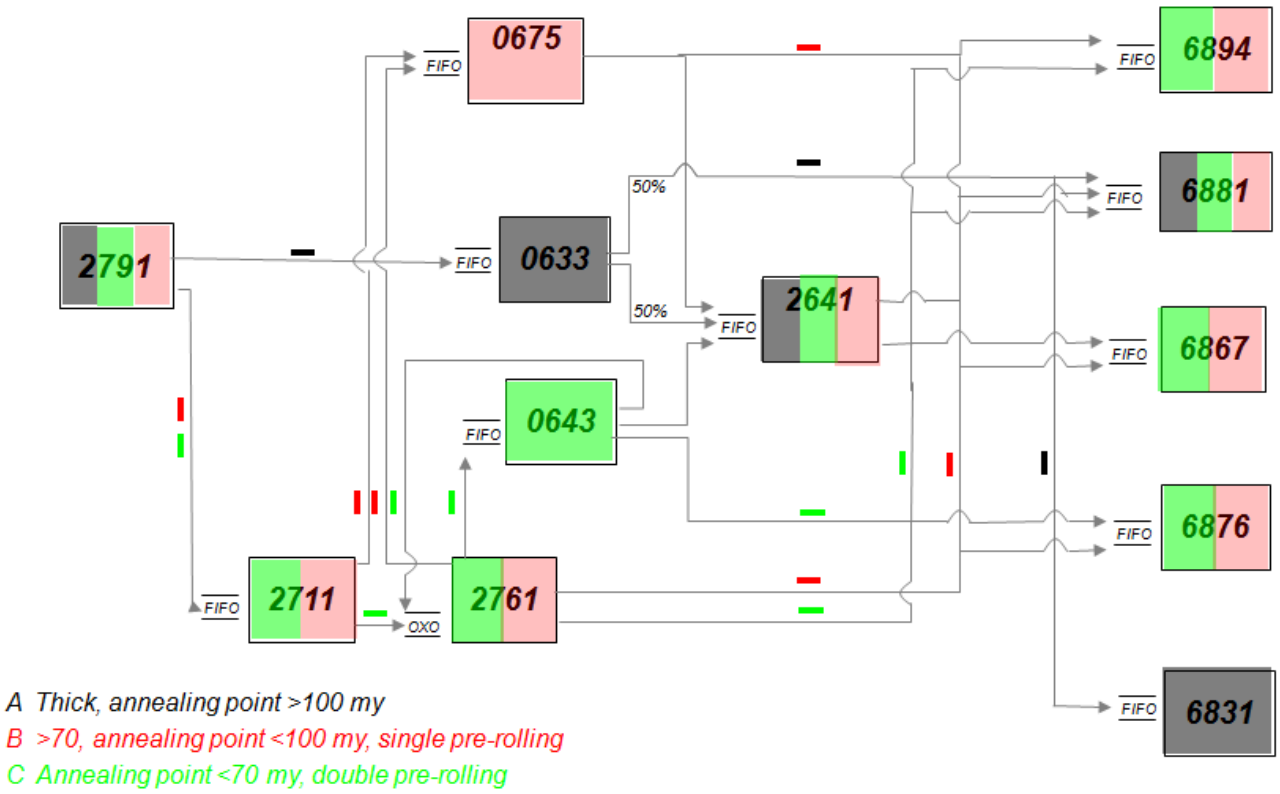


Figure 21: Dedicated flows of product families

The challenges have been faced during this implementation is the mix of product (A, B, C) with no agreement with sales to fit customer demand to capacity. Lack of continuity on implementing these changes, but the long term results are quite significant like in reduction in buffer time that bounds the people (management) to follow this approach.

3.6.3 Future Inventory Levels

The future inventory levels of all kinds of inventory after lean implementation are shown below in table 9:

Table 9: Future levels of inventory

Inventory type	**Quantity (ton)**	**Time (days)**
Raw Material	400	5.6
Work-In-Process (WIP)	800	11.2
Finish Goods (FG)	400	5.6
Total	**1600**	**22.4**

3.6.4 Future process performance and Inventory Turnover

The calculation are done with the help of equation 1.1 and 1.2

Raw material inventory conversion rate: $R_i = 400 / 5.6 = 71.4$ tons/day
Raw material inventory turnover: $ITR_i = 1 / 5.6 = 0.18$ per day = 5 per month

WIP inventory turnover conversion rate: $R_p = 800 / 11.2 = 71.4$ tons/day
WIP inventory turnover: $ITR_p = 1 / 11.2 = 0.09$ per day = 3 per month

Finish Good inventory conversion rate: $R_o = 400 / 5.6 = 71.4$ tons/day
Finish Good inventory turnover: $ITR_o = 1 / 5.6 = 0.18$ per day = 5 per month

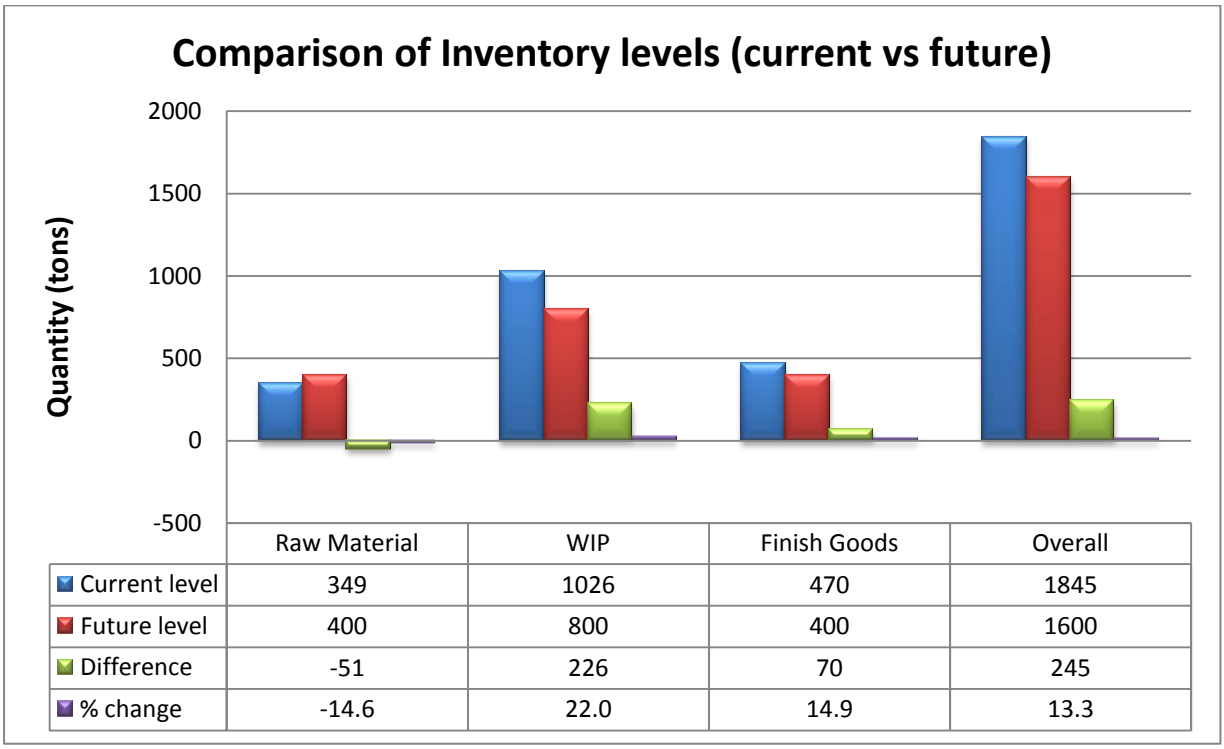
Overall Inventory conversion rate: $R = 1600 / 22.4 = 71.4$ tons/day
Overall Inventory turnover: $ITR = 1 / 22.4 = 0.045$ / day = 1.5 / month

Cost of copper (raw material):		€5900/ton
Processing cost is 5% of copper:		€295/ton
Total cost of a product:		€6195/ton
Total overall inventory cost:	6195 x 1600 =	€9912000 = €9.9 M

The difference (reduction) in overall inventory cost: 11.4 - 9.9 = €1.5 M

Improvement in inventory levels: (1845 – 1600) / 1845 = 13.2 %

The following graph (figure 22) shows a comparison between current and future state for all kind of inventory levels along with percentage change.



	Raw Material	WIP	Finish Goods	Overall
Current level	349	1026	470	1845
Future level	400	800	400	1600
Difference	-51	226	70	245
% change	-14.6	22.0	14.9	13.3

Figure 22: Comparison graph Current Vs Future

3.6.5 Ishikawa Diagram for solutions

The suggested solutions for the causes that create problems in current state are briefly portrayed in the cause and effect (Ishikawa) diagram as we can see in figure 23.

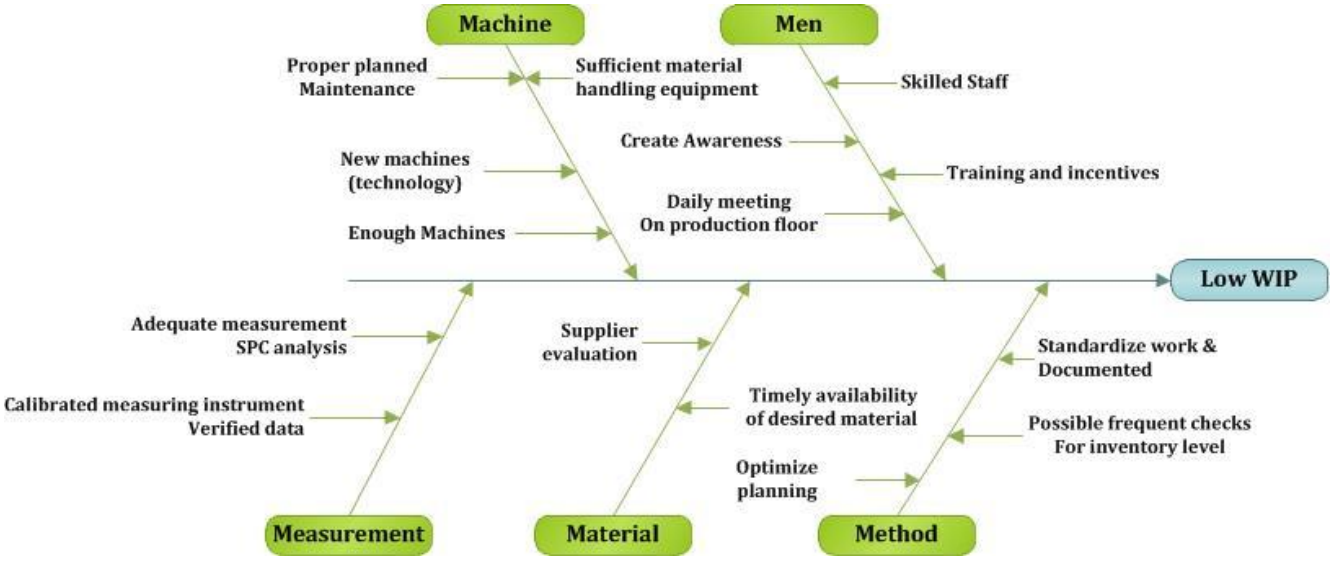


Figure 23: Ishikawa Diagram for low WIP

To sum-up this case study I would like to say that the lean approach is not a short term approach it's a long term philosophy that required continuous practice to get bigger achievements. Although, we have seen some improvements in the process of LT copper by terms of reduction in inventory levels and smooth flow after lean implementation in a short period of time but it can be enhanced by doing more and more efforts in order to strive for perfection and lean area to see huge improvements.

4. CASE STUDY – SERVICE SECTOR

The company involves for the case of service sector is a train company that provides transportation service in Sweden. The name of this company is Easy Train that has been involved in a small business relatively. Easy Train is a small Swedish train company that owns two train sets. These go round trip between Stockholm and Gothenburg each day, all days. The customer segment is lower price customers. Moreover, trains have designated crew team for the trips and on the other hand maintenance and cleaning of trains are scheduled with some outsource companies.

4.1 Organizational Chart

The organization chart of this small train company is defined as:

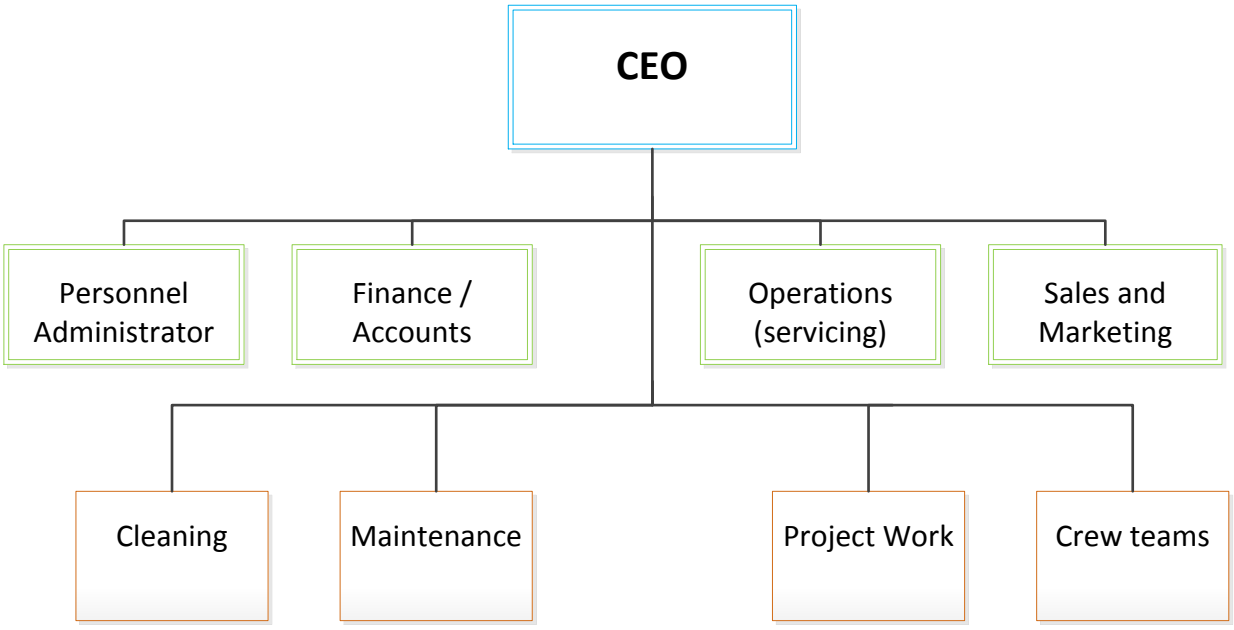


Figure 24: Organizational chart of Easy Train

We can in figure 24, the head of company is CEO with four administrative staff, the rest personnel are from trains' crew. There are six train crew teams working in shifts on the two train sets. Each team consists of 1 Driver and 2 Train hosts. Stockholm based teams: S1, S2, and S3, Gothenburg based teams: G1, G2, and G3. If someone is ill, a person from another team will work that day. There are no other train crew personnel. Maintenance and Cleaning are outsourced firms directly report to CEO.

Trains are maintained (workshop overhaul) weekly.

- Train set 1001 maintained in Stockholm night between Monday and Tuesday
- Train set 1002 maintained in Gothenburg night between Wednesday and Thursday

Maintenance is out sourced to a major train operator with workshops in Stockholm and Gothenburg. Trains are cleaned inside every night (at home base) by local cleaning firm, trains schedule are depicted in the table 10.

Table 10: Train Timetable and Crew Table

Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun	
Train no.	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2	ET-SG-1	ET-SG-2
Train Crew team	S1	G1	S2	G2	S2	G2	S2	G2	S3	G3	S3	G3	S1	G1
Train Set	1001	1002	1001	1002	1001	1002	1001	1002	1001	1002	1001	1002	1001	1002
Train no.	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2	ET-GS-1	ET-GS-2
Train Crew team	G1	S1	G2	S2	G2	S2	G2	S2	G3	S3	G3	S3	G1	S1
Train Set	1002	1001	1002	1001	1002	1001	1002	1001	1002	1001	1002	1001	1002	1001

EASY TRAIN Timetable Stockholm - Göteborg				EASY TRAIN Timetable Göteborg - Stockholm			
All Days	Train no	ET-SG-1	ET-SG-2	All Days	Train no	ET-GS-1	ET-GS-2
Stockholm	Departure	6:00	16:00	Göteborg	Departure	6:00	16:00
Katrineholm	Arrival	7:12	17:12	Herrljunga	Arrival	6:50	16:50
Katrineholm	Departure	7:15	17:15	Herrljunga	Departure	6:53	16:53
Hallsberg	Arrival	8:09	18:09	Skövde	Arrival	7:27	17:27
Hallsberg	Departure	8:12	18:12	Skövde	Departure	7:30	17:30
Skövde	Arrival	9:09	19:09	Hallsberg	Arrival	8:27	18:27
Skövde	Departure	9:12	19:12	Hallsberg	Departure	8:30	18:30
Herrljunga	Arrival	9:46	19:46	Katrineholm	Arrival	9:24	19:24
Herrljunga	Departure	9:49	19:49	Katrineholm	Departure	9:27	19:27
Göteborg	Arrival	10:39	20:39	Stockholm	Arrival	10:39	20:39

4.2 Problem statement

Easy Train was earning a good profit in previous years but now the situation is comparatively changed and problems are raised as they have high complaints rate from customers about the delaying of trains that leads to customer dissatisfaction and at the same time they lost the customers and also the profit is getting down, the number of customers had been reduced by 20% and profit was down to 2%. The main problem is whether the trains are arrived and departed within specified time or not, what is the current performance level.

4.3 Voice of the Customer (VOC)

Table 11: VOC according to KANO Model

TYPE OF QUALITY REQUIREMENT	WHAT DOES THE CUSTOMER EXPECT?	WHO IS THE CUSTOMER?
more is better = specified demands and expectations	The trains should arrive and depart on the specified time within the defined limits. Less crowdedness in the carriages, stations and platforms. A cheap ticket.	Passengers
must be = absolute demands	The trains must be available for journey means not be cancelled and bring passenger safely to their destination. A clean train	Passengers
delighters = wishes and unknown delighters (surprises)	Offer free refreshments during the travel, free Wi-fi	Passengers

4.4 Goal Statement

Fulfilled the customer demands according to VOC that means trains should be arrived and departed from stations within the specified time. On the other hand the estimation of the benefit will be to recover at least the lost profit margin again, along with customer gain that the Easy Train has been lost during this non-conformance.

4.5 Scope and Boundaries

The work will be conducted according to lean approach which means first will be the study to current performance as it now and then analyzes the performance level after implementation of lean methods with focus on VSM, Root Cause Analysis, Lead time and process yield (efficiency). In the end there will be suggestions to Easy Train with how to improve the company and the current performance level, localization of the root problems that are causes to the delays and high inventories but also other problems that found, Improvements to the current process and set up measurement and control process. Another aspect is to see how lean approach affects QTC (Quality-Time-Cost), where if used correctly it can give higher quality, shorter lead time, lower costs and flexibility in the process.

The boundaries of this case study project are time frame and limited information (data) like only data for arrival and departure times not for maintenance and cleaning time of trains. As the time period is limited to implement the lean approach on the other hand lean is not a short term program it’s a long and continuous approach to improve the processes. Some information is confidential that cannot be used in this thesis work.

4.6 Current State of Process

Currently, there are two major problems (defects) that results in customer and profit lost, they can be formulated in terms arrival and departure time of trains, and hence the yield (Y) of the process is the combination of arrival and departure time according to the voice of the customer (VOC).

Problem-1 = Late arrival of a train by more than 15 minutes at the end station

$$\text{Yield (Y1)} = 100\% - \frac{\text{\# of Late arrivals}}{\text{\# of Arrivals}} \qquad (1.3)$$

Problem-2 = Early departure of a train or later than 15 min of the scheduled departure time from any station

$$\text{Yield (Y2)} = 100\% - \frac{\text{\#of Early depatures} + \text{\# of Late departures}}{\text{\# of Departures}} \qquad (1.4)$$

4.6.1 Set Target

To achieve the arrival time goal – the Y1 should be 90% or more and to achieve the departure time goal – Y2 should be 95% or more in order to avoid delays and for customer satisfaction.

Despite of some other wastes the company more focuses on customer and the waste according to customer point of view i.e., the delaying of train when it arrives at end station and departure of train at each station, this is the core service that provided by the Easy Train and high performance in this area leads the customer satisfaction and thus high profits.

4.6.2 Current Value Stream Mapping

The process map of Easy Train is defined in the figure 25 below. The maintenance of train by outsourced company is consider to be starting point and as a supplier of well maintained train, the next step is the cleaning of train before the start of journey and it also done by a cleaning firm. Departure of train from a station is one of the main and kickoff step for this process, transportation (travelling) is followed by departure and in the end arrival of train at a station is the last process step. The main problems are also highlighted in the process flow.

There are many other variables associated with each of process step, these input and output variables have more influence on process performance. The detailed process step with input and output parameters of each step are shown is the table 12.

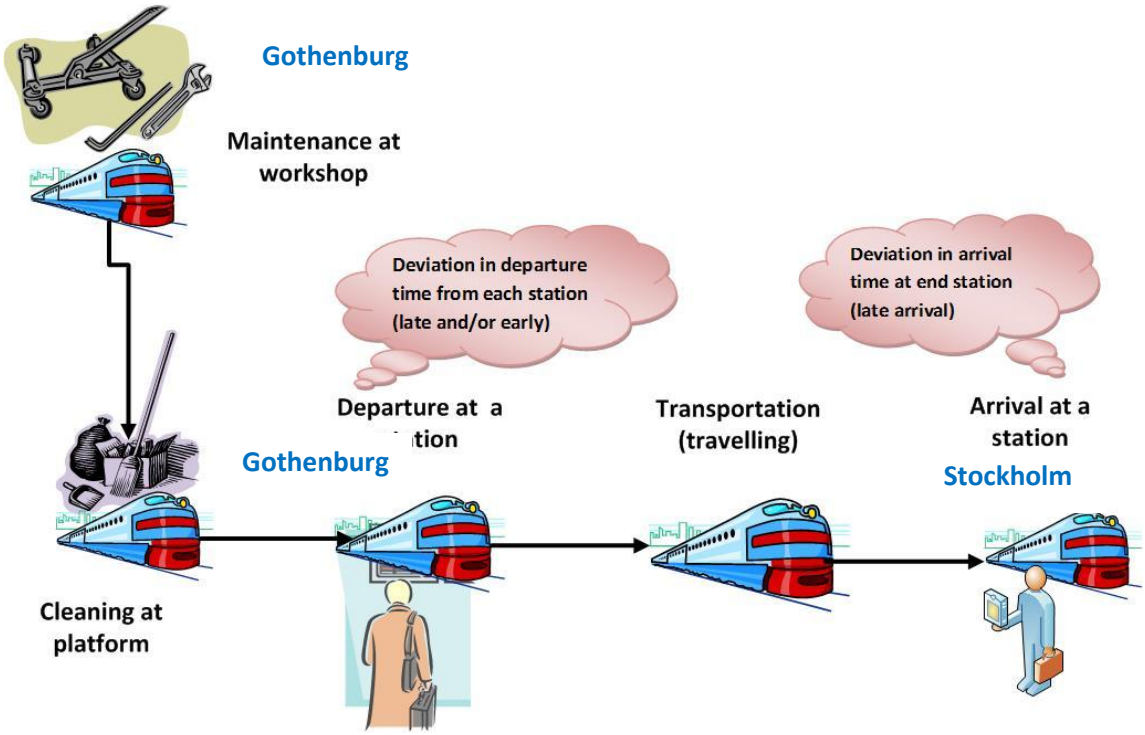


Figure 25: Process flow

Table 12: Process Map of Easy Train

Input variables	*PROCESS (steps)*	*"Inside the process" variables*	*Output variables*
Staff, workshop, Information, delivery time	**Maintenance of train**	Maintenance performance, time of maintenance	Delivery time at station, Train starts
Staff, equipment, Arrival time at the cleaning spot	**Cleaning of train**	Cleaning performance, time of cleaning	A cleaned train - ready for departure
Actual arrival time for each station	**Departure from each station**	Waiting time, door closing, engine start	Actual departure time from each station
Weather, Train condition, crew, passengers, departure time	**Transportation (travelling)**	Weather, skills of driver, condition of the train, traffic	Travel time between two stations
Departure time from the last station, travel time	**Arrival at a station**	Opening doors, unloading and loading of passengers	Actual arrival time to each station
Departure time from the first station, whole travel time	**Arrival at the end station**	Opening doors, unloading and loading of passengers	Actual arrival time to the end station

4.6.3 Measuring Variables

The main problems have occurred in departure and arrival of train with respect to time i.e., late and early departure of train from each station within specified time, Late arrival of train at end of station within specified time and this is the main waste (buffer) in the process, major area to be improved. Therefore, the measuring variables are related to timing of the whole process (lead time) such as arrival time at end station, arrival and departure time at each station, Number of arrival of train at end station, number of arrival and departure from each station. In order to get the current yield of process these variable should be measured.

- **ARRIVAL AND DEPARTURE TIME AT EACH STATION** – It's an actual time of arrival and departure of train at each station and countdown timer/stopwatch can be used for measure. It is a continuous variable in hour, min or sec. It can be measured every day, at each railway station, Swedish Transport Administration (in process - recorded automatically) can be a source to get this data. Used for monitoring the performance of departure process and its impact on delaying of trains at the end of station.

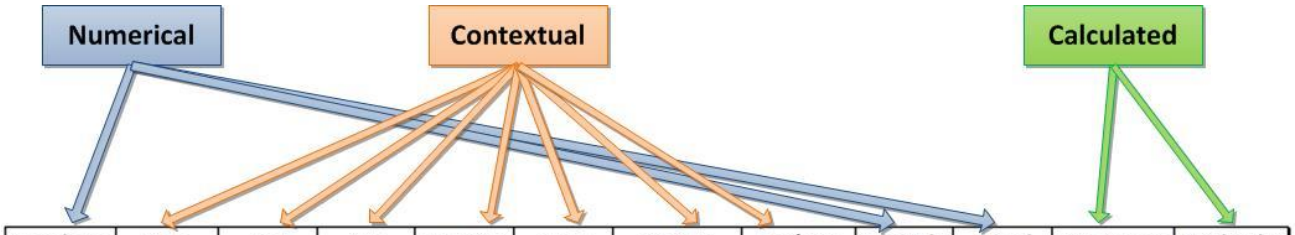
- **NUMBER OF ARRIVAL AND DEPARTURE OF TRAIN** – How many times a train is arrived and departed at each station and also number of arrival at end station, counter can be used to measure these variables. It can be measured every day, at each railway station, Swedish Transport Administration (in process - recorded automatically) can be a source to get this data. It's used to calculate the process yield.

- **ARRIVAL OF TRAIN AT THE END OF STATION WITHIN SPECIFIED TIME LIMIT = Y1** – Yield of the whole process, It's a ratio of no. of arrival within specified limit over the total no. of arrival at end station and can be measured in percentile as it's a discrete percentage variable. It can be measured every day, at the end railway station by Easy Train consultant.

- **DEPARTURE OF TRAIN FROM EACH STATION WITHIN SPECIFIED TIME LIMIT = Y2** – It is also a yield of the whole process, It's a ratio of no. of departure within specified limit over the total no. of departure from each station and can be measured in percentile as it's a discrete percentage variable. This can be measured every day, at the end railway station by Easy Train consultant.

Both Y1 and Y2 are the measure of whole process performance and the key performance indicators; they have a high impact on the company's improvement and sustainability.

The figure 26 represents the data collection criteria and the measuring variables that would be included in the measurement analysis of this case, facilitate to calculate lean measures and improvement in the process.



Sample no	Date	Day	Set	Train no	Crew	Station	Arr/Dep	Schedule	Actual	Added time	Total delay
81	1/5/2012	Thu	1001	ET-SG-1	S2	Stockholm	Departure	6:00	6:02	2	2
82	1/5/2012	Thu	1001	ET-SG-1	S2	Katrineholm	Arrival	7:12	7:12	-2	0
83	1/5/2012	Thu	1001	ET-SG-1	S2	Katrineholm	Departure	7:15	7:18	3	3
84	1/5/2012	Thu	1001	ET-SG-1	S2	Hallsberg	Arrival	8:09	8:15	3	6
85	1/5/2012	Thu	1001	ET-SG-1	S2	Hallsberg	Departure	8:12	8:15	-3	3
86	1/5/2012	Thu	1001	ET-SG-1	S2	Skövde	Arrival	9:09	9:19	7	10
87	1/5/2012	Thu	1001	ET-SG-1	S2	Skövde	Departure	9:12	9:24	2	12
88	1/5/2012	Thu	1001	ET-SG-1	S2	Herrljunga	Arrival	9:46	10:02	4	16
89	1/5/2012	Thu	1001	ET-SG-1	S2	Herrljunga	Departure	9:49	10:07	2	18
90	1/5/2012	Thu	1001	ET-SG-1	S2	Göteborg	Arrival End	10:39	10:47	-10	8

Figure 26: Types of data used in performance measurement

4.6.4 Lean measures to assess current process performance

Historgram – A histogram shows the shape of distribution of data set; in figure 27, histograms are for the data set of arrival delays at the end of station (Y1) and departure delays at each station. The distribution looks skewed to the right around the average delay of 10 min and it can see that the trains delaying time range from about -10 min up to 110 min, with most of the trains are delayed between -5 and 20. While the delaying in departure from each station (Y2) is averaged 8 min and ranges from 0 (no early departure) to 108 minutes.

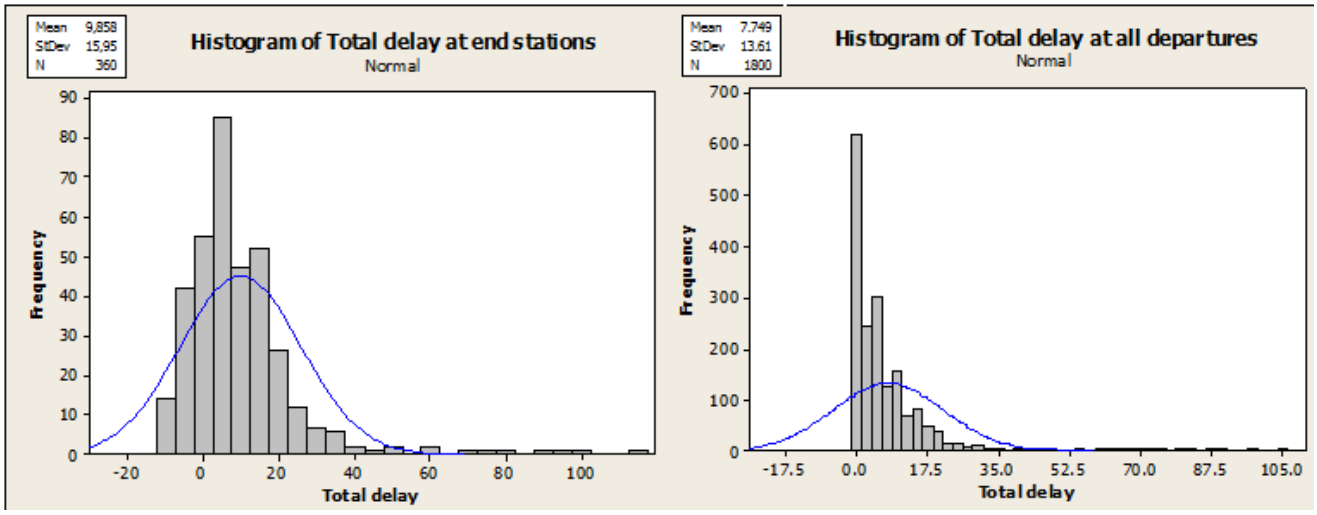


Figure 27: Histogram of delaying of train

Control Charts – I-MR chart is a control chart that shows time series plot of a process. The time series plot of the data set of trains delay at the end of stations is shown in figure 28 with control limits (UCL & LCL) that are set at +/- 3 sigma away from the average (x-bar). It can be seen that there are some outliers - alarms (points outside the control limits) in the process and hence the process appears to be unstable.

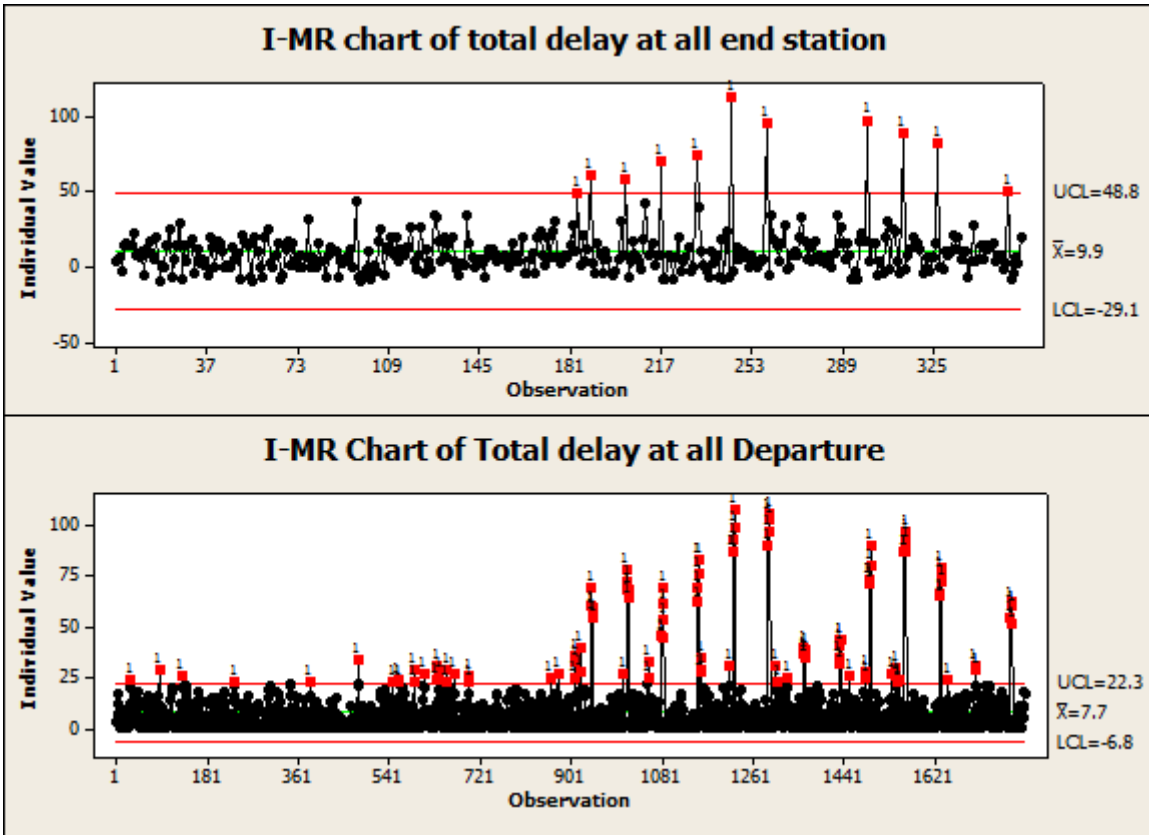


Figure 28: Control charts of process delaying time

Pareto Chart – Pareto charts are used to identify the most important factors (variables) among a set of factors usually highlights the most common sources of problems. The Pareto charts that are shown in figure 29 refer the most frequent causes of problems (defects) in the process of Easy Train for the customers' dissatisfaction and we can see that train set – 1002, train no. ET-GS-1, Crew team – G2 on Thursday from Gothenburg to Stockholm is the most prominent factors to causing problems that means these causing delaying of train to arrived and departed from the station.

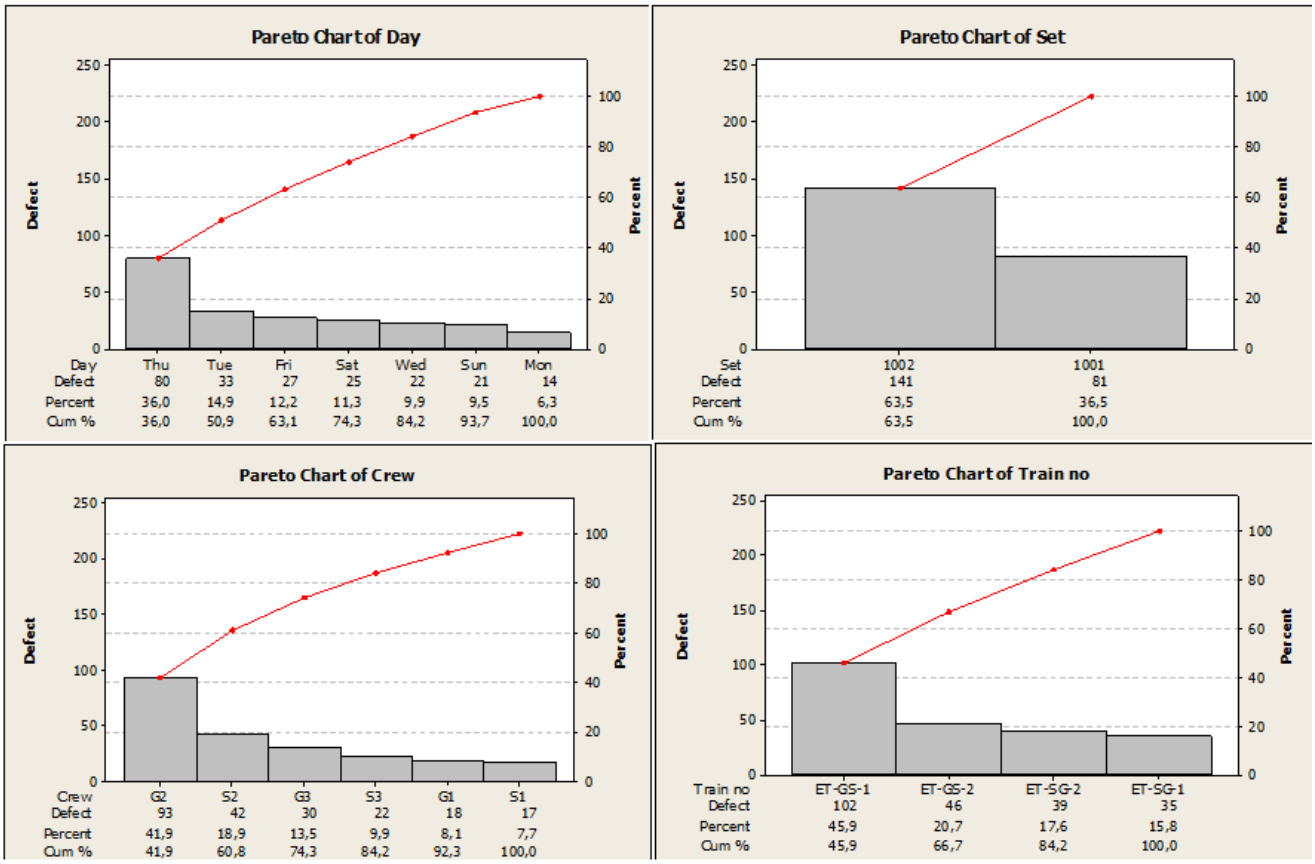


Figure 29: Pareto Charts of different process parameters

4.6.5 Current process performance and Yield

For measuring of current performance (yield) of the process, process capability chart are drawn. It shows the ability of the process to how well it fulfills the customer demands, the process capability of the process of easy train by means of arrival delays at the end stations (Y1) and departure delays at each stations (Y2) are shown below and we can see that the performance of process is not according to the voice of the customer with delaying rate at the end of stations is about 24% and 13% at each station.

According to the equations 1.3 and 1.4, following results are calculated

Y1 (yield) = 76 %

Y2 (yield) = 87 %

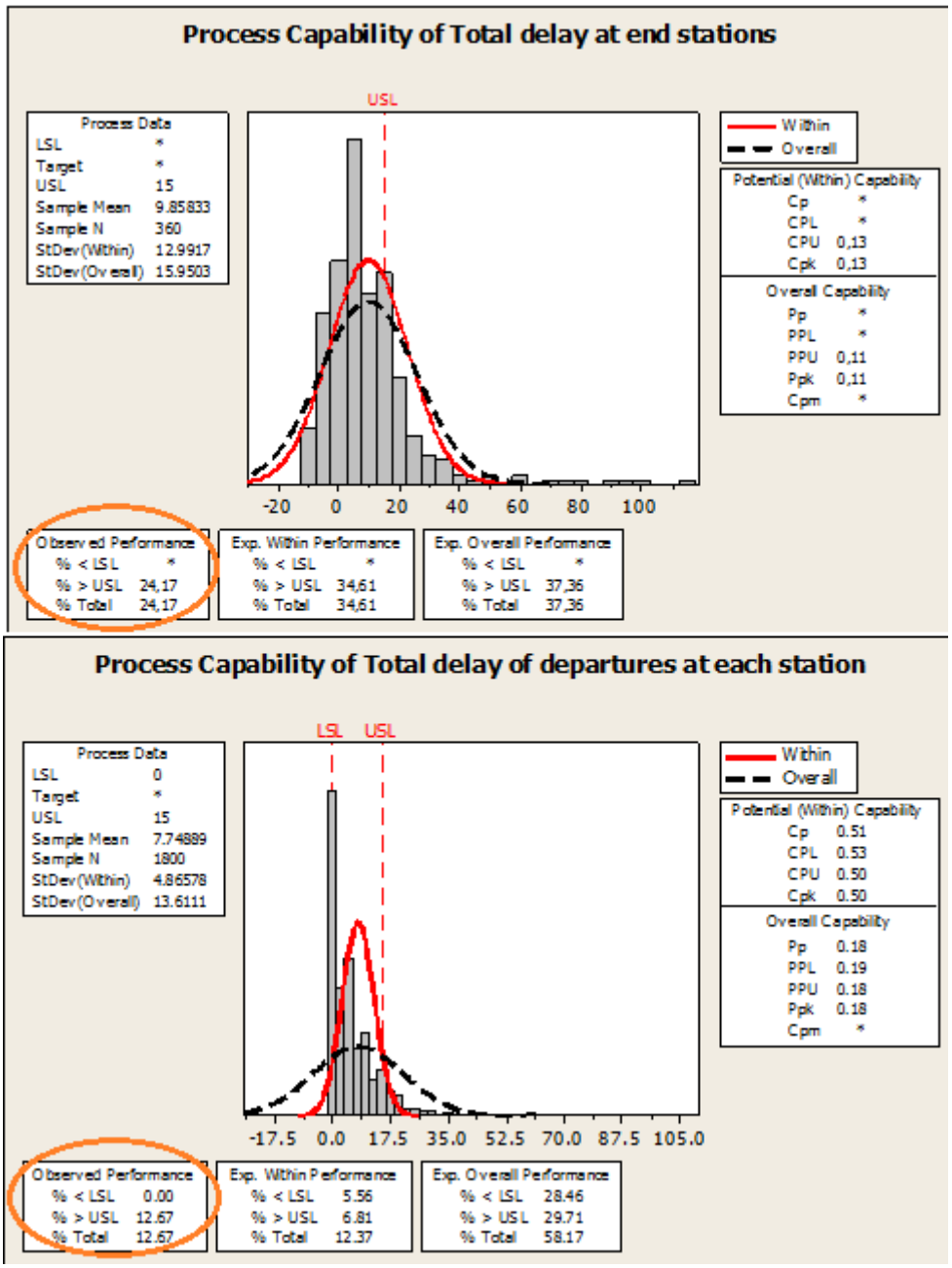


Figure 30: Process capability of Easy Train

The process capability of current state of easy train represents that the current process performance is not satisfied as per customer expectations as shown in figure 30. It seems there are some problems in the whole process overall but major problems i.e., late arrival and departure of trains are due to either by the train set – 1002, or train transit – ET-GS-1, specially on Thursday from Gothenburg with crew team G2.

4.6.6 Root Cause Analysis (5 Whys)

After the assessment through some lean measures, it is identified that transit ET-GS-1 creates more problems among others and causes more delaying of train from departure at each station and arrival at end stations. In order to find the root causes of this effect (failure), cause and effect diagram also known as Ishikawa diagram (Figure 31) is formed with the help of 5 Whys method, this method facilitates to investigate real root causes of problems through brainstorming. 5M terminology – consists of man, machine, material, method and measurement factors are used because of more influence on the process.

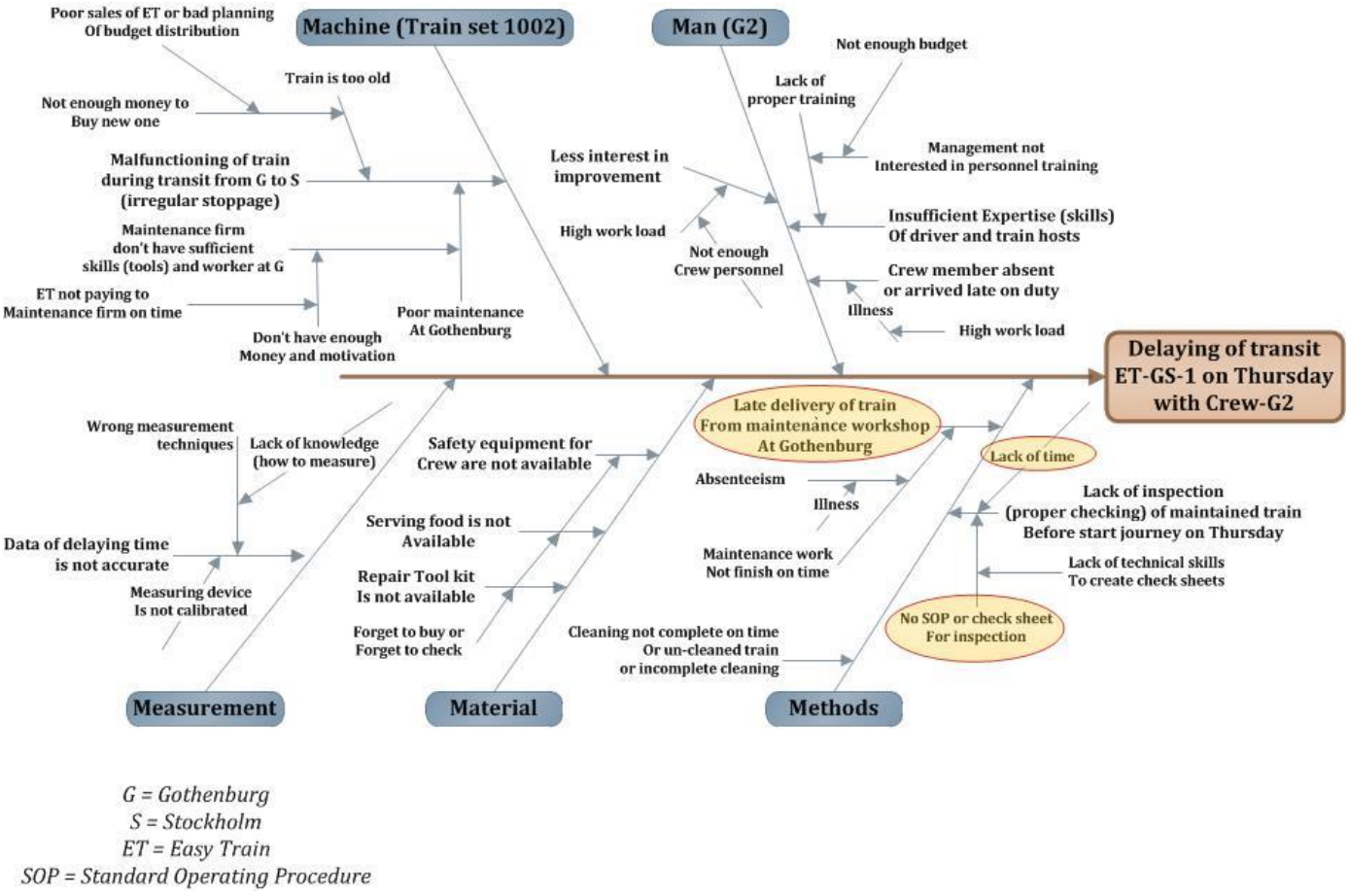


Figure 31: Cause and effect diagram of delaying of transit ET-GS-1

The major causes of problems are highlighted in circles, they are contributed almost 70 percent of problems and failure of process to arrival and departure of train on schedule time. Late delivery of train from maintenance workshop, Lack of time and no check sheet for inspection are the main and certain root causes for delaying of trains.

4.6.7 Process Map with Problems and Causes

The root causes are identified after root cause analysis through Ishikawa diagram for the problems have been encountered by Easy Train. The process map with the problems and causes for those problems is shown in the figure 32.

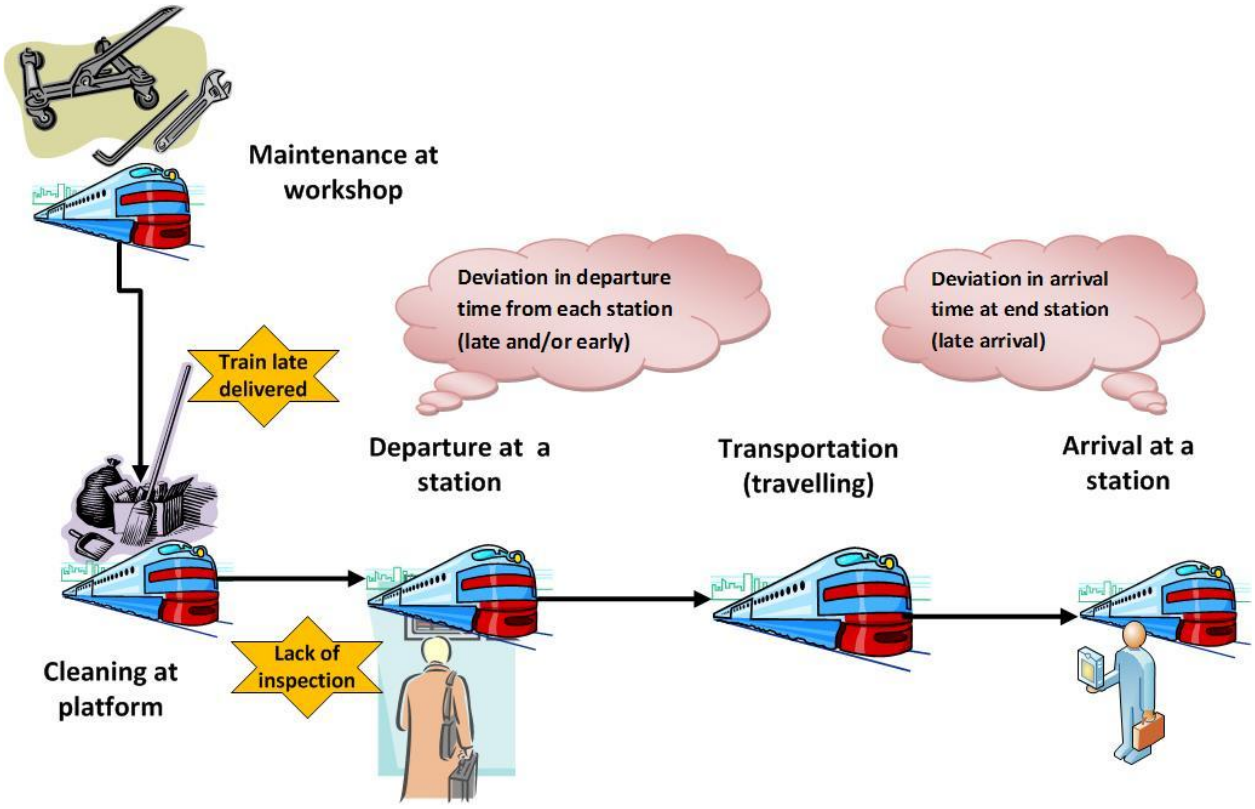


Figure 32: Process Map with major root causes

4.7 Future State of Process

4.7.1 Major Root Causes

The main root causes that lead delaying of train on arrival and departure at stations are:

- Late delivery of the maintained train at Gothenburg station
- Insufficient inspection after the maintenance because of lack of time
- Insufficient inspection after maintenance because no proper check sheet exists

4.7.2 Solution Generation (Mind Map)

In order to create the solution to mitigate the certain root causes a brainstorming session is conducted with assumption busting and 5 whys techniques for encounter the limitations that suppose to be faced while implementing solutions. The mind map is constructed after

brainstorming session as shown in figure 33. The following criteria are taken into account for the selection of the possible solutions.

- Can be implemented
- Will solve the problem
- Economically feasible
- Will satisfy customer
- Will fulfill laws and requirements

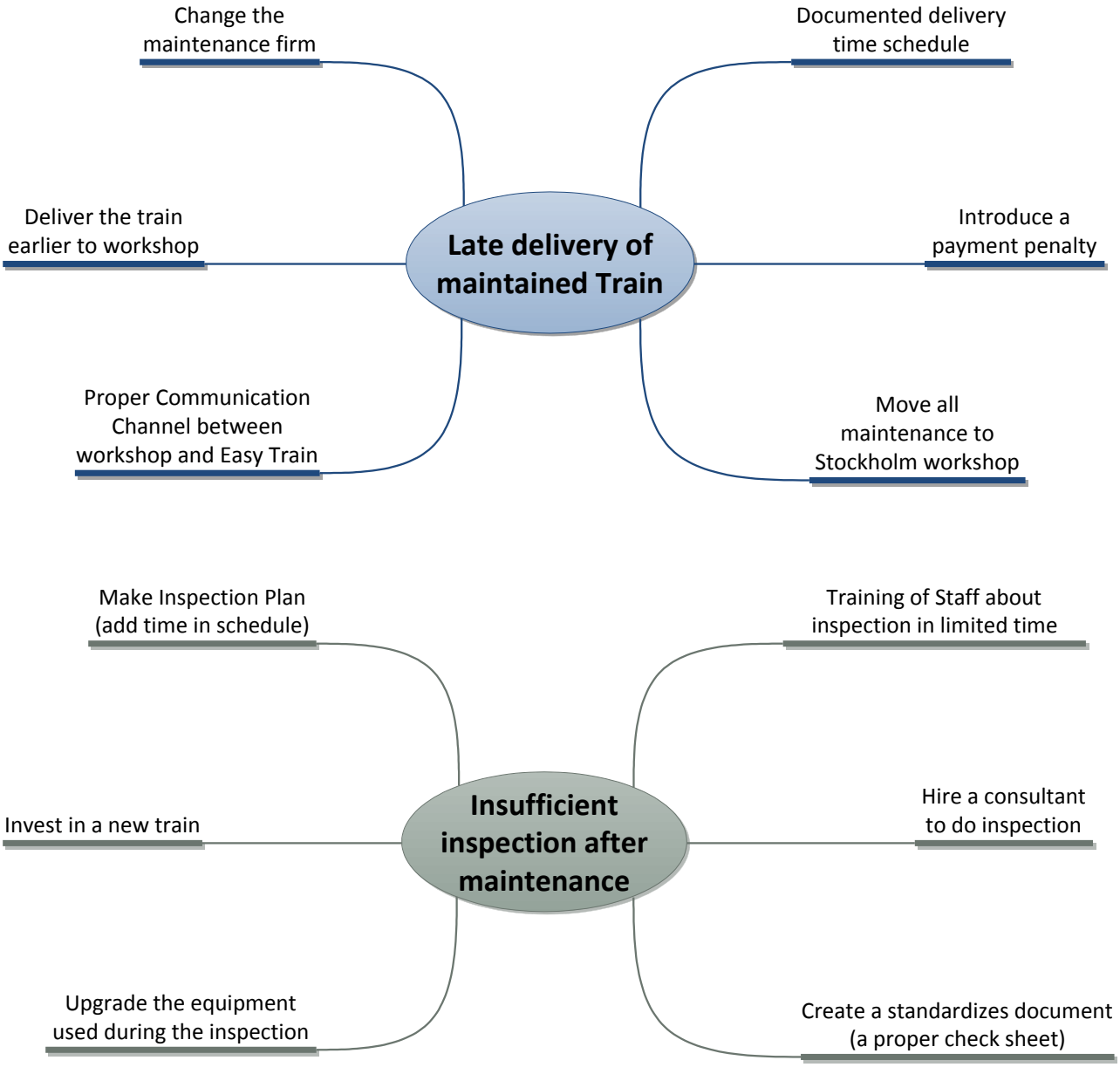


Figure 33: Mind Map of Possible Solutions

The main implemented solutions for the mitigation of verified and identifies root causes are:

- Proper communication channel between workshop and Easy Train (Introduced small ERP software for better information flow and monitoring of delivery time)
- Documented action plan for late delivering of train to the train station by maintenance workshop (long lead times), it consists of delivery time schedule and payment penalties
- For inspection after maintenance an inspection plan is created along with a proper check sheet for testing and designated time for checking, appropriate distribution of inspection tasks
- Training of staff for how to do inspection in designated limited time, awareness of 5S and Visual management (feedback) system, empowers driver to not drive a faulty train
- Upgrade and calibrate the equipment that are using during the inspection process

4.7.3 Improved Process Map

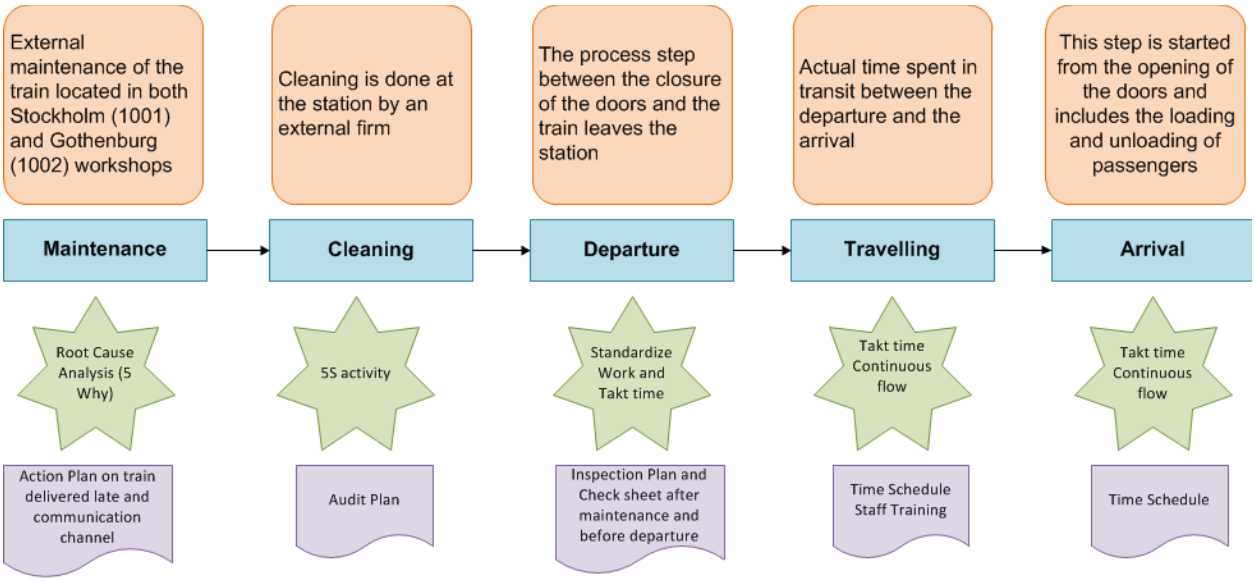


Figure 34: Improved Process Map

The process map is made after the implementation of lean tools and solutions for identified problems as shown in figure 34. The main process steps are the same as before but there is a description of each process step in this improved process map in order to more clarification of tasks within the process. Moreover, the implemented lean techniques are mentioned below the each step that followed by corrective actions that have been taken during the implementation.

4.7.4 Risk Analysis

The risk analysis of selected solutions is carried out by process FMEA (Failure Mode and Effect Analysis). FMEA tool is used to identify the risk level if a certain improved process step is being failed; FMEA starts with the list down the steps/solutions of the process that is followed by potential failure and effects of respective process, if the process is failed then what happened and who would be affected by the failure mode. Furthermore, the potential causes are being identified with the estimation of current control if there is any. The severity of failure effects, frequency of occurrence and detection of these failure are numbered from 1 to 10 corresponding low to high and in the end the multiplication of severity, occurrence and detection gives the RPN – risk priority number that indicates which process is more vulnerable if it not done properly, highest the RPN greater the process risk. The actions recommended and taken are further implemented to reduce the RPN; the FEMA of Improved process of Easy Train is shown in the table 13:

Table 13: Process FMEA

Name of Solution / Improved Process: Improved maintenance process (on time delivery of maintained train and proper time for inspection with check sheet after maitenance at Gothenburg station)

FMEA Date (Orig) 2014 - 05 -11 (Rev) 1

Solution / Process step	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
Documented delivery time schedule (Kind of agreement)	No delivery time schedule or schedule not followed	Nobody knows when to receive the maintained train exactly, Train delivered late	7	Bad communicaton, Careless ET management, no responsible for evaluate manitenance perfromance	9	No current control	9	567	Internal audit for delivery time by authorize person	ET management	A proper delivery schedule is made and person is nominated for take care this matter and deal with maintenance firm	6	5	5	150
Introduce a payment penalty	No penalty to maintenance firm for late delivered train	Train delivered late from maintenance workshop, hence delaying in departure and arrival at end station	8	No agreement for such kind of penalty and lack of management skills	7	No current control	9	504	Training and audits	ET management	Periodic checking (audits)	7	4	5	140
Move all maintenance to Stockholm workshop (No maintenance of train in Gothenburg)	Late delivery of train from stockholm workshop	Every train delivered late from maintenance workshop, hence delaying in departure and arrival at end station for both train set	9	No proper planning and high work load at stockholm workshop	8	Distributed maintenance work into two workshops	6	432	Compare stockholm and gothenburg workshops, Facilitate gothenburg workshop same as stockholm. Keep distribution of maintenance work	ET management and maintenance firm	Maintenance firm evaluation plan, periodic visit of maintenance workshops, Assest workers skills and facility of both workshops	7	5	4	140
Proper communication channel between workshop and EasyTrain	No proper communication and exchange of word about train technical problems and delivery time	Nobody knows what is the actual problem and train delivered late	7	No one responsible for evaluate manitenance perfromance and no information system for proper information flow between ET and maintenance workshop	8	No current control	9	504	Introduce information system for direct reporting of problems in train and make sure train delivered on time	ET management	Information system has introduced, a kind of ERP software for reporting, monitoring and feedback	6	4	5	120
Make inspection plan (Add inspection time to the schedule)	Inspection plan and time schedule for inspection are not followed	No proper inspection after maintenance and hence breakdowns in train causes train delayed	8	Not enough time for inspection and inspection plan is not understandable or not user friendly	8	No current control	9	576	Create awarness and make inspection plan understandable, deliver train on time or ealier for inspection	ET management and staff	Delivered train to maintenance firm on schedule time or ealier and training of staff to follow schedule	7	4	5	140
Training of staff for how to do inspection in limited time	No training or inadequate training	No proper inspection after maintenance and hence breakdowns in train causes train delayed	8	Not enough time for training or no budget for training or unqualified trainer	7	Sufficient hiring process and normal training for new staff	5	280	Training and improvement program (5S and Kaizen) to reduce inspection time and other waste	ET management and staff	Consultant work on different improvement project to reduce waste that causes delays	6	5	3	90
Upgrade the equipment used during the inspection	Equipment for inspection are not working or malfunctioned	No proper inspection after maintenance and hence breakdowns in train causes train delayed, also ambiguity to address what's wrong!	8	No calibration plan and testing of equipment	8	Durable equipment from reliable supplier or No current control	7	448	Periodic testing plan of inspection equipment (GR &R activity) or buy new and modern tech. equipment	ET management	GR&R process for inspection equipment is planned and replaced old with new ones	6	5	4	120
Create a standardize document for how a proper inspection is made	No standardize checklist or wrong checklist or not user friendly	Insufficinet inspection and inspection process takes time that ultimately leads to delaying in departure and arrival at end station	8	No or inadequate expertise for how to create a proper checklist	6	No current control	9	432	Create a proper check sheet for inspection that makes this process easier with the help of driver and technical consultant	ET management and train driver	Inspection checksheet is established with training of drivers and standardize the process	6	4	5	120
Hire a consultant (third party) to do inspection	Takes more time to do inspection and improper work	Insufficinet inspection and inspection process takes time that ultimately leads to delaying in departure and arrival at end station. An extra cost in process - additional expenses	8	Unreliable consultant	5	No current control	9	360	Consultant evaluation plan and feedback from train crew, introduce payment penalty for improper work	ET management and staff	Consultant evaluation plan is made with feedback from train crew	7	4	5	140

Implement ISO 9001:2008 could be one recommended solution if company don't have this certification

4.7.5 Comparison of Before and After process

In this section we are comparing the before and after situations with the help of control charts, Pareto charts and box plots in order to show the elimination/reduction of the root causes. A hypothesis test is also conducted for the same reason.

The control charts (time series plot) for monitoring the process of Easy Train are shown below. There are four charts two for each train set in terms of Y1 and Y2, along with the comparison of before and after state of the process. After chart shows the stability of improved process subsequent to implementing the possible solutions

Control Charts – From the following control charts in figures 35 and 36, we can see that the process became more stable after implementing the solutions as we have reduction in delay times for both arrival at end stations and departure from each station. Especially, for the train set 1002 which we are more focused on, the average arrival delay at end stations is reduced to 7.2 min from 12 min and average departure delay at each station is dropped down to 5.9 min from 10.2 min with number of reduction in outliers and in upper and lower process control limits as well.

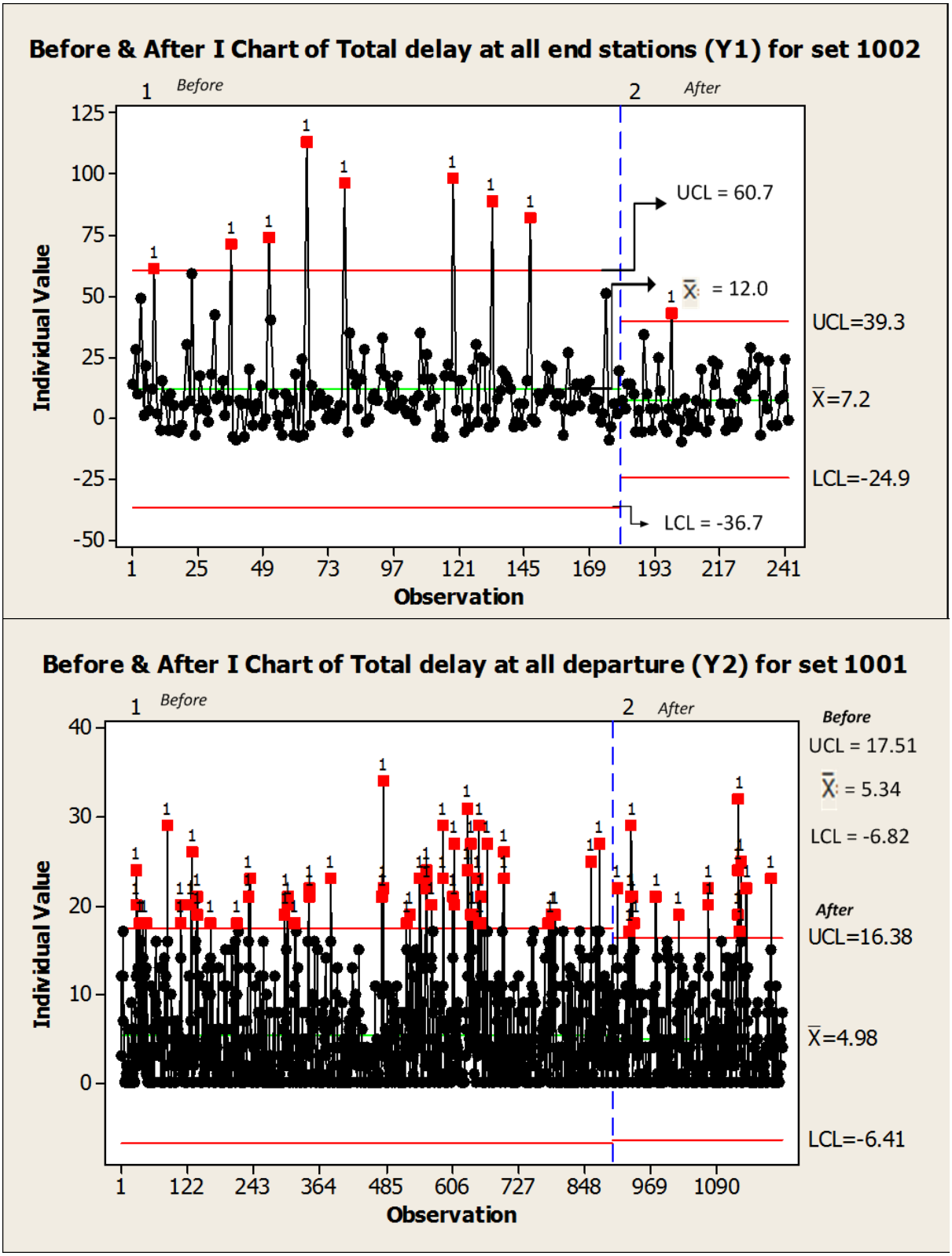


Figure 35: Before and after control charts - 1

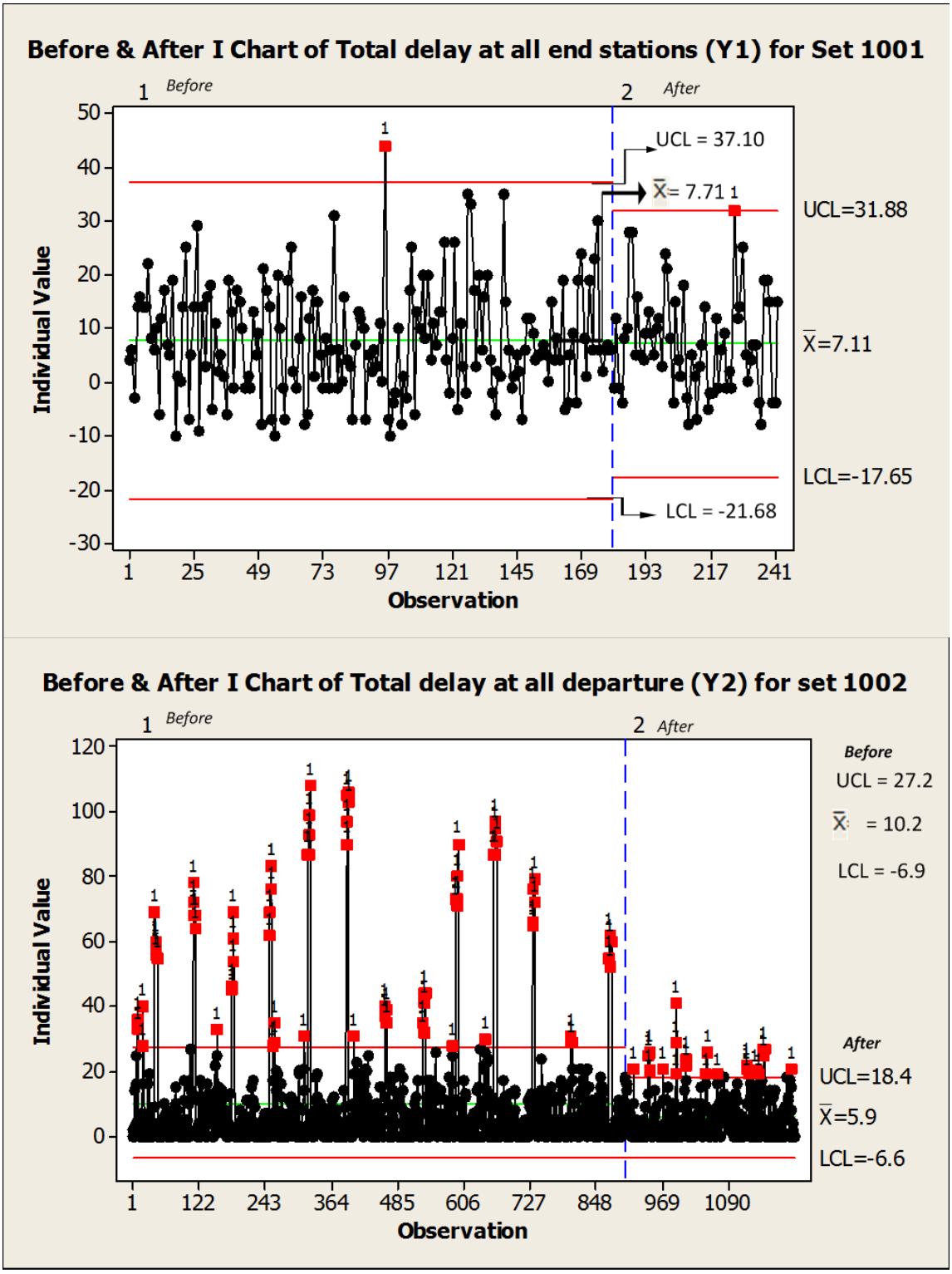


Figure 36: Before and after control charts - 2

Quality Control Plan – Table 14 represents a quality control plan is made for future controlling and monitoring of process that integrates a process map with output from control charts

Table 14: Quality control plan

Simplified Quality Control Plan

Process:	Easy Train Transportation	
Issuer and date:	CEO of ET	5/19/2014

Flow Chart	Indicators	Corrective Actions
Maintenance	*Late delivery of train after maintenance*	*Evaluate the delivery time schedule and make sure maintenance firm follow the schedule plan*
	No proper maintenance and breakdowns after maintenance	*Inform the maintenance firm immediately and Meeting with them for better communication and discuss the action plan* *Review the inspection checklist of maintained train*
Cleaning	*Cleaning is not done on time* *Train is not cleaned properly*	*Evaluate the time schedule of cleaning process* *Face to face meeting and payment penalty*
Departure	*Train is not departed within the specified time limit (delaying of departure at all station > UCL)*	*Examine all data and conduct root cause analysis* *Make sure it is not a special cause variation*
Travelling		
Arrival	*Train is not arrived at end station within the specified time limit (delaying of arrival at end station - one point is outside control limit)*	*Examine the difference between the individual points and implement action on individual point for both train sets*

Improved process performance – The improved process yield after lean implementation is calculated with the help of equations 1.3 and 1.4

Y1 = Ratio of number of arrivals on time within specified limit to the total number of arrivals at end stations

Yield (Y1) = 79.03 %

Y2 = Ratio of number of departures on time within specified limit to the total number of departures at each station

Yield (Y2) = 91.1 %

Process Capability – Process capability shows the ability of the process to how well it fulfills the customer demands, the process capability of the improved/verified process of easy train by means of arrival delays at the end stations (Big Y1) and departure delays at each stations (Big Y2) are shown in figure 37 and we can see that the performance of process is improved, as delaying rate at the end of stations is decreased to 20.9 % and 8.8% at a station.

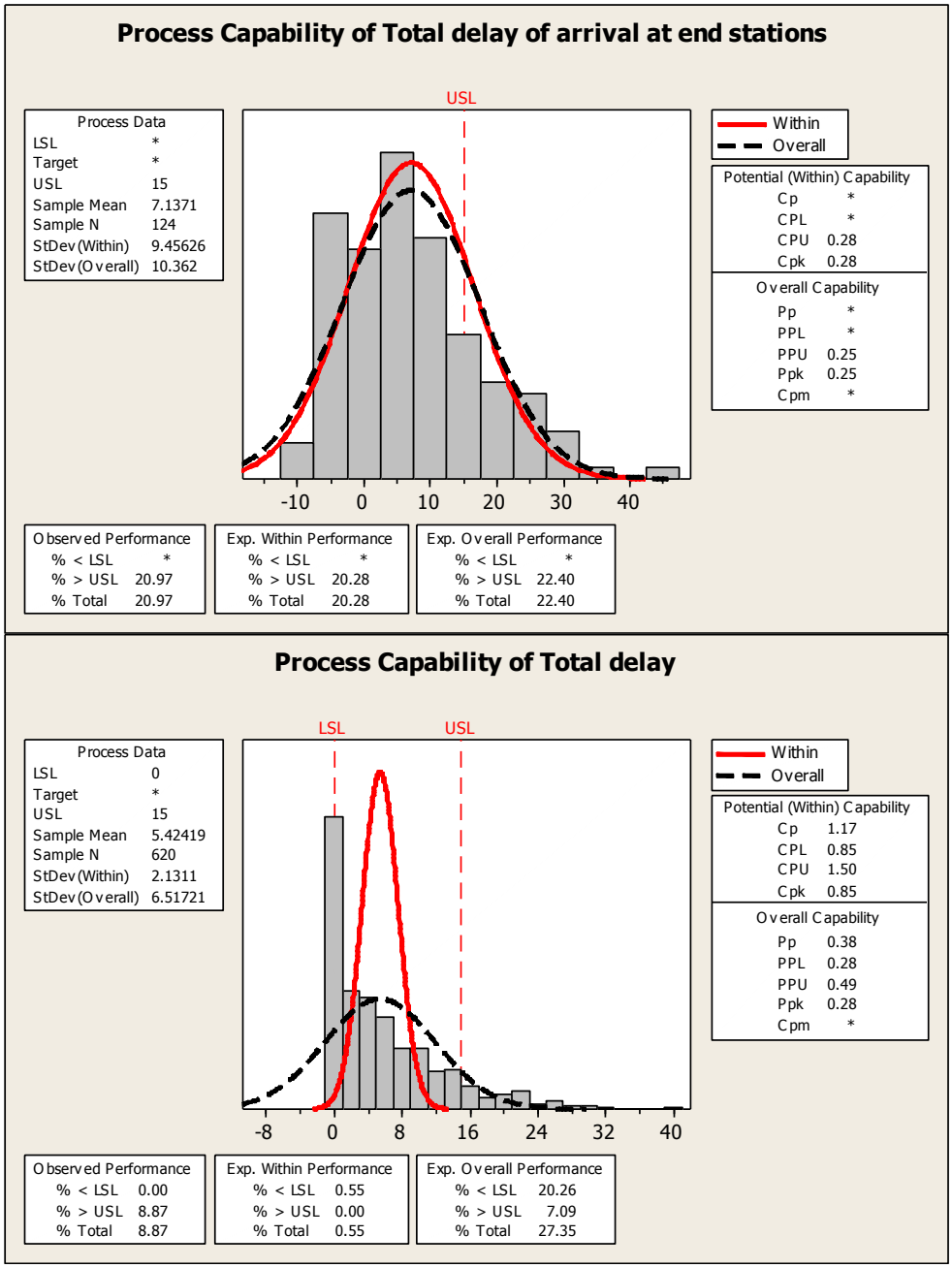


Figure 27: After Process capability

Pareto Charts for total delay of arrival at end Station for different transit

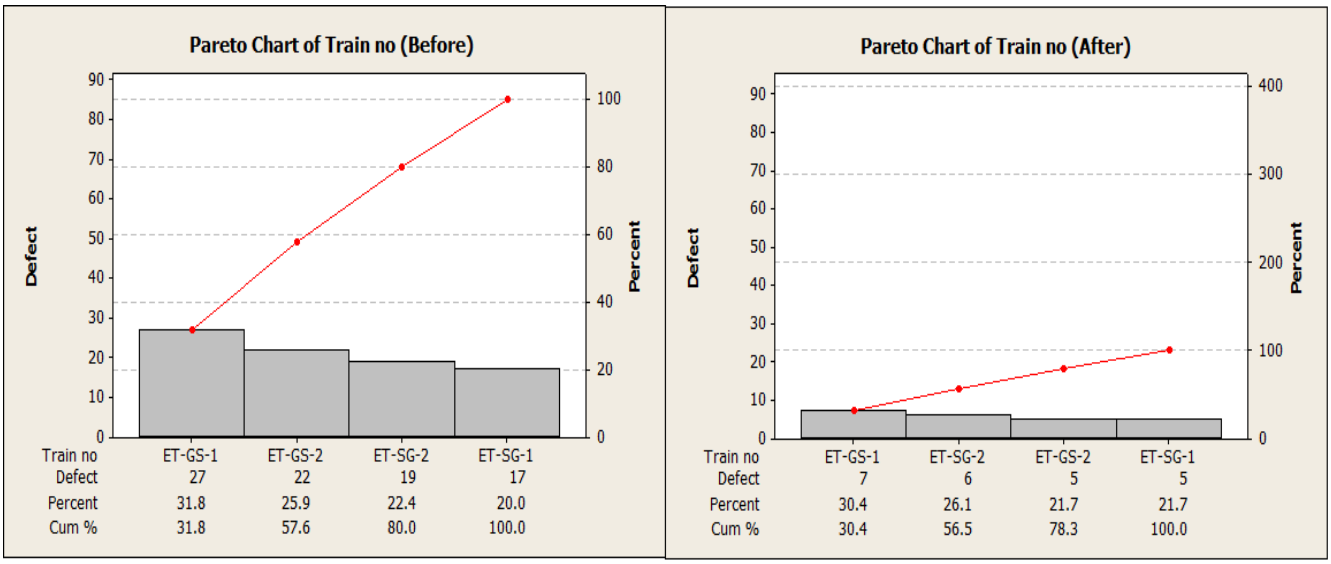


Figure 38: Before and after charts of train transit

Pareto Charts for total delay of departure at each station with respect to days

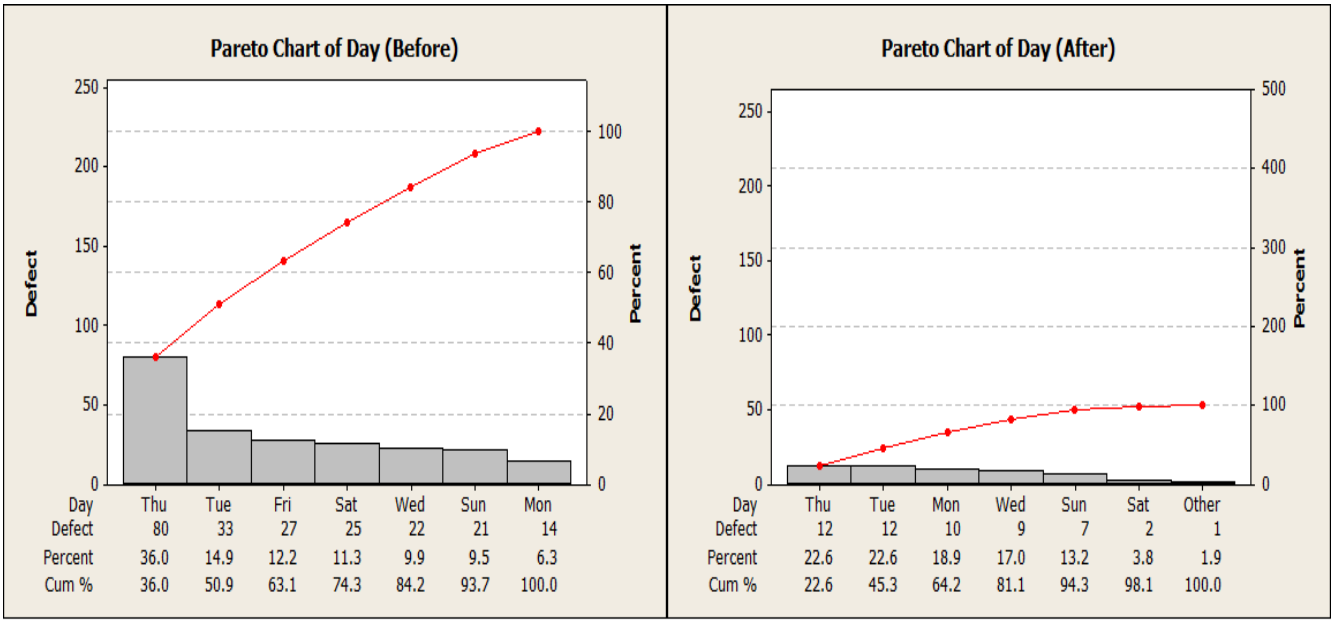


Figure 39: Before and after charts of days

The above Pareto charts in figure 38 and 39 are shown the reduction in defects by means of delaying in departure at each station on Thursday and delaying in arrival at end station for transit ET-GS-1. The defects rate is decreased which is the delaying in arrival and departure of trains at stations.

The box plot is used to describe the variation inside the specific process if the process is not working properly.

Box plot of delaying in departure from each station for different transit

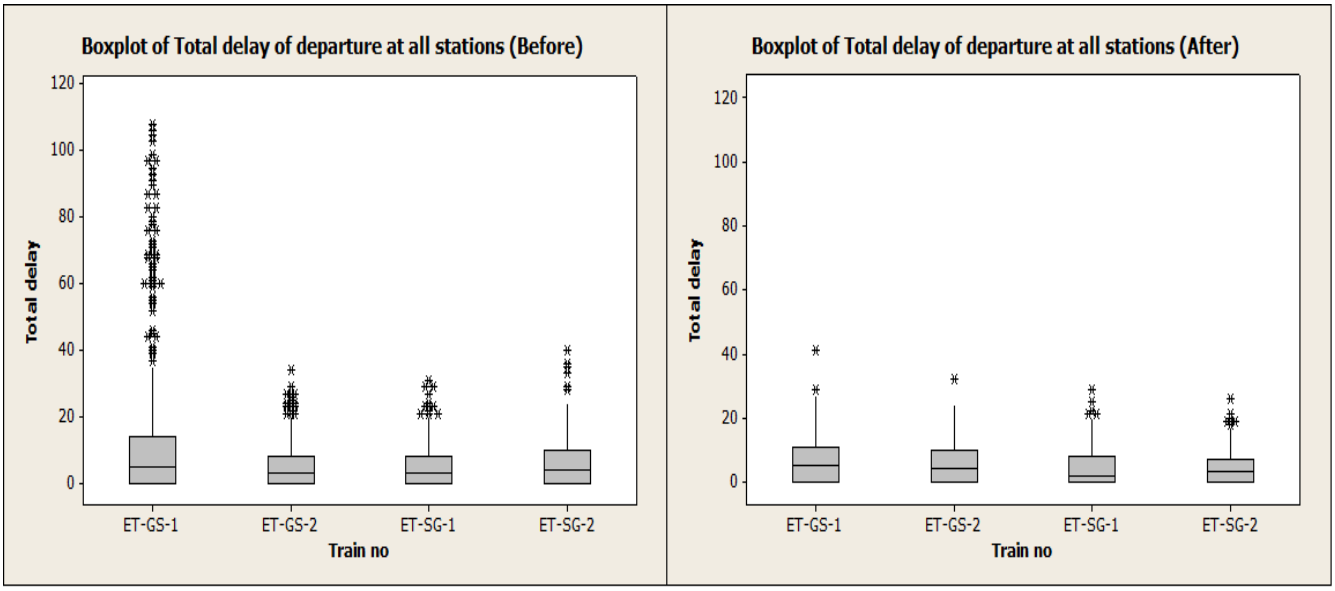


Figure 30: Before and after box plot of train transit

Box Plot of delaying in arrival at end station

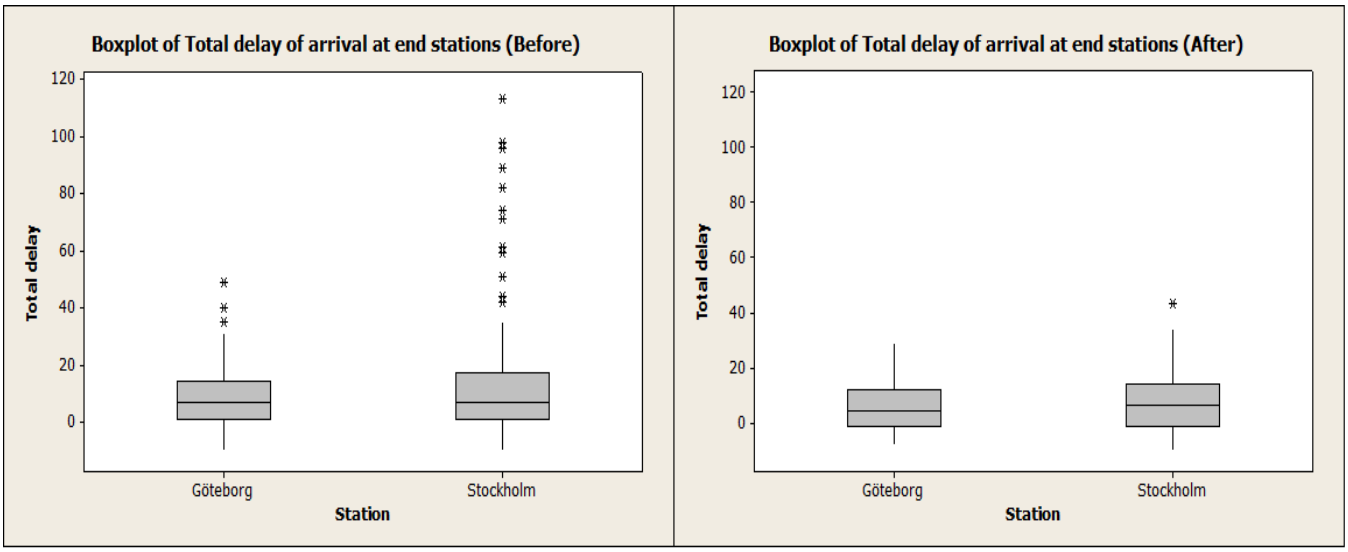


Figure 41: Before and after box plot of train end stations

The above box plots in figures 40 and 41 have shown that there is reduction in delaying of departure time at each station for the transit ET-GS-1 after the mitigation of root causes. Also the reduction of variation in total delay of arrival at end station can be noticed from the after chart.

Hypothesis Tests – As we have identified the problems i.e., more delaying with train set - 1002, crew team – G2, train no – ET-GS-1, on Thursday departed from Gothenburg. So here we are going to verify and visualize these conclusions with the help of hypothesis testing with confidence level 95% which means alpha (α) level = 0.05 (5%) – risk to be wrong in conclusion.

Null Hypothesis (H_o) for train no.(transit) in terms of total delay at end stations

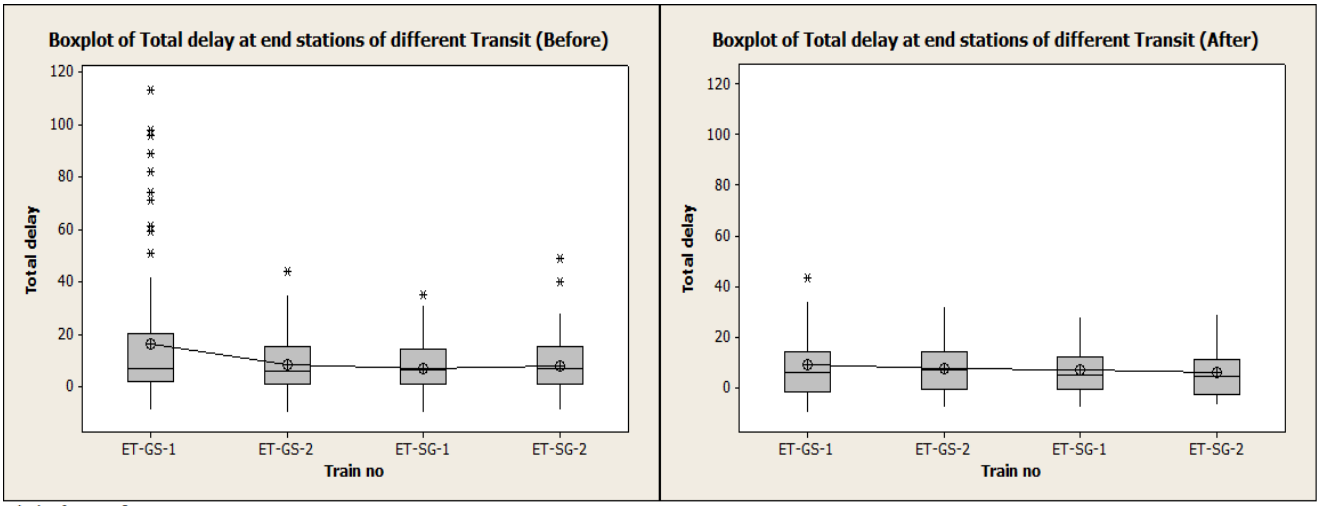
There is no difference in average total delay at end stations among train numbers ET-SG-1, ET-SG-2, ET-GS-1 and ET-GS-2.

ANOVA test for train no. (Transit) versus total delay at end stations (before & after)

The results of ANOVA test for before and after state are shown in the figure 42:

Before: From the result we can see that P-value (zero) is less than α level (0.05) hence there is a difference in the average delay time at end stations among the trains. But there is significant difference in the delay time between ET-GS-1 (more outliers) and other trains as shown below in the box plot. Hence, null hypothesis can be rejected.

After: From the result we can see that P-value (0.731) is *greater than* α level (0.05) hence we *cannot* say there is a significant difference in the average delay time at end stations among the different train transits. Thus, null hypothesis *cannot* be rejected.



Minitab Results
One-way ANOVA: Total delay versus Train no

Source	DF	SS	MS	F	P
Train no	3	5076	1692	6.98	0.000
Error	356	86258	242		
Total	359	91334			

S = 15.57 R-Sq = 5.56% R-Sq(adj) = 4.76%

Level	N	Mean	StDev
ET-GS-1	90	16.30	25.58
ET-GS-2	90	8.44	10.79
ET-SG-1	90	6.98	9.47
ET-SG-2	90	7.71	10.44

Individual 95% CIs For Mean Based on Pooled StDev
4.0 8.0 12.0 16.0

Pooled StDev = 15.57

Minitab Results
One-way ANOVA: Total delay versus Train no

Source	DF	SS	MS	F	P
Train no	3	141	47	0.43	0.731
Error	120	13066	109		
Total	123	13207			

S = 10.43 R-Sq = 1.07% R-Sq(adj) = 0.00%

Level	N	Mean	StDev
ET-GS-1	31	8.61	12.14
ET-GS-2	31	7.52	9.99
ET-SG-1	31	6.71	9.06
ET-SG-2	31	5.71	10.31

Individual 95% CIs For Mean Based on Pooled StDev
3.0 6.0 9.0 12.0

Pooled StDev = 10.43

Figure 42: Hypothesis testing results

The above conclusions from different before and after charts, verified the reduction of root causes after improvements have been made in the process of Easy Train.

Benefits – The benefits from process capability point of view are calculated with the help of improved process yield that is shown below. Although, there is not a significant improvement in Y1 and the after process is behind to achieved the goal but the continuous improvement, monitoring and controlling will lead to reach desired goals as lean implementation is not a short term program it will be beneficial and provided more improvement by focusing on long term continuous development of process.

Simplified Calculation

	BEFORE	**AFTER**	**GOAL**	*Improvement*	*Factor*
yield Y1	76%	79%	90%	*Y1*	*0.23*
yield Y2	87%	91%	95%	*Y2*	*0.48*
				average	*0.35*

5. COMPARISON OF CASE STUDIES

In this section the comparison between case studies i.e., manufacturing and service sector is being carried out in terms of lean principles with corresponding practices and techniques. The main focus on the lean techniques that are implemented during the improvement phase of both case studies with some diffculties and ambiguity were faced when applying these techniques. Further, the lean principles and tools that are more often and easily consider for implementation would be discussed especially in service case. Following is the comparison of case studies with respect to lean principles and respective tools.

5.1 IDENTIFY VALUE FROM THE END CUSTOMER POINT OF VIEW

This principle is applicable in both cases without any difficulty and complexity, it is important to know the end customer and customer definition for the successful application of this lean principle. Along with what are their ultimate desired for which the customer is willing to pay and valued for it, that value identification is eventually the goal of manufacturer and service provider. The customer and its desired values are more prominent and focused in the service case study.

Manufacturing Case – For this case the value is specified by direct customer involvement as we can see the customer (the end user of product of LT copper) complaints and feedback about the quality of product and the on-time shipment were not executed accordingly, which are the most valuable stuff from customer point of view and the failure to achieve these values ultimately created the chaos situation that happened due to the internal LT copper problems by means of wastes of high inventories and time buffer, on the other hand cost of raw material was also increased. The practices used to identify these values are information flow on customer need and end customer focus, the customer involvement and value stream mapping are the lean techniques used for implementing this principle.

Service Case – For this case the value is identified by customer involvement through voice of the customer (VOC). As the customer (passengers of Easy Train) were complaining about the delaying of arrival and departure of train from the station that correspond to the critical waste. On time arrival and departure of trains within the specified limit are the ultimate customer's demands and expectations that became the values from customer point of view and also for the service provider i.e., easy train. The practices used to identify these values are end customer focus through voice of customer while critical to quality (CTQ) tree and value stream mapping are the lean techniques used for implementing this principle.

5.2 VALUE STREAM MAPPING TO EXPOSE AND ELIMINATE WASTE

The most easily and frequently applied lean principle and method in both cases is the value stream mapping that is used to expose the waste within the process. The process is organized in both cases according to identified customer values and keep focus on the improvement in order to eliminate problems and the root causes of problems. This principle is equally valuable and prominent during the implementation of lean approach for both case studies.

Manufacturing Case – For this case the mapping is done by visual management and wastes/problems are identified by proper mapped the value in the process from upstream to downstream. In this case high raw material, work-in-process and finish goods inventories are the outstanding waste along with re-working due to quality issues and re-scheduling of dispatching the finish goods that are highlighted during the value stream mapping (VSM). The methods used for map value to expose and eliminate waste are internal value chain analysis and waste reduction while FIFO, Pull and dedicated flow techniques are take into account for the execution of this principle.

Service Case – In the service case mapping is made by process flow charts from and problems are identified through eye-ball the data by statistical process control (SPC) method. In this case the main problems are identified in departure and arrival process i.e., late and early departure of train from the schedule time and late arrival of train from the schedule time while the causes of these problems are late delivery of train from maintenance firm (long lead times) and insufficient inspections after maintenance – lack of standardize work. The practices used for map value to expose and eliminate waste are SPC and value chain analysis, on the other hand root cause analysis (5 whys), brainstorming, standardize work and employees involvement techniques are considered to carrying out this principle.

5.3 ESTABLISH FLOW

This principle is equally deployed and important for both case studies as it commonly used to reduce the delay in the process with continuous flow. In order to achieve continuous flow lean solutions are implemented for both case studies but the major application of this principle is required in Easy Train service case where the delaying of train causes the high value and customer lost. The whole system organization have been worked together in order to sustain this principle thorough cause and effect diagrams are generated in both cases for evaluate any discontinues flow and unnecessary delays in the process.

Manufacturing Case – In this case study the flow is established through the grouping of similar products that have to move together under the defined and designated path according to machines on which the product has to be processed. A dedicated flow and First-in-first-out (FIFO) methods are introduced in order to avoid time buffer and reduce the inventory levels. Moreover, an effective communication and relationship plan between departments of LT copper is created and a workshop is organized to ensure the proper understanding of

continuous flow of material and information. The methods used to establish the flow are strong and effective relationship, waste reduction while smart sequencing, dedicated flow, FIFO and standardize work techniques are utilized to set-up this principle.

Service Case – For the service case the flow is already created that means the process is highly rigid and it has to follow the schedule of train. But there are delays in arrival and departures and that are due to delaying in maintenance firm and lacking in inspection process of train after maintenance by Easy Train staff. These problems are lead to discontinuous flow and corrective actions are taken to avoid these delays. A proper communication channel with maintenance firm and action plans are the practices used for ensuring continuous flow while standardize work (check sheets), risk analysis (FMEA) and training of staff are the techniques used to unfold this principle.

5.4 PULL THE PRODUCTS

This principle allows the customer to pull the product as per its demand. It is highly applicable during the implementation of lean in manufacturing case by means of external and internal customers both, its implementation is highly recommended and has brought certain improvement in the case of LT copper. But in service case it cannot be fully applicable especially by means of passenger as a customer; it is because the process of easy train is not flexible and has certain constraints. If the customer demands are high, Easy Train can't bring the new train for accommodate the customer demands. On the other hand due to the sensitivity of process that has to follow time schedule this rigidity neither allow the customer (passenger) to pull the train and nor the company (Easy Train) can push the train. But still pull system would work better in internal value chain of Easy Train in terms of departure and arrival process of train.

Manufacturing Case – In this case the pull system is established by Kanban card that eventually improve the production process of LT copper while lowering down the inventory levels and fulfilled customer demands. Just-in-time (JIT) concept is introduced between LT copper and its suppliers in order to avoid surplus raw material inventory and cost that incurred due to this waste and non-value added stuff. Production of exact customer needs only when needed along with strong and effective relationship are the practices used while JIT and Kanban techniques are setting up for implementing this principle.

Service Case – For the service case the situation is ambiguous due to the nature of process to implement pull system by Kanban or any other technique. But all the improvements by brainstorming, root cause analysis, standardize work and SPC are pulled the train to be arrived on time at the end stations.

5.5 STRIVE FOR PERFECTION

This principle is aim for continuous improvement in terms of increasing quality, as well as producing what customers' want, when they want, with a reasonable price with no waste, this continuous cycle should never end. In both cases this principle is highly applicable and implemented with the help of preceding principles and the assurance of starting four lean principles would finally lead this fifth one. Its importance is clearly affirmed in order to sustain the improvement process in both cases – PDCA cycle is the ultimate tool.

Manufacturing Case – In the manufacturing case study this principle is acknowledged by continuous problem searching methods while VSM, 5Whys, employee involvement with Kaizen workshops are the techniques used for practice this principle.

Service Case – In this case study strive for perfection is carried out by continuously monitoring the process and problem solving by quality control plan is generated that reflects the waste indicators and their respective corrective actions. This plan would be updated on regular basis while training, 5Whys and employee involvement tools are considered for deployment of this principle in Easy Train Service Company.

6. CONCLUSION

The aim of this thesis is to show how lean approach can be implemented and what benefits lean can bring in the process improvement of manufacturing and service companies. In order to stay competitive in this global and innovative world, it is essential for companies to continuously strive for improvements, lean philosophy play a key role and widely followed around the world to achieve certain improvements in the organizations. The lean tool has become a sign of improvement in both manufacturing and service facilities throughout the last decade. The necessity to implement this dominant improvement tool will be increased for all types of organizations in the future in order to sustain their businesses. Since lean is also renowned for not easy to implement in a short period of time, so this study is also intend to enhanced my knowledge that what difficulties are being faced for proper lean implementation and the barriers encountered to execute lean within the organization.

To sum-up this work I would like to say in order to sustain lean in an organization the people of that organization must respect the change in the whole facility not only a production line but also sales, logistics, research and development all departments will taste this change and put their efforts to accomplish improvement by this change, if one of them does not follow, they will be completely lost on what they are searching for development. The conclusion is drawn from this thesis work that the application of lean tools and techniques depends on the nature of company, especially the processes that a company owned and wants to implement lean on them. The company has to pick the right lean tools and technqies which are applicable and confers certain improvement by means of their desired goals; on the other hand companies should be prepared to make some sacrifices if they want a good impact on their business by following lean approach. From case studies it is depicted that the people want change in terms of improvement but they are not ready to spend appropriate resources to achieve it, lean does not support such way of working as it requires daily and continuous efforts.

In case of manufacturing sector the impact of lean tools and techniques is quite noticeable as the case company had a big problem of high work-in-process inventory and it is consider to a fat that has been reduced by lean approach and lean implementation have shown improvement by reducing WIP inventory from 1026 tons to 800 tons while overall inventory level has fallen down from 1845 tons to 1600 tons. Especially, the Kanban (Pull system), dedicated flow and VSM are the implemented lean tools to achieve case objectives. FIFO system, root cause analysis, product grouping and sequencing and reduction in setup times are other techniques that used to support lean program with tremendous employees involvements and understanding to get rid of traditional way of working in the LT copper improvement marathon.

The objectives fixed for service case were to increase process yield from 76% to 90 % in arrival and from 87% to 95% in departure of train. Although, these goals were not achieved

but still Easy Train has been succeeded to find out the root causes for the certain problems with some improvement 3% and 4% in arrival of train at end station and departure of train from each station respectively after implementation of lean tools. The root cause analysis, VSM, reduction in lead time and SPC are the major tools that have been applied to solve the problems, the risk analysis of possible solutions was also conducted to carry forward this lean approach in order to get desired goals. The staff training and supplier (maintenance firm) involvement are considered to be more focused task to resolve in future for continuous improvement sprint.

To conclude the comparison of case studies in terms of lean principles, it is found that among the five lean principles – Identify value from customer point of view, Map value to expose and eliminate waste and Establish flow are the most suitable and easily applicable lean principles in service case as compare to manufacturing case and it is due to the nature of process the service company owned and practice. Hence, it depends on the attributes of the process and the company itself that how and in what way they are willing to adopt lean approach and the efforts they put to implement lean for searching for improvement in their business. Lean itself a long term method to accomplish desired results, lean tools and techniques are similar to other management theories but in the near future it can be shown a huge scope and growth for implementation in every organization and can be adapted to any environment.

7. KOKKUVÕTE

Antud töö eesmärk on uurida ja juurutada lean tootmise põhimõtteid tootmise ja teenuse sektoris. Analüüsitakse erinevaid lean tootmise põhimõtteid ning pakutakse välja erinevatele sektoritele sobivaimad, pärast mida uuritakse, kuidas antud muutused mõjutasid erinevate ettevõtete tootlikkust ja toote omahinda. Lean tootmise põhimõtteid on kasutatud tootmise sektoris erinevate raiskamiste vähendamiseks, kuid tänapäeval ei vaadata ainult tootmist, vaid püütakse antud meetodeid juurutada ka teeninduse sfääris. Saavutamaks madalat toote omahinda ja töötlemisaegasid ning kõrget toote kvaliteeti tuleb lean tootmise põhimõtted ja vastavad tegevused sobitada igasse ettevõttesse ja protsessi just selle protsessi ja ettevõtte eesmärkidele kõige ligilähedasemalt. Antud tegevused võimaldavad ettevõttel, nii tootmise kui ka teeninduse sektoris, keskenduda klientide vajaduste rahuldamisele ning raiskamiste vähendamisele.

Antud magistritöös teostatakse erinevaid juhtumiuuringuid mõlemas sektoris ning võrreldakse tootlikkust ja toote omahinda pärast lean põhimõtete juurutamist. Töö viimases osas teostatakse tootmissektori ja teenindussektori juhtumiuuringute analüüs, mille tulemusena leitakse, et lean tootmise juurutusel on oluline mitte niivõrd sektor kuhu ettevõte kuulub, vaid protsesside iseloom ja eesmärkide tajumine, mida ja kuhu tahetakse muutusi tuua.

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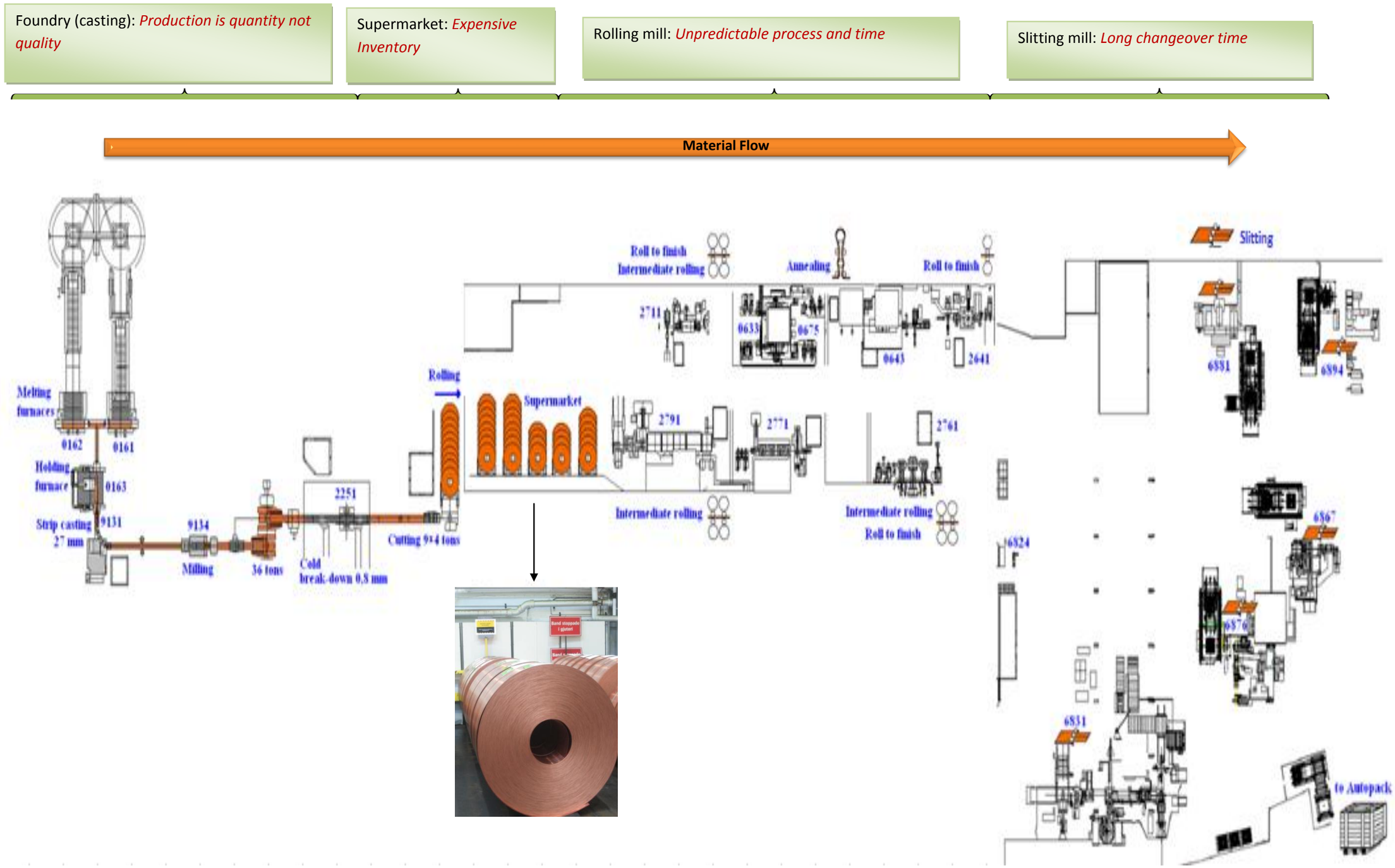
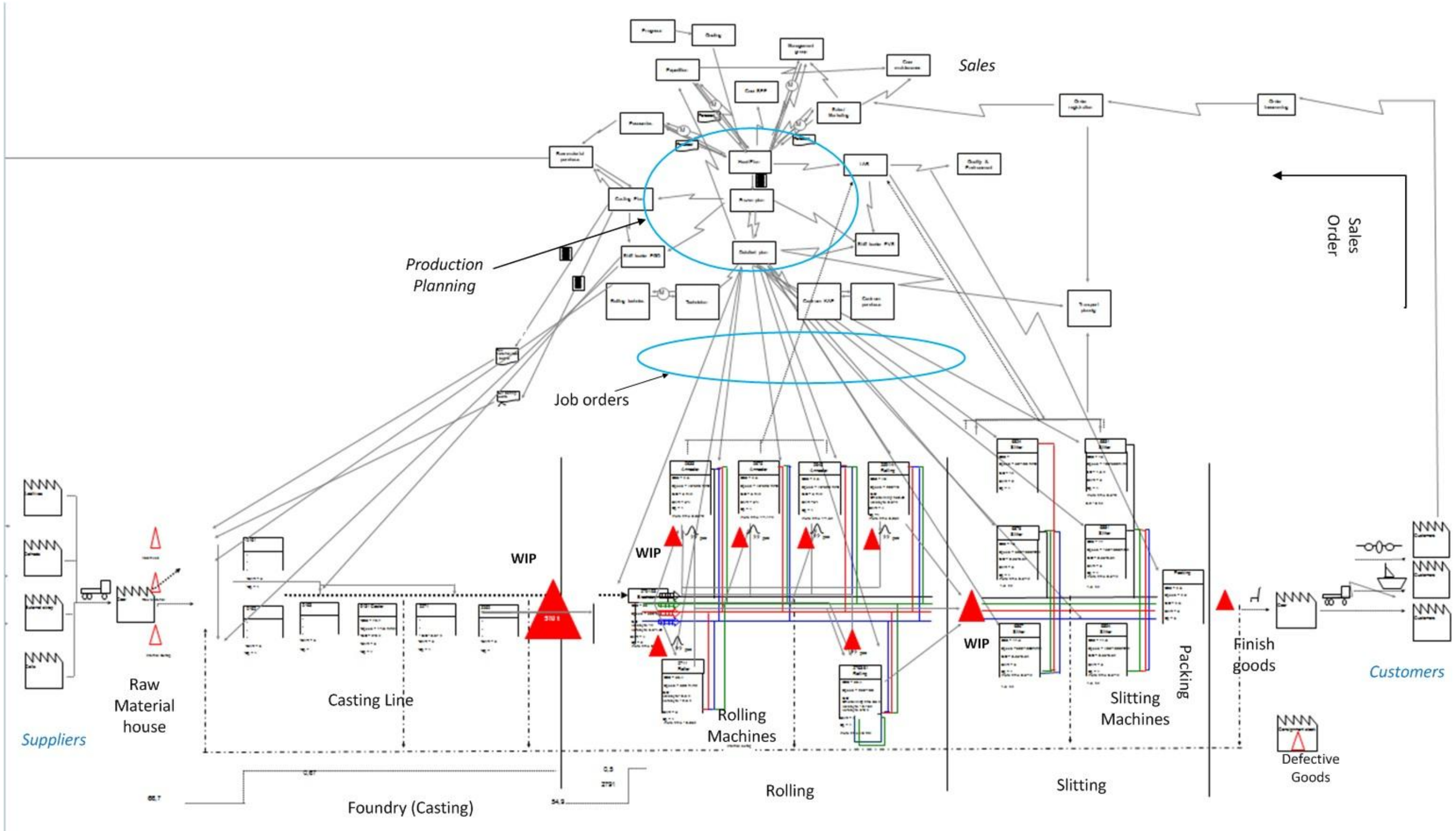
9. APPENDICES

Appendix 1: Product Layout of LT Copper (Figure 11)



Appendix 2: Current Stream Mapping (Figure 13)



Appendix 3: Process FMEA (Table 13)

Name of Solution / Improved Process: Improved maintenance process (on time delivery of maintained train and proper time for inspection with check sheet after maitenance at Gothenburg station)

FMEA Date (Orig) 2014 - 05 -11 (Rev) 1

Solution / Process step	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
Documented delivery time schedule (Kind of agreement)	No delivery time schedule or schedule not followed	Nobody knows when to receive the maintained train exactly, Train delivered late	7	Bad communicaton, Careless ET management, no responsible for evaluate manitenance perfromance	9	No current control	9	567	Internal audit for delivery time by authorize person	ET management	A proper delivery schedule is made and person is nominated for take care this matter and deal with maintenance firm	6	5	5	150
Introduce a payment penalty	No penalty to maintenance firm for late delivered train	Train delivered late from maintenance workshop, hence delaying in departure and arrival at end station	8	No agreement for such kind of penalty and lack of management skills	7	No current control	9	504	Training and audits	ET management	Periodic checking (audits)	7	4	5	140
Move all maintenance to Stockholm workshop (No maintenance of train in Gothenburg)	Late delivery of train from stockholm workshop	Every train delivered late from maintenance workshop, hence delaying in departure and arrival at end station for both train set	9	No proper planning and high work load at stockholm workshop	8	Distributed maintenance work into two workshops	6	432	Compare stockholm and gothenburg workshops, Facilitate gothenburg workshop same as stockholm. Keep distribution of maintenance work	ET management and maintenance frim	Maintenance firm evaluation plan, periodic visit of maintenance workshops, Assest workers skills and facility of both workshops	7	5	4	140
Proper communication channel between workshop and EasyTrain	No proper communication and exchange of word about train technical problems and delivery time	Nobody knows what is the actual problem and train delivered late	7	No one responsible for evaluate manitenance perfromance and no information system for proper information flow between ET and maintenance workshop	8	No current control	9	504	Introduce information system for direct reporting of problems in train and make sure train delivered on time	ET management	Information system has introduced, a kind of ERP software for reporting, monitoring and feedback	6	4	5	120
Make inspection plan (Add inspection time to the schedule)	Inspection plan and time schedule for inspection are not followed	No proper inspection after maintenance and hence breakdowns in train causes train delayed	8	Not enough time for inspection and inspection plan is not understandable or not user friendly	8	No current control	9	576	Create awarness and make inspection plan understandable, deliver train on time or ealier for inspection	ET management and staff	Delivered train to maintenance firm on schedule time or ealier and training of staff to follow schedule	7	4	5	140
Training of staff for how to do inspection in limited time	No training or inadequate training	No proper inspection after maintenance and hence breakdowns in train causes train delayed	8	Not enough time for training or no budget for training or unqualified trainer	7	Sufficient hiring process and normal training for new staff	5	280	Training and improvement program (5S and Kaizen) to reduce inspection time and other waste	ET management and staff	Consultant work on different improvement project to reduce waste that causes delays	6	5	3	90
Upgrade the equipment used during the inspection	Equipment for inspection are not working or malfunctioned	No proper inspection after maintenance and hence breakdowns in train causes train delayed, also ambiguity to address what's wrong!	8	No calibration plan and testing of equipment	8	Durable equipment from reliable supplier or No current control	7	448	Periodic testing plan of inspection equipment (GR &R activity) or buy new and modern tech. equipment	ET management	GR&R process for inspection equipment is planned and replaced old with new ones	6	5	4	120
Create a standardize document for how a proper inspection is made	No standardize checklist or wrong checklist or not user friendly	Insufficinet inspection and inspection process takes time that ultimately leads to delaying in departure and arrival at end station	8	No or inadequate expertise for how to create a proper checklist	6	No current control	9	432	Create a proper check sheet for inspection that makes this process easier with the help of driver and technical consultant	ET management and train driver	Inspection checksheet is established with training of drivers and standardize the process	6	4	5	120
Hire a consultant (third party) to do inspection	Takes more time to do inspection and improper work	Insufficinet inspection and inspection process takes time that ultimately leads to delaying in departure and arrival at end station. An extra cost in process - additional expenses	8	Unreliable consultant	5	No current control	9	360	Consultant evaluation plan and feedback from train crew, introduce payment penalty for improper work	ET management and staff	Consultant evaluation plan is made with feedback from train crew	7	4	5	140

Implement ISO 9001:2008 could be one recommended solution if company don't have this certification