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Energy Value Stream Mapping a Tool to develop Green Manufacturing

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Abstract-

Value stream mapping is an effective tool of lean manufacturing to reduce the wastage in any process by segregating value added and non-value added activities. The present work uses the concept of value stream mapping and developed energy value stream mapping to address the non productive energy consuming processes. This paper focuses on achieving Green Manufacturing as overall productivity which has already reached an acceptable value. The main problem identified is that there is a void when it has been looked for a tool to achieve Lean Manufacturing along with Green manufacturing. It deals with the development of a method that allows a first quick, easy and comprehensive analysis of energy and material flows within the production processes. The paper concludes with discussing improvements in the processes.

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Keywords: VSM, EVSM, Energy consumption, Lean Manufacturing, Small scale industry.

1. Introduction

Manufacturing is a leading energy consumer of the world along with being the aspects for prosperity. With rise for the environmental concerns countries are being pressurized to make their industries energy efficient. This has made researcher to analyze means and methods to develop energy efficient machine or reduce the energy consumption in existing methods. Improvement in existing setup can be made by eliminating the processes which consumes energy and replace them with energy efficient and less costly methods. In recent, studies have been made towards achieving lean and green manufacturing which minimize wastes. Lean techniques are focused on reducing lead time and eliminating wastes in all kinds of forms. Green Manufacturing is a method for manufacturing that minimizes waste and pollution. Its emphasis on reducing parts, rationalizing materials, and reusing components, to help make products more efficient to build. Green Manufacturing involves not just the use of environmental design of products, use of environmentally friendly raw materials, but also eco-friendly packing, distribution, and destruction or reuse after the lifetime of the product. Authors in the present work have focused on using value stream mapping (VSM), a tool of lean manufacturing, and used it in reducing energy and making the process energy efficient.

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2. Literature Review

A VSM classifies all the processes into value adding and non-value adding ones. The ultimate goal of VSM is to identify all types of waste (non-value added) in the value stream and to take steps to eliminate them.

Authors (Fawaz & Rajgopal, 2007) state VSM as one of the best tool for Lean Manufacturing. The authors in their work have summarized the calculation of energy as value adding and non-value adding energy to optimize value streams in a more holistic way.

(Murugananthan, et al., 2014) This paper details with the use of the VSM in reducing waste in manufacturing company. The production process path is visualized by mapping the current state value stream mapping .After tracking the entire process, wastage affecting the cycle time has been identified and its causes are analyzed. A future state value stream mapping is developed and improvement ideas are suggested. Value stream mapping is proved as a useful technique to minimize the cycle time and increase the productivity.

The paper (Solding & Gullander, 2009) presents concept using simulation for creating dynamic VSM. Creating dynamic value stream maps makes it possible to analyze more complex system than traditional VSMs are able to and still visualize the result in a language the lean coordinator recognize. The value stream mapping is presented in a spread sheet that can be altered in the way the teams want.

The authors (Fawaz & Rajgopal, 2007) identify that Lean Manufacturing is applied more frequently in discreet manufacturing rather than in the continuous/process sector and they formulate a simulation model which showed the difference between the past and present scenario clearly which is acceptable to the managers who until now are skeptical about the application of lean methods in continuous/process manufacturing.

(Egon, et al., 2014), describe a method to extend VSM to an energy value stream mapping method (EVSM) by maintaining its original character and its inner logic. Also, this paper includes the time and energy input during the transportation processes into the EVSM. This paper goes on to show the application of EVSM in Supply Chain Management to reduce the Energy footprint on a global level. Inclusion of transport into EVSM not only shows the lead time extending effect but also its non-value adding energy consumption.

(Keskin, et al., 2013), in their paper suggest a future oriented energy value stream mapping approach that aims to improve energy efficiency in small and medium sized manufacturing companies.

(Tyagi, et al., 2015), in their paper introduces the concept of VSM to the product development process (PDP) stresses on the importance of faster product development for the right edge on the market. The main focus of this article is to exploit lean thinking concepts in order to manage, improve and develop the product faster while improving or at least maintaining the leve1 of performance and quality.

Authors (Chatterjee, et al., 2014) have first reported the use of energy value stream mapping (EVSM) as a tool to analyze the energy consumption in any manufacturing process. The authors in there research work have used the EVSM tool to analyze energy consumption in production of biodiesel.

(Nassehi, et al., 2012), in their paper, present a framework to validate the introduction of energy consumption in the objectives of process planning for CNC machining. The paper considers the critical aspect of energy efficiency in manufacturing and in particular process planning of products. Computer Aided Process Planning (CAPP) has continued to be developed for over 40 years with its early origins dating back to the1960s.

A good basis for analyzing energy use in machining is through (Gutowski, et al., 2006) mathematical model for direct energy requirement in machining.

2.1: Objective of the research work

Manufacturing of any product in CNC involved following steps in total or partial

a. Work holding process
b. Tool Holding Process
c. Alignment
d. Coolant on & off

e. Tool changing

f. Work piece orientation changing

g. Tool approach and retracted back

h. Loading and unloading of work piece/ pallet fixture.

i. Moving and waiting

If total time on machining is considered as 100% than 5 % of it is the actual time spend on machining. If this 5% machining time is consider as100%, than it is found that 30 % of it is actual machining rest 70% is used for other process like positioning, gauging etc. (figure.1).

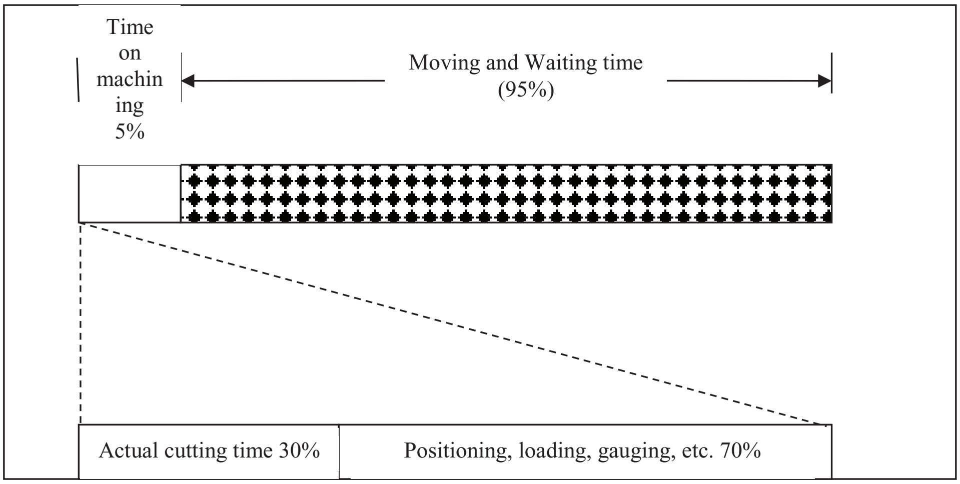

Figure 1: Machining time breakup

A lot of research work has been done to make process green for the time spend on moving and waiting but a less or no work has been reported to make process green during positioning, loading, gauging etc.

The time consumed in positioning, loading, gauging etc. is very small but it has been found that during this period the coolant flow and cutter movements are not stopped in many cases. The present work concentrate analyzing this time to make process green using a new tool called energy value stream methodology (EVSM).

3. Energy Value Stream Mapping

EVSM (Energy Value Stream Mapping) is developed based on the standard of Value Stream Methodology. This has been done by adding Energy components in addition to the cost in VSM and the same has been analyzed with respect to time. The EVSM identifies the level of energy utilize and wastage in each step and hence determines the opportunities for energy conservations. To analyze the possible outcomes of improvement options, future scenarios are also developed using EVSM. The suggested model can be used not only for diagnostic purposes but also for energy budgeting and saving measures.

A small scale industry has been taken for implementation and validation of the model. The Industry selected is an ISO 9001-2008 certified unit. Due to confidentiality matters the products manufactured by the industry is named as product A, B, C. The product A consists of 21 components out of which component X, Y and Z are manufactured in-house and the other components are either purchased or outsourced. Only component X will be taken for analysis because this component covers the entire shop floor moving through all the machines.

3.1. Assumptions

The following assumptions are made in order to develop the energy value stream map (EVSM) –

1. Component X is the final component and needs no further assembly.
2. Only the machines with high energy consumption are taken up for energy analysis.

3. Energy consumption during transportation between machines are been ignored.
4. There is no internal loss of energy in the machine by friction; heat etc. and energy used by machining are same as that of power rating of motors.

3.2. Process Flow

The process flow diagram of component X is shown in figure 2. The component X is produced using all the CNC machines present in the shop floor. The process starts with cutting raw material in the band saw and ends with anodizing operations. The rod raw material from the store is being cut through the band saw and transferred to CNC-1 where various processes like facing, rough turning, drilling, boring, and threading are performed. Then it is transferred to CNC-2 where operations like facing, with taper turning, and V drilling are performed. Next step includes the transfer of component to VMC-1 where operations like flash hole, detent and tape-hole takes place. After this it is transferred to VMC-2 where hinge pin-hole, and locking pin-hole operations are performed. Finally the component is transferred to machine shop and anodizing section. The process flow diagram for the component X is shown in Figure 2.

Figure 2: Process flow diagram of component "X"

4. Current State Value Stream Map

The current state value stream map for the process flow diagram (fig2) is being made and is summarized in figure 4 (Verma & Sharma, 2015). The standard symbols depicted in fig. 3 are used to make the current state value stream map (fig 4). The energy components are added in the current value stream mapping and current energy value stream is developed (fig 5). In order to understand the effect of energy future energy value stream map is developed (fig 6).

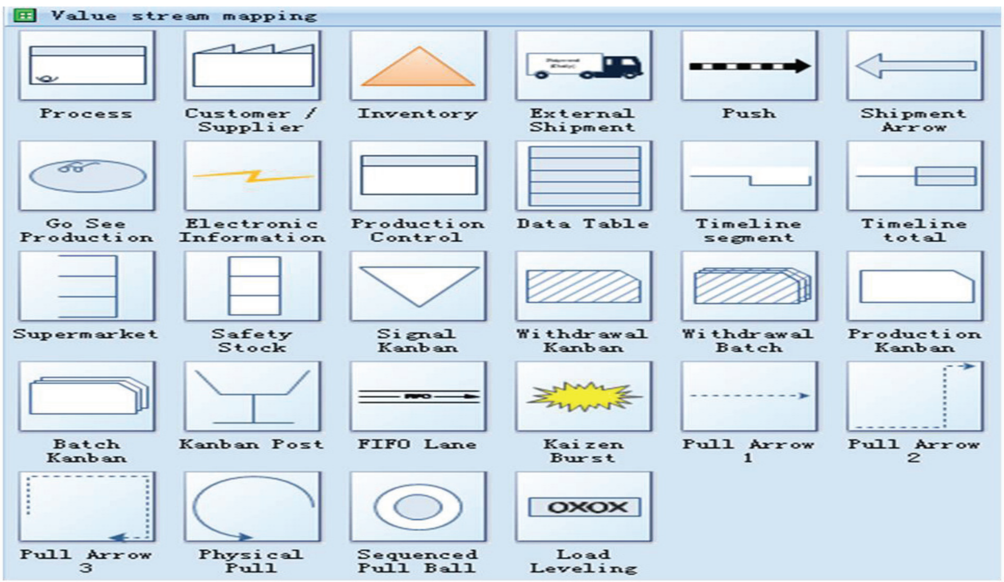

Figure 3: Symbols used for Value Stream Mapping (Egon, et al., 2014)

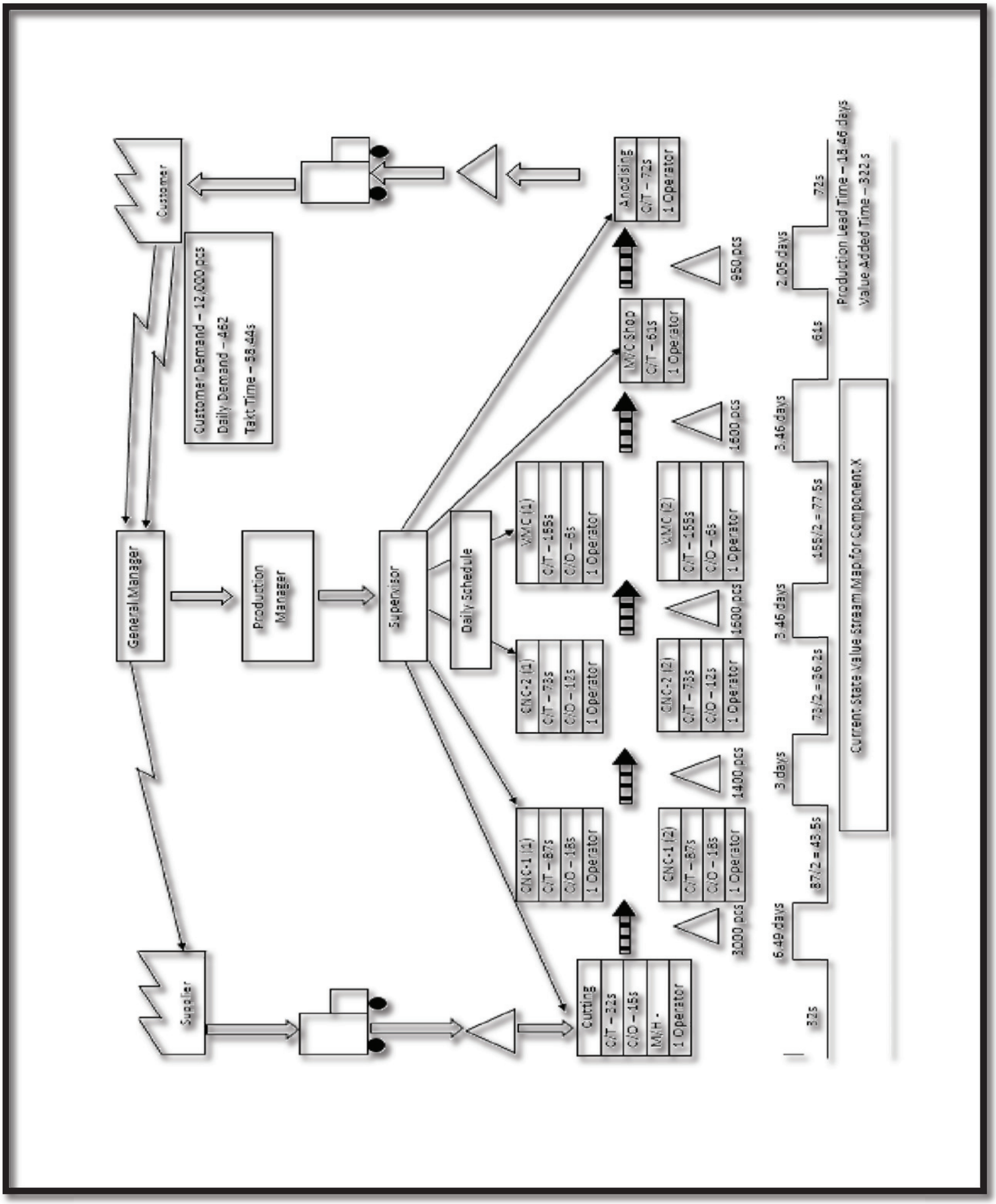

Figure 4: Current state value stream mapping for component "X" (Verma & Sharma, 2015)

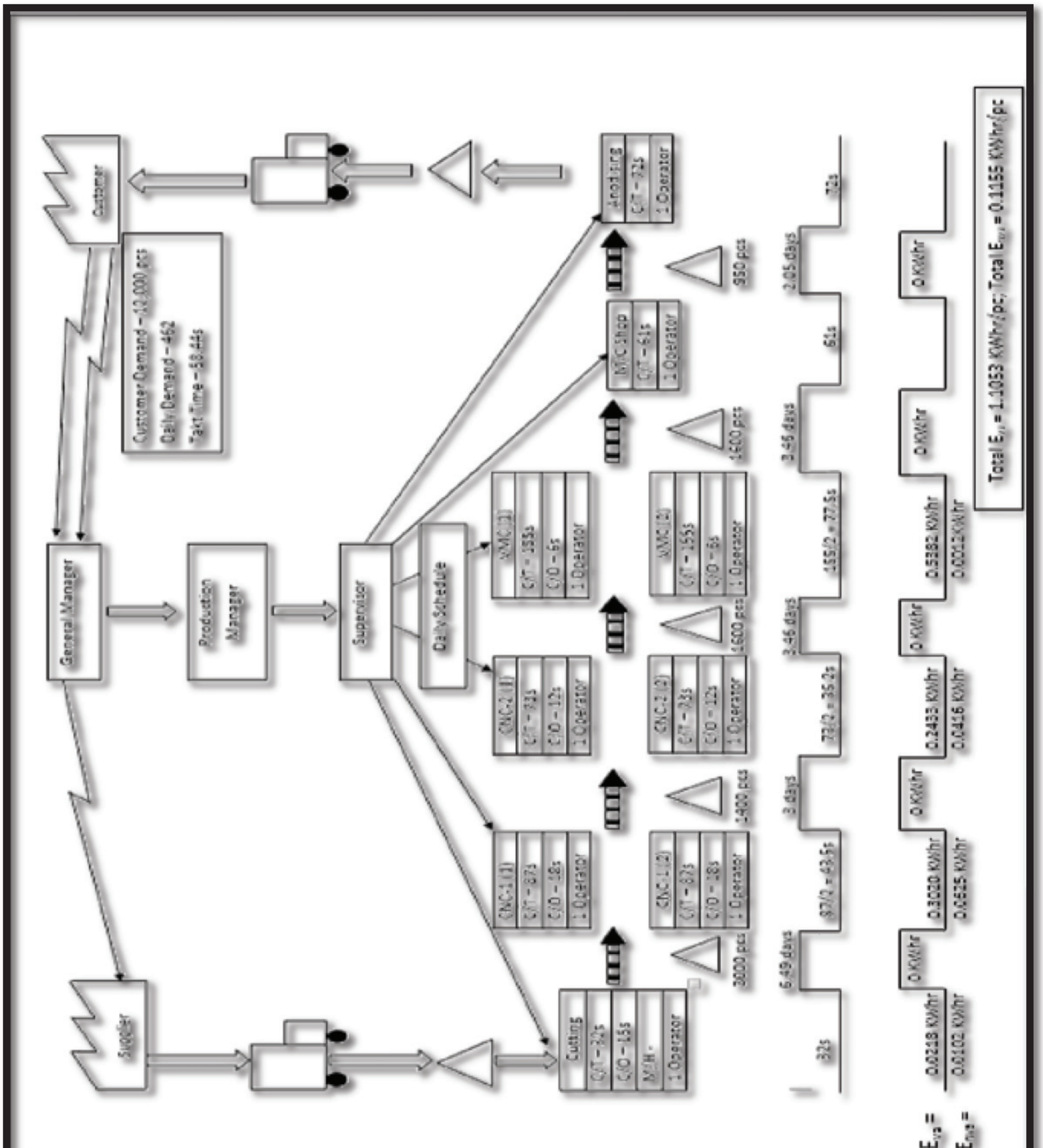

Figure 5: Energy value stream mapping for component "X"

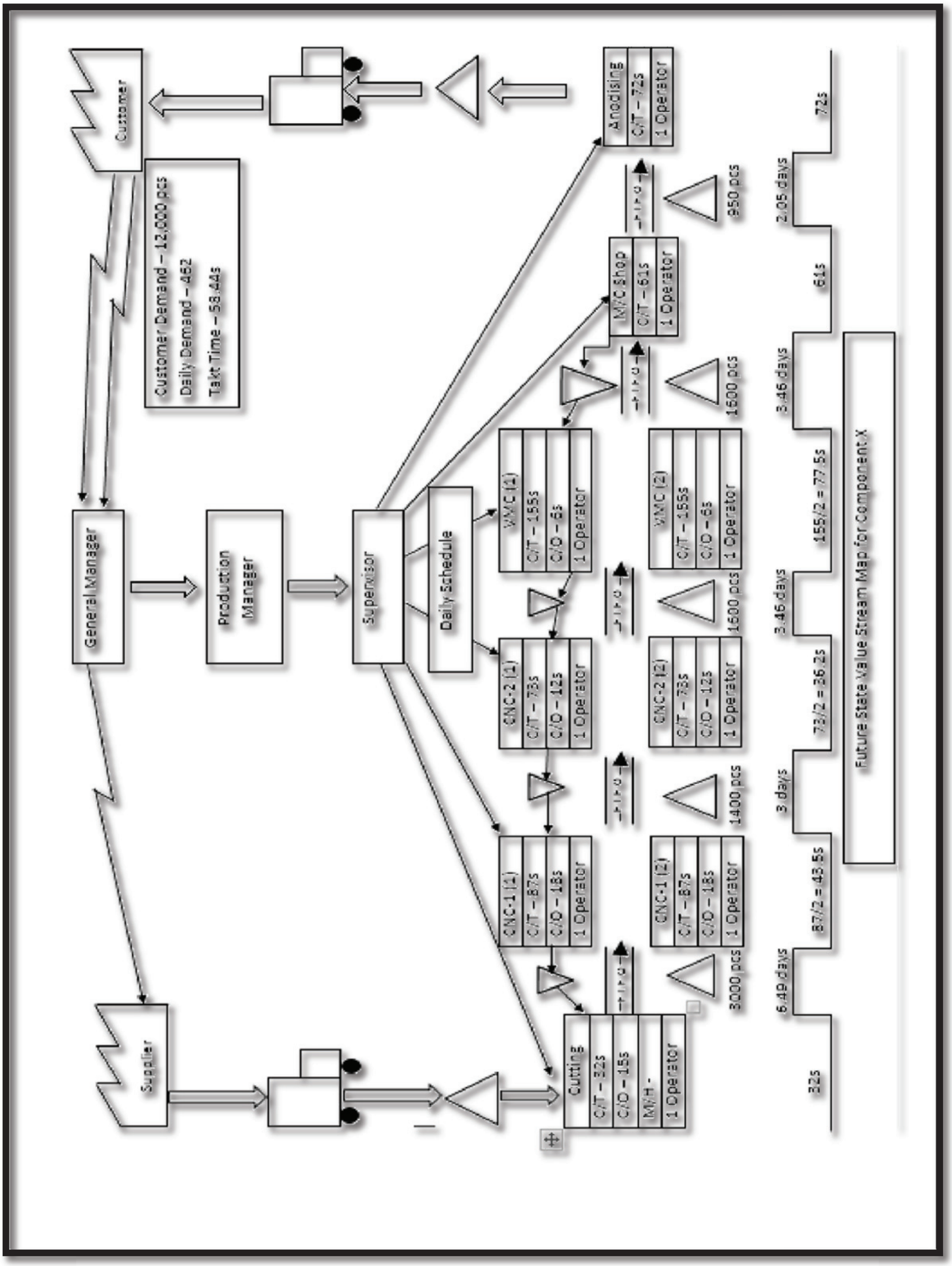

Figure 6: Future state energy value stream mapping

5. RESULTS AND DISCUSSIONS

Energy usages are calculated for the above value stream map (fig 4) and an energy span are added to the current state map. The energy calculations are done by using the power rating of the motors. The current energy value stream map is shown in figure 5.

The power ratings used for the calculations are stated below –

- Cutting Machine : Cutting Saw Motor Power – 2.2 KW , Coolant Motor Power – 0.25 KW
- CNC -1 : Spindle Motor Power – 6 KW , Coolant Motor Power – 0.25 KW
- CNC-2 : Spindle Motor Power – 6 KW , Coolant Motor Power – 0.25 KW
- VMC : Spindle Motor Power – 6 KW , Coolant Motor Power – 0.37 KW

For calculation of value adding energy and non-value adding energy the cycle time is divided into value added time when cutting is actually taking place and non-value added time when there is no cutting operation performed, i.e. tool change time and bed travel time etc.

For coolant, the energy used during cutting are termed as value added energy whereas the continuous coolant flow during air cutting and tool change etc. are termed as non-value added energy.

The continuous spindle movement during non-cutting time is also termed as non-value added energy.

Referring to the current state energy value stream map fig 5, the total non-value added energy in the energy span per piece of component "X" is.

$\varepsilon = non\ value\ added\ energy = 0.1155\ \ kw.hr/piece$

Monthly demand of component "X" is 12000 units (As per data collected).

Thus,

$\varepsilon_{month} = total\ non\ value\ added\ energy\ per\ month = 0.1155 \times 12000 = 1386\, kw.hr/month$

Assuming the demand of component "X" to be same throughout the year than non-value added energy in a year is

$$\varepsilon_{year} = 1386 \times 12 = 16.632\, kw.hr/year$$

As per the MSME (Micro, Small and Medium Enterprise) data of [MSME 2012-13] , the total numbers of MSME enterprises in India (registered + unregistered) are 115.01 lakhs.

Assuming all the above mentioned small scale industries to be of the same stature as the one taken in the case study, Therefore the total energy which can be saved in India alone per year is equivalent to –

$$E = total\ energy\ saved = \varepsilon_{year} \times 115.01 = 16632\ \times 115.01$$

$$= 1{,}912{,}846.32\, kw.hr = 1912.83\, MWhr$$

Further the non-value added energy calculated in the present case study is limited to only following operations:

1. Coolant Flow when no cutting is taking place.

2. Spindle rotation during air cutting and tool change operation.

This is the kind of energy which can be saved in a small scale industry if they are producing only one component. The total energy saving potential is large if small modifications are made in the existing machine in operation in the entire Industries worldwide.

5.1 Future State Energy Value Stream Map

Future Energy value stream map for the process is shown in figure 6. Form the future EVSM following conclusion are drawn for process improvement-

- Pull type system should be implemented instead of the prevalent push type. This will reduce the excessive inventory being produced which is then associated with high storage costs for the inventory. Also, a lot of energy is wasted in producing such excessive inventory and the machines are not used judiciously.

- The sizes of the bins on the floor are not fixed. That is the work in process inventory is not clear at a point of time. The size of bins should be fixed because the first concept of lean manufacturing is make thing visible.
- Energy wasted during the process is very large, small change in the existing setup may lead to a higher energy saving.

6. CONCLUSION

The above results clearly show the kind of cost saving which can be made by small changes in the process flow. Thus, now conclude that designing time- and energy- efficient energy value streams mapping become very important in today's scenario. With the help of this new Value Stream mapping a lean and green manufacturing system can be developed. This paper recommends the path of reducing the environmental impact and suggests an approach for the implementation of green system for various manufacturing unit. The importance that energy saving holds need not be listed down as the whole world is well aware of it. The direction in which the world is going it may soon land in an energy crisis when the prime focus will not be on saving money or increasing productivity, but it will be finding alternate sources of energy and most of the current machinery will become obsolete. What this study focuses on is how one can save energy today and postpone that energy crisis time as much as possible. The world as known today may not exist in the same form tomorrow. Therefore the EVSM is and effective tool to identify the area where the energy is wasted and new design of machine tool or modification in existing setup will help to reduce energy wastage.

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