Design of New Plant Layout Using Lean Tools by Eliminating Wastes in Material Flow Process

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Abstract
The Service Mold company examined in this study is leading aerospace parts manufacturing industry located in Windsor, Ontario. The company demanded a new plant layout for the better material movement to improve the actual productivity by eradicating all the wastes in the process with the help of lean tools. In this paper, the authors analyzed old layout which was in random shape and identified non-value added material movements. Authors prepared a new layout based on the present scenario from random layout to U shape layout by utilizing cellular manufacturing to minimize the travel distance of both employees and material. Tools like 5W1H, Value Stream Mapping (VSM), Cause and Effect Diagram and 5Why are used to find the root cause of the current obstacles. And Kaizen tool was used with Pareto chart to identify the primary reason for the problem. The future layout is expected to have better productivity in the company.

Keywords
Manufacturing industry, Productivity and Layout design

1. Introduction
The authors made Gemba walk in one of the aerospace manufacturing companies named Service Mold + Aerospace for Improvement, which is located in Windsor, ON. The company mainly works on pull based system whose supplier and customer is Sonaka, Montreal. The manufacturing units consist of automatic and manual cutting, two 5-Axes Computer Numerical Control (CNC) machines as well as manual and laser inspection process.
This paper is focused on eliminating waste by removing excess movement of man and materials. The major objective here is to improve the quality rate and implement a continuous production between processes using Lean methodology and its associated tools.

2. Literature review
2.1 Lean manufacturing
Industry's main motive is giving a product/service with the full satisfaction to clients by reducing the wastes, improve the productivity, to train the people and create a quality-oriented mindset. Lean Manufacturing tools and techniques are widely used in the most of the companies and exported all over the world. So, final execution means of high-quality products is carried out by the senior management team in order to sustain in competitive world. [1]

In modern era, manufacturing process is due to two main factors. One of the main factors is a high competition with an economic growth while Second is the old manufacturing style are not meeting the society criteria in terms of requirements and service execution. Many firms are reconstructing to lean manufacturing processes with some goals in hand. In order to maintain the sustainability in society, manufacturers are producing good quality products with low capital cost and ultimate numbers of employee. Albeit, combination of quality, cost and time gives better result but sometimes skill employees are playing vital role for success path.

Lean manufacturing is all about removing waste from process by means of transportation, inventory, motion, weighting, over processes, over production and defects. Eliminating waste is reducing non-value-added activities which are not valued by customers in financial way. In continuation to receive this information, firstly, the company has to specify the value-added activities' information to the customer. The company should analyze the project details and should give detailed overview about value added and non-value-added activities to the customer. Secondly, industries must find the way to reduce nonvalue added activities. In present scenario, lean tools such as Supplier Input Process Output Customer (SIPOC) and value stream mapping (VSM) are generally utilized to identify the further process steps. Lastly, companies must eradicate all the non-value-added steps and streamline every other step which is going to add value to the product as well as to the end customer. To prevent financial crises, corporation must examine the results that are being produced and start the evaluation process again.

2.2 Industrial Waste

In any business, the greatest opposition of improvement and productivity is waste. In lean manufacturing, waste is something which is not going to add value to the product or to the customer. At the end external customer is not willing to pay for this activity. There are eight types of waste in lean manufacturing. Seven of the eight wastes are linked to the production process, while the eighth waste is related to top management's ability to use their personnel. [2]

2.2.1 Transportation:

Usually moving material costs money and excessive unwanted moves result in waste. That is why transportation is subdivided as a manufacturing waste category. Because there is no value in moving material around the shop floor. Moreover, greater amount of resources and time are consumed while no value is being sent to the customer.

2.2.2 Inventory:

It is the valuable product or material waiting in the shop-floor to be getting sold or being sent to the next process area. Huge amount of cost would be associated to maintain this inventory which is going the affect the revenue/profit.

2.2.3 Motion:

Moving the human body more than is necessary is also considered as waste. And excessive movement of people or equipment that does not add value. Inefficient shop floor layout and improper equipment could contribute this waste.

2.2.4 Waiting:

When product/people waits, no value is being added but the cost associated with this continues to grow. Waiting generally kills the material and information flow. It also generates excess inventory.

2.2.5 Over Processing:

Doing more to the product than the customer requires. If the customer's requirements are not clear, more work will be put in place in the product, even though customer did not order this. Repairing and remanufacturing are examples of this.

2.2.6 Over Production:

Producing more than the customer needs is considered as the main form of waste. Japanese industrial engineer described this as the root of all manufacturing evils. Because over production causes other types of waste.

2.2.7 Defects:

One of the most easily recognizable wastes in lean manufacturing is the production of defects. Mistakes or producing defective products mean repeat a process. Rework or fix things required that are not done right the first time.

2.2.8 Non-utilized talent:

This waste occurs when top management fails to recognize the talent of the employees. If the management does not engage with the employees and allow employees to do the changing process for the better, it is considered as waste.

2.3 Value stream mapping

The value stream mapping is a very important lean manufacturing tool which is used to collect and analyze data visually which helps to describe the process flow of the industry. The VSM includes all activities from the customer demand to transform a product from raw material into the finished product. The VSM is drawn for every process involved in the material and information flow. Thus, by creating a process flow we can identify the value-added and non-value-added activities involved in the process. The VSM consists of current and future state mapping. The current state is used to describe how the process is being done and by identifying the problem. The further improvements are mapped in the future state. The future state is created to show the implementation of the process by eliminating or reducing non-value-added activities

2.4 Cellular manufacturing

It is a process of manufacturing which helps material to move as quickly as possible and to make a wide variety of similar products requiring similar operations. Cellular manufacturing consists of a series of product-focused work-cells-which house all operations to manufacture those products requiring similar operations. While a traditional manufacturing environment is organized functionally with similar machines in one area (for example, all molding machines in Molding Dept.), cellular manufacturing operates like a series of plants-within-a-plant, each starting with raw materials and ending with finished product, with all operations being performed in the cell. Machines in manufacturing cells are located within close proximity to minimize product transportation (a form of manufacturing waste) and to maintain continuous flow with zero inventory between operations (inventory holding cost will be cut down). The manufacturing cell is operated by a team of empowered, multi-skilled operators who have complete responsibility for quality and delivery performance within the cell.

Cells reduce the distance a part or product has to move. This reduces material handling costs, allows quicker feedback on potential quality problems, reduces work-in-process inventories, permits easer scheduling and reduces throughput time. Cell teams better understand the whole process of making parts/assemblies. Cell members feel the responsibility to a small group. [3]

Because a small change in the position of a machine in a factory affects the flow of materials. There are various types of cell layout designs available. We have designed the optimum layout considering different objectives in mind. The main goal is to increase the productivity and reduce the walking distance of workers and provide a smooth material flow. [4]

3. Methodology

3.1 Current Process Analysis

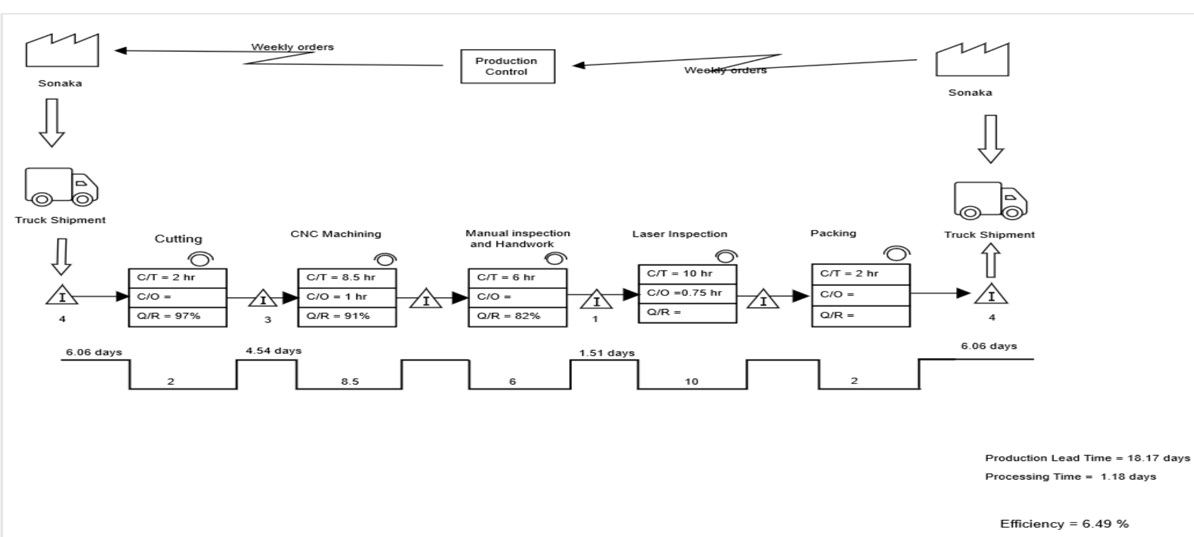

Figure 1 current state VSM

Value stream mapping is a tool to identify the information, material and time flow inside the organization. First, the customer, Sonaka (At the top right corner) has ordered some parts to the production control. Based on that, raw material order has been sent back to the supplier electronically and it is being shipped at the right time. There are five processes in the current state where raw materials can be converted to finished goods. Cycle time and changeover time of the individual processes have been mentioned in the data boxes available. At-last the finished goods have been sent to the customer. Production lead time is 18.17 days and processing time is 1.18 days.

3.2 Current layout diagram:

Raw material from the supplier end has been collected and stored in the storage area shown in Figure 2. All the materials have been pulled from the storage area whenever needed by production control. To begin with, Material has been sent to cutting process. Huge amount of inventories will be stored here. Material handler comes and takes the material to the next step. Then the material is being sent to the other processes to get a final finished output. Packing of the finished product takes place near the exit gate. In this current layout, movement of material as well as man will be more than the standard movement. This will definitely be the waste which eventually affects the productivity of the company.

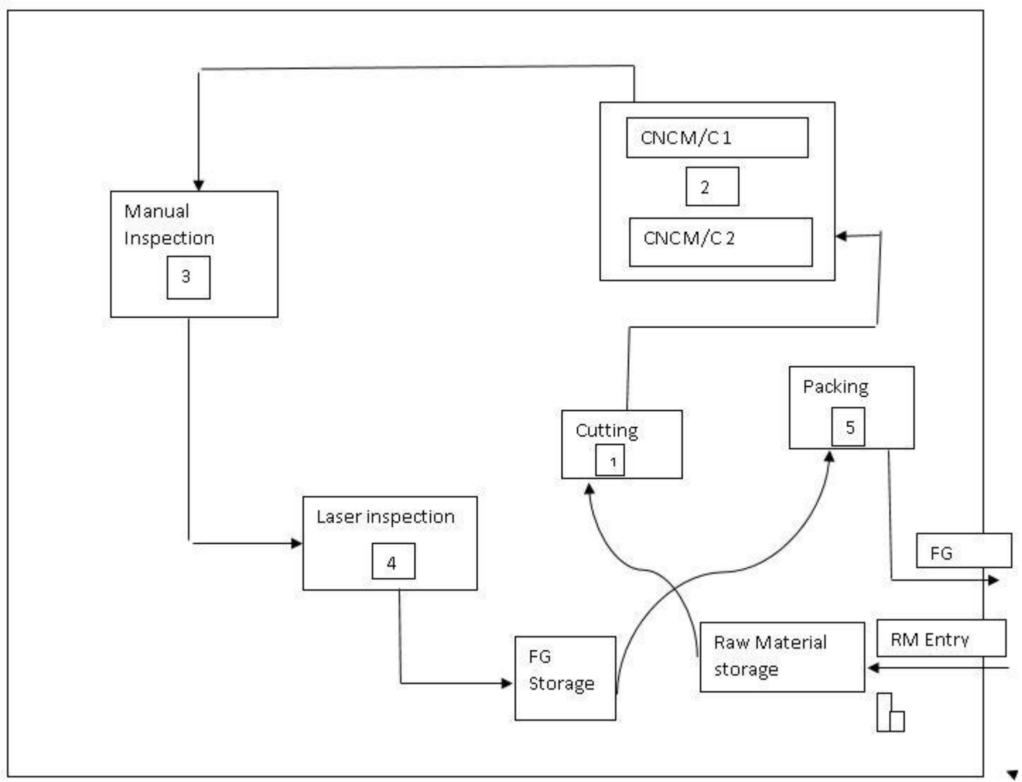

Figure 2 current plant layout

3.3 Root cause analysis

There is a famous saying in a book called Toyota Way by Jeffrey K Liker which is "See America, Then Design for America". To follow this saying, we followed 5G and 5W1H to understand the real problem in the company. Table 1 shows information regarding root cause analysis.

At first, we have done a Gemba walk throughout the shop floor to understand the problem. Because, it is the most powerful location for any team. 5W1H is the important tool to understand the problem more deeply. We should work on 5W1H as we move along the shop floor. If we had mapped all 5G and 5W1H sitting in a conference room, the results would have changed the other way around.

Table 1 5W1H diagram

What is the problem?	Excessive movement of material and man
When is it occurring?	All the time during production
Where is it occurring?	CNC to Inspection; Packing to Dispatch
Who is doing it?	Material Handler
Which pattern does it have?	Twice in a day. (30 minutes/each)
How is it being done?	Changing the layout

Understanding the problem is the first step in solving it. We identified the problem as we move along the shop floor (Excessive Movement of Materials and Man). It is more qualified and structured approach to understand the problem in each and every aspect (I.e. Who, When and Where). As we have noticed, every step in 5W1H strategy points to a different question and the answer to each question is the trigger for the next one.

3.3 Cause and effect diagram

Potential probable causes of the problem has to be identified. A Cause and effect diagram can help in brainstorming to find possible causes of the problem which may be more. The problem is shown at the head of the fish. Possible causes are displayed through brainstorming on the smaller bones under different categories like Man, Machine and Material.

In our case, the problem (identified through 5G & 5W1H) is Excessive movement of material and man. Possible causes are identified through benchmarking and listed under various categories. Cause and effect diagram helps us to provide a path to find out the root cause of the problem effectively. There are ten possible causes of the problem identified through this. In most of the project, experts will be doing Design of Experiments to find out the real cause. But, in our case we can identify the problem directly through our experience.

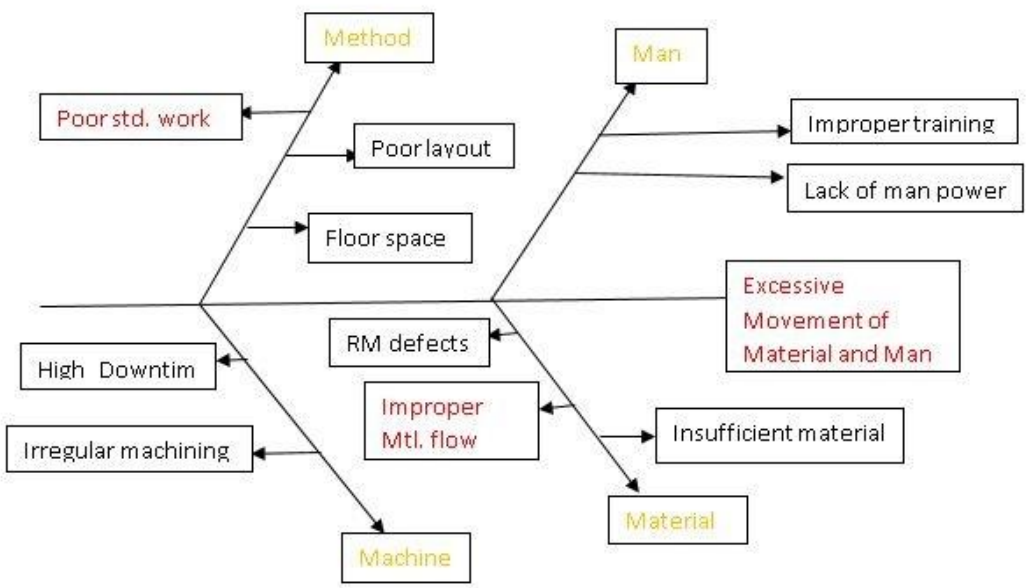

Figure 3 cause and effect diagram

3.4 5why analysis

Root cause of the problem can be found out using 5Why Analysis which is one of the oldest methods in finding the root cause. We can do the 5why to the most influential potential cause identified in Cause and effect diagram. In our case, it is the improper flow of materials. We have done the analysis to find out the root cause of the problem which is the poor layout. So, by repeatedly asking the question "Why", we can peel away the symptoms which can lead to the root cause of the problem. So here, excessive movement of material and worker within the shop floor is due to the poor layout/arrangement of machines.

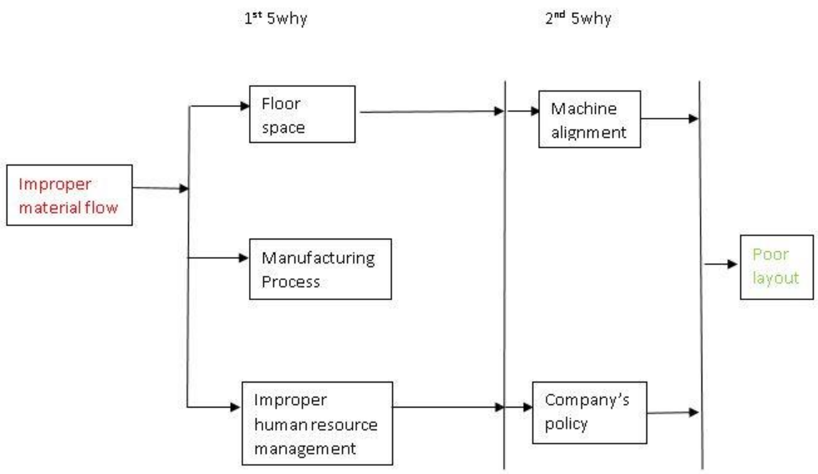

Figure 4 5why analysis

4. Result and discussion

4.1 Current work distribution

Figure 5 shows the detail work distribution per week including value added and non-value-added activities such as changeover, manual inspection and many more. In addition, Table 2 is showing almost 40hrs non-value-added activities during the cycle time while 70hrs for value added activities.

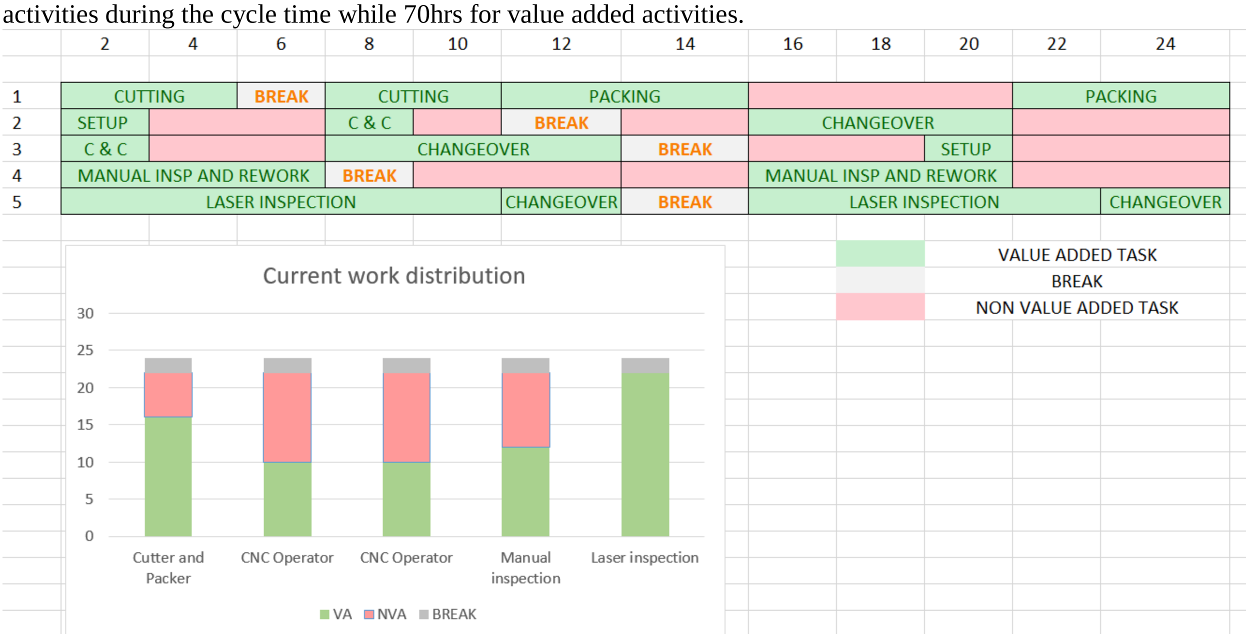

Figure 5 Current work distribution

	Duty	**VA**	**NVA**	**BREAK**
1	Cutter and Packer	16	6	2
2	CNC Operator	10	12	2
3	CNC Operator	10	12	2
4	Manual inspection and Handwork	12	10	2
5	Laser inspection	22	0	2
	Total	70	40	10

Table 2 current work distribution

4.2 Future work distribution

After introducing cellular manufacturing in plant layout, there are some positive change which helped to increase production rate. The non-value added activities are decrease from 40 hrs to 10 hrs and break time will be reduced by 2 hrs which directly impacting on production rate by means of value added activities as per Table 3.

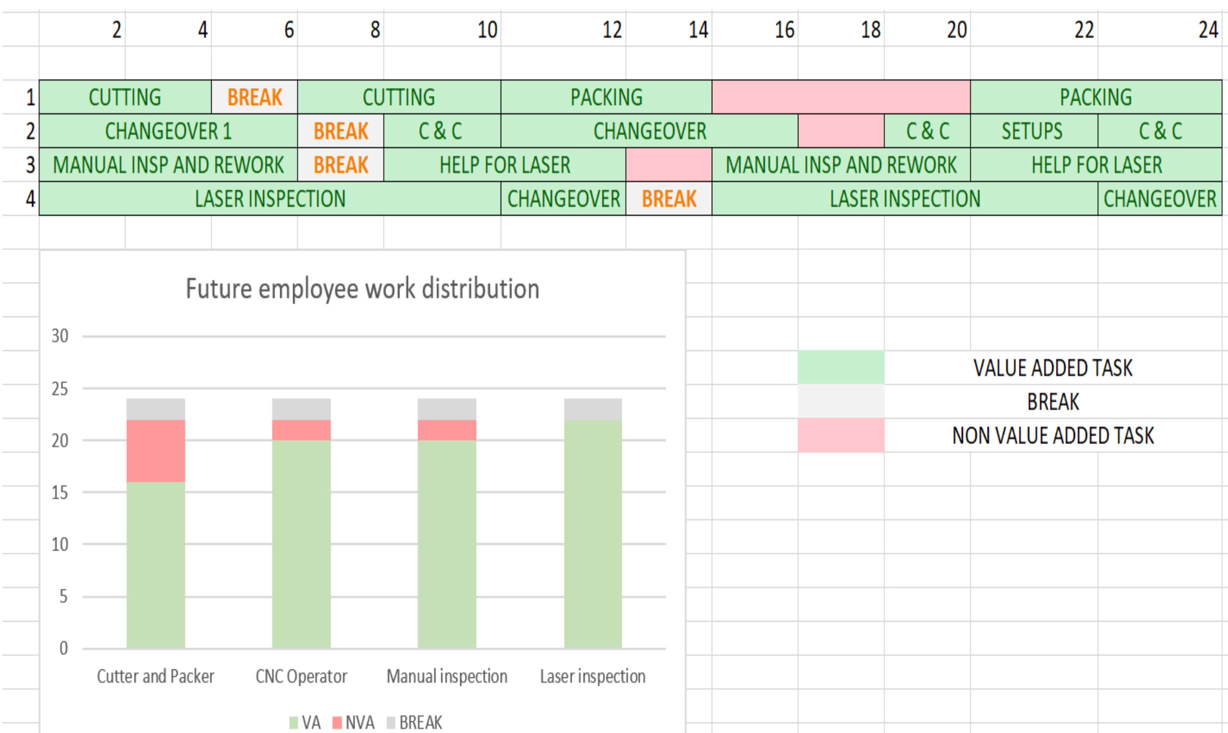

Figure 6 future work distribution

	Duty	VA	NVA	BREAK
1	Cutter and Packer	16	6	2
2	CNC Operator	20	2	2
3	Manual inspection and Handwork	20	2	2
4	Laser inspection	22	0	2
	Total	68	10	8

Table 3 future work distribution

4.3 Future plant layout

The current layout has been replaced by Figure 7 this future U-Shaped layout which is also called as continuous flow. It causes mainly the rapid movement of materials inside the layout which in turn reduces the inventory as well as the excessive movement of the workers. Essential conditions of a U-shaped layout are proper design of the machine layout and well trained multi-skilled operators. There will be limited number of inventories in between the processes and no excessive movement of material and man throughout the entire layout. In this layout, entrance and exit region is not in the same area. After all the processes, packing will be done which triggers the finished goods to go towards the customers from the nearest exit point.

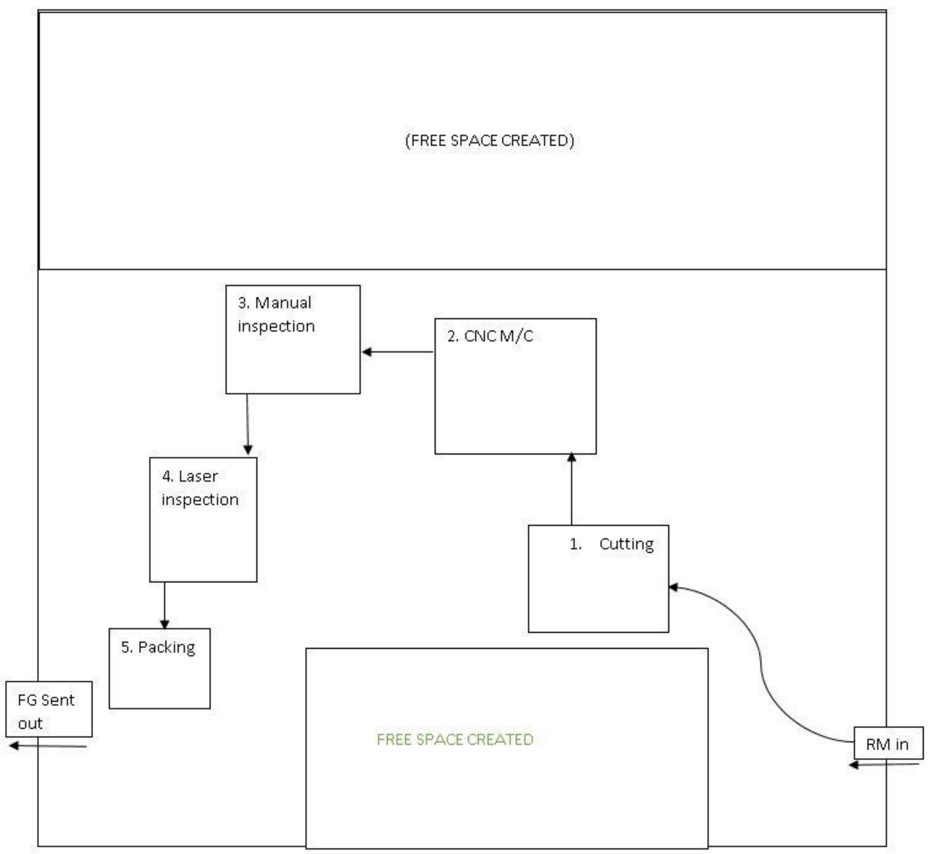

Figure 7 future plant layout

4.4 Future Value stream mapping

After implementing cellular manufacturing layout and line balancing for employees the efficiency can increase up to 9.9%. This can also remove the inventory between 2 stations – manual inspection and laser inspection. Moreover, the quality rate can increase up to 4% and 7% for CNC machining and handwork respectively (assumption) that describe in Figure 8.

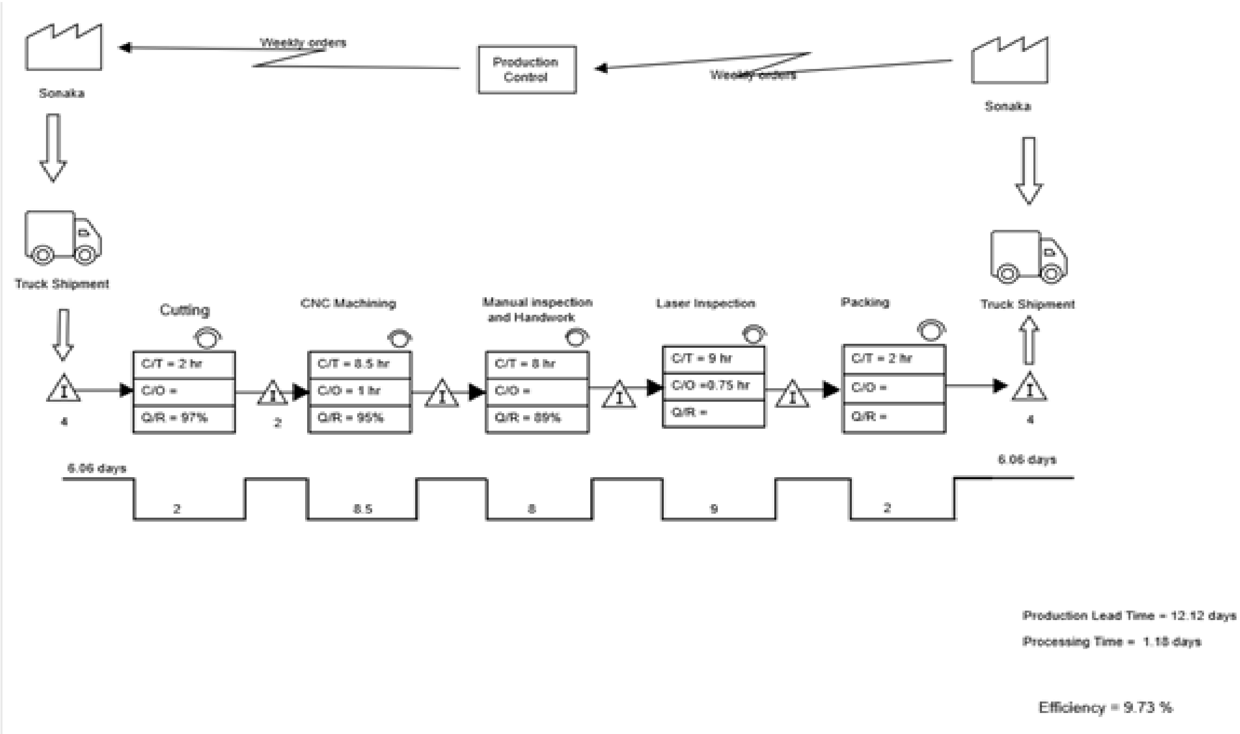

Figure 8 Future Value stream mapping

4.5 Overall equipment effectiveness

Table 4, Table 5and Table 6are showing data related to current status.

Table 4 current OEE data

Production Data		
Number of Shifts Per Day = **2**		
	Hours Per Day	Minutes Per Day
Shift Length	18.20	1100
Short Breaks	0.5	30
Meal Break	0.5	30
Downtime	0	0
Changeover time	3	180

Ideal cycle time	10hrs/product
Total Pieces	2 per day
Scrap Pieces	0

Table 5 Current OEE calculation

Support Variable	Calculation	Answer
Planned Production Time	Shift Length – (Short Break + Meal Break) = 1100-120	980
Operating Time	Planned Production Time – (Downtime + Changeover time) = 980-180	800
Good Pieces	Total Pieces – Scrap Pieces = 2-0	2

OEE Factor	Calculation	Actual OEE Percentage
Availability	Operating Time / Planned Production Time = 800/980	81.6
Performance	Ideal Cycle time / (Operating time/Total pieces) = 600/(800/2)	75
Quality	Good Pieces / Total Pieces = 2/2	100

Table 6 Current OEE

Overall OEE Calculation
OEE = Availability X Performance X Quality = 0.81*0.75*1
OEE = 0.615 = 61.5%

4.6 Future overall equipment effectiveness

Table 7, Table 8and Table 9 are showing information regarding future OEE calculations.

Table 7 Future OEE data

Production Data		
Number of Shifts Per Day = **2**		
	Hours Per Day	Minutes Per Day
Shift Length	18.20	1100
Short Breaks	0.5	30
Meal Break	0.5	30
Downtime	0	0
Changeover time	1.5	90

Ideal cycle time	10 hours per product
Total Pieces	3 per day
Scrap Pieces	0

Table 8 Future OEE calculation

Support Variable	Calculation	Answer
Planned Production Time	Shift Length – (Short Break + Meal Break) = 1100-120	980
Operating Time	Planned Production Time – (Downtime + Changeover time) = 980-90	890
Good Pieces	Total Pieces – Scrap Pieces = 3-0	3

Table 9 Future OEE

OEE Factor	Calculation	Actual OEE Percentage
Availability	Operating Time / Planned Production Time = 890/980	91
Performance	Ideal Cycle time / (Operating time/Total pieces) = 600/800	75
Quality	Good Pieces / Total Pieces = 13485 / 13496	100
Overall OEE Calculation		
OEE = Availability X Performance X Quality = 0.91*0.75*100		
OEE = 0.6825 % ≈ 68.25 %		

5. Conclusion

Lean Manufacturing is a systematic tool which is very much useful in identifying and eliminating non-value added activities. In the current process, there is a real root cause in it. It has been identified and eliminated with the help of lean manufacturing techniques. End customer satisfaction will also be improved thereby improving its productivity. By using the cell manufacturing technique, one of the wastes (excessive movement) is removed. So Mura-unevenness., Muri-overburden would be reduced. Inventory of the material is also been reduced by implementing this. Eventually inventory holding cost will not cross its limit.

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Biographies

Sriram Srinivasan is an Industrial Engineering Graduate student at University of Windsor. He earned his Bachelors of Engineering Degree in Mechanical Engineering from Velammal College of Engineering and Technology, India. He has got two patents in his core field. One patent is for his project "Arduous Therapist" which provides passive exercise to the hands, fingers and wrists of stroke patients. Designing the work and design calculations for these mechanisms won him the promising innovator of the year award which was presented at 'i3' national fair in the year 2016. He also fabricated and patented a real time machine titled "Semi-Automatic Flower Knotting Device" with Arduino and Mechanical Core Mechanisms. Programming the Arduino and assembling the device led him to secure the Gandhian Young Technological Innovation (GYTI) Award at Rashtrapati Bhavan, New Delhi. His research interests include manufacturing, optimization, reliability, scheduling, manufacturing, and lean. He worked as a Junior Operational Engineer at Thissan Industries, Chennai, where he taken care of machine utilization and downtime. He performed the sampling quality checks of incoming and outgoing materials. He supported his operational manager with the development of risk assessments, Failure Mode Effect Analysis (FMEA) and Quality procedures.

Harita Zikre is a graduate student in a mechanical department at University of Windsor. She specialized her study not only in Finite element analysis, multi-body dynamics but also in lean manufacturing and material science too. She completed her bachelors of technology from Navrachana University in mechanical field with particularized in tribology, vibration engineering, composite manufacturing, machine design and manufacturing technologies. She had fabrication experience in TATA MOTORS, BANCO Industries and also in BOMBARDIER TRANSPORTATION with continuous improvement department. She published experimental research related to material science specifically in composite at one of the well-known journals. The paper briefly explained the comparison of homemade and natural fiber with respect to mechanical strength. She designed non-conventional wind turbine during her bachelor studies project. Later on, she proposed manufacturing assembly line for the turbine production in one of the companies by using lean tools for instance Value stream mapping (VSM), 5S and Kizen.