Improving Productivity by Reducing the Assembly Time of Rotary Tillers in a Manufacturing Industry in Maharashtra, India.

Shantanu Ravindra Kale

Third Year Industrial Engineering Student, Dept. of Industrial Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur-440013, Maharashtra, India

---***---

Abstract - *A rotary tiller is a mechanized agricultural implement popularly used to save time, human effort and fuel in preparation of soil bed. This popularity has resulted in rising demand for the rotary tiller. The aim of this study is to reduce the time required to assemble a rotary tiller using work-study and in-turn improve the productivity by saving time and resources to keep up with the heavy demand. This study was carried out in an industry located in Maharashtra that manufactures agriculture implements like rotary tillers, shredders, power harrow, etc. The aim was carried out by observing the complete assembly process, plotting flow process charts and flow diagrams based on the activities of the operator, identifying potential spots of improvement in the existing process through critical analysis and calculations for elimination of various unnecessary factors and finally developing an improved and more efficient method for the assembly of the rotary tiller.*

***Key Words*: Rotary tiller, Work-study, Flow Process Chart, Flow Diagram, Critical analysis.**

1.INTRODUCTION

Rotary tillage machine which is used in soil-bed preparation and weed control in arable field and fruit gardening agriculture. It has a huge capacity for cutting, mixing to topsoil preparing the seedbed directly. And also, it has more mixing capacity, approximately seven times than a plough. Thus, it has become very popular and is in huge demand in the agriculture sector. In India, this demand for agriculture implements is expected to grow at a CAGR of 9.9% during the period of 2019-2025. To cater to this huge demand, industries have been running round the clock and thus, time, since it is directly associated with cost, is very crucial to industries and cannot be wasted. Small industries need to maximize the time they have available to grow their business and reducing the production time can help them to do that. One of the major processes in the production is the assembly process. It's a fact that a greater number of units can be produced if the time required to assemble a unit is less. Thus, reducing the assembly time becomes crucial in the process of production. In this study, I have applied work study and its concepts to develop an improved and more efficient method than the current existing process to reduce the time required for assembly thus, improving the productivity of the production process.

1.1 PRODUCTIVITY

Productivity is the measurement of efficiency of production. It is the relationship between the amount of output and the amount of input used to make the product goods. in other words, *it is ratio of output to input.*
Productivity=output/input.
Forms of input can be:

- Land
- Equipment
- Men
- Material
- Energy
- Capital
- Technical information

Forms of output can be:

- Materials
- Product
- Service

Productivity can be improved by changing or increasing the ratio of output and input. So, this ratio can be increased in the following conditions:

1. By using same amount of input and increasing the output.
2. Reduced input resources while output being the same.
3. Higher output with less amount of input.
4. Increased rate in output compared with rate of increase of input.
5. Higher decrease in input, less decrease in output.
6. Productivity of the system can increase by income from the sales of the output i.e., higher the output, higher the income from sales.

Additionally, productivity can be improved by the following:
1. Time efficient production methods:
Productivity can increase if workers work more to produce more unit products in less hours. This can be achieved by combining operations and reduction of non-productive time.

2. Efficient use of resources:
All the resources like land, man, machine, material, energy, investment must be use efficiently.as by decreasing in resources may increase the output as well as productivity.

1.2 INTERMITTENT PRODUCTION SYSTEM

Intermittent production is a term used for manufacturing processes that use irregular production schedules to create several different products using one production line.
It's used by manufacturers who produce low-volume, high-variety products for either mass customization or bespoke manufacturing.
If a manufacturer produces products, either one-by-one or in a batch, but the next product(s) requires a different manufacturing route or machines to be taken down and set back up in a different configuration, it would be an example of an intermittent production system.
Intermittent manufacturing workflows that use this method are:

- Batch manufacturing:
  It is a method of producing finished goods or sub-assemblies by compiling the different components of a product, through a step-by-step process. And the quantity of these finished goods or sub-assemblies produced in a batch will also depend on different factors, such as raw material levels and demand planning. In this process, raw materials move along the production line, leading to pauses between each step as the batch moves through each workstation.

- Job shop manufacturing:
  This intermittent production system is for manufacturers who have a shop floor populated with workstations that have different tools and machines for performing different tasks. The outcome of a production run with this intermittent process could be one product or a small batch of varying quantities. But, regardless of quantity, due to the workstation separations and the nature of job shop manufacturing, customers have the opportunity to customize their orders. This, in turn, means that products aren't standardized and are produced in a low volume. However, a smaller quantity of finished goods means that job shop manufacturers can offer a level of personalization that cannot be matched by factory owners producing items in masses.
  Products pass different routes on the shop floor, since one customer's order may travel an entirely different route to another customer's order, depending on the amount of customization they requested on their product.

- Discrete manufacturing:
  Discrete manufacturing concerns anything that uses components and sub-assemblies that can be easily taken apart. What separates discrete manufacturing and the other methods is that the final product can have parts replaced and is used by assemble to order (ATO) businesses. However, discrete manufacturing might also only produce sub-assemblies as the final item, which will then be used elsewhere to build the finished product.

2. ROTARY TILLER

Rotary tiller is a tillage machine designed for preparing land suitable for sowing seeds (without overturning of the soil), for eradicating weeds, mixing manure or fertilizer into soil, to break up and renovate pastures for crushing clods etc. It offers an advantage of rapid seedbed preparation and reduced draft compared to conventional tillage. It saved 30-35 % of time and 20-25 % in the cost of operation as compared to tillage by cultivator. It gave higher quality of work (25-30 %) than tillage by cultivator. The rotary tiller is the most efficient means of transmitting engine power directly to the soil with no wheel slip and a major reduction in transmission power loss.

The rotary tiller will produce a perfect seedbed in fewer passes. It is the ideal implement for cash crop farmers who need to bury and incorporate crop residues quickly, between crops. Tillage tools direct energy into the soil to cause some desired effect such as cutting, breaking, inversion, or movement of soil. Soil is transferred from an initial condition to a different condition by this process. A rotary tiller is a mechanical gardening tool with power blades attached to a spinning surface to plough soil and give optimum tillage. Different rotary tillers are designed to suit different gardening needs. A gardening rotary tiller is a compact machine which can be used on any land size but is more appropriate for gardening. Gardeners usually use a variation of this appliance as sometimes; only small flower beds or miniature vegetable patches need to be tilled. Gardening rotary tiller cannot really break up huge amounts of soil, but can efficiently churn up the soil and remove unnecessary weeds on the flower beds and can also ensure infusion of the fertilizer into the soil. Such a machine is usually powered by electricity, as it is not heavy-duty, making it easier to handle. In addition to this they are usually inexpensive and can be afforded by the avid gardener compared to the varieties that are run on gas or petrol. Detection is described on a 10-point scale where 10 is highest. The detect ability of failure varies from (1 = likely to be detected to10 = very unlikely to be detected.[1]

2.1 COMPONENTS OF ROTARY TILLER

The Rotary tiller has 5 main components (Fig-1)

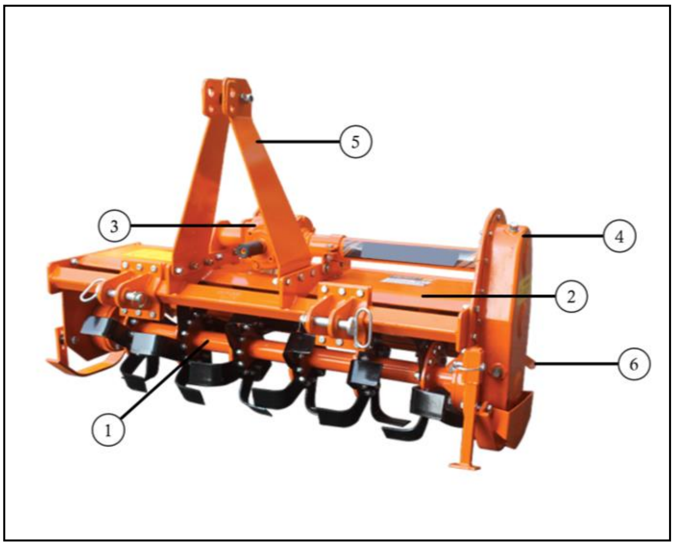

Fig-1: Five components of Rotary Tiller

1. Rotor Shaft
2. Mainframe
3. Single/multi speed gearbox
4. Gear drive
5. Top mast/hitch
6. Bonnet flap

2.2 THE ASSEMBLY PROCESS OF ROTARY TILLER

The assembly process starts by placing the rotor shaft on a moving assembly trolley (Fig-2) with the help of an overhead crane. The trolley makes it easier for the operator to move the assembly forward in order to assemble next components and the crane makes it easier to lift, drop, and hold the components in place while assembling them. Almost all components are lifted and assembled using the overhead crane. Once the rotor shaft is placed on the trolley, a gear plate is mounted on one side of the rotor shaft and another side plate is mounted on the other side of the rotor shaft (Fig-3). The pre-fabricated mainframe is then mounted between these two plates with nuts & bolts. The supports/holders which hold the gearbox and its shaft in place are then mounted on the mainframe. Then the gearbox itself is mounted on the mainframe. The gear drive which is made of three gears is then installed on the gear plate. The power from the gearbox is transmitted to the rotor shaft through the gear drive. The top mast/hitch is then mounted on the mainframe and the gear drive is covered with gear cover. At last, the bonnet flap is mounted on the mainframe with the bonnet rod by inserting it through the bonnet flap and bushes of the mainframe. Finally, the entire assembly is sent for testing.

Fig-2: Assembly Trolley with rotor shaft

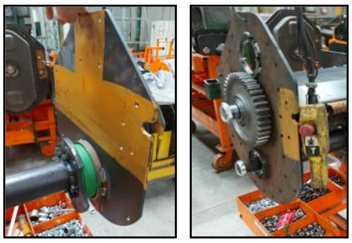

Fig-3: Gear side & other side plate

2.3 FLOW PROCESS CHART

A Flow Process Chat is a symbolic representation that illustrates the sequence of activities within a process. It is used to record and analyse the activities that make up a process to determine which add value and which do not. Activities can be any operation, inspection, storage, transportation, and delay actions that are carried out by an individual person, a team, a machine, a computer system, or a combination of all. Flow process charts are preferred over other process mapping techniques when the process is sequential in nature and contains few decision points. For this reason, it is sometimes referred to as 'process sequence chart'. A useful feature of this technique is that it can be drawn up as the process is happening, thus providing an accurate description of the process. Later on, and when analysing the process, some steps become obvious candidates for improvement, such non-value-added activities, long delays and excessive transportation. There are three common types of flow process charts based on what is being charted. A man-type chart shows the activities of a person or group of people, a material-type chart shows what happens to a product or item as it moves, and an equipment-type chart shows the activities from the viewpoint of the machine or equipment involved. Activities are often recorded along a vertical or horizontal line using common symbols and descriptive words. These symbols have been accepted by many Lean practitioners and organizations. Other symbols can be used based on the situation. The following is a brief explanation of each of the five categories, along with examples for each of them:

- OPERATION (O): Produce, add, change, or process something.
- INSPECTION (□): Checking of items to ensure correct quality and/or quantity.
- STORAGE (▽): The storing of something until later time.
- TRANSPORT (⇨): The movement of people, materials, or other items between locations.
- DELAY (D): The temporary waiting of something or somebody.

2.4 CURRENT-STATE FLOW PROCESS CHART OF THE ASSEMBLY PROCESS

Table -1: Current-state flow process chart.

Flow Process Chart

Chart type: Man

Project: Reduction of assembly time for rotary tiller

Process: Assembly of Rotary Tiller

State: Current

Step #	Activity description	Time (minutes)	Distance (meters)	Operation ○	Transport ⇨	Inspection □	Delay D	Storage ▽	Value Category (VA,ENVA,NVA)	Inputs, outputs, rejection points, remarks, ...
1	Moves assembly trolley to position	0.16	1.5	X					VA	Assembly trolley is movable
2	Takes overhead crane to rotor stack	0.16	2		X				VA	
3	Mounts the rotor onto the crane	0.25		X					VA	
4	Brings the rotor to the trolley	0.33	2		X				VA	
5	Mounts it on the trolley and moves trolley forward	0.16		X					VA	
6	Takes overhead crane to G.S. plate stack	0.25	2		X				VA	
7	Mounts the plate onto the crane	0.33		X					VA	
8	Brings the G.S plate to the trolley	0.5	2		X				VA	
9	Mounts it on the rotor	1.5		X					VA	
10	Takes overhead crane to O.S. plate stack	0.25	2		X				VA	
11	Mounts the plate onto the crane	0.33		X					VA	
12	Brings the O.S plate to the trolley	0.5	2		X				VA	
13	Mounts it on the rotor and moves trolley forward	1.5		X					VA	
14	Takes overhead crane to Mainframe stack	0.25	2		X				VA	
15	Mounts the mainframe onto the crane	0.5		X					VA	
16	Brings the mainframe plate to the trolley	0.5	2		X				VA	
17	Mounts it on the rotor and moves trolley forward	4		X					VA	
18	Goes to gear shaft supporters	0.33	2		X				VA	
19	Paints them	0.25		X					VA	
20	Brings them to trolley	0.33	2		X				VA	
21	Mount them on the mainframe	1.5		X					VA	
22	Takes overhead crane to top Hitch stack	0.16	2		X				VA	
23	Mounts the top hitch onto the crane	0.25		X					VA	
24	Brings the top hitch to the trolley	0.33	2		X				VA	
25	Mounts it on the mainframe	1.5		X					VA	
26	Takes overhead crane to Gearbox stack	0.16	2		X				VA	
27	Mounts the gearbox onto the crane	0.33		X					VA	
28	Brings the gearbox to the trolley	0.33	2		X				VA	
29	Mounts it on the mainframe	2.5		X					VA	
30	Takes overhead crane to reinforce stack	0.16	2		X				VA	
31	Mounts the reinforce onto the crane	0.25		X					VA	
32	Brings the reinforce to the trolley	0.33	2		X				VA	
33	Mounts it on the mainframe	2		X					VA	
34	Goes to top/bottom gear stack	0.33	3		X				VA	
35	Brings the gears to the trolley	0.33	3		X				VA	
36	Mounts them on the G.S. plate	1		X					VA	
37	Goes to gear cover stack	0.25	3		X				VA	
38	Takes a gear cover and applies gasket onto it	1		X					VA	
39	Brings it to the trolley	0.25	3		X				VA	
40	Mount it on the G.S. plate	3		X					VA	
41	Goes to bonnet stack	0.25	4		X				VA	
42	Waits for another operator	4					X		NVA	The second operator leaves his work to join the first operator
43	Picks up a bonnet	0.5		X					VA	Both pick up the required bonnet
44	Brings it to the trolley	0.5	4		X				VA	Both carry it to the trolley
45	Waits for third person to bring the rod from rod stack	0.5					X		NVA	Rod is brought to the trolley by a third worker
46	Mounts the bonnet with rod on the mainframe	0.5		X					VA	All three people are involved
47	Sends the assembly for testing	0.25		X					VA	
48										
			Count:	23	22	0	2	0		
			Time per process step:	23.56	6.78	0	4.5	0		

2.5 OPERATION ANALYSIS

In current-state process, it was observed that, in some steps the operator took more time to travel a certain distance than the required standard time while in some other steps he took more time to perform certain operations than the required standard time. The distance travelled to get the gear-cover from its rack, apply gasket on it and return to mount it on the assembly is quite more than what it should be. This adds extra lead time to the process and can be reduced to shorten the distance travelled by the operator which in-turn reduces the time taken to perform this step. The non-availability of over-head crane to lift bonnets cause delays in the process. To lift the bonnet, the first operator is accompanied by a second operator who has to leave his process to join the first operator, also the bonnet-rod is brought to the station by a third operator and in this way the bonnet rod assembly is performed by three operators. This causes a substantial amount of delay in the processes of all operators. All these factors contribute to the excess lead time and the delays caused in the process.

The following results were obtained from the current-state flow process chart of the assembly process:

Table 2: Results from current-state flow process chart

Total VA	45		Total NVA	2		Total ENVA	0
VA Time	30.34	Minutes	NVA Time	4.5	Minutes	ENVA Time	0
Distance travelled	54	Meters	Lead Time	35	Minutes	VS Ratio	87.08%

The operator completes the assembly in 47 steps and covers a distance of 54 meters during the entire assembly process. In the entire process the total number of value-adding steps is 45 and it took the operator 30.34 minutes to complete them. While the total observed non-value-added steps were 2 and the operator spent about 4.5 minutes performing those steps. The total lead time then came out to be 35 minutes. Due to the delays and excess lead time, the ratio of value-added time to the lead time comes out to be 87% which is less than that of a standard ratio i.e., 100%.

The disadvantages of using an Intermittent production system are clearly visible here. The disadvantages of this system are as follows:

- It's a complex method. It offers customization, but without a standardized approach, and thus, these machines have a long manufacturing lead time.
- Production planning and scheduling is complicated since manufacturing orders (MOs) come in at different times.
- The raw materials and work-in-progress inventories remain high because of the irregular flow of work.

Additionally, the company uses 'Piece-rate pay' system which means the worker is paid per unit of creation i.e., one assembled machine. Although this system has some good advantages, it also has some concerning disadvantages. The disadvantages are as follows:

- It makes production difficult: It is difficult to predict how much machines can be assembled within a set time under this system, because the system doesn't easily lend itself to regulating and encouraging a production line.
- Risk of liability: Working for piece-rate pay means that workers might come to work when they are ill, thereby risking the health of their coworkers. This could shut down or seriously reduce production output. Additionally, depending on the materials and equipment, if workers are working too quickly in an attempt to produce more, workers could potentially injure themselves, which could open up the company to liability.
- Reduced quality: When the focus is on quantity, the output the quality may suffer. Such a system requires dedicated employees who are determined to learn their craft thoroughly and then to increase the output. Employees are human, however, and it can be difficult to work at a rapid pace over a long duration. This can mean that employees may continue to work at a rapid pace but that production may produce items of reduced quality.

3. PROPOSED METHODOLOGY

After studying and critically analyzing the current-state process, I developed and proposed a new method for the assembly process. In the proposed method all the issues, delays and addition of excess lead time in the process were addressed and eliminated. The proposed method suggested reduction of travel time of certain distances in some steps. Use of over-head crane was suggested to lift the bonnet which would then eliminate the need of a second worker required to help the first operator in lifting the bonnet. A change in layout was proposed to utilize the available cranes at their full capacity which would in-turn improve the productivity of the machines. The over-head cranes would reach the bonnet section and could pick the bonnet of required size. The shifting of gear-cover stack closer to the assembly station was also proposed to reduce the travel time of the operator in-turn reducing the excess lead time. In the proposed layout, it was also suggested that the tool station should be kept near the assembly station so that the operator travels less distance to grab the required tools for the assembly. This would significantly reduce the process time and number of steps involved in the process. Since the need for other operators is eliminated, there would be a substantial increase in productivity of the entire batch as each operator would not leave their station in order to accompany other operators to lift the bonnets.

3.1 FUTURE-STATE (PROPOSED) FLOW PROCESS CHART OF THE ASSEMBLY PROCESS

Table 3: Future-state (proposed) flow process chart.

Flow Process Chart

Chart type: Man

Project: Reduction of assembly time for rotary tiller | Process: Assembly of Rotary Tiller | State: Future

Step #	Activity description	Time (minutes)	Distance (meters)	Operation ○	Transport ⇨	Inspection □	Delay D	Storage ▽
1	Moves assembly trolley to position	0.16	1.5	X				
2	Takes overhead crane to rotor stack	0.16	2		X			
3	Mounts the rotor onto the crane	0.25		X				
4	Brings the rotor to the trolley	0.33	2		X			
5	Mounts it on the trolley and moves trolley forward	0.16		X				
6	Takes overhead crane to G.S. plate stack	0.16	2		X			
7	Mounts the plate onto the crane	0.25		X				
8	Brings the G.S plate to the trolley	0.33	2		X			
9	Mounts it on the rotor	1		X				
10	Takes overhead crane to O.S. plate stack	0.16	2		X			
11	Mounts the plate onto the crane	0.25		X				
12	Brings the O.S plate to the trolley	0.33	2		X			
13	Mounts it on the rotor and moves trolley forward	1		X				
14	Takes overhead crane to Mainframe stack	0.16	2		X			
15	Mounts the mainframe onto the crane	0.33		X				
16	Brings the mainframe plate to the trolley	0.33	2		X			
17	Mounts it on the rotor and moves trolley forward	3		X				
18	Goes to gear shaft supporters	0.25	2		X			
19	Paints them	0.16		X				
20	Brings them to trolley	0.16	2		X			
21	Mount them on the mainframe	1		X				
22	Takes overhead crane to top Hitch stack	0.16	2		X			
23	Mounts the top hitch onto the crane	0.25		X				
24	Brings the top hitch to the trolley	0.33	2		X			
25	Mounts it on the mainframe	1		X				
26	Takes overhead crane to Gearbox stack	0.16	2		X			
27	Mounts the gearbox onto the crane	0.33		X				
28	Brings the gearbox to the trolley	0.33	2		X			
29	Mounts it on the mainframe	2.5		X				
30	Takes overhead crane to reinforce stack	0.16	2		X			
31	Mounts the reinforce onto the crane	0.25		X				
32	Brings the reinforce to the trolley	0.33	2		X			
33	Mounts it on the mainframe	1		X				
34	Goes to top/bottom gear stack	0.08	1		X			
35	Brings the gears to the trolley	0	0		X			
36	Mounts them on the G.S. plate	1		X				
37	Goes to gear cover stack	0.08	1		X			
38	Takes a gear cover and applies gasket onto it	1		X				
39	Brings it to the trolley	0.08	1		X			
40	Mount it on the G.S. plate	1.5		X				
41	Goes to bonnet & rod stack	0.16	3		X			
42	Picks up a bonnet & a rod	0.16		X				
43	Brings it to the trolley	0.16	4		X			
45	Mounts the bonnet with rod on the mainframe	0.5		X				
46	Sends the assembly for testing	0.25		X				
47								
			Count:	23	22	0	0	0
			Time per process step:	17.3	4.4	0	0	0

VA.ENVA.NVA

Value Category	Inputs, outputs, rejection points, remarks, ...
VA	Assembly trolley is movable
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	
VA	Now, goes alone with the crane
VA	uses crane to pic up the bonnet
VA	
VA	Takes help of a second person if required
VA	

4. RESULTS

Table 4: Outcomes from proposed flow process chart

Total VA	45	Minutes	Total NVA	0	Minutes	Total ENVA	0
VA Time	21.7		NVA Time	0		ENVA Time	0
Distance travelled	44	Meters	Lead Time	22	Minutes	VS Ratio	100.0%

The entire process will be completed in 45 steps and the distance travelled by the operator will be reduced to 44 meters. Thus, the value-added time will come out to be 21.7 minutes. The elimination of the non-value-added steps, causing delays and resulting in excess lead time will bring down the total lead time of the process to 22 minutes. Hence the process will be free from any non-value-added steps and in-turn more efficient and productive that the current method. Thus, the ratio of value-added time to the lead time will be 100%.

5. CONCLUSIONS

The value added-time is reduced to 21.7 minutes from 30.34 minutes, which is 28.47% reduction in the lead time. Similarly, the Total lead time is reduced to 22 minutes from 35 minutes which is 37.14% reduction in the total lead time.

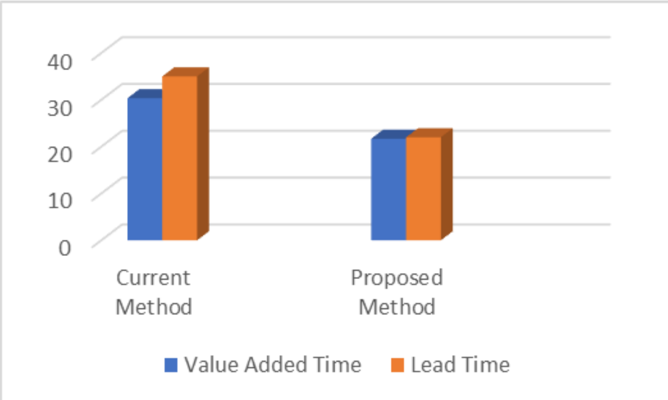

Chart -1: Difference in Value-added time and Lead time of current and proposed method

In the current state, the operator took 35 minutes to assemble one machine. In an 8 hour shift the operator is given total allowances of 80 minutes. Thus, the operator works for 400 minutes and assembles 11 machines in that period of time. But in the proposed method the time required for an operator to assemble a machine is 22 minutes. Thus, the operator can assemble up to 18 machines in his 8 hours shift. Which is 63.63% increase in the number of machines assembled by a single operator.

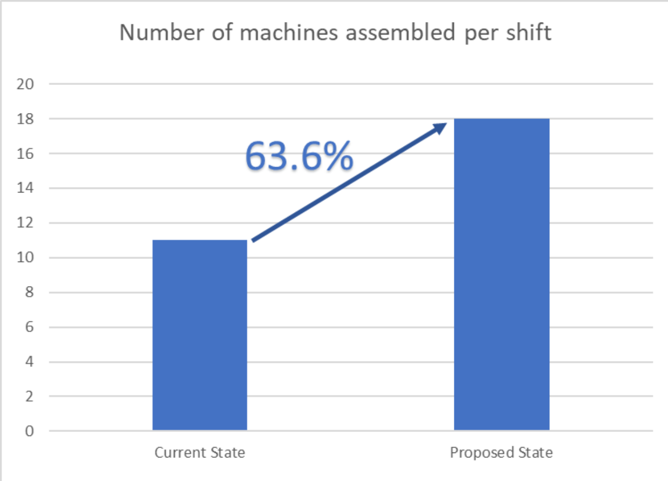

Chart -2: Increase in the number of machines assembled by a single operator.

Since,
Performance Index = 100*(Time required to assemble a unit * Total number of units assembled)/working time of the operator

The performance index of the operator in the current state is
P.I.= 100*(35*11)/400 = 96.25%

Whereas the performance index of the operator in the proposed state is
P.I.= 100*(22*18)/400 = 99%

Thus, the productivity index of operator increases by 2.75%.

Table 5: Comparison of number of machines assembled in Current & Proposed State

	Current State	Proposed State
Number of machines assembled per shift	11	18
Time taken for assembly of 1 machine	35 minutes	22 minutes
Direct labour hours	8 hours	8 hours

Thus, the labour productivity index (LPI) comes out to be:

LPI = 100*(18*8) / (11*8) = 163.63%.

And, Total percentage increase in output of a single operator comes out to be 63.63%.

Also, the assembly time is reduced 22 minutes, which is a reduction of 13 minutes or 37.14% from the time required in current state method.

Increased Profitability:
Since, productivity and profitability are directly related to each other, the increase in productivity increases the profitability. A high rate of productivity in a company ensures that the company is profitable. Thus, reduction in the time taken by an operator to assemble a machine will result into greater number of outputs which in turn increases company's capacity to produce and generate profit from increased number of sales without affecting the level of customization and variety offered to the customer.

REFERENCES

[1] Jeevarathinam.A, Velmurugan.C, “Design Modification and Analysis of Rotavator Blade,” IOSR Journal of Mechanical and Civil Engineering, pp. 43-50.

[2] I.P. Troyanovskayaa,b , B.M. Pozinb, N.K. Noskovb,“Ploughing Tractor Lateral Withdrawal Model”, International Conference on Industrial Engineering, ICIE 2017, pp. 1540-1545.

[3] Maurizio Cutini, Massimo Brambilla, Carlo Bisaglia. “Assessment of a ride comfort number for agricultural tractors: A simplified approach”, Biosystems engineering, pp. 35-44

[4] S. Yuki H. Yasuda T. Matsubayashi H. Ishizuka, “Development of Tractor Automatic Controlled Boom Sprayer Using CAN-BUS”, 4th IFAC Conference on Modelling and Control in Agriculture, Horticulture and Post-Harvest Industry, August 27-30, 2013. Espoo, Finland

[5] Amardeep Singh Kanga, Gurmeet Singh Cheemaa, Shivali Singlab,” Wear behavior of hardfacings on rotary tiller blades”, Procedia Engineering 97 (2014) 1442 – 1451

[6] Ming-Zhang Song, Sin-Woo Kang, Sun-Ok Chung, Ki-Dae Kim, Young-Seok Chae, Dae-Hyun Lee, Yong-Joo Kim, Seung-Hwa Yu, Kyeong-Hwan Lee, “Development of Path Planning Algorithm for an Autonomous Mower Tractor”, 4th IFAC Conference on Modelling and Control in Agriculture, Horticulture and Post-Harvest Industry, August 27-30, 2013. Espoo, Finland.

[7] Shantideo gujar & manish r. Moroliya, “increasing the productivity by using work study in a manufacturing industry - literature review”, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 8, Issue 2, Apr 2018, 369-374

[8] S. Nallusamy, S. Muthamizhmaran,” enhancement of productivity and overall equipment efficiency using time and motion study technique -a review”, Advanced Engineering Forum Vol. 14 (2016) pp 55-62.

[9] Mutombozana Tapiwa, Mugwindiri Kumbirayi , Chikuku Tauyanashe,“The use of Work Study Techniques in Optimizing Manufacturing Plant Maintenance Processes: an Investigation into a Fertilizer Manufacturing Company in Zimbabwe”, International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, Volume 2 Issue 2, February 2013, pp 98-103.

[10] https://www.nibusinessinfo.co.uk/content/improve-productivity-increase-profits

[11] https://katanamrp.com/blog/intermittent-production/

[12] https://www.corporatesuites.com/productivity-and-profitability-relationship

[13] D.Ramesh Kumar and P.Mohanraj, “Design and Analysis of Rotavator Blades for its Enhanced Performance in Tractors”, Asian Journal of Applied Science and Technology (AJAST), Volume 1, Issue 1, Pages 160-185, February 2017.

[14] Introduction to work study. (3RD ED.). (1979). National Book Foundation. ISBN: 922101939X