JÖNKÖPING UNIVERSITY
School of Engineering

PRODUCTION SYSTEM WASTE REDUCTION THROUGH VALUE STREAM MAPPING.

An Industrial Case Study

PAPER WITHIN *Production System*
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Abstract

The rapid rise in global population and market demands have mandated industries to introduce better and quality products to meet up their rushing needs. However, achieving such goals need optimal production system and robust strategies. Exploring in depth it can be visualized that most of the manufacturing set ups suffers losses or relatively lower benefits due to improper and high wastages. Hence it is very important for manufacturing industries to explore the techniques which help them to improve their production system. The key techniques from Lean Manufacturing (LM) such as Value Stream Mapping (VSM) and Ishikawa diagram were explored in this work for enhancing production capacity, reducing rework, reducing wastages and arriving to a well-defined optimal process flow which in turn help in achieving higher productivity. However, the implementation of Lean and Value stream mapping depends on the production scale and has its own significance to different manufacturing setup. With that motive, in this thesis work the emphasis was made on exploring VSM technique for better production optimization in manufacturing sector.

Key Words: Manufacturing process, Lean Manufacturing, techniques of lean manufacturing, Value stream mapping, VSM key challenges, wastage in manufacturing process, Material handling.

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1 Introduction

For any research or study a well-defined structured approach and research matter discussions play key role (Saunders, M, Lewis, P., Thornhill, A.., 2009). Introductory of a research helps audiences to understand research matter better and on a comprehensive way (Jenkins., 1995). Hence the structured discussion of research variables and its related constructs often plays vital role in any thesis work. With this motive, in this chapter introduced research objective, problem description, purpose and research questions, delimitations and thesis outline.

1.1 Background

The rapid rise in global population and market demands have mandated industries to introduce better and quality products to meet up their rushing needs. Most of the manufacturing set ups suffers losses or relatively lower benefits due to improper and high wastages. (Harrison, A., Hoek, R. v. & Skipworth, H, 2014)

In the last few years manufacturing sector has undergone dynamic changes in the below area (Boamah, 2014)

- Wastages
- Improper material handling
- Inefficient supply chain management

Under such circumstances improving production mechanism is of the paramount significance. Numerous approaches such as Lean manufacturing (LM), Value stream mapping (VSM) have been explored across industries to enhance production capacity and associated goals (Dues et al., 2013). In this relation, lean manufacturing concept can be of great significance. It can help reducing wastage generation, retaining high quality of products, competitive cost etc that as a result could help firms to achieve better gain (Rahman, A and Karim, A., 2013), such paradigm can be of great significance; however, their implementation in different manufacturing units having diverse products-lines/types and production scales varies significantly. On the other hand, lean approaches such as VSM has its own significances and efficiency to the different manufacturing set up (Rother, M., & Shook, J., 2003). However, VSM has emerged as one of the best lean approaches towards productivity optimization (Rother, M., & Shook, J., 2003). With this motive, in this thesis the emphasis is made on exploring efficiency of VSM for production or manufacturing sector including optimal material handling, resource utilization, waste management and to enable a proper material handling approach in unison with performance measurement. Implementing both these approaches will help industries, especially manufacturing industries to ensure higher productivity, less wastage, better market acquisition.

A brief description of these processes of the manufacturing industry has been provided in the next chapter (Chapter-2).

1.2 Problem description

In produce to order production system, the production depends on the demands. In most of the manufacturing industries if the demand is high the products are produced in fully automated hard tooling section and if the demand is low the products are produced on the soft tooling/semi-automated/manual labour section. Also, during the production, the flow of materials begins from raw materials area to the finished goods area. However, the prime issue hindering was the efficiency of process flow, the amount of waste production in terms of materials, workforce and utilization of machines. Hence, considering this as a significant problem here it has been aimed to optimize the production by reducing the waste incurred. In other word, the aim of the research conducted is to improve the production flow and material handling process by exploiting the VSM approach and encourage the industries to outperform their competitors and demonstrate significant modifications in their classical approaches in order to raise the bar of efficient production. The production logistics in SMEs face severe issues once the production system is producing high volumes of products. To achieve the objective of research, the following problems have been identified to be accomplished optimally.

- Design and implement an optimal production flow process using the concept of lean manufacturing.
- Facilitate reduction in waste generation using the technique of VSM to enhance the productivity levels.

1.3 Purpose and research questions

The baseline of key challenges associated with any manufacturing industry is lack of optimal production flow which occurs due to numerous reasons such as excess production of waste materials, lack of proper management of resources and materials etc. These challenges cause the industries to incur loss and eventually shutdown. (George, B.; Dann, P.; Trimmer, B., 2003). Considering these challenges as a motivation and aiming at enabling a proper management system at the organisations by optimizing different related constructs, in this research focus has been made on optimizing the production flow and streamlining the material handling process by implementing certain techniques in unison with value stream mapping, an approach for managing the production process in industries.

The purpose of conducting this study can be defined under certain specific objectives, which are given as follows:

- To explore efficiency of VSM in lean manufacturing processes for better production and waste management.
- To study VSM assisted lean manufacturing process for optimized production.
- To implement VSM concept to identify root causes influencing manufacturing productivity and losses and conceptualize and develop a production estimation for higher productivity and low loss.

Considering the purpose of conducting this study, some of the key research questions for which the current study intends to get suitable answers are given as follows:

RQ1. How can production logistics be improved for small or medium size enterprise to support high volume production?

The above RQ1 can be achieved by analysing material flow in all stations, identify and eliminate the activities which were not needed and by providing suggested changes in the existing process.

RQ2. How can the suggested improvements help in better resource utilization and to increase production?

The above RQ2 can be achieved by analysing the As -Is state production processes, using techniques from lean manufacturing and effective material handling the process.

1.4 Delimitations

It is imperative to mention that this case study is being conducted for Veer-O-Metals, an India based company located in Bangalore and specially dealing in metal fabrication. The analysis of production planning and material flow at veer-o-metals is limited to PVS-980 frame and its production station. Hence, considering this as a motivation here it has been aimed to perform in-depth quantitative and qualitative assessment and suggested the required improvements only for PVS-980 frame.

1.5 Outline

A brief outline of the presented thesis work is as follows

Chapter 1: Introduction

This chapter provides the details of the special significance on the need to conduct the study. Further the research problem, its purposes, aim research questions etc have been discussed. Additionally, delimitations and outline of the thesis has been presented.

Chapter 2: Literature Survey

This chapter introduces the methodology opted for this study. This section consists of a literature review, case study and triangulation, where it specifies the details of the procedures necessary for collecting the required data to structure and solve the problem.

Chapter 3: Method and implementation

This chapter introduces the methodology opted for this study. This section consists of a literature review, case study and triangulation, where it specifies the details of the procedures necessary for collecting the required data to structure and solve the problem.

Chapter 4: Finding and data analysis

This chapter presents a brief description of the findings and data analysis of this study by exploiting the data gathered. It incorporates literature review, case study and triangulation where it specifies the details of the procedures necessary for collecting the required data to structure and solve the problem.

Chapter 5: Discussion and Conclusion

In this chapter the research methods used, and the finding of this study have been discussed in context of existing literature. Additionally, a summary of the results obtained has also been provided.

2 Theoretical background

The primary focus of this chapter has been focused on discussing the processes and techniques associated with the manufacturing industries. Considering the overall research goal where it is intended to explore efficiency of VSM technique for lean manufacturing, understanding key constructs can be vital to make better contribution. In this section, the key variables such as different manufacturing processes, lean manufacturing, VSM in lean manufacturing, pertaining to the above stated terminologies were discussed.

2.1 Material Handling

Green, J. C., Lee, J. and Kozman, T. A., (2010) defined material handling as movement of materials and it includes many parameters such as utility, storage etc. Myers, F.E. and Stephens, M.P., (2000) stated that for the successful completion of the manufacturing process it is necessary to have material handling even though it does not add any value during production. Material handling helps by making production flow possible, as it activates elements that are in static such as raw materials, equipment, human resources. Products and layout (Stock, J. R., Lambert, D. M, 2001; Chopra, S. and Meindl, P, 2001).

According to Childe, (2003), resources at manufacturing facilities must be dealt with efficiently in order to support operations and achieve high success rates. Undeniably, one of the important parameters for effective resource utility is planning and design. If the material handling system is well designed, it will help the manufactures to increase their productivity, product quality and minimize the manufacturing cost. Without a well-designed material handling system manufacturing process might experience stern delays on delivering the end product, production time may increase, damages on the product can be encountered and internal material movement cost may be increased which in-turn increases manufacturing cost (Hassan, 2010).

As per Asef-Vaziri, A., and Laporte, G (2005) a significant part of manufacturing cost is associated with material handling. The most crucial material handling decisions are planning and designing of patterns that are related to material handling and flow. Loannou, (2002) supported by saying that a significantly important parameter of a production system is a material handling system and its design of material flow. Flinchbaugh (2005) reported that when lean manufacturing is enforced to material handling, it must enclose all the tools that are related to lean manufacturing and must exhibit a complete view of lean manufacturing and not a part of lean manufacturing. Additionally, the top management must also consider all the key concepts and techniques irrespective of lean implementation before launching the system for material handling (Cutcher-Gershenfeld., 2002).

The key steps to implement lean manufacturing and ensure a better material handling system are given below (Harris, C., and Harris, R., 2006):

- Develop a plan for every station
- Delivery roots must be designed
- Pull signals implementation and
- Continuous improvement

Regardless of its importance, it has been asserted that material handling is treated superficially by many companies and therefore it is inevitable to enhance internal material handling process. To achieve it is vital to consider both human and technical factors which in turn increase production performance (Chakravorty, 2009). The process of material handling is predominantly employed in order to improve customer service, lessen deliver time and reduce overall handling costs allied with manufacturing, distribution and transportation. Considering these aspects, it can be affirmed that while planning the design of a material handling system it is of paramount significance to assure that all the equipment and processes including manual, automated and semi-automated work together as an integrated system. Predominantly, there should be considered 10 principles of material handling while designing a system so as to ensure it robustness, simplicity and efficiency towards the respective industry it is designed for. These principals include (Nzuve, 2018)

- **Planning:** This factor emphasizes on defining the needs and establishes the fact that the performance objectives should be strategic. It also signifies that while planning the system suggestions or discussions with different stakeholders such as consultants, suppliers, end users etc should be incorporated.
- **Standardization:** This principle refers that all the material handling equipment, approaches etc should be in accordance with the standards and must be able to perform different tasks under different operating conditions.
- **Work:** This principle emphasizes on reducing the complexities of the process by mitigating unnecessary movements in order to enhance the productivity.
- **Ergonomics:** It explains that the working conditions and work should be in accordance with the potential of workers, should be helpful for them in avoiding the iterative and tedious labour and should be focused on their safety.
- **Unit load:** This principal emphasizes the use of a unit load such as pallets, container etc since they require comparatively less effort.
- **Space utilization:** This principle of the material handling focuses on efficient utilization of space. It explains that there should be a proper utilization of the space in order to avoid any issues related to scarcity of space.
- **System:** It emphasizes on following a systematic approach for the movement and storage of material and also it should be applied to all the processes.

- **Environment:** As can be understood from the term environment, this aspect focuses on using environment friendly materials and incorporating safe or non-hazardous practices.
- **Automation:** This principle of the material handling signifies that in order to achieve higher efficiency, productivity etc the technologies deployed should be automated.
- **Life cycle cost:** This principle explains that for all equipment specified for the system, an analysis of life cycle costs should be conducted.

2.2 Performance Measurement

Performance measurement is an integrated term where performance refers to the outcomes derived from products, processes that enables evaluating and comparing on the basis of the standards, aims, results obtained previously etc. On the other hand, measurement refers to the numeric data that quantifies input, output and other parameters associated with products and the overall organization.

The performance measurement approach is followed by almost all the companies so as to gauge the overall performance of their organization. To maintain market demand, it is important for the company to consider performance related to production. Andersen, (1999) defined performance measurement as a process that continuously measures the production activity by identifying defects and implementing improvements regularly. Performance measurements has been a very important aspect at manufacturing firms since the 1960s and in recent years many aspects such as self-assessment, benchmarking, ISO 9000, balanced scorecard, workflow control, etc have become popular in the field to evaluate production performance (Denkena, B.; Apitz, R.; Liedtke, C.,2006).

Performance measurement is known as one of the challenging areas in manufacturing company because it is essential for the modern-day companies to maintain their customer satisfaction (Denkena, B.; Apitz, R.; and Liedtke, C.,2006). On the other hand, Zairi, (2000) argues that performance measurement can not only be used for customer satisfaction but also for long-term improvements. Performance measure has become an important parameter to specify the efficiency or effectiveness of the process (Neely, A., Gregory, M., and Platts, K., 1995). It has become a significant part of production and management. It is noteworthy that manufacturing companies feel immense pressure to improve their production performance in order to stay competitive in the market (Hvolby, H.H and Thorstenson, A.,(2000)).

Among these approaches benchmarking is most popularly exploited by the manufacturing firms to measure their production performance (Denkena, B.; Apitz, R.; and Liedtke, C.,2006). Benchmarking can be defined as the search for best practices that will be helpful to increase companies’ performance. Many companies regard benchmarking as a significant parameter to assess their production performance to maintain their competitiveness in the market. The core concepts of benchmarking are enumerated as follows:

- Comparison of one's own benchmarking performance level, process, practice, etc with business partner's performance level.
- Learning from partners and implementing improvements in your own organization.
- With the help of benchmarking the main objective of the companies, i.e. improvement is attained (Talluri ., 2002).

Hence, performance measurement must be considered while evaluating the production process as it helps us to measure the performance of the production facility at a manufacturing firm. Lean manufacturing also helps the industries to maintain their production performance.

2.3 Lean Manufacturing

Lean manufacturing has been an interest for many organisations to optimize their production (Dues et al., 2013). The major aspects of lean are waste reduction and increase in productivity (Anand et al, 2008). Lean manufacturing and its concept were derived from Toyota Production System (TPS) with the primary aim of eliminating waste, the non-value adding products from the customers' point of view (Rahman, A and Karim, A., 2013).

Womack, J. P., Jones, D. T., and Ross, D. (2003) stated that lean manufacturing demonstrates the relationship between value adding products and waste (Non-value adding products). They also added that the main agenda of lean manufacturing is to increase value adding when compared to non-value adding activities and reduce waste. The authors defined lean as a process of manufacturing products in quantities that are needed by customers. Hence the production must be done from the customer's point of view (Lian, Y. -H., and Van Landeghem, H. (2003)).

Lean manufacturing is one of the important parameters that must be considered in a company because it mainly focuses on continuous improvements in their production process. Hence, long-term strategies and short-term strategies, as well as goals, can be planned and implemented using lean manufacturing techniques. Nevertheless, many organizations incorporate preliminary strategies from lean manufacturing and provide a complete roadmap for the production (Green, J. C., Lee, J. and Kozman, T. A., 2010). Noticeably, often top management does not provide adequate time and resources to sustain lean manufacturing (Biddle., 2006). Denkena, B.; Apitz, R.; and Liedtke, C., (2014) stated that in manufacturing industries the primary aim is to achieve higher productivity and cost reduction in order to stay competitive in the market. Appropriate management of material flow impacts the manufacturing costs (Christopher., 2011) and contrary to this improper management may lead to cost increment and a decrease in productivity eventually resulting in waste production (Hassan, 2010).

Ohno, (1988) defined waste as a product produced due to needless or unnecessary movement or improper management of raw materials and hence needs to be eliminated.

Waste can also occur due to reasons such as inventory storage, overproduction, transporting, waiting, over processing, unnecessary movements and production of defective parts or products. Aiming at waste reduction, industries should lower their inventories and optimize the process of material handling. Keyser, R. S., and Sawhney, R. S., (2013) stated that the primary focus of lean manufacturing is to use the scarce resource effectively and to minimize all types of waste and other non-value adding operations in a manufacturing firm.

As already discussed in previous sections, in manufacturing material handling and waste management are the key factors that requires critical attention to achieve better productivity and product's success. Typically, waste is defined as an unavoidable bi-product occurred during the manufacturing process and therefor establishing a better control over the production process or in other words bringing reduction in waste can help achieving higher quality, success and financial savings (USEPA, 2011). Reducing waste during the production process helps companies to gain benefits in terms of reduced operation and waste removal cost and it is regarded as a challenging task for manufacturing industries (USEPA, 2011).

To enable optimal waste management, different approaches have been implemented so far, amongst which lean manufacturing Pullin., (2000) stated that lean manufacturing helps to get through the root cause of waste production on the basis of following principles:

- **No waste is witnessed when the process becomes perfect**

This means that when every step in a process is fully efficient and the amount of waste produced is less.

- **Customer focused sales**

It signifies that ultimately the customers are the ones who decide the value that they are willing to pay. Hence, the analysis begins from the customers' point of view.

- **Creating value for the process**

Before the product reaches its final stage, it undergoes various stages such as design production, marketing, processing and delivery. To achieve higher productivity and gain, it is must to ensure value with all aforesaid stages.

- **Waste creation decreases the value**

Waste signifies certain unwanted and insignificant factor that reduces eventual product quality. Furthermore, it affects overall cost of the product thus making it difficult to compete in current market condition. The created value gets decreased by the amount of waste generated during the production process, and therefore it becomes inevitable to reduce wastes in manufacturing process. This as a result could help firm achieving higher productivity, low cost of production, better quality and perception across market. A snippet of the waste reduction measure or process is given in Figure 2.1.

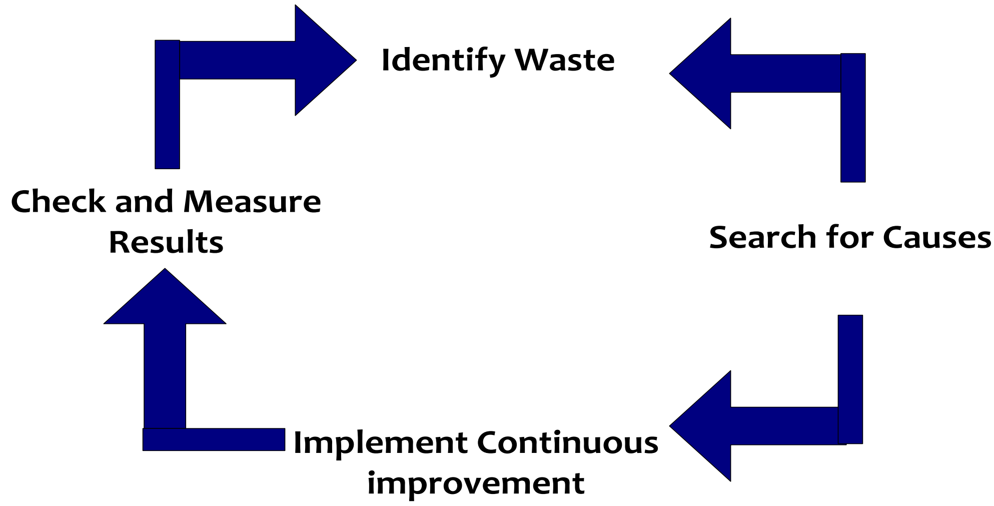


Figure 2.1. Waste elimination process (Rahman, A and Karim, A., 2013)

Observing Figure 2.1, waste elimination is a continuous and cyclic process which commences with the identification of the waste followed by analysing the root cause, implementing improvements in the product and finally ending at checking the work progress in unison with providing feedback for further improvements (Rahman, A and Karim, A., 2013).

2.4 The concepts of waste in Lean manufacturing

When the elements of waste exist, all they do is increase costs and add zero value to the manufacturing process (George, B.; Dann, P.; Trimmer, B., 2003). The fundamental waste is to be Identified as overproduction (Liker et al., 2004 and Ohno, T., 1988). Producing more than the customer desires by any operation in the manufacturing process necessarily leads to a build-up of inventory somewhere down stream: the material is just sitting around waiting to be processed in the next operation.

The concept of lean provides tools and methods that are used to evaluate production and eliminate waste generation continuously. There are three major types of wastes identified, namely muri, mura and Muda (Rahman, A and Karim, A., 2013). They are described as follows:

- **Muri** means overburden. It is focused on the work that must be avoided through design. This means that because of poor organization unreasonable work that is given to machines and employees must be viewed seriously during the design phase (Rahman, A and Karim, A., 2013)
- **Mura** refers to unevenness. It primarily focuses on the implementation of work design and ensures smooth flow at scheduling work process with respect to maintaining quantity and quality (Rahman, A and Karim, A., 2013.

- **Muda** refers to non- value adding work. This type of waste is concerned with all the unwanted activities that are exposed when working in progress on the shop floor and deals with them instantly (Rahman, A and Karim, A., 2013). Muda is further classified into nine types of waste (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, Harrison, A., Hoek, R. v. and Skipworth, H, 2014). Though primarily it was classified with eight wastes, but the ninth waste was considered based on the belief system on the behavioural aspects of an employee. A brief description of each of these wastes is given as follows:

i. Overproduction:

The products that are produced without any need result overproduction, eventually causing high inventories storage. The common cause of overproduction is just-in-case mind-set, improper scheduling, irregular workloads, and exploitation of automation (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, Harrison, A., Hoek, R. v. and Skipworth, H 2014).

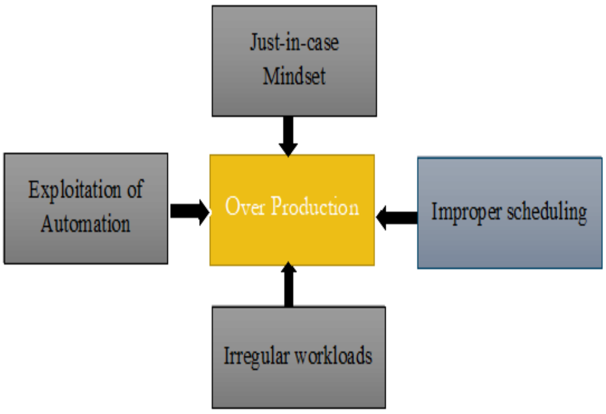


Figure 2.2 Overproduction (Voehl et al., 2014)

ii. Excessive inventory:

Excess inventory refers to storing up inventory with materials that are more than required. It usually results due to the process that do not function properly i.e. improper market forecast, defective manufacture of complex products, improper scheduling, unequal workloads, worst quality or improper shipping of raw materials from the suppliers (Voehl et al., 2014., Harrison, Harrison, A., Hoek, R. v. and Skipworth, H, 2014).

iii. Defects:

The occurrence of defective products is a common issue during production or after delivering the products to the customer. Defective products are something that are not built properly and are hence rejected by the customer. The reason for the cause of defects is lack in understanding customers' point of view, inexperience in purchasing quality raw materials or lack of experience in transportation of raw materials from the suppliers, employees working with insufficient knowledge, improper design and maintenance of products etc. (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, A., Hoek, R. v., and Skipworth, H, 2014).

iv. Over processing:

Processing a defective product several times or repetition of a process that does not add any value to end product is termed as over processing. The main cause of over processing is updating products but not the process, miscommunication, not fully understanding customers' point of view, employees getting more than required information from top management, making product copies that are more than required, Just-in-case mindset etc. (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014) and Harrison, A., Hoek, R. v. and Skipworth, H, 2014).

v. Waiting:

The time period between the completion of one process and beginning of another is called waiting period. The processes that are considered to be waiting are the machine process, anticipating for the materials process to be finished. Waiting period can be due to numerous reasons such as slow shipping of raw materials, improper workload schedule, low maintenance, defective equipment, unplanned facility layout, unnecessary use of automation etc (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, A., Hoek, R. v., and Skipworth, H., 2014).

vi. Motion:

Motion can be defined as unnecessary movements that do not add any value to the process. There are many reasons for motion such as employees not following the systematic way of production, inconsistent working methods, improper management of information system, not providing the right information at the right station, unfavorable facility layout used for production etc. (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, A., Hoek, R. v., and Skipworth, H, 2014).

vii. Transportation:

Transportation must be less in order to achieve a very less non-value process. Predominantly, a higher rate of transportation is observed due to inefficient buying techniques, big sized batch production, large storage area, limited understanding of process flow etc. (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014., Harrison Harrison, A., Hoek, R. v. and Skipworth, H, 2014).

viii. Personal Management:

There are many firms that still follow the concept of personal management. This may be due to lack of firm in utilizing creative and innovative skills of an employee. The main reason of occurrence of personal management is old style of thinking, business politics and works culture, lack of provision of training for low-level employees etc. (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, A., Hoek, R. v. and Skipworth, H., 2014).

ix. Employee Behavior:

This waste occurs as a result of unwanted human interactions. It is present in almost every organization and is the root cause of all other eight wastes. This waste is divided into two types, employee and people waste. Employee waste refers to the waste that can be controlled by the employee by identifying how the work must be done, will the work add any value to the process etc while people waste occurs between two employees (Voehl, F., Harrington, J., Mignosa, C., and Charron, R., 2014 and Harrison, A., Hoek, R. v. and Skipworth, H, 2014).

Summarily, it can be stated that waste management at a production firm is a challenging task. Hence, tools such as VSM help the industries to identify waste generation. VSM is a well -known method that can be used to identify waste. Value stream is a tool that is used to map the process from the customer’s view. It results in a Improved state map that demonstrates the changes that are necessary to be considered while designing a new layout or a production process (Rother, M., and Shook, J., 2005). The main objective of VSM is to eliminate waste, meet customer demands and maintain customer satisfaction (Womack, J. P., Jones, D. T., and Ross, D.2003).

2.5 Value Stream Mapping (VSM)

VSM is a technique from lean manufacturing that is used to assess the information and material flow to bring the products to a customer (Rother et al., 2003). It is one of the most persuasive lean manufacturing tools which help the manufacturing firms to visualize and figure out the materials and process flow through the value stream (Lacerd A. P, Xambre A.R, and Alvelos H.M, 2016).

VSM gives a universal view of the production facility and helps in the identification and minimization of waste, eventually bringing reduction in costs related to production, increase in response time and production of better-quality products (Rother, M., and Shook, J., 2003). VSM helps to map the flow of information and materials in a manufacturing firm and hence can be regarded as the collection of all the flows (Rother, M., and Shook, J. 1999). VSM helps to generate a common ground with regards to manufacturing facility hence, helping the administrators to take favourable decisions on waste elimination (McDonald, T., Van Aken, E. M., and Rentes, A. F., 2002).

Teichgräber, U. K., and Bucourt, M. d. (2012) reported that nowadays it is important for the organizations to map their production process using VSM because it helps them to reduce their expenses on raw materials and stay competitive in the market. Abdulmaleka, F. A., and Rajgopal, J. (2006) suggested that VSM must include the material flow, information flow and revenue that are related to production because it gives a holistic view of the production facility and helps the organization to take an appropriate decision with respect to waste management. Similarly, Chiarini., (2013) defined the intention of VSM as recognizing the process and other activities in order to demonstrate the difference between value adding and non-value adding activity in a manufacturing firm. VSM development is done two steps (Abdulmaleka, F. A., and Rajgopal, J., 2007 and Rahman, A and Karim, A., 2013). They are as follows:

- **AS-IS state development:**

The present working condition of the production process at a manufacturing firm is understood at this stage. This can be done by going through the current process and facilitating analysis and waste identification.

- **Improved state development:**

After removing flaws in the production process, an image of the improved production system can be visualized at this stage. The Improved map can be created by posing a set of questions related to effectiveness and technical aspects of the manufacturing system. With the help of a Improved map, existing production system can be modified or rebuilt.

2.5.1 Advantages of Value Stream Mapping

VSM is a powerful tool that helps the organization to assess their productivity. Rother, M., and Shook, J. (2009) stated that when a product is produced, the company has value stream. VSM can be done with the exact same way as the facility and may alter the stream according to the analysis and results. Predominantly, the advantages of VSM can be stated as follows:

- VSM helps the management to find the defects because lean manufacturing showcases the eight wastes and paves proper vision for improvements (Singh, B et al., 2010).

- Differentiating value adding and non-value adding in an organization is considered to be merit because it helps the organization to improve their value stream performance (Rother, M., and Shook, J., 2009). AR, R., and al-Ashraf, M. (2012) stated that implementation of value stream is advantageous in terms of decreasing lead time and inventory storage while featuring a remarkable increase in productivity.

2.5.2 Disadvantages of Value Stream Mapping

Even though, VSM is a powerful tool to assess the production process it is having its own limitations. They are described as follows:

- VSM is an important tool to implement lean manufacturing at a production firm but its only key concept is a pull system. The evaluation and analysis of one system at a manufacturing firm cannot be directly taken to another system at a different manufacturing firm but the evaluation and results can only be adopted with some modification (Bertolini, M., Braglia, M., Romagnoli, G., and Zammori, F., 2013).

- VSM gives only a holistic view of the production facility which helps the management to identify the flaws and defects at each station, but it fails to give an in-depth analysis at each station.

2.6 Ishikawa Diagram

Ishikawa diagram is popularly known as a Fish bone diagram. It is defined as the diagram that is traced backwards from the problem area. This diagram is helpful to identify the main cause of the problem and maintaining the quality of each department. A Fish-bone diagram is drawn according to following steps (Laws., 2016 and Rahman, A and Karim, A., 2013):

- Problem identification
- Identification of sub-classes in a problem when reviewed under process flow
- Identification of details on the problem noted
- Record the cause of the problem in the form of a diagram.

A sample Ishikawa diagram can be drawn as shown below:

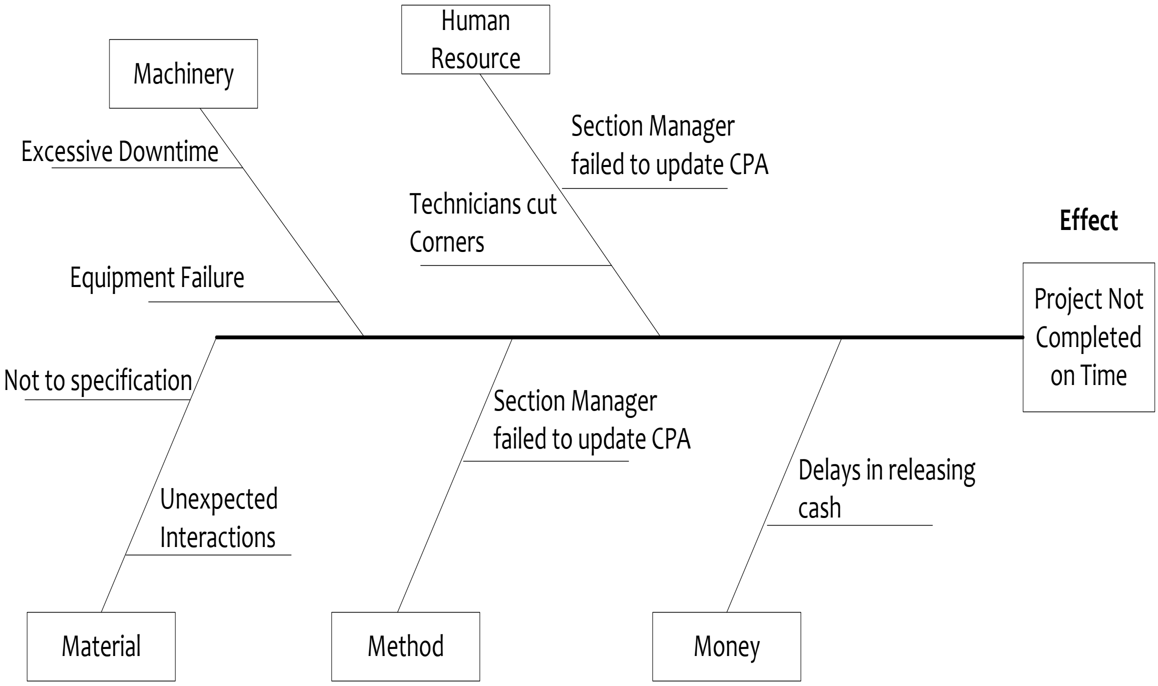


Figure 2.3: An example of Ishikawa diagram (Law., 2016)

2.7 Summary

This section primarily discussed some of the key theoretical aspects of the manufacturing processes, key challenges, different wastages in manufacturing process, lean manufacturing, VSM and its significances to reduce wastages etc. Observing overall discussion, it can be found that amongst the different lean manufacturing processes, VSM does have decisive role to enhance overall manufacturing process and can be effective to enhance production or manufacturing. With this motive, in this dissertation VSM has been assessed for its efficacy to achieve higher productivity, optimal wastage management and material handling. In addition, focus is made on identifying key factors causing wastages in typical manufacturing set up so that it could be eased to accomplish eventual production goal.

3. Method and implementation

This chapter deals with the method and implementation that are used to carry out the research or in other words methods that are used to carry out research of the research conducted. Research methodologies is one of the vital sections for the As-is study that represents overall research and study pattern to be incorporated or implemented for accomplishing overall research objective. This Study adopts both qualitative and quantitative methods in identifying the problem statement, literature review, collection and analysis of data and discussion of the results. Undeniably, to explore these factors exploring both available literatures as well as first hand data, also called primary (response) data is must. Both qualitative and quantitative research methods were used (Porter and Coggin 1995). The qualitative method has been proposed because it can enable answering to the questions of why, how and in what way. Meanwhile, quantitative approach is also having great significance to assess various key aspects of intended research work and is equally important as quantitative research. As already stated, this study encompasses a mixed research paradigm that uses both qualitative as well as quantitative research methods.

3.1 Research design

A well oriented and proper outlined research design is of paramount significance for any research work since it helps to answer research questions by designing a systematic approach with a suitable procedure (Saunders, M, Lewis, P., Thornhill, A.., 2009). The research design starts with the decision on the research and its type. Predominantly, there are two types of research explanatory and descriptive.

The explanatory study deals with the review of existing research in the form of literature and aims to justify the problem statement. On the other hand, descriptive statistics depends upon a careful and in-depth analysis of the present topic. It imperative to mention that the As-Is study deals with the implementation of lean manufacturing in order to reduce waste generation and to increase output. Additionally, the research aims to derive consolations from the existing theory hence, it can be termed as a deductive approach (Williamson.k, 2002).

As stated, the As-is study includes qualitative as well as quantitative approaches and therefore the overall research approach considers descriptive and evaluative or analytical research paradigm to perform intended study.

3.1.1 Qualitative Research

Qualitative research is basically important for achieving specific target information which helps the researcher to stay on top from the huge amount of data that were collected for analysis. Also, parameters such as behavioural facts, values, perceptions, opinions and varied significant social contexts of certain targeted populations can be analysed with the help of qualitative research (Williamson.k, 2002).

The study design consists of data collection and research questions that are adjusted according to what has been learnt. Unlike quantitative research investigation, which is based upon seeking answers to questions, systematic use of predefined set of procedures to answer the questions, collecting evidence, producing findings etc.

3.1.2 Quantitative Research

Airasian, Peter and L. R. Gay. (2000) defined quantitative research as the process of data gathering especially the numerical data to characterize, predict and control region of interest (ROI) or the process of interest. In a simple way, Creswell (1994) defined quantitative method as

"The process of assessing or investigating a social or human problem, on the basis of certain defined and testing approach containing research variables, estimated with numbers and assessed with statistical procedures, so as to estimate whether the predictive generalizations of the theory hold true or not"

3.2 Data Collection

To meet the objective of the study both primary and secondary data have been collected. The two methods adopted for data collection are positivistic and interpretative. The positivistic approach follows theories testing that is formulated using data deduction which is generated from experimental setup (Saunders, M, Lewis, P., Thornhill, A.., 2009.).

The study has been carried out with a metal fabrication company. Veer-o-metals through purposive stratified random sampling method. The company is Indian based, located in Bengaluru and specialized in sheet metal fabrication. In this research an attempt has been made to apply VSM on the key product of the company, PVS- 980 frame. A brief of the data collection process and sources based on data nature is discussed as follows.

3.2.1 Primary Data Collection

In this research work the primary data has been collected through an approach known as triangulation.

Triangulation

Though in the previous sections, a brief description of the different processes applied for performing the research have been discussed, but there is a special term, triangulation used in the research work. According to Bauwens., (2010) the term triangulation means use of more than one method to test and confirm the variance of an experiment. Triangulation refers to the process of verification of findings by showcasing the independent measure of mutual agreement (Miles and Huberman et al, 1994).

Predominantly, there are four types of triangulation (Bauwens., 2010). A brief description of the different types of triangulation has been presented in table below.

Table 1. Types of triangulation

Type of Triangulation	Description
Data source Triangulation	This means that data were collected from diverse types of the source or various places and analysed
Method Triangulation	It implies the use of diverse methods such as observation, interviews and pre-recorded documents were considered and evaluated.
Researcher Triangulation	It signifies that in the study more than one researcher such as our guide at the firm and people from R&D department as involved and different views about an existing problem are collected.
Theory Triangulation	It signifies that various theories were considered while addressing the problem.

The As-Is study consists of the data that was collected through observation, interviews and pre-recorded documents and detailed assessments. Based on the assessment the suggestions were given for improvements. Triangulation has been considered significant for the research because it emphasizes on analysis of documents, interviews and observations and provides a basis to assess findings and check for mutual agreement (Bauwens., 2010).

The advantages of method triangulation are that the observation provides the holistic view of interviews and helps to understand the context of the result with the help of document analysis. Triangulation also helps to understand the similarities and the differences that are observed during interviews and formal daily talking (Bauwens., 2010).

This data collection technique was used to address research question 2.

3.2.2 Secondary Data Collection

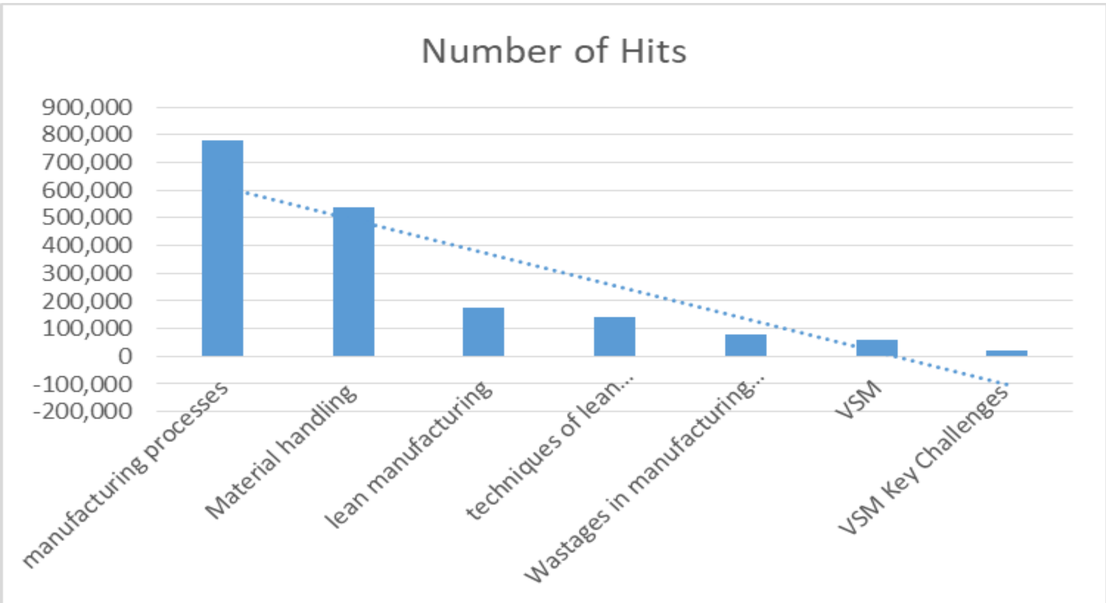
In the presented research paradigm, both primary and secondary data have been considered, where the primary data has been obtained by performing extensive review of the literature discussing the need of lean manufacturing, challenges encountered by lean manufacturing, VSM and its significance for lean manufacturing etc. Being a mixed research paradigm, it involves data from both the primary sources such as literatures, articles, magazines, catalogues, journals, newspapers etc. Similarly, to enable quantitative research need, the responses from company management officials are also inevitable to perform respective perception towards lean manufacturing and techniques such as value stream mapping. Various available resources on internet have also been taken into consideration to perform survey and knowledge retrieval about various strategies required to promote lean manufacturing in manufacturing companies in order to enhance their productivity.

The literature review is inevitable for planning a properly-oriented research design. This method was chosen because the process of reading articles will help us to understand the current status and will also help to relate to present research, to find gaps. The researchers can develop and connect with their own ideas (Galvan, J. L., 2006).

In this phase of study, the predominant emphasis was made on assessing or exploring the key theoretical aspects of the manufacturing processes, key challenges, different wastages in manufacturing process, lean manufacturing, techniques of lean manufacturing, VSM and its significances to lessen wastages etc. This phase revealed that among the different lean manufacturing process, VSM can have vital role to augment overall manufacturing process and can be effective to enhance production or manufacturing.

Table 1 – literature review hits

key theoretical aspects	Number of Hits
manufacturing processes	779,103
lean manufacturing	176,946
techniques of lean manufacturing	142,634
VSM	60,363
VSM Key Challenges	2,0950
Wastages in manufacturing process	76,900
Material handling	538,527



This data collection technique was used to address research question 1.

3.3 Case Study

In the previous sections a clear description of the methodologies used for data collection, paradigms etc followed have been presented. Thus, in this section of the chapter a brief introduction of the case studied for this research has been presented.

The research work time line was planned from January 2019 to May 2019. As planned in early stages all the required documents were gathered to assess the production flow and later the required contacts were established within the company to get the clear picture about their production process. After getting the clear view of the production facility the As-Is state VSM was drawn for the further assessment. The material flow was checked and tracked at the stations and the improvements were suggested based on the analysis.

The production facility of the work station at Veer-O-Metals consists of different workstations such as laser cutting, plunging, tapping, bending, welding and final assembly. The current material handling process and production flow was identified. The activities such as value adding and the non-value adding were identified using customer complaint sheets. VSM was conducted on a PVS-980 Frame that was being manufactured for their clients. The stand has 3 major parts, each being manufactured separately. The plan was discussed with the production in charge and drafted before data collection because inappropriate planning might provide misleading or confusing results.

The observations were made at each station before collecting data because it is very important to have a holistic view of production process before drafting a plan. To get the detailed assessment of the companies' production process it was essential to observe the process flow of the material at each station. The observations at each station were noted for Improved state analysis. Cohen.L, Manion. L, Morrison. K., (2000) asserted that interviews help to exchange views with two or more people hence the questions were designed based on the problem identified and the interviews were conducted with the management responsible for production as well as with the personnel at each station to know about the production process and the work culture in detail.

3.4 Data Analysis

Cohen.L, Manion. L, and Morrison. K., (2000) stated that it is important for the researcher to consider the proper techniques for data analysis. The author also specified that before starting the analysis it is important for the researcher to draft a plan. The analysis of data involves organizing, reasoning, and explaining the data which was collected during the observations. Further, noticing the pattern flow will help the researchers to understand the As-Is state of research. Hence, the observation was made at each station of research. Hence, the observation was made at each station before transcribing while a detailed transcription was made after the observation. Additionally, the interviews were carried out at each station and the data was collected for analysis purpose. Pre-recorded documents were also considered for performing analysis.

3.5 Reliability and Validity

The validity of any study can be defined as "the degree to which an interpretation precisely denoted the social events while reliability is defined as "the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions" (Hammersley et al. 2016).

Hence considering the reliability and validity, it becomes imperative to mention that Cohen.L, Manion. L, and Morrison. K., (2000) defined triangulation as a method that is used to assess various aspects in a problem. Triangulation helps to deeply understand the problem that has occurred by analysing it from more than one point of view. Hence, triangulation shows high content validity. The content validity branches out for reliability (Cohen.L, Manion. L, and Morrison. K., 2000).

The advantage of using triangulation is that it gives multiple approaches to a problem identified. Further, the confidence of researcher is increased when various aspects of methods give same results. Issues related validity and reliability was thoroughly considered during the questionnaire phase and the questions were framed accordingly during the study.

3.6 Summary

In this chapter discussion of the various methodologies and associated constructs were discussed. Various approaches such as research design, data collection methods, and the nature of data, triangulation etc. and their implementation to accomplish overall research objectives were briefed.

4. Findings and analysis

The focus of this chapter is to discuss in detail the AS-IS state and Expected Improved state analysis and the problems that are identified during material handling and value stream mapping for PVS 980 Welded Frame at Veer-O-Metals.

4.1 Company's Description and operations

Veer-O-Metals manufactures PVS 980 Welded Frame for one of their clients. When the client rolled out their requirement in their vendor pool, Veer-O-Metals evaluated the requirement and submitted their quote. Finally, the client has identified Veer-O-Metals as their vendor to outsource their product in the global market.

Initially, Veer-O-Metals company was operating to produce a prototype which was primarily examined for its quality. Achieving successful quality check, the pilot production was accepted by the client and Veer-O-Metals initiated the production process. Before beginning the actual production process, the company listed all the material required for production and raised the purchase request. The purchase orders will be placed among the suppliers as soon as the purchase request is received. The supplier delivers raw materials in accordance with the order. At Veer-O-Metals, the quality of the raw materials was checked in the departments, called GRN and SQA to ensure that the raw materials meet the required standards. In case of unsatisfactory quality, the raw materials will be sent back to the suppliers. After performing quality check process, the raw materials are moved to stock.

Production order is an internal document within the organization exhibiting details about how the work will be carried out, the numbers of personnel and the employee who is responsible at each station. The production will be carried out based on the production order and the raw materials from the storage area will be moved based on the requirements mentioned in the production order. The production is monitored by the management of the organization. After the production, the products are inspected for defects. In case of no defects the products are shifted to finished goods area and stored over there until they are dispatched to clients. After the inspection, the invoice is generated for logistic purpose and is delivered to the desired client location.

4.2 As-Is state Analysis

VSM was carried out at Veer-O-Metals on their core product called PVS-980 Frame. The material handling process has been carried on the raw materials right from storage area where it was stored till the finished goods area where the final products after production are kept. There are multiple stations between storage area and finished goods area. they are as follows:

- Laser Cutting
- Plunging
- Tapping (Threading)
- Bending

- Final assembly

Sequence of interviews and observations were carried out at Veer-O-Metals to understand the process involved in producing the final assembly of PVS-980 frame. During the interviews and observations, it was found that every day at least one frame (PVS-980) was being assembled and shipped to the clients. The assembly of the frame was initiated based on the clients' demand.

The frame was assembled using its sub-parts (roof, base and pillars) that are produced in advance and stored in the assembly storage area before assembly station. It was also observed that the sub-parts were enough to sustain for the period of ten days and on every seventh day the storage area was re-filled with sub-parts. There was an existence of 3 days of gap ensuring the supply of sub-parts to the assembly station. Even though some delays occurred between the stations or production schedule with respect to other stations, the production at the assembly station never stopped. This As-Is state working was designed by the company's research and development department.

Figure 4.1 Production facility Layout

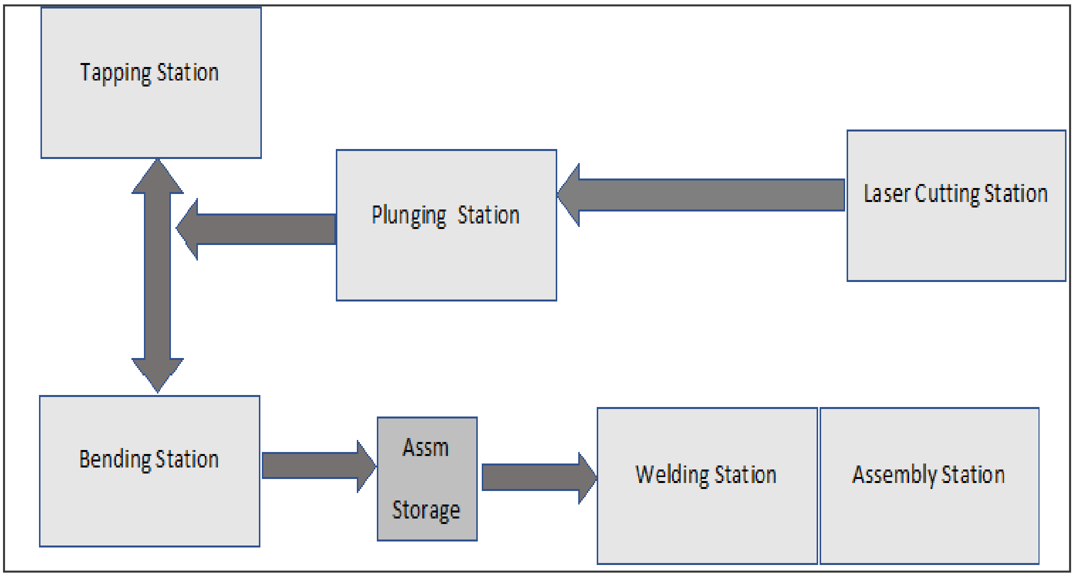


Figure 4.1 represents the diagram of a production layout that indicates the material flow from laser cutting station to the final assembly station. The original layout map cannot be used for external purposes as per company's rules and regulations. Hence, a diagram like a layout was drawn to increase the understandability for the readers.

4.3 Study of Process Flow

As depicted in the production layout chart there are numerous stations performing different tasks in a manufacturing industry. A snippet of these stations and the task performed is provided below.

- Laser cutting

This is a highly automated station and a CNC program was written and installed in the machine at this station. The raw materials are placed on a bed and CNC machine cuts the materials with high precision in required shapes/sizes as per the customer's requirement. This process was fully outsourced in order to maintain quality. This station supplies the raw materials to other station whenever the basis of demand.

- Plunging station

This station is a semi-automated station. It receives materials from laser cutting station for plunging operation. The materials were brought to this station in a movable stand and are stored at desired place before plunging operation. The purpose of the machine at this station is to punch holes on the profiles (different sized raw materials). This station consists of two personnel (operator and helper) and station in charge, helper and operator were working on the project and the station in charge checks the work in progress. The materials were brought to this station based on the production order.

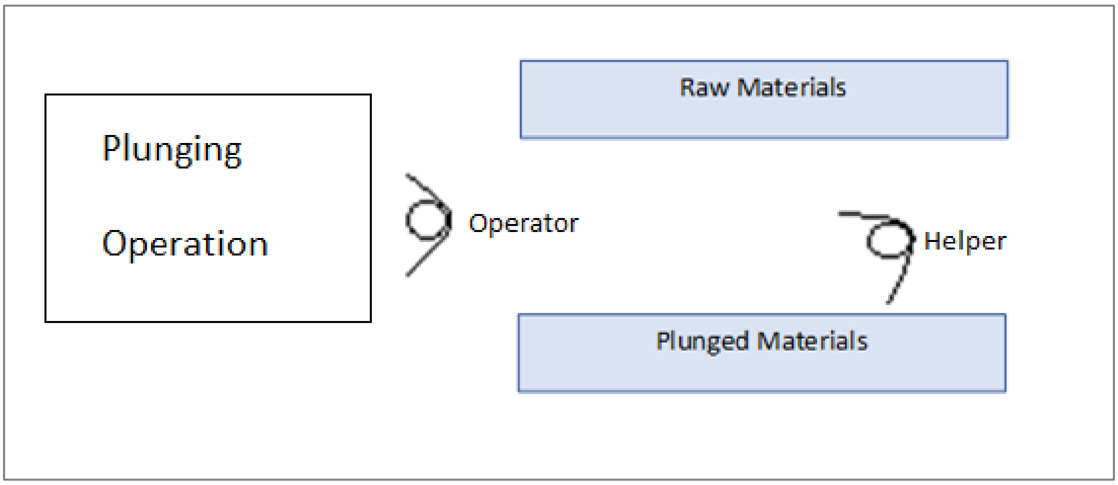


Figure 4.2 Plunging operation

At first, the required profile was searched among other profiles and the time taken for this search operation was 1.50 min per profile. Prior to the beginning of plunging operation, the helper and the operator search for the required raw materials in a pile of raw materials. Once the profiles were found, the helper assists the operator in fixing the profiles to the machine and the machine operator punches holes based on the drawing issued. During the operation, there are different types of plunges made on the profile using different tools such as M5 and M6. The time taken to change the tools is 30 seconds. Employees at this station are not multi skilled, rather they are highly skilled at doing only one operation at a time. The total production time to make the required number of holes on per profile is 161.5 seconds.

- Tapping Station

This station is also semi-automated station. After plunging operation, the materials were moved to this station with the help of movable stand and stored at the desired places. At this station the task was to perform threading operation at the plunged areas was performed. This station also employs helper and operator and the station-in-charge. While the helper and operator are responsible for finishing the work, the station in charge monitors the work in progress. The operator's job is to make threading at the plunged areas while the helper's job is to assist the operator in terms of material handling and tool changing. The required profiles are searched in a pile of profiles before the operation starts and the average time taken to sort the materials is 2.30 min per profile. The materials are tapped in the plunged areas with the desired tool based on the drawings and the time required to change the tools (M5 and M6) is 1 minute. The total production time required per profile at this station is 220.15 seconds

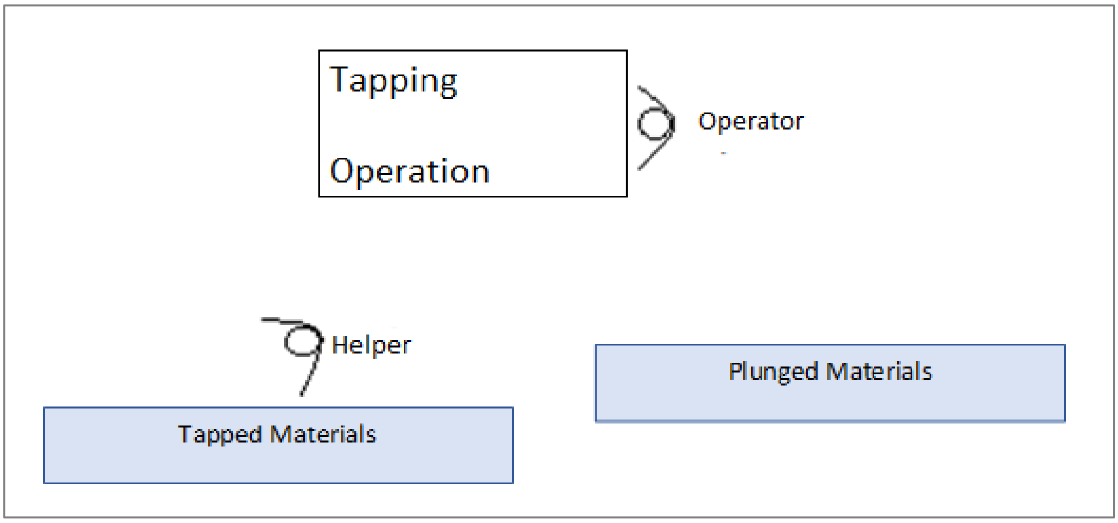


Figure 4.3 Tapping operation

- Bending operation

The purpose of this station is to give actual shape to raw materials by bending them to the required shapes. The tapped materials are brought to this station and bent to actual shapes such as roof, pillars and base. A helper and an operator employed at this station are responsible for bending operation and station in charge is responsible for progress of work. Initially, the required die is setup for the operation and the time required is 40 minutes. The required materials are sorted from the pile of profiles and placed on the machine for the required bend. Average time taken to set up this operation is 1.50 minutes per profile. Before the actual production starts the accuracy of the bending machine is checked with trail profiles and the bend accuracy is checked by trial and error method using instruments such as Vernier calliper and Bevel protractor. The time required to perform this action was 710 seconds per profile. The total production time taken in this station was approximately 745 seconds.

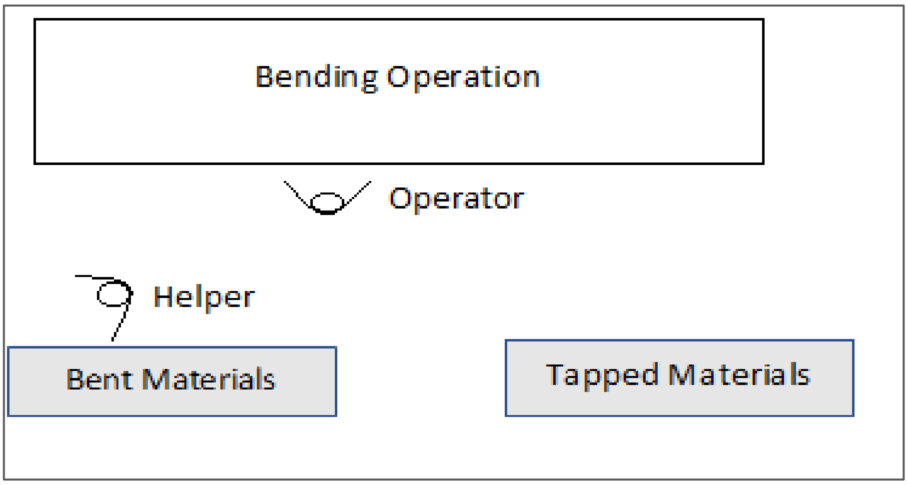


Figure 4.4 Bending Operation

- Assembly storage area

This station is a prime storage area. At this station, the parts that are needed inclusive of all sub-parts were produced well in advance and were stored and utilized as per the need. The management ensures that this section is always filled and supplies the raw material profiles based on the requirement. As mentioned above, the sub-parts were produced for every 10 days and stored in this section. At this station, it was difficult to track the levels of the stock for top management hence they asked the shop floor employee to check with the stock levels and release orders for production

- Welding station and Final assembly

At this station, the final assembly is witnessed. The raw materials from assembly storage section are transported here. Three stands were assembled separately and later welded (refer diagram 4.5) as one single stand and shipped to the customer. The process employs a total of eight helpers, operators etc. At the welding station, the welding used to join the profiles are Mig-brazing. It is considered suitable because of the utility of the finished products and because it holds the profiles intact. The average time taken to bring the raw materials from the assembly storage area to the welding station was noted to be 80 sec and for the operation is 50 sec. The frame is made to rotate in the required direction without any help from the machines and the time consumed is 272 sec. The total production time taken in this station was approximately 416.68 seconds.

In Final assembly station, three stands are made separately and then assembled as one before shipping. The required profiles are taken up from the assembly storage area and are assembled with the fixtures and rivets. The average time taken for this action is 160sec. For, every fixture and rivets the employee fetches from the table which is placed at a distance from the process and the time taken for the movement is 110sec. The assembly stage is the final stage where all the sub parts take up their final structure and the frame is ready for shipment. The total production time taken in this station was 29182 seconds.

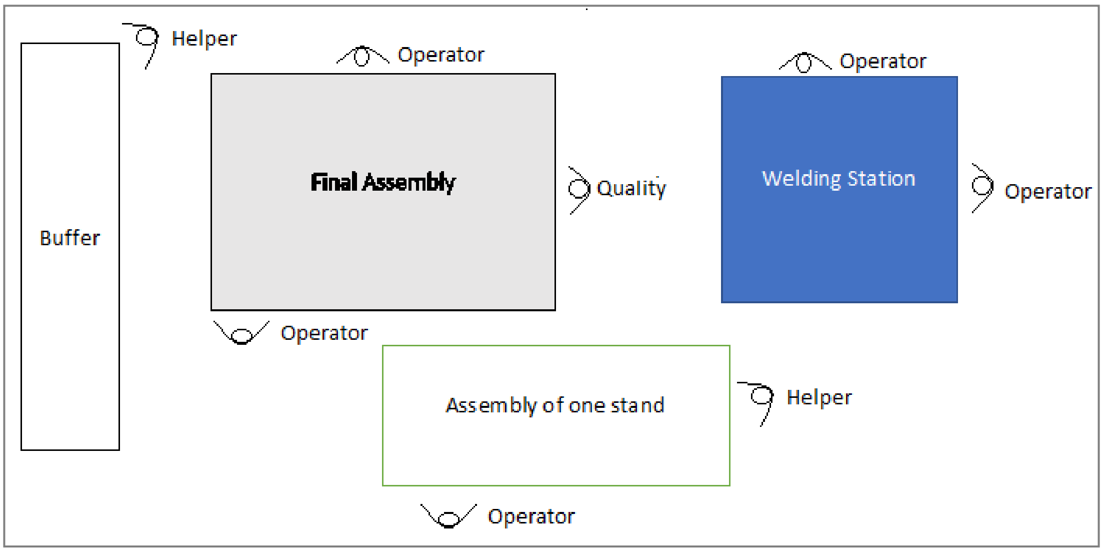


Figure 4.5 Final assembly and welding station

The VSM was drawn from the observations that were made at each station for As- Is state analysis for the sub-part pillar was plotted based on the observations at each station. The takt-time is computed for one product per shift.

Table 4.1 Time spent on material handling in relation and production time per profile

	Laser	**Plunging (In Seconds)**	**Bending (in Seconds)**	**Tapping (in Seconds)**	**welding (in Seconds)**	**Assembly (in Seconds)**
Time identified as waste	Work is outsourced	110	710	180	272	382
Production time		161.5	745	220.15	416.68	29182
% of Time spent on waste in relation to production time		68%	95%	82%	65%	1%

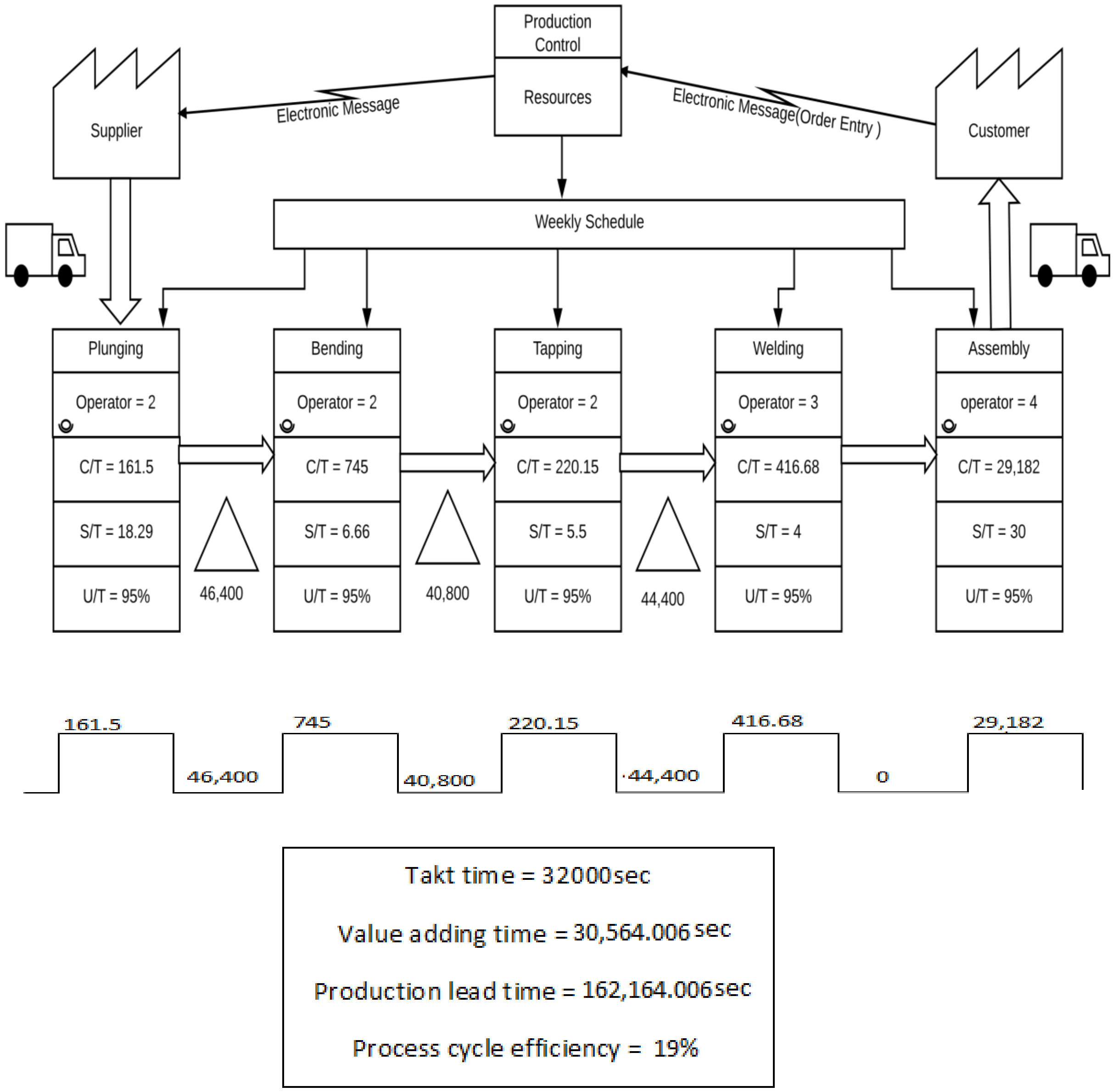


Figure 4.6 As-Is state analysis Value Stream Mapping

The figure 4.6 represents the As-Is state of the production process, the order was received from the customer through electronic communication and the production control plans the weekly schedule and dispatched to each station to perform production operation. From the above map the **As-Is cycle efficiency was observed as 19%.**

4.4 Waste Identification

The raw materials were mixed at almost every station. However, the reason for the materials mix up was identified with the help of the fishbone diagram shown below.

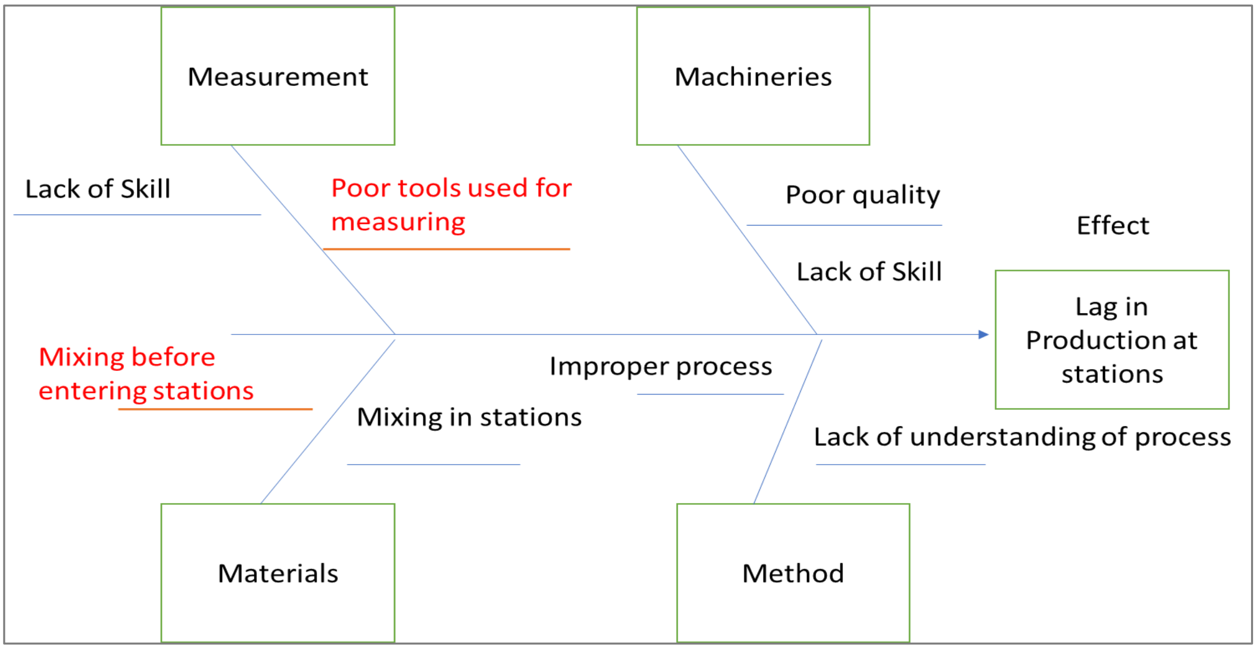


Figure 4.6 Fishbone diagram

The above Figure 4.6 was plotted to identify the root cause for lag in production at stations, it was identified that the root for the problem was in system due to unstructured management where the materials were mixed up. The above diagram helped in getting a holistic view of the production facility and the root causes for Lag. The analysis was done at each station and it was observed that plunging, bending and tapping stations received mixed profiles. Operators at this station spent lot of time to find and segregate profiles before each operation. The questions were asked at the target stations to identify where exactly the materials were mixed but the answers given by the operators were not satisfactory. Hence, the fishbone diagram and root cause analysis were performed to identify the allied problems. The analysis was carried out all the stations and it was concluded that when the company received profiles from suppliers the operators checked and counted the raw material profiles and it was identified that materials were mixed up during the count.

A brief description of the waste identification problems occurring at each station is presented below.

- <u>Laser station</u>

At Laser station generally, the materials have to be cut at the laminated side, but in few instances, materials were cut on the opposite direction hence operator was confused and made plunging in the wrong direction which resulted in waste accumulation.

- <u>Bending station</u>

At bending station, two types of wastes have been witnessed, re-work and time.

  - After completion of bending operation, it was observed that the raw material profiles have shown bends at non-desirable places which were because punching die has become old and worn out. This eventually resulted in rework.
  - Some raw materials profiles were chosen for trial bend and to check their accuracy the operators used Vernier calliper and bevel protractors. Since there was only one Vernier calliper and bevel protractors available at station, so the operators had to wait for their turn, hence waiting time of 250 seconds was witnessed here.

- <u>Tapping station</u>

Similarly, at the tapping station also two types of waste have been witnessed, time and rework.

  - Materials were brought here to make threads at plunged areas. Certain raw materials profiles consisted burrs from laser cutting. To remove burrs workers had to invest extra time rather spending effective time on tapping operation which led to wastage of time.
  - Some completed and delivered materials also came back for some kind of rework and that too without any prior schedules which significantly delayed the main schedule activities.

- <u>Assembly storage area</u>

At Assembly storage area, the materials were brought and stored before welding and assembly. Since there was no tracking system available for stock maintenance, it led to huge difficulty in identifying shortage of products. Hence, top management had faced difficulties in identifying raw material profiles which were in shortage and need to be produced immediately. Hence a visual management system was developed in order to help the management to view the scarce products.

- <u>Welding station</u>

Primarily, there were three major issues observed at the welding station. They are witnessing brazing cracks, re-work and lack of safety.

- Since the roof gap consists of 0.05mm thickness and the gap was not enough for brazing purposes, there were observed brazing cracks on the roof of the product. The operator used stool which had very little space to stand and caused the fear of falling. This is also one of the reasons why welding cracks were observed.

- After laser cutting operation the materials were not cleaned properly which resulted in extra laser burrs and caused blow holes on a welded strip leading to the crack in a weld joint. Hence, the operator invested his time in removing the laser burrs leading to the wastage in terms of time. In addition, during welding entire stand is tilted clockwise without any support because welding must be done at certain angle hence it is dangerous for the operator as there is a fear of falling from stand.

- No proper coverings were done for welding wire and it was left open which made employees feel that it was not a safe place for work.

- Final assembly station

For performing riveting operations at final assembly section, operators utilized small stool which made them feel uncomfortable. Also revisiting the rivets storage section for getting the rivets wasted a lot of time. The operators repeated this operation several times in a shift. Welding misalignment can also be attributed to the manual lifting of three stands without any support.

During the material handling process, it was observed that the pillars had defects at various areas and took time more than required to come to assembly storage area hence value stream mapping was exclusively plotted to check the defects related to materials, man power, and schedule for PVS – 980 Frame.

4.5 Suggested Improvements

After observing the processes taking at each station and the defects or waste being produced due to different reasons, there have been presented a few useful suggestions. These suggestions are enumerated as follows:

- The mixing up of materials during counting must be avoided or they must be sorted before the start of the operation.
- New instruments such as punches, dies, Vernier calliper and bevel protractor must be issued at different stations for checking the accuracy of products without any delay.
- There should be a proper schedule followed for performing re-work on materials since they consume extra time and cause delay.
- Damaged materials or materials having extra projections leads to re-work and hence must be taken care at each station. They can also be a major issue hindering the safety of workers.
- Proper cleaning of materials after laser cutting operation must be done since the extra burrs formed result in weak weld joints and thus lower efficiency.
- To avoid brazing cracks on the roof, fusion welding can be preferred instead of MIG Brazing (only at the roof top).
- Materials must be free from dust and oil before brazing operations.
- A stool must be provided with an adequate space where an operator can stand comfortably during welding process.
- A belt bag must be provided with the rivets and bolts so that the operators can reduce their walking time.
- A torch light must be provided to the quality inspector so that he can check properly.

At the assembly storage area, visual management system was suggested in such a way that top management can easily find which profiles were in shortage and which had to be produced. The suggestion was that stickers with magnets or hooks must be placed at the bottom of every storage cell. The coloured stickers such as red, yellow and green was given to helpers to paste on every storage cell where green indicated that storage cell is full, yellow indicated that inventories are moderately full and red indicated that storage cell is empty. This helped the management to visualize and manage the assembly storage area and produce product well in advance.

During pillar production it was observed that materials were being searched before the production process. The materials must be sorted before the operation, during bending operation it was observed that pillars had extra bend at non-required areas. This was due to old and worn out dies that were used during the bending operation due to this time was spent for correction. If new dies were used instead of old dies re-work time could be saved at each station.

4.6 Improved State Analysis

This analysis was done based on AS-IS state. The waste was identified, and the improvements were suggested at each station. Based on the suggested improvements at each station VSM was performed. There is mentioned some information about the improvements that must be implemented at each station.

- Plunging station: It should be noted that the raw materials profiles were not sorted before beginning the operation. If they would have been sorted, the time taken (per profile) to search would be reduced consequently leading to an increase in the productivity in unison with other parameters such as tool changing time, time required to punch holes remained same.
- Tapping station: Unlike plunging station, at this station the raw materials were sorted before initiating the operation, however this station had lot of unscheduled rework coming in. If the rework materials come in according to the control plan then the productivity at this station can be increased.
- Bending station: This station needs to be provided with new die and punches in order to minimize the bends occurring at non-desired areas. Additionally, by providing new instruments the waiting time will be reduced by 5min per profile.
- Welding station and final assembly: At this station, blow holes were observed after the weld which can be avoided up to great extent if the materials were cleaned for burrs and hence re-work could be avoided. Noticeably, brazing cracks were seen at the roof top because of 0.05 mm gap. Instead of brazing if fusion welding is preferred then the time invested on rework can also be reduced.

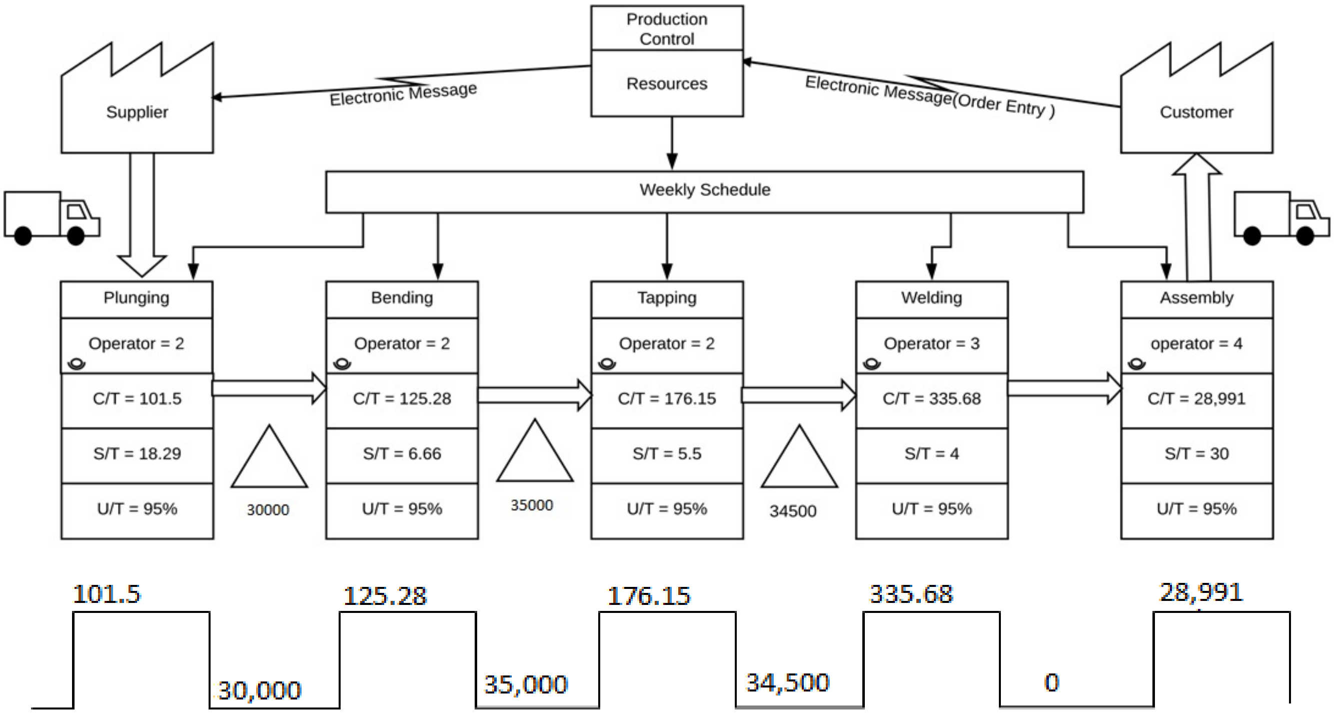
  Apart from the welding issue, if the belt for bolts and nuts would have been provided, then the walking time at this station would be reduced.

Also providing a spacious stool would allow the operators to weld materials easily. To conclude it can be affirmed that addressing the problems would significantly increase the productivity.

Table 4.2 Expected time spent on material handling in relation and production time

	Laser	Plunging (In Seconds)	Bending (in Seconds)	Tapping (in Seconds)	welding (in Seconds)	Assembly (in Seconds)
Time identified as waste	Work is out-sourced	50	355	90	136	191
Production time of the product		101.5	125.28	176.15	335.68	28,991
Time spent on waste in relation to production time		49%	72%	77%	57%	1%

Below shown the value stream mapping for the expected Improved state analysis for Pillar production.



Takt time = 32000sec

Value adding time = 29,729.61 sec

Production lead time = 129,229.61sec

Process cycle efficiency = 23%

The estimated cycle efficiency of the improved state was calculated based on the comments given from brain storming sessions with the production manager, his team and considering the implementation of suggested improvements in each station. After the implementation of the suggested improvements it was expected that the **cycle efficiency will be increased to 23% units.**

4.7 Summary

In this chapter the issues prevailing at each station have been discussed and also the measures to rectify such issues have been suggested (suggested improvements). It is noteworthy that these issues hinder the productivity of the process and hence increasing them would be helpful for the organization and motivate them to increase their productivity.

5. Discussion and conclusions

This chapter deals with the discussion of the method followed by the findings and analysis. This chapter also discusses about the research question individually and also provides reason for choosing this methodology for this study research.

5.1 Discussion of method

The methodology that was opted to solve the research problem was case study. Initially literature review was used to gain the experts view about VSM and to get a holistic view of the production facility at Veer-O-Metals. Literature review forms the basis for our As-Is research topic and has been a prime guiding source to carry out the research process. Galvan, J. L., (2006) asserted that a part of literature selected in accordance with the case and in-depth analysis done on that selected topic gives a broader view of the case.

The case study chosen to analyse the case was considered appropriate because it is very well suited for analysing the problem. Williamson.k, (2002) quoted that the case study can be used to gather and analyse information through which the new data emerges which can be further used to solve the existing problem. Hence, this method was chosen to gather information on the shop floor. The main reason was that while analysing the documents it was found that a set of information was missing, and other existing information was insufficient but when information was collected from shop floor it gave a holistic view of the production process and helped to map the material flow from raw material storage area to finished goods section.

Bauwens.,(2010) identified that the concept of triangulation helps the researcher to understand and verify the findings by comparing the independent results obtained from different techniques. Techniques such as interviews, observation, text analysis and pre-recorded documents were assessed before providing any conclusions. In order to obtain appropriate solution diverse types of information were collected and analysed at different process stages. In addition, the process of noting observations at different stations was considered to be the trickiest part since it demands reliability and validity of the information. While performing data collection, validity and reliability were maintained by choosing appropriate measures such as time measurement, material handling etc. Noticeably, before initiating data collection observations were obtained to get the ideology of the production facility.

The data that was collected from the literature review and case study were analysed together to get a better picture of the production process. In addition, by exploiting certain techniques the waste occurring in the forms of time, rework etc were identified and noted at each station.

5.2 Discussion of findings

The aim of this research was to find the waste incurred during production process and to suggest better and efficient methods for material handling with the help of techniques such as value stream mapping. The As-Is production state was observed, and the improvements were suggested in order to improve the production efficiency. Methods to optimize material handling and reduce waste incurred during production are discussed in the following section through the research questions discussed for this study.

RQ1. How can the production logistics be improved for small or medium size enterprise to support high volume production? (Research question 1)

The above question is answered by analysing material flow at all stations, by identifying and eliminating the unnecessary waste and by implementing suggested changes in the existing process.

Hassan, (2010) stated that the main purpose of material handling is to help the production operations at a manufacturing firm by providing the correct materials in required quantities at the correct locations and at correct time. Such support is conveyed by lifting, loading, unloading, pushing etc. Hence, the work stations in the company were tracked to check the material flow. Childe, (2003) stated that raw materials at a manufacturing firm must be handled efficiently so as to optimize the production process. Thus, the raw materials flowing into the company were assessed to identify waste. Moreover, Green, J. C., Lee, J. and Kozman, T. A., (2010) stated that material handling is seen as a non-value adding function that is required for the completion of the production at a manufacturing firm. They also added that by taking appropriate measures for material handling process the cost incurred can be reduced significantly. Hence, during production value adding activities and non-value adding activities were noted down and segregated. While value adding activity were identified as the necessary work required for successful completion, the non-value adding activity was identified as the waste but necessary for the operations to be completed such as setup time and preliminary check before the actual production. As discussed previously, value stream was utilized to identify waste that has been incurred during the production process. The waste was identified successfully, and the suggestions were given accordingly.

RQ 2. How can the suggested improvements help in better resource utilization and to increase production? (Research question 2)

The improvements suggested have been put down after deeply analysing the shortcomings observed during the As-Is state production process. It is noteworthy that As-Is state production process has been performed by implementing Lean manufacturing techniques in unison with facilitating effective material handling process.

Before commencing the operation, the raw materials were being sorted per profile which wasted a lot of time as well as resources and hence should have been done prior to performing the operation. On the other hand, during the material handling process it was found that the material was mixed up even before reaching the destined station. Moreover, it was also observed that the pillars reaching the assembly storage area did not meet the expected quality. While few of them accompanied bents, the others had extra burrs, and some were not even properly cleaned after the laser cutting operation. Considering all these issues of paramount significance, value stream mapping technique had been implemented to assess the production process and suggest improvements for better resource utilization. Through this technique, the defects occurring in the components manufactured were identified and the suggestions were given accordingly. Considering the wastage of time, it is significant to mention that after including VSM the time takes to sort the material at various stations such as plunging, tapping and bending can be remarkably reduced. Basis on the suggested recommendations and estimated waste reduction in each station the below table shows the expected increment in the Expected Improved state production time after implementation.

Table 5: Comparison between As-Is and Expected Improved state

Stations (in seconds)	**"AS-IS" state Production Time**	**Measures considered to reduce waste**	**Improved State Production Time (If recommender measures are implemented to reduce waste)**	**Estimated Improvement in percentage**
Plunging	161.5	Proper sorting of profiles, punching holes at laminated side.	101.5	37%
Bending	745.28	Considering new die and punches are provided & additional new tools are provided to avoid waiting time	125.28	83%
Tapping	220.15	Control plan must be made available to execute unscheduled work and re-work.	176.15	20%
Welding	416.68	Cleaning of materials after laser cutting operation. Avoid blow holes if the materials were cleaned for burrs. If fusion welding is preferred in place of brazing	335.68	19%

Assembly	29182	Bags must be given to carry nuts and bolds to reduce walking time	28991	1%

Interestingly, it has been observed in As-Is state analysis company used to produce the products with 36.55 hours of buffer time. Basis on improved state analysis the buffer time is expected to reduce by 9 hours and the expected buffer time will be 27.63 hours and the cycle efficiency for Production unit is expected to increase by 4% units.

5.3 Conclusions

The purpose of this research work was to optimize the day to day processes of the manufacturing firm such as material handling, waste reduction and incorporate certain techniques such as VSM for increasing productivity and exhibiting a significant reduction in waste. To optimize production logistics, it has to be ensured that there exists proper material flow, instruments and tools required must be provided, and Suggested welding techniques must be followed in order to reduce waste incurred during production. In addition, it also is noted that company must follow certain procedures in order to mitigate losses incurred during production. A safe and flexible environment must be provided for the employees working in the company to avoid any accidents.

On the basis of the findings it has been inferred that for optimizing the productivity of an organization it is necessary that certain measures such as proper material flow, proper welding techniques, must be implemented. Additionally, it should be ensured that the operators are provided with appropriate stock bags with nuts, bolts and other materials so that they do not waste their time in running for getting the materials required. It was also observed through the findings that most of the operators had not been provided sufficient safety measures so that they can perform their work in a better and faster manner

Further, It can be inferred that if suggested measures were followed the productivity would enhance generating profits as well as resulting in the growth of the company. Notably, following the suggested improvements will increase the satisfaction among the clients. Implementing the suitable technique for welding would also result in the production of better and finished products. Also, it is very important to mention that safe and flexible environment must be provided along with the desired tools and equipment would motivate the employees to perform faster and better. Implementing a safe environment will help employees to develop a sense of security.

The findings obtained from the study conducted can serve as a base for the Improved research on material flow and production optimization of a manufacturing firm. The significant attention given to the safety and comfortability of operators and helpers could lead to a feeling of being concerned about the workers and hence enable them to work towards achieving higher productivity and efficiency. Additionally, the method such as statistical process control can be incorporated to monitor and control the quality of the products that were being produced. The methods and implementation is used for single case study. The same can be implemented on a different case with some modifications.

6. References

AR, R., & al-Ashraf, M. (2012). Production Flow Analysis Value Stream Mapping: A Lean Manufacturing Process Case Study. *Engineering Procedia,* 1727 - 1734.

Abdulmalek, F., & Rajagopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. International Journal of Production Economics, 107, 223–236.

Abdulmaleka, F. A., & Rajgopal, J. (2006). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. International Journal of Production Economics.

Anand, G., and R. Kodali. (2008). "Selection of Lean Manufacturing Systems Using the PROMETHEE." Journal of Modelling in Management 3 (1): 40–70.

Anisur Rahman & Azharul Karim (2013) Application of lean production to reducing operational waste in a tile manufacturing process, International Journal of Management Science and Engineering Management, 8:2, 131-139, DOI: 10.1080/17509653.2013.798948.

Andersen, B. (1999),"Industrial bench marking for competitive advantage", *Human system management,* Vol.18 Nos3/4, pp.287-96.

Airasian, Peter and L. R. Gay. (2000). Educational research: Competence for analysis an application (6th ed.). New Jersey: Merrill Prentice Hall.

Asef-Vaziri, A. & Laporte, G (2005). Loop based facility planning and material handling. *European Journal of Operational Research,* n. 164, 2005, p. 1–11.

Boamah (2014), Problems associated with material management. Practise in construction industry.

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices.

Bauwens, A. (2010). The use of method triangulation in probation research**.** *European Journal of Probation University of Bucharest* Vol. 2, No. 2, 2010, pp 39 – 52. *www.ejprob.ro*

Bertolini, M., Braglia, M., Romagnoli, G., & Zammori, F. (2013). Extending value stream mapping: the synchro-MRP. *International Journal of Production Research,* 5499-5519.

Bellgran, M.; Säfsten, K. (2005) *Production development: Design and Operation of Production Systems,* Springer, London, UK, ISBN 9781848824942

Biddle, J., (2006). Lean talk doesn't equal lean walk. Manufacturing Business Technology, April, 36.

References

Chiarini, A. (2013). *Lean Organization: from the tools of the Toyota Production System to Lean Office.* Springer.

Childe, S.J. (2003), "Six things to manage – equipment", Production Planning & Control, Vol. 14 No. 7, p. 587.

Chen, C.-C.; Cheng, W.-Y. (2007) *Customer-focused and product-line-based manufacturing performance measurement*, International Journal of Advanced Manufacturing Technology 34, pp. 1236-1245

Christopher, M., (2011). *Logistics & supply chain management.* 4th red. Harlow: Pearson Education.

Chakravorty, S., (2009). S. Improving distribution operations: Implementation of material handling systems. International Journal of Production Economics, n. 122, p. 89–106.

Chopra, S. & Meindl, P (2001). *Supply chain management* – strategy, planning and operation. Englewood Cliffs: Prentice-Hall, 2001.

Cohen.L, Manion. L, Morrison. K (2000). Research Methods in Education *5th Edition*

Cutcher-Gershenfeld, J., (2002). Lean transformation in the US aerospace industry: appreciating interdependent social and technical systems. Cambridge, MA: Center for Technology, Policy and Industrial Development, MIT.

Creswell, J. W. (*1994*). Research Design Qualitative and Quantitative Approaches. Thousand Oaks. CA Sage.

Dües, C. M., K. H. Tan, and M. Lim., (2013). "Green as the new Lean: How to use Lean Practices as a Catalyst to Greening Your Supply Chain." Journal of Cleaner Production 40: 93–100.

Denkena, B.; Apitz, R.; Liedtke, C., (2006) *Knowledge-based benchmarking of production performance*, Benchmarking: An International Journal, Vol. 13 No. 1/2, pp. 190-199.

Denkena, B. et al., (2014). Interpretation and optimization of material flow via system behavior reconstruction. *Prod. Eng. Res. Devel.,* Volume 8, pp. 659-668.

Galvan, J. L. (2006). *A Guide for Students of the Social and Behavioral Sciences*. Pyrczak Publishing.

Green, J. C., Lee, J. & Kozman, T. A., (2010). Managing lean manufacturing in material handling operations. *International Journal of Production Research,* 48(10), pp. 2975-2993.

Groover, M. P., (2001). *Automation, Production Systems, and Computer-Integrated Manufacturing*, 2nd ed. New Jersey: Prentice-Hall.

References

George, B.; Dann, P.; Trimmer, B., 2003. Tagasaste (tree lucerne). Agfact P2.1.7., first edition 1986, reviewed May 2003, Brendan George

Hammersley, M., (2016). Reading ethnographic research. Routledge.

Hassan, M. D., (2010). A framework for selection of material handling equipment in manufacturing and logistics facilities. *Journal of Manufacturing Technology Management,* 21(2), pp. 246-268.

Harrison, A., Hoek, R. v. & Skipworth, H., (2014). *Logistics management and strategy -competing through the supply chain.* 5th ed. Harlow: Pearson Education.

Harris, C., and Harris, R., (2004). Five steps to implementing a lean material handling system [online]. Society of Manufacturing Engineers, 9 March 2004.

Hvolby, H.H and Thorstenson, A.(2000) "Performance measurement in small and medium-sized enterprise", presented at the Third Conference on Stimulating Manufacturing Excellence in small and media, Enterprise", Coventry, April, pp. 324-33.

Ioannou, G (2002). An integrated model and a decomposition-based approach for concurrent layout and material handling system design. *Computers & Industrial Engineering*, n. 52, 2007, 459–485.

Jenkins., S (1995) How to write a paper for a scientific journal. Australian Journal of Physiotherapy 41(4): 285 - 289

Keyser, R. S., & Sawhney, R. S. (2013). Reliability in lean systems. International Journal of Quality & Reliability Management, 30, 223–238.
Law, J. (2016) Fish-Bone diagram, Oxford University Press A Dictionary of Business and Management

Lynnette R. Porter, William O. Coggin (1995), Research strategies in technical communication.

Lacerd A. P, Xambre A.R, and Alvelos H.M (2016). Applying Value Stream Mapping to eliminate waste: a case study of an original equipment manufacturer for the automotive industry, International Journal of Production Research, Vol. 54, No. 6, 1708–1720.

Lian, Y. -H., & Van Landeghem, H. (2003). An application of simulation and value stream mapping in lean manufacturing. Belgium: Department of Industrial Management, Ghent University.

McDonald, T., Van Aken, E. M., & Rentes, A. F. (2002). Utilizing simulation to enhance value stream mapping: A manufacturing case application. International Journal of Logistics: Research and Applications, 5, 213–232.

Miles, M. and Huberman, A. (1994) *Qualitative Data Analysis: An Expanded Sourcebook.* Thousand Oaks, CA: Sage Publications.

References

Myers, F.E. and Stephens, M.P., (2000). Manufacturing facilities design and material handling. 2nd ed.Upper Saddle River: Pearson Hall.

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations and Production Management*, *15*(4), 80−116.

Nzuve, J., (2018), Ten principles of material handling.

Ohno, T., (1988), *Toyota Production System – Beyond Large-Scale Production,* New York: Productivity Press, ISBN 0-915299-14-3

Rahman, A and Karim, A., (2013). Application of lean production to reducing operational waste in a tile manufacturing process, International Journal of Management Science and Engineering Management, 2013 Vol. 8, No. 2, 126–134

Rother, M., & Shook, J. (2009). *Learning to see - Value stream mapping to create value and eliminate Muda.* Cambridge: Lean Enterprise Institute.

Rother, M., Shook, J., (2005), *Learning to see*, Brookline: Lean Enterprise Institute, ISBN 978-09-66-78430-5.

Rother, M., & Shook, J., (2003). *Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda: Version 1.3 June 2003*. Lean Enterprise Institute.

Rother, M., & Shook, J. (1999). Learning to see: Value stream mapping to add value and eliminate Muda. Brookline, MA: The Lean Enterprise Institute.

Singh, B., Garg, S. K., Sharma, S. K., & Grewal, C. (2010). Lean implementation and its benefits to production industry. *International Journal of Lean Six Sigma Vol. 1 No.2* , 157 - 168.

Shingo, S., (1996), O sistema Toyota de produção: do ponto de vista da engenharia de produção. Porto Alegre: Bookman.

Stock, J. R. & Lambert, D. M. *Strategic logistics management*. 4th edition. New York: McGraw-Hill, 2001.

Saunders, M., Lewis, P., Thornhill, A. (2009). Research methods for business students, 5/e. Pearson Education India.

Teichgräber, U. K., & Bucourt, M. d. (2012). Applying value stream mapping techniques to eliminate non-value-added waste or the procurement of endovascular stents. *European Journal of Radiology, 81*, 47-52.

Tangen, S. (2003) *An overview of frequently used performance measures*, Work Study, Vol. 52, No. 7, pp. 347-354.

Underdown, R. and Talluri ,S.(2002) “cycle of success: a strategy for becoming agile benchmarking”, *Benchmarking: An international Journal,* Vol.9 No.3 pp.278-92.

References

USEPA. (2011). Lean manufacturing and environment: The lean and environment toolkit. US Environmental Protection Agency.

Voehl, F., Harrington, J., Mignosa, C., & Charron, R. (2014). *The Lean Six Sigma Black Belt Handbook.* Boca Raton: CRC Press.

Williamson, K., (2002). *Research methods for students, academics and professionals: information management and systems.* Second ed. Wagga Wagga: Centre for Information Studies.

Womack, J. P., Jones, D. T., & Ross, D. (1990). The machine that changed the world. New York: Macmillan.

Womack, J. P., and D. T. Jones. (2003). Lean Thinking – Banish Waste and Create Wealth in Your Corporation. 2nd ed. London: Free Press.

Zairi., (2000) *"Managing customer satisfaction: a best practise perspective'*, The TQM magazine, Vol.12No.6, pp. 389-94.

7. Appendices

Appendix 1 Interview with the Organization

- **Interview with the organization (Manager).**
  - How many employees are working at each station?
  - How do you receive orders from your customer?
  - Did your shop floor employees are well trained to meet the demand?
  - Did your shop floor employees are aware of the drawing to be used?
  - How often you train your employees?
  - How the critical information will get cascaded to your employees?
  - Are your workers multi-skilled?
  - Where you think waste of time is happening?
  - Do you have any suggestion for improving production time?
- **Interview with the shop floor employee.**
  - Are you provided with the adequate tools and resources to meet your production targets?
  - Where have you been trained for this operation?
  - Are top management being flexible in sharing the critical information?
  - How is the work load at your station?
  - How often your tool set needs to be changed?