DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

USING THE EXTENDED VALUE STREAM MAPPING TOOL IN LEAN SIX SIGMA METHODOLOGIES FOR LEAN SUPPLY CHAINS

by
Aygül ÇALIŞKAN

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İZMİR

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We have read the thesis entitled **"USING THE EXTENDED VALUE STREAM MAPPING TOOL IN LEAN SIX SIGMA METHODOLOGIES FOR LEAN SUPPLY CHAINS"** completed by **AYGÜL ÇALIŞKAN** under supervision of **ASSIST. PROF. ÖZCAN KILINÇCI** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Aygül ÇALIŞKAN

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ABSTRACT

Various tools and techniques have been developed to improve the flows of value streams in manufacturing facilities. But the effectiveness of lean implementation is usually constrained by business partners. Supply chain management focuses on cutting overall costs. For shorter lead times, lower costs, and higher levels of customer satisfaction in the whole supply chain lean flows need to be created throughout the supply chain.

This study presents the implementation of an effective lean tool: extended value stream mapping in the methodology of DMAIC the Lean Six Sigma framework in order to achive the lean supply chain of overall value stream from raw material suppliers to the end customers. A case study is also presented for total lead time reduction and on time delivery increase of a product family using the extended value stream mapping to apply lean tools.

Keywords: Extended Value Stream Mapping, Lean Production, Six Sigma, Lean Supply Chain.

YALIN TEDARİK ZİNCİRİNE ULAŞMADA ALTI SİGMA METEDOLOJİSİNDEN YARARLANARAK GENİŞLETİLMİŞ DEĞER AKIŞ HARİTASININ UYGULANMASI

ÖZ

İşletmelerde değer akışını iyileştirmek için şimdiye kadar pek çok farklı teknikten yararlanılmıştır. Yalın üretim uygulaması bu tekniklerden biridir. Yalın üretim uygulamaları işletmenin üretim sınırları içinde oldukça başarılı sonuçlar elde eder iken, asıl genel hedefin yakalanmasında zaman zaman işletme partnerlerinin bir kısıt teşkil ettiği görülmektedir. Tedarik zinciri yönetiminin odak noktasının işletmenin toplam maliyetlerinde iyileştirme sağlamak olduğu düşünüldüğünde, kısa teslimat süreleri, düşük maliyetler, yüksek müşteri memnuniyeti gibi hedeflere ulaşmak için yalın akışı tüm tedarik zinciri içerisinde uygulama gerekliliği kaçınılmaz olmaktadır.

Bu çalışmada bir yalın üretim tekniği olan 'genişletilmiş değer akış haritası' kullanılmıştır. Uygulama adımlarını belirleme ve çözüme yaklaşımda Altı Sigmada bir problem çözme tekniği olan DMAIC metodolojsinden yararlanılmıştır. Yalın bir tedarik zinciri yapısı kurabilmek için hammadde tedariğinden başlanarak bitmiş ürün elde edene kadarki tüm süreçler detaylı olarak incelenmiştir. Genişletilmiş değer akış haritası kullanılarak toplam ürün teslimat süresinin azaltıldığı ve müşteri sevkiyat kalitesinin iyileştiriliği bir örnek uygulamaya da yer verilmiştir.

Anahtar sözcükler: Genişletilmiş Değer Akış Haritası, Yalın Üretim, Altı Sigma, Yalın Tedarik Zinciri.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of the Problem

"Marketing is too important to be left to the marketing department." is a quote from a CEO which Douglas M. Lambert Martha C. Cooper expressed in their 'Issues in Supply Chain Management' article. Everybody in the company should have a customer focus. The marketing concept does not apply just to the marketing department. It is everybody's responsibility to focus on serving the customer's needs (Lambert M.&Cooper C.,2000).

It has been expressed in the 'Competetive Advantage' by Michael E.Porter that satisfying customer needs is at the core of success in business endeavor. Satisfying customer needs may be a prerequisite for industry profitability, but in itself is not sufficient. The crucial question in determining profitability is whether firms can capture the value they create for buyers, or whether this value is competed away to others. In 'Competetive Advantage' it is the industry structure determines who captures the value. The threat of entry determines the likelihood that new firms will enter an industry and compete away the value, either passing it on to buyers in the form of lower prices or dissipating it by raising the costs of competing. The power of suppliers determines the extent to which value created for buyers will be appropriated by suppliers rather than by firms in an industry. It determines the extent to which firms already in an industry will compete away the value they create for buyers among themselves, passing it on to buyers in lower prices or dissipating it in higher costs of competing (Porter E.,1998).

This exhaustive competition in disputed market has obliged firms to implement new strategies to face the new challenges. The constant changes in a shared market is another factor that can only be handled with an action plan to not only meet but exceed the customer needs. Several techniques have been proposed, combined or adapted to satisfy the needs of the firms. Efforts on developing new methodologies and improving existing ones have been undertaken by researchers all over the world. At the end the resulting techniques are intended for improving the product and for increasing the process efficiency of an industry (Astogra,2008).

Some of these techniques are:

1.Design for Manufacturability (DFM). This is a methodology with a high impact on manufacturing costs adopted by many organizations to increase their profitability.

2.Six Sigma. This is an effective approach for process improvement and problem solving methodologies.

3.Lean manufacturing is a tool adopted by multiple organizations for eliminating waste and to make products for meeting customer requirements.

4.Value stream mapping (VSM) is a lean manufacturing tool to identify opportunities of cost reduction by eliminating non value added activities.

The hybrid approach is incorporated by integrating Lean and Six Sigma strategies into a more powerful and effective hybrid, addressing many of the weaknesses and retaining most of the strengths of each strategy. Lean Sigma combines the variability reduction tools and techniques from Six Sigma with the waste and non-value added elimination tools and techniques from Lean Manufacturing to generate savings to the bottom-line of an organisation.

In our study we present a case study implementing a Lean Sigma framework in order to apply extended value stream mapping for lean supply chain.

1.2 Purpose of This Study

The purpose of this study is to achive better results in the supply chains by integrating two systems ‘Six Sigma’ and ‘Lean Manufacturing’ using the lean tool ‘the extended value stream mapping’.

In this study the value stream mapping method is selected as the lean tool because it is the main tool used to identify the opportunities for various lean techniques. And its main issue is to reduce inventories that are waste from costumer's point of view. Also the main advantage of extended value stream mapping (eVSM) in lean method indicates the problems with integration of the companies within the supply chain.

Usually the separate actions are undertaken by the companies to implement lean tools for production systems and external logistics processes. This situation leads to minor results or moving the costs between production and logistics processes instead of reduction. Extended Value Stream Mapping method focuses on synchronised reorganisation of company production system, external logistics processes between the company and its suppliers as well as suppliers' production processes.

Six Sigma is chosen because it uses DMAIC (Define, Measure, Analyse, Improve, Control) methodology for problem solving which successfully integrates a set of tools and techniques in a disciplined fashion. Six Sigma can also solve complex cross functional problems where the root causes of a problem are unknown and help to reduce undesirable variations in processes.

So the main purpose of this study is to indicate the greater benefits yielded in a faster way by the use of Lean tools in the Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control) methodology. And to show that the integration of the two systems can achieve much better results than either system can achieve alone. While, lean strategies play an important role in eliminating waste and non-value added activities across the organisation, Six Sigma, through the use of statistical tools and techniques, takes an organisation to an improved level of process performance and capability.

1.3 Overview of Chapters

The thesis is divided in 5 Chapters. Chapter 1 presents an introduction. In Chapter 2 value stream mapping is described. In Chapter 2 we also investigate the studies and methodologes which are established before by using the value stream method and extended value stream method for lean supply chains.

In Chapter 3 we defined the reason of our methodology that we have chosen to apply extended value stream mapping in the framework of DMAIC (Define, Measure, Analyse, Improve, Control) in the Lean Six Sigma concept. Lean concept with lean manufacturing history and six sigma history are explained. Extended value stream mapping tool is also described in detail in Chapter 3.

In Chapter 4 a case study is explained in order to reduce the Total Lead Time by decrease of work-in-process inventory and to increase the on time delivery of a specific product group by using the effective tool of Lean Manufacturing: extended value stream mapping by the help of DMAIC methodology.

Finally in Chapter 5 conclusion of the study is summarised and future researches are suggested.

CHAPTER TWO

VALUE STREAM MAPPING

2.1 Value Stream Mapping

Value Stream Mapping (VSM) is a lean visualization tool to identify opportunities of cost reduction by eliminating non value added activities improving profitability in a company. With another description VSM is an enterprise improvement technique to visualize an entire production process, representing information and material flow, in order to improve the production process by identifying waste and its sources. This technique visually maps the flow of material and information from the time that the raw material enters into the production line, up to the dock yard as the finished product. It uses specific tools to decrease operating costs, shorten the time to market a new product and to reduce inventory. Value Stream Mapping (VSM) works on the big picture and not on individual processes.

The principle of VSM dates back to 1980 when Toyota's chief engineer Taiichi Ohno and Shigeo Shingo pioneered the use of waste removal to drive competitive advantage inside organizations. In recent years, VSM has emerged as the preferred way to implement lean. This mapping tecnique is used to describe supply chain networks. It maps not only material flows but also information flows that signal and control the material flows. The material flow path of the product is traced back from the final operation in its routing to the storage location for raw material. This visual representation facilitates the process of lean implementation by helping to identify the value-added steps in a value stream, and eliminating the non-value added steps/waste (muda) (Rother and Shook 1999).

Because VSM is a pencil and paper tool, it is created using a predefined set of standardized icons (Rother and Shook, 1999). These set of standard icons provide a common language for describing manufacturing processes. The list of VSM icons provided by Rother and Shook (1999) fall into three categories: Material flow icons, information flow icons and general icons. In Figure 2.1 there are the material flow icons used in VSM and in Figure 2.2 there are the information flow icons used in VSM.

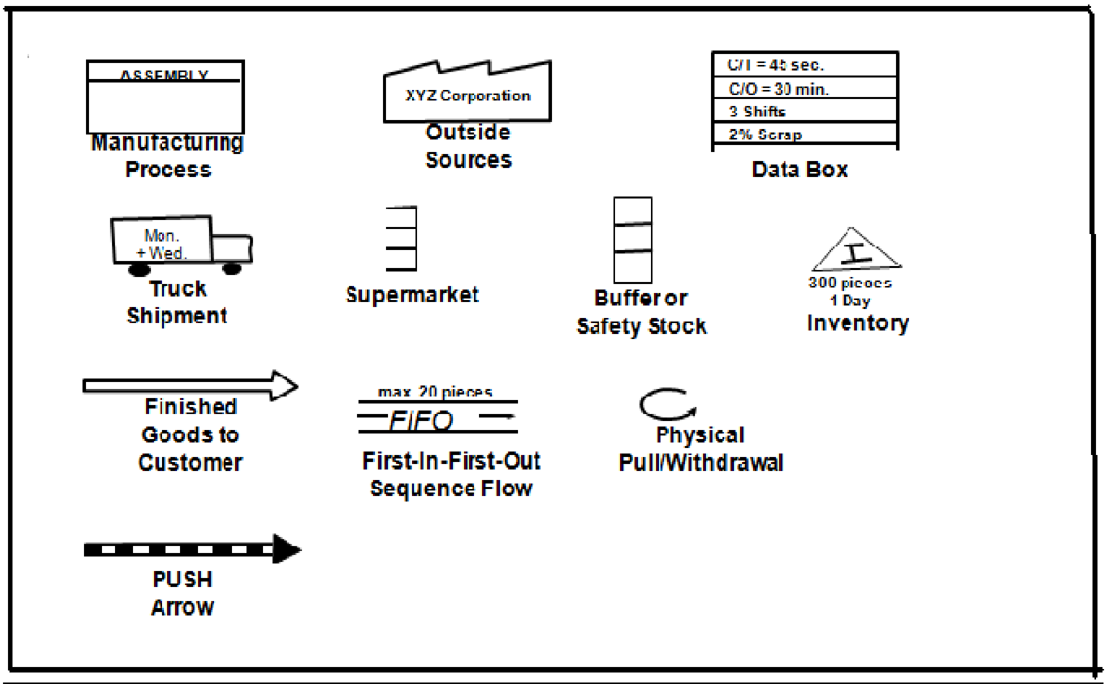


Figure 2.1 Material flow icons

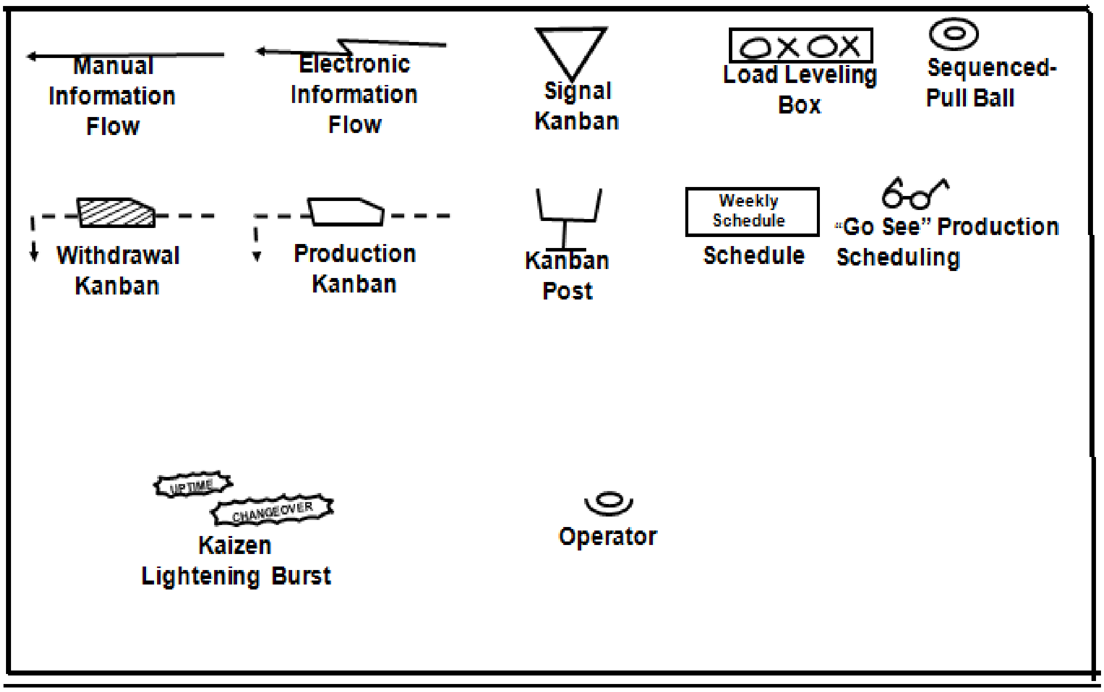


Figure 2.2 Information flow icons

The goal of lean manufacturing is to minimize waste in terms of non-value-added activities, such as waiting time, motion time, set-up time, and WIP inventory, etc. Further, waste in a manufacturing environment can be defined as any redundant application of resources that does not add value to the product, i.e., activities for which the customer is not willing to pay. Namely, few of the manufacturing wastes are over-production, WIP inventory, finished parts inventory, waiting time, inappropriate processing, unnecessary motion, transportation, defects, etc. Also, scrap, unneeded items, old broken tools, and obsolete jigs and fixtures are considered as waste. In a value stream there is a collection of all actions (value added as well as non-value-added) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer (Rother and Shook, 1999). These actions consider the flow of both information and materials within the overall supply chain. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Rother and Shook, 1999). While researchers have developed a number of tools to optimize individual operations within a supply chain, most of these tools fall short in linking and visualizing the nature of the material and information flow throughout the company’s entire supply chain. Taking the value stream viewpoint means working on the big picture and not individual processes. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al., 2002). To implement lean principles in any organization, the first step is to identify the value stream, i.e., all those activities, both value-adding and non-value-adding, required to manufacture a product, or to provide a specific service, to a customer. The numerous activities performed in any organization can be categorized into the following three types:

1. Value-adding activities (VAA). These include all of the activities that the customer acknowledges as valuable, i.e., for which he is ready to pay. For example, forging raw material, machining, welding, pouring molten metal into a mold, etc.

2. Non-value-adding activities (NVAA). These include all of the activities that the customer considers as nonvaluable, either in a manufacturing system or in the service sector. These are pure wastes and involve unnecessary actions that should be eliminated completely. Some examples of these are waiting time, double handling, etc.

3. Necessary but non-value-adding activities (NNVAA). These include activities that are necessary under the current operating conditions, but are weighted as nonvaluable by the end user, i.e., the customer. These types of operations are difficult to remove in the short run and, hence, should be targeted in the long run by making major changes in the operating system. These include activities like walking long distances to pick up goods and unpacking vendor boxes.

Rother and Shook (1999) delineated a structured approach for improving a value stream. For drawing the value stream map they suggested to compose both current and future states. To draw the VSM the first step is to choose a particular product or product family as the target for improvement. The next step is to draw a current state map that is essentially a snapshot capturing how things are currently being done. This is accomplished while walking along the actual process, and provides one with a basis for analyzing the system and identifying its weaknesses. The third step in VSM is to create the future state map, which is a picture of how the system should look after the inefficiencies in it have been removed. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of lean tools. This map then becomes the basis for making the necessary changes to the system (Abdulmaleka Fawaz A.&Rajgopal J.,2007).

In VSM applications generally used key measurements terms are explained by Hopp and Spearman (1996) and Rother and Shook (1999):

•Throughput (TH)

The average output of a production process per unit time (e.g. parts per hour).

•Work in Process (WIP)

The inventory between the start and end points of a product routing.

•Lead Time (LT)

The total time a customer must wait to receive a product after placing an order. When a scheduling and production system are running at or below capacity, lead time and throughput time are the same. When demand exceeds the capacity of a system, there is additional waiting time before the start of scheduling and production, and lead time exceeds throughput time.

•Utilization

Fraction of time a workstation is not idle for lack of parts (If a workstation increases utilization without making other changes, average WIP and lead time will increase in a highly nonlinear fashion – bottleneck).

2.2 Advantages of Value Stream Mapping

The VSM method allows managers to perceive their companies from the final customer perspective. VSM helps the practitioners to understand how their plants work at present (the Current State Map) and to plan the improvements in approaching 9-12 months (the Future State Map). The VSM analysis is usually performed for plant level from raw materials to finished goods. It allows identifying the status of manufacturing system in any plant and to plan improvements with use of lean techniques such as level pull system, one piece flow cells, Single Minute Exchange of Die (SMED), Total Productive Maintenance (TPM) and others. Usually the VSM analysis takes a few days. The result is a Future State Map drawn by managers and engineers depicting precisely what tools should be used in what areas of the plant (Eisler M., Horbal R., Koch T., 2007).

2.3 Value Stream Mapping Applications

In this section recent studies on VSM will be given. These studies focus on the research conducted by several authors based on the content of value stream mapping and extended value stream mapping.

Yang-Hua Lian, Hendrik Van Landeghem (1998) developped two simulation models for two respective scenarios in the application VSM, push and pull (kanban) systems. They explained the model templates and the key measurements such as lead times, throughput rates, value-added ratios. In their study they demonstrated the effects of lean clearly by the simulation and VSM. Because the implementation of the recommendations for future state is likely to be both expensive and time-consuming, they developed a simulation model in order to quantify the benefits gained from using lean tools and techniques. By the help of simulation model they could consider different lean senarios results in the future state of VSM. With the simulation model they could change many parameters for different key performance indicators (KPI's).

M. Braglia, G. Carmignani and F. Zammori (2006) proposed an alternative and innovative framework for a structured application of VSM to products requiring nonlinear value streams. Because VSM can be effectively used only for productive systems characterized by linear product routings. If the production process is complex breaks down, as it fails to map value streams characterized by multiple flows that merge. This typically happens for products described by a complex Bill of Material (BOM), manufactured in a job-shop facility. In their study, their described framework is based on a recursive procedure and integrates the classic VSM technique with different tools derived from the manufacturing engineering area. They use the the Temporized Bill of Material (TBOM) to execute a preliminary analysis to identify the longer critical production path. The improvement process would start from the critical path that is responsible for the whole lead time of the productive process. Once the critical path has been identified, possible improvements are searched, considering all sharing with secondary paths as further constraints. Finally, when the main value stream has been improved, a new path may become the critical one. Thus, the analysis proceeds iteratively until the optimum is reached or the Work in Process (WIP) level has decreased under the desired level. In this way, the framework makes it possible to explore the overall production process determining the correct order of the path to be improved.

M. Kumar, J. Antony, R. K. Singh, M. K. Tiwari and D. Perry (2006) propose a Lean Sigma framework for the reduction of the defect occurring in the final product (automobile accessories) manufactured by a die-casting. They integrate the Lean tools (value stream mapping and TPM) within Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control) methodology and achive dramatic improvements in the key metrics. In our case study during the thesis we use the same method as their Lean Sigma framework. Our objective is to decrease the lead time and increase the on time delivery performance of a specific product group by using the Lean tools within Six Sigma DMAIC methodology. Similar approach is used in our study too, so we will give detailled explanations about Kumar and Antony’s study in the next paragraphs.

In their study, the researchers implement their proposed framework which shows dramatic improvement in the key metrics such as defect per unit (DPU), process capability index, mean and standard deviation of casting density, yield, and overall equipment effectiveness (OEE) and a substantial financial savings. In the study the authors have described in detail the reasons for using Lean Sigma as a continuous improvement methodology in the case study. They also identified the steps involved in implementing the proposed framework to identify the root cause of the problem and propose corrective action to minimise the impact of the problem on customer satisfaction. At the end of the study the effectiveness of proposed Lean Sigma framework was discussed by the authors.

In the study the authors with the team members have developped the framework which is seen in the Figure2.3. In their proposed framework, they used lean tools within the Six Sigma (DMAIC) problem-solving methodology to reduce the defects occurring in the final product. In the first phase Define: Problem definition; critical to quality (CTQ) characteristics were identified based on the voice of customer (VOC) input. A current state map was developed which gives a closer look at the process so that opportunities for improvement can be identified.

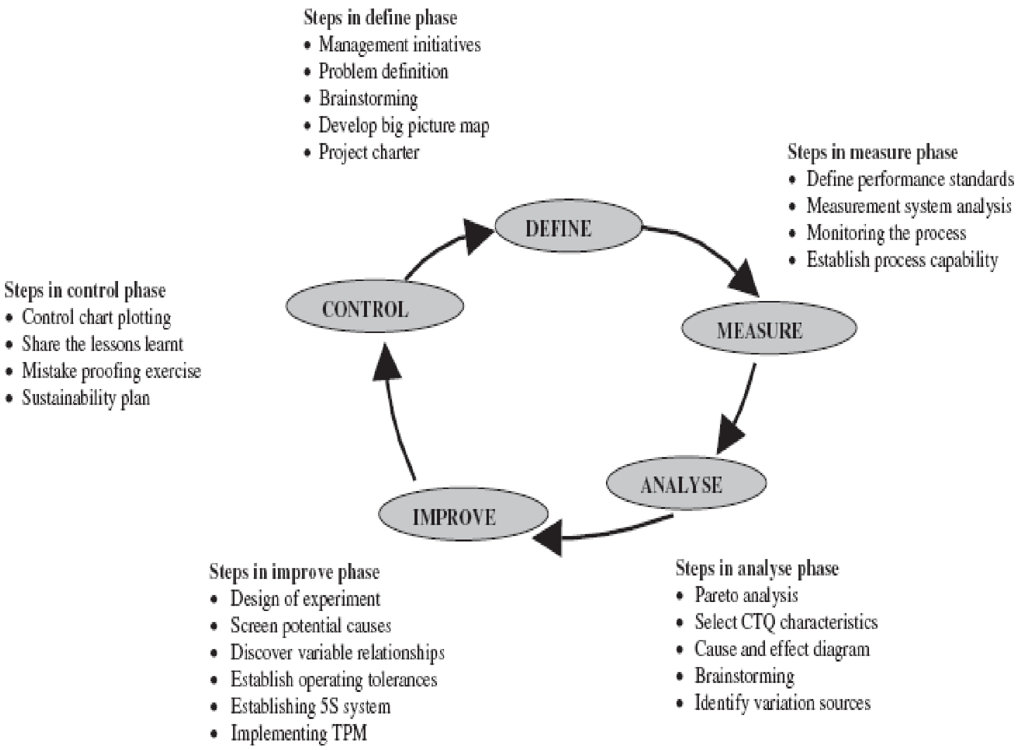


Figure 2.3 Proposed framework for lean sigma implementation in the organization.

In the measure phase; the team members collected data of defective product. A Gauge repeatability and reproducibility (R&R) study was conducted to identify the sources of variation in the measurement system and to determine whether it was accurate or not. The Gauge R&R study performed on the system showed a variation of 8.01%, which implied that the measurement system was acceptable. In the analyse phase; the researchers applied the Pareto chart analysis to illustrate the percentage contribution of internal and external defects in the process. After conducting several brainstorming sessions, the team members concluded the problematic process with the most important critical quality characteristic in the process as it was related to many internal defects. To have a clear picture of the process parameters they constructed the 'cause and effect' diagram. The cause and effect diagram indicated the the most important process parameters that affect the process.

In the improve phase; the team carried out a designed experiment to identify the significant process parameters affecting the process. At the end of the study the optimum process parameters were identified. Also they decided to implement 5S system and total productive maintenance (TPM) to establish a clean environment within the shop floor and also to reduce the idle time of machine and employees on the shop floor. In the control phase; because the main purpose of the Six Sigma methodology is not only improving the process performance but also having the improved results sustained in the long run, standardisation of the optimal process parameters setting were required for the study. To check that the product is meeting the desired specification, from time to time, control charts were plotted.

By that study the organisation by achieved also improvements in aforementioned areas such as:

- The decrease in machine downtime and increase in the overall plant effectiveness (OPE) and overall equipment effectiveness (OEE).
- Work in process inventory reduction.
- Significant improvements were measured in the key performance metrics after implementation of Lean Sigma methodology. (Defect per unit (DPU), process capability index (Cp), mean and standard deviation of casting density, first time yield (FTY), and OEE).

Fawaz A. Abdulmaleka, Jayant Rajgopalb (2007) used VSM as the main tool to identify the opportunities for various lean techniques in process sector. The ‘‘lean’’ approach has been applied more frequently in discrete manufacturing than in the continuous/process sector. So in the study they described a case where lean principles were adapted for the process sector. They used a simulation model that was developed to contrast the ‘‘before’’ and ‘‘after’’ scenarios to indicate reduced production lead-time and lower work-in-process inventory. In their study VSM is used to identify sources of waste and to identify lean tools for reducing the waste.

They drew the current state map according to the approach recommended by Rother and Shook (1999). In creating the ideal future state map they identified lean manufacturing tools looking at the schedule across the entire value stream. To analyze and evaluate different scenarios for the future state map, a full factorial experimental design was planned for the simulation. They used the Arena 5 software. Analysis of variance (ANOVA) was used to formally study the results and determine the significance and magnitude of all effects and interactions. The statistical analysis was done using Minitab.

Lian H.Y. & Landeghem Van H.(2007) used simulation method in VSM because of VSM's limitations such as being time-consuming, its inability to detail dynamic behaviour of production processes and to encompass their complexity. They introduced two new elements to the VSM method. First, they described how the value stream mapping paradigm (VSMP) can be adapted for use in simulation, introducing specially designed VSM objects. Secondly, based on the VSMP and these objects, they presented a formal modelling method and its related database structure, that drived a generator which automatically yielded a simulation model of the value stream map. In that way, a model generator, using the set of objects and the model database, could generate simulation models of Current and Future VSM scenarios quickly and automatically. Additionally, they developped algorithms for converting raw ERP data and information from a VSM drawing into tables of the structured database. In their study they also applied the formal modelling method to a real company case.

Lian H.Y. & Landeghem Van H. with their study proved benefits for using simulation models in VSM some of which are 'simulation as a cost saving tool before the application of future state maps of VSM': The use of a simulation model can help managers to see the effects before a big implementation: the impact of layout changes, resource reallocation, etc. on key performance indicators before and after Lean transformation and this without huge upfront investments (Van Landeghem and Debuf 1997, Rahn 2001). Another benefit is that simulation is used as a training tool in VSM applications: Simulation has proven to be a powerful eyeopener (Van Landeghem and Debuf 1997, Van Landeghem 1998, McDonald et al. 2000, 2002; Whitman et al. 2001). Lian H.Y. & Landeghem Van H. with their study showed faster adoption and less resistance to change from the workforce by combining simulation with the visual power of Value Stream Maps. And by the integration of standard VSM icons and generated simulation models they would enable non-expert users (e.g. companies) to develop simulation models after a few practice sessions. Through their simulation-based VSM, static VS maps of Current or Future States are transformed automatically into dynamic simulation models. The enhanced information, obtained from the simulation results, can provide feedback to guide continuous improvements and hopefully will lead more enterprises to a Lean status.

Ajit Kumar Sahoo & N. K. Singh & Ravi Shankar &M. K. Tiwari (2007) describes implementation of lean philosophy in a forging company. They aim to evolve and test several strategies to eliminate waste on the shop floor. In their research, a systematic approach is suggested for the implementation of lean principles. They described an application of VSM. The present and future states of value stream maps are constructed to improve the production process by identifying waste and its sources. Also by using the Taguchi's method of design of experiments in their study succeeded to minimize the forging defects produced due to imperfect operating conditions.

The prime objective in the study was to develop different strategies to eliminate waste by means of work-in progress (WIP), motion time, set-up time, lead time, defects, etc. considering the economical needs of the problem. The main stratigies they implemented to reduce the lead time were as follows: 1.Reducing lot size, 2.Reducing set-up time, 3. Reducing process defects.

Leonardo Rivera, Hung-da Wan, F. Frank Chen, and Woo Min Lee, (2007) studied applying the lean concepts to a supply chain. They integrated supply chain management and lean thinking to cover both local and overall leanness, which leads to a truly lean supply chain. And they described 'Extending the value stream map' as the tool from a lean company to its partners which allows the company to widen the pursuit for perfection to the whole supply network. The researchers uses VSM in order to establish an appropriate performance measurement system, a graphical representation of a supply chain, i.e., a VSM. Both types of VSM used in the study ;

VSM in the supply chain level (Jones and Womack 2002) and the factory level (Rother and Shook 1998). At the supply chain level, it showed the big picture of the whole system, including product flows, information flows, and time-based performance metrics. Detailed flows in a facility were also shown in a factory level VSM. Based on the maps, the problematic areas could be identified. In this research They indicated that the supply chain formed within lean companies may not be lean after all, due to lack of cooperation and synchronization among participating companies.

Marek Eisler, Remigiusz Horbal and Tomasz Koch (2007), illustrates the problem with integration of the companies within the supply chain. They present the new version of VSM method, focused on synchronised reorganisation of company production system, external logistics processes between the company and its suppliers as well as suppliers' production processes. The techniques currently used to support cooperation between enterprises and their incompleteness are demonstrated and a new extended value stream mapping with the incorporation of transportation route design is introduced.

CHAPTER THREE

METHODOLOGY

3.1 Reason for Lean Six Sigma DMAIC Methodology to Apply Extended Value Stream Mapping

While Lean streamlines processes and eliminates waste (idle time, machine downtime, in-process-inventory), reduces overall complexity, and helps to uncover the value added activities of a process, Six Sigma can solve complex cross functional problems where the root causes of a problem are unknown and help to reduce undesirable variations in processes.

The integration of two approaches eliminates the limitations of individual approach. Six Sigma uses DMAIC methodology for problem solving which successfully integrates a set of tools and techniques in a disciplined fashion. So we decided to use Lean tools in the Six Sigma DMAIC methodology to yield greater benefits, and in a faster way.

Lean tools are used within the Six Sigma (DMAIC) problem-solving methodology.

In our study we combine three methods Lean – Six Sigma – Extended Value stream map (eVSM) as the case study methodology. Because each technique has its own advantages and they are both have better effects on the results when applied together. eVSM is a lean tool, so many lean applications and solution techniques are used in the extended value stream map (eVSM) applications such as kanban, set-up time reductions, WIP decrease, Milkruns…etc. Without awareness of these techniques eVSM can not find optimum solutions, then eVSM as in our case must be powered with the other Lean tools in the studies.

We also combined our Lean & eVSM study with the Six Sigma tecnique in order to set the key performance indicators (KPI's) correctly in the beginning of the problem, which Six Sigma has many tools guiding for problem definition. In the next steps Six Sigma is again an effective tool for Lean appliations to show the way to focus on next action by the DMAIC methodology. It helps by guiding to apply correct steps at correct time. With Six Sigma's statistical tools Lean applications can easily follow up the results of current and future values.

So in our case study we used both of these three tecniques in order to achive better results in the desired indicators. In the next sections now we describe in detail for better understanding of three tecniques before they are applied in the case study.

3.2 History of Lean Manufacturing

During the beginning of the industrial revolution of 1860 there was a need for managing machines with huge product outputs. In 1885 Frederick Winslow Taylor proposed that all the work should be broken down into individual tasks. Henry Ford began building the model assembly line production transforming an individual craft production to mass production. The hallmark of his system was standardization. By the 1930's with the innovations in marketing and organization at General Motors brought the Ford's dominance standardization to an end. During that decade there was a shift towards the product variety. The innovation in technology kept the manufacturers competitive. In the 1950's computers had an effect on business manufacturing processing. In the beginning of 1960's, Joseph Orlicky, George Plossl and Oliver W. Wight began the development of the first Material Requirement Planning (MRP) systems. The search for solutions to the rigid rules mandated by their MRP systems led to the Lean Manufacturing techniques. Such techniques are a compilation of tools used in the past, but they were known as lean manufacturing in Japan after the end of second world war, when there was a need to develop a new, low cost manufacturing process. The pioneers of lean manufacturing systems in that time were Eiji Toyoda, Taiichi Ohno and Shingeo Shingo of Toyota Motor

Company. The concept was applied in the U.S. until the 1990's because of the fierce competition between the U.S. and Japanese automakers (Dennis P. Hobbs,2004).

3.3 Lean Idea

In the United States many major businesses have been trying to adopt 'Lean Manufacturing' in order to remain competitive in an increasingly global market. Because in the lean philosophy, "value" is determined by the end customer. It means identifying what the customer is willing to pay for, what creates "value" for him. The whole process of producing and delivering a product should be examined and optimized from the customer's point of view.

Womack, Jones, and Roos (1990) defined ''Lean'' as the elimination of muda (waste) in the book The Machine that Changed the World".

3.4 Lean Manufacturing

Lean manufacturing is an approach that integrates the production of different tools for eliminating waste and make products for meeting the customer requirements.

Lean Manufacturing approach focuses on cost reduction by eliminating nonvalue added activities. This approach especially originates from the Toyota Production System, has been widely used in many different manufacturing areas with various techniques and tools such as; just-in-time (JIT), cellular manufacturing, total productive maintenance, single-minute exchange of dies, production smoothing.

In "Lean Thinking" (Womack and Jones 1996), Womack and Jones illustrated many cases. In many various business cases with different cultures and mentalities (America, Germany, Japan), within several industries (manufacturing tools, cars, airplanes,...etc.), from a little company with 400 people to a big enterprise with 29000 employees, are illustrated with the key principles of lean philosophy (Womack and Jones 1996; Rother and Shook 1999):

(1) Definition of the value from the perspective of the customer,
(2) Identification of the value streams,
(3) Draw the Flow,
(4) Pull,
(5) Strive to perfection.

Once "value" is defined by the end customer – what customer is willing to pay for and what creates ‘’value for him’’, we can explore the value stream, being all activities – both value-added and non-value added – that are currently required to bring the product from raw material to end product to the customer (Rother and Shook 1999).

Next, wasteful steps have to be eliminated and flow can be introduced in the remaining value-added processes. The concept of flow is to make parts ideally one piece at a time from raw materials to finished goods and to move them one by one to the next workstation with no waiting time in between. Pull is the notion of producing at the rate of the demand of the customer. Perfection is achieved when people within the organization realize that the continuous improvement process of eliminating waste and reducing mistakes while offering what the customer actually wants becomes possible (Womack and Jones 1996; McDonald et al. 2000).

Hines and Rich (1997) proposed a set of seven tools derived from industrial engineering to support the waste-removal process. Hines and Taylor (2000) defines Lean Production as a concept based on the Toyota Production System, which has emerged recently as a global approach that integrates different tools to focus on waste elimination and to manufacture products that meet a customer's needs and expectations in a better way. The main concept of Lean Production consists in the specification of what creates value for the end customer and in the accomplishment of this specification with a production system striving for perfection and characterized by a strained and levelled flow, driven by the customer's demand. In technical literature, various authors have defined a suite of tools and techniques to implement Lean Production in a structured way. Emiliani(2000) used the primary Lean Production support tools to develop a practical solution-oriented method to achieve business goals. The final result consists in a framework that unifies technical and behavioural components of management.

Many 'Lean tools and methodologies' have been adsressed in the literature before. In (McDonald et al. 2000; Rahn 2001), the pull technique of only producing what is required when it is required is used in the improved phases. The results are less rework and scrap, lower work-in-process, reduced lead time, increased throughput rate and higher service level. Other tools also explained in the literature such as standard work (Cudney and Fargher 2001), quick changeover (Van Goubergen and Van Landeghem 2001; 2002), 5S (Henderson and Larco 2000), etc. In contrast to the well-defined and rich set of lean tools and methods (Henderson and Larco 2000), as promoted by the Lean Enterprise Institute, there exist very few implementation methods. Here in the next paragraphs we give some definitions about the lean tools.

One of the lean tools 'standart work' is a precise description of each work activity specifying cycle time, takt time, the work sequence of specific tasks, and the minimum inventory of parts on hand needed to conduct the activity.

Pull system is to produce or process an item only when the customer needs it and has requested it. The customer can be internal or external. A pull system is where processes are based on customer demand. The concept is that each process is manufacturing each component in line with another department to build a final part to the exact expectation of delivery from the customer.

Quick Changeover is a process that allows a person to reduce the time to changeover a production process from making one part or product to another part or product. The process to reduce the time elapsed from the last good part A to the first good part B at the same station or process. Quick Changeover is also referred to as SMED or Single Minute Exchange of Die. This quick changeover process must take less than ten minutes (hence single minute).

5S is five terms beginning with 'S' utilized to create a workplace suited for visual control and lean production. 'Seiri' means to separate needed tools, parts, and instructions from unneeded materials and to remove the latter. 'Seiton' means to neatly arrange and identify parts and tools for ease of use. 'Seiso' means to conduct a cleanup campaign. 'Seiketsu' means to conduct seiri, seiton, and seiso at frequent, indeed daily, intervals to maintain a workplace in perfect condition. 'Shitsuke' means to form the habit of always following the first four Ss.

- SORT
  Eliminate everything not required for the current work, keeping only the bare essentials.
- STRAIGHTEN
  Arrange items in a way that they are easily visible and accessible.
- SHINE
  Clean everything and find ways to keep it clean. Make cleaning a part of your everyday work.
- STANDARDIZE
  Create rules by which the first 3 S's are maintained.
- SUSTAIN
  Keep 5S activities from unraveling

3.5 History of Six Sigma

The roots of Six Sigma can be traced back to the early industrial era, during the eighteenth century in Europe. Carl Frederick Gauss (1777-1855) introduced it as a conceptual normal curve metric. The evolution of Six Sigma took one step ahead with Walter Shewhart showing how three sigma deviations from the mean required a process correction. Later in 1980, Six Sigma got a definitive form when a Motorola engineer coined the term Six Sigma for this quality management process. Motorola not only implemented this system in their organization, but they copyrighted it as well. The CEO of Motorola became a leader in this system, and with his help later a four stage logical filter became the skeleton of the present day Six Sigma. The four stages were known as Measure, Analyze, Improve and Control. Later in the Six Sigma methodolgy the ‘Define’ stage is used as the first phase and formed the DMAIC six sigma problem solving approach.

DMAIC is a basic component of the Six Sigma methodology- a way to improve work processes by eliminating defects. The Six Sigma methodology is widely used in many top corporations in the United States and around the world. It is normally defined as a set of practices that improve efficiency and eliminate defects. The DMAIC process is the heart of Six Sigma. DMAIC refers to a data-driven quality strategy for improving processes, and is an integral part of the company's Six Sigma Quality Initiative. DMAIC is an acronym for five interconnected phases: Define, Measure, Analyze, Improve, and Control.

Define: A segment that defines the problem or opportunity for a problem, in a process or procedure that effects the customer's requirement or specifications. A hypothesis statement can be used in this used for this item.

Measure: The act of defining and identifying key measurements and collecting data, (with quality inspections using in most cases stratified sampling and a systematic sampling plan), on the assembles, and presenting a conclusion for a quantified evaluation of any given characteristics and/or level of operation based on the observed data collected.

Analyze: The action where a processes, procedure, or service, details are examined for process improvement opportunities.

Improve: A segment that defines where solutions and ideas may be generated and ruled on. Once a problem has been successfully identified, measured, and analyzed for potential solutions, the results can be evaluated to solve the problem.

Control: Once improvement opportunities have been implemented, by continuing to measure the process, using SPC, (statistical process control), to trace and confirm the stability of the implemented improvements and the expected results in the process. (also see our pages on Statistical Process Control and Range or R-Bar and mean also known as X-Bar for more details on SPC control charts).

3.6 Lean Six Sigma

The last two decades has witnessed an increased pressure from customers and competitors for greater value from their purchase whether based on quality, faster delivery, or lower cost (or combination of both) in both manufacturing and service sector (Basu, R.,(2001), (George, M.,2002). This has encouraged many industries to adopt either Six Sigma (as their process improvement and problem solving approach) or Lean Manufacturing (for improving speed to respond to customer needs and overall cost) as part of management strategy to increase the market share and maximise profit. All the large companies such as Toyota, Danaher Corporation, General Electric, Motorola, Honeywell, and many others, have achieved dramatic results by implementing either Lean or Six Sigma methodologies in their organisation (Harry, M.J.,1998), (Murman,2002), (Sharma, U.,2003), (Arnheiter, E.D. and Maleyeff, J.,2005).

The core thrust of Lean Production is that it works synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste.

Lean strategy brings a set of proven tools and techniques to reduce lead times, inventories, set up times, equipment downtime, scrap, rework and other wastes of the hidden factory.

The statistically based problem solving methodology of Six Sigma delivers data to drive solutions, delivering dramatic bottom-line results.

Each methodology proposes a set of attributes that are prerequisites for effective implementation of the respective program: top management commitment, cultural change in organisations, good communication down the hierarchy, new approaches to production and to servicing customers and a higher degree of training and education of employees (Salzman 2002), (Antony 2003).

Companies across the spectrum have found the most effective way to eliminate the flaws that lead to rework and scrap, and create one unified idea of continuous improvement, is the integration of Lean Manufacturing and Six Sigma (Smith 2003).

While, Lean strategies play an important role in eliminating waste and non-value added activities across the organisation, Six Sigma, through the use of statistical tools and techniques, takes an organisation to an improved level of process performance and capability.

The two methodologies emphasise the unfathomable involvement of top executives and communication with the bottom line to develop robust products and processes in their organisation. Most companies using the integrated approach apply basic Lean tools and techniques at the beginning of their program, such as current state map, basic house keeping using 5S practice, standardised work, etc. After implementing the above tools and techniques some wastes are eliminated from the system. Now, the tools and techniques of Six Sigma are used to offer powerful solutions to chronic problems. The comprehensive set of tools, techniques and principles that can be employed in the integrated approach of Lean and Six Sigma business strategies is delineated in Figure3.1.

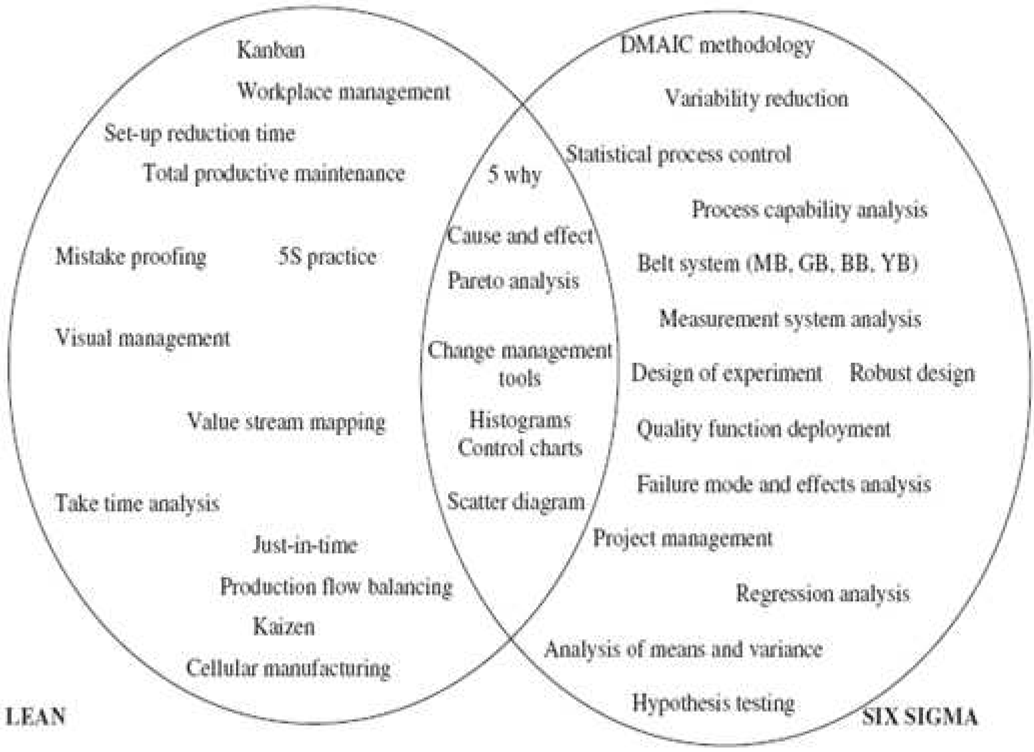


Figure 3.1 The tools and techniques of lean and six sigma, (Womack and Jones, 1996)

Figure3.1 is based on the previous works of experts in Lean and Six Sigma (Womack and Jones 1996, James-Moore and Gibbons 1997, Hoerl 1998, Rother 1998, Breyfogle III 1999, Harry and Schroeder 1999, Emiliani 2000, Hines and Taylore 2000, Pyzdek 2000, Antony et al. 2003, Snee and Hoerl 2003).

The use of the comprehensive set of tools mentioned above can help to reduce all kinds of waste (rework, over production, waiting, material, human skills, transportation and unnecessary movement) from the organisation (Ohno 1988, Womack et al. 1990, Shingo 1992, Hines et al. 1998, Liker 1998).

3.7 Extended Value Stream Map (eVSM)

VSM method is not limited only to a single manufacturing plant. Jones and Womack (1996), Rother and Shook (1999) suggest starting VSM process on a plant level and then extend the analysis for supply chain level. Such analysis should encompass in the beginning only selected, manageable part of the whole supply chain. It is obvious that if eVSM would be used to analyze OEM and all of its cooperating companies, the map would be very complex and therefore difficult for analysis. That is why eVSM teams usually start to draw maps only for limited fragment of the supply chain. After recognizing problems and implementing the solutions for the chosen fragment the team might repeat eVSM analysis for other suppliers. The eVSM method functions in following way: the mapping team members draw a Current State Map, including both material and information flows, for selected branch of supply chain, then using the lean tools and methods they design the Future State Map. The output of this process, beside a Future State Map, is an implementation plan including the set of projects that must be put in action (Eisler M., Horbal R., Koch T., 2007).

3.8 Needs For eVSM in Supply Chains

The eVSM method is a very supportive tool to begin supply chain improvement by implementation of Lean techniques as pull system, just-in-time deliveries and others.

Lancioni points out that Supply Chain Management is and will be the main source of competitiveness (Lacioni, R. A.,2000). According to Lambert and Cooper (2000) "individual businesses no longer compete as solely autonomous entities, but rather as supply chains.". The need of competitiveness is now of paramount importance. Therefore, companies need to perform no longer as individuals, they must think about cooperation with other players in supply chain. The source of competitiveness of supply chain was also pointed out by numerous authors (Porter E. Michael,1998).

Zdzislaw Arlet (2007), managing director of Fiat Auto Poland, claims that suppliers nowadays must be treated as business partners rather than just as suppliers.

Numerous manufacturing companies become aware of the waste that exists on their shop floors and in the offices, especially after publication of The Machine that Changed the World (J.P. Womack, D.T. Jones,1990). and Lean Thinking by Womack and Jones (J.P. Womack, D.T. Jones,1996). Companies have been implementing those techniques and nowadays can demonstrate significant achievements. Many companies try to implement the lean techniques already known well from literature. In spite of the fact that managers around the globe are aware of problems that exist in their plants and even though they have some achievements with solving those problems, supply chains are not transparent to everybody involved in process of product creation. Many problems can be found not inside the isolated facilities but rather within the relations that occur between cooperating companies. Managers responsible for supply chains need to be equipped with tools that will help them to resolve such kinds of problems. Valuable method in this matter is eVSM proposed by Womack and Jones in 2002. (Womack, James P., & Jones, Daniel T.,2002).

While applying an eVSM, managers of cooperating companies need to share the knowledge about their plants and warehouses. Also managers of particular plants should not think that they will not benefit from the whole improvement process (Lacioni, R. A.,2000), (Rother M., Shook J.,1998). Witkowski in "Logistics of Japanese firms" claims that Western companies (Europe, USA) are not willing to cooperate with their business partners to find better and cheaper solutions for their problems (Rother M., Shook J.,1998). They usually focus on unit price and quality level accepted by customers. It is hardly to find fair rules that would allow benefiting both supplier and costumer from the outputs of improvements made together within supply chain. It is observed that common effort of suppliers and consumers is mostly made to improve quality, but the efforts to reduce the waste are rather limited to the separated actions within the plants.

So the main advantage of eVSM is this Lean method indicates the problems with integration of the companies within the supply chain.

Usually the separate actions are undertaken by the companies to implement lean tools for production systems and external logistics processes. This situation leads to minor results or moving the costs between production and logistics processes instead of reduction.

eVSM method focuses on synchronised reorganisation of company production system, external logistics processes between the company and its suppliers as well as suppliers' production processes. The main issue of the eVSM method is to reduce inventories that are waste from costumer's point of view. When users of eVSM try to reduce excessive inventories it is often related to increased frequency of deliveries.

3.9 Methodology of Using the Extended VSM in Lean Six Sigma Framework

In our study we use the lean tool extended value stream map. The application of the tool in the case study for finding the improvement solution was done by the help of Six Sigma problem solving methodology which is called DMAIC (define, measure, analyse, improve, control). The main reason we follow-up the DMAIC approach for lean application is because in DMAIC the system helps us to take actions according to a methedology and follow-up correct steps next. This Six Sigma systematic problem solving approach guides us for applying right lean and statistical tools in right phases of the case.

In DMAIC system each phase helps the users to solve the problem in a systematic way and because it guides which tools to use in each step it is also considered a methodolody for solution any lean problem.

Different tools according to the problem specifications can be used in each phase. In Define phase, project charter is first prepared. In project charter detailled definition of the problem is set especially with numeric values of present situation of the problem and the numeric values of target that the future situtation is expected. For detailled problem definition in the define phase of the DMAIC other tools can be used, such as ‘Supplier – Input – Process – Output – Customer’’ (SIPOC), stakeholder analysis, Voice of Customer (VOC), Voice of Business (VOB), completion check list, tree diagram. By the help of any of the each tools above critical to qualites (CTQ) of the problem are set in the define phase.

In the Measure phase, data is collected about the problem. Data collection plan is set, this can be a process chart, a value stream map of the process…etc. According to the problem requirements in the define phase. If necessary Gage R&R anaysis is applied for validating the measurement system. Process capability and completion checlist are other alternatives that are used in measure phase.

In the Analysis phase, potential causes of the problem are organized by using the datas gathered in the measure phase. Causes are verified and if necessary hypothesis tests are done. If the problem is anaysed in the process dimenasion sugh as value stream maps, the map results of the current state are analysied. For statistical anaysis desing of experiment can be set.

In the Improvement phase, solutions are generated. For the improvement solutions assesing risks and pilotting solutions could be found. Planning tools for the application of improvement solution is used. Actions to be applied are derived.

In the Control phase, standardization is established with the actions applied in the improvement phase for the solution. The results of the CTQ’s are monitored for a time interval. The results are evaluated and the improved indicators are tracked regularly.

CHAPTER FOUR

USING THE EXTENDED VALUE STREAM MAP IN DMAIC METHODOLOGY FOR TOTAL LEAD TIME REDUCTION

4.1 Overview of Methodology Applied in the Case Study

In the case study the Six Sigma DMAIC methodology steps are followed up for finding Lean solutions by the main tool used extended VSM.

In Define phase; critical to qualites (CTQ) of the problem are set according to Voice of Customer and Voice of Business views. To identify the CTQ's a ‘’Tree diagram’’ is constructed. For selecting the correct product family ‘’Pareto Anaysis’’ is applied. Delivery Performance Measurement is followed for last one year by using the tool Minitab –‘’Time Series Analysis Graphics’’. An effective six sigma tool ‘SIPOC’ is also used in the Define phase.

In the Measure phase; ‘’takt time calculation’’ is applied using the customer order demands and working period of the company. Current State Maps are drawn for injection factory processes in detail, operations are defined and work-in-process quantities are set to the current state map. Process lead times are calculated for all operations by using the cycle time and efficiency values of each operation. Work-in process quantities are converted into work - in- process times to sum up the total lead time.

In the Analysis phase; current state map results are compared with the takt time requirements and needs for e-VSM are defined. For extended value stream map, subcontractor processes are defined. Current state map of the subcontractor is drawn. And VSM of injection operations and the vendor–subcontractor VSM are combined with the work-in-process quantities in the extended value stream map.

In the Improvement phase; extended value stream map is used to find the types of potential wastes. After the wastes are identified the improvement opportunities of these wastes are clearified. For the improvement solution two actions are realized: Kanban system is constructed with the subcontractor and the Milkrun application is started with the raw material vendor.

In the Control phase; CTQ values of ‘’total lead time’’, ‘’inventory quantities’’and ‘’on time delivery’’ are measured and tracked after the realization of actions in the future state map .

4.2 Define

4.2.1 Company Background

The manufacturing company considered in this case study is established in Turkey over 500 employees, in the sector of electric&electronics industry. It is one of the leading forging companies in Turkey. The identity of the company is protected; however, we shall refer to the plant as ABC.

The organisation is engaged in designing and manufacturing various types of switches and sockets and the components of switches and sockets especialy used in houses and industrial plants. The main customers of the company are any factories using industrial series such as standard segment products, multi contacts and combination boxes, also the local and global range customers for wiring devices products with various series of switches and sockets, waterproof series and installation boxes. So the company is producing much more for its customers related in the construction and the building sector.

There are two main manufacturing buildings in the plant, injection and the assembly production buildings. Serial manufacturing is applied in the injection building and the descrete manufacturing is applied in the assembly building.

The employees work in three shifts per day, each shift of 8 hours, and six days a week in the injection plant. In the assembly plant the employees work in two shifts per day, each shift of 8 hours, and six days a week to meet the market demand.

There are also more than one subcontractors that the company works with, for interval operations before the assembly of the final product. Subcontractors work six days in a week.

4.2.2. Process Overview

Process flow in the company is given in Figure 4.1.

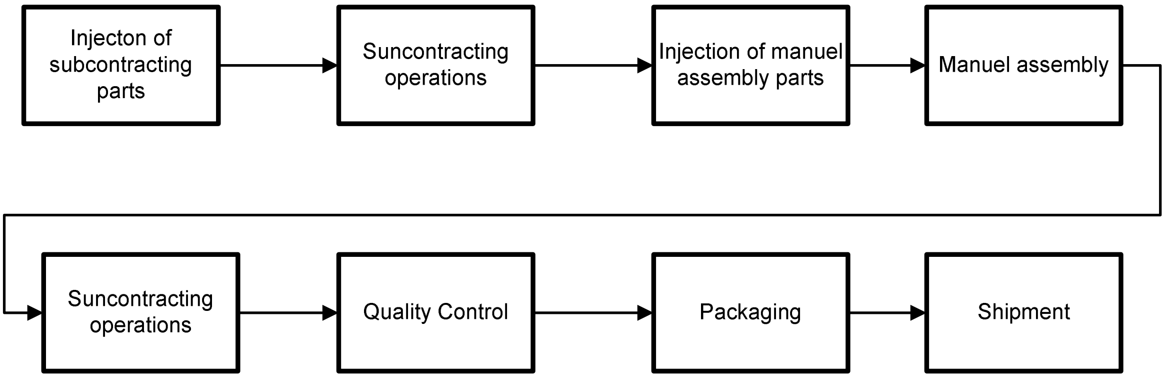


Figure 4.1 Flow diagram of the process

The general workflow is as follows: The process starts in the injection plant by injecting the raw materials into large injection machines with high level pressure and in very high heat conditions for a sufficient duration. In Figure 4.2 there is an example of manuel automated injection process of ABC company. The injected parts which are the semifinished products of the final product are placed into bins to be stored in the warehouse and stocked till the need for the next process. While some type of the injection parts are stored for buffer in the warehouse to be used in the last operation during the assemblies, the other types of injection parts goes to subcontractors with other supplying materials for following processes according to subcontractors production plans prepared by planning engineers.

Figure 4.2. Injecton process

In subcontractors diffrent operations are carried out considering the product type and the bill of material and the route of the product. After the subcontracting operations the semifinished products from the subcontractors are arrived to the plants warehouse and wait for the last assembly operation with the other type of injection parts in the assembly plant.

Mostly the last assembly operation is applied in the assembly plant but for some type of products the assembly process is carried out in the injection plant according to materials producability specifications. In Figure4.3 there is the picture of manuel assembly process carried out in the injection plant.

Figure 4.3. Manuel assembly process

In the next step, the assembled products go to the packaging operation where they are packed with speacial machines. Both the injection plant and the assembly plant has their own special packaging machines.

Finally, the finished product is stored in the dispatch area of the warehouse from where it is sent to the customer directly on the same day it is produced. Customer orders are taken care of on the basis of first come first serve (FCFS) stock policy.

The company faces with severe pressures, both externally and internally to improve the performance of the long lead times and on time deliveries to the customers. The management decided to implement lean philosophy to find which group of product need to be improved in their process for achieving better CTQ's (critical to quality) in 'On Time Delivery Measurements' (OTDM) and in order to success this CTQ, to decrease the lead time of the product group by examining the problems with the tool of VSM.

4.2.3 Problem Definition

In order to focus on the process the first necessary action is to choose the right product family. Because any different product family produced in this company has its own process flow and should be analysed seperately. So the first critical point before starting the project is to decide the right product familiy to apply the VSM.

For the selection method of the product family, critical to quality (CTQ) characteristics based on the input of voice of customer (VOC) are identified. In next paragraphs there are the explanations of CTQ and VOC processes.

CTQs (Critical to Quality) are the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. They align improvement or design efforts with customer requirements.

CTQs represent the product or service characteristics that are defined by the customer (internal or external). They may include the upper and lower specification limits or any other factors related to the product or service. A CTQ usually must be interpreted from a qualitative customer statement to an actionable, quantitative business specification.

The "voice of the customer" is a process used to capture the requirements/feedback from the customer (internal or external) to provide the customers with the best in class service/product quality. This process is all about being proactive and constantly innovative to capture the changing requirements of the customers with time.

After a number of brainstorming activities with many people from different departments, three important CTQ’s are decided. First CTQ is for the voice of the customer: the performance measurement of the ‘On Time Delivery Measurement’

(OTDM), which shows the service quality of the company monthly for a specific product family to the customers.

The second CTQ is ‘Lead Time’ of the product familiy, for which customers expect from the company to meet their orders in a shorter period than at current situation.

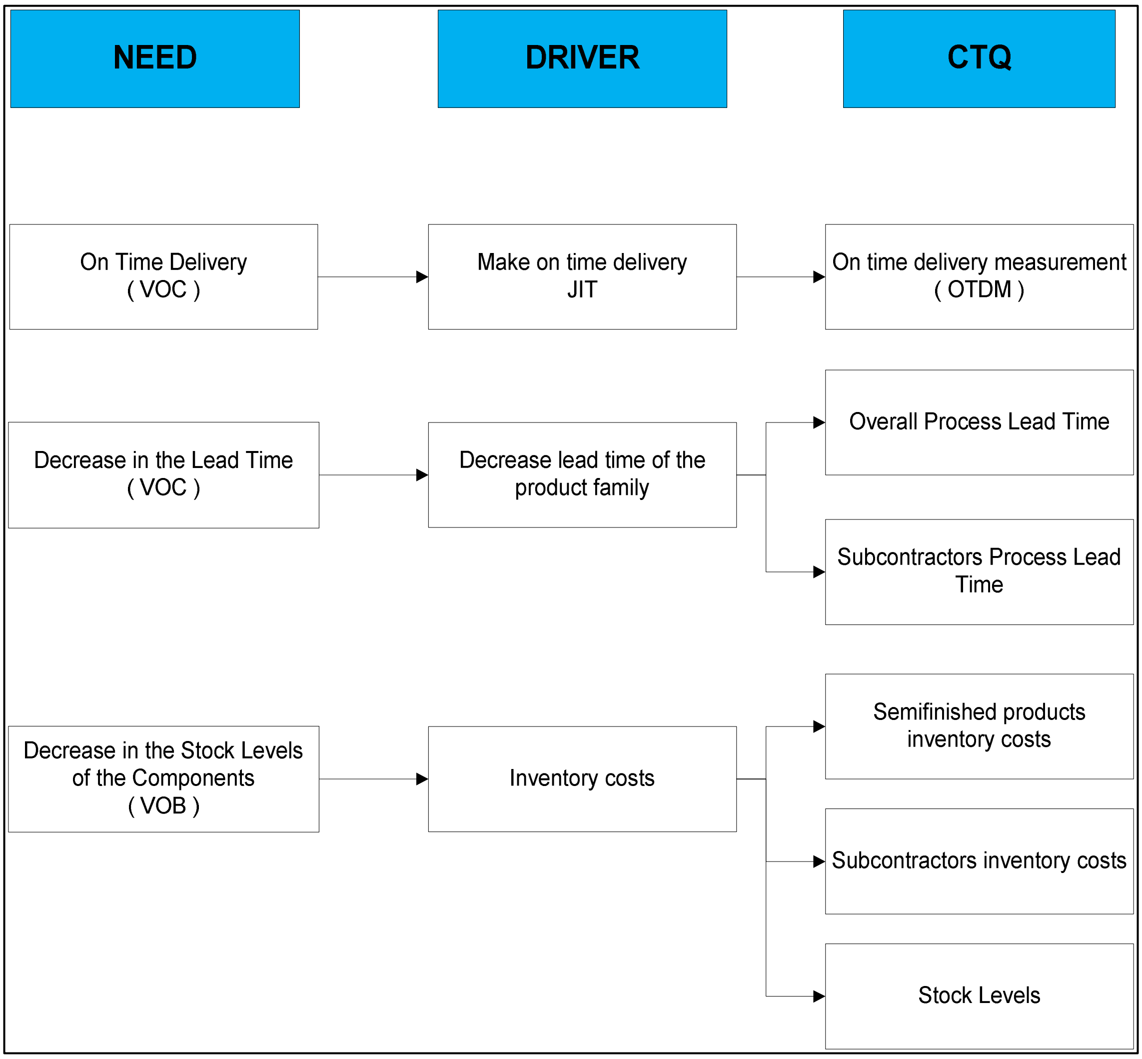
The third CTQ is decided from the voice of the business as ‘stock levels&inventory costs’.

The "voice of the business" is the term used to describe the stated and unstated needs or requirements of the business/shareholders. The voice of the business is derived from financial information and data. By dissecting the financials, analysts can identify market weakness, utilization of investment capital, research and development status, and process complexity. Based on organizational strategy and direction, understanding the voice of the business assists in identifying potential projects to aid in moving the organization closer to its goals and objectives.

Because the improvements in the second and the third CTQ will directly effect the OTDM, it is decided the first CTQ to be selection variable for the critical product family.

In Table4.1 there is the CTQ tree diagram for the defined parameters above which are selected for the problem. In table4.1 Tree Diagram is formed with three pillars. Tree diagram starts with identifying the needs, which we defined in our study as ‘On Time Delivery’ for the need of customer, ‘Lead Time Decrease’ for the need of customer and ‘Decrease in the Stock Levels’ for the need of business. These needs that comes from customer of business derives the cases called as ‘drivers’. Drivers means the sources of the CTQ’s defined. Drivers are the factors which derive the CTQ’s. So there is a link between the driver and the CTQ and a link between the need and driver. The CTQ’s of each drivers are given in Table4.1.

Table 4.1 Tree diagram for CTQ's (visio)



4.2.4 Selecting a Product Family

As it is explained in the previous section OTDM value was decided to be the selection variable for the ctitical product family. So in order to compare the OTDM values of each product families, customer orders of last two years are analysed. First of all expected delivery dates of customer orders and realized delivery dates of customer orders are found. According to the calculation policy of OTDM value in ABC company, the difference between the realized and expected delivery dates of customer orders month by month is figured out by each product family. For example in the case there was 100 customer orders of a product family expecting to be delivered in a specific month, and if only 60 of customer orders are met for that product family during the month, the OTDM value is: $60 \div 100 = \%60$ calculated with the formula:

$$\text{OTDM} = \text{Re}\,alizedCustomerOrders \div ExpectedCustomerOrders$$

OTDM value is calculated by month and by product family with the above formula. In Table4.2 there are the OTDM values of each product families.

When all the OTDM values for each product families are calculated as a result ‘XYZ product family’ is selected to be improved with the lowest OTDM value between the other product families of last two years on average. Figure4.4 shows the OTDM results of different product families with the lowest OTDM % value of XYZ product family.

The aim of this study is to increase the OTDM for the chosen XYZ product family by identifiying the root cause of the problem for long process lead times. In order to discover the current situation of the OTDM, last one years on time delivery performance measurements are calculated and average of the OTDM for XYZ product family is revealed by using the MINITAB.

MINITAB is used for defining the current rate of average OTDM for XYZ product family. In figure4.5 there is MINITAB I chart of OTDM for XYZ product family with last one years % values.

Table 4.2 OTDM results of different product families by month.

		MONTH																
		Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Average
Product Family	R2TY	85	89	88	90	93	92	89	91	90	90	87	88	86	94	92	92	89,75
	XYZ	70	100	84	61	61	38	72	67	61	61	88	78	88	87	72	96	74,00
	WTRP	92	91	92	90	93	88	89	88	90	93	96	91	91	89	88	90	90,69
	CE32	89	80	85	88	88	89	93	94	92	95	94	90	96	93	93	93	90,75
	KBTO	91	90	91	92	89	86	90	97	95	92	89	90	88	88	92	90	90,63

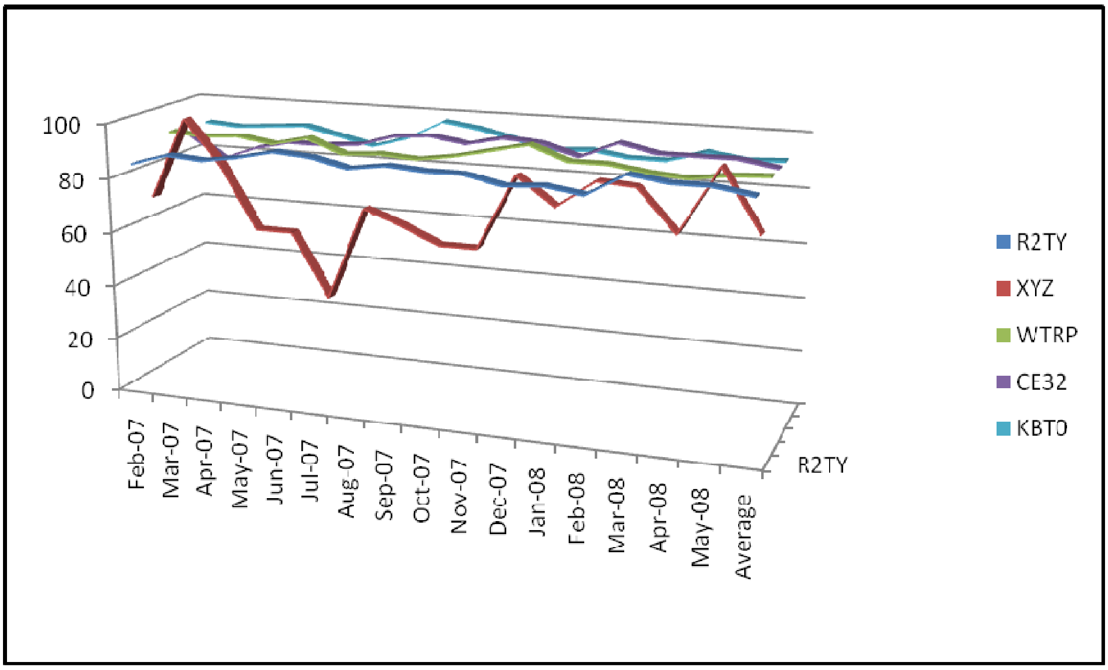


Figure 4.4 OTDM results of different product families by month

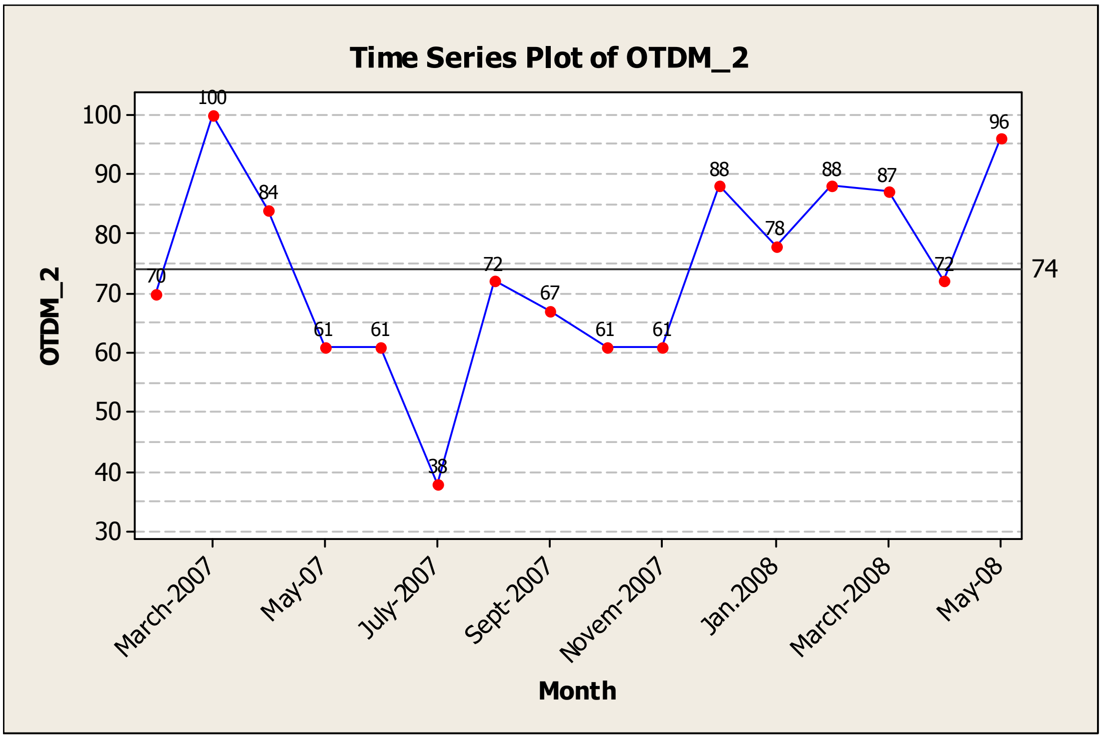


Figure 4.5 Time series of OTDM for XYZ product family for last 1 years % values

As it is shown in the figure4.5 the average value of OTDM for XYZ product family is 74 per cent for the last year, which means that only 74 of 100 orders were met without delay to the customers. According to the voice of the customer the OTDM and total lead time targets were set. The aim is %20 decrease in the Process Lead Time of XYZ Product family and increase and stabilize the on time delivery measurements. Also high work-in-process and inventory costs of stock levels need to be decreased for lean manufacturing to achive overall cost reduction and satisfy the customer needs.

On time delivery performance by month is 74 per cent on average, which means that only 74 of customer orders can be met during a month when 100 orders in total are set, which is (%74 OTDM) is really a low value when considered the increasingly competetive marketting environments.

In order to find the bottlenecks and the current real lead time of the process a value stream map of the current state is drawn. VSM is a tool more focused on the entire value stream of a productive process. It maps not only material flows but also the information flows that signal and control production.

In order to create VSM the first step consists in the selection of a one specific product type as the target for the improvement and in the construction of the 'Current State Map' (CSM) for the selected product family value stream. In our case, the specific product type is chosen between the XYZ product family by the analysis of 'Pareto Chart' for the production quantities of last one year.

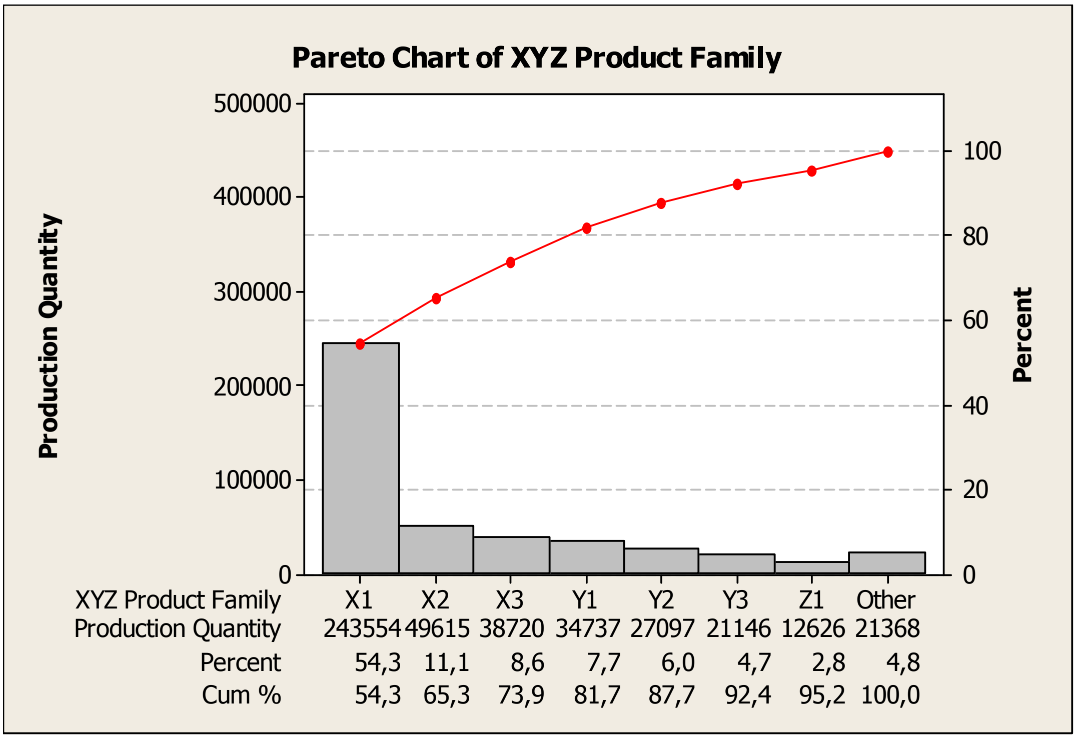


Figure 4.6 XYZ product family using the pareto analysis to create value stream map

After the pareto analysis, it is shown in figure4.6 that the product type 'X1' has more than %54 of the produced quantities for the customer demands of XYZ product family for the last year.

Because product ‘X1’ has the highest production (demand) quantity it is chosen as the specific product type whose Value Stream Map will be drawn as it will represent more than half of the other product types of the XYZ Product Family .

Before starting to draw the detailed current state map, a lean six sigma tool ‘SIPOC’ (in figure4.7) is used to show the ‘High Level Road Map’ for the movement of materials through different processes/facilities during manufacturing. In the SIPOC diagram we can see the whole picture for the process of X1 product.

The production process is mainly carried out in the injection plant and in the subcontractors for X1 product as it can be seen in the SIPOC diagram in Figure4.7. Even the final processes of ‘assembly’ and packaging’ are operated in the location of ‘injection plant’.

The manufacturing process starts with subcontracting operations. After necessary subcontracting parts are ready then they are trasported into ABC warehouses from the subcontractors and then carried into the injection plant to be assembled with the other injection components. After the assembly operation they are again packaged in the injection plant and get ready for the dispatch.

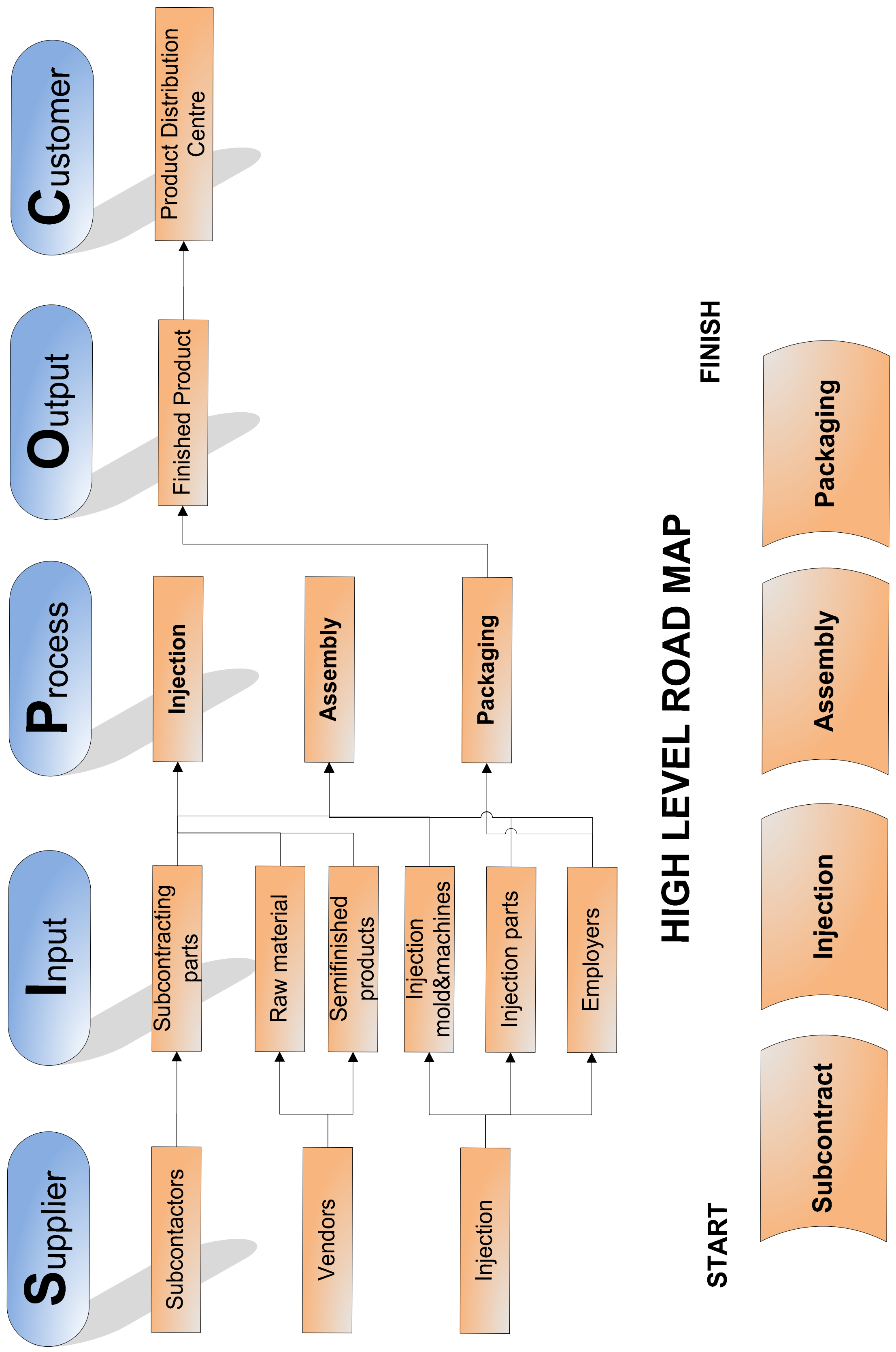


Figure 4.7 SIPOC diagram

4.3 Measure

4.3.1 Current State Map

In order to have an insight into the current situation of the X1 product, a current state map is developed which gives a closer look to the process so that opportunities for the improvement can be identified.

In our case, mapping out the activities for X1 product flow with cycle time, down time, WIP inventory, material movements, and information flow paths help to conceptualize the current state of the process activities, and, hence, guide us towards the desired future state.

The first step to draw the Current State Value Stream Map is the calculation of Takt Time.

4.3.2 Takt Time Calculation

‘‘Takt time’’ refers to the rate at which customers are buying products from the production line; i.e., the unit production rate that is needed to match customer requirements. It is calculated by dividing the total available time per day by the daily customer demand.

The throughput required for the annealed products is an average of 12425 pc per week. Assuming 6 working days per week, the average daily requirement is thus 2070 pc per day.

$$AverageDaily\,\mathrm{Re}\,quirement = 12425 \div 6 = 2070$$

The manufacturing company continuously runs three shifts per day, which translates to 1440 working minutes per day, resting per shift is 0.25 hours and the time for meal breaks 0.5 hours per shift . Then it is calculated as the 1305 effective working minutes per day. So that the takt time is thus approximately; $1305 \times 60 \div 2070 = 37.8$ seconds.

Working Minutes in a day = $(3 \times 8 \times 60) - (0.25 \times 3 \times 60) - (0.5 \times 3 \times 60)$

Working Minutes in a day = 1305 minutes

Working Seconds in a day = $1305 \times 60 = 78300 \sec onds$

Takt Time = $78300 \div 2070 = 37.8 \sec onds$

There is below the detailed takt time calculation table:

Table 4.3 Takt time calculation table

TAKT TIME CALCULATION		
DEMAND	12425	pc / week
Working Days	6	days / week
Shifts	3	shifts / day
Working Hours	8	hours / shift
Lunch	0.5	hours / shift
Break	0.25	hours / shift
Working Time	130.5	hours / week
Takt Time Calculation =	$130.5 \times 60 \times 60 \div 12425$	
Takt Time	37.8	seconds
		Workingtime/Demand

4.3.3 Drawing the Current State Map

4.3.3.1 Getting Started With Current State Map

Current state value stream mapping is the understanding how the shop floor currently operates. So in order to construct the present state value stream map, relevant informations are collected by interviewing people on the shop floor.

First of all data pertinent to the customer such as quantity to be delivered, delivery frequency, packaging type are learned. Information related to the production line, such as run time at each work stations, machine down time for each process, inventory storage points, inspections, rework loops, cycle time, set-up time, number of workers, and operational hours per day are also collected and documented properly. To complete the value map, a timeline is added at the bottom of the map recording the production lead-time and the value-added time. Finally the value stream map for the current state is constructed as shown in Figure4.8.

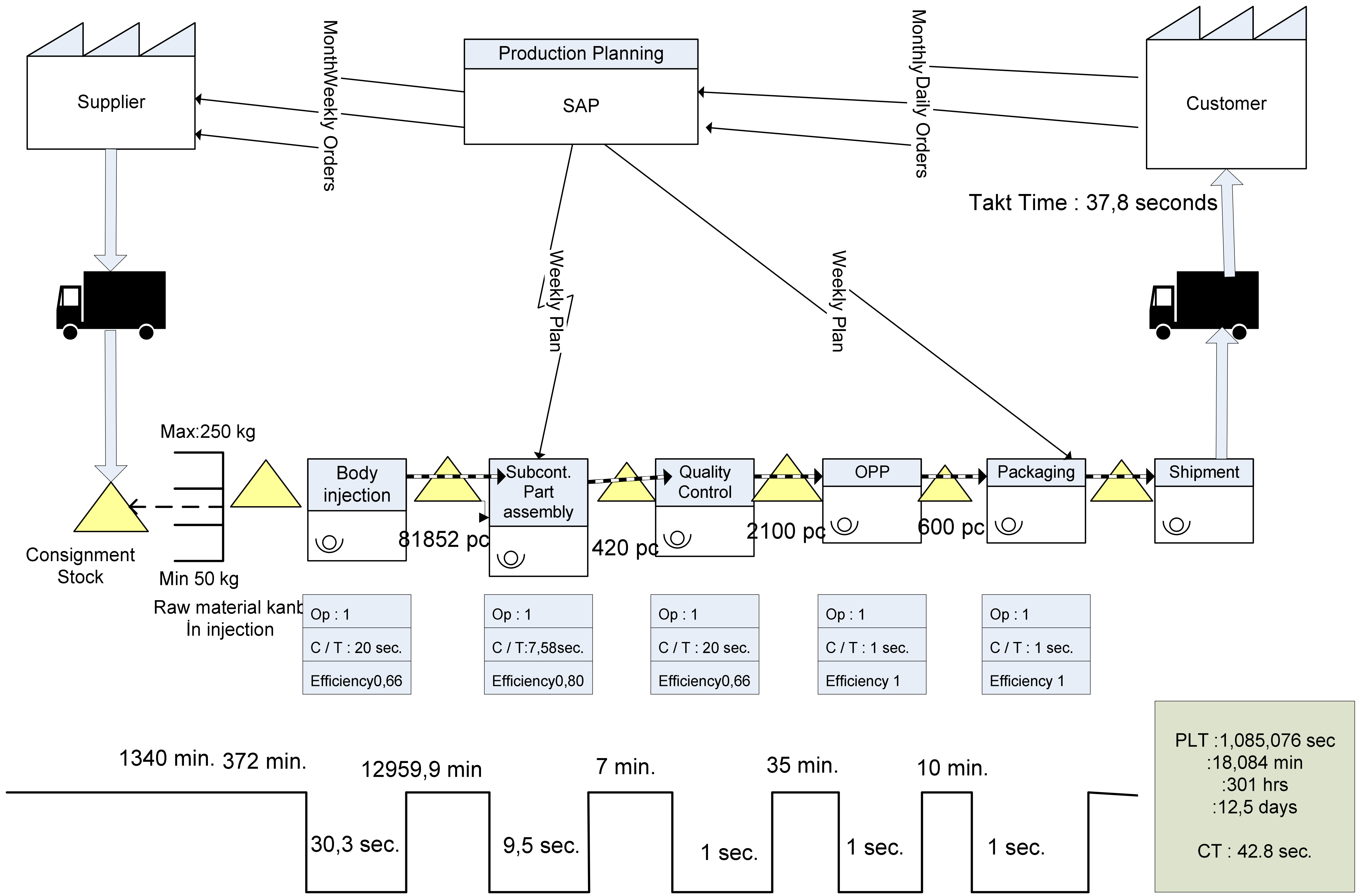


Figure 4.8 Current State Map

Always starting from the customer side as VSM policy, calculated target takt time value is first applied in to the ‘customer icon’ which is on the right top of the value stream map.

Calculation of takt time is described in detail in section 4.2.2. According to customer demands ’37.8 seconds’ of takt time is enough to meet the weekly average customer demands, which means that any process operation working with less than or equal to 37.8 seconds process time it can respond the customer demands without delay. But any operation time with greater than 37.8 seconds process time, it is a candidate for beeing a bottleneck operation and can not meet the average customer demand.

After the takt time is placed onto the customer icon in the VSM table, production processes are defined, which are in order: ‘body injection’, ‘seed assembly with body’, ’quality control test’, ‘OPP (a type of header plastic packaging bags)’, ‘packaging’. The products are then shipped to the vehicles for customers on a daily basis. After the intoduction of process names they are all seperately applied via the process icons into the value stream map. Before drawing the material flow, each process step is analyised in detail by gathering information for each processes.

The necessary information that will be collected for each operation are ‘cycle time’, ‘efficiency’ and ‘the set-up time’. Below each process icon cycle time, efficiency and set-up time are written. Here we add some definition for these three terms.

Cycle Time is the average time between completed units "coming out the end of the pipe".

Efficiency is a measure of speed and cost. It is the ratio of the effective or useful output to the total input in any system.

Set-up time is the time that is spent setting up the fixture, calculating tool offsets, and performing all the necessary tasks to produce the first accurate part.

4.3.3.2 Process Time Calculations

For the ‘body injection’operation cycle time is observed as 20 seconds. It is the machine theoretical run time without taking into consideration the operation flexibility and machine down times, which means that without any stop it is calculated in the shopfloor that in every 20 seconds 1 piece of material is produced in the body injection machine. Then the cycle time of body injection operation is set to as 20 seconds per piece.

The efficiency rate is calculated as 66 per cent for body injection operation. This ratio is calculated by using the datas of last 3 months theoretical and realized production quantities per day. Efficiency is calculated as realized production quantity divided by theoretical production quantity per time. The difference between the realized poduction quantity per time and the theoretical production quantity per time is because of reasons like operation flexibility, machine downtime, machine breaks, raw material shortages..etc. All the data for the result of 66 per cent efficiency is related in the appendix.

Setup time for body injection is observed as 30 minutes for body injection operaion. 30 minutes set-up time is the machine stop time between the last piece of product that comes from the machine and the first piece of correct product that comes from the machine next run.

Then the real process time is calculated as 30.3 seconds via the formula:

Process Time = Cycle time/Efficiency

Process Time = $20 \div 0.66 = 30.3 \sec onds$

For other processes, the same formula is applied to calculate the real process times. For the ‘seed assembly with body’operation cycle time is observed as 7.58 seconds. The efficiency is calculated as 80 per cent. Related datas are enclosed in the appendix. Then the real process time is calculated as 9.5 seconds.

Process Time = Cycle time/Efficiency.

Process Time = $7.58 \div 0.80 = 9.5 \sec onds$

The remaining three operatons ‘quality control test – OPP –packaging ’ have the same cycle time of 1 second and their efficiencies are 100 per cent, so process time of last four operations are 1 second each.

4.3.3.3 Inventory Time Calculations

After drawing the process icons and the informations, material flow is defined by using the material flow icons. Next step is the counting of work in processes between the operations.

Work in process (WIP) is the inventory between the start and end points of a product routing. Inventory levels are converted to ‘inventory time’ in a VSM map according to Rother and Shook (1999). There are eight levels of work in process inventories which are shown in detailed different locations between the operations in our current state value stream map. Starting from the beginning of the process ‘the raw material work in process inventory’ stock quantities are counted and written to the current state map later to be converted into inventory times. The inventory time calculation formula is below:

Inventory Time (minutes)=Work in Process inventory quantity $\times$ Process Time $\div 60$

At the end of the formula by dividing the Inventory time to 60, it is written in the current state map in minutes. All of the eight work in process inventories are converted into inventory times in minutes to calculate the process lead time .

Inventory times are calculated by converting the inventory quantities to time according to the inventories next operation process time, which means that for example if you have 100 pc of WIP (work in process inventory on hand) for the next operation with the process time of '20 seconds' of the operation, then you are having $100 \times 20 \div 60 = 33.3 \min utes$ of inventory.

In the first stock of work in process inventory with the consignment raw material stock quantities, it is calculated as the average stock of 750 kg raw material. Average raw material consignment stock is calculated as the average of minimum and maximum of consignment stock quantities that is carries on the inventory.

Average raw material inventory of consignment stock= $(600kg + 900kg) \div 2 = 750kg$

When 750 kg of raw material is converted to 'pc' of 'body injection parts' for the next operation, the Bill of Material is used. In the bill of material of the product itis seen that 0.112 kg of raw material is used in order to produce 1 piece of body injecton part. That means the 750 kg raw material is equal to 6653 pc of body parts, calculated as $= 750kg \div 0.113$

So the 6653 pc of inventory (raw material ready to be converted to body parts) is calculated for inventory times as follows by using the first operation 'body injection process time':

Inventory Time1= $6653 \times 30.3 \div 60 = 3360 \min utes$

The next inventory time is calculated by using the next work in process inventory, the kanban stock inventory of min=150 kg raw material and max=450 kg raw material. Because in the next inventory there is the kanban stock of raw materials which is worked with the minimum 150 kg and maximum 450 kg stock on hand parameters. The average raw material quantitiy is calculated like the formula as consignment stock, by taking into consideration the minimum and maximum stock quantities of kanban parameters.

Average raw material inventory of kanban stock= $(150kg + 450kg) \div 2 = 300kg$

When 300 kg of raw material is converted to 'pc' of 'body injection' for the next operation, the Bill of Material is used. That means the 300 kg raw material is equal to 2655 pc of body parts.

So the 2655 pc of inventory (raw material ready to be converted to body parts) is calculated for inventory times as follows by using the first operation 'body injection process time':

Inventory Time2= $2655 \times 30.3 \div 60 = 1340$ minutes

The stock just before the body injection machine is when converted from bill of material is equal to 736 pc of body injected part. Then the inventory time3 is calculated as follows:

Inventory Time3= $736 \times 30.3 \div 60 = 372$ minutes

For the other work in process inventories here in Figure4.9 in detail the stock quantities between the operations and the results of inventory times calculations are written in minutes into the timeline at the bottom of the map.

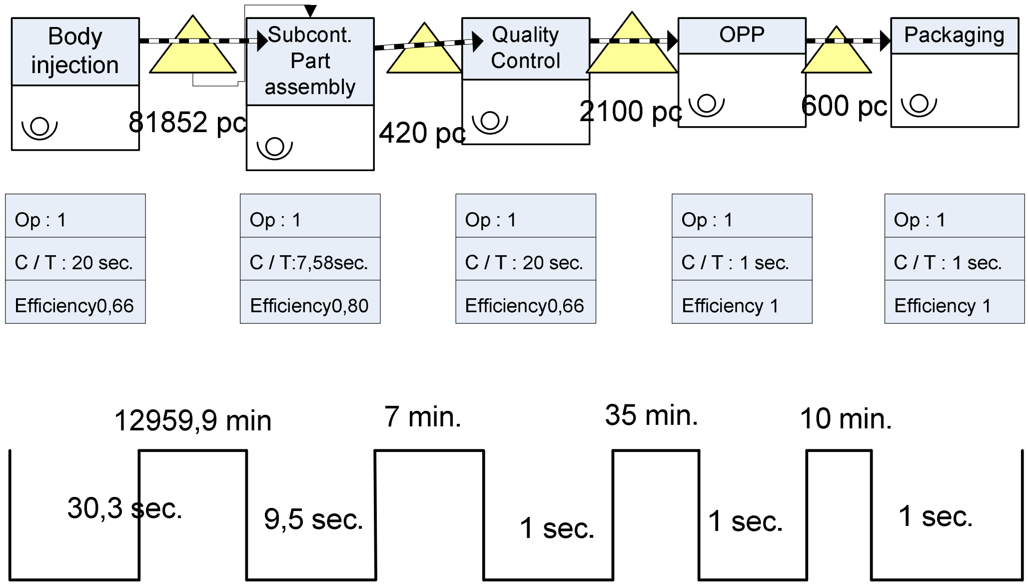


Figure 4.9 WIP quantities in detail.

At the end of the timeline, the cycle time is calculated by the sum of total process times which are the only value added times and it is written into the end of timeline.

Process lead time is calculated by summurizing the inventoy times and the process times in the current state map. As shown in the map, it is 1085076 seconds when converted into days 12.5 days.

PLT :1,085,076 sec
:18,084 min
:301 hrs
:12,5 days

CT : 42.8 sec.

Total Process Lead Time =

$$3360\,\text{min} + 1340\,\text{min} + 372\,\text{min} + 30.3\,\text{sec} + 12959.9\,\text{min} + 9.5\,\text{sec} + 7\,\text{min} + 1\,\text{sec} + 35\,\text{min} + 1\,\text{sec} + 10\,\text{min} + 1\,\text{sec} = 1085076\,\text{sec}$$

Total Process Lead Time = $1085076 \div 3600 \div 24 = 12.5 days$

But only the summary of the process times are ’30.3 + 9.5 + 1 + 1 + 1+ 1’ = 42.8 seconds. Which means that in the current state map of the injection plant the total process lead time is 12.5 days while the real value added time is only 42.8 seconds. The reason is so much work in process inventory is kept and it is the result of having many non value adding activties such as waitings, components missings..etc..between the operations.

4.4 Analyse

4.4.1 Need for eVSM

As it is shown in the current state map of X1 product in the injection plant, the target takt time is 37.8 seconds. Target takt time means that if any operation working with greater process time than the takt time there will be delays in meeting the customer orders on time. Because in our case 37.8 seconds means that customer demands one product in every 37.8 seconds, and if in any case working with greater operation time than the 37.8 then demand would not be met and the customer is forced to be waiting.

According to the current state map, process times of the injection operations are not constraints for meeting customer demands because any operation do not have greater process times than takt time. All the operations are ‘body injection with 30.3 process time’, ‘subcontracting part assembly with 9.5 seconds’, and following three operations with 1 second process times, working with smaller process times than the takt time. So we must be expressing easily that for the processes there is not a bottleneck operation when we consider only the process times of the operations.

Although any operations in the injection plant do not excess the takt time value with their process times, when we look at the whole picture and the value of PLT at the end of the current state map we see that real lead time of X1 product is 12.5 days including the waiting times of inventories. That means although summary of process times of all operations are 42.8 seconds, the order delivery lead time to the customer actually realizes in 12.5 days. There is a huge difference because of the inventory times that causes long waitings of inventories on stock. Because of these work in process inventories the injection plant is not lean enough. There are high work in process inventories between the operations which finally increase the total lead time of the whole process.

As it is seen in the current state map because of these high inventory rates the total process time reaches to 12.5 days. But this is not the main reason for not meeting the customer orders on time, because OTDM rates per month can still be met by working with these cycle times and efficieny of the operations. Then the problem must be in the other operations of subcontractor parts which effects the work in process inventories in front of the subcontractor assembly operation. 12.5 days lead time is mostly because of the waiting inventories between the operations.

The assembly operation starts only if there is enough subcontracting parts on hand. In this case the sencronization of arrival times of subcontracting parts and the body injected parts is very crucial for preventing stock quantity on hand. For this reason body injection operation does not start unless the necessary subcontracting parts are ready on hand, otherwise it would cause more body injected parts waiting in front of the assembly operation. So the body injection machine is only dowloaded when subcontractor parts are ready in front of the machine. Hence this process makes and forces us to see the whole picture with the subcontracting operations that effects its parts arrival times to our injection value stream mapping.

Therefore as the next step we draw the value stream by extending the flow to the vendors of subcontractor processes. In the following chapter there is the value stream map of subcontractors with the detailed operations.

4.4.2 Subcontractor Current State Map

As shown in Figure 4.10 the total lead time of the subcontractor is 384 hours which is equal to 16 days (with 3 shifts per day – 8 hours per shift). 384 hours is calculated by summary of all the process times and the inventory times during the subcontractor processes.

Here in detail each operations process time calculation details are explained. Then we come up with the result of 'total process time of the subcontracting map' and adding the inventory times between the operations we find the 384 hours of subcontractor total lead time.

The first operation in the subcontractor is the 'Control&Distribution' process. For the 'Control&Distribution'operation cycle time is observed as 7.68 seconds. The cycle time of 'Control&Distribution' is set to as 7.68 seconds per piece. The cycle time definition is given in detail in section 4.3.3 while describing the Current State Map of the injection process.

The efficiency rate is calculated as 80 per cent for control&distribution operation. This ratio is calculated by using the datas of last 3 months theoretical and realized production quantities per shifts. The efficiency definition is given in detail in section 4.3.3 while describing the Current State Map of the injection process.

Then the real process time is calculated as 9.6 seconds via the formula:

Process Time = Cycle time/Efficiency

Process Time = $7.68 \div 0.80 = 9.6 \sec onds$

For other processes, the same formula is applied to calculate the real process times. The next operations are named as ascending order ‘operation1’, ‘operation2’, ‘operation3’, ‘operation4’, ‘operation5’, ‘operation6’ and ‘’operation7’.

For the ‘operation1’ cycle time is observed as 16 seconds. The efficiency is calculated as 90 per cent. Then the real process time is calculated as 17.78 seconds.

Process Time = Cycle time/Efficiency.

Process Time = $16 \div 0.90 = 17.78 \sec onds$

The remaining six operations have the cycle time and efficiencies of ’16 seconds cycle time with 0.90 efficiency rate, 4.26 cycle time with 1 efficiency rate, 28 seconds cycle time with 0.90 efficiency rate, 7 seconds cycle time with 0.90 efficiency rate, 15 seconds cycle time with 0.90 efficiency rate and 10 seconds cycle time with 0.90 efficiency rate’. With these information for each operations, the process times of each operation is calculated using the same formula:

Process Time = Cycle time/Efficiency

Process Time of Operation2 = $16 \div 0.90 = 17.78 \sec onds$

Process Time of Operation3 = $4.26 \div 1 = 4.26 \sec onds$

Process Time of Operation4 = $28 \div 0.90 = 31.1 \sec onds$

Process Time of Operation5 = $7 \div 0.90 = 7.8 \sec onds$

Process Time of Operation6 = $15 \div 0.90 = 16.6 \sec onds$

Process Time of Operation7 = $10 \div 0.90 = 11.1 \sec onds$

Total cycle time of the subcontractor processes are equal to 116 seconds which is calculated as the summary of the each process times:

$TotalCycleTime:$

$$9.6\sec + 17.78\sec + 17.78\sec + 4.26\sec + 31.1\sec + 7.8\sec + 16.6\sec + 11.1\sec = 116\sec$$

Next step is the counting of work in processes between the operations. As described before work in process (WIP) is the inventory between the start and end points of a product routing. There are eight levels of work in process inventories which are shown in detailed different locations between the operations in our subcontractor current state value stream map. Starting from the beginning of the process 'the subcontractor assembly inventory' stock quantities are counted and written to the current state map later to be converted into inventory times.

The inventory time calculation formula is below:

Inventory Time (minutes)= Work in Process inventory quantity $\times$ Process Time $\div 60$

At the end of the formula by dividing the Inventory time to 60, it is written in the current state map in minutes. All of the eight work in process inventories are converted into inventory times in minutes to calculate the process lead time .

In the first stock of work in process inventory with the subcontractor assembly inventory, the stock qauntities, it is calculated as the average stock of 65640 pc of stock in front of the control&distribution operation. So the 65640 pc of inventory is calculated for inventory times as follows by using the first operation 'control&distribution' process time:

Inventory Time1= $65640 \times 9.6 \div 60 = 10502 \min utes$

The next inventory time is calculated by using the next work in process inventory, the 36000 pc of stock waiting in front of the operation1. So the 36000 pc of inventory is calculated for inventory times as follows by using the next operation 'operation1':

Inventory Time2= $36000 \times 17.78 \div 60 = 10668$ minutes

The inventory time3 is calculated as follows by using the stock of 2868 pc before the operation2:

Inventory Time3= $2868 \times 17.78 \div 60 = 849.8$ minutes

For the other work in process inventories here in formulas the inventory times are calculated:

Inventory Time4= $989 \times 4.26 \div 60 = 70$ minutes
Inventory Time5= $750 \times 31.1 \div 60 = 388$ minutes
Inventory Time6= $890 \times 7.8 \div 60 = 116$ minutes
Inventory Time7= $720 \times 16.6 \div 60 = 199$ minutes
Inventory Time8= $1336 \times 11.1 \div 60 = 247.2$ minutes

Total process lead time of the subcontractor processes are calculated as the summary of the inventory times and the process times:

$$Total\,\Pr ocessLeadTime(PLT):$$
$$9.6\sec + 17.78\sec + 17.78\sec + 4.26\sec + 31.1\sec + 7.8\sec + 16.6\sec + 11.1\sec + 10502\min$$
$$+ 10668\min + 849.8\min + 70\min + 388\min + 116\min + 199\min + 247.2\min = 23.042\min$$
$$= 384 hours = 16 days$$

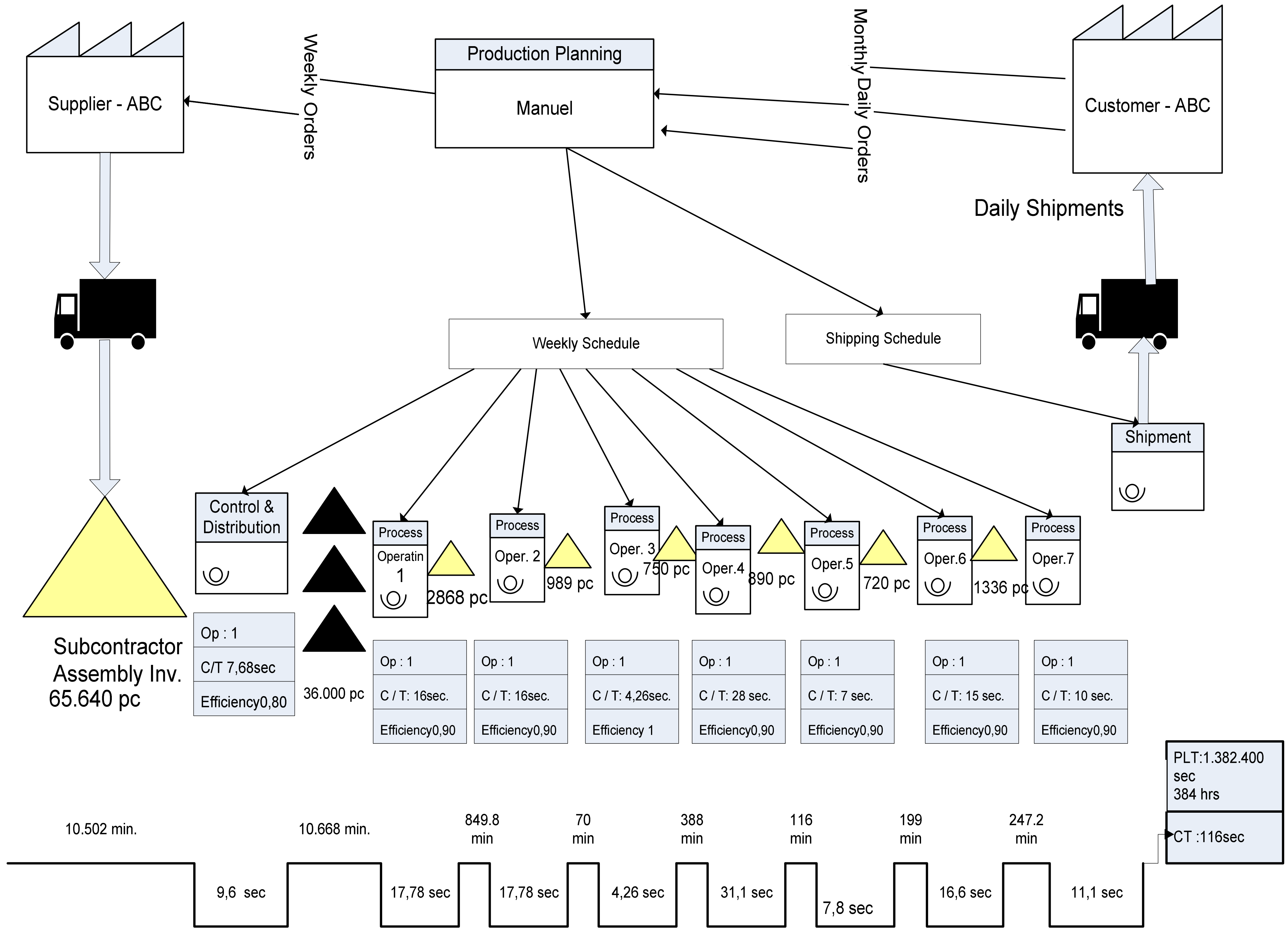


Figure 4.10 Subcontractor current state map

4.4.3 Extended Value Stream Map

In this part in order to see the whole picture we combine the value stream maps that we have already drew both for injection factory operations and the vendor of subcontractor detailled operations. In Figure4.11 there is the extended value stream map of the whole picture.

Seeing the whole map will help us to find the improvement opportunities in the supply chain not only in the production factory.

As we have seen in the injection current state map, no operations were greater than the desired takt time, but still the total process lead time was too long to meet the customer orders on time.

So it is absolutely certain that the ABC company can not decrease the total lead time of X1 product (so the XYZ product family) without decreasing the inventory levels in the whole supply chain which actually increasing at the current state the total process lead time.

The extended value stream map in Figure4.11 will be used to identify the improvement opportunities in the supply chain.

In Figure4.11 there is the extended value stream map inculing all the operations of both the injection process operations and the subcontractor operations.

We can see the whole picture in the extended value stream map for the X1 product starting from raw material to the end process of shipment.

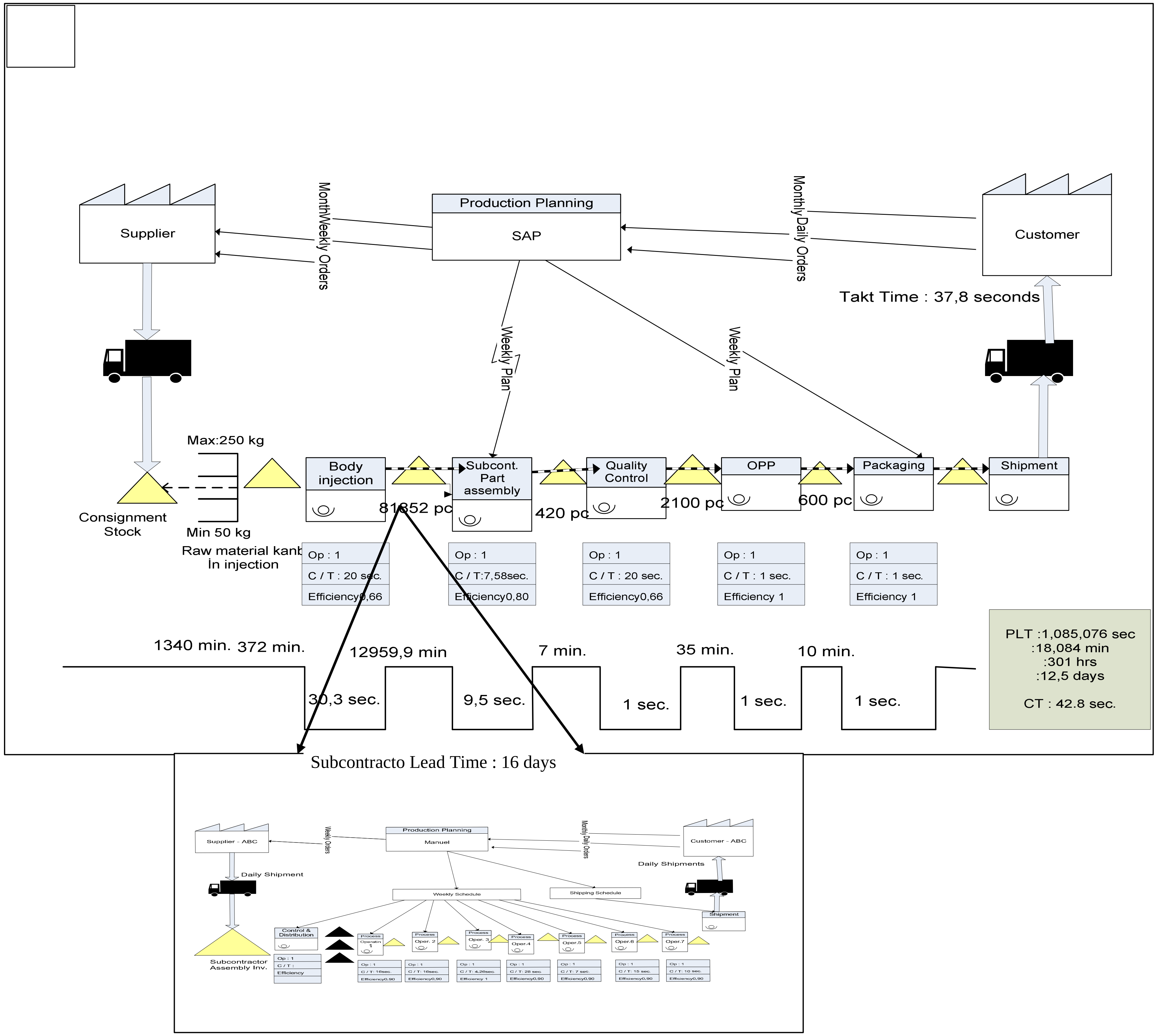


Figure 4.11 Extended value stream map

4.5 Improve

4.5.1 Types of Wastes Identified & Improvement Opportunities

Improvement opportunities in the current state map are the circulled in red lines below the map with the most inventory levels which are effective in the increasing parameters of total process time.

4.5.2 Kanban Application with Subcontractor

The first improvement opportunity as clearly shown in the extended value stream mapping is the high inventory level kept in front of the ‘subcontractor part assembly’ operation with 81852 pc on average inventory quantity which is equal to 12959 minutes.

The top inventory waiting time with 12959 minutes equal to 8.9 days makes up the most of the total lead time of 12.5 days. Then when we improve this excess inventory in this part we will expect the total lead time to decrease as well according to the decreasion of parts waiting to be come from subcontractors.

Kanban is the best solution to apply with the subcontractor to manage the flow of materials in this inventory area.

The Japanese word ‘kanban’ means card, ticket, sign, or signboard. Kanban originated from the Toyata producton system as a tool for managing the flow of production and materials in a JIT ‘’pull’’ production process.

In Figure 4.12 we can see the kanban application opportunity in the extended value stream map for improvement opportunities.

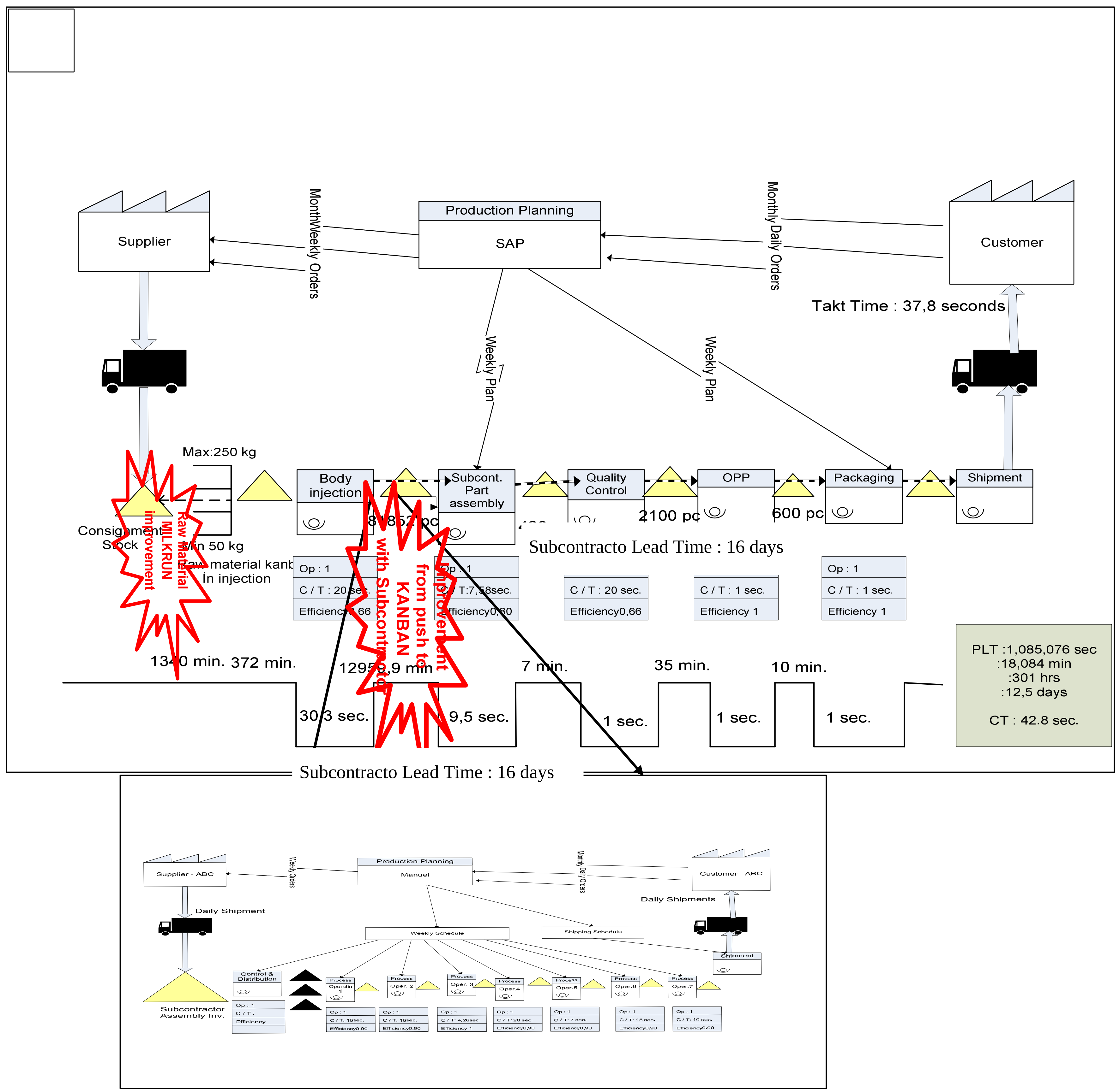


Figure 4.12 Improvement Opportunities

We will adapt a kanban system for pull production to make more parts only when the next process withdraws parts.-in effect pulling the parts from the earlier process when needed. In our case we will use the kanban as the pull system in which work centers signal with a card that they wish to withdraw parts from feeding suppliers. In this kanban application we will pull the materials from external suppliers, which is exactly the subcontractor into our inventory area before the subcontractor assembly operation.

In the supplier kanban application, the supplier which is in this case study the subcontractor that feeds the material from outside, is required to provide materials in the right quantity within a designated lead time.

Kanban quantity is calculated for product A, for the application of the kanban system between the subcontractor and the injection factory. Kanban quantities are calculated according to Replenishment Pull System rules.

The replenishment pull system parameters are set in the case study as below: The parameters are set by the help of ‘’Optimal numbers of two kinds of kanbans in a JIT production system’’ (Ohno K.,Nakashime K.&Kojima M.,1995) book we summarised as below:

Demand (D) : Average daily or weekly consumption (or demand).

Process Lead Time (PLT) : The lead time of the supplier to replenish the parts.

Cycle Time Interval : The frequency of parts consumed in production.

Safety Stock : Defines the inventory quantity as the buffer for demand deviation, quality problems and machine breakdowns.

As it is shown in the takt time calculation the weekly average demand for product X1 is 12425 pc. Here in Figure 4.13 there are weekly demands for last 50 weeks: The weekly demand quantities are attached in the appendix of the thesis.

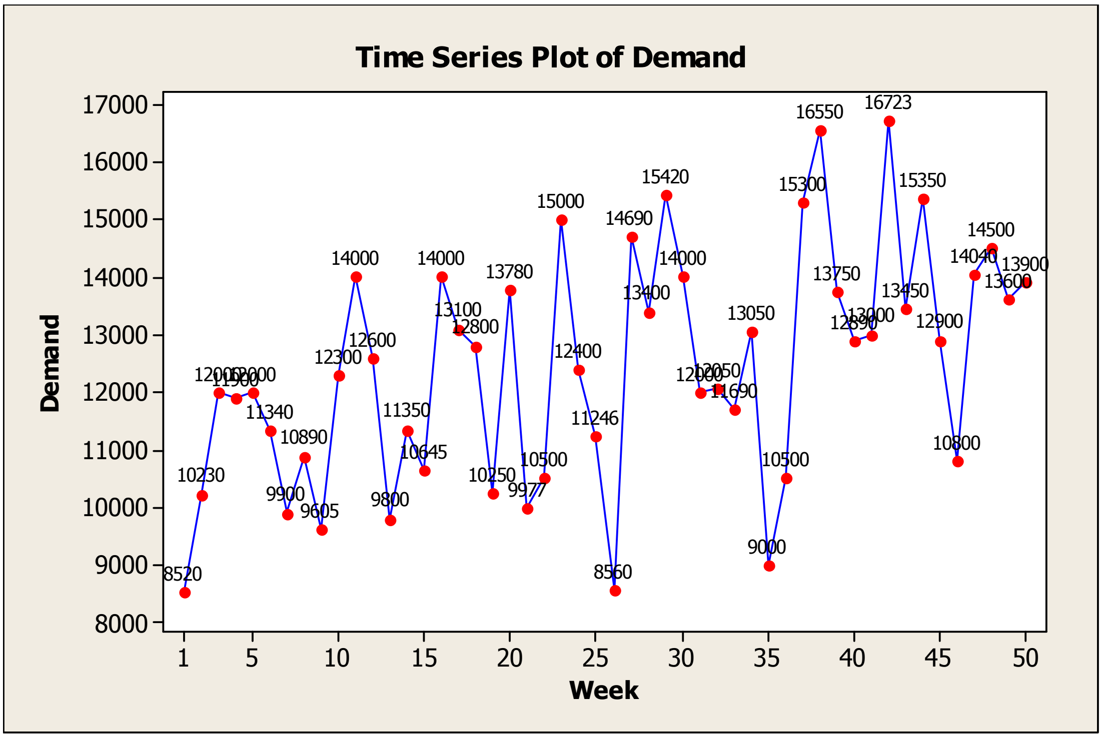


Figure 4.13 Time series anaysis of average weekly demand for X1 product.

PLT (process lead time) of the supplier as analysed in detail in the extended value stream map is 16 days which is equal to 2.3 weeks.

Cycle time interval is calculated with the formula:

$$\text{CTI} = \textit{Lotsize} \times \textit{Efficiency} \div \textit{Demand}$$

In our case 'lot size' is the number of pieces that one container carries for subcontractor parts, because the ABC company uses standart containers for all types of materials and parts that supplied from all vendors and subcontrators. Then each order sent to subcontractors must be the multiple of one container lot size.

For our product X1, the number of pieces that one container includes is 10000 pc for the subcontractos parts. The efficiency is known in our case as %95. The detailled calculation is attached in the appendix. And the average weekly demand is 12425 pc which is equal to 2070 pc daily demand (as six working days in a week).

CTI = $10000 \times 0.95 \div 2070 = 4.58 days$

Safety Stock is calculated as the formula below:

Safety Stock = $\sigma \times ServiceLevel \times (\Pr ocessLeadTime)' \beta$

In our case for σ value of weekly demand we use Minitab tool, the result is as follows:

Descriptive Statistics: Demand

Variable	Mean	StDev
Demand	12425	2009

So we will use 2009 pc standart deviation for ‘σ’. Servise level is generally used in the ABC company for its type of production as ‘2’. Procsess lead time is 16 days which is equal to 2.6 weeks for subcontracting parts average arrivals.

β is the on time delivery performance of the subcontractor which is calculated for the subcontractor as %70,that is β is 0.7 in the case as well.

Safety Stock = $2009\,pc/week \times 2 \times (2.6 weeks)'0.7$

Safety Stock = 7843 pc

For the subcontractor parts of X1 product we calculated all the necessary parameters to apply the ‘’kanban minimum’’ and ‘’kanban maximum’’ quantities. Then our main formula to define the ‘’kanban minimum quantity for X1 subcontracting part’’ is:

Kanban Minimum Quantity = $SafetyStock + PLT \times D$

Kanban Minimum Quantity = 7843 pc + 2,6weeks$\times$12425pc

Kanban Minimum Quantity = 40148 pc

Kanban Max. Quantity is calculated as summing up the Kanban Minimum Quantity with cycle time interval quantity. Here is the formula we define:

Kanban Maximum Quantity = $KanbanMinimumQuantity + CTI \times D$

Kanban Maximum Quantity = 40148 + 4.58days$\times$2070pc/day

Kanban Maximum Quantity = 49628 pc

The container size for each kanban box is set to 2500 pc, which means there will be a kanban board in the injection factory in front of the operation ‘’subcontractor part assembly’’. For minimum kanban quantity 40148 pc it is rounded to 40000 pc and 40000 pc / 2500 =16 boxes of minimum kanban box is set. For maximum kanban quantity 49628 pc is rounded up to 50000 pc max. Kanban quantity and 50.000 / 2500 = 20 kanban boxes for maximum kanban box is set.

After the kanban application between the subcontractor and the injection factory – the assembly operation, whenever the assembly operation consumes one box of subcontractor part an automatic order (which is a kanban signal) arrives to the subcontractor. And as soon as subcontractor gets the kanban signal they prepare for the shipment for the required number of boxes. The subcontractor always has the buffer stock of parts ready for shipment enough to feed the minimum kanban requirements.

The average inventory in front of the 'subcontractor part assembly operation' after the kanban application is:

$$AverageWIP = MinimumKanbanQuantity + (MaximumKanbanQuantity - MinimumKanbanQuantity) / 2$$

AverageWIP = 40000 + (50000 – 40000)/2

AverageWIP = 45000 pc

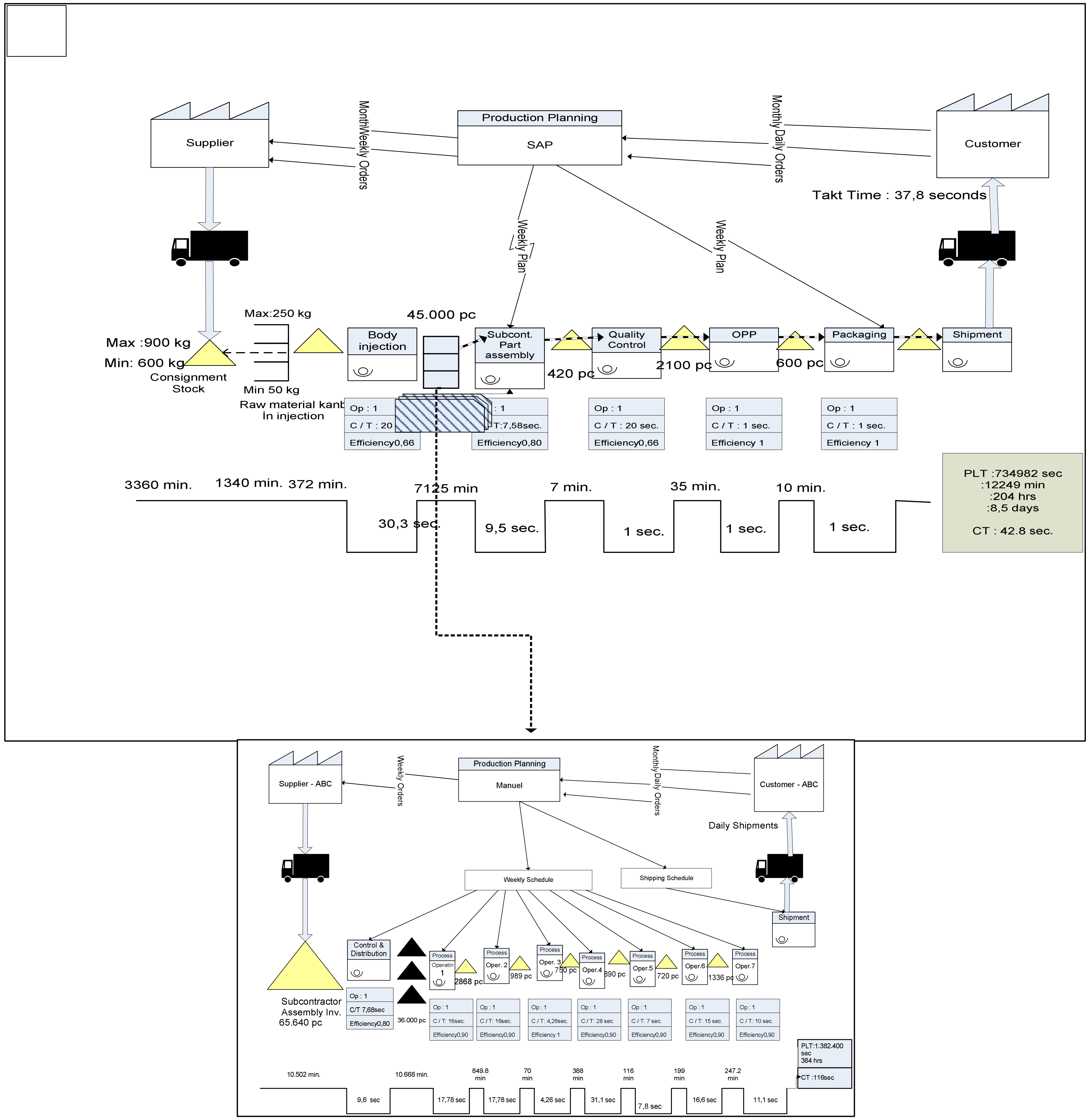


Figure 4.14 Withdrawal kanban application with the subcontractor

4.5.3 Milkrun Application with Raw Material Vendor

In the current state map of extended value stream mapping the other improvement opportunity has been identified with the second higher inventory time which was at the beggining of the process but had a noticeable effect on the total lead time of 12.5 days. It was the raw material stock which has been observed 3360 minutes effect in lead time with average 750 kg raw material inventory on hand.

Until the raw material is processed in the ‘body injection operation’ it is seen in the current state map that the same raw material is kept as inventory in three different locations. So all the inventory locations are the candidates for incereasing the non value added times.

For decreasing the raw material inventories an improvement in the supplier delivery frequencies needed to be applied. When users of eVSM try to reduce excessive inventories it is often related to increased frequency of deliveries.

Higher frequency of deliveries results in smaller transportation batches, however it might lead to higher transportation cost. This will be the case if the delivery frequency is increased without redesigning of transportation routes.

Jones and Womack(2002) suggest taking advantages of optimizing transportation with "milk runs". As Baudin M.(1989) claims "a supplier milk run is a scheduled pickup of parts from multiple suppliers in matching quantities. Milk run idea is depicted in the Figure 4.15.

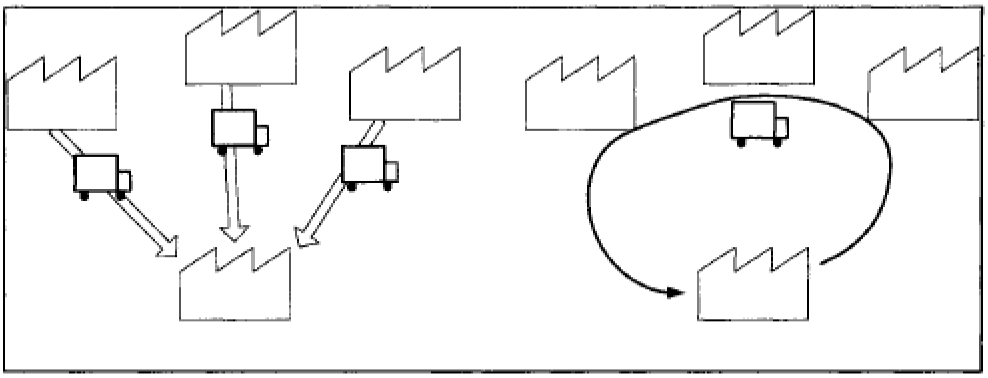


Figure 4.15 The concept of milkrun versus direct shipment.

The JIT concept requires frequent deliveries with small amounts of products, which increases transportation costs dramatically if vehicles are dispatched frequently and half empty every time.

The milkrun is developed to realize JIT delivery without adding significant cost. The approach uses “a routing of a supply or delivery vehicle to make multiple pickups or drop-offs at different locations” in the article Cooperation of Lean Enterprises - Techniques used for Lean Supply Chain (Eisler M., Horbal R., Koch T.,2007). It is commonly applied within and among lean manufacturing facilities to facilitate JIT production and can also be implemented by chain members within a closer range.

Using the milk run, a mixloading truck picks up and/or drops off goods at every stop like a city bus, where the loads are carefully scheduled to maintain leveled production at every facility. It can reduce inventory, facilitate predictable replenishment lead times, provide better inventory visibility, and improve supplier communication, Baudin(2004). However, the applicability is limited when the demand fluctuates significantly, the quantity is too large for mix-loading, or simply when the distance is too far to be effective.

In our case study a milkrun application is used with 7 vendors of the ABC company. One of these 7 vendors was chosen the X1 product’s raw material supplier.

It is chosen with the aim of improving the inventory levels of raw material which is held in the injection factory.

The application steps of Milkrun project is below listed:

1. Vendors to work with Milkrun deliveries are selected.

   1.1. Most frequently consumed materials are first selected.
   1.2. Vendors of most frequently consumed materials are defined.
   1.3. Vendors selected with the most frequent materials are this time arranged according to their geographical locations.
   1.4. Vendors in the same location are chosen.

2. Truck organization is designed.

   2.1. Truck capacity for the most frequent vendors in the same location is analysed.
   2.2. Truck frequency is decided according to production demand and lot sizes.
   2.3. The logistic organization company is selected for truck allocation.
   2.4. Information with the vendors and the carrying logistic organization truck responsible is organized.

3. Material scheduling plans are established.

   3.1. Fixed milkrun schedules are defined for each material.

Milkrun truck frequency is set to ‘two times in a week’. By taking into consideration average weekly demand of X1 product with the Milkrun supply frequency average raw material inventory is 705 kg . When it is converted to ‘’pc’’ using the bill of material it is nearly 6255 pc.

6255 pc of material is converted into work-in-process time with the following equation:

Inventory Time = $6255 \times 30.3 \div 60 = 3158 \min$

The average raw material just before the injection machine is the same with the current state which is equal to 736 pc, and the average raw material inventory in the warehouse is equal to 5519 pc. It is shown in the map in Fıgure4.16 the inventory times of raw material after the Milkrun application with the twice in a week supply frequency.

The total lead time effect after the Milkrun application and the inventory levels of raw material with the Milkrun system adaptation to our process case is shown in the map in Figure4.16 in the next page.

The total lead time is decreased to 11.2 days from the current state 12.5 days. Then the effect of Milkrun is 1.3 days decrease in the total lead time by the help of more frequent shipments which decreases the average raw material inventory.

In Figure4.16 there is the mlkrun application value stream map of our case study. We can see the milkrun effect clearly on the lead time in Figure4.16. The milkrun is applied with the raw material vendors and it is seen in the Figure4.16 as the seven suppliers in bold in the value stream map below:

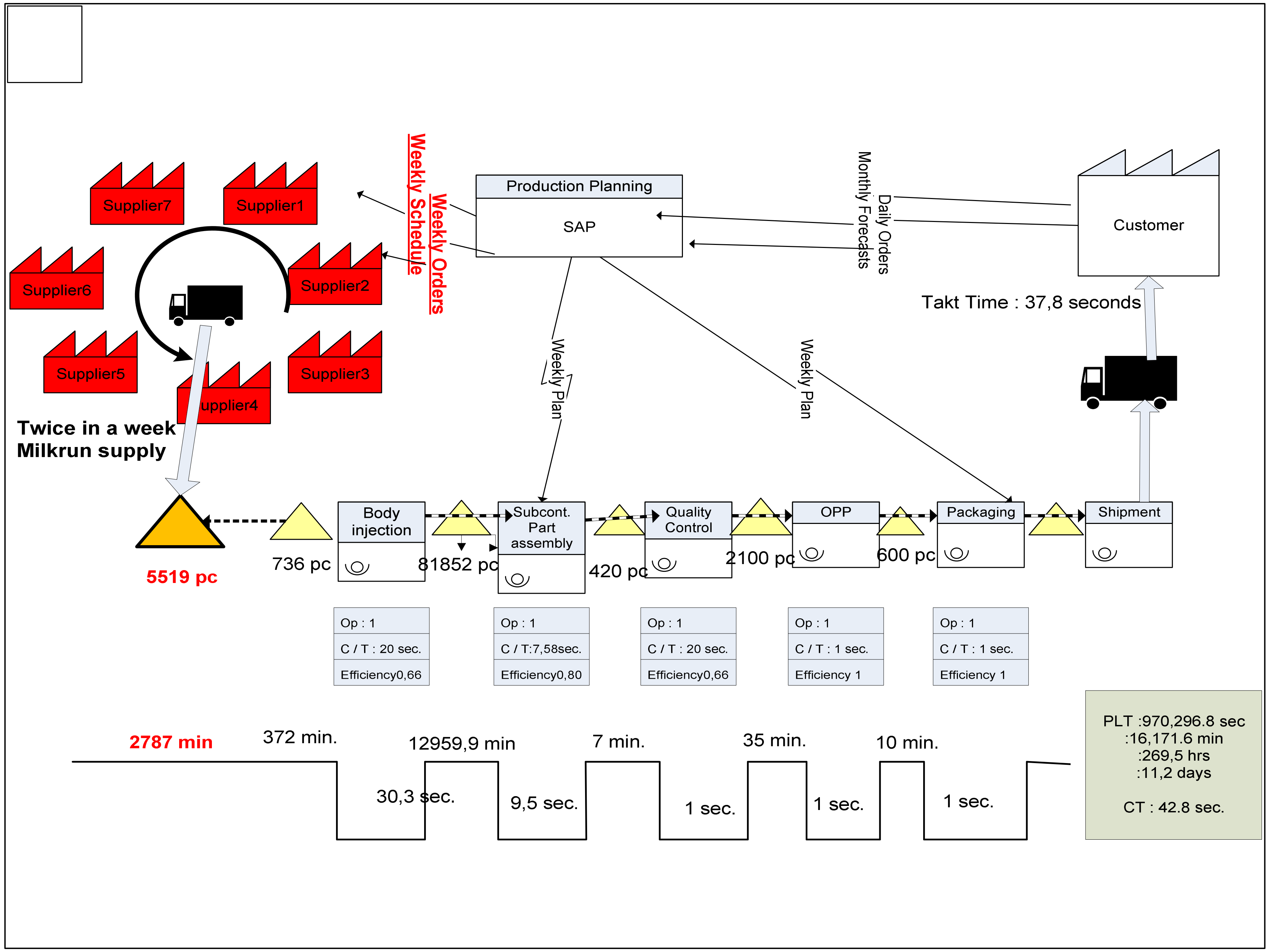


Figure 4.16 Milkrun effect on the lead time

4.5.4 Future State Map

After the improvement actions are adapted into system succsessfully the future state is started to be drawn. There are two main improvement actions carried on which is first ‘kanban with the subcontractor vendor’ and the second ‘Milkrun with raw material vendor’. We have seen the individual results of both applications in the improvement phase. Now to see the real case of future state we are combining the two applications in the future state map which is shown in Figure4.17.

The improvement applications are colored in red in the future state map in Fıgure4.17. Total Lead Time in the future state is equal to ‘7.1 days’. It is calculated by the sum of Inventory Times and process times. Here below we explain all the values that compose the total lead time of ‘7.1 days’.

Inventory times in the future state are calculated by using the average inventory quantities in each inventory kept areas after the improvement actions. The first inventory hold as seen in the future state map in Figure4.17 is the raw material inventory that is hold in warehouse and in front of the injection machine. After the Milkrun applications, the Milkrun truck started to deliver the raw material to the ABC factory twice in a week by touring the 7 vendors one of which is the raw material supplier of the X1 product. Then the quantities of each Milkrun shipment for X1 products raw material is decided accordng to the average weekly demand of X1, so is is observed that the average inventory of raw material is almost equal to half weeks demand quantity. After the Kanban application with the subcontractor the average inventory of subcontractor part is 45000 pc which is shown in the future state map in Figure4.17.

Total Inventory Times = $2787 + 372 + 7125 + 7 + 35 + 10 = 10336 \min$

Total Process Times = $30.3 + 9.5 + 1 + 1 + 1 = 42.8 \sec$

As a result when we sum the inventory times and the process times, $10336 \times 60 + 42.8 = 620202.8 \sec = 10.33 \min = 172.2 hrs = 7.1 days$

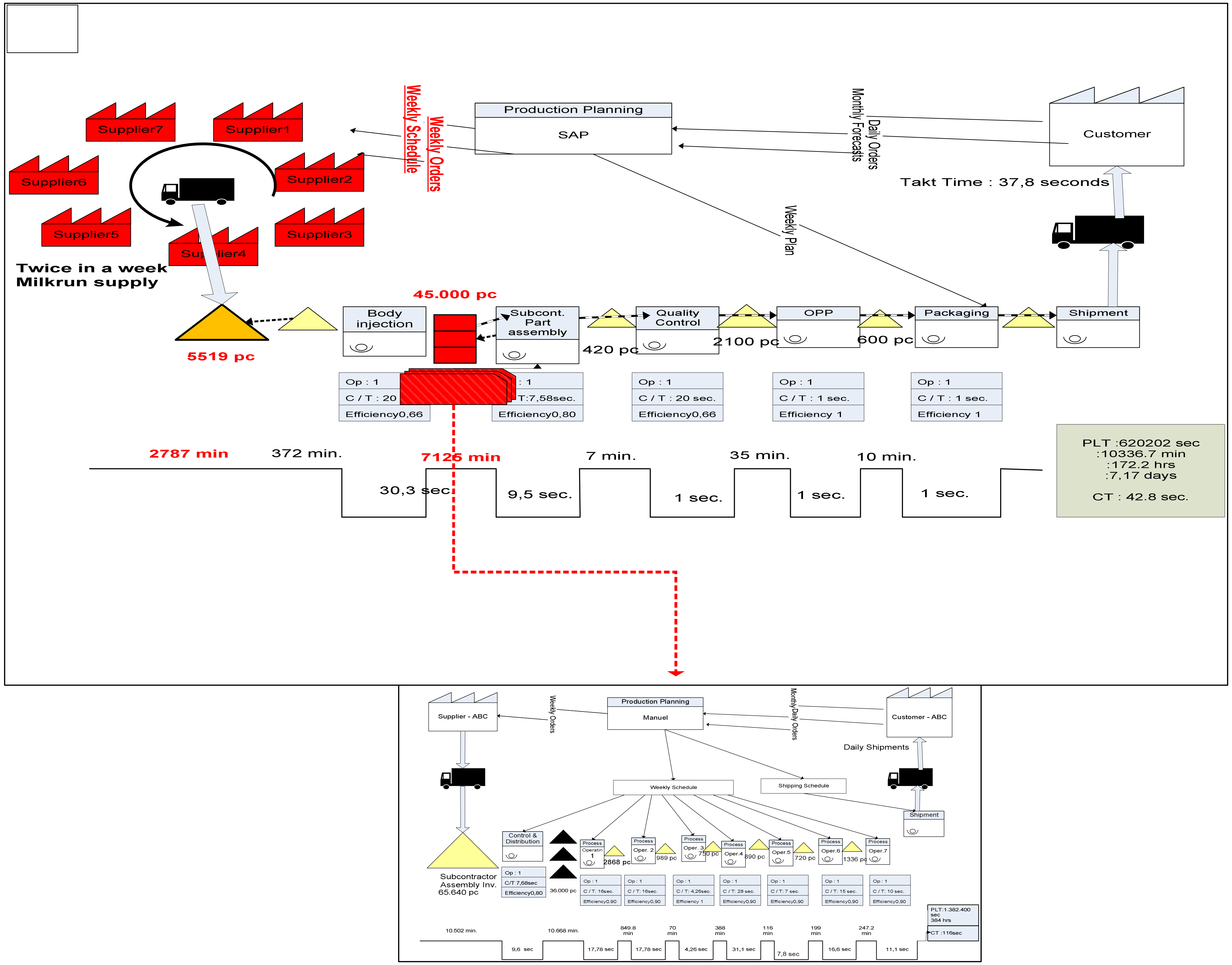


Figure 4.17 Future state map

4.6 Control

4.6.1 Results

The future state results for the critical to quality indicators which are ‘total lead time’, ‘inventory’ and ‘on time delivery performance’ are compared with the previous current state.

Table4.4 shows the lead time reduction with the seperate effects of each improvement solutions and the total lead time effect of both two improvement actions together which makes the future state. As it is clearly seen in the Table 4.4 from 12.5 days we reach the 7.1 days of lead time by using the effective lean tool extended value stream map in the methodology of six sigma DMAIC problem solving approach.

Table 4.4 Lead time reduction

	Before (Current State)	After Mil*krun*	After Kanban	After Kanban+Milkrun
Total Lead Time (days)	12,5	11,2	8,5	7,1
Lead Time Reduction (%)		10,4%	32,0%	43,2%

Table4.5 shows the inventory reduction in ‘pc’ with the seperate effects of each improvement solutions and the total inventory effect of both two improvement actions together which makes the future state. As a result 42.8 percent of inventories are decreased in the future state compared with the previous state. It is an important indicator for the companies especially if the factory does not have enough space to allocate the large amount of inventories on hand. That means the physical inventory reduction also brings in the company free space for location.

Table 4.5 Inventory reduction

	Before (Current State)	After Mil*krun*	After Kanban	After Kanban+Milkrun
Total Inventory (pc)	95014	91227	58162	54375
Inventory Reduction (%)		4,0%	38,8%	42,8%

On time delivery performance is increased to % 97 on average in the first 7 months observed after the improvements. The values of service rate performance results are shown in the MINITAB grapic of Figure 4.18.

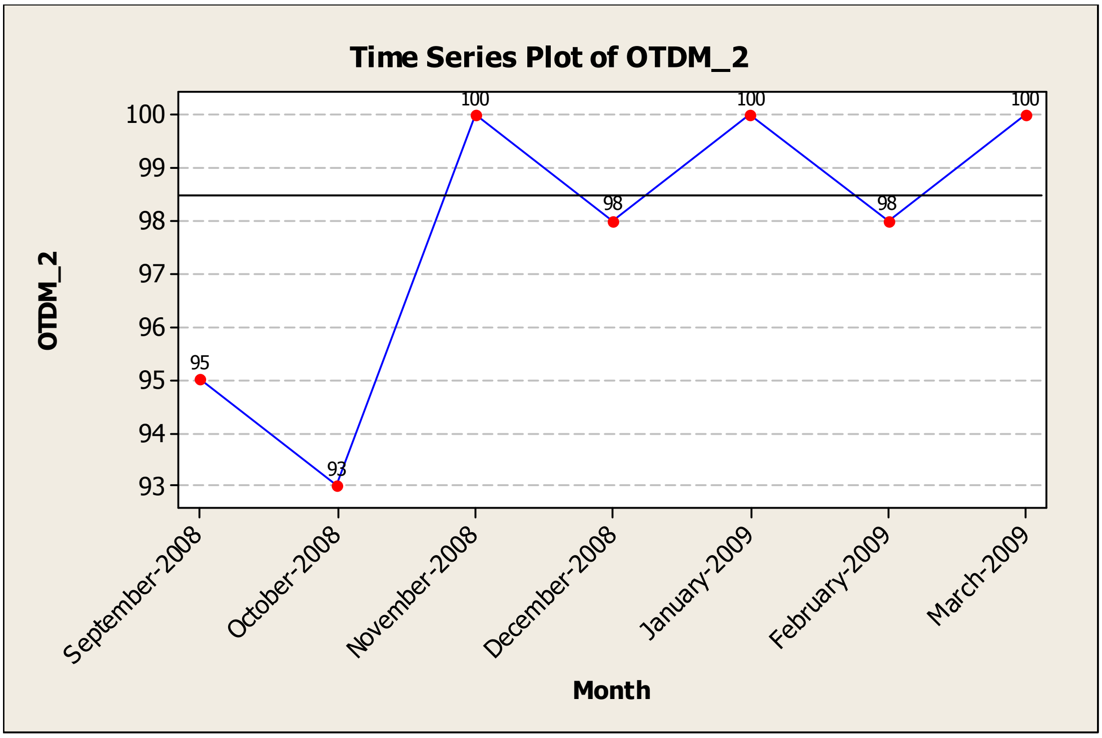


Figure 4.18 OTDM average after the improvements

CHAPTER FIVE

CONCLUSION

5.1 Conclusion and Future Research

This study introduces the usage of an effective lean tool 'extended value stream mapping' in the DMAIC problem solving approach in six sigma methodology. Lean and the six sigma concepts are combined to find the optimum solutions for the problems by using the proper tools of each methodology.

The literature of lean idea is explained in the study. Value stream mapping which is a lean tool is described in detail and its application areas are referenced in some article examples. The necessities to enhance the value stream map with the suppliers which results in the usage of extended value stream map are explained. A case study is also presented with the results of total lead time reduction and on time delivery increase of a product family using the extended value stream mapping tool. In the case study it is obviously shown that with a systematic problem solving approach such as DMAIC used in this case study, the most important points that must be focused on in a problem can easily be detected. The effectiveness of extended value stream mapping tool is indicated with its complete feature that sees the whole picture of processes starting from raw material supplier to the end customer.

Significant improvements are observed in the critical to quality indicators such as lead time, on time delivery measurements and inventory quantities after implementation of the extended value stream map. OTDM increased to %97 from %74 after the improvement actions. %42.8 total inventory reduction is observed. %43.2 lead time reduction is provided. Collaboration with the suppliers showed improvements also in the main companies key performance indicators.

The study also indicated a successful implemantation of intagrated framework for Lean and Six Sigma approaches. The integration of these two systems showed greater benefits yielded in a faster way and achieved much better results than either system can achieve alone.

For future research we propose to use the simulation method in the implemantation of extended value stream mapping. By the help of simulation technique different parameters such as cycle time of the operations, inventory values, kanban quantities..etc can be changed at the same time and the effects of each change could be seen and compared immediately. Alternative future states can be drawn in a short time easily with the simulation tool. Also with high variety types of products simulation teqnique can be a supporting tool for drawing the current and future states of more than one types of products in a noticably short time rather than as traditional ‘paper and pencil’ VSM teqnique.

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APPENDIX

The efficiency calculation table for body injection

DAY	OPERATION NAME	PLANNED QUANTITY	REALIZED QUANTITY	EFFICIENCY
01.01.2008	Body Injection Operation	7120	6.580	92%
02.01.2008	Body Injection Operation	544	330	61%
03.01.2008	Body Injection Operation	9600	6.600	69%
04.01.2008	Body Injection Operation	7533	4.395	58%
05.01.2008	Body Injection Operation	1160	340	29%
06.01.2008	Body Injection Operation	6000	4.340	72%
07.01.2008	Body Injection Operation	5440	4.142	76%
08.01.2008	Body Injection Operation	5090	4.080	80%
09.01.2008	Body Injection Operation	12816	5.718	45%
10.01.2008	Body Injection Operation	9760	4.567	47%
11.01.2008	Body Injection Operation	9760	9.765	100%
12.01.2008	Body Injection Operation	1149	800	70%
13.01.2008	Body Injection Operation	1560	1.200	77%
14.01.2008	Body Injection Operation	520	452	87%
15.01.2008	Body Injection Operation	1200	952	79%
16.01.2008	Body Injection Operation	24192	17.412	72%
17.01.2008	Body Injection Operation	776	600	77%
18.01.2008	Body Injection Operation	3909	3.123	80%
19.01.2008	Body Injection Operation	78720	43.956	56%
20.01.2008	Body Injection Operation	6339	3.738	59%
21.01.2008	Body Injection Operation	12508	6.754	54%
22.01.2008	Body Injection Operation	14700	3.456	24%
23.01.2008	Body Injection Operation	33764	21.700	64%
24.01.2008	Body Injection Operation	21360	3.658	17%
25.01.2008	Body Injection Operation	3720	2.564	69%
26.01.2008	Body Injection Operation	1380	322	23%
27.01.2008	Body Injection Operation	1090	670	61%
28.01.2008	Body Injection Operation	373	170	46%
29.01.2008	Body Injection Operation	23	16	69%
30.01.2008	Body Injection Operation	8057	5.098	63%
31.01.2008	Body Injection Operation	263	147	56%
01.02.2008	Body Injection Operation	503	482	96%
02.02.2008	Body Injection Operation	1563	880	56%
03.02.2008	Body Injection Operation	1246	1.064	85%
04.02.2008	Body Injection Operation	112	86	77%
05.02.2008	Body Injection Operation	720	200	28%
06.02.2008	Body Injection Operation	630	500	79%

07.02.2008	Body Injection Operation	1440	1.050	73%
08.02.2008	Body Injection Operation	9600	9.000	94%
09.02.2008	Body Injection Operation	1644	1.000	61%
10.02.2008	Body Injection Operation	1580	1.380	87%
11.02.2008	Body Injection Operation	37080	35.000	94%
12.02.2008	Body Injection Operation	10640	6.450	61%
13.02.2008	Body Injection Operation	1560	1.200	77%
14.02.2008	Body Injection Operation	1200	952	79%
15.02.2008	Body Injection Operation	215423	121.624	56%
16.02.2008	Body Injection Operation	720	611	85%
17.02.2008	Body Injection Operation	1246	398	32%
18.02.2008	Body Injection Operation	520	452	87%
19.02.2008	Body Injection Operation	1580	1.380	87%
20.02.2008	Body Injection Operation	7120	6.580	92%
21.02.2008	Body Injection Operation	503	300	60%
22.02.2008	Body Injection Operation	1160	456	39%
23.02.2008	Body Injection Operation	630	400	63%
24.02.2008	Body Injection Operation	1149	500	44%
25.02.2008	Body Injection Operation	1644	1.400	85%
26.02.2008	Body Injection Operation	23	16	69%
27.02.2008	Body Injection Operation	24192	17.412	72%
28.02.2008	Body Injection Operation	6000	4.340	72%
29.02.2008	Body Injection Operation	1440	1.050	73%
01.03.2008	Body Injection Operation	112	86	77%
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03.03.2008	Body Injection Operation	12816	5.718	45%
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21.03.2008	Body Injection Operation	33764	21.700	64%

22.03.2008	Body Injection Operation	9600	6.600	69%
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24.03.2008	Body Injection Operation	23	16	69%
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26.03.2008	Body Injection Operation	6000	4.340	72%
27.03.2008	Body Injection Operation	1440	1.050	73%
28.03.2008	Body Injection Operation	112	86	77%
29.03.2008	Body Injection Operation	1560	1.200	77%
30.03.2008	Body Injection Operation	1200	952	79%
31.03.2008	Body Injection Operation	9600	6.600	69%
			EFFICIENCY	
			Average	**66%**

The efficiency rate of seed assembly with body operation

DAY	OPERATION NAME	PLANNED QUANTITY	REALIZED QUANTITY	EFFICIENCY
01.01.2008	Seed Assembly with Body	6408	4.000	62%
02.01.2008	Seed Assembly with Body	6408	5.678	89%
03.01.2008	Seed Assembly with Body	23040	23.000	100%
04.01.2008	Seed Assembly with Body	10560	8.900	84%
05.01.2008	Seed Assembly with Body	280	134	48%
06.01.2008	Seed Assembly with Body	2160	1.720	80%
07.01.2008	Seed Assembly with Body	82800	61.080	74%
08.01.2008	Seed Assembly with Body	6480	6.796	105%
09.01.2008	Seed Assembly with Body	19752	5.300	27%
10.01.2008	Seed Assembly with Body	13824	9.728	70%
11.01.2008	Seed Assembly with Body	7848	6.054	77%
12.01.2008	Seed Assembly with Body	72960	48.375	66%
13.01.2008	Seed Assembly with Body	18000	4.532	25%
14.01.2008	Seed Assembly with Body	12240	12.593	103%
15.01.2008	Seed Assembly with Body	7618	7.794	102%
16.01.2008	Seed Assembly with Body	46080	48.520	105%
17.01.2008	Seed Assembly with Body	69120	77.640	112%
18.01.2008	Seed Assembly with Body	26184	13.944	53%
19.01.2008	Seed Assembly with Body	2088	2.008	96%
20.01.2008	Seed Assembly with Body	552	300	54%
21.01.2008	Seed Assembly with Body	10800	9.800	91%
22.01.2008	Seed Assembly with Body	1488	1.104	74%
23.01.2008	Seed Assembly with Body	43200	48.840	113%
24.01.2008	Seed Assembly with Body	46080	43.000	93%

25.01.2008	Seed Assembly with Body	6912	5.643	82%
26.01.2008	Seed Assembly with Body	17900	12.866	72%
27.01.2008	Seed Assembly with Body	7848	6.878	88%
28.01.2008	Seed Assembly with Body	184320	128.925	70%
29.01.2008	Seed Assembly with Body	46080	52.125	113%
30.01.2008	Seed Assembly with Body	66960	80.460	120%
31.01.2008	Seed Assembly with Body	26184	24.000	92%
01.02.2008	Seed Assembly with Body	1368	890	65%
02.02.2008	Seed Assembly with Body	5760	1.312	23%
03.02.2008	Seed Assembly with Body	3600	2.280	63%
04.02.2008	Seed Assembly with Body	3296	2.280	69%
05.02.2008	Seed Assembly with Body	43200	51.160	118%
06.02.2008	Seed Assembly with Body	46080	45.000	98%
07.02.2008	Seed Assembly with Body	7680	7.500	98%
08.02.2008	Seed Assembly with Body	17900	16.990	95%
09.02.2008	Seed Assembly with Body	7848	6.738	86%
10.02.2008	Seed Assembly with Body	184320	141.600	77%
11.02.2008	Seed Assembly with Body	46080	50.895	110%
12.02.2008	Seed Assembly with Body	3728	3.200	86%
13.02.2008	Seed Assembly with Body	62640	35.421	57%
14.02.2008	Seed Assembly with Body	696	332	48%
15.02.2008	Seed Assembly with Body	43200	40.216	93%
16.02.2008	Seed Assembly with Body	12960	13.616	105%
17.02.2008	Seed Assembly with Body	2160	1.720	80%
18.02.2008	Seed Assembly with Body	82800	61.080	74%
19.02.2008	Seed Assembly with Body	6480	6.796	105%
20.02.2008	Seed Assembly with Body	19752	17.600	89%
21.02.2008	Seed Assembly with Body	13824	9.728	70%
22.02.2008	Seed Assembly with Body	7848	6.054	77%
23.02.2008	Seed Assembly with Body	72960	48.375	66%
24.02.2008	Seed Assembly with Body	18000	9.087	50%
25.02.2008	Seed Assembly with Body	12240	12.593	103%
26.02.2008	Seed Assembly with Body	7618	7.794	102%
27.02.2008	Seed Assembly with Body	46080	48.520	105%
28.02.2008	Seed Assembly with Body	69120	77.640	112%
29.02.2008	Seed Assembly with Body	26184	19.800	76%
01.03.2008	Seed Assembly with Body	2088	2.000	96%
02.03.2008	Seed Assembly with Body	8880	4.900	55%
03.03.2008	Seed Assembly with Body	1905	2.232	117%
04.03.2008	Seed Assembly with Body	55200	48.600	88%
05.03.2008	Seed Assembly with Body	7920	2.020	26%
06.03.2008	Seed Assembly with Body	3280	2.200	67%
07.03.2008	Seed Assembly with Body	9216	7.905	86%
08.03.2008	Seed Assembly with Body	2616	1.300	50%

09.03.2008	Seed Assembly with Body	11934	11.900	100%
10.03.2008	Seed Assembly with Body	10616	9.000	85%
11.03.2008	Seed Assembly with Body	2043	1.720	84%
12.03.2008	Seed Assembly with Body	16200	13.026	80%
13.03.2008	Seed Assembly with Body	2770	1.900	69%
14.03.2008	Seed Assembly with Body	11520	8.000	69%
15.03.2008	Seed Assembly with Body	7200	8.040	112%
16.03.2008	Seed Assembly with Body	92160	83.040	90%
17.03.2008	Seed Assembly with Body	46080	37.617	82%
18.03.2008	Seed Assembly with Body	69120	56.745	82%
19.03.2008	Seed Assembly with Body	26184	24.980	95%
20.03.2008	Seed Assembly with Body	2088	1.130	54%
21.03.2008	Seed Assembly with Body	10800	1.752	16%
22.03.2008	Seed Assembly with Body	69120	53.072	77%
23.03.2008	Seed Assembly with Body	2770	1.450	52%
24.03.2008	Seed Assembly with Body	11520	8.000	69%
25.03.2008	Seed Assembly with Body	7200	8.040	112%
26.03.2008	Seed Assembly with Body	92160	83.040	90%
27.03.2008	Seed Assembly with Body	46080	37.617	82%
28.03.2008	Seed Assembly with Body	69120	34.572	50%
29.03.2008	Seed Assembly with Body	26184	25.000	95%
30.03.2008	Seed Assembly with Body	2088	1.130	54%
31.03.2008	Seed Assembly with Body	16200	13.026	80%
			EFFICIENCY	
			Average	**80%**

The efficiency rate of control & distribution operation

DAY	OPERATION NAME	PLANNED QUANTITY	REALIZED QUANTITY	EFFICIENCY
01.01.2008	Control & Distribution	18432	12893	70%
02.01.2008	Control & Distribution	4608	5213	113%
03.01.2008	Control & Distribution	6696	8046	120%
04.01.2008	Control & Distribution	2618	2400	92%
05.01.2008	Control & Distribution	137	89	65%
06.01.2008	Control & Distribution	576	131	23%
07.01.2008	Control & Distribution	360	228	63%
08.01.2008	Control & Distribution	330	228	69%
09.01.2008	Control & Distribution	4320	5116	118%
10.01.2008	Control & Distribution	4608	4500	98%

11.01.2008	Control & Distribution	768	750	98%
12.01.2008	Control & Distribution	1790	1699	95%
13.01.2008	Control & Distribution	785	674	86%
14.01.2008	Control & Distribution	18432	14160	77%
15.01.2008	Control & Distribution	4608	5090	110%
16.01.2008	Control & Distribution	373	320	86%
17.01.2008	Control & Distribution	6264	3542	57%
18.01.2008	Control & Distribution	70	33	48%
19.01.2008	Control & Distribution	4320	4022	93%
20.01.2008	Control & Distribution	1296	1362	105%
21.01.2008	Control & Distribution	216	172	80%
22.01.2008	Control & Distribution	8280	6108	74%
23.01.2008	Control & Distribution	648	680	105%
24.01.2008	Control & Distribution	1975	1760	89%
25.01.2008	Control & Distribution	641	400	62%
26.01.2008	Control & Distribution	641	568	89%
27.01.2008	Control & Distribution	2304	2300	100%
28.01.2008	Control & Distribution	1056	890	84%
29.01.2008	Control & Distribution	28	13	48%
30.01.2008	Control & Distribution	216	172	80%
31.01.2008	Control & Distribution	8280	6108	74%
01.02.2008	Control & Distribution	648	680	105%
02.02.2008	Control & Distribution	1975	530	27%
03.02.2008	Control & Distribution	1382	973	70%
04.02.2008	Control & Distribution	785	605	77%
05.02.2008	Control & Distribution	7296	4838	66%
06.02.2008	Control & Distribution	1800	453	25%
07.02.2008	Control & Distribution	1224	1259	103%
08.02.2008	Control & Distribution	762	779	102%
09.02.2008	Control & Distribution	4608	4852	105%
10.02.2008	Control & Distribution	6912	7764	112%
11.02.2008	Control & Distribution	2618	1394	53%
12.02.2008	Control & Distribution	209	201	96%
13.02.2008	Control & Distribution	55	30	54%
14.02.2008	Control & Distribution	1080	980	91%
15.02.2008	Control & Distribution	149	110	74%
16.02.2008	Control & Distribution	4320	4884	113%
17.02.2008	Control & Distribution	4608	4300	93%
18.02.2008	Control & Distribution	691	564	82%
19.02.2008	Control & Distribution	1790	1287	72%
20.02.2008	Control & Distribution	785	688	88%
21.02.2008	Control & Distribution	1382	973	70%
22.02.2008	Control & Distribution	785	605	77%
23.02.2008	Control & Distribution	7296	4838	66%

24.02.2008	Control & Distribution	1800	909	50%
25.02.2008	Control & Distribution	1224	1259	103%
26.02.2008	Control & Distribution	762	779	102%
27.02.2008	Control & Distribution	4608	4852	105%
28.02.2008	Control & Distribution	6912	7764	112%
29.02.2008	Control & Distribution	2618	1980	76%
01.03.2008	Control & Distribution	209	200	96%
02.03.2008	Control & Distribution	888	490	55%
03.03.2008	Control & Distribution	191	223	117%
04.03.2008	Control & Distribution	5520	4860	88%
05.03.2008	Control & Distribution	792	202	26%
06.03.2008	Control & Distribution	328	220	67%
07.03.2008	Control & Distribution	922	791	86%
08.03.2008	Control & Distribution	262	130	50%
09.03.2008	Control & Distribution	1193	1190	100%
10.03.2008	Control & Distribution	1062	900	85%
11.03.2008	Control & Distribution	204	172	84%
12.03.2008	Control & Distribution	1620	1303	80%
13.03.2008	Control & Distribution	277	190	69%
14.03.2008	Control & Distribution	1152	800	69%
15.03.2008	Control & Distribution	720	804	112%
16.03.2008	Control & Distribution	9216	8304	90%
17.03.2008	Control & Distribution	4608	3762	82%
18.03.2008	Control & Distribution	6912	5675	82%
19.03.2008	Control & Distribution	2618	2498	95%
20.03.2008	Control & Distribution	209	113	54%
21.03.2008	Control & Distribution	1080	175	16%
22.03.2008	Control & Distribution	6912	5307	77%
23.03.2008	Control & Distribution	277	145	52%
24.03.2008	Control & Distribution	1152	800	69%
25.03.2008	Control & Distribution	720	804	112%
26.03.2008	Control & Distribution	9216	8304	90%
27.03.2008	Control & Distribution	4608	3762	82%
28.03.2008	Control & Distribution	6912	3457	50%
29.03.2008	Control & Distribution	2618	2500	95%
30.03.2008	Control & Distribution	209	113	54%
31.03.2008	Control & Distribution	1620	1303	80%
			EFFICIENCY	
			Average	**80%**