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Implementation of a Lean Model for Carrying out Value Stream Mapping in a Manufacturing Industry

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ABSTRACT

Value Stream Mapping technique involves flowcharting the steps, activities, material flows, communications, and other process elements that are involved with a process or transformation. In this respect, Value stream mapping helps an organization to identify the non-value-adding elements in a targeted process and brings a product or a group of products that use the same resources through the main flows, from raw material to the arms of customers. In this study, a practical study carried out in a manufacturing industry for the manufacture of Machining center is discussed. The main aim was to draw the current state value stream mapping for the main components like Base, Column, Cross Slide, Milling Head and Table. Further, the paper has identified some of the processes which can be carried out by the sub contractor and suggested measures to be taken up by the higher level management in reducing the non value added process. It discusses the reduction in the set up time and cycle time that can be obtained through the implementation. This paper also discusses the plan of action for improving the Future State Value Stream Mapping (FVSM). A FVSM for the manufacture of Base is drawn.

***Keywords*:** Current state value stream mapping (CVSM), Future state value stream mapping (FVSM), Value added time.

1. INTRODUCTION

The research study was carried out in a CNC manufacturing unit located in Bangalore, which manufactures cylinder heads, cylinder blocks, crank case crank shaft, connecting rod etc, to the Automobile, Textile, Defense, Agricultural, Railway and Electrical sectors. They are also the manufacturers of Special Purpose Machines. The study discusses the implementation of Value Stream Mapping carried out in the CNC machining center division of the industry. The main aim was to reduce the cycle time and to eliminate unwanted facilities and suggest improvement measures from the lean manufacturing perspective. Hence, the research work focuses on mapping the current state, reducing the cycle time and the setup time and suggests a future state value stream mapping for the manufacture of a machining center.

The objectives for the implementation of the lean manufacturing tools in this industry are

- To study the Current State Value Stream Mapping by collecting the preliminary data.

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- To identify the problems faced by the Industry in terms of Non Value Added time

- To propose Future State Value Stream Mapping which can increase the Value added time and reduce non value added time.

2. LITERATURE SURVEY

Taiichi Ohno (1988), Womack et al (1990), Womack and Jones (1998, 2005), Daniel. T. Jones (2006), Rother and Shook (1999), and Peter Hines and Nick Rich (1997) have studied the implementation of Value Stream Mapping effectively.

In essence, Value Stream Mapping (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process. Waste being any activity that does not add value to the final product, often used to demonstrate and decrease the amount of ‘waste’ in a manufacturing system. VSM can thus serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes. As a result, Value Stream Mapping is primarily a communication tool, but is also used as a strategic planning tool, and a change management tool. Toyota have been benefiting since 1940’s, from Material and Information Flow Mapping (Value stream mapping).

Taiichi Ohno (1988) could not see waste at a glance (especially across a geographical area). He developed Material and Information Flow Mapping (VSM) as a standard method for mapping the flows visually and it became the standard basis for designing improvements at Toyota - as a common language. It became one of their business planning tools. VSM is now utilized throughout the world, in many businesses to strategically plan and it is the starting point to any lean transformation and implementation.

Womack and Jones (1998) and Moore (2006) have stated that, the organizations of many types are implementing lean manufacturing, or lean production, practices to respond to competitive challenges. They have mentioned that lean initiatives can be taken up in the fields of automotive sector, aerospace, and consumer goods industries around the world. Moore has discussed various implementation tools of Lean Manufacturing, which can be incorporated in the industries.

Rother and Shook (1999) have discussed that Value Stream Mapping (VSM) is used to define and analyze the current state for a product value stream and design a future state focused on reducing waste, improving lead-time, and improving workflow. The use of VSM appears to be increasing, particularly since the publication of “learning to see” by Rother and Shook (1999). One of the unique characteristics of VSM in comparison with other process analysis techniques is that one map depicts both material and information flow that controls the material flow. The focus of VSM is on a product “value stream” (all actions required to transform raw materials into a finished product) for a given “product family” -- products that follow the same overall production steps.

Doolen et al (2002) have extended the applications of lean production techniques in the electronics manufacturing perspectives. Hyer (2002) has implemented Lean manufacturing in the office service and administrative processes.

Badrinarayana and Sharma (2007) discusses that the interdependent components form the value stream and Value Stream is the set of all *specific actions* required to bring out a *specific product*.

In order to attain noteworthy improvements the Zayko, et.al (1997) have decided to use value stream mapping to visualize the entire flow and select lean tools that yielded maximum benefits.

Hines and Rich (1997) has opined that, the value stream is "the specific activities within a supply chain required to design order and provide a specific product or value".

Simchi-Levi et al (2004) are of the opinion that the customers are always concerned with their order status, and sometimes they value the order status more than a reduced lead time. But, McDonald et.al (2002) point out that the VSM creates a common language for production process, thus facilitating more thoughtful decisions to improve the value stream. This will effectively reduce the wastes and improves the productivity. While researchers and practitioners have developed a number of tools to investigate individual firms and supply chains, most of these tools fall short in linking and visualizing the nature of the material and information flow in an individual company. McDonald et.al (2002) have used simulation techniques for the high-performance motion control products manufacturing system to demonstrate that, simulation can be a very crucial tool in assessing different future state maps. They demonstrate that simulation can provide and examine different scenarios to complement those obtained from future state mapping.

The value stream mapping was extended in the field of aircraft manufacturing also. Abbett and Payne (1999) have discussed the application of value stream mapping in an aircraft manufacturing unit. They have developed the current and future state maps with the objective of reducing lead-time according to customer's requirements.

New (1993), and Jones et.al (1997) and other researchers developed individual tools to understand the value stream. VSM extends guidance for improvements in the process, identifies the need to improve workflow and finally shows avenues to reduce waste.

Shingo (1989) has discussed the strategies for the effective implementation of Value Stream Mapping in a wood industry. He also opines that loops can be formed to identify the similar processes and these loops will be helpful in identifying the non value activities in a systematic manner. He has suggested the ways to eliminate non value added activity and proposed measures to increase the Value added ratio.

Yang-Hua and Valandeghem (2002) describe, Value stream mapping as a mapping tool that is used to describe supply chain networks. It maps not only material flows but also information flows that signal and control the material flows. The material flow path of the product is traced back from the final operation in its routing to the storage location for raw material. This visual representation facilitates the process of lean implementation by helping to identify the value-added steps in a value stream, and eliminating the non-value added steps / waste (muda).

Often, key questions in examining these types of processes are: what is the value-added ratio of these supporting processes to the organization? Should the current plans of manufacturing should remain internal or has to be outsourced? All these discussions have prompted the authors to carry out VSM as a useful tool to explore additional redesign opportunities, set targets and to propose for the future performance levels.

This prompted the authors to study the processes of manufacture of machining centers and have drawn CVSM for all the processes (I objective) and carried out brain storming sessions with the managers and engineers concerned to arrive at FVSM and have suggested action plans to be taken to effectively implement FVSM.

3. A MODEL PLAN FOR THIS STUDY

A model plan was arrived at after the detailed discussions with the management. As the industry was manufacturing many products, it was proposed to carry out a case study in the CNC vertical machining center division. A model for carrying out Value stream mapping in this industry was devised. The model proposed for the implementation of VSM is shown in the Figure 1. The model proposed is applicable for any Medium Scale Industries in India. The plan starts with problem statement and discusses the issues relating to the commitment from the management. A detailed plan is discussed herewith for the implementation in the phased manner. However, the paper discusses the issues relating to CVSM and FVSM for the manufacture of machining center.

Figure 1. Implementation model for the Value Stream Mapping in a Medium Scale Industry

The model parameters to be considered during the implementation are,

Problem Statement- The main aim is to identify the problems prevailing and to fill the gap in order to establish lean compliancy.

Management Commitment- This is an important step for lean implementation initiative. The management has not only to be committed but also should be willing to implement change.

Current State Data collection- This is an important step in VSM analysis. The data is collected while walking along the actual pathways of material and information flow. The data collection begins at the shipping end and work towards the upstream. Data has to be collected using the stopwatch and should personally collect the data of cycle time and change over time for the process of manufacture. Hence, as per the requirements, the appropriate data has to be collected. The analysis of the current data collection is based on the bottle necks observed in the process of manufacture.

Lean Implementation teams – The team should have managers, engineers and workers, who are multi skilled, should be ready to accept the changes which the proposals suggest. This plays an important step in the lean tool implementation. A survey with interviews has to be carried out.

Lean Tool Box- A detailed knowledge on the implementation and the use of Lean Manufacturing tools like Kanban, Value Stream Mapping, One piece flow, Pareto diagram, Cause & effect Diagrams, Why-Why analysis, PQ analysis, Total Productive Maintenance, Total Quality Management etc are required. However, in this case, an attempt has to be made in mapping the Current and future Value Stream Mapping.

Select appropriate Lean Tool- Once the data is collected, depending on the problems and the gaps prevailing in the manufacturing activity, an appropriate lean tool need to be applied. This is based on the customer's requirements in the downstream.

Establish desired state – the desired state is based on the objectives set by the management.

Formulate the tool as per the organization's culture & requirements- This is the most critical step for effective implementation in any medium scale industry from the Indian context. The medium scale Industries in India as a policy stated by Government of India are intended for high contribution to domestic production, significant export earnings, low investment requirements, operational flexibility, location wise mobility, low intensive imports, capacities to develop appropriate indigenous technology, import substitution, contribution towards defense production, competitiveness in domestic and export markets. But, the limitations the medium scale Industries face are low Capital base, concentration of functions in one / two persons, inadequate exposure to international environment, inability to face impact of World Trade Organization (WTO) regime, inadequate contribution towards R & D and lack of professionalism. Further, these companies face problems of cultural factors in their implementation initiatives as many medium scale industries are launched in regional belts with cultural barriers. Further, the training initiatives form one of the core need areas in the implementation.

Validate with test runs – The model has to be validated by carrying out test runs before launching the proposal on a full scale.

Finalize blue print for the implementation – use flow chart, Supplier- Input-Process-Output-Customer (SIPOC) system of implementation, Value Stream Mapping, Kaizen etc. In this study, the research scholar has planned to propose a future state value stream mapping.

Train all the employees/ employers concerned with the implementation plan. This is the most crucial step, as the workers should cultivate the lean thinking. It is proposed to the management to carry out training program for the effective implementation.

Launch & Monitor This is the final step in the work.

4. CASE STUDY – CURRENT STATE VALUE STREAM MAPPING

Rother and Shook (1999) has discussed that, mapping helps to see the sources of waste in the value stream. The reward of VSM is the elimination of large amounts of wastes in the organization. The extended value stream mapping includes suppliers and customers in their decision to suggesting Future State Value Stream Map.

Further, many research scholars opine that it is possible to identify and eliminate waste and they opine that the problems faced by every industry is case specific. In this connection, it was felt that the machining center section in this industry was having some non value added processes, which can be avoided. Hence, as per the model suggested, the study was carried out. Further, Value Stream Mapping (VSM) is a visual tool that integrates material flow and information flow into a critical path chart to understand the relationships and importance of all Value Added and Non-value Added actions. This methodology enables the team to prioritize projects for a systematic Lean approach.

It was observed that BMV 45 Vertical Milling Center was one of the popular machines manufactured by the industry. It was felt that there was enough scope to carry out value stream mapping in this section. It was decided to carry out VSM analysis for the manufacture of Machine Base, V- Column, Cross-Slide, Table and Milling Head.

The study involved in identifying a team consisting of a representative from TQM dept, a lean consultant, engineers and workers were involved in carrying out the study. The data required for plotting the Current State Value Stream Mapping (CVSM) was collected.

Further, the following procedure was adopted to draw the Current State Map.

- Identification and drawing the product flow from the raw-material entry point of the manufacturing division (MFD) to the finished goods exit point of the MFD.

- Calculating the number of Work-in-process (WIP) for each component at each work cell.

- Calculating the cycle time set up time and utilization percentage of each process

- Plotting the Current State Value Stream Map based on the data collected

4.1. Data Collection and Study of the Process

The data regarding the cycle time, setup time was calculated for the manufacture of BMV 45 Machining. Further, the details regarding the various processes involved in the manufacture was noted down. It was observed that the flow of the process of manufacture was fettling Yard, Fettling, Priming, Roughing, Finish Machining, Fitting, inspection, putty, drying, polishing and painting. Hence, the cycle time, set up time and the details regarding the speed of the spindle ,feed rate, WIP quantity required, WIP others, distance to be traveled, utilization in percentage, Number of shifts

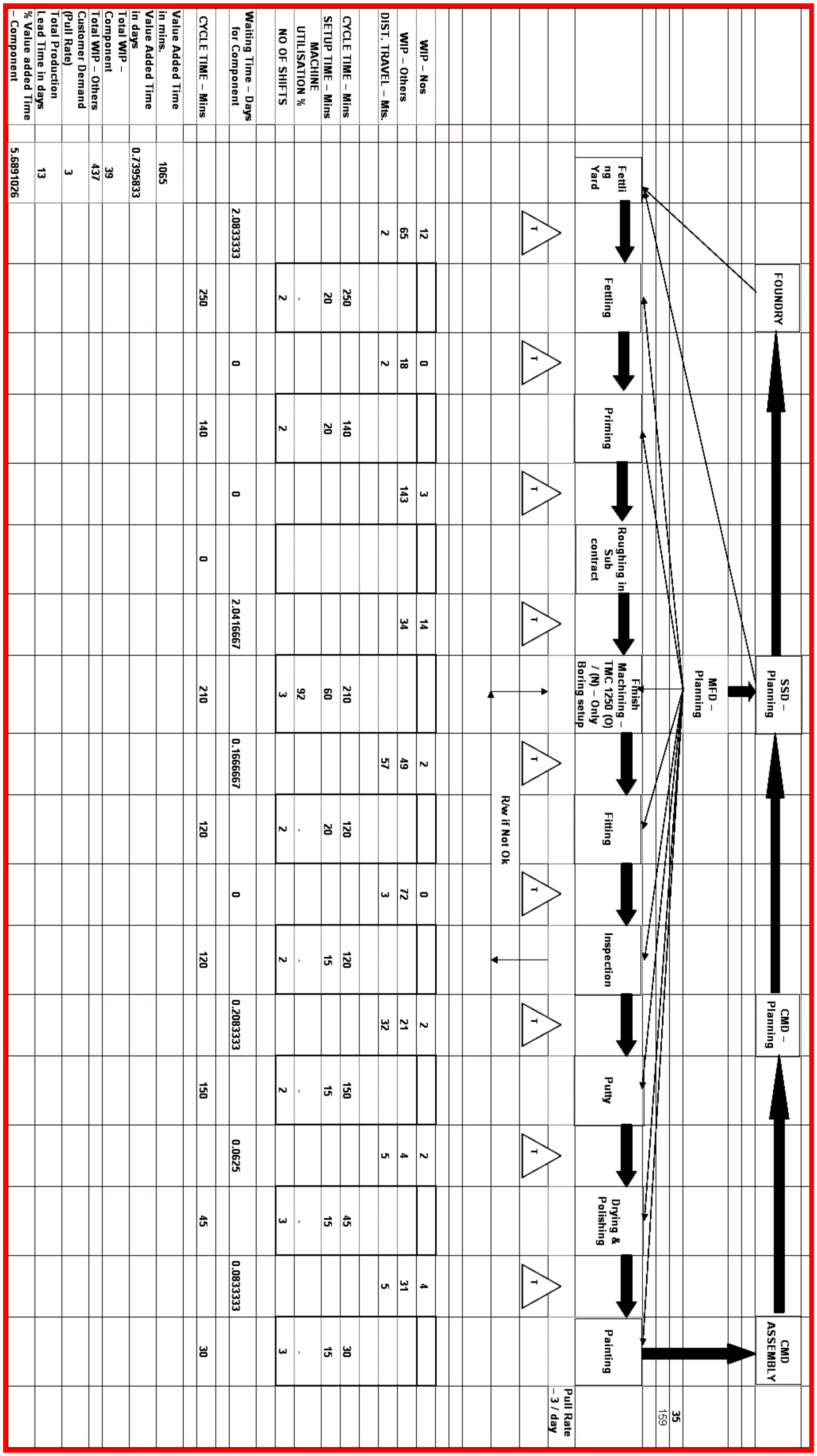

Figure 2. CVSM for the Base of the Machining Center

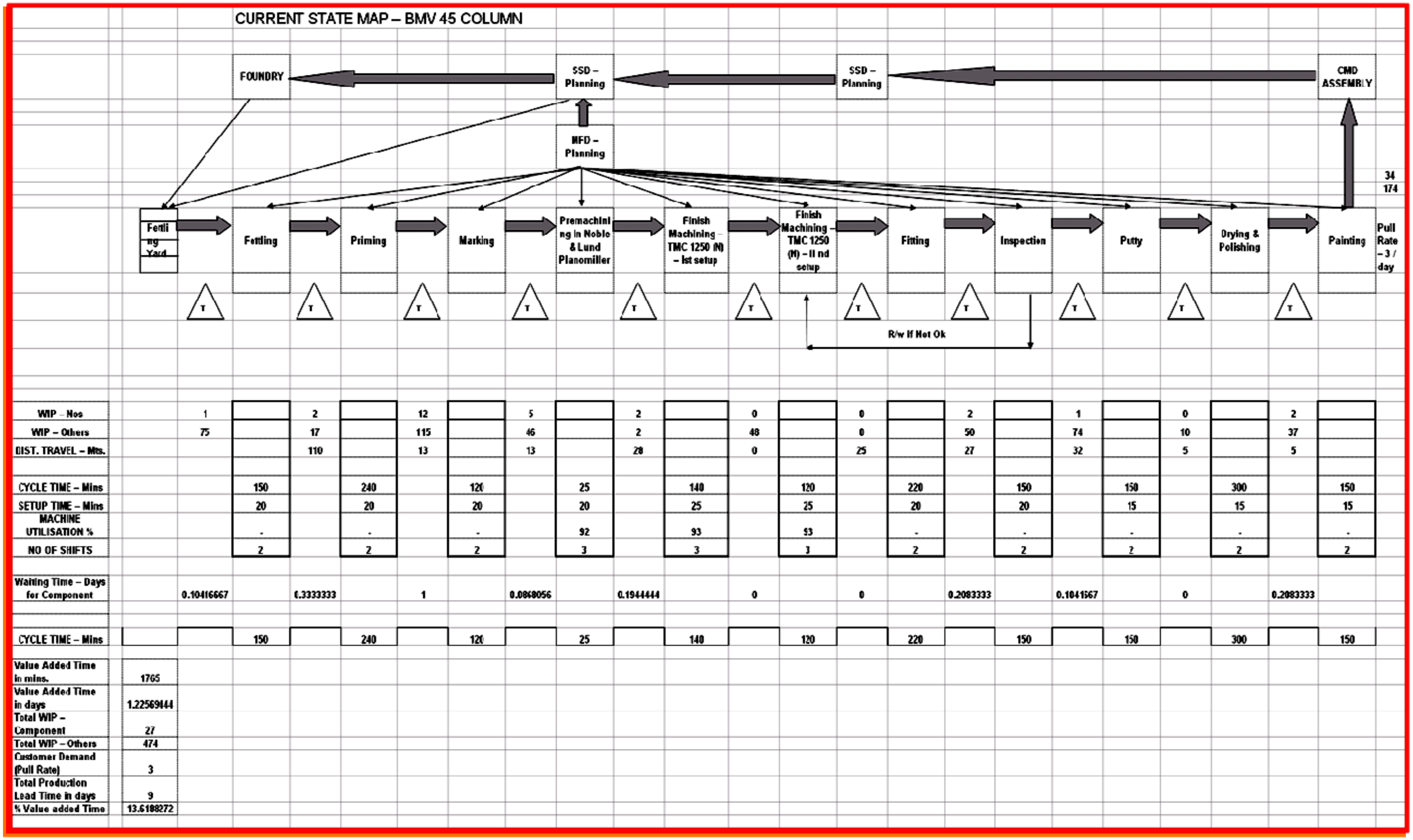

Figure 3. CVSM Diagram for the Column of the Machining Center

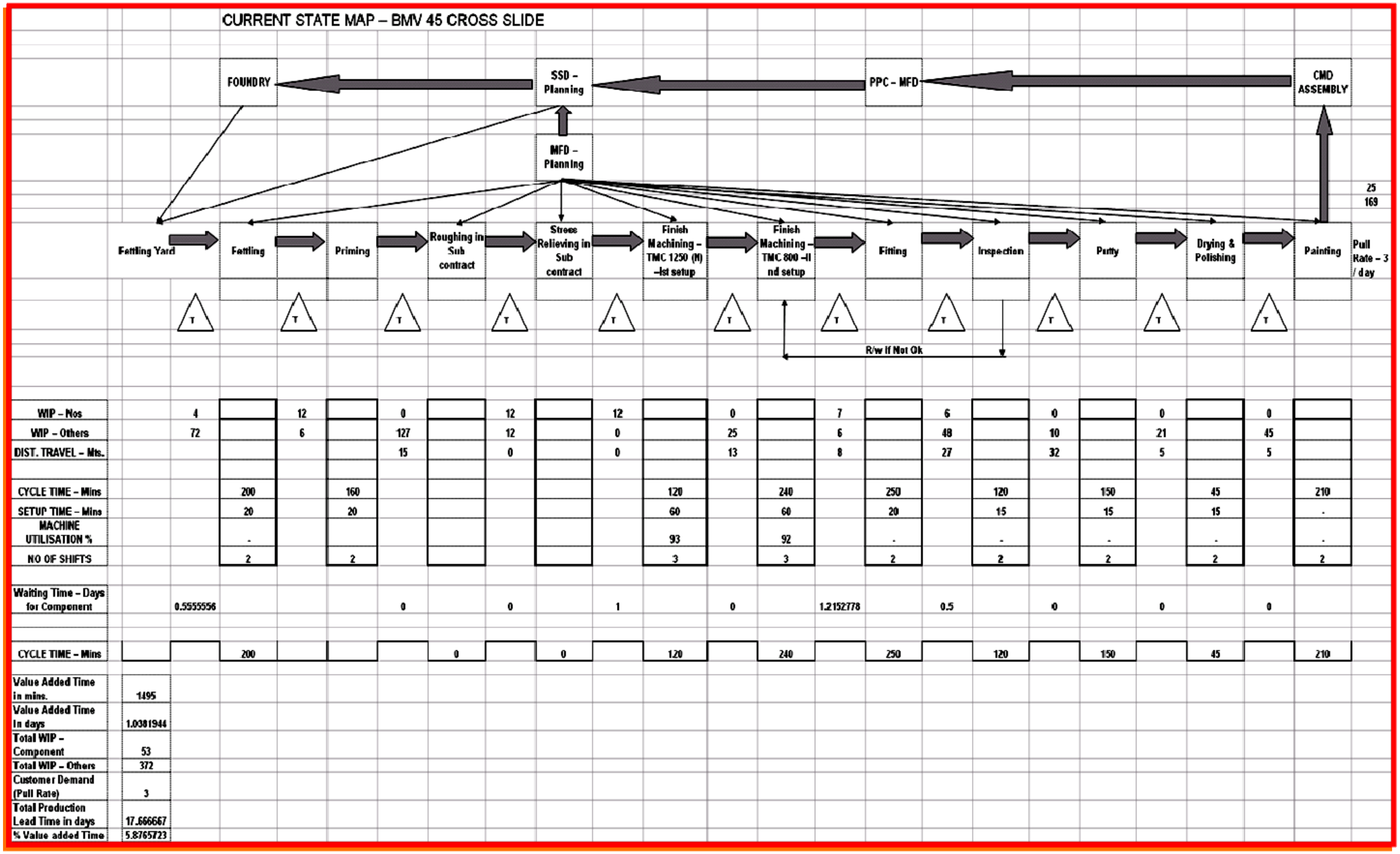

Figure 4. VSM Diagram for the Cross Slide of the Machining Center

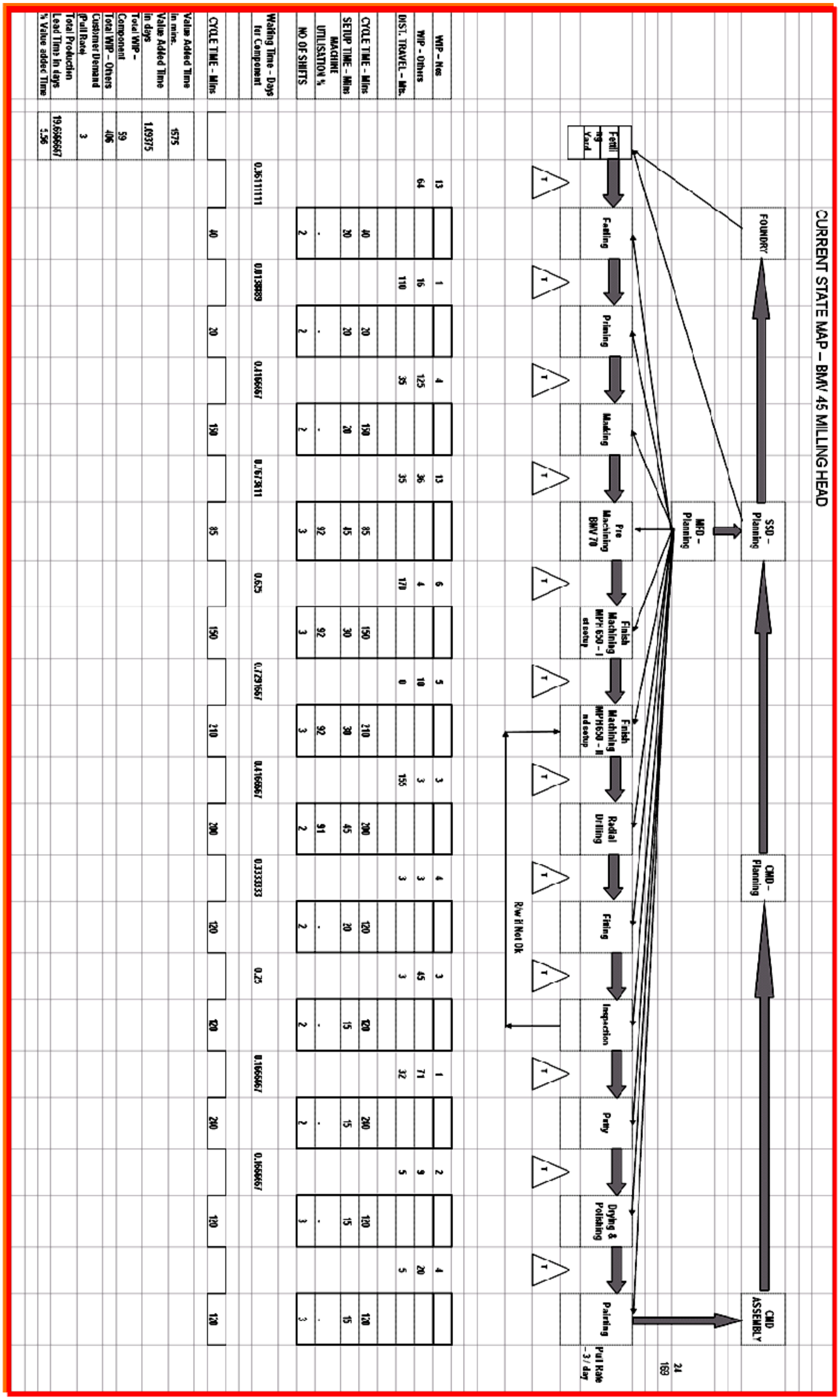

Figure 5. VSM Diagram for the Milling Head of the Machining Center

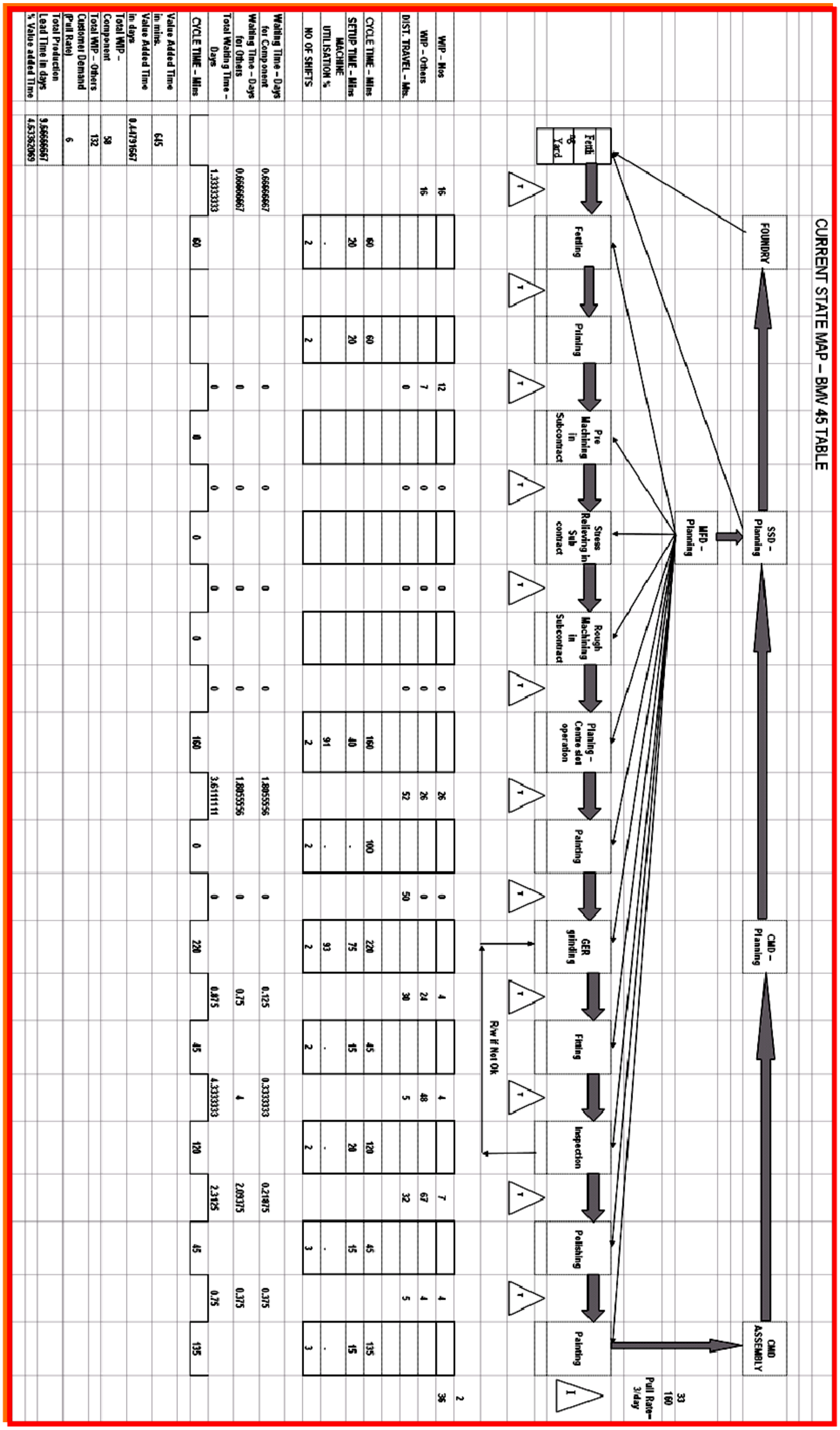

Figure 6. VSM Diagram for the Table of the Machining Center

were noted down. Finally, a current state value stream map was drawn for the manufacture of Base, Column, Cross slide, Milling head and Table of the Machining center and is shown in the Figures 2, 3, 4, 5 and 6 respectively. It is to be noted that these data have been entered directly in the Value Stream Map drawn.

4.2. Analysis of Current State Value Stream Mapping

The Value stream mapping of the components namely Base, Column, Cross Slide, Milling Head and the Table required for the manufacturing and the assembly of BMV 45 Machining center showed the following value added time, set up time and other details. The details of the activity are shown in the Table 1.

Table 1. Analysis of Value Added Time for the manufacture of Machining Center

Details of Activity	Base	Column	Cross Slide	Milling Head	Table
Value Added (Cycle time) Time in Mins	1065	1765	1495	1575	645
Set up Time in Mins	180	215	225	290	220
Total WIP Component in tons	39	27	53	59	58
Total WIP Others in tons	437	474	372	406	132
Customer Demand in days	3	3	3	3	6
Total Production Lead Time in days	13	9	17.67	19.67	9.67
Percentage Value added Time	5.69	13.62	5.88	5.56	4.63

It was observed that the percentage value added time ranged from 4.63 to 13.62 %. It was also observed that the overall setup time was ranging from 180 mins to 290 minutes. In addition, there was a need to look into the production lead time. The lead time was ranging from 9 days to 19.67 days. It was also observed that WIP of others was as high as 474 tons, which was leading to higher working capital and the buffer stock issues. These were observed as the wastes attributing to the decrease in the value added time.

These scenarios provided the authors an opportunity to propose a lean manufacturing tool to improve the value added time. In this direction, it was decided to carry out discussions with the mangers, engineers and workers and the issues relating to the increase in value added time were pointed out. Further, the authors used the questionnaires and collected the data regarding the awareness, knowledge and implementation difficulties faced by the employees and the management in its effective implementation. Finally, based on the feedbacks collected, it was decided to suggest the following lacuna in the process of manufacture and suggested remedial measures for the same. Finally, a future state value stream map was proposed to be implemented.

4.3. Analysis for the Future State Value Stream Mapping

It was observed that processes like Fettling, Marking, Pre-machining can be eliminated / reduced by improving the quality of castings at the supplier level. The industry took up this issue seriously and requested the higher level management to implement as early as possible. It was felt that, follow up measures are required in the incoming inspection section. This would reduce the set up time and cycle time considerably and would increase the value added ratio. The plan of action for improving the Future State Value Stream Mapping (FVSM) were,

- To develop a new layout, where the line flow of the components was possible. This makes the inspection and quality control tasks much easier.

- To carry out online inspection and scrap reduction programs.

- To implement Kanban systems for the effective material and process control. It was suggested to implement a pull type Kanban system to reap the benefits.

- To review the work sequence in order to reduce idle time and

- To Identify value added versus non value added elements and minimize / eliminate non value added operations

4.4. Proposal for the Future State Value Stream Mapping

It was proposed to suggest the following steps to be taken to implement a Future State Value Stream Map (FVSM). In this connection, the research scholar decided to provide suggestions based on standard nine types of wastes of lean manufacturing as proposed by Womack [2] and others. It was observed from the literature survey that the non value adding activity is the activity, which is performed by the workers, will not add value to the product. These activities are considered as wastes. Lean manufacturing tools will strive in eliminating these activities and in turn eliminate the wastes in the manufacturing process.

FVSM for the manufacture of the parts of the machining center were drawn, however, a Sample proposed FVSM for the manufacture of Base is shown in the Fig 7. Since, these steps have to be taken up in the phased manner, the proposed FVSM has indicated the processes that can be avoided to reap the benefits of value added time and reduce the non value added time (marked in red lines and texts).

Hence, the following steps were suggested for the improvement of the process of manufacture. Table 2 shows the detail of CVSM, cause, effect and the improvement measures to be undertaken for improving the Future Value Stream.

Hence, in summary, the following suggestions were proposed for FVSM implementation

- Use of Special Dial stand for the alignment of component in Y and Z axis on alternate pallet, which can reduce the set up during the machining of Loading Palette. The reduction in the dialling time is estimated at 10 mins/ piece (40 components per month). Therefore, Total setting time saved / month =10 * 40 = 400 mins. Hence, Estimated Saving / month = 400 /60 = 6.67 Hours/month (i.e., 30 days x 2 shifts = 60 shifts per month).

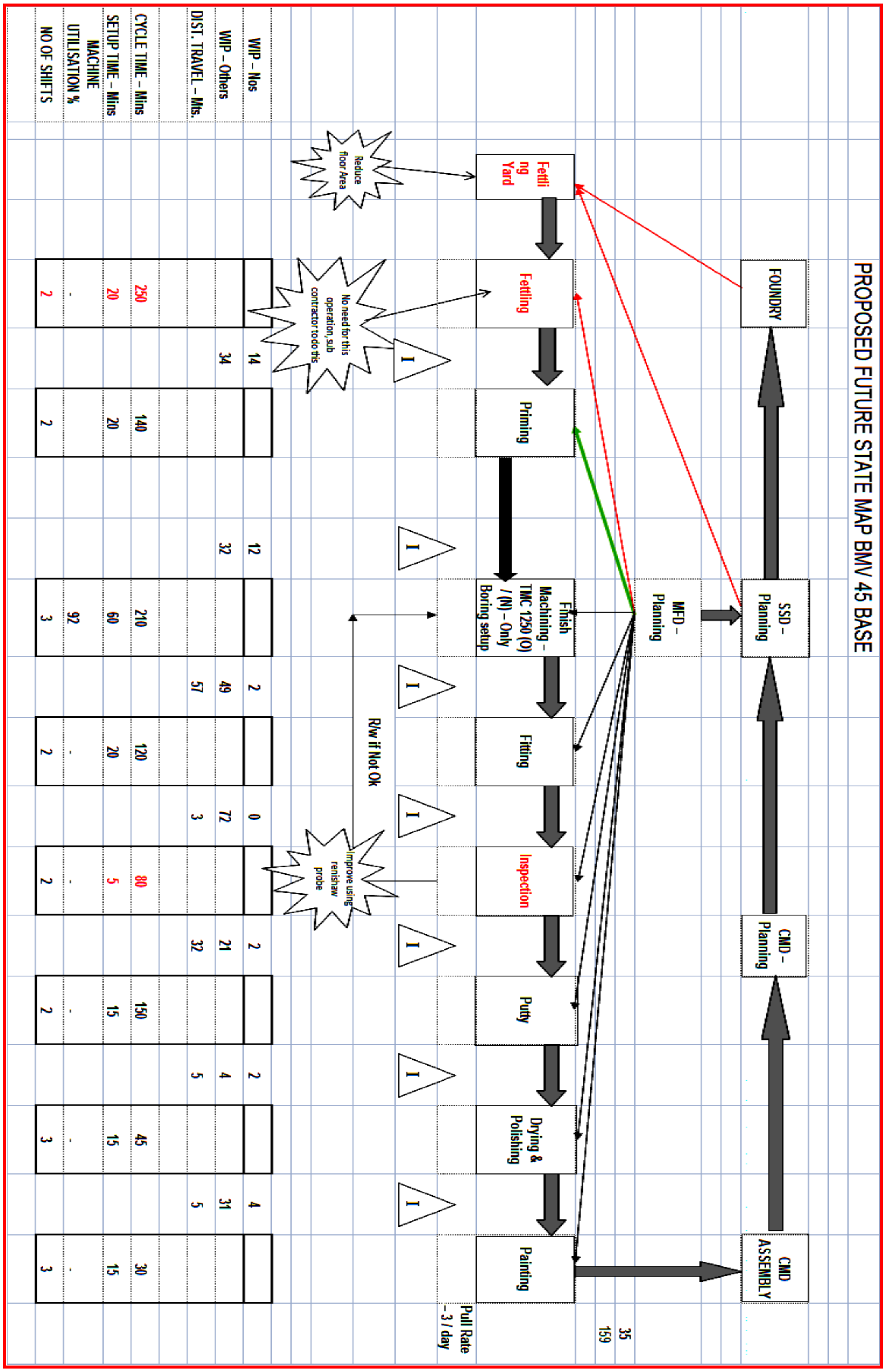

Figure 7. Future State Value Stream Mapping for the manufacture of BMV 45 B

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Table 2. Nine types of waste and the proposal for future state value stream mapping

Type of Waste	**CVSM**	**Cause**	**Effect**	**FVSM**
Unnecessary/ Excessive Human motion	Movement of the workers between the processes and other additional movements.	Layout, location and procedural issues	Leads to fatigue (Muri. and Mura)	Layout planning was not taken up in this case research work. However, use of Special Dial stand for the alignment of component in Y and Z axis on alternate pallet will reduce the worker movements and also reduces the set up time
Conveyance of the Material	The conveyance material using material handling equipments	Layout, location and logistics	Integrity of material and care	It cannot be avoided. But, use the pull system approach to reduce this effect
Over-production	Not seen	Strategic, capacity balancing	More storage space. Preservation requirements	No change seen in CVSM and FVSM approaches
Inventory	Shop floor Work in process inventory with buffer stock	Lead time	Space requirements	Apply JIT principles to reduce lead time and to reduce the space requirements
Over processing or inappropriate processing	Information flow	Manual system	Extra time on NVA	Modify the policy decision as regards to the purchasing procedures. Attach responsibility to the sub contractors for the supply of right quality products to the buyers' premises.
Spillage/ Rework/ Salvage	Issues were less	Could be caused due to the mishandling of machines by the employees	It could lead to unclean environment and wastages	To control the rework, online inspection using Reni Shaw probe is suggested.
Space	Issues not taken up	Could be caused due to improper Layout and machinery location	More material movements, more time and controls required	Apply the cellular / one piece lean line design concept if necessary in the later stages
Waiting	Between processes and at interim locations.	Layout, location and balancing.	More space required for materials and spoilages	Apply line balancing to reduce the wait time
Talent utilization	Need for additional training	Quality of the product and other issues related to the expertise level of the worker	Leading to the isolation in the work culture and the work becomes monotonous	Extend good lean related training and explore multi skilled avenues.

• Use of Reni Shaw probe for work offset measurement can help in eliminating the need for expensive fixtures and manual setting with dial indicators. This will reduce the machine downtime and eliminate manual setting errors and can save 5 minutes /piece / setup. Therefore, Estimated Saving / month = 5 * 40 Components = 200 mins/month**.** Further, turret mounted probes can be used for the in-cycle gauging and part measurement with automatic offset correction. Proposed to carry out online inspection.

• Cycle time can be reduced considerably with the effective use of tools in the magazine of Machining Center. The policy decision regarding extending responsibilities to the sub contractors for the supply of quality products will reduce the need to supply the material from fettling yard to the Fettling station and carrying out Fettling, Marking, Pre-machining operations. This implementation resulted in the reduction of cycle time to the extent of 1080 mins. As shown in the Table 6.3. In summary, the stoppage of bringing the material from fettling yard has reduced the cycle time of 250 mins, 150 mins, 200 mins, 40 mins and 60 mins in the manufacture of Base, Colum, Cross Slide, Milling Head and Table respectively. Further, the marking operation has resulted in 120 mins of savings in time. The stoppage of pre machining process has resulted in the reduction of cycle time to the extent of 110 mins as shown in the Table 3.

Table 3. Reductions in cycle time after the implementation of FVSM

Reduction in Cycle Time in Mins.	**Base**	**Column**	**Cross Slide**	**Milling Head**	**Table**
Fettling	250	150	200	40	60
Marking		120		150	
Pre Machining		25		85	

5. CONCLUSIONS

It was observed that, due to enormous potential in the lean manufacturing tools, value stream mapping study was carried out in a medium scale industry for the manufacture of machining center. It was observed from CVSM that the value added time was less. Hence, the study was carried out in the manufacture of Base, Column, Cross Slide, Milling Head and Table and various parameters like cycle time, set up time, WIP were recorded. By carrying out interviews with the managers, engineers and workers, the authors have proposed measures to reduce cycle time and improve the process of manufacture. A CVSM was drawn for all the processes as it was one of the main objectives of this study and identified the reasons for increase in cycle & set up time. The authors have suggested FVSM for improving the value added time by reducing the cycle time and the set up time. Finally, the reductions in the cycle time after the implementation is estimated and proposed.

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