Design and Implementation of Cost Integrated Value Stream Map in MSMEs

Thesis submitted to

UNIVERSITY OF CALICUT

in fulfilment for the award of the degree of

DOCTOR OF PHILOSOPHY

By

RAJESH MENON B

Department of Mechanical Engineering
Government Engineering College, Thrissur-9
University of Calicut

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Dr. SHALIJ P R
Professor
Department of Production Engineering
Government Engineering College, Thrissur-9
University of Calicut

December 2020

DEPARTMENT OF PRODUCTION ENGINEERING
GOVERNMENT ENGINEERING COLLEGE, THRISSUR
Engineering College P.O, Ramavarmapuram,
Thrissur, Kerala, India, Pin Code - 680009
Phone No. 0487-2334144 Fax: 0487-2336124
Website: www.gectcr.ac.in

CERTIFICATE

This is to certify that the thesis entitled "**Design and Implementation of Cost Integrated Value Stream Map in MSMEs**" is the record of bonafide research work done by **Mr. RAJESH MENON B** under my supervision and guidance at Department of Mechanical Engineering, Govt. Engineering College, Thrissur in fulfilment of the requirements for the Degree of Doctor of Philosophy under the Faculty of Engineering, University of Calicut.

Thrissur-9
22.12.2020

Dr. Shalij P R
(Supervising Guide)
Professor
Production Engineering
Government Engineering College, Thrissur

Certified that all corrections and suggestions by the thesis examiners in their report of evaluation as communicated in the letter No. 212585/RESEARCH-C-ASST-1/2020/Admn dated 27.05.2021 are incorporated in the thesis.

Thrissur-9
12.06.2021

Dr. Shalij P R
(Supervising Guide)
Professor, Production Engineering Department
Government Engineering College Thrissur
On Deputation to APJ Abdul Kalam Technological University,
as Dean (Research)

DECLARATION

I **RAJESH MENON B,** hereby declare that the thesis entitled “**Design and Implementation of Cost Integrated Value Stream Map in MSMEs**" is based on the original work done by me under the guidance of **Dr. Shalij P R**, Professor, Department of Production Engineering, Govt. Engineering College, Thrissur for the award of Ph. D under University of Calicut. I further declare that this work has not been included in any other thesis submitted previously for the award of any Degree, Diploma, Associateship or Fellowship or any other title for recognition.

Thrissur **RAJESH MENON B**

22.12.2020

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ABSTRACT

Value stream mapping (VSM) is one of the most efficient lean tools for assessing the present condition of any manufacturing or service-oriented company. It can also be used for identifying the wastages in the production line and propose the measures to eliminate those wastages using any of the commonly known lean tools. Value stream map is a tool which measures the wastages associated with production depicted in the time domain. It is easy to appreciate if these are shown in terms of cost of production from the procurement of raw material until the finished products are ready for the despatch. In this context, it will be beneficial to combine time and cost aspect related to all production activities that can be effectively used for the productivity monitoring and elimination of wastages as defined by the lean manufacturing paradigm.

This research work proposes a new method for combining the time and cost domain in production using another tool for calculating the direct cost in manufacturing a product named Cost Time Profile (CTP). CTP gives a reasonably fair accounting of all the aspects that contribute to the addition of costs in the production line. CTP method equips to account the Time value of the investment during production. Combining CTP concept along with the traditional VSM becomes a very effective tool for identifying the wastes associated with production in monetary terms that is appreciated by any working personnel in the production floor.

The proposed ‘cost integrated value stream map’ (CVSM), by combining the two very effective tools namely VSM and CTP, was used for implementing the lean tools in two different companies that are coming under dissimilar production nature. Two companies in Kerala having different production types namely assembly manufacturing and a process industry were selected for implementation studies. This tool proved to be very effective in assessing and identifying wastages in the production process and preparing it for further lean implementation.

An internet enabled data collection software, MSME value tracker, was also designed for the collection and analysis of production parameters for arriving at the condition of the company with regard to its Leanness in operation. This tool helps us to assess the cost wise status of production and suggest remedial lean measures for a better future state of productivity.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND NOMENCLATURES

ABC	Activity Based Costing
AI	Artificial Intelligence
CD	Cost Deployment
CTI	Cost Time Investment
CTP	Cost Time Profile
CVSM	Cost integrated Value Stream Mapping
DES	Discrete Event Simulation
ERW	Electric Resistance Welded
FP	Fuzzy Proximity
GDP	Gross Domestic Product
IoT	Internet of Things
IT	Information Technology
JIT	Just in Time
KPI	Key Performance Indicator
LM	Lean Manufacturing
LMCS	Lean Manufacturing Competitiveness Scheme
MRP	Material Requirements Planning
MSME	Micro Small and Medium Enterprises
NVA	Non-Value Added
NVAT	Non-Value-Added Time
OEE	Overall Equipment Effectiveness
PDC	Product Direct Cost
PERT	Program Evaluation and Review Technique
QFD	Quality Function Deployment
RFID	Radio Frequency Identification
SME	Small and Medium Enterprises
SMS	Short Message Service
SOP	Standard Operating Procedure
TMT	Terms Mining Technique
TPM	Total Productive Maintenance
TPS	Toyota Production System
VA	Value Added
VAT	Value Added Time
VSC	Value Stream Costing

VSM	Value Stream Mapping
WIP	Work in Process

Cw	Cost of Waiting
$Cmat$	Cost of Material
Ca	Activity Cost
Tc	Cycle Time
Tw	Waiting Time
IRR	Internal Rate of Return
Cp	Cost of Production
Cu	Utility Cost
Cf	Fixed Cost / Product
$Crej$	Cost of rejection of defective product in each machine
Cr	Cost of manufacturing resources
Cd	Depreciation Cost
Co	Operator Cost
Cm	Machine maintenance cost
$\dot{C}d$	Machine depreciation cost rate
Ce	Cost of equipment
Cm	Machine maintenance cost
Ly	Expected life of equipment in years
$\dot{C}m$	Machine maintenance cost rate
$\dot{C}r$	Resource cost rate
$\dot{C}o$	Operator cost rate
$\dot{C}a$	Activity cost rate
Tu	Total time units the machine is in use in a year

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Micro small and medium enterprises (MSMEs) play important roles in bringing wealth and prosperity to the societies, contrary to the belief that only large size organizations contribute to the development of Industrial sector in the Indian context. This is due to the reason that; large industries outsource their operations to the MSMEs. The survival and success of these large organizations are ensured only if their performance is at par with that of MSMEs to whom their operations are outsourced(Ministry of MSME 2006). This situation warrants the application of manufacturing management models in MSMEs too.

Lean manufacturing philosophy concentrates on the elimination of waste in connection with manufacturing activities. There are many established lean tools available which have evolved from the Toyota production system (TPS) in 1940. 5S, Total productive maintenance (TPM) Value stream mapping (VSM), Just-In-Time (JIT), KANBAN are some of the important and commonly used lean tools. These tools are used around the world for assessing and removing the wastes associated with the production of products or service. Improvement of productivity and profit is the bottom-line result obtained by the implementation of all these lean tools.

Lean manufacturing philosophy induces a motivating working environment on the employees and on the customers by offering them quality products or services. Thus, the quality and variety of product or service are improved with the reduced cost and wastages in production. Lean manufacturing takes a holistic approach by considering all the micro-level production activities as value-added activities which are ultimately valued by the customer other than separating the functional departments such as maintenance, operations, quality, marketing and finance.

The core philosophy of lean manufacturing is waste elimination. The focus is not quick or more production but, to eliminate waste of any kind which has no value addition. Companies by focusing and following the philosophy of “do it faster, do it better” hide the symptoms of problems, which hamper quicker and better production. Lean manufacturing mainly eliminates ‘muda’ for increasing productivity and reducing the cost of the product. Muda is a Japanese term meaning “waste”.

Fierce competition in globalised markets necessitates the adoption of manufacturing strategies that help in improving competitiveness. Implementation of lean practices is one such approach to improve the production process. Initiatives from Toyota production system (TPS) which has later been referred to as lean manufacturing (Shingo, 1989), were applied to redesign the manufacturing systems to reduce wastages in production and to improve the quality of the product (Seth and Gupta, 2005; Vinodh et al., 2013).

The term ‘wastage’ in an organization includes extra inventory, defects in products, inadequate processing, waiting of inventory, overproduction, unnecessary motion and avoidable transportation (Jones and Womack, 2002). Various lean tools used in this context are QFD, TPM, TQM, 5S, Kanban, Kaizen and VSM (Rother and Shook, 1998; Singh et al., 2011; Singh and Sharma, 2009). Among all these lean tools, VSM is a pictorial representation of the flow of material and information through the various stages in a system which can be easily understood by the top management and workers in an organization. VSM also includes all the information regarding the manufacturing process, suppliers and customers to which the products are distributed (Singh et al., 2011).

VSM is used as a lean tool in various industries including automotive (Kumar et al., 2018; Seth and Gupta, 2005), high precision tool room (Batra et al., 2016), camshaft manufacturing (Vinodh et al., 2010), rope manufacturing (Yuvamitra et al., 2017), plastic products fabrication (Rohac and Januska, 2015), casting industry (Singh et al., 2017), pharmaceuticals (Chowdary and George, 2011), coffee (Taylor et al., 2012), aircraft (Luciana and Lestari, 2015), construction field (Gunduz and Naser, 2017), biodiesel production (Rajeshwari Chatterjee, Vinay Sharma, Samrat Mukherjee, 2014), steel (Abdulmalek and Rajgopal, 2007) and electronics (Chiu and Lin, 2016). Various works on improving the performance of the service sector, including healthcare (Teichgraber and de Bucourt, 2012), education, auditing, service business process (Forbes et al., 2004), supply chain management (Suarez-Barraza et al., 2016), logistics (Ingeniería, 2012), maintenance services (Ahmed En-nhaili, Anwar Meddaoui, 2015; Stadnicka and Ratnayake, 2017; Tyagi et al., 2015) and government services (Andreadis et al., 2017) were also reported in the literature.

Although VSM is widely demonstrated in the assembly-based industry, it was also reported that the same can be applied in the process industries as well (Abdulmalek and Rajgopal, 2007). By implementing VSM, there will be a reduction in total cycle time, total lead time, the rejection rate of the product, work in process inventory and improvement in uptime (Vinodh et al., 2010). With the implementation of lean manufacturing tools using VSM, the efficiency of operation and resources in terms of machines, workers, and inventory can be improved. Space utilisation can also be made more effective for optimising the financial losses of the company (Kumar and Kumar, 2012).

VSM is difficult to be applied when the manufacturing process is complex with many branches of value streams merging into a line and when the production process is dynamic (Braglia et al., 2006). Traditionally VSM was applied only to linear production systems and systems having non-variability in data during the processes (Taylor, Braglia, et al., 2009). Several additions were suggested by researchers for overcoming these shortcomings of VSM. VSM is combined with fuzzy set theory (Seyed M.S., et.al 2013.) or discrete event simulation (DES) (Schmidtke et al., 2014) to overcome the limitations of conventional VSM.

Improved VSM with simulation can handle complex systems by finding the critical production path using an improved Program evaluation and review technique (PERT) and statistical tools to change the production process (Andrade et al., 2016). Dynamic modelling system can be used with VSM to enhance the current state map when the changes required in the process are as per the lean policies and resource requirements (Ajaefobi, et al., 2009). These improved VSM methods identify the wastages associated with the value addition process and help to implement the lean manufacturing tools suitable for reducing all categories of waste.

In sustainable value stream mapping (Sus-VSM) energy related matrix is added with VSM to redesign the operation to develop green and sustainable production (Carmignani, 2017; Faulkner and Badurdeen, 2014). Similarly, energy wastes can be mapped in VSM to plot energy value-stream map (EVSM) to accomplish lean manufacturing (Rezaeian, Parviziomran, and Mahdavi 2018).

In green modified VSM (GMVSM), time, energy, material and transportation information between the various production processes are mapped on the perspective of lean tools and are converted into carbon traces and carbon efficiency terms to produce the future state map (Zhu et al., 2019). In another work, energy and cost matrices are associated in VSM to improve the production process (Rajeshwari Chatterjee, Vinay Sharma, Samrat Mukherjee, 2014). The effect of combining the VSM with overall equipment effectiveness (OEE) to find the corrective approach which can negatively affect the production process is also reported in the literature (Dadashnejad and Valmohammadi, 2017).

Different types of practices are adopted by organisations to ascertain costs incurred in manufacturing and product costing. In traditional methods of costing, accumulation of direct costs was considered to quantify the cost of the product. The traditional costing method does not account the support costs which end up in errors while calculating the actual production cost. Although an Activity-based costing (ABC) method provides a better cost when compared to traditional costing methods, frequent update of ABC cannot be possible. This may lead to a wrong estimation of the product cost.

Value stream costing (VSC) proposed by Ruiz-de-Arbulo-Lopez et al., (2013) helps to identify various costs, including support cost, labour, equipment, facilities, maintenance and materials. VSC can be implemented in those organisations that have already adopted lean production practices. However, VSC is less accurate than other costing systems like ABC (Chiu and Lin, 2016; Gunduz and Naser, 2017). VSC does not distinguish between the direct costs, indirect costs and costs outside the value streams. In the VSC method, all categories of costs are considered equal, which works well for short term decision making. Thus, the Product Cost indicated by the VSC is less accurate than ABC (Ruiz-de-Arbulo-Lopez et al., 2013). In another work, VSM is added with Cost deployment (CD) tool to quantify the losses in the current state map and rectify these losses in the prioritized process in future state map (Abisourour et al., 2019).

1.2 PROBLEM definition

VSM as a lean tool is having indisputable versatility as far as visualizing the entire operations of a manufacturing firm but it fails in representing the results in monetary terms. People appreciate and understand productivity-related parameters when represented in terms of cost rather than in the time domain. However, CTP gives everything related to production in terms of the cost. CTP includes the cost related to materials, activity and waiting, but it fails to include the overheads in the production process such as administrative and utility costs involved in the production process.

These shortcomings of both VSM and CTP can effectively be overcome by the design of a new tool which combines all the vital features of both these tools and incorporates the overhead charges associated with the production process. Here the final cost of the product obtained from the tool can easily be verified with the actual cost for the accuracy of the tool. There are overheads and cost investments associated with the production process along with the direct costs of the product. Information related to these overheads and cost associated with waiting will give a good opportunity for waste reduction in MSMEs.

1.3 OBJECTIVES OF THE STUDY

This research work is undertaken with the aim of developing custom-made models suitable for implementing lean techniques in contemporary MSMEs and assessing the productivity improvement using the proven lean techniques practiced today. Accordingly, this research work is undertaken with the following objectives:

- To conduct a comprehensive study of the Lean Techniques as reported by researchers.
- To develop a model for facilitating the easy implementation of the Lean Techniques in MSMEs.
- To study the feasibility of implementation of the model in selected MSMEs.
- To draw the inferences from the implementation experiences using CVSM.
- To develop and test a software tool for easy implementation of the model.

1.4 METHODOLOGY

Methodology adopted for the research is depicted in figure 1.1. The research was initiated with an extensive literature survey on topics related to the implementation of lean manufacturing in the context of productivity improvement in MSMEs in India, design of an apt tool that can measure the current state of production in terms of cost and time domain, implementation of this tool in various manufacturing enterprises, assessing the effectiveness of the tool in converting the production information into understandable information by the lean team for suggesting further action and finally, validating the accuracy of this tool in predicting the condition of production so that it can be utilised for suggesting measures to improve productivity further to the future state level.

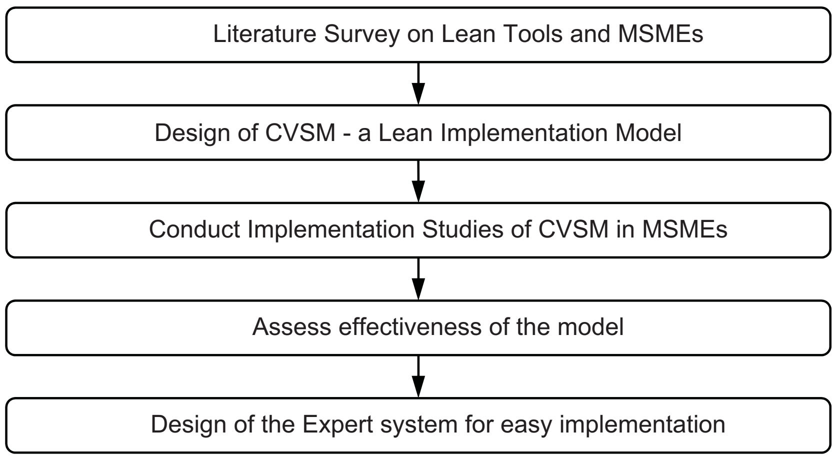


Figure 1.1 Methodology of Research

Literature review on MSMEs and its relevance in the Indian industrial sector is conducted to get a picture of its contribution to the Indian economy. Then a detailed study on works published in refereed journals about Lean Manufacturing is done to learn more about the different lean tools and its functioning in reducing the wastes associated with production. An exhaustive study of the researches reported in Value Stream Mapping is conducted to identify the various industrial sectors in which VSM is implemented and various types of environments in terms of product or the nature of manufacturing.

Publications about enhancements attempted by researchers have also been studied in detail to learn the different opportunities further to get a clear picture of the possibilities of modifying this versatile tool in view of designing our specific lean tool. There were a few papers available on the topic of Cost time profile which describe the quantification of the investment cost of unfinished products or investment on accrued inventory by the concept of Cost time investment. Finally, the works carried out by researchers on relating the cost of production into VSM is also collected and studied.

Design of the new lean tool is carried out by combining the conventional VSM by incorporating the cost aspects of production. Test implementation of this new tool was carried out in two different industries. An easy to operate expert system was developed as a part of the implementation procedure.

1.5 THESIS OUTLINE

Chapter 1 contains an introduction to the relevance of VSM in Lean Manufacturing paradigm and its limitations. The concept of CTP is elaborated and how it eliminates the handicap of VSM is detailed. The research gap, problem, objectives of the study and the methodology adopted are also explained in this chapter.

Chapter 2 contains the literature review in the area of VSM and CTP. The research works carried out by previous researchers in different lean tools are explained in this chapter. The modifications to VSM attempted by many researchers are given in this chapter. The summary of findings from the literature review is added in the last section.

Chapter 3 contains the methodology of the research in regard to the approach of lean measurement of any company, the redesigning of existing VSM and CTP tools and the design of a new assessment tool and the procedure for its implementation in an industrial environment.

Chapter 4 contains the implementation estimation and analysis of CVSM tool implementation in an assembly manufacturing company in Palakkad, Kerala that produces scaffolding pipe assembly and the results obtained are discussed in this chapter.

In Chapter 5 contains the implementation of CVSM in a surgical glove manufacturing company in Palakkad, Kerala and the results are analysed.

Chapter 6 explains the development of a web enabled software tool that is capable of data collection and processing the production parameters of these companies for analysis.

Chapter 7 discusses the results of implementation and the checking effectiveness of the developed tool by conducting a survey among the lean implementation team in the two companies.

Chapter 8 summarises the conclusion of the research work conducted by implementing the designed lean tool in two different MSME companies.

Chapter 9 lists all the relevant reference journal papers and conference proceedings cited in this research work.

1.6 SUMMARY

The research problem, objectives and methodology of the doctoral work were presented in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explains the literature survey conducted in connection with the research work. The contents of the literature survey are explained in six subsections. The first subsection describes the importance of MSMEs in India and their impact on our economy. The second subsection explains the methodology of Lean Implementation for attaining productivity improvement in MSMEs. The third gives information about the versatility of VSM, as a lean assessment tool, in visualising the current condition of industry in terms of its productivity. The fourth subsection observes the modification attempts carried out by many researchers in various sectors of manufacturing and the concept of Cost time profile. The fifth subsection combines the concept of cost and time for measuring the productivity parameters. Last section of the literature survey is about the introduction of Information Technology enabled expert systems for facilitating the advantage of collecting and processing the complex data related to production.

2.2 LITERATURE SURVEY METHODOLOGY

The methodology followed to carry out the literature survey reported in this chapter is given in Figure 2.1. During the first stage of the literature survey, the research on MSMEs was reviewed. The results of this stage of literature survey espoused the establishment of the fact that MSMEs play major roles in enhancing the wealth of the societies situated in all parts of the world. Yet the MSMEs are found to suffer from many deficiencies that prevent them from competing globally along with large size organizations.

Next, the literature was surveyed to identify the research on implementing Lean tools in MSMEs. At this juncture, the literature was searched to locate any research reporting the implementation of Value stream mapping in MSMEs. Papers reporting cost time profile were reviewed for analysing the cost profiles of the processes. Reported works on the integration of costs into VSM were studied and the various methods of associating cost into VSM were identified. Finally, papers reporting the design of expert systems on value stream mapping were also reviewed. The details of the papers and the summary of the work carried out in these areas are presented in the subsequent paragraphs.

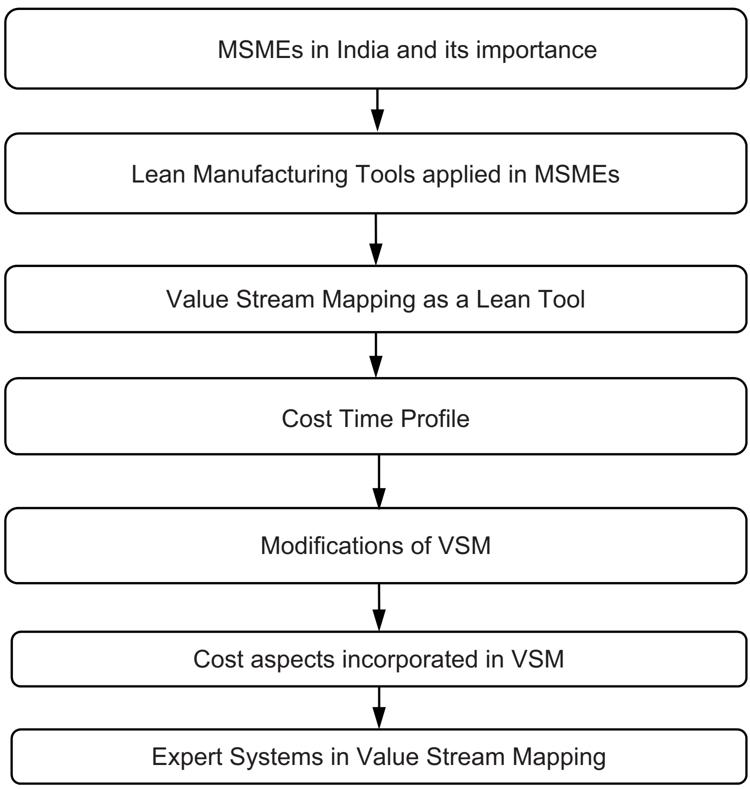


Figure 2.1 Literature Survey Methodology

2.2.1 Importance of MSMEs In India

MSMEs in India play a major role in the industrial sector when considering the share to GDP(Gross domestic product), export potential, contribution towards innovation, employment generation and rural empowerment. An improvement in the MSME sector as suggested by Asghar et al. (2011); Das (2017); Syal (2015) directly contributes to the Indian economy. This growth is essential to achieve our projected target of USD 5 trillion GDP in 2024 as envisaged by the Ministry for MSME. This will increase MSMEs contribution to India's GDP to over 50% from the current 29%. The export's contribution will be increased to 75 % from the current figure of 50% and the employment generation will go up to 15 Cr employees as against the current strength of 11.1 Cr. The role of MSME in the Indian economy establishes a strong need of searching for measures in improving the productivity of all the companies functioning under the definition of MSME.

MSMEs in India have started manufacturing complex and technologically advanced products compared to the earlier scenario. In spite of these technological milestones of achievements, MSMEs in India are facing many barriers to achieve the targeted growth and are also unable to catch up with the global competition. Hence, Indian MSMEs need to device new strategies to face the future's competition. A detailed literature review on how Indian MSMEs can adopt strategic innovation for achieving the competitive advantage was conducted by Lohith et al. (2018).

Singh, et al., (2018) investigated the literature related to MSMEs in India to find out major issues faced by them in this highly competitive environment. This study focuses on the contributing factors towards improved manufacturing performance of Indian MSMEs. Chawan and Vasudevan (2014) aim to bridge the gap between MSMEs and academia by the mutual exchange of knowledge for solving the real problems in the manufacturing sector and by providing training for the upcoming students to get them equipped with the job skills which the industry currently demands.

Das (2017) explained the huge growth potential of MSMEs and its opportunities for development in the Indian context. It also addressed important challenges faced by this sector and proposed suggestions for the improvement. Boateng and Nagaraju (2019) conducted an exhaustive study about the functioning of MSMEs across India collecting inputs from 10 states, selected based on the number of MSMEs existing in all the states in India. The study establishes the representation of MSMEs in rural and urban areas in India, total export contribution, share in GDP and the number of employment opportunities created for male and female employees.

Kumar (2018) identified the role of MSMEs as the backbone of Indian economy. Kumar (2017) proposed a skill development methodology to increase productivity in MSMEs for the contribution to economic growth. Esubalew and Raghurama (2020) investigated the mediating effect of the competence of entrepreneurs on the relationship between bank finance and performance of MSMEs and bridge the gap between them.

2.2.2 Lean Manufacturing Tools applied in MSMEs

Lean manufacturing paradigm ensures a win-win situation among all the stakeholders associated with a company. Customers are happy with the quality and cost of the product, the company is satisfied with the steady orders from the customers, quality raw materials from suppliers and happy and contented employees, the employees are satisfied with their working environment and their remuneration. The suppliers are also happy to deal with the company because of the prompt payment and consistent orders. In addition to this, the environment is also protected because of the specific recycling/ disposal protocol for the products.

The philosophy of waste reduction primarily focuses on the reduction of the cost involved in the production using traditional lean manufacturing tools appropriate to the type of waste. In contrast, lean manufacturing aims to reduce the time of production by eliminating Non-value added (NVA) activities and is a common underlying principle in many production facilities around the world introduced through the works of Abdulmalek and Rajgopal (2007); Melton 2005; Womack and Jones (1997). In essence, lean manufacturing preserves value within an organisation by emphasising reductions in time and thus maximising efficiency through the reduction of waste. The development of lean manufacturing techniques originated from Toyota production system focuses mainly on pinpointing and eliminating waste as proposed by Howard Gitlow and Gitlow (1988); Lian and Van Landeghem (2007).

A series of tools were developed to map and consequently eliminate three areas. These were: 'Muda', also known as the seven wastes, 'Muri' known as the overburdening of people or equipment and 'Mura' known as unevenness or irregular production suggested by Hicks (2007); Hines and Rich (1997); Womack and Jones (1997). The categories developed to describe the seven primary wastes (Muda), plus the eighth waste of underutilisation of creativity of people added later in development followed by explanations of the terminology.

Abdul Rashid Abdul Aziz (2006) presented a methodology for implementing Lean-Kaizen concept using VSM to identify continuous improvement opportunities in an SME in India. Jasti and Kodali (2015) have performed a detailed analysis of the literature review of lean production. The analysis involved studying 546 research articles published from 1988 to 2011 in selected 24 Operations-research journals. Kumar and Kumar (2015) made an attempt to study the implementation of Lean manufacturing tools in the Indian industries. The results of this survey support the opinion that Lean manufacturing had the potential to improve the organizational performance of Indian industries.

Jorgensen *et al.*, (2007) suggested that sustainable-lean requires attention to both performance improvement and capability development in the Danish Industrial scenario. Achanga et al. (2006) presented the critical factors that constitute a successful implementation of lean manufacturing within manufacturing SMEs. The results of this study provide MSMEs with indicators and guidelines for the successful implementation of lean principles. Alsyouf et al. (2011) suggested a methodology for assessing the cost-effectiveness of implementing lean tools. Chowdary and George (2011) pointed out the scope of improvement opened up by the implementation of lean principles combined with current good manufacturing practices in a pharmaceutical enterprise. Mayatra et al., (2019) introduced different lean manufacturing tools and their implementation in the automobile and pharmaceutical industries. Bittencourt et al., (2019) conducted a review from 2011 to 2018 and focused on the effect of Lean Thinking within the scope of Industry 4.0.

2.2.3 VSM as a Lean Tool applied in MSMEs

Numerous researchers have described the characteristics of Value Stream Mapping. Among the many established Lean tools, Value stream mapping (VSM) is superior and always acts as a starting point for any lean implementation initiative. VSM and analysis as proposed by, Adepu et al. (2015); Parthanadee and Buddhakulsomsiri (2014); Reddy et al., (2013); Rohac and Januska (2015), is a tool that allows to see the waste and plan the measures to eliminate it.

A value stream is a series of steps that occur to provide the product or service that the customers want. In order to provide the product or service that the customers desire, every company has a set of steps that are required. VSM as pointed out by Vinodh et.al. (2013) enables us to better understand what these steps are, where the value is added, where it is not and more importantly, how to improve upon the collective process. It provides a structural visualization of the key steps and corresponding data needed to understand and intelligently make improvements that optimize the entire process. VSM is a versatile Lean tool to document, analyse and improve the flow of information and material required to produce the product or service.

There are many reasons for selecting the VSM analysis as a starting point for every successful lean implementing procedure. However, there are also certain shortcomings for this tool. The limitations shown by Forno et al., (2014) are the lack of procedural clarity on the product modularity, skilled operators, process stability, the standard method of measuring data in processes and documentation for current state map.

Table 2.1 gives a list of VSM implementation attempted in various industrial sectors and the details of the improvement achieved in each case. There are different industries such as automotive, coir, piping, aircraft, etc. involved in the given list of work. The productivity improvement is also achieved by initially visualising the current state map of operations and then proceeding to design a proposed future state value stream map for suggesting the improvement measures.

Table 2.1 VSM Implementation Studies Reported in Literature

No:	Author & year	Details of the work carried out
1	Huang *et al.*, (2019)	Value stream mapping tool is integrated with digitalisation to help the decision-makers efficiently capture the non-value-adding processes on the factory floor
2	Knoll, Reinhart and Prüglmeier, (2019)	Integration of multidimensional process mining techniques with principles of value stream mapping
3	Agarwal and Katiyar, (2018)	A review of VSM implementation studies in different industries
4	Meudt, Metternich and Abele, (2017)	Implementation of digitalisation of lean implementation for recording, handling, processing, analysing and optimising the production information
5	Singh *et al.*, (2017)	Addresses the application of lean manufacturing using value stream mapping concept in a casting organisation.
6	Andreadis, Garza-Reyes and Kumar, (2017)	Statistical tools are integrated into the analysis of Lean tools
7	Ghushe *et al.*, (2017)	Value stream mapping is applied on a coir manufacturing industry.
8	Pandya, Kikani and Acharya, (2017)	Implementation of value stream mapping for directional control valve in the Bosch Production System.

No:	Author & year	Details of the work carried out
9	Yuvamitra, Lee and Dong, (2017)	Case study of VSM implementation performed on a rope manufacturing process.
10	(Ali, Petersen, and Schneider 2016)	Combination of VSM and FLOW to identify and alleviate information and communication-related challenges in large-scale software development.
11	Batra *et al.*, (2016)	Value stream mapping in the lean transformation of automotive manufacturing sector and then apply the same in a precision tool room.
12	Tomar and Tiwari, (2016)	Methodology of implementation of value stream mapping and its benefits to various production industries and service sectors.
13	Kumar and Kumar, (2016)	Real life example of improvement gained through implementation of VSM as an enabler of lean manufacturing.
14	R Nivya and T Sunil, (2016)	VSM implementation in a forging industry.
15	Patel, Chauhan and Trivedi, (2015)	Review of VSM techniques and its benefits in machining industry.
16	Singh, Singh and Garg, (2015)	Implementation of value stream mapping technique in a fastener manufacturing industry.
17	Kumar KR, (2015)	VSM application in a pump assembly manufacturing company is detailed
18	Luciana and Lestari, (2015)	Implementation of VSM in an aircraft industry for the reduction of waste during production.
19	Briciu and Ofileanu, (2015)	Value stream cost analysis conducted in a footwear industry is elaborated
20	Tyagi *et al.*, (2015)	VSM tool is used to explore the non-valued added steps in the complete product development process.
21	Dighe and Kakirde, (2014)	VSM has been used to document current lead time, inventory levels and cycle times to determine the ratio of value added to total lead time of the product line being analysed.
22	Sheth, Deshpande and Kardani, (2014)	Implementation of value stream mapping in automotive industry. Value stream mapping aim is identified waste in terms of non-value-added activities.
23	Wahab *et al.*, (2014)	Value stream mapping implementation for the analysis of production in an aircraft manufacturing company.
24	Ikatrinasari and Haryanto, (2014)	Implementation of VSM for enabling leanness in Directorate airworthiness and aircraft operation in Indonesia
25	Forno *et al.*, (2014)	VSM tool can sometimes lead to mistakes that can cause problems of interpretation of intended results. Considering the problems identified, the paper suggests future works for improving the use of VSM for mapping processes.
26	Gupta and Sharma, (2014)	Demonstrates the implementation of lean philosophy through layout modification of a manufacturing case study.
27	Vinodh, Somanaathan and Arvind, (2013)	Explores the practical feasibility of deploying Value Stream Mapping for enabling lean manufacturing in a camshaft manufacturing industry in Trichy, Tamil Nadu.

No:	Author & year	Details of the work carried out
28	Singh and Singh, (2013)	The application of lean manufacturing using value stream mapping concepts in an automobile spare-parts manufacturing organization.
29	Reddy, Lingareddy and Jagadeeshwar, (2013)	A detailed methodology of implementing the VSM tool in a manufacturing environment in a general perspective
30	Songar *et al.*, (2013)	VSM implementation in an automotive industry is explained
31	Belokar, Kharb and Kumar, (2012)	A flow diagram showing the process is drawn to reflect the current state of the operation. The non-value actions are identified in each step and between each step by their waste of time and resources.
32	Parihar, Jain and Bajpai, (2012)	The method of value stream analysis, which is a tool for helping manufacturing companies to go lean and to achieve larger control of their value stream.
33	Silva, (2012)	Identifies the applicability of one of Value Stream Mapping for the apparel industry in Sri Lanka. The current state map was developed after making necessary observations and calculations. Then various improvement proposals had been identified based on lean manufacturing theories and the future state map was developed.
34	Chen, Li and Shady, (2010)	Presents a case study of lean implementation at a small manufacturer in the United States. Starting with collecting process information, a current value-stream map was created that reflected the current operation status. A future value stream map was then proposed to serve as a guide for future lean activities.
35	Vinodh, Arvind and Somanaathan, (2010)	The implementation study has been conducted in a typical Indian industrial cam shaft manufacturing company to apply VSM for enabling leanness.

2.2.4 Cost-Time Profile (CTP)

Conventional cost accounting systems consider the accrual of costs without considering the time delay information of the waiting inventory. VSM provides clarity regarding the time spent and the whole operations carried out during the production, but it is unable to trace the cost information. Rivera and Frank Chen (2007) suggested a term called Cost-Time investment (CTI) which is a direct indicator of the resources spent on the product during its downstream travel. Cost time profile and Cost time investment techniques are the fundamental concepts used for assessing the leanness of the organization through this approach.

Chaudhari and Nave (2007) introduced Cost-Time profile as a tool that accounts for the accumulation of cost during each unit of time across the entire production cycle. Authors suggested the application of this tool to larger value engineering process. Value stream costing eliminates the need for overhead allocation and calculation. According to the work of Gracanin et al. (2013) Cost Time Profile is a powerful tool for visualization and calculation of cost accumulation occurring during manufacturing flow. Keykavoussi and Ebrahimi (2018) explored the use of VSM by considering cost as another major selection factor along with time. The variability of production parameters is solved by accounting the variables using the fuzzy approach of CTP.

2.2.5 Modifications of Value Stream Mapping Methodology

Numerous authors have attempted many modifications in the existing methodology of VSM for enhancing the capabilities in various environments of analysis. These modifications have made this tool very effective in dealing with peculiar situations of production and analysis due to its flexibility in accommodating all the production parameters in a single analysis.

Verma and Sharma (2016) combined the principle of VSM with Energy measurement along the production stream of a manufacturing plant. This methodology enabled visualisation of the energy consumption associated with the production process to achieve green manufacturing objectives. It emphasized energy reduction along with the green manufacturing initiatives such as the design of products, use of raw materials, packaging, distribution and destruction/reuse of product in the most environment-friendly manner.

VSM methodology is integrated into the Six-Sigma approach of lean thinking towards managing industrial operations as explained by Jagdeep Singh, Harwinder Singh and Amandeep Singh (2019). The methodology to increase system robustness through design for Six-Sigma is also provided and demonstrated through the extension of the case study of crankshaft journal lobing design robustness improvement. The production cost is reduced by identifying the negative energy of biodiesel and an unwanted production step is removed as proposed by Chatterjee et al., (2014). The concept of VSM and energy VSM to address the non-productive energy spending processes is studied and proposed by Verma and Sharma (2016). Use of Kanban, setup time reduction, and TPM along with VMS in plastic industry is proposed by Sabaghi (2015).

An enhanced VSM method which utilizes discrete event simulation was proposed by Ali et al., (2015); Schmidtke et al., (2014). Quality value stream mapping provides a suitable tool for the visualization, analysis and design of quality assurance measures in manufacturing as suggested by Haefner et al. (2014). In his research study, Stadnicka (2019) has carried out the integration of VSM with the concept of System-Dynamics-Analysis in the automotive industry. Guide for practising engineers and managers to undertake process improvement by the application of VSM is proposed by Saboo (2014).

The combination of quality function deployment (QFD) with VSM for the identification of wastes and suggesting remedial measures for waste elimination was implemented by the work of Mohanraj (2012). Lean and sustainable manufacturing are two independent theories in industrial engineering. A conceptual hybrid framework integrating lean manufacturing with sustainable manufacturing theories, known as sustainable domain value stream mapping (Sus-VSM) has been proposed by N. Kumar et al (2015).

Lean maintenance modelling through an original model, and secondly an application using technical and financial data were proposed by Bertolini et al., (2013). The proposed models help to map maintenance process and identify the cost of activities and potential wastes in order to implement appropriate lean maintenance actions. An approach to combine parameters and indicators of sustainability and value stream mapping is proposed by Edtmayr and Sunk (2016). The method of drawing a cost line along with the timeline that exists in the VSM for enabling the productivity improvement is established in the work of Abuthakeer et al., (2010).

Taleghani (2013) investigated VSM and its implementation in new product development affecting organizational learning. Modified PERT and statistical analysis methods are used to determine the critical VSM in the current and future state. Agyapong-Kodua et al., (2009) proposed a dynamic modelling approach to value stream mapping which enhances current best practice when reasoning about changing process and resource systems requirements. Here, coherent use of enterprise and simulation modelling techniques were deployed to develop value streams of an enterprise which is a make-to-order furniture manufacturing SME.

Sunk et al. (2017) described how the rationalization concepts namely Lean principles, VSM, Process management, short-cyclic improvement routine, Methods-Time measurement are used in industry in order to manage and improve processes and value streams. Despite its wide application in almost all types of industries and proving its power in enabling the organizations to acquire competitiveness, the deployment of VSM modification is largely restricted to large size organizations.

2.2.5.1 Simulation and Modelling of VSM Methodology

Different research works carried out in the context of simulation and modelling in combination with lean manufacturing in general and value stream mapping, in particular, are described in Table 2.2.

Table 2.2 Simulation and Modelling of Value Stream Mapping

No	Author(s)	Specific area of Modification
1	Abdulmalek and Rajgopal (2007)	Describes a simulation model that was developed to differentiate the current and future states in detail. This model illustrates the potential benefits such as reduced production lead-time and lower work-in-process inventory.
2	Anand and Kodali (2009)	Simulation and implementation of multiple lean manufacturing elements in a time and temperature-dependent batch manufacturing environment is explained in this work.
3	Agyapong-Kodua, Ajaefobi, and Weston (2009)	Presents a dynamic modelling system to VSM which enhances current practice when reasoning about changing process and resource systems requirements. Use of simulation modelling techniques was deployed to develop value streams of a case study enterprise which is a make-to-order furniture manufacturing SME
4	Gurumurthy and Kodali (2011)	Application of value stream mapping with simulation during the design of lean manufacturing systems using a case study of an organisation following a job shop production system to manufacture doors and windows.
5	Xie and Peng (2012)	Value stream mapping is used to represent the entire value addition process and patient flow to identify problems in a health care environment. Simulation is applied to model human behaviours in the operating theatre.
6	Xia and Sun (2013)	Value stream mapping application enhanced by the discrete event simulation to a dedicated tubular manufacturing process. A comprehensive model for the tubular manufacturing process is constructed, and distinctive scenarios are derived to uncover an optimal future state of the process.
7	Schmidtke, Heiser, and Hinrichsen (2014)	Targets to overcome these limitations, specifically in production environments involving significant demand variability, complex routing and cost factors which potentially increase with lean implementation. For this purpose, an enhanced VSM method is developed, which utilises discrete event simulation (DES). The method features feasibility and trade-off analysis which is incorporated into the VSM procedure. A case study covering a process of exhaust gas purification catalyst production is then conducted to test the newly developed method.
8	Parthanadee and Buddhakulsom siri (2014)	The simulation model imitates a real production system so that improvement alternatives can be evaluated without disrupting actual production. The simulation can also optimise the levels of resources required for the bottleneck operations. The production process at a roasted and ground coffee plant that had serious capacity shortage problem is used as a case study.
9	Helleno et al. (2015)	This paper aimed to apply the Value Stream Mapping (VSM) and discrete events simulation as decision-making tools to direct the management invest in the best option among the available scenarios generated by the simulation system.
10	Mahdi Sabaghi (2015)	Based on simulation and the results obtained from ANOVA, Kanban and TPM are recognised as the two most significant techniques in comparison with the setup time reduction technique which has the least significance.

No	Author(s)	Specific area of Modification
11	S. Alvandi, W. Li, M. Schönemann (2016)	Despite the recent integration of VSM with simulation or environmental studies, still neglected is the dynamic assessment of all the resources involved in a multi-product production environment. This presents a methodology for modelling multi-product manufacturing systems with dynamic material, energy and information flows with the aim to generate economic and environmental value stream maps.
12	Aziz, Qasim, and Wajdi (2017)	Investigates the integration of discrete event simulation and Value Stream Mapping to enhance the productivity of road surfacing operations by achieving high production rates and minimum road closure times.
13	Samant, Mittal, and Prakash (2018)	Suggests the usage of a simulation tool to gain meaningful insight into an assembly line to minimise waste. Constraint programming using combinatorial optimisation helps in efficient resource planning of an automotive chassis assembly line. Although the primary focus of this paper is manpower optimisation, the methodology discussed in this paper can be used for the optimisation of machine resources.

2.2.5.2 Integration of other Parameter Related to The Production Paradigm into The Traditional VSM Tool.

Researchers have attempted augmenting the traditional value stream map with any production parameter of special interest to the researcher other than time. Thus, the already versatile VSM tool can further be enhanced in the required specific situation of production. These parameters vary with different situations such as the quantity to be measured, the production environment and the sector in which the study is conducted. Papers reporting these augmentations are described in Table 2.3.

Table 2.3: Integrating other parameter related to the production paradigm into the traditional VSM tool

No	Author(s)	Specific Area of Modification
1	Abuthakeer, Mohanram, and Kumar (2010)	Integrates VSM with the cost aspects. A value stream map provides a blueprint for implementing lean manufacturing concepts by illustrating information and materials flow in a value stream.
2	Agyapong-Kodua et al. (2012)	Presents an integrated multi-product dynamic cost and value stream modelling methodology with the embedded capability of capturing aspects of dynamics associated with multiple product realisations in manufacturing enterprises.

No	Author(s)	Specific Area of Modification
3	Mohanraj (2012)	Presents a study in which quality function deployment technique has been used for the systematic prioritisation of wastes and techniques for waste elimination.
4	Ingeniería (2012)	VSM methodology has been extended to help in the design of improvement programmes oriented to eliminate waste in logistics and service operations in this work.
5	Seyed.M et al., (2013)	The proposed method applies the fuzzy set theory to map the value stream in order to incorporate the variability of data. In addition, the proposed method considers data variability to determine the critical path and map the current state map and to choose the best future state map (FSM) among the existing FSMs.
6	Tabanli and Ertay (2013)	Presents a case study about deployment of radio frequency identification technology-based electronic Kanban system in an automotive industry supplier firm. In this project, by deploying RFID technology in a pilot area within the current manual Kanban system of this company, it has been possible to measure the true value-added time in the production process.
7	Mohanraj et al., (2015)	The purpose of this paper is to apply a framework for value stream mapping integrated with fuzzy quality function deployment for enabling scientific prioritization of improvement proposals to improve leanness.
8	En-Nhaili et al., (2015)	Firstly, a contribution to lean maintenance modelling through an original model, and secondly an application using technical and financial data. The proposed model gives managers the possibility to map maintenance process and identify easily cost of activities and potential wastes in order to implement appropriate lean maintenance actions.
9	Suarez-Barraza and Miguel-Davila (2016)	Describes the implementation of supply chain value stream mapping in order to thoroughly understand competitive priorities of volume and delivery for any supply chain in organizations
10	Tyagi and Vadrevu (2015)	Numerous iterations and improper usage of resources make lean application costly. In order to tackle this, an immersive virtual reality approach to visualize and interact with the image of real models in a computer graphics environment is presented in this article. This allows conducting quick experimentation in a virtual world to reach optimal future state without exhausting resources or incurring additional cost.
11	Ali et al., (2016)	Proposes and evaluates the combination of VSM and FLOW to identify and alleviate information and communication-related challenges in large-scale software development. Using case study research, FLOW-assisted VSM was used for a large product at Ericsson AB, Sweden. Both the process and the outcome of FLOW-assisted VSM have been evaluated from the practitioners'

No	Author(s)	Specific Area of Modification
		perspective. It was noted that FLOW helped to systematically identify challenges and improvements related to information flow.
12	Chiu and Lin (2016)	Identifies the shortcomings of traditional cost accounting techniques in lean companies and then it seeks to analyse the validity and convenience of value stream costing as a tool in a company that has adopted some concepts of lean manufacturing.
13	Carmignani (2017)	An innovative methodology to improve the supply scrap management process, based on value stream mapping, is presented. VSM is one of the best tools to map a process and eliminate its critical issues, that produces good results if applied to production processes, but can be ineffective for management processes as the supply scrap management process.
14	Rezaeian et al., (2018)	Investigates the energy productivity in an auto body paint shop of an automobile manufacturer. In this study, energy wastages are detected by using the energy value-stream mapping approach based on lean production system. Then, a group of improvement plans are proposed and are evaluated by using a questionnaire which is filled by a group of specialists.
15	Lugert et al., (2018)	Evaluates the current status of the method from the user's point of view and addresses its future sustainability in the context of the ongoing digitalization.
16	Kumar. S et al., (2018)	Presents the methodology of implementation of Lean-Kaizen concept in an SME in India. The existing situation of the shop floor of selected SME was recorded, and the current state map was prepared. The takt time was calculated, and bottlenecks were identified.
17	Kumar. S et al., (2018)	Demonstrates the application of Lean-Kaizen concept using value stream mapping (VSM) for eliminating waste. Based on data collected from shaft swing arm, current and future state maps have been constructed. The high rejection rate and increased lubrication oil consumption are identified as waste.
18	Huang et al. (2019)	Aims to enhance the competitiveness and efficiency of manufacturers by bridging the gap between industrial manufacturing and information technology. Through digitalisation, it provides the advantage of enabling the real-time/near-real-time monitoring of manufacturing. This digital information allows monitoring tools such as value stream mapping to help the decision-makers efficiently capture the non-value-adding processes on the factory floor
19	Singh.J et al., (2019)	The purpose of this paper is to cover the significance of lean thinking using value stream mapping and Six-Sigma methodology in managing industrial operations

No	Author(s)	Specific Area of Modification
20	Muñoz-villamizar et al., (2019)	Introduces a methodology called overall greenness performance for value stream mapping. Using value-added concepts, this approach has the potential to integrate, measure, control and improve productive and environmental performance in accordance with a company's context.
21	Dadashnejad and Valmohammadi (2019)	Aims at examining the effect of improvements identified through VSM on the overall equipment effectiveness (OEE) metric. In order to do so, a structured questionnaire was designed and employed
22	Stadnicka and Litwin (2019)	Integration of VSM with a system dynamics analysis may increase the possibilities for waste identification and elimination. At first, the methodology of extended VSM is described. Then, an extended value stream map is developed and a system dynamics model for a case study from the automotive industry is presented.
23	Menon. R et al., (2020)	A new tool called cost value stream map is proposed, which addresses the problems encountered in conventional VSM and cost-time profile and maintaining the advantages of both. The determination of work in process inventory and non-value-added costs incurred by using CVSM are demonstrated by presenting a case study.
24	Zhu et al., (2020)	Presents a green-modified value stream mapping model, which uses carbon efficiency and carbon emission as evaluation indicators. The model identifies the integrating level of time flow, energy flow, material flow, and transportation flow at each phase of the production process from the perspective of seven wastes and converts them into carbon emission flow.

2.2.5.3 Fundamental Improvements and Extensions on the Traditional Value Stream Mapping Tool

This section describes the research on the improvements conducted in value stream map. The works of improvement in value stream mapping by augmenting it with appropriate extensions suitable for different manufacturing situations are presented in Table 2.4.

Table 2.4 Fundamental Improvement and Extensions on the Traditional Value Stream Mapping Tool

No	Author(s)	Specific Area of Modification
1	Kuhlang et al., (2013)	The outlined approach to systematise the application of VSM is the conjunction of volatile and short-cyclic improvements of a value stream and the determination of target-conditions in order to develop the value stream towards an ideal-state which is specified by productivity and quality criteria.
2	Bertolini et al., (2013)	Presents an enhancement of the standard VSM, which supports the user in designing the future state map of a synchro-MRP system. This new tool includes new mapping icons, simple mathematical formulas and operating guidelines that make it possible to assess the benefits of a synchro-MRP system, with respect to the usual Kanban tool.
4	Schulze et al., (2013)	Investigates how value stream mapping and its implementation in new product development affect organisation learning in development processes.
5	Vinodh et al., (2013)	VSM has been selected as a technique for solving the problems existing in the case organization. The current state map has been developed after making necessary observations and calculations. Then various improvement proposals have been identified and the future state map has been developed. The simulation approach has been used for validating performance improvements.
6	Taleghani. A. (2013)	The proposed method incorporates the variability in timed data through using an improved programme evaluation and review technique and statistical analysis methods in order to determine the critical value stream for mapping the current state as well as select the best proposed future state map.
7	Faulkner and Badurdeen (2014)	This paper presents a comprehensive methodology to develop sustainable value stream mapping by identifying suitable metrics and methods to visually present them. The approach is validated through the application to an industry case study and opportunities for further improvement are discussed.
8	Chatterjee et al., (2014)	In this paper, negative energy for biodiesel production has been identified. Also, the production cost is reduced by removing the unwanted production step. The new method of biodiesel production with double filtration method in place of the transesterification method not only reduces production cost but also saves energy.
9	Seyedhosseini and Ebrahimi-Taleghani (2014)	The accurate estimation of product costs, as one of the aspects of competitive priorities, has always been a matter of great importance and delicacy in regard to manufacturers' approach towards competitors and customers. The efforts made in this paper are aimed at direct cost estimation for multiple production stream different from the approaches used in accounting systems.

No	Author(s)	Specific Area of Modification
10	Aayush Saboo. A (2014)	This paper presents a successful application of VSM in an Indian manufacturing SME. The results of the study and operational improvements achieved indicate that the application of VSM is an effective strategy for organisations of this type to improve their processes and thus meet their current challenges. This paper contributes by providing empirical evidence of the application of VSM in India and thus it can be used as a guiding reference for managers and engineers to undertake specific process improvement projects.
11	Sunk et al. (2017)	Presents developments of traditional value stream mapping related to enhancing system and method competencies of both individuals and organisations. Since systematic immersions in traditional VSM–a highly accepted technique for improving production systems–are necessary, this paper describes from a production research point of view approaches for systematic productivity increases, reduction of lead time and an approach to improve sustainability indicators of value streams.
12	Oberhausen and Plapper (2017)	Assessment of value streams within complex cross-company networks is described. After a presentation of relevant KPIs in the fields of value stream management and supply chain management, an approach for a cross-enterprise evaluation of value streams on different levels of detail is shown.
13	Wahi and Ahuja (2017)	The changes in the organisational ecosystems which will pave the way for the evolution of the business systems for 2020 and will study the diverse applications of the internet of things. IoT can help companies in creating new value streams for customers, speed time to market and respond more rapidly to customer needs.
14	Seth et al., (2017)	Demonstrate, how with some approximations and simplifications in VSM application, lean can be successfully achieved in these environments. The research follows the case study method and systematically guides about the segregation and treatment of non-value-adding and value-adding activities of heavy-duty industrial power transformer making process.

2.2.6 Cost-Infused Lean Tool Models

Many researchers and Lean experts had attempted to infuse the cost data into the value stream analysis. Papers reporting cost infused in the conventional VSM are enumerated in Table 2.5. All these attempts point towards the need for devising a new tool which is capable of addressing the importance of integrating the time and cost data of production-related parameters for the effective assessment of productivity and thereby reduce the wastages.

Table 2.5: Cost as the Major Component with VSM

No.	Author & Year	VSM Improvement Strategy	Approach
1	Balcı (2010)	Value stream costing calculates the total actual costs of value streams by regarding the direct cost components of those value streams. The information prepared by value stream costing is represented in value stream cost statements.	Lean alternative for traditional accounting system is employed for the lean improvement.
2	Ruiz-de-Arbulo-Lopez. (2013)	The purpose of this paper is to identify the shortcomings of traditional cost accounting techniques in lean companies and then it seeks to analyse the validity and convenience of value stream costing as a tool in a company that has adopted some concepts of lean manufacturing.	Application of value stream costing in assembly production scenario
3	Gunduz and Naser (2017)	Cost implementation study of VSM to improve productivity in an underline pipeline installation project is discussed.	Implemented in the construction industry to add sustainability and effective cost management.
4	Menon.R et al., (2020)	Cost value stream map addresses the problems encountered in conventional VSM and cost-time profile (CTP) and maintains the advantages of both.	CTP integration with conventional VSM methodology
5	Agyapong-Kodua et al., (2012)	Application of an enhanced and integrated use of process mapping and enterprise modelling techniques in a manufacturing company.	Multi-product cost and value stream modelling specified for manufacturing enterprises
6	Abuthakeer. et al., (2010)	Attempts to integrate value stream map (VSM) with the cost aspects. A value stream map provides a blueprint for implementing lean manufacturing concepts by illustrating information and materials flow in a value stream.	Cost analysis integrated with VSM in a motor manufacturing company
7	Seyedhosseini and Ebrahimi-Taleghani (2014)	Product Direct Cost (PDC) estimation for multiple production stream different from the approaches is used in accounting systems. On this basis, both factors of cost and time in PDC are studied using lean thinking approach, Value stream mapping and cost-time profile techniques.	Costing with CTP
8	Tabanli and Ertay (2013)	Value stream mapping is used to exhibit the mandatory requirements of RFID technology deployment in the shop floor.	RFID technology for time measurement

Seyedhosseini and Ebrahimi-Taleghani (2014) explained the estimation of direct cost of a product for multiple production streams. Both cost and time are analysed using lean thinking approach, VSM and CTP techniques. Cost calculation based on cost time profile showed that the cost of the resources spent on the product accrues as the time delays due to many reasons of production and other reasons until it is realized as revenue.

Ruiz-De-Arbulo-Lopez et al., (2013) explained the shortcomings of cost accounting in their research work. The necessity and validity of value stream costing in lean manufacturing are described in detail. In order to make continuous improvement decisions, value stream map and value stream costing give complete information on the performance of the manufacturing stream.

Gunduz and Naser (2017) presented an improvement in the project management context by adopting cost of VSM implementation for pipeline projects. This improved project management tool was designed by Line-of-Balance technique for balancing the resources. Balcı. (2010) has attempted to define value associated with a product and established ways to identify this value throughout the production stream. The wastages or non-value-added elements have also been identified by this approach. A box score card method is adopted to account for the value addition and to remove the non-value addition during the production.

The main advantages of value stream costing proposed by Ruiz-de-Arbulo-Lopez. et al., (2013) were that it simplified the traditional accounting process in industries, and it is made simple to compute, maintain and understand. This ensured continuous improvement since it reflected operational enhancements. The major shortcomings were that it required a perfectly lean company and that it only offered a rough estimation of the cost of the product. Here the integration of value stream costing was attempted with other tools of lean manufacturing such as VSM.

Gunduz and Naser (2017) attempted to address the application of Value Stream Mapping in a real-life problem of an underground pipeline project. It analysed the improvement of VAT (value added time) and reduction of NVAT (non-value-added time) compared with the cycle time. It studied the reduction opportunity in total lead time. The Line-of-Balance tool with VSM as a new tool provided a powerful attempt for proper resources utilization and monitoring to improve the VAT and decrease the total lead time. Applying VSM for construction-oriented activities and the introduction of a simulation-based VSM software that can be used to study the time and cost in advance, for future construction.

The conventional VSM tool is enhanced with cost data for the cost-wise determination of non-value-added activities and resources is elaborated by (Menon. et al., 2020). Here the bottom-line results are shown by a timeline as well as a Cost line to account the wastages associated with production in terms of cost directly. The rejection loss, production overheads, utility charges, machine depreciation and the physical distance between the machining centres are taken into account while calculating the product cost.

Agyapong-Kodua et al., (2012) described how the multi-product cost and Value Stream Modelling technique was enacted to capture relevant process data, create models with data captured, and analyse results derived from the model. The method demonstrated how multiple high-volume product flows can be simplified through a process-based classification. Identification of process similarity ensures that products following similar processing routes are grouped together. Further segregation of products with similar process properties was achieved using a work-content approach to process-based classification. This ensured that a wide variety of products were grouped into six different product families, hence limiting complexities associated with managing large product types. Although there might be some differences in products belonging to the same family, these differences were minor.

The approach introduced a means of identifying networks of processes involved in the realisation of specific product families giving room for detailed process-product based analysis, planning, and improvements. This was necessary to discern process routes and hence provide a better means of analysing multiple products. Most importantly, because processes were decomposed from parent processes to their minute activities, a rich understanding of how processes are interconnected and how materials, resources, and information are transferred across process segments was gained.

The hierarchical approach to modelling cost and value streams ensures a better understanding of processes, therefore providing an enhanced means of analysing cost and values generated through the top or down. Because the cost and value stream modelling technique depends on enterprise modelling, for companies already involved in the use of enterprise models, the application of the cost and value stream modelling technique will be the most suitable. However, for companies without any knowledge of the creation and application of enterprise models, additional work will be required to create enterprise models that will form the basis of the modelling technique.

One added advantage through the use of this technique is that once first-stage enterprise models are created, other benefits associated with the use of enterprise models, such as improved communication among functional entities in companies, instrumentation of business process re-engineering, and managing system complexities, among others, can be obtained. The challenge, however, is that a large amount of time is always required to create a fairly representative enterprise model. An improvement in the technique is perceived along the lines of decomposing only relevant processes of interest when the desire is to conduct a cost and value stream analysis of business processes.

Abuthakeer et al., (2010) established an evidence of genuine advantages of applying lean principles in a small-scale motor manufacturing company. It was evidenced that VSM is an ideal tool to expose the waste in the value stream and identify improvement areas. They were able to substantiate the effectiveness of lean principle in a systematic manner with the help of various tools, such as cost analysis in value stream mapping, single minute exchange of dies and so on.

The estimation of product costs, as one of the aspects of competitive priorities, has always been a matter of great importance and delicacy in regards of manufacturers approach towards competitors and customers (Seyedhosseini and Ebrahimi-Taleghani 2014). The efforts made were aimed at product direct cost (PDC) estimation for multiple production stream, which was different from the approaches used in accounting systems. On this basis, both factors of cost and time in PDC were studied using lean thinking approach, value stream mapping and cost-time profile techniques. The main difference between accounting methods and the method of PDC estimation was that not only the costs were estimated based on the longest lead time, but also the time value of money was considered in both PDC of parts manufactured and the final product, which is not seen in any of other methods. Cost estimation based on cost-time investment showed that the later the cost spent on production was recovered by the manufacturer, more will be the increase in the product costs and consequently in the final price of the product.

Companies aiming to have cost reduction focus on monitoring and controlling manufacturing and supplier-related activities by means of manual/electronic control devices in order to enhance the efficiency in the supply chain management and logistics process (Tabanli and Ertay 2013). This work presented a case study on the deployment of radio frequency identification (RFID) technology-based electronic Kanban system in an automotive industry supplier firm. In this project, by deploying RFID technology in a pilot area within the current manual Kanban system of this company, it has been possible to measure the true value-added time in the production process. Value Stream Mapping is used to exhibit the mandatory requirements of RFID technology deployment on the shop floor.

2.2.7 Expert Systems on Value Stream Map

Expert systems utilizing the capabilities of Information Technology (IT) is the order of the day. The complex industrial production processes can be accurately simulated with predictable deviation from the actual real-life situation. The changes in these production parameters from time to time can also be accommodated using the capability of IT tools. There are a lot of attempts done in this sector to simulate and automate the data collection, processing and analysis in the lean manufacturing domain in the context of improving the productivity of manufacturing processes. IT tools are also integrated into many well-known lean tools such as 5S, VSM, KANBAN, TPM, etc. Table 2.6 shows some of the research works carried out in integrating IT with the implementation of VSM and as a package of Expert system used for the industrial sector.

Table 2.6 Expert systems for lean implementation in the manufacturing sector

No.	Author & Year	VSM Improvement Strategy
1	Dave et al., (2016)	Provides evidence of how the Internet of Things and related standards can contribute to improvement in the manufacturing environment.
2	Ante et al., (2018)	A tree-like structure of key performance indicators is proposed to describe the performance measurement system of a lean production system.
3	Das.K, (2018)	The objective of this research is to integrate applications of lean systems in the design and planning model of a supply chain to improve the sustainability performances of the overall business. The study defines and identifies antecedents, enablers, and ingredients of a sustainable supply chain based on the literature.
4	Kruse et al., (2019)	This adds to the existing discourse and theory pertaining to the integration of environment, safety, and health management systems. The research was exploratory and inductive in nature and used mixed methods.
5	Passath and Mertens (2019)	The more complex and diverse assets are, the more important it is to have a standard to dynamically adapt the maintenance strategy due to the changing environmental and production conditions.
6	Antosz. et al., (2019)	Presents the possibility of using intelligent systems to support decision-making processes in the implementation of the lean maintenance concept, which allows to increase the operational efficiency of the company's technical infrastructure.
7	Romero et al., (2019)	Proposes Jidoka at shop floors in an economic, social and technologically sustainable way. It stresses the forgotten dual nature of Jidoka as an ‘automation approach' as well as a ‘learning system', capable of simultaneously improving the efficiency of manufacturing processes and cultivating the workforce skills needed to develop and/or adopt advanced automation solutions.

No.	Author & Year	VSM Improvement Strategy
8	Perico et al., (2019)	Explores the application of manufacturing execution systems to support the waste identification and elimination process. The majority of MES vendors have now incorporated lean functionality in their software, but a comprehensive methodology that explains how MES can be used to enable and promote lean manufacturing is still lacking. This paper aims at filling this gap by presenting a Lean-MES framework
9	Kumar.L (2019)	An effort has been made for intense review of knowledge-based expert system applications in manufacturing planning. The uniqueness of the present review work is addressed in terms of analysis on published review articles and their review gap.
10	Weldeslasie and Ahmed (2019)	The researchers assess the need and application of expert systems in the textile and garment industries. They had also assessed the training programs of both textile and garment industries. As a result, textile and garment industries have not yet applied an expert system, and they have also limited training programs.
11	Secchi and Camuffo (2019)	Discovers how the lean implementation process that is organized can generate variation in lean implementation outcomes, and how the conditions for lean implementation failure might be built in the lean implementation process. We develop a testable research proposition that contributes to lean implementation literature, draw some theoretical and managerial implications and suggest directions for future research.
12	Wang et al., (2020)	Investigates how Value Stream Mapping can be applied to help improve operation training performances through an immersive virtual reality based personalized training program. A before–after experiment based on a virtual scaffolding erection scenario is established to simulate the training process.
13	Jing et al., (2020)	This paper presents a general framework for driving force analysis, combining the terms mining technique (TMT) and fuzzy proximity (FP), named TMT-FP, and applies it to analyse the driving force of participants on the management innovation process in the case enterprise. In the first phase of the methodology, the terms mining technique (TMT) is used to analyse the results of interview cases from enterprises, and to discern participant's character patterns in the management innovation process
14	Kamble et al., (2020)	This study uses a combination of exploratory and empirical research design to identify and validate the performance measures relevant to the evaluation of SMS investments in auto-component manufacturing SMEs based in India. The study found that an Industry 4.0 enabled SMS offers more competitive benefits compared to a traditional manufacturing system.

Dave et al., (2016) presented an insight into the field of lean construction management systems such as VisiLean and KanBIM. These tools are enhanced by utilizing IoT techniques in order to report real-time task status from the field, while improving interoperability between all major information systems and organizations throughout the construction project. These standardized IoT interfaces can be of great use as far as maintaining the information flow consistency in lean construction management systems.

Ante et al., (2018) recommended a hierarchical structure for the key performance indicators which allows supporting and measuring the performance under strategical, tactical and operational perspective. This structure acted as a useful tool for manufacturing engineers in measuring the performance of the studied Bosch production system and allow identifying the relationships among the different KPIs, consistently with operational improvement and floor shop control. Das.K., (2018) introduced a model-based approach for integrating contributions and outcomes of lean tools and practices in supply chain planning process for improving sustainability performances of the overall business. The research facilitated supply chain managers in selecting lean and green practices in addition to benign technology based on their unique business situations for achieving their triple-bottom-line targets.

An important conclusion by Kruse et al., (2019) was that the outcomes of an integrated-lean management system, such as value-added and reduced waste and risk, were supported by the specific management, structural and financial strategies adopted by the sampled companies, as evidenced by our case studies. The above-mentioned domains back up the overall focus of management systems for continuous improvement. A standard procedure devised by Passath and Mertens (2019) to adapt dynamically with the rapidly changing industrial production scenario to manage the maintenance. This can significantly reduce the human effort and create a standard independent of the data quality and reduce the human factors influencing such maintenance decisions and to create a more objective and comparable evaluation. Antosz et al., (2019) presented the possibility of using intelligent decision support systems in the maintenance management paradigm. The use of Artificial intelligence(AI) for the assessment of the lean maintenance methods.

Industry 4.0 is supposed to be the fourth industrial revolution that represents the new concept of organization and control of various activities of the industrial value chain. Smart systems integrated into every manufacturing system making use of IoT as the tool for this change. In this perspective, we make use of an expert decision support system for the data collection and analysis of lean implementation in a small-scale industrial unit.

2.3 CONCLUSION

During the last one decade, MSMEs in India are forced to undergo some kind of productivity improvement exercises as visioned by Asghar et al. 2011; K. A. Kumar (2017); Boateng. K and Y. Nagaraju (2019); Lohith et al. (2018); Syal (2015) and initiated by the Government of India under the strong support and schemes of the Ministry of MSME. Our aspirational goal to reach 5 trillion-mark economy by 2025 can only be achieved by the productivity improvement of our MSMEs. These measures will improve our GDP, exports, employment opportunities and quality of products. Hence, it is high time the studies had concentrated on the contemporary research on MSMEs so that they can be managed effectively. It is possible with the help of employing the existing Lean tools as suggested by Achanga et al. (2006); Jasti and Kodali (2015); Stamm (2008) and researching new ways of attaining lean in the true letter and spirit.

All the general methods of implementing lean in MSMEs, are by utilising the many well-known lean tools evolved from Toyota production system. Most of the refereed journals have works associated with lean implementation in various sectors of Industries and value stream map has a vital role in initially visualising and assessing the productivity and suggesting the lean tool to be adapted in improving the present condition. Many modifications are attempted by numerous authors in this regard.

CHAPTER 3

DEVELOPMENT OF CVSM

3.1 INTRODUCTION

Value is exactly what the customer values or desires to own in a product or service. Naturally the customer will be willing to pay for these features that they really desire to be associated with that product or service. Value stream is the chronological step by step activities involved in the production process to convert the raw material to the finished product. This chapter reports the development of cost value stream mapping, which is proposed for use in MSMEs.

3.2 VALUE STREAM MAPPING

Value stream mapping is a tool intended to picturise the production streamline using symbols to describe various elements of production and to improve the flow of material and information. It helps to identify the non-value-added production activities in the production stream. It also helps to identify the strategy to be applied or the lean tool to be selected for reducing the identified wastes. VSM is not able to measure wastes associated with production in terms of cost. This shortcoming is overcome by another tool which is effective in accounting all the costs involved in the production stream as suggested by Rivera and Chen.F (2007). Value stream mapping also called as VSM is a diagrammatic tool used in lean manufacturing to represent and streamline ‘current’ as well as ‘future’ work processes.

3.3 COST TIME PROFILE

Cost Time Profile (CTP) shows the accrual of product direct cost as it is produced in a step-by-step value downstream in its production process. It is unlike the conventional cost accounting practiced in organizations producing product or service. CTP clearly depicts the accumulation of all costs associated with the production of a product. Costs can be due to material addition, production activity and waiting in between the processes or the so-called work in process (WIP) inventory waiting. Time taken for material addition is assumed to be instantaneous or by the Just in Time (JIT) mode.

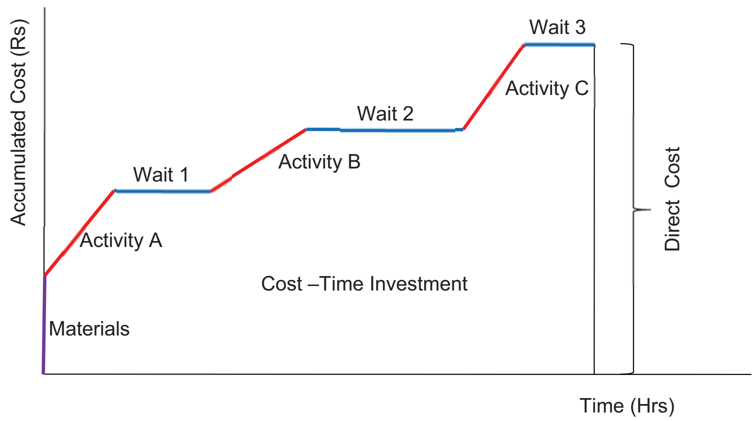


Figure 3.1 Basic Cost Time Profile

Time consumption for the production activity is observed from the cycle time of that individual process. Waiting in between the two successive processes is also taken into account. As per the CTP graph there is no visible cost addition due to the waiting of semi-finished items lying in between the processes. The components of CTP are activities, materials, wait and the direct costs.

3.3.1 Activities

These are value addition in workstations of production stream which are represented as ascending lines. The slope represents the speed at which the process is completed. For the analysis it is assumed a linear for every activity, assuming it to have value addition in a linear manner. So, the steeper the line the activity is faster compared to a low value of slop. The cost of the activity is usually decided by the cost of employees and the cost of resources in that workstation. The cost of activity consists of costs associated with operator and resource during the machining operation at a workstation. Cost of operator contains both the cost of operator and supervisor at that section of production. Resource cost comprises of machine depreciation and machine maintenance costs.

3.3.2 Materials

The addition of materials to the process is presented as a vertical line, assuming that a portion of the materials is received instantaneously. Material addition at each processing stage is to be added in terms of cost of raw material, additives and other ancillary items such as packing materials and finishing materials. Rejection cost at every stage is also accounted for calculating the total material cost.

3.3.3 Waits

No direct addition of cost to the total accumulated cost and waits are represented as horizontal lines. But in the CVSM methodology, the time investment cost is to be calculated. The amount of money invested in the form of activity and materials is still pending to be converted to monetary terms until it is sold to a customer and the revenue generated is realized as money. This warrants the accounting of investment on semifinished products in between the production stages and unsold finished goods. The principle of cost time investment is utilized for quantifying the investment in waiting time of semifinished goods.

3.3.4 Direct Cost

This is the height of the graph at its ending. It represents the amount that has been spent as cost in the manufacture of the product. This is the conventional way of calculating the production cost of any product. The shortcoming of this method is that it does not account for the cost investment of unfinished goods during its waiting along with the production downstream.

3.4 COST-TIME INVESTMENT

Cost of money which is already invested upon the raw materials and the manufacturing processes which is performed on semi-finished item should also be taken into consideration. This leads to the determination of Cost time investment (CTI) of the process right from the material addition until the waiting is over in one station in the production stream. It gives a measure on how much money is spent on the manufacture of a product and for how much time it remains spent before being recovered through sales.

CTI is the investment in the raw materials up to its finished product. This is the total area under the curve. It represents the amount of cost spent in the manufacture of the product multiplied by the time this cost has been present before recovered through sales. It is also a measure of the time value of money, since it is evidently better to spend an amount and recover that in 2 days than spending the same amount and recovering that in one month. This figure has an impact on the bottom line of the company and its financial management.

Total cost investment is the product of CTI and %IRR (Internal Rate of Return). IRR is the expectation of minimum return from all the investments in the form of materials, processing and the waiting. If we add the cost of waiting to the direct cost, we will have the Total Cost of Production. It is a measure of the minimum amount that the company should recover when selling the product in order to cover costs caused both by the expenditures of money and the way those expenditures incurred in time.

$$\boldsymbol{Cost\ of\ Production} = \boldsymbol{Direct\ Cost} + \boldsymbol{Total\ Cost\ Investment}$$

$$\boldsymbol{Total\ Cost\ Investment} = (\boldsymbol{Cost\ Time\ Investment} \times \%\,\boldsymbol{IRR})$$

where,

Direct Cost – The cost accrued by the addition of material and cost of activities.

Total Cost Investment – The cost accumulated by the waiting of raw material/ Work in process inventory/ waiting of finished goods in the warehouse.

3.5 FRAMEWORK FOR CVSM IMPLEMENTATION

A framework for adoption of cost value stream map (CVSM) as a lean tool in a manufacturing organization is described in this section. Adoption of this framework is expected to help MSMEs in implementing CVSM, as a lean tool. The proposed framework is shown in Figure 3.2

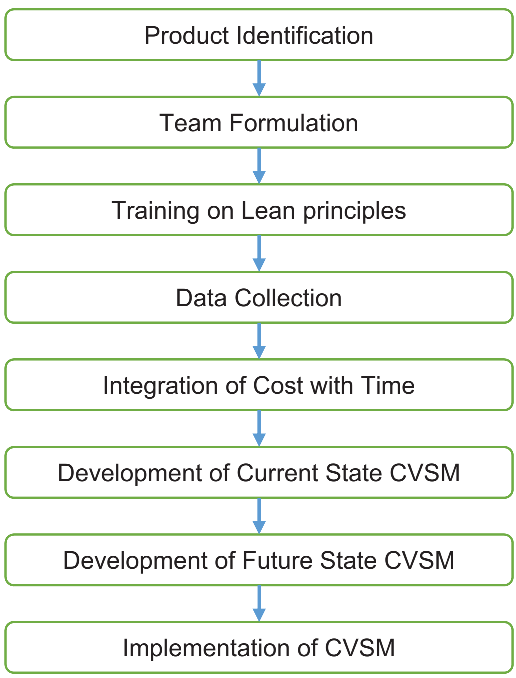


Figure 3.2 CVSM Framework

The framework has eight stages starting from product identification and ending with CVSM implementation. Activities carried out during each stage of the framework are explained in the subsequent sections. An organisation desiring to develop CVSM can follow these stages for easy implementation.

3.5.1 Product Identification

Organisations have different products having a different configuration. The selection of the product family, to which CVSM is implemented is the first step. Selection can be based on the total revenue generated or based on the number of operations that is required for manufacturing, or by the number of units produced in a year.

Process flow starting from raw material to finished stage of the selected product is to be prepared initially. In the process flow chart, the machining processes involved the raw material to the finished product, cycle time, change-over time, waiting time of the semi-finished product in between the various activities, number of operators and the work in process inventory (WIP) are noted.

3.5.2 Formation of CVSM Implementation Team

A team is to be formed for the CVSM implementation with Production/Operations Head of the company as team leader. While forming the teams it is advisable to include all the heads of different departments of the company namely, Operations, Maintenance, Quality Control, Marketing and Finance. The team members shall be introduced to the benefits of implementing Lean approach and the savings accrued by implementing this tool. A general meeting of the company including all employees is to be convened before the data collection. A systematic review system should be put in place throughout the period of lean implementation. Normally once in a month advisable for assessing the progress of implementation after the data collection is over.

3.5.3 Training on Lean Principles

A training program for introducing the principles and methodology of CVSM is to be designed for every industrialist. Initially, a meeting including all the employees is to be conducted to introduce the basics of Lean manufacturing concepts. We need to elaborate on the different wastages associated with the manufacturing process of a product. Training on 5S and VSM is to be given subsequently for the Team members. These team members are responsible for training their employees, about the benefits of implementing Lean tools and the resulting improvements.

3.5.4 Data Collection

All the team members along with the operators/supervisors in the concerned department of production are responsible for the data collection. For the CVSM approach time as well as cost data are required. Time-related data is for preparation of Value Stream Map and the cost related data will add the cost domain of production into the Cost Value Stream Map. Time data include both value-added and non-value-added component of production. Cost data comprises of all the cost adding parameters such as material, operator/supervisor, machine maintenance, machine depreciation, rejection of product at each stage, utility costs and fixed costs associated with production. The data required to be collected are the following

i. *Time Data*
   - Cycle Time
   - Value Added
   - Non-Value Added
   - Waiting Time (WIP)

ii. *Cost Data*
   - Cost of material added at each processing stage
   - Cost of Operator / Supervisor for each operation
   - Cost of waiting calculated as per the CTP principle

- Cost of Machine maintenance and depreciation

iii. *General Data*

- Number of operators
- Number of supervisors
- Information Flow
- Number of Inventory
- Frequency of Customer supply
- Distribution frequency of raw materials from the supplier
- Year of installation of each machine

3.5.4.1 Prepare Current VSM

Preparation of the current state VSM is carried out with the data collected. Manufacturing operations of the identified product are to be studied by constructing the process flow diagram. The data such as number of operators, cycle time, change over time, uptime and number of shifts of operation are to be collected for each manufacturing operation Takt time is to be calculated by recording the customer demand and the available production time in a shift. Time taken during each activity shall be measured to plot cycle time which is compared with the calculated Takt time. Using the above information, the current state map of VSM is to be prepared.

3.5.4.2 Preparation of CTP and Determination of CTI

Further, various costs namely activity cost, material cost, operator cost, resource cost, machine depreciation and maintenance cost are collected for all the selected activities. CTP of the processes is prepared and the area under the CTP graph which is the CTI of the process is calculated. CTI is calculated for the determination of cost involved in the waiting of unfinished products or in the waiting of inventory during production.

The time cost of money is the expected return on the investment in the raw materials and other inputs involved in the process of production. This is accounted for a company by calculating the average interest rate on the total borrowings for running the company at that time. This will just account for the cost of money which is invested. If there are no borrowings involved in running the company, it is advisable to take the value of interest which is expected to be accrued on the investment.

3.5.5 Integration Cost with Time

Indirect cost for the product includes utility cost and the fixed cost which has to be collected from the company. Cost of utility consists of the cost of water consumed, electricity charges and fuel. The fixed cost associated with every production process is related to the cost involved in the salary of administrative and security personals, bank charges, audit expenses, travelling expenses, unloading of goods arrived and loading of goods in despatch section, lab expenses, employee welfare, annual employee insurance charges, various taxes, festival allowance and rent of building or equipment. Total cost of production can be found by adding the direct cost, indirect cost and the non-value-added cost.

In this stage, the cost of waiting (Cw) for the different processes are added along with the timeline of VSM. Cw is determined by accounting the total investment cost due to the waiting of raw material, Work in Process inventory and finished goods waiting to be sold to the market.

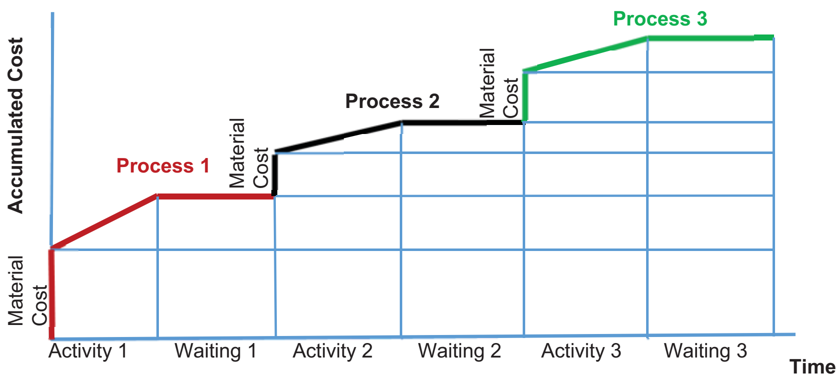


Figure 3.5 Total Cost Investment as the Area under CTP Curve

As shown in Figure 3.5, Cw is the product of the area under the CTP line and %IRR. Cw is calculated using equation 3.1.

$$Cw = \sum_i \left[\left(Cmat_{i,k} \times Tc_i \right) + \frac{1}{2} \left(Ca_{i,k} \times Tc_i \right) + \left(Ca_{i,k} + Cmat_{i,k} \right) \times Tw_{i,k} \right] \times IRR\ \% \quad \text{.............} \ 3.1.$$

Where

Cw	-	Total cost investment due to waiting
$Cmat$	-	Material cost
Tc	-	Cycle time
Ca	-	Activity cost
Tw	-	Waiting Time
i, j & k	-	different activities, materials and machines respectively

Total cost of production (Cp) is calculated using the equation 3.2.

$$Cp = \sum_i (Ca + Cmat + Cw + Cu + Cf + Crej) \text{..} \ 3.2$$

Where

Cp	-	Cost of Production
Ca	-	Activity cost
$Cmat$	-	Material cost
Cw	-	Total cost investment due to waiting
Cr	-	Cost of Manufacturing Resources (Cost depreciation and Maintenance)
Cu	-	Utility cost per product
Cf	-	Fixed cost per product
$Crej$	-	Cost of rejection of defective product at each machine

Activity cost refers to the sum of operator cost (Co) and the cost of the various resources (Cr) that are consumed. Operator cost can be calculated from the annual emoluments given to the operator. Cost of resources (Cr) is the sum of depreciation cost (Cd) of the machine and machine maintenance cost (Cm). Machine depreciation cost rate ($\dot{C}d_k$) can be found out by dividing the cost of the equipment with the product of the equipment's service life and the time the equipment was used in a year as shown in equation 3.3

$$\dot{C}d_k = \frac{Ce_k}{Ly \times Tl_k} \qquad \text{.......... } 3.3$$

Tl – Time units it is used in a year

Ce - Cost of Equipment

Ly – Expected life of equipment in years

The machine maintenance cost rate ($\dot{C}m$) is found out by dividing the maintenance cost per year with the time units it was used in a year. This calculation is shown in equation 3.4 .

$$\dot{C}m_k = \frac{Cm}{Tu_k} \qquad \text{.......... } 3.4$$

The resource cost rate ($\dot{C}r$) can be found by adding the machine depreciation cost rate ($\dot{C}d$) and machine maintenance cost rate ($\dot{C}m$) as shown in equation 3.5.

$$\dot{C}r_k = \dot{C}d_k + \dot{C}m_k \qquad \text{.......... } 3.5$$

$\dot{C}r$ - Resource cost rate (Resource cost/hour)

$\dot{C}d$ - Depreciation cost rate

$\dot{C}m$ - Machine maintenance cost rate

Effective cost rate of the operator ($\dot{C}o$) is calculated by dividing the annual remuneration with the effective time of work in the company. Resource cost rate can be added with the operator cost rate for obtaining the activity cost rate ($\dot{C}a$). Activity cost rate and the corresponding activity cost in the production can be found from equations 3.6 and 3.7 respectively.

$$\dot{C}a_k = \dot{C}o_k + \dot{C}r_k \qquad \text{.......... } 3.6$$

$\dot{C}a$ - Activity Cost Rate

$\dot{C}o$ - Labour Cost per hour (Operator & Supervisor)

$\dot{C}r$ - Resource Cost Rate

$$Ca_i = \dot{C}a_i \times Tc_i \quad \text{......} \quad 3.7$$

Ca - Activity Cost

$\dot{C}a$ - Activity Cost Rate

Tc - Cycle Time

Waiting cost of the work in process (WIP) inventory, which is the major non-value-added cost in manufacturing a product, is further termed as 'cost of waiting'. From the conventional CTP, horizontal lines indicate the waiting cost for WIP and the area below the horizontal lines in CTP will imply the term Cw.

The time information obtained from the value stream analysis is to be integrated along with cost details at every processing stage of production. Along the production stream line, the cost of value added and non-value-added activities operations pertaining to all steps is recorded in monetary terms so that the value addition can be visualised in terms of cost rather than metering it in terms of time in the case of VSM approach. This makes the CVSM a better tool for assessing and optimising the production stream line. This optimisation is made easy using this tool in any type of industry where the time and cost data of value addition is available.

At each process box we add one additional column for the cost of processing and at the space in between two processes the cost of waiting. This cost of waiting is to be addressed by the CVSM implementation team to make the production stream leaner than the current state of production. Cost value stream map pinpoints the non-value-added cost associated with the production stream.

3.5.6 Development of Current State CVSM

Combining the time data from VSM and cost investment data from CTP, a current state map of the CVSM is to be developed. In the present state CVSM, a cost line is also drawn along with the timeline that depicts the cost and the time of all non-value-added activities. Information related to production parameters, including lot size for an activity, cycle time, available time, uptime, number of operators and supervisors, the distance between work stations, percentage rejections activity and waiting period for the various production processes are recorded by the implementation team in the CVSM.

The cycle time, uptime, change over time, work in process inventory and the number of operators is entered with the corresponding symbols in the prepared CVSM. During this process Takt time for the product is also to be calculated. For calculating the takt time data on the daily demand of the selected product and net available working time in a day for manufacturing the product are required. A comparison of the cycle time and the takt time is to be made in a bar chart. Non-value-added time during the production is to be identified from this bar chart.

3.5.7 Development of Future State CVSM

The non-value-added activities are easily identified from the Current state CVSM. The identified non-value-added activities are to be ranked according to the CTI of the processes, for the purpose of adopting appropriate lean tools. The current CVSM is redesigned by considering the ranked non-value-added activities for preparing the future state CVSM. Production processes having higher non-value-added costs, which are identified from current state CVSM have to be reduced by applying the lean tools. Here the wastages identified in terms of cost and time are addressed to achieve a better future state for the production process.

3.5.8 Implementation of Lean Tools

The lean tools identified are implemented in the production floor as per the future state CVSM to achieve productivity as projected into the future state CVSM. This framework is repeated for further analyzing and improving the processes.

3.6 CONCLUSION

The methodology explained so far is considered as the standard procedure for implementing cost integrated value stream mapping in a company which is classified under the MSME sector. The Lean analysis is conducted by first drawing the value stream of the current production process. Here the shortcomings of VSM analysis are addressed by incorporating the cost information in connection with the production process. The data collected for VSM is to be augmented with the cost data associated with the production in visualizing the process in terms of cost of production. In other words, we are able to visualize the production streamline not only in terms of time but also in cost terms. So, the wastages in production are to be visualized easily at each processing stage in the production streamline. Then the remedial measures for eliminating these wastages can be done using various available lean tools that exist as per the Toyota production system.

The bottom-line result of this analysis is that it shows the timeline and cost line below the cost value stream map similar to the timeline in VSM. From the cost-line, any operator with minimum awareness about the production process can understand the entire value addition happening along with the production streamline. Normally the cost involved in a production process can only be effectively read and understood by a person from financial background so as to interpret the efficiency of the production process and to suggest and decide upon any lean improvement initiatives.

CVSM gives a simple and very effective analysis tool in any MSME for the pre-lean implementation analysis to assess the present condition of functioning and propose an effective lean tool which is suitable for implementation considering the future state to be reached.

CHAPTER 4

IMPLEMENTATION OF CVSM IN A SCAFFOLDING MANUFACTURING COMPANY

4.1 INTRODUCTION

This section describes the implementation of CVSM framework in an MSME. Activities carried out in different stages, suggested in the implementation framework is explained in this chapter.

4.2 ABOUT THE COMPANY

The company selected for implementation was an ISO 9001 certified small-scale company established in the year 1999 and located in Palakkad, Kerala state. This company is engaged in manufacturing various construction equipment such as props, spans, centering boards and scaffoldings which replace the conventional method of using bamboos and wood for making form works in civil construction projects. The challenges of high labour cost and the issues of labour management can now be solved to a considerable extent by using these pieces of equipment.

This company offers a wide range of state-of-the-art facilities for the construction industry and remains as a reliable partner for the construction industry. The company adheres to the policy of supplying quality products at the right price and assures delivery strictly as per commitments. This company has the capacity to manufacture various civil construction supporting equipment like props, spans, centering boards and all scaffoldings to cover an area of 4 lakh square feet per month.

The company has 40 permanent employees. Working time is from 8 am to 5 pm with a lunch break of 1 hour and two tea breaks of 15 min duration. The entire company is managed by a Production Supervisor.

4.3 PRODUCT IDENTIFICATION

The main products of the company are supporting structures for civil constructions including adjustable props, adjustable spans, centering sheets, frames, column and boxes. The raw material for the above products is mild steel and galvanized iron pipes. Figure 4.1 shows a typical adjustable prop used in civil construction jobs.

Figure. 4.1 Adjustable Prop

There are many supporting structures such as centering boards, props and structures manufactured in this company for the civil engineering construction purpose. Adjustable props are used in the construction field for supporting beams and slabs from the ground / floor. Telescopic props can bear the necessary load and can be locked at any desired length using a malleable Cast Iron nut and lock. Components and features of an adjustable prop consists of the following.

- Outer tube 50 NB (OD 60.3 mm) ERW Mild Steel.
- Inner tube 40 NB (OD 48.3 mm) ERW Mild Steel.
- Conform to IS -1161 • 1998 YST 210.
- Props available Standard S Beam head models.

- Degreasing & Derusting to ensure proper surface before coating.
- Zinc Phosphate to get additional anti corrosive protection.
- Co polymer paint coat for both inner and outer surface of the tube.

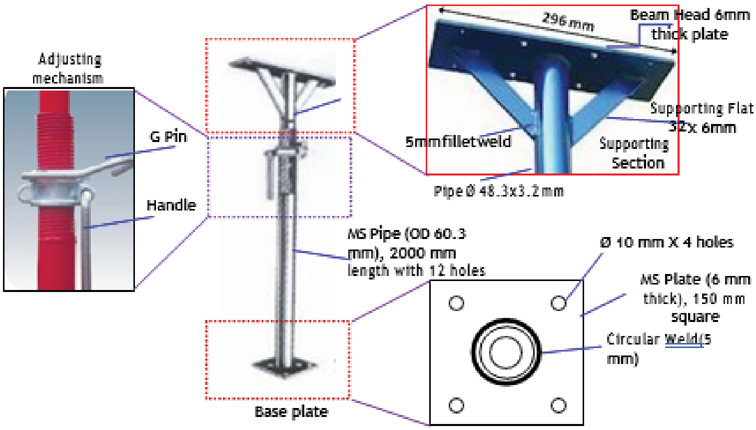


Figure 4.2 Adjustable prop with dimensions

The image of the finished product with the components labelled is shown in Figure 4.2. The outer pipe and inner pipe are fabricated in the company itself and the other parts namely open-nut, handle and the G-pin are outsourced. There are many variants of adjustable props manufactured in this company in terms of the size range and load carrying capacity and it is shown in Table 4.1.

Table 4.1 Different Models of Adjustable Prop

Models	Minimum Height (mm)	Maximum Height (mm)	Load Capacity Closed (Kg)	Load Capacity Extended (Kg)
AP-3600	2000	3600	300	2200
AP-3750	2150	3750	3000	2000
AP-3900	2150	3900	2750	1750
AP-4650	3000	4650	2400	1250

Among the many products, the adjustable prop is the one product which contributes 80% of the sales revenue of this company. Hence this product is considered for our CVSM implementation. Another reason for selecting this product was that it passes through almost all operations in the company.

4.4 FORMATION OF CVSM IMPLEMENTATION TEAM

A lean implementation team is formed from among the employees of this company. Managing Director, Production Manager, Finance Manager, Production Supervisor were selected as internal team members and two consultants hired by the company also took part in the implementation. All the stake holders of this company are made aware about the benefits desired to be accomplished by the implementation of this methodology. Team met at an interval of once in a month.

4.5 TRAINING TO TEAM MEMBERS

A training was conducted at the company facility to all operators and supervisors. The first session was about lean manufacturing and the wastages associated with it. Then subsequent training sessions were on different lean tools such as 5S, VSM and elements contributing to the cost addition of a product. The concept of value addition was discussed along with value-added and non-value-added Time and Cost in manufacturing. Since 5S was already implemented in this company under the Lean Manufacturing Competitiveness Scheme (LMCS) of the ministry of MSME in 2017, the training was limited to VSM alone. The training schedule designed for this company is given in Table 4.2.

Table. 4.2 Training schedule for CVSM implementation

Session	Topic	Members
Week 1	Introduction to lean manufacturing and different wastages associated with production	Owner of the company and the lean team
Week 2	General Introduction to 5S principles and value stream mapping methodology	All employees and lean team
Week 3	Value stream mapping methodology	Lean team
Week 4	Discussion on cost aspects of production	Lean team
Week 5	Verification of production data	Lean team
Week 6	Discussion on current state CVSM to identify wastages	Lean team
Week 7	Discussion on preparation of Future State CVSM	Lean team
Week 8	Initiation of implementation	Lean team
Week 12	Results of Implementation	Top Officials + Lean team
Week 14	Interpreting the results of implementation on an annual basis to calculate results	All employees + Lean team

4.6 DATA COLLECTION

The production flow data is collected and the flow diagram is prepared for identifying the production stream line and the machines involved in the production of the selected product. The process flow diagram is given in Figure 4.3. Production related data in time and cost domain was collected with the help of operators and supervisors of respective sections of the production line. Cycle time of each process and waiting time in between the processes are collected to build the value stream map. All the relevant cost data which are required for construction of CVSM are also collected.

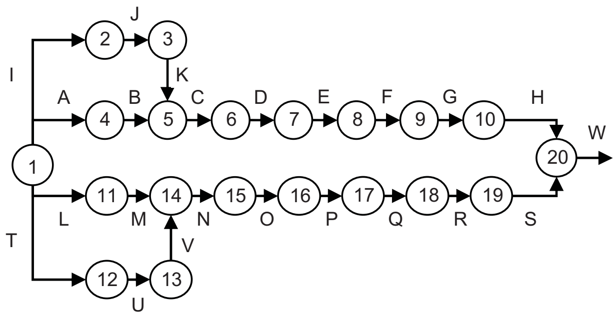


Figure 4.3 Process Flow Diagram

Table 4.3 Various production parameters of machining processes involved

Activity	Description	Cycle time (min) Tc	Change over time (min)	Waiting Tw	Operators	WIP
A	Band saw cutting (outer)	1.71	5	15.48	1	50
B	Thread rolling (outer)	0.86	-	21.16	1	18
C	Base plate welding (outer)	0.92	-	0.60	1	23
D	Outer pipe slotting	0.20	-	10.64	2	3
E	Nut assembly (outer)	1.33	-	30.5	2	8
F	Slag removal and cleaning	1.22	-	44.1	2	50
G	Painting (outer)	1.47	-	-	1	50
H	Curing (outer)	4.44	-	-	-	-
I	Outer plate cutting	0.41	-	11.55	1	35
J	Outer plate punching	0.21	-	15.84	1	55
K	Outer plate grinding	0.36	-	21.30	1	44
L	Inner pipe cutting	2.08	5	27.6	1	48
M	Drilling (inner)	1.38	-	6.25	1	20
N	Top plate tack welding (inner)	1.25	-	6.25	1	10
O	Welding one side (inner)	1.25	-	6.25	1	10
P	Welding opposite side (inner)	1.25	-	27.5	1	10
Q	Slag removal and cleaning (Inner)	1.10	-	49.92	2	50
R	Painting (inner)	1.56	-	-	2	18
S	Curing (inner)	4.4	-	-	-	-
T	Inner plate and flat cutting	0.23	-	8.64	2	48
U	Inner plate punching	0.24	-	33.55	1	36
V	Inner plate drilling, straightening and grinding	3.05	-	20.00	3	33
W	Assembly and stacking	2.50	-	-	4*	-

This product consists of an outer pipe and an inner pipe which is concentrically inserted into the outer pipe and a lock is provided to anchor this prop to support various temporary civil structures at the required height. This product has to undergo cutting, welding and drilling processes in general and a final painting process during its production. The process flow diagram as shown in Figure 4.3 is constructed by identifying the processes involved in production. The activities are labelled as A, B, C etc., and are listed in Table 4.3. The various production parameters involved in the production process are cycle time, change-over time, waiting time, number of operators and the work in process (WIP) inventory are also collected as shown in Table 4.3.

A comparison of the cycle time and the takt time which can be made from a bar chart, is given in Figure 4.4. The processes like curing, cutting, inner plate preparation and assembly are found to be well above the takt time value in the graph.

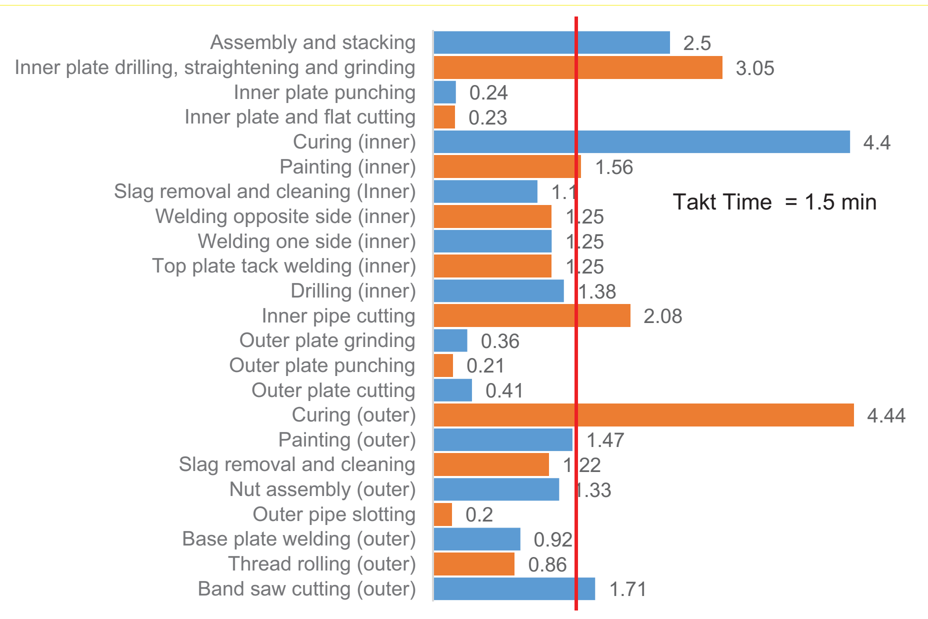


Figure 4.4 Comparison of TAKT Time and Cycle Time

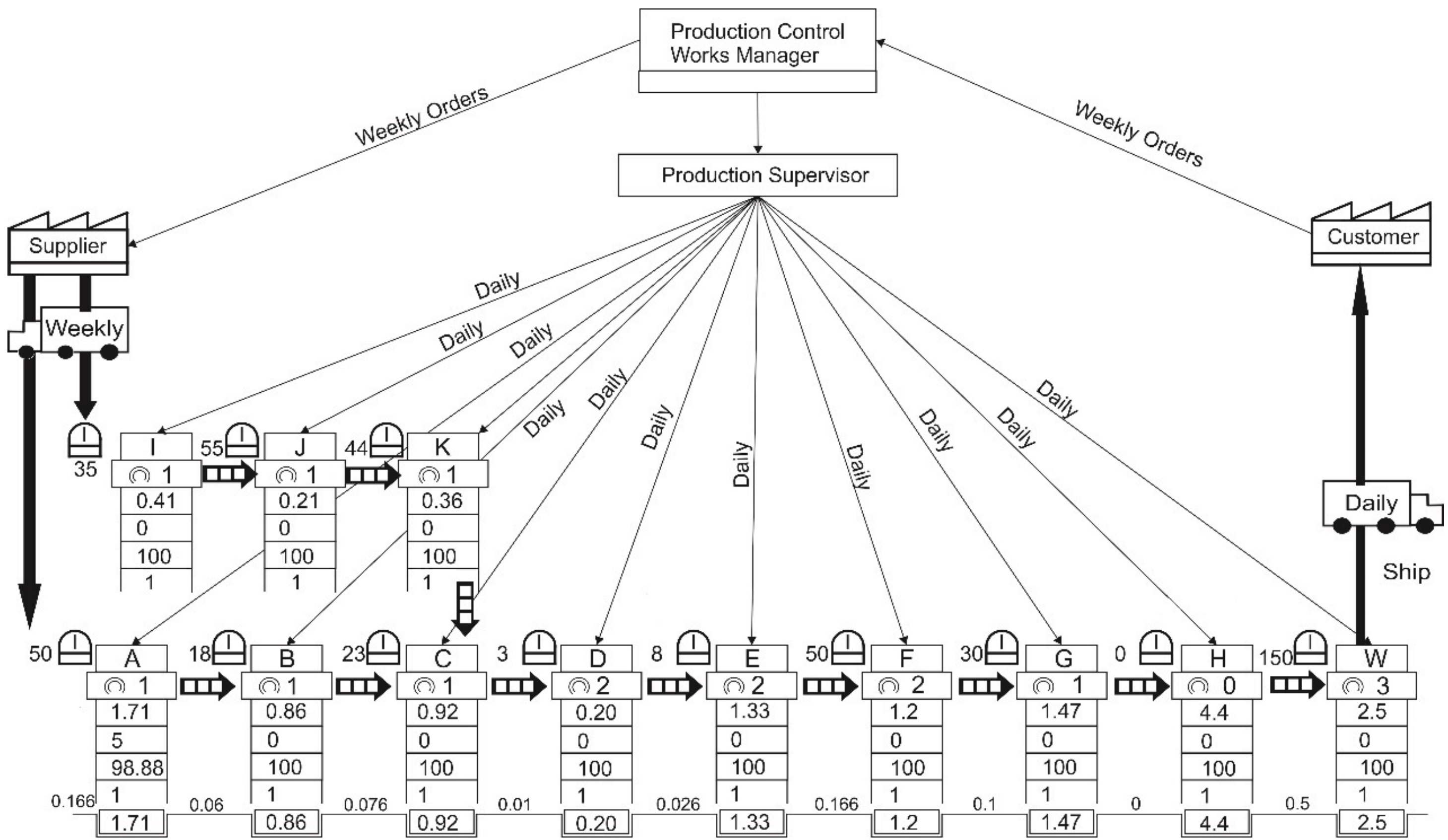


Figure 4.5 Value Stream Map of Outer Pipe Production Process

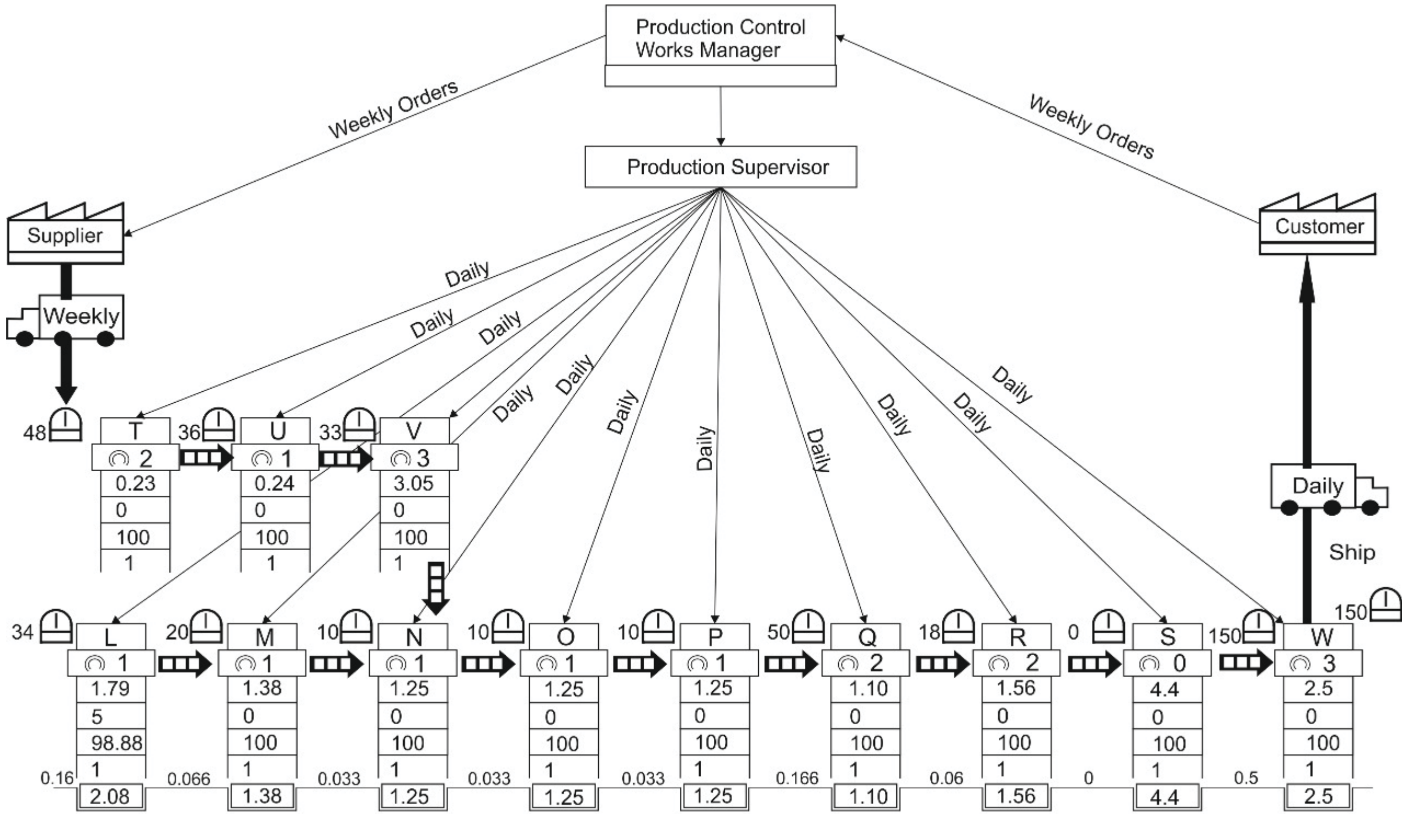


Figure 4.6 Value Stream Map of Inner pipe Production Process

All the information required for preparing the current state VSM was collected during the production process. The material and information flow within the company was obtained from the production line. The information collected from the company for preparing the current state VSM is also detailed in Table 4.3. The current state VSM for the outer pipe and inner pipe of the adjustable prop is prepared separately for easy understanding and is shown in Figures 4.5 and 4.6, respectively. The cycle time, change over time, WIP inventory and the number of operators is entered with the corresponding symbols in the prepared VSM.

The investment cost is to be calculated based on the value of internal rate of return (%IRR) on the investments made by the company and the interest rate accrued annually. Repayments on the loans taken by the company on machinery purchase, on material procurement and on working capital is worked out to calculate %IRR for each company for the calculation of cost time investment. Considering the current debts and repayments the company has given the value of 15% as the internal rate of return for calculating the cost time investment.

4.7 COST TIME INTEGRATION

Various costs associated CTI are calculated for integration with CVSM. These calculations are carried out using the Equations 3.1 to 3.6. Costs and cost rates of different activities arrived at are summarised in Tables 4.4, 4.5 and 4.6.

Table 4.4 Resource Cost Data for All Processing Stations

Activity	$\dot{Cd}_i$	$\dot{Cm}_i$	$\dot{Cr}_i$
A	0.214	0.231	0.445
B	0.109	0.266	0.375
C	0.2444	0.185	0.4294
D	0.0603	0.138	0.1983
E	0.00483	0.046	0.0508
F	0.00071	0.023	0.0237
G	0.0057	0.092	0.0977
H	0.0155	0.115	0.1305

I	0	0	0
J	0.1028	0.185	0.2878
K	3.525	0.254	3.779
L	0.00394	0.069	0.07294
M	0.1923	0.069	0.2613
N	0.1923	0.069	0.2613
O	0	0	0
P	0.00915	0.094	0.10315
Q	0.0161	0.101	0.1171
R	0.00483	0.069	0.0738
S	0	0	0

$\dot{C}d_i$ – Depreciation cost rate (Rs/min)

$\dot{C}m_i$ – Maintenance cost rate (Rs/min)

$\dot{C}r_i$ – Resource cost rate (Rs/min)

Table 4.5 Cost Calculation for Different Operations

Activity Description	**N**	$\dot{C}o_i$	$\dot{C}r_i$	$\dot{C}a_i$	Tc	Tw	Ca	$Cmat$
Band Saw Cutting	1	1.82	0.45	2.27	1.71	15.48	3.86	378.00
Thread Rolling	1	2.22	0.38	2.60	0.86	21.16	2.23	0.00
Base Plate Welding	1	1.95	0.43	2.38	0.92	0.60	2.19	0.00
Outer Slotting	2	3.37	0.20	3.57	0.20	10.64	0.71	0.00
Nut Assembly & Drilling	2	3.54	0.05	3.59	1.33	100.00	4.78	80.00
Painting	3	5.24	0.02	5.26	8.00	14.35	42.11	16.00
Outer Plate Cutting	1	1.68	0.10	1.78	0.41	11.55	0.73	42.00
Outer Plate Punching	1	1.68	0.13	1.81	0.21	15.84	0.38	0.00
Outer Plate Grinding	1	1.60	0.00	1.60	0.36	21.30	0.58	0.00
Inner Pipe Cutting	1	1.77	0.29	2.06	2.08	66.24	4.28	327.00
Driiling	1	2.22	3.78	6.00	1.38	12.50	8.28	0.00
Top Plate Tack Welding	1	1.60	0.07	1.67	1.25	3.75	2.09	0.00
Welding (one side)	1	1.80	0.26	2.06	1.25	5.00	2.58	0.00
Welding (Opp side)	1	1.80	0.26	2.06	1.25	75.00	2.58	0.00
Painting	4	6.80	0.00	6.80	8.00	11.04	54.40	16.00
Inner Plate & Flat Cutting	2	3.37	0.10	3.47	0.23	8.64	0.80	85.00
Inner Plate Punching	1	1.68	0.12	1.80	0.24	100.65	0.43	0.00
Inner Plate Driiling, Straightening and Grinding	3	4.80	0.07	4.87	3.05	20.00	14.87	0.00
Assembly+ Loading	4	2.66	0.00	2.66	2.50	0.00	6.65	0.00

N – Number of operators

$\dot{Co}_i$	–	Operator Cost rate (Rs/min)
$\dot{Cr}_i$	–	Resource Cost rate (Rs/min)
$\dot{Ca}_i$	–	Activity Cost rate (Rs/min)
Tc	–	Cycle Time (min)
Tw	–	Waiting Time (min)
Ca	–	Activity Cost (Rs)
$Cmat$	–	Material Cost (Rs)

Table 4.6 Direct Cost and Waiting Cost

Description	% IRR	Cw	Direct cost (Rs)
Band Saw Cutting	0.15	983.85	1365.71
Thread Rolling	0.15	7.23	9.46
Base Plate Welding	0.15	0.35	2.54
Outer Slotting	0.15	1.15	1.86
Nut Assembly & Drilling	0.15	1288.07	1372.85
Painting	0.15	169.55	227.66
Outer Plate Cutting	0.15	76.63	119.36
Outer Plate Punching	0.15	0.91	1.29
Outer Plate Grinding	0.15	1.86	2.43
Inner Pipe Cutting	0.15	3394.29	3725.57
Drilling	0.15	16.38	24.66
Top Plate Tack Welding	0.15	1.37	3.46
Welding (one side)	0.15	2.17	4.75
Welding (opposite side)	0.15	29.23	31.81
Painting	0.15	168.42	238.82
Inner Plate & Flat Cutting	0.15	114.14	199.94
Inner Plate Punching	0.15	6.52	6.95
Inner Plate Drilling, Straightening and Grinding	0.15	48.00	62.86
Assembly + Loading	0.15	1.25	7.90

Cw – Total Waiting Cost of Inventory (Rs)

4.8 Current State CVSM

Current state CVSM depicts the present state of manufacturing activities in Time and Cost domain so that any person with a minimum knowledge about the manufacturing environment can understand the waiting inventory and the costs associated with these delays. This map shows the time and cost related production activities associated with the transformation of the raw material into finished product just as it is prevailing before the implementation of the proposed lean tool. This map can be used to identify the losses in terms of money spend and to rank those wastages according to the quantity of loss.

From the current state CVSM of the outer pile, as shown in Figure 4.7, the total lead time required for a finished product is 1.052 days and the actual value-added time is only 16.77 min. It can be observed that the non-value-added time and the cost incurred for the production is much higher, which needs to be identified and reduced. Lean techniques including 5S, Six Sigma, KAIZEN, SMED etc. can be applied to reduce these types of wastes in the production process. It can be noted that the total cost investment and activity cost for the outer pipe of an adjustable prop is Rs 1509.93 and Rs 544.99 respectively. Current state CVSM for the inner pipe of the adjustable prop is shown in Figure 4.8. It can be observed that the total cost investment and value-added activity cost for the inner pipe of the adjustable prop is Rs 1703.18 and Rs 479.66.

Apart from the conventional CTP and VSM, CVSM gives the real production cost including the cost of non-value-added activities involved during the production processes.

4.9 Ranking of Non-Value-Added Activities

Value-added costs and the non-value-added costs including the total cost investment can be observed from the current CVSM. From this current CVSM, it is easy to pinpoint the wastages of time and cost on various activities. Further a ranking can be assigned to various processes and WIP inventory, based on the cost investment values. The processes in the order of their cost investment are outer pipe band saw cutting (A), inner pipe cutting (L), nut assembly (E), curing of painted inner and outer pipes (H and S).

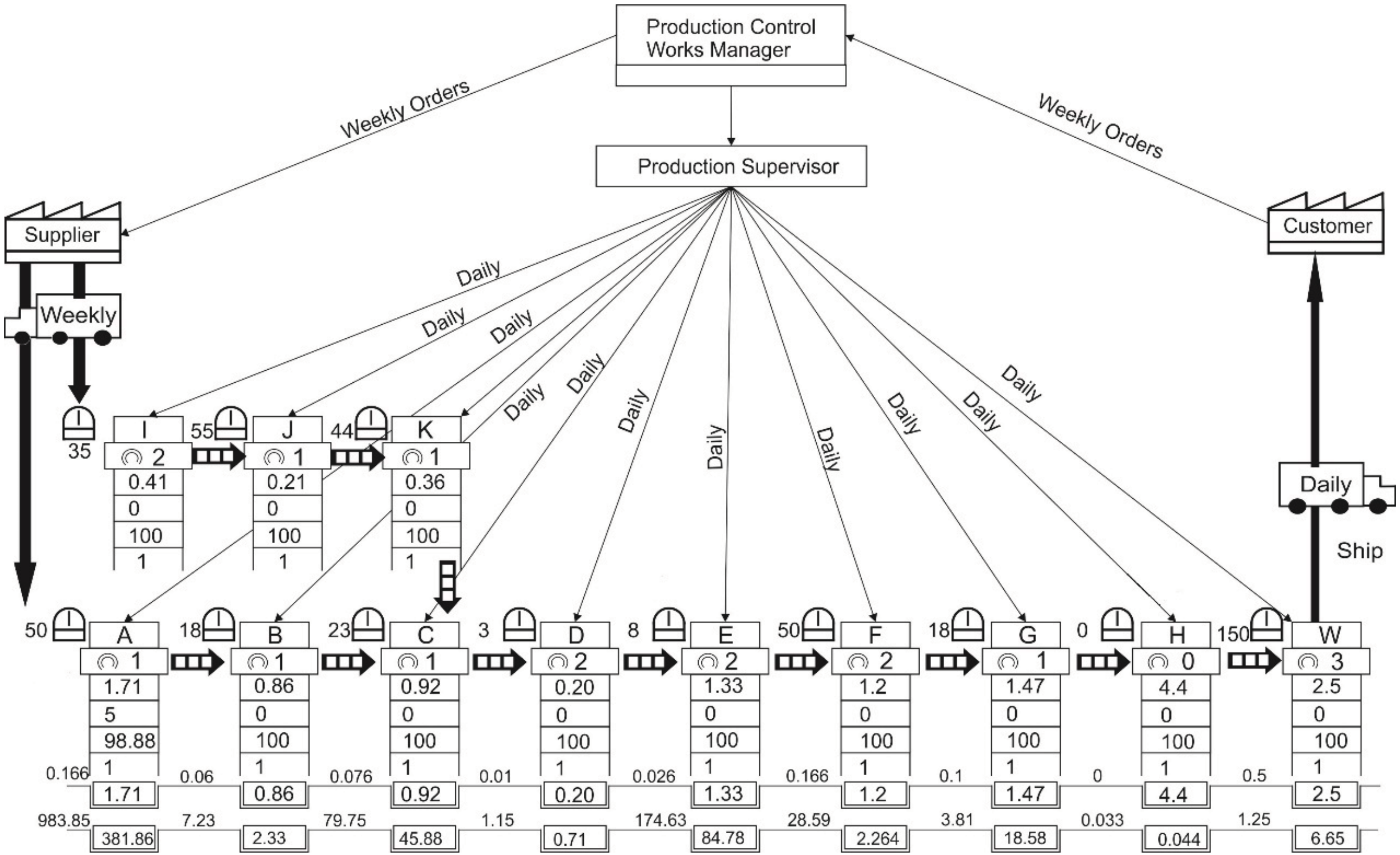


Figure 4.7 Current State CVSM of Outer pipe

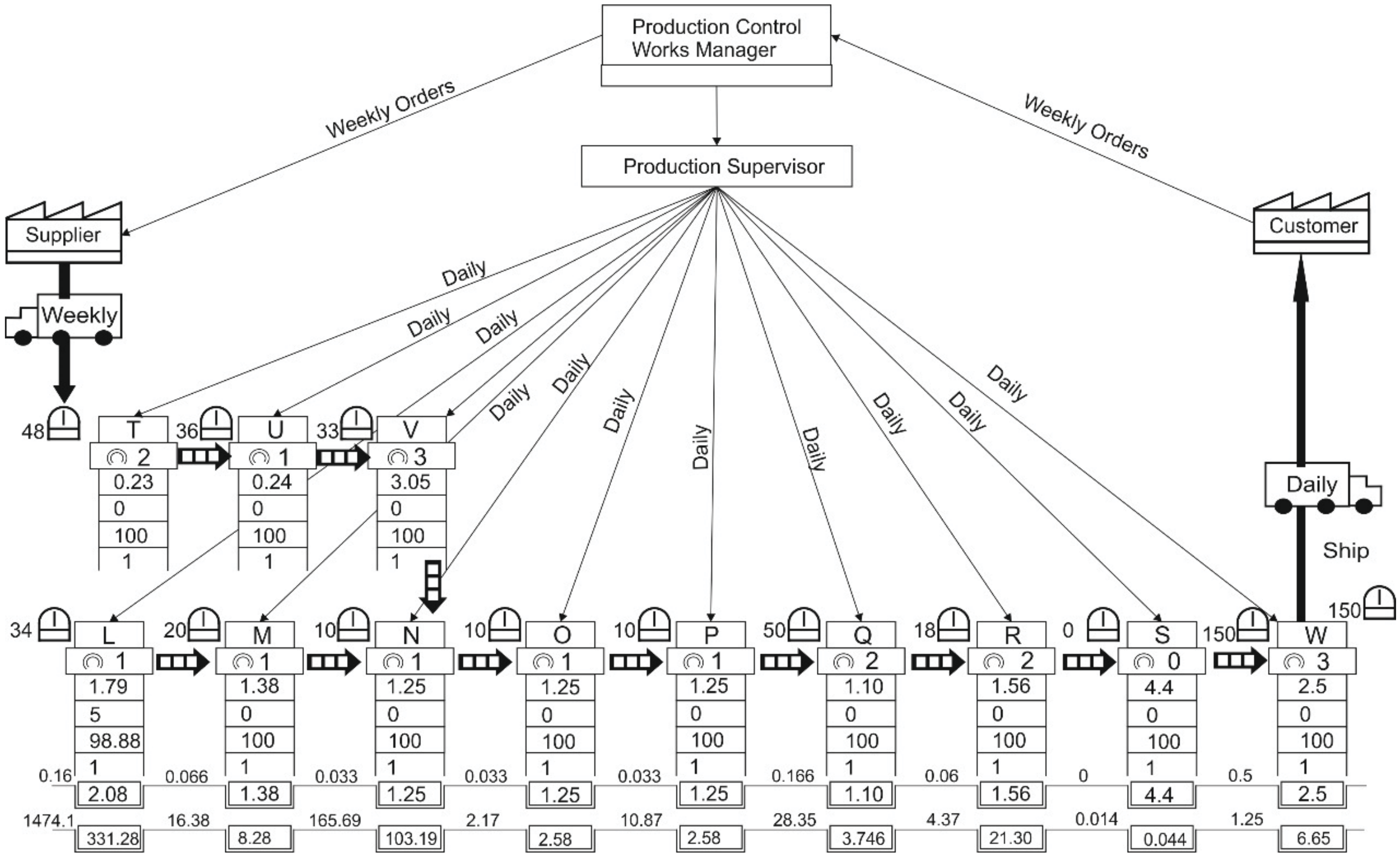


Figure 4.8 Current State CVSM of Inner pipe

4.10 FUTURE STATE CVSM

Non-value-added costs Production processes that are higher, as identified from current state CVSM have to be reduced by applying the lean tools. Cycle time for cutting the outer and inner pipe of adjustable prop appears to be slightly higher than the Takt time. Initially, 5S can be applied to the outer pipe cutting area for material stacking and movement. Subsequently, inner pipe cutting machine facility can be modified for loading two pieces of inner pipe simultaneously and bringing the cutting time close to the Takt time. A KANBAN system can be implemented in the outer and inner pipe cutting operation to further reduce the wastage and making it in rhythm with the Takt time.

Nut assembly is also contributing as one of the major activities for cost investment. By analyzing the micro motions during the nut assembly, the procedure for nut assembly can be standardized and thus the waiting time for the semi-finished product can be reduced. The assembly time can be further reduced by keeping the standard nuts and bolts in proper racks and close to the worker.

Curing of inner and outer pipes are the major non-value-added costs. This waiting time and the cost inventory can be reduced by accelerating the curing process. It will be possible by introducing low-cost improvements in the curing process such as air blowing, providing roof ventilation and providing translucent roof sheets that allow natural heating. Future state CVSM for the outer and inner pipe of the adjustable prop, indicating these lean tools are shown in Figure 4.9 and 4.10.

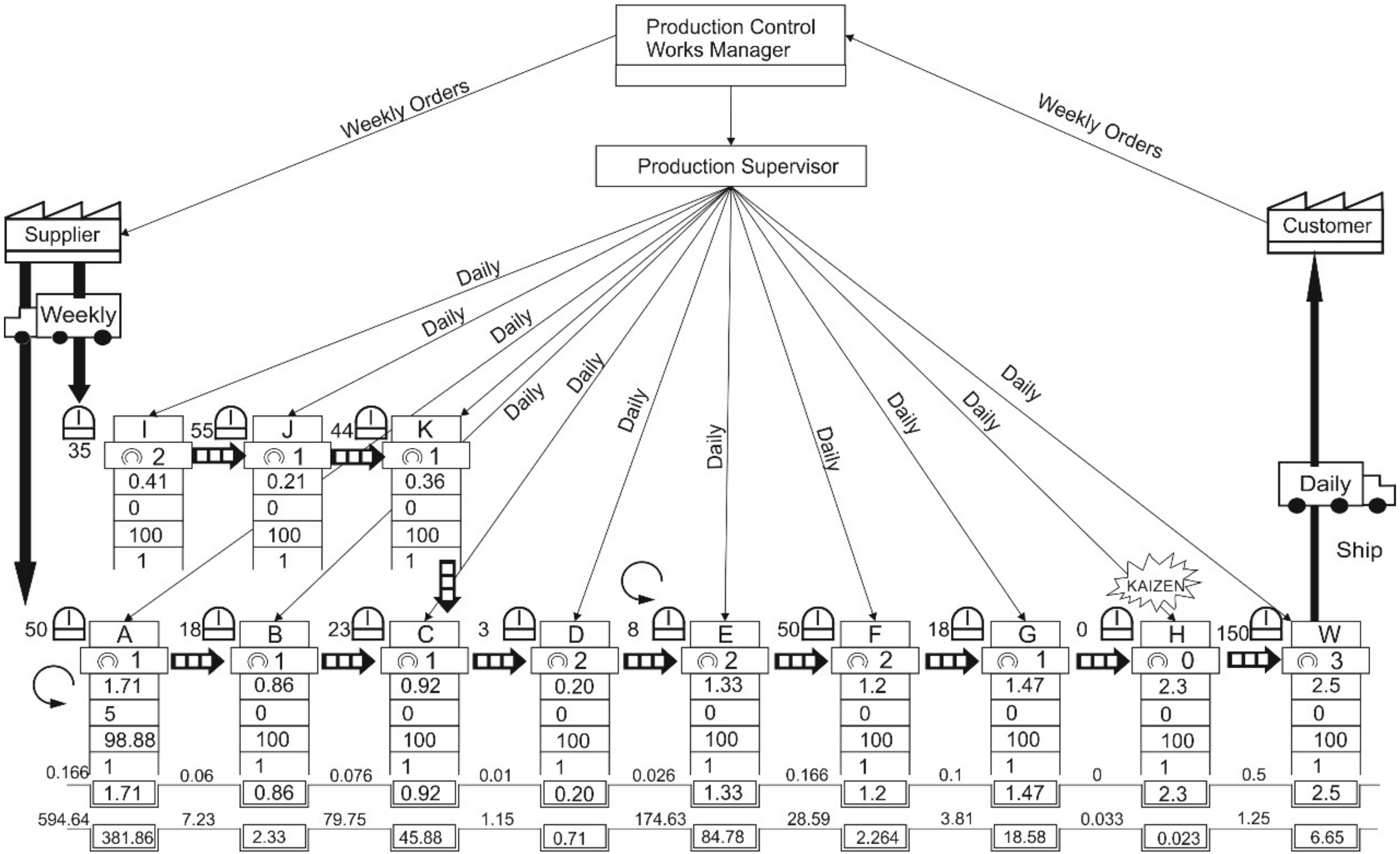


Figure 4.9 Future State CVSM for the outer pipe

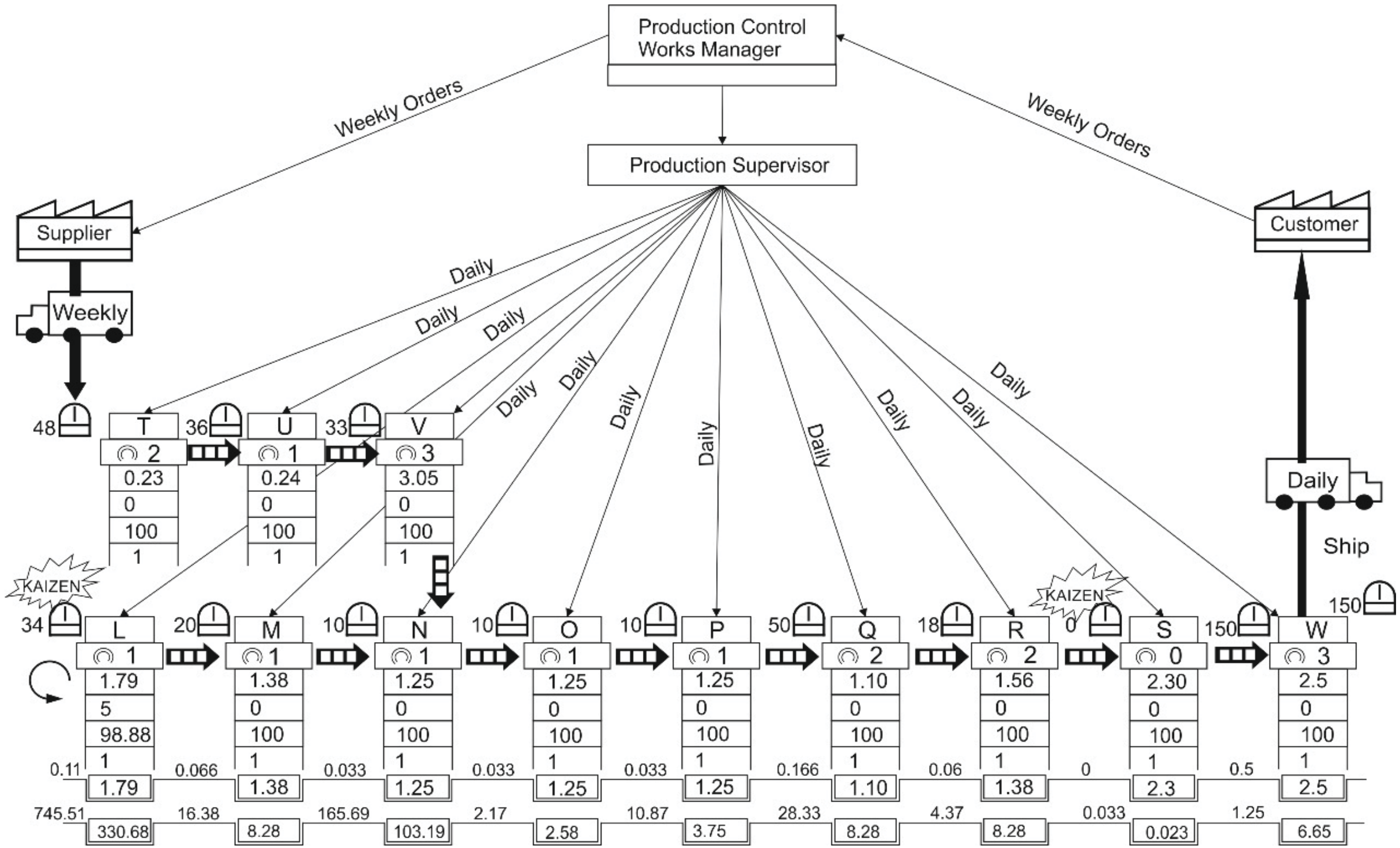


Figure 4.10 Future State CVSM for the inner pipe

4.11 ANALYSIS OF RESULTS

After applying the lean tools, it is observed that total lead time and the value-added time is reduced to 0.804 days and 12.14 min. respectively. Whereas the total cost investment and activity cost for the outer pipe of an adjustable prop is further reduced to Rs 892.85 and Rs 544.04 respectively in future state CVSM. From Figure 4.11, it can be seen that the lead time and the value-added time for the inner pipe is reduced to 0.771 days and 14.03 min. The total cost investment and value-added activity cost for the inner pipe of the adjustable prop is also reduced to Rs 976.59 and Rs 478.09 respectively. By applying the lean tools, there is a reduction in value-added time, lead time, WIP inventory, cost investment and value-added cost as presented in Table 4.7

Table 4.7 Comparison of Current state CVSM and Future state CVSM

Variables	Current state CVSM		Future state CVSM		% Reduction	
	Outer pipe	Inner pipe	Outer pipe	Inner pipe	Outer pipe	Inner pipe
Value added time (mins)	14.59	16.77	12.14	14.03	16.79	16.33
Lead time (days)	1.10	1.05	0.80	0.77	27.17	27.05
WIP inventory (no. of units)	332	316	242	212	27.10	32.91
Cost investment (Rs)	1509.9	1703.2	892.9	976.6	40.86	42.66
Value added cost (Rs)	545.0	479.7	544.0	478.0	0.17	0.32

From the CVSM analysis there is a reduction in the value-added cost. Savings in value-added cost can be calculated by multiplying the difference in total value-added cost of the prop assembly multiplied by the number units produced annually. This is found out as Rs 2,17,728 when considering the minimum unit as 300 per day.

4.12 CONCLUSION

The framework suggested for implementing CVSM is employed for conducting a case study in the selected industry. CVSMs and the various costs associated with it are developed with the help of the implementation team.

Cost investment for the outer pipe and inner pipe of the adjustable prop was found out to be Rs 1509.93 and Rs 1703.18 respectively, whereas the value-added costs are Rs 544.99 and Rs 479.66 respectively. As per the modified method, cost of the outer pipe and inner pipe of the adjustable prop shows an increment of 2.7 times and 3.55 times that of the conventional value-added cost. After applying the lean techniques for the various non-value -added activities in the order of their cost investment, future state CVSM can be made with nearly 27% reduction in lead time, 27-32 %reduction in WIP inventory and 40-42% reduction in cost investment.

The proposed CVSMs were able to expose the important non-value-added activities and their cost investment in the organization. Through these data, the requirement of lean tools and the priority of the implementation of these lean tools are easily identified through the CVSM.

CHAPTER 5

IMPLEMENTATION STUDY IN A SURGICAL GLOVE MANUFACTURING COMPANY

5.1 INTRODUCTION

Another implementation study of the CVSM framework was carried out in a small-scale industry. The details of the activities followed in this implantation are described in this chapter

5.1.1 Company Details

The company manufacturing sterile latex examination gloves situated at KINFRA Integrated Industrial and Textile Park, Palakkad, Kerala, India is selected for test implementation of the CVSM. This small-scale export-oriented industry was started in the year 2013, with an initial investment of INR 6 crores, their products and quality standards following ISO13485:2016. This company employs around 116 workers and supervisors and 10 supporting staff. The company works in three shifts of eight hours and in a general shift of eight and half hours, with 60-minute unpaid break per day. At present the company produces 150,000 gloves per day. Fierce competition from producers around the world has forced the company to reduce their prices to rock bottom, and in turn lose their profit margin. This situation made them think of identifying the wastages in the production flow and taking remedial measures to bring down the non-value-added expenses involved in the production streamline.

5.2 IDENTIFICATION OF THE PRODUCT

The Company manufactures sterilized, beaded, examination gloves, both powdered and powder-free, in seven different palm sizes, ranging from 6 to 9 inches, with a difference of 0.5 inches. From the matrix of products, the Powder free surgical glove of size 7.5” has been selected for the case study. This product undergoes all the manufacturing processes and has contributed to the major sales revenue of the company over the last 10 years.

5.2.1 Process Flow Chart

Concentrated Latex of 60% DRC is the major raw material for manufacturing the gloves. Chemicals including Sulphur, Zinc Diethyl Dithio Carbamate and Zinc Mercapto Benzthiazole, Zinc Oxide, Wingstay L and Potassium Hydroxide are respectively added as curing agents, accelerators, activators, antioxidants and stabilisers to concentrated latex. The process flow diagram for manufacturing the gloves is shown in Figure 5.1. As shown, the chemicals are ground in a ball mill before being added to the concentrated latex. This preparation process is called compounding (A). The compound latex is kept for maturation for 60Hrs. After maturation, the latex is fed to a coagulant dipping section, where formers are dipped into the latex to make gloves. Calcium Nitrate, with a suitable wetting agent, is used as the coagulant bath before dipping the formers into latex. Latex film over the formers is gelled in an oven and then it proceeds to the edge rollers where the film is rolled at the cuff to aid in gripping the gloves during the former donning process. Excess chemicals in the latex film are removed by the pre-curing process called leaching. Further, vulcanization process is carried out in an oven which cross link the latex to form the glove. Post leaching process removes the residual protein in the gloves. These formers with film are then dried in another oven and dipped in corn-starch slurry. On drying, this will act as donning powder for the gloves when the gloves are stripped from the formers.

These stages of the process after compounding are termed as dipping and curing process (B).

The next stage in the manufacturing stage is tumbling drying (C) where excess moisture and powder carried by the gloves during the earlier stages are removed. Glove washing (D) and drying (E) with water reduces the surface tackiness of latex and are done to enable non-sticky wearing of gloves. G-1 Single Sampling method is used for the inspection (F) of the gloves in a lot. After this, one pair of gloves are walleted (G) in a paper.50 such wallets are packed (H) into the inner cartons, and then 8 inner cartons into a master carton. Based on customer requirement, the glove is then sterilized (I) with Ethylene Oxide before being despatched (J) to the ware house.

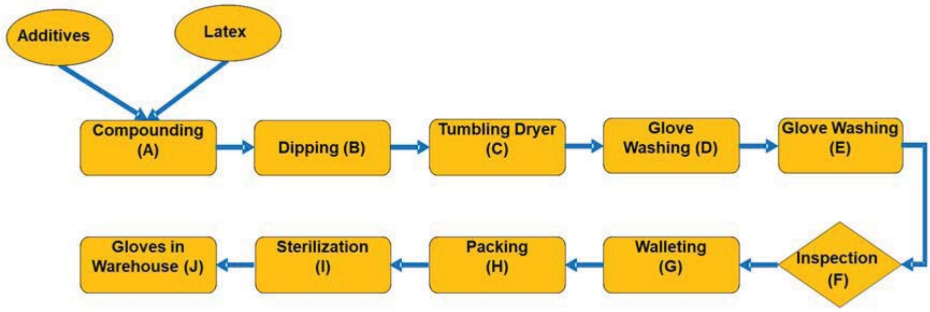


Figure 5.1 Process Flow Diagram

5.3 FORMATION OF CVSM IMPLEMENTATION TEAM

A Team comprising the Head of Operations, Marketing Manager, HR manager, Manager (Accounts), Head of Quality Control, Production Supervisor and Inspection Manager is formed for the implementation of CVSM. Two members are from outside the company to do the analysis and interpret the results to the company officials.

5.3.1 Training for Team members

Training sessions conducted in the company to familiarize the concepts of lean manufacturing in general and the principles of value stream mapping in particular are conducted according to the schedule shown in Table 5.1

Table. 5.1 Training Schedule for CVSM Implementation

Session	Topic	Members
Week 1	Introduction to Lean Manufacturing and knowing the company profile	Chief Operating Officer, Production Manager
Week 2	General Introduction to 5S principles and Value Stream Mapping Methodology	Operators, Supervisors, heads of all department
Week 3	Value Stream Mapping Methodology	Lean Team
Week 4	Discussion on Cost aspects of Production	Lean Team
Week 5	Verification of Production Data	Lean Team
Week 6	Discussion on Current State CVSM to identify wastages	Lean Team
Week 7	Discussion on preparation of Future State CVSM	Lean Team
Week 8	Initiation of implementation	Lean Team
Week 12	Results of Implementation	Chief Operating Officer and Production Manager
Week 13	Interpreting the results of implementation on an annual basis to calculate results and suggesting measures for improvement	Lean Team

5.3.2 Data Collection

The designated team for lean implementation, with the assistance and verification of supervisors and operators, collected the production related data for the preparation of current state CVSM and the projected future state CVSM. Data related to production parameters, lot size, cycle time, available time, uptime, number of operators and supervisors, distance between work stations, percentage rejections activity and waiting period for the various production processes from A to J is recorded by the selected team. Various costs calculated according to Equations 3.1 to 3.6 are also shown in Table 5.2.

Table 5.2 Calculation of Different Costs in Production Processes

Process	Next Stage of Production	Lot size (Nos)	N	No	$\dot{C}_o$	T_c	$\dot{C}_d$	$\dot{C}_m$	$\dot{C}_r$	$\dot{C}_a$	C_{mat}	C_a	Direct Cost	%rejection
Compounding		1,50,000	1	2	205	8	0.64	0.03	0.67	206	230.7	1.65	232.35	1.35
	Maturation	1,50,000				60								
Dipping & Curing		1,952	3	10	866	23.68	4.15	89.28	93.43	959		22.73	22.73	0.5
	Waiting					23.43								
Tumbling Dryer		6,000	1	3	268	12.5	0.35	7.44	7.79	276		3.45	3.45	0
	Waiting					24								
	Maturation	1,50,000				168								
Glove Washing		7,500	1	3	268	20	0.7	14.88	15.58	283		5.67	5.67	0
	Waiting					19								
Glove Drying		7,500	4	12	1071	5	0.35	7.44	7.79	1079		5.4	5.4	0
	Waiting					24								
Inspection		1,50,000	2	36	2411	8				2411		19.29	19.29	5
	Transportation	1,50,000				240								
Walleting		1,50,000		20	1250	8				1250		10	10	0
	Waiting					24								
Packing		1,50,000	1	17	1143	8	0.35	7.44	7.79	1151	7.8	9.21	17.01	0
	Waiting	1,50,000				24								
Sterilization		1,50,000	1	3	268	21	0.7	14.88	15.58	283		5.95	5.95	0
	Waiting	150000				1								
Warehouse		1,50,000	1	6	455	1	-	-		455		0.46	0.46	-

The cycle time the processes in the order of value addition as shown in Figure 5.2. As far as the production of glove is concerned, there are certain maturation processes in between the production stages which are mandatory. Some maturation requires 6 to 7 days to prepare the semi-finished product to the next processing stage. These uncontrollable factors make the Takt time related analysis irrelevant in this case study.

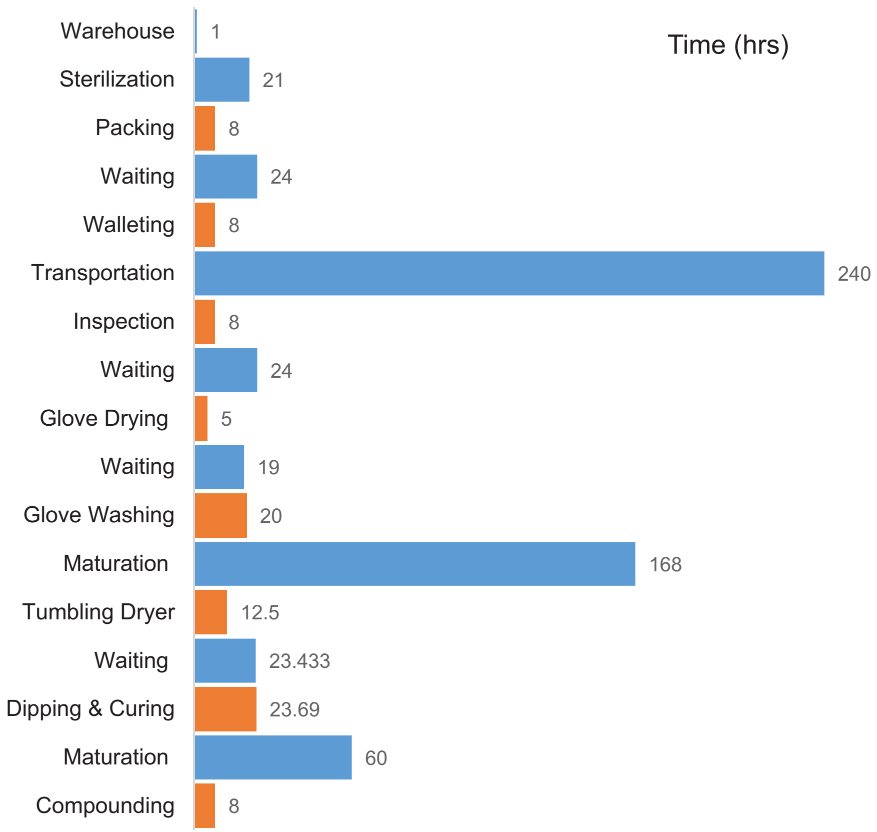


Figure 5.2. Processes and Cycle times

The cycle time, uptime, change over time, work in process inventory and the number of operators is entered with the corresponding symbols in the prepared VSM which is shown in Figure 5.3.

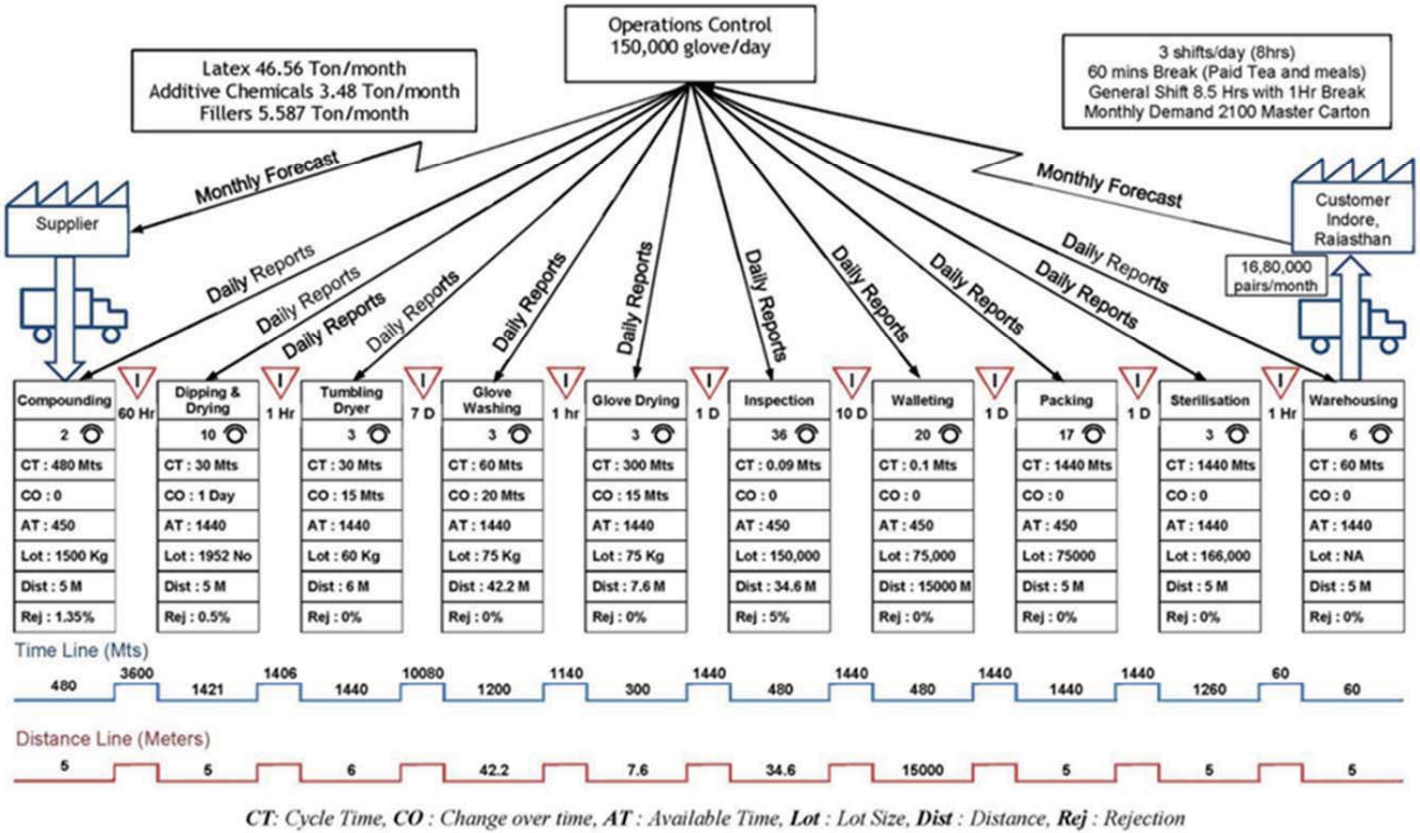


Figure 5.3: Current state Value Stream Map

5.4 COST TIME INTEGRATION

The Cost details of individual operations are calculated and included in the VSM. The details of calculations are shown in Table 5.2. In order to construct the CVSM, the different costs incurred in the time domain are required to be established. Hence different costs incurred in an hour for carrying out different processes are calculated.

For the total number of 150,000 gloves produced in a 3-shift day, the material cost and packing cost incurred are Rs 230,699 and Rs 7,800 respectively. The hourly cost of the operator and the supervisor is Rs 62.5 and 80.35 respectively. Depreciation cost of individual equipment is calculated by dividing the capital cost of equipment with the total usage time in a year. The maintenance cost is the ratio of the yearly maintenance cost of a machine with the time duration in which the machine is used in a year.

Resource cost for each process is the sum of the depreciation cost rate and maintenance cost of the machines involved in the process. Further the activity cost for the various processes involved is found by adding the resource cost with the operator cost. Total activity cost for each activity from A to J is calculated by multiplying the activity cost with cycle time for each process. Total cost investment, accounting the rejection after inspection during each process, is calculated using the Equations 3.1 to 3.6.

The expression for determining the entire area of CTI graph is formulated considering the area under the CTP graph accounting for all the rectangles and triangles in the CTP Fig 5.4.

Indirect cost for the product includes utility cost and the fixed cost. Cost of utility is consisting of cost of water consumed, electricity charges, fuel (Gas, Furnace Oil, Firewood, etc.). Fixed cost associated with every production process is related to the cost involved in the salary of administrative and security personals, bank charges, audit expenses, travelling expenses, unloading of goods arrived and loading of goods in despatch section, lab expenses, employee welfare, annual employee insurance charges, various taxes, festival allowance and rent of building or equipment. Finally, the total production cost was found by adding the direct cost, indirect cost and the non-value-added cost.

Total cost investment with rejection accounted in all the stages is Rs. 326,500 for a lot size of 150,000 gloves. Indirect cost for each glove has to be included to arrive at the total cost of production. As per the information collected Rs 0.52 and Rs 0.75 are the utility cost and the fixed cost respectively for each glove. The indirect cost for the lot size of 150,000 gloves is Rs 226,500. So total value-added cost for the lot size is Rs 553,000. Hence the total manufacturing cost for one glove is Rs 3.69.

The total area of the CTP profile is 197,002,230 Rs-Hr. IRR is 13.75%, which is determined from the sales and cost of investments of the company. Cost investment for a daily lot size of 150,000 gloves is Rs 309,221 which makes an additional non-value-added cost of Rs 2.06. This makes the total production cost of the glove Rs 5.75.

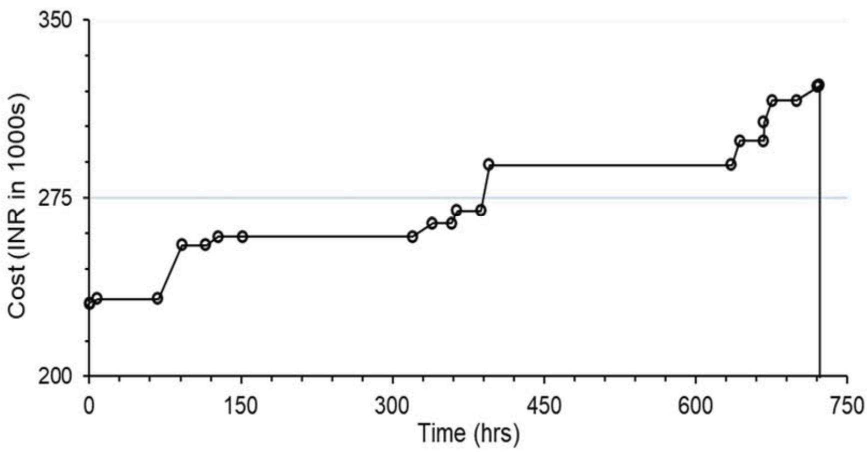


Figure 5.4. Cost Time Profile (CTP) of all the activities

5.5 CURRENT STATE CVSM

As observed from the Current state VSM, total lead time for a lot size was 722.62 Hr. The value-added time for the manufacturing process was only 390.62 Hr. Current state CVSM was plotted by adding the cost of production with the time domain in conventional VSM. Cost line is added below the timeline of VSM. Various value-added and non-value-added costs accounted into the CVSM are shown in Figure 5.5. As explained, the total manufacturing cost including the direct and indirect value-added cost for one glove was Rs 3.69. Considering the non-value-added costs, final production cost of one glove was Rs 5.75.

5.6 FUTURE STATE CVSM

Time required for various value-added and non-value-added activities are shown in Figure 5.6. Transportation from the manufacturing facility to the walleting and packing facility and the maturation process are the major time-consuming processes, requiring 240 and 168 hrs. respectively. The maturation process is inevitable in glove manufacturing. By introducing “distance travelled” as a parameter in the traditional VSM, the wastage occurring due to unwanted transportation can be identified. The processes up to inspection are carried out at a manufacturing facility and the rest of the operations are completed at another location situated 150 km away. This forces the company to wait for the completion of an entire truckload of products before transporting them to the packaging facility. This is the major contributor towards the losses of the company, considering the cost of production.

Installing the walleting, packing and sterilizing facility at the place of manufacturing will substantially reduce the cost of production. By installing an in-house walleting and packing facility, the total production cost including the non-value-added cost will come to Rs 5.03 per glove. The initial investment cost required to establish such a facility in the company is nearly Rs 5,500,000. This new facility can produce an annual savings of around Rs 1,094,400 in the company, making the payback period for this investment is nearly 5 years.

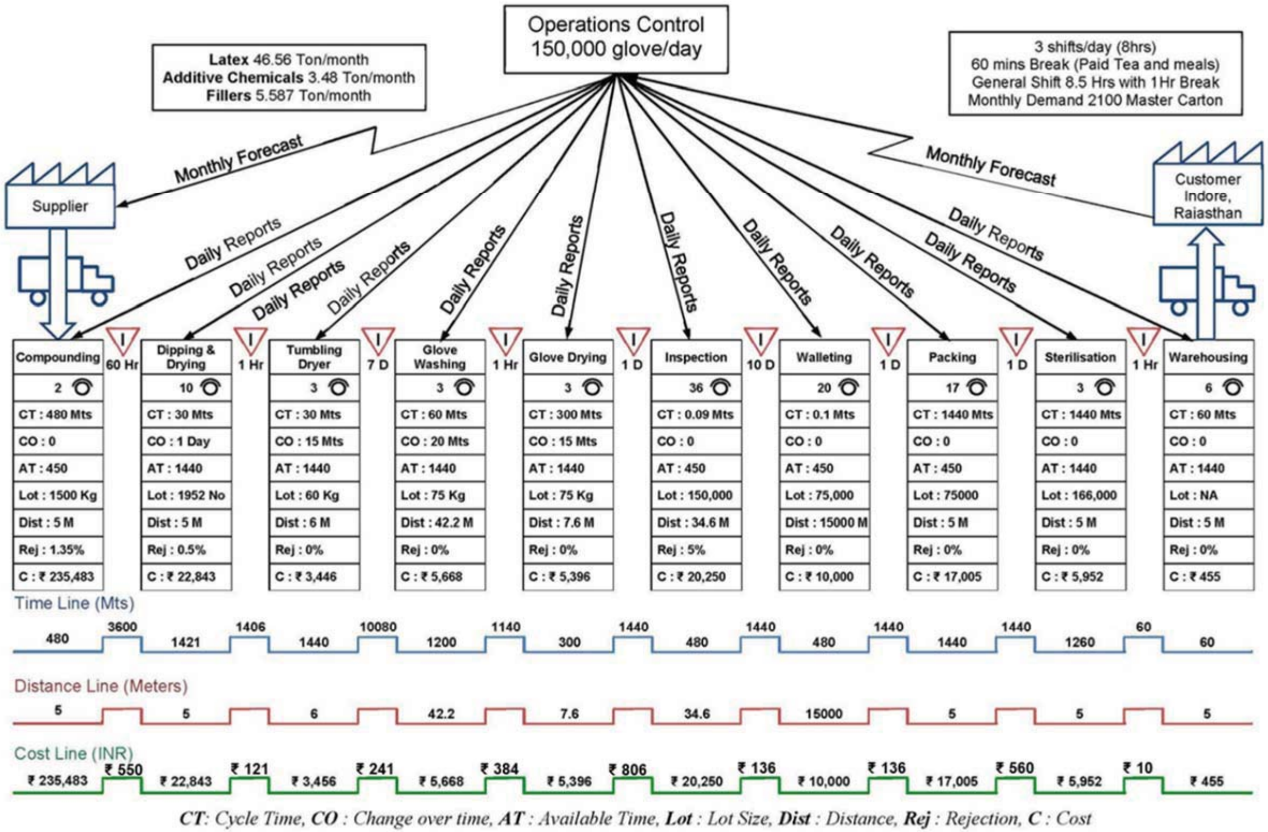
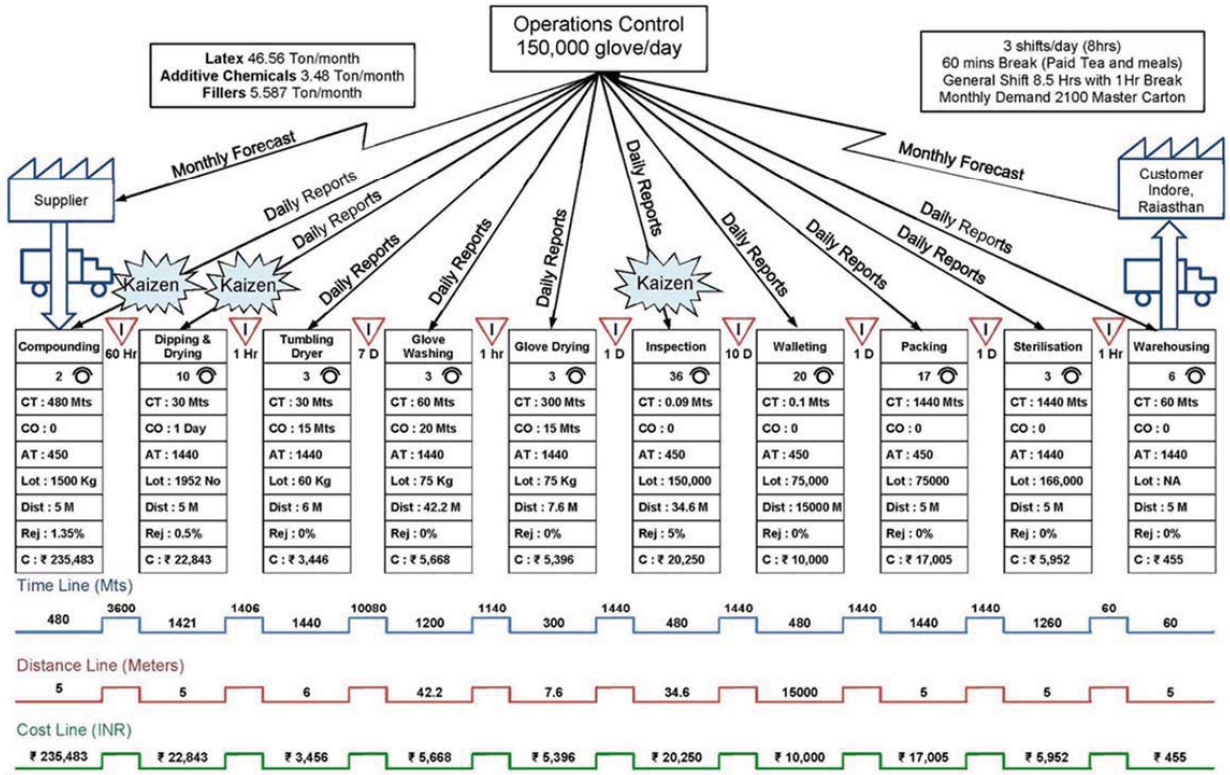


Figure 5.5. Current State CVSM of 7.5 inch Powderfree Surgical Glove



CT: *Cycle Time*, ***CO*** : *Change over time*, ***AT*** : *Available Time*, ***Lot*** : *Lot Size*, ***Dist*** : *Distance*, ***Rej*** : *Rejection*, ***C*** : *Cost*

Figure 5.6. Future State CVSM of 7.5 inch Powderfree Surgical Glove

From the current CVSM the wastages in production in their order of importance and value can be identified. They are (i) rejections at the inspection station, that account for 5% (ii) reconfiguration of thermic fluid heater (Wood fired) and (iii) installation of a water recycling system. Some defective products not conforming to its pre-specified quality occur at each processing station. Percentage rejections are recorded at every processing station in the CVSM.

Measures to reduce rejection at inspection stations are (i)introducing KAIZEN trials at dipping and curing stations (ii)introducing 5S in the Tumbling Dryer, and at Washing and Inspection, and (iii) displaying SOP at each inspection station. By adopting the above measures, the rejection rate can be reduced to 2.25% from the present 5%. It is possible to enhance the maximum capacity of the existing company to 175,000 gloves/day from the present 150,000 by enhancing the capacity of the thermic fluid heater. This facility needs an investment of Rs 3,500,000. At the same time, it reduces the production cost for a glove by 25%. Thus, the annual saving of the company is nearly Rs 84,525,000.

The production process requires 12,000 L of water every day. Considering the cost of water as per the current commercial rate of water in Kerala for industrial use (40 Rs/kiloliter), it was advised to set up a recycling plant so that a considerable amount of water can be reused, not only because of economic consideration but also from the angle of sustainability. This facility needs an installation cost of Rs 2,000,000. It is accounted to benefit an accrued annual saving of Rs 900,000 by installing an in-house water recycling plant with a payback period of 2 years and 3 months. After applying the above lean tools, future state CVSM is shown in Figure 5.6.

5.7 CONCLUSION

An improved method, namely the Cost Value Stream Map (CVSM), for addressing the implementation of lean manufacturing, is proposed in this work. This method makes use of the advantage of both VSM and conventional CTP methods. By constructing the current CVSM, the wastages in production in their order of importance and value were identified. Methods of reducing the manufacturing cost and manufacturing cycle time were proposed and detailed in the future CVSM. This proposed Cost-Value Stream Map helps to identify the major non-value-added activities and their cost investment in an organization.

CVSM gave a direct opportunity to identify wastes in the production line in terms of cost. This enables everyone, irrespective of the hierarchical position in the company, to quantify the wastages in production in cost terms. Identification of 'muda' and selection of the suitable lean tool to eliminate it is made easy by implementation of CVSM.

CHAPTER 6

DEVELOPMENT OF EXPERT SYSTEM FOR CVSM IMPLEMENTATION

6.1 INTRODUCTION

Implementation of Lean tools in small and medium scale enterprises in India had been an initiative by the Ministry of MSMEs for improving its productivity. These measures improve the competitiveness and subsequently enhance the quality of products of these companies. This ensures all the existing manufacturing firms to survive the global competition and contribute towards Indian economy. MSMEs normally have optimum number of operators in their organization due to the higher overhead component of employee wages when considering the cost of production.

Many of the companies in Kerala registered as small or medium enterprises are facing severe competition from even other parts of the world. The cost of raw materials, labour, utilities, administration, etc. are the primary components deciding the cost of a product. MSMEs usually have the scope for optimization only in the area of production related expenses. Cost of raw materials remain same among competing companies. In this situation, cost of a product can be further reduced by eliminating the wastes associated with the production process. Shifting the traditional manufacturing into Lean manufacturing paradigm is one of the solutions to this problem.

In order to eliminate the manufacturing wastages, MSMEs should be able to assess their process for identifying various costs incurred in the processes. The need of an assessment tool for quantifying the lean competitiveness is relevant in the Lean manufacturing paradigm. As a part of the research work, the principles of

CVSM were used to develop an assessment tool to visualize the changes due to the implementation of the Lean tools.

6.2 CVSM AS A LEAN ASSESSMENT TOOL

Cost Integrated Value Stream Map (CVSM) is a versatile tool which can completely visualize the production process for further analysis of production related parameters in a micro level as far as each production process is concerned. CVSM establishes the entire spectrum of production transactions in a clear manner which is even understood by the lower-level operators in the production floor. Transactions in production includes the information, material and the activity flow during the production in terms of money and time. This analysis and the final reports can be easily understood by the employees and it empowers them to be a change agent in the improvement of competitiveness and thereby reducing cost and ensuring better quality of products.

Enterprises aspiring to implement Lean tools in their organization can hardly spare employees for this exercise due to the busy schedule normally prevailing in the industrial environment. The following difficulties are found in every organization which acts as a barrier for the implementation of the Lean tools:

6.2.1 Unavailability of a standard format for the data collection for lean analysis

Standard format for implementing different lean tools in MSMEs in India is not well established as in other countries like Japan. This is supposed to be the most important hurdle in the lean implementation initiative for small and medium enterprises.

6.2.2 Sparing employees for meeting, data collection and brainstorming

In MSMEs, all employees, supervisors and managers are normally preoccupied with their routine job responsibilities in every company. This is because, the cost of maintaining an employee is considerable compared to the other overheads of production. With this optimum number of employees, companies are not normally able to spare the time for some other additional work such as lean auditing and related meetings.

6.2.3 Manual Data Collection

Data collection needs to be done with the help of supervisors of each process station and it should be accurate for further analysis. This is the next most challenging factor in the implementation of Lean, because the data can vary in a wide range of value. Picking the exact value from such a wide range can only be done with the help of an experienced operator. They can arrive at the most likely value of the production parameter in their process station.

6.2.4 Large number variants for products

Every enterprise makes a variety of product in their production line suiting different customer requirements. Analyzing each of this product individually is another difficulty in the manual lean analysis.

6.2.5 Regular review regarding the results of analysis

The results obtained through lean analysis is to be conveyed back to the team so that in the next brain storming session each one of the committee member will have some simple suggestion that can considerably change or eliminate the wastes associated with those production areas during the production of a specific product.

6.2.6 Data sharing and collection

The data which is collected from each organization specific to a single product is to be first recorded, processed and then interpreted for taking remedial measures such as suggesting the most appropriate lean technique for waste elimination. Manual data collection, processing and interpretation method have got their own disadvantages.

All the above-mentioned challenges of data collection and analysis point towards the use of Information Technology solutions to overcome the entire issues regarding this situation.

6.3 MSME VALUE TRACKER

A software named “MSME Value Tracker” is designed for data collection, analysis and interpretation of results of the lean implementation in MSMEs. This internet enabled software equips the entire team to share the data collected in their own comfort and convenience. This software can be installed and operated by the entire team members through their mobile phone or computer. This package ensures convenience of uploading the concerned values of parameters related to a specific team member which can be consolidated in a common platform for further analysis. Every team member is free to see the values in each process stage. Finally, everyone in the team will get an overall view of the costs of operations during the production. This helps in identifying the wastages in each department during production.

6.4 DESIGN AND FUNCTIONS OF MSME VALUE TRACKER

The welcome page of the MSME Value Tracker is shown in Figure 6.1. Upon clicking the Go to Admin Dashboard, the Dashboard for adding a company will be displayed. As shown in Figure 6.2, the name of the company can be added by the administrator. Login details of the team leader is also created by the administrator of the company. Login details are assigned to the team members by the team leader. Actual data of a company M/s SANREA Healthcare Products Pvt Limited are entered into the MSME Value Tracker, in order to explain the working of the system.

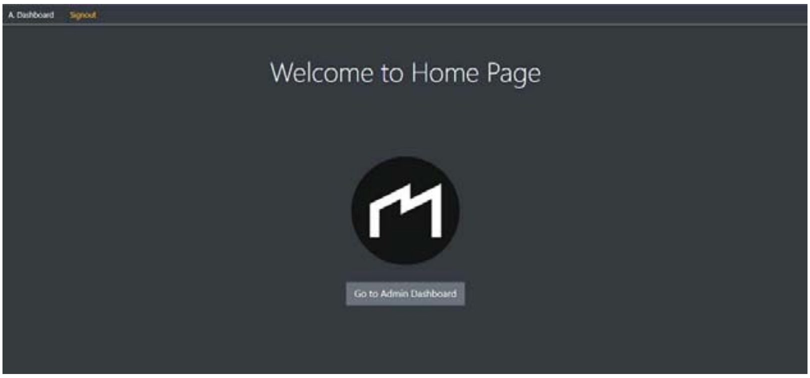


Figure 6.1. Home page of Value Tracker

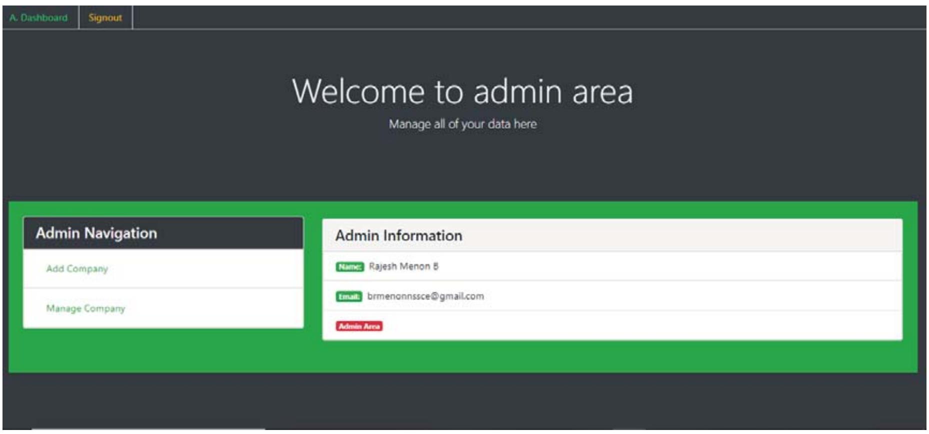


Figure 6.2 Dashboard for adding Company

6.4.1 Company Profile

The following general details about the company are initially uploaded at the time of adding the company.

- Company Name
- Company Description (A general description of products and the category)
- Company Address
- Company Contact (Team Leader for this Lean Implementation)
- Products (All products and its variants)
- Annual Turn Over (INR)
- Investment Cost (INR)
- Customers (Regular clients/customers for the last two years)
- Monthly Demand (number of product pieces)
- Monthly Production Capacity (Numbers)
- Number of Employees
- Departments (Production, Marketing, Quality, Maintenance, etc.)
- Utilities (Water, Electricity, Fuel, Oil, etc.)
- Temporary Employees (Not included in the company Roll)
- Area of Land (cents/acres)
- Area of Factory Building (Sq ft/Sq m)

The company details entered for M/s Sanrea Healthcare Products Pvt. Ltd. is shown in Table. 6.1.

Table 6.1 Company Details entry to the MSME Value Tracker

Details	**Data to be entered**
Company Name	SANREA Healthcare Products Pvt Limited
Description	SANREA HEALTHCARE PRODUCTS PRIVATE LIMITED is a Medical Glove manufacturing company established in 2012 located in KINFRA Integrated Industrial & Textile Park, Palakkad, Kerala, India. The factory is equipped with state-of-the-art multi glove production facility capable of manufacturing disposable gloves using natural and synthetic latex. The promoters of SANREA with their past experience in the glove manufacturing field have come up with this facility (having a capacity of 2 Million Pairs per month), for development of disposable gloves with innovative production technologies keeping at par with the international standards. SANREA guarantees a safe and reliable glove manufactured under stringent production hygiene and quality check parameters.
Address	KINFRA Integrated Industrial & Textile Park, Pearl Road, Kanjikode, Palakkad, Kerala, INDIA
Contact Details	XXXXXX3076
Products	SURGICAL/PHARMA GLOVES

Details	Data to be entered
Annual Turnover	49.8 Cr
Investment Cost	9.12 Cr
Customers	Sun Pharma Industries, Lupin, Sreeji Distributors
Monthly Demand	21,00,000 Pairs
Monthly Production Capacity	16,00,000 Pairs
Number of Employees	140
Departments	Production, Quality, Marketing & Finance
Utilities	Water, Firewood, Furnace Oil
Temporary Employees	5
Area of Land	185 cents
Area of Factory Building	80000 SQ FT

6.4.2 Add Product

After adding the company and company details, the products details are added in the screen shown in Figure 6.3. The products of M/s SNERA Healthcare Products Pvt Ltd, as added are shown in Table 6.2. After adding all the products, the screens for entering Information flow, Material flow and Activity flow will be displayed by clicking the 'eye' symbol near the product name.

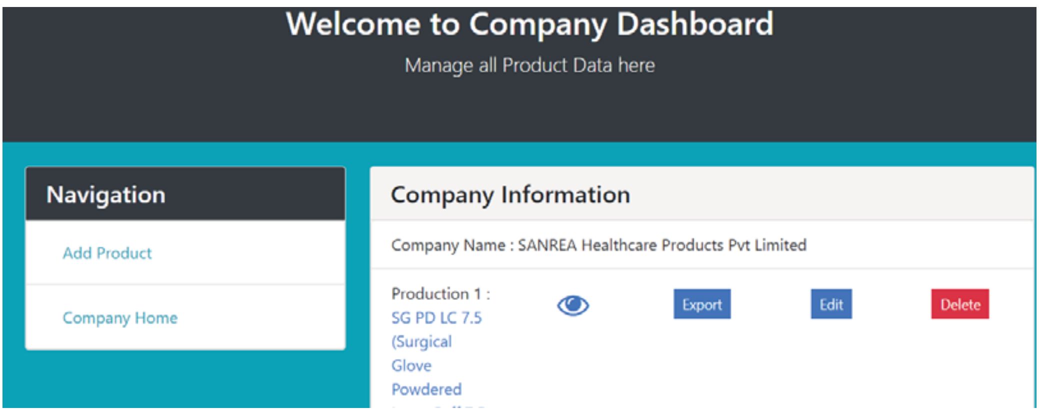


Figure 6.3 Add product screen

Table 6.2 Products added into the MSME Value Tracker

Product	Product Code	Lot Size (Nos)
Powdered Long Cuff Palm size 7.5 inch	SG PD LC 7.5	120,000
Powdered Long Cuff Palm size 8 inch	SG PD LC 8.0	119,000
Powder Free Long Cuff Palm size 7.5 inch	SG PF LC 7.5	120,000
Powder Free Long Cuff Palm size 8 inch	SG PF LC 8.0	119,000
Powdered Short Cuff Palm size 7 inch	SG PD SC 7.0	122,000
Powdered Short Cuff Palm size 7.5 inch	SG PD SC 7.5	120,000
Powdered Short Cuff Palm size 8 inch	SG PD SC 8.0	119,000
Powder Free Short Cuff Palm size 7 inch	SG PF SC 7.0	122,000
Powder Free Short Cuff Palm size 7.5 inch	SG PF SC 7.5	120,000
Powder Free Short Cuff Palm size 8 inch	SG PF SC 8.0	119,000

6.4.3 Material Flow

Tracing the material flow of the production process is another important aspect of visualizing the production with the help of VSM. These details are entered in the 'Materials Flow Details' screen shown in Figure 6.4. On clicking the 'Add' button, a screen for entering the details will be displayed. This screen is shown in Figure 6.5. There are provisions for adding material and denoting the type of material handling for all the processes. A sample of the materials flow data entered is shown in Table 6.3.

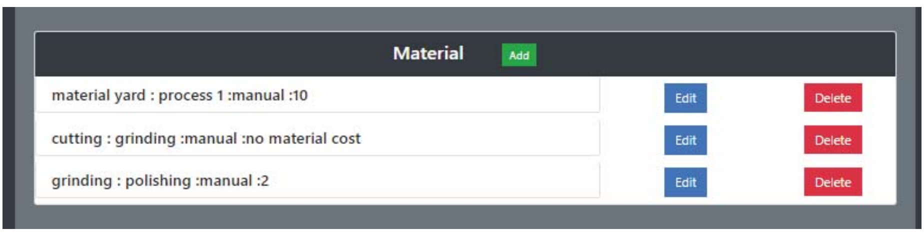


Figure 6.4 Material Flow Details Window

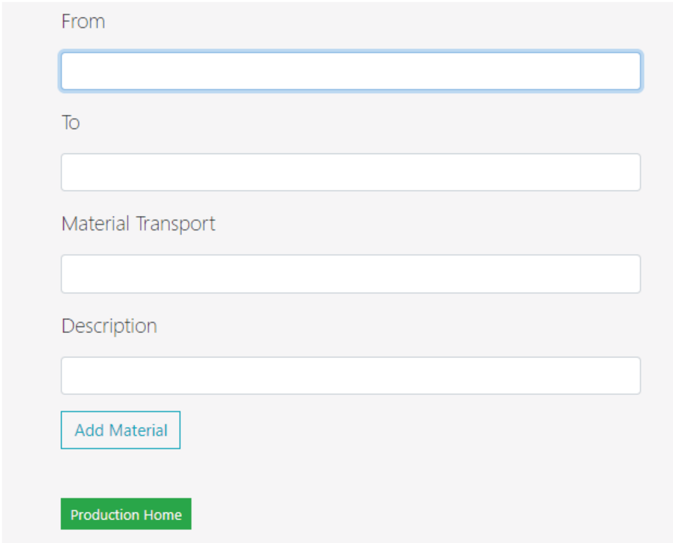


Figure 6.5 Materials Flow Entry Window

Table 6.3 Sample data of Material Flow

From	**Type of Flow**	**To**
Store	Manual	Compounding
Compounding	Through Pipes	Dipping & Curing
Dipping & Curing	Manual	Tumble Dryer
Dipping & Curing	Manual	Tumble Dryer
Tumble Dryer	Manual	Inspection Section
Inspection section	Manual (Trolly)	Glove Washing
Glove washing	Manual	Glove Drying
Glove Drying	Manual	Despatch
Despatch section	Truck	Kochi Unit
Warehouse	Manual	Packing Unit
Packing Unit	Trolly	Sterilization unit

6.4.4 Activity Flow

Process parameters are uploaded by the concerned department team member into the main pool of data. These data are entered through the ‘Activity Flow Window’ shown in Figure 6.6. A sample of the activity flow entered is shown in Table. 6.4. Activity details of all the sections as shown in Table 6.4 are entered into the MSME Value Tracker.

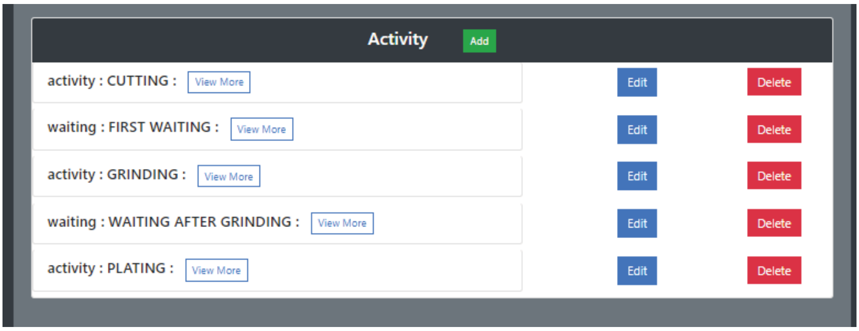


Figure 6.6 Activity Details Window

Table 6.4 Activity Details of each Processing Station

Activity Code	Activity Name	Distance to the Next Station(M)	Description
A	Compounding	5	Mixing of chemicals with latex
B	Dipping & Curing	5	Dipping The ceramic former into latex compound and then curing with heat
C	Tumble Drying	6	Drying the gloves after curing
D	Inspection	6	Inspecting the acceptable quality level
E	Glove Washing	5	Chlorinated to remove the powder present in the gloves
F	Glove Drying	5	Drying the gloves after washing
G	Despatch	150000	Sending the finished gloves for packing and sterilization to kochin plant
H	Packing	5	Packing the gloves in a pouch (both left and right hand), packing pouches into inner carton and finally placing the inner cartons to master carton
I	Sterilization	5	Sterilization is done to a lot of 88000

The following parameters are uploaded in a production line.

- Name and code of the Process
- Activity cycle Time
- Value Added Time (VA)
- Non-Value-added time (NVA)
- Lot Size (if any)

- Material cost
- Operator cost rate and Number of operators
- Supervisor cost rate and number of supervisors
- % Rejection
- Distance between processing stations
- % Internal Rate of Return
- Machines, Investment on machinery, Annual Maintenance cost and age of the machine

6.4.5 Activity Parameters

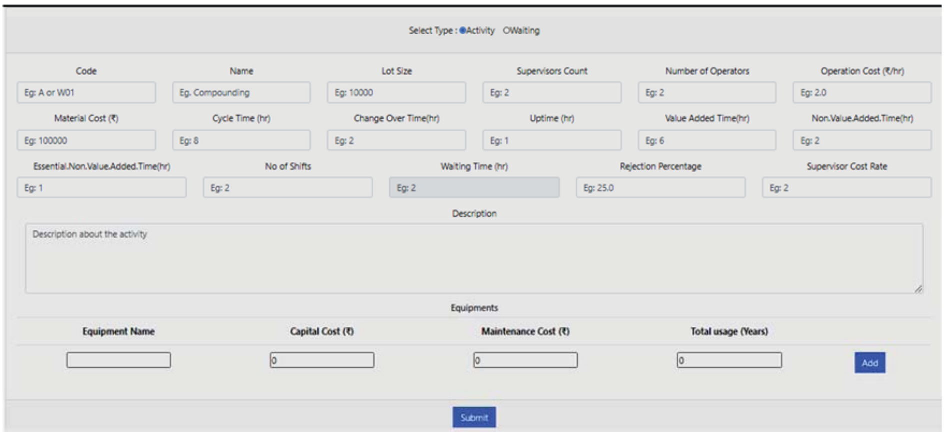


Figure 6.7 Activity parameters Window

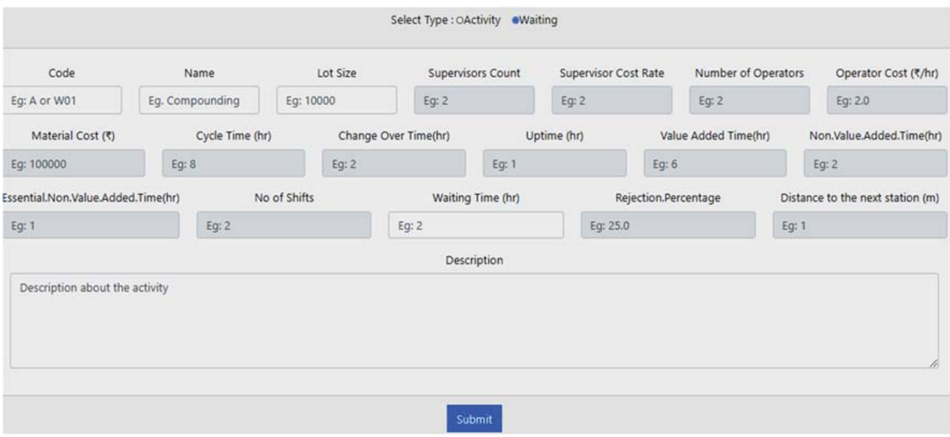


Figure 6.8 Waiting parameters Window

By clicking the add button of the screens ‘Activity’ and ‘Waiting’, the listed parameters are entered as shown in Figure 6.7 and 6.8 respectively. These data are to be entered for all the activities.

6.4.6 Information Flow

Details of Information flow are mainly used for the preparation of Value Stream Map for picturizing the complete transactions involved in the production. These data are entered in the ‘Information Flow’ screen shown in Figure 6.9. The flow of information between the customers and company, within the company and the communication between the company and its suppliers are entered in this screen. By clicking the ‘Add’ switch the screen shown in Figure 6.10. will be displayed, Information entry screen.

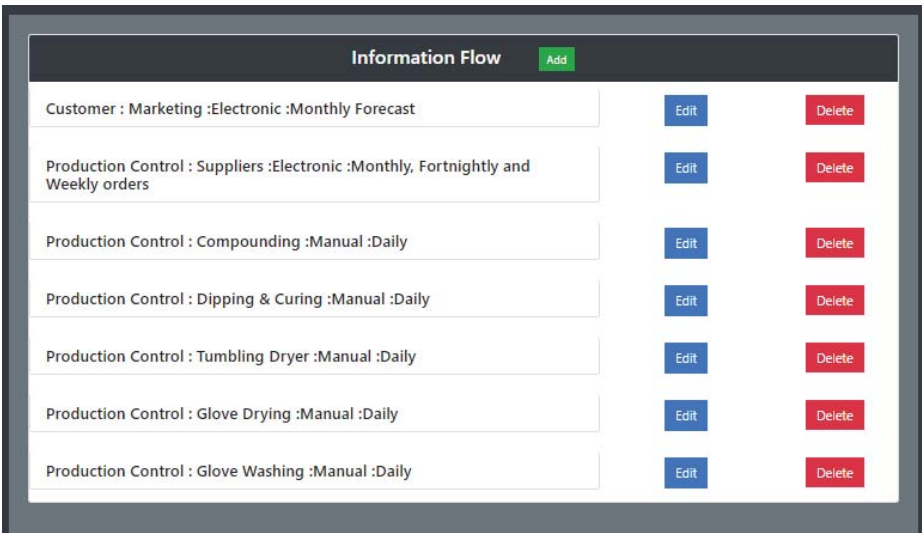


Figure 6.9 Information Flow Add / Edit Window

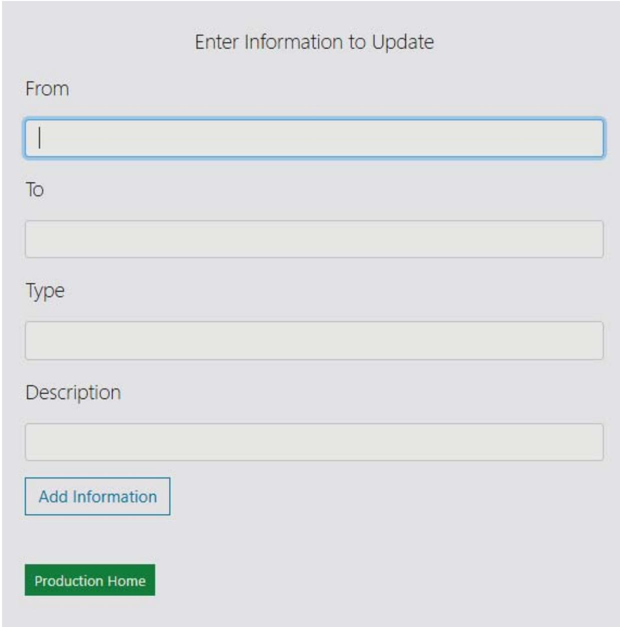


Figure 6.10 Information Flow Entry Window

On Completing the entry of data, by clicking the 'Export' button, in screen shown in Figure 6.11, the details of costs and other information will be exported in the Excel format. The information obtained are shown in Tables 6.5 to 6.7. Table 6.5 gives the details of cycle time, costs and cost rates arrived at using Equations 3.1 to 3.6.

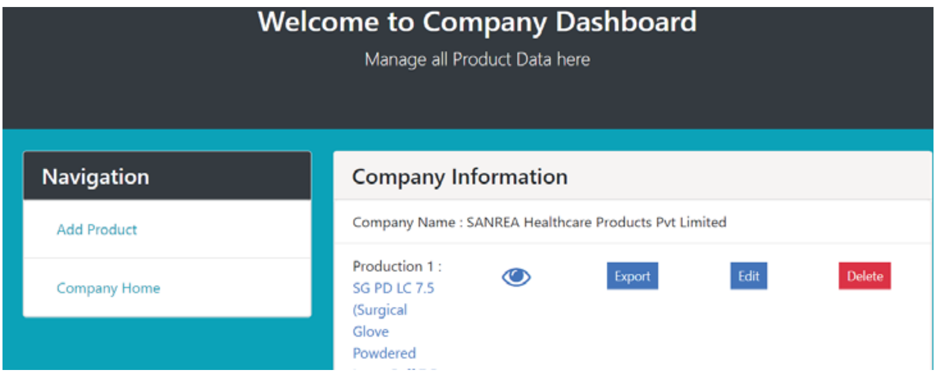


Figure 6.11 Export the results of analysis Window

Table 6.5 Process Parameters in Time and Cost Domain

Activity Code	Process	In between stage/ waiting stage	Lot Size	Supervisors	Operators	Cycle Time	Waiting time before process	Operator cost rate	Supervisor cost rate	Depreciation Cost Rate	Maintenance Cost	Resource Cost	Activity Cost Rate	Material Cost	Activity Cost	Total Cost	% Rejection	Cost with rejection accounted	CTI*IRR%
A	Compounding		120000	1	2	60	-	37.5	76.92	21.69	0.18	21.87	136.29	286000	8177.53	294178	-	294177.5	550.25
		Maturation1	120000	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-
B	Dipping & Curing		120000	3	10	24	-	37.5	76.92	42.94	0.61	43.55	157.97	-	3791.19	3791.2	0.5	3810.15	120.89
		Waiting1	118050	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
C	Tumble Drying		6000	-	3	24	-	43.75	76.92	4.95	0.04	4.98	125.65	-	3015.71	3015.7	-	3015.71	906.57
		Waiting 2	114000	-	-	-	168	-	-	-	-	-	-	-	-	-	-	-	-
D	Inspection		120000	1	30	8	-	76.13	76.92	0.55	0.04	0.59	153.64	-	1229.09	1229.1	4.5	1284.4	835.01
		Maturation 2	12000	-	-	-	168	-	-	-	-	-	-	-	-	-	-	-	-
E	Glove Washing		8000	1	3	15	-	62.5	76.92	4.57	0.04	4.60	144.02	-	2160.36	2160.4	-	2160.36	85.76
		Waiting 3	112000	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
F	Glove Drying		8000	-	4	75	-	37.5	76.92	3.81	0.04	3.84	118.26	-	8869.74	8869.7	-	8869.74	717.72
		Waiting 4	120000	-	-	-	72	-	-	-	-	-	-	-	-	-	-	-	-
G	Despatch		480000	-	3	288	-	43.75	76.92	-	-	-	120.67	-	34752.96	34753	-	34752.96	1494.92
H	Packing		120000	1	10	72	-	76.12	76.92	0.15	0.01	0.16	153.20	14500	11030.39	25530	-	25530.39	838.21
		Waiting 5	12000	-	-	-	72	-	-	-	-	-	-	-	-	-	-	-	-
I	Sterilization		88000	1	3	24	-	62.5	76.92	105.02	0.09	105.11	244.53	-	5868.82	5868.8	-	5868.82	141.85

6.4.7 CTI Calculation

The time and costs of waits in the processes as exported from the MSME Value tracker are given in the table 6.6.

Table 6.6 Time line Costs

	Process	Wait	Process	Wait	Process	Wait	Process	Wait	Process	Wait	Process	Wait	Process	Wait	Process	Wait	Process	Wait
Process	A		B		C		D		E		F		G		H		I	
Time (VA) in min	60		24		24		8		15		75		96		72		24	
Time (NVA) in min		0		0		0		0		0		0		0		0		0
Cost (VA) in Rs.	294,177.5		3,810.15		30,15.71		12,84.4		2,160.36		8,869.74		34,752.96		25,530.39		5,868.82	
Cost (NVA) in Rs.		550.25		120.89		906.56		835.00		85.763		717.71		1,494.92		838.20		141.84

Finally, all the direct, indirect and investment cost is accounted for calculating the actual production cost.

Table 6.7 Unit Production cost

Cost Time Investment (Rs.)	Utility Cost (Rs.)	Fixed Cost (Rs.)	Total Unit Cost (Rs.)
5,691.17	0.52	0.75	4.47968

6.5 VALIDATION OF VALUE TRACKER

Actual set of product data for a company was entered into MSME Value Tracker. Costs of 10 variants of products as obtained from MSME value tracker are shown in Table 6.8. The system was able to perform the following functions.

- Collection of all production related data from the production floor
- Time related data such as cycle time, waiting time, etc. can be recorded
- Cost related data can be recorded (Material, activity, etc.)
- Analysis can be carried out and a timeline and cost line can be drawn for each process
- A distance line is drawn to assess the efficiency of the production layout

Table 6.8 Cost comparison between CVSM and from accounting data

Product	Product Code	Lot Size	Cost (CVSM Analysis)	Cost as per Accounts	% Deviation
Powdered Long Cuff Palm size 7.5 inch	SG PD LC 7.5	120000	4.48	4.22	1.062
Powdered Long Cuff Palm size 8 inch	SG PD LC 8.0	119000	4.52	4.26	1.061
Powder Free Long Cuff Palm size 7.5 inch	SG PF LC 7.5	120000	4.78	4.51	1.060
Powder Free Long Cuff Palm size 8 inch	SG PF LC 8.0	119000	4.82	4.57	1.055
Powdered Short Cuff Palm size 7 inch	SG PD SC 7.0	122000	4.41	4.15	1.063
Powdered Short Cuff Palm size 7.5 inch	SG PD SC 7.5	120000	4.42	4.17	1.060
Powdered Short Cuff Palm size 8 inch	SG PD SC 8.0	119000	4.45	4.19	1.062
Powder Free Short Cuff Palm size 7 inch	SG PF SC 7.0	122000	4.74	4.39	1.080
Powder Free Short Cuff Palm size 7.5 inch	SG PF SC 7.5	120000	4.72	4.46	1.058
Powder Free Short Cuff Palm size 8 inch	SG PF SC 8.0	119000	4.76	4.49	1.060

By conducting the lean costing of the entire range of products coming under the production, the production cost determined based on CVSM analysis was very close to the value predicted by the accounting department, considering the cost of material, employees, infrastructure, utility and indirect overheads related to the production of each product.

6.6 CONCLUSION

Industries can use MSME value tracker to collect all production data and calculate the cost of production of each product manufactured in the facility. This costing can be used to identify nonvalue-adding activities. Measures can be taken for improving the processes. This tool can be used as an assessment tool for measuring leanness in a company producing different variants of products and to accurately identify the wastages during production. This becomes an efficient tool to predict the production wastage and to suggest a suitable remedial lean tool for resolving the issue.

The accuracy of this tool is validated by comparing the cost determined by the tool with the cost calculated using the conventional accounting methods. The accuracy of cost calculation is found to be varying in a consistent deviation range.

CHAPTER 7

RESULTS AND DISCUSSION

7.1 INTRODUCTION

The important contributions of this research work were the CVSM proposed for MSMEs for the adoption of lean manufacturing and an expert system for helping MSMEs assessing activities in terms of costs. The effectiveness of CVSM as a lean assessment and implantation tool and the analysis of the case studies are reported in this chapter. A post implementation survey was conducted among the team members who were involved in the lean analysis using CVSM in two MSMEs. The questionnaire prepared was to assess the effectiveness of this tool in implementing CVSM and to measure the ease with which this can be implemented.

7.2 RESULTS OF IMPLEMENTATION CASE STUDY 1

The CVSM methodology is implemented with the help of the selected team members from the company by integrating the Time measure involved in Value Stream Map and the cost accounting involved in the Cost Time Profile method. The most important support received was the commitment from the top management in implementing this tool in this company. The Top Management expressed their willingness to implement the CVSM model in their company as they were facing competition globally from the other competitors. The MSME-A had implemented 5S in their organisation and they sustain those practises regularly. All employees are trained in all machines so that the absenteeism will never affect their regular production anymore.

This company manufactures adjustable prop assembly as a support structure for civil construction. It consists of one outer pipe and an inner pipe with a lock nut assembly which locks the prop for different height requirements. CVSM analysis which combines the time and cost domain of production was conducted. With the help of CVSM, the cost investment for the outer pipe and inner pipe of the adjustable prop is Rs 1509.93 and Rs 1703.18 respectively, whereas the value-added costs are Rs 544.99 and Rs 479.66 respectively.

As per the modified method, cost of the outer pipe and inner pipe of the adjustable prop shows an increment of 2.7 times and 3.55 times than that of the conventional value-added cost. After applying the lean techniques for the various non-value -added activities in the order of their cost investment, future state CVSM can be made with nearly 27% reduction in lead time, 27-32%reduction in WIP inventory and 40-42% reduction in cost investment. All these savings are given in Table 7.1.

Table 7.1. Results of CVSM implementation in Prop Company

Variables	Current State CVSM		Future State CVSM		% Reduction	
	Outer Pipe	Inner Pipe	Outer Pipe	Inner Pipe	Outer Pipe	Inner Pipe
Value added Time (min)	14.59	16.77	12.14	14.03	16.79	16.33
Lead Time (days)	1.10	1.05	0.80	0.77	27.17	27.05
WIP inventory	332	316	242	212	27.10	32.91
Cost Investment (₹)	1509.9	1703.2	892.9	976.6	40.86	42.66
Value added Cost (₹)	545	479.7	544	478	0.17	0.32

This proposed Cost-Value Stream Map addresses the major non-value-added activities and their cost investment in an organization point towards the fact that the production process is carried out in a near perfect manner and it requires only a slight improvement but the huge loss which is reflected in the cost investment figure can be minimized by addressing the work in process inventory and the delay in the process.

7.3 RESULTS OF IMPLEMENTATION CASE STUDY 2

Cost Value Stream Map was implemented successfully to visualise the production stream in terms of both Time and Cost domain as envisioned during the design stage of CVSM. This method makes use of the advantages of both VSM and conventional CTP methods. The methodology of CVSM is demonstrated by conducting a case study in a surgical glove manufacturing unit. By constructing the current CVSM, the wastages in production in their order of importance and value were identified. Methods of reducing the manufacturing cost and manufacturing cycle time were proposed and detailed in the future CVSM. This proposed Cost-Value stream map helps in identifying the major non-value-added activities and their cost investment in an organization.

From the CVSM analysis we could identify certain areas where the resources were lost due to several reasons. The remedial measures were suggested and those were under implementation stage. The details of areas where remedial measures were suggested, the investment and the payback period are given as per the Table 7.2.

Table 7.2 Improvement measures suggested from lean analysis

Facility	Installation Cost (₹)	Annual Savings (₹)	Payback period (years)	Remarks
Walleting	2,60,00,000	72,00,000	3.6	3,00,000 gloves can be produced additionally / month
Sterilization	55,00,000	5,76,000	9.5	Transportation cost to Kochi unit is saved. Two extra truck loads per month.
New Boiler	32,00,000	18,00,000	1.78	Production volume is enhanced from the current value of 150000 to 175000
R/O Water Purifier Plant	15,00,000	7,20,000	2.08	Reduction in normal water charges due to recycling

CVSM gives a direct opportunity to identify wastes in the production line in terms of cost. This enables everyone, irrespective of their hierarchical position in the company, to quantify the wastages in production in cost terms. Identification of ‘muda’ and selection of the suitable lean tool to eliminate it is simplified by the implementation of CVSM.

7.4 RESULTS FROM DECISION SUPPORT SOFTWARE

The MSME value tracker was able to track all production data and calculate the cost of production of each selected product. These results are validated with the actual results available with the company for the accuracy of the tool in predicting the cost of a product. This becomes an efficient tool to predict the production wastage and suggest a suitable remedial lean tool for resolving the issue.

By conducting the lean costing of the entire range of products of a company the production cost determined based on CVSM analysis is pretty close to the value predicted by the accounting department, considering the cost of material, employees, infrastructure, utility and indirect overheads related to production of each product. The deviation of the predicted cost using CVSM tool seems to be accurate in predicting the cost of each product. This makes the method a valid tool in assessing the productivity of operations related to the production process. The results obtained by the software are given in table

7.5 SURVEY RESULTS OF CVSM IMPLEMENTATION

A survey was conducted among the implementation team of both the MSMEs. A questionnaire was circulated through Google Form and the responses were collected. The questionaaire has 5 questions on the effectiveness of the CVSM implementation framework and 5 questions of the implementation of CVSM in their organisations. A sample of the filled in questionnaire is given in Appendix. The analysis of the responses are summarisd in the subsequent sections.

7.6 CVSM PERFORMANCE

Four representatives of CVSM lean team,each from both MSMEs, were selected for collecting the responses of effectiveness of implementation. The variables of the questionnaire and mean responses of the respondents corresponding to the CVSM are shown in Table 7.3 and 7.4.

Table 7.3 - Mean response CVSM as a lean tool

Question Number	Variables on CVSM Implementation	Mean response from survey	
		MSME - A	MSME – B
1	Effectiveness of the CVSM	4.25	4.5
2	Enabling of Lean principles with CVSM	4.25	4
3	Extent to which the Lean principles are appended to the CVSM framework	4	4.25
4	Easiness for implementation of CVSM in MSMEs where 5S is already implemented	4.25	4.5
5	Role of CVSM in implementing Lean Principles in MSMEs	4	4.75

Table 7.4 - Mean response on test Implementation

Question Number	Variables on the documentation of the system based on LSIQMS	Mean response from survey	
		MSME - A	MSME – B
6	Extent to which CVSM framework identify the Cost Patterns	4	4.75
7	CVSM framework help in disseminating Lean Principles among employees	3.75	4.5
8	Perception on the CVSM implementation	4.5	4
9	CVSM framework help in adopting Lean Tools	4.5	4.75
10	CVSM framework help in suggesting Lean Tools for further improvement	4	4.5

Table 7.5 shows the data collection responses based from the survey for MSMEs A and B on the ten performance indicators .

Table 7.5.- Responses from the survey for MSMEs A and B.

Performance indicators	MSME – A				MSME - B			
1	4	4	5	4	4	4	5	5
2	5	4	5	3	3	4	5	4
3	4	4	4	4	4	4	4	5
4	4	5	5	5	4	4	5	4
5	4	4	4	4	5	5	5	5
6	5	4	4	3	4	5	5	5
7	4	4	3	4	4	4	5	5
8	5	5	5	3	4	4	4	4
9	5	4	5	4	4	5	5	5
10	4	4	4	5	4	5	5	4

The responses were then converted to point values corresponding to each performance indicator to determine the individual and overall average value to find out the effectiveness and impact of CVSM in the two MSME companies and are shown in Table 7.6.

Table 7.6 -Responses of two companies and the average

Performance indicators	MSME- A					MSME- B					Overall Average
	1	2	3	4	Average	5	6	7	8	Average	
1	4	4	5	4	4.25	4	4	5	5	4.5	4.375
2	5	4	5	3	4.25	3	4	5	4	4	4.125
3	4	4	4	4	4	4	4	4	5	4.25	4.125
4	4	5	5	5	4.25	4	4	5	4	4.5	4.375
5	4	4	4	4	4	5	5	5	5	4.75	4.375
6	5	4	4	3	4	4	5	5	5	4.75	4.375
7	4	4	3	4	3.75	4	4	5	5	4.5	4.125
8	5	5	5	3	4.5	4	4	4	4	4	4.25
9	5	4	5	4	4.5	4	5	5	5	4.75	4.625
10	4	4	4	5	4	4	5	5	4	4.5	4.25

7.7 CONCLUSION

This study enlightens all the stake holders of the company on different aspects of implementation of CVSM in MSMEs to achieve the overall improvement in productivity, customer satisfaction, increase in quality of product and reduction of production wastages in micro, small and medium enterprises. The cost aspect enables every employee to quantify the losses in terms of money spent on the product during production. This model is superior in its easy understandability and ease of interpretation even among the operators who are not well versed in conventional accounting practices.

CHAPTER 8

CONCLUSION

8.1 INTRODUCTION

Value Stream Mapping has widely been used as a lean tool for assessing the manufacturing activities and identifying the need for improvements. However, VSM could not assess costs associated with each of the manufacturing activities. Understanding the costs involved in the value-adding and non-value-adding activities in an organisation help to assess the activities and initiate measures for improving the activities. This is especially important for MSMEs, as the reduction of costs are very important for them to compete with the leaders in the market.

This research work was undertaken with the objective of designing and implementing a Lean assessment tool which can measure the production related resources in terms of cost and time in MSMEs. A lean assessment tool namely CVSM was designed by incorporating cost aspects into the conventional value stream mapping which is versatile in measuring the time associated with value addition activities during the production process.

An examination of the value stream mapping methodology was conducted for evaluating the level of effectiveness in measuring the production processes in terms of time and cost. Various modifications of VSM as proposed by researchers were reviewed. The limitations of assessing the production parameters were found out and a structure of a new tool, cost integrated value stream map, which can measure and visualise the production process in terms of both cost and time was proposed.

Finally, this newly developed CVSM model was test implemented in a manufacturing industry and a process industry and the evaluation was carried out.

The results of this implementation study revealed that CVSM can be adopted by any MSMEs for assessing the productivity and for using lean analysis for wastage reduction. CVSM tool enables everyone to understand the areas of improvement for wastage removal better and to have an upper edge compared to the interpretation of traditional accounting systems for productivity analysis.

8.2 RECOMMENDATIONS

Implementing CVSM in an MSME is a new approach that compares the conventional financial accounting system which gives the statements for analysing the profit of a company or losses associated with the production process. This normally takes more time to get to the crux of the problem as to what the real causes of production losses are. The CVSM methodology helps in identifying the production wastages after every analysis and easily pinpoints the area where we should focus to reduce the losses in production.

An improved method, namely the Cost Value Stream Map (CVSM), for addressing the implementation of lean manufacturing, is proposed in this work. This method makes use of the advantage of both VSM and the conventional CTP methods. The methodology of CVSM is demonstrated by conducting a case study in a hand-glove manufacturing unit. By constructing the current CVSM, the wastages in production in their order of importance and value were identified. The methods of reducing the manufacturing cost and manufacturing cycle time were proposed and detailed in the future CVSM. This proposed Cost-Value stream map helps to identify the major non-value-added activities and their cost investment in an organization.

CVSM gives a direct opportunity to identify wastes in the production line in terms of cost. This enables everyone, irrespective of their hierarchical position in the company, to quantify the wastages in production in cost terms. Identification of ‘muda’ and selection of the suitable lean tool to eliminate it is made easy by the implementation of CVSM.

8.3 RESEARCH CONTRIBUTIONS

This work accomplishes a new Lean Tool combining the positive features of both value stream mapping and cost time profile and thereby enables the analysis of production process in the Time as well as Cost Domain. CVSM is a new methodology to assess and analyze the production streamline of MSMEs. This Lean tool could be implemented in different Industries and the results can be used for further productivity improvement.

The following are the contributions of the research work:

1. Conducted a comprehensive study on the Lean Techniques applicable to MSMEs.
2. Studied the environment prevailing in MSMEs with respect to the implementation of Lean Principles.
3. Designed a new Lean Tool for facilitating the implementation of Lean Techniques in MSMEs
4. Studied the practicality of the designed model in the selected MSMEs
5. Drawn inferences from the implementation experiences using CVSM
6. Designed a smart decision-making tool to collect data and interpret the information regarding the productivity improvement.
7. Refined the model and an expert system for lean measurements was developed for data collection and analysis for multiple products.

This newly developed lean tool will provide a methodology to assess and implement productivity improvement of the MSMEs in India. The CVSM may be considered as a tool for improvement of the MSMEs in our country. It was evident from the literature review conducted and the responses received through the personal interviews in the case study that, at present the MSMEs in India are facing challenges in their manufacturing processes. The study could establish the necessity of this new system and its favourable acceptance in the selected MSMEs in their manufacturing process.

8.4 RESEARCH LIMITATIONS

The following were the limitations of implementing this tool in the selected MSME:

1. It is difficult to implement CVSM tool for products having many branches in their production line because the methodology follows the principle of value stream map.

2. The implementation of CVSM in a company with the involvement of employees was a major hurdle in our case study. Sparing the time of employees during their regular working hours for training and data collection was a difficult task. Convincing the top-level management about the benefits of this analysis was another challenging task for the researcher.

3. There are certain limitations found out at the implementation stage and those points are listed below:

   • The production process flow should be sequential as per the process layout

   • A single product is made at a time

   • The analysis is done taking data from a single batch of production. Because the production data like time of process or cost of material may vary from batch to batch.

   • The analysis is done under the assumption of maintaining the same workforce throughout the entire batch of production.

8.5 SCOPE FOR EXTENDING THE DOCTORAL WORK

The following are the scope for extending the research work further to gain benefits of the tools and methods utilised in this work.

1. The CVSM developed in this work may be applied to other sectors namely processes industries and continuous production processes.

2. Software package used for analysing the CVSM implementation in a company needs refinement in terms of data acquisition and interpretation for more clarity.

3. Several studies need to be conducted for refining the CVSM as a Lean assessment tool for productivity improvement in MSMEs.

8.6 CONCLUSION

The proposed model could be implemented in all the MSMEs as well as in the large manufacturing industries in their core business areas to meet the customer satisfaction with a better productivity perspective to the organisation in total.

The CVSM can be defined as an effective tool which can be applied for assessing the current condition and propose elimination measures for reducing the production wastages. This will help the company to produce more quality products, improve employee involvement towards the growth of the company and will help everyone to know every activity in the company for the future lean journey.

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LIST OF PUBLICATIONS

1. National Conference on Latest Trends in Mechanical Engineering, *Cost time profile as a lean methodology,* NCLTME-2017, 23-25 March 2017 Organized by Department of Mechanical Engineering, NSS College of Engineering, Palakkad

2. International Conference on Aerospace and Mechanical Engineering, ICAME'18, *Methodology for preparing a Cost-Value Stream Map,* Journal of Physics: Conference Series 1355 (2019) 012021 IOP Publishing

3. International Journal of Productivity and Quality Management, Vol. 30, No. 1, 2020, *Cost Value Stream Mapping as a Lean assessment tool in a Small-Scale Industry* (Scopus Indexed-Inderscience Journal)

4. South African Journal of Industrial Engineering, May 2021 Vol 32 (1), pp157-170, Cost Value-Stream Mapping as a Lean Assessment Tool In a Surgical Glove Manufacturing Company (SCI Indexed)

APPENDIX

POST IMPLEMENTATION QUESTIONNAIRE

PART A (Question on the CVSM Framework)

1. How effective is CVSM as an assessment tool for assessing the present cost patterns of the MSMEs? *

- ( ) Extremely Ineffective
- ( ) Ineffective
- ( ) Effective
- (•) Very Effective
- ( ) Extremely Effective

2. To what extent does CVSM enable to implement Lean principles in the company: *

- ( ) Extremely feeble
- ( ) Feeble
- ( ) Good Extend
- ( ) Exhaustive
- (•) Extremely Exhaustive

3. To what extent are the Lean principles appended to the CVSM framework? *

- [ ] Extremely feeble
- [ ] Feeble
- [ ] Good Extend
- [x] Exhaustive
- [ ] Extremely Exhaustive

4. In your opinion, how easy is the implementation of CVSM in industries where 5S is already implemented? *

- [ ] Extremely difficult
- [ ] Difficult
- [ ] Easy
- [x] Very Easy
- [ ] Extremely Easy

5. In your opinion, what role do you perceive for CVSM for implementing Lean Principles in MSMEs.? *

- ( ) Extremely feeble
- ( ) Feeble
- ( ) Good Extend
- (•) Exhaustive
- ( ) Extremely Exhaustive

PART B (IMPLEMENTATION RELATED)

6. To what extent did the CVSM framework identify the Cost Patterns in your organisation? *

- ( ) Extremely Feeble
- ( ) Feeble
- ( ) Good Extend
- ( ) Exhaustive
- (•) Extremely Exhaustive

7. To what extend did the CVSM framework help in disseminating Lean Principles among employees of your organisation? *

- ○ Extremely Feeble
- ○ Feeble
- ○ Good Extend
- ◉ Exhaustive
- ○ Extremely Exhaustive

8. What is your perception on the CVSM implementation in your organisation? *

- ○ Extremely Ineffective
- ○ Ineffective
- ○ Effective
- ○ Very Effective
- ◉ Extremely Effective

9. To what extend did the CVSM framework help in adopting Lean Tools in your organisation? *

- ◯ Extremely Ineffective
- ◯ Ineffective
- ◯ Effective
- ◉ Very Effective
- ◯ Extremely Effective

10. To what extend did the CVSM framework help in suggesting Lean Tools for further improvement in the organisation? *

- ◯ Extremely Ineffective
- ◯ Ineffective
- ◯ Effective
- ◉ Very Effective
- ◯ Extremely Effective

Lean Team

Official Details

Name of Company *

Sreerama Scaffoldings Pvt Ltd

Name of Official *

K. K. Babu

Designation *

Managing Director

Date *

MM DD YYYY

12 / 01 / 2020