



## Effect of Combined Processing Lines on Production Efficiency and Productivity



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**Abstract:** The production process usually involves several processes that are divided into production lines. The processes in this production line affect the costs incurred by the company. From the analysis results, the costs arising from production line activities are very high. Therefore, the company strives to reduce production costs by paying attention to the aspects that result in the emergence of waste. The method used is by combining the process on the machining line. This study was conducted to find out the effect of combining process lines on production efficiency. The results of this study are expected to be an input in determining production planning in the enterprise. This study didn't use sampling. From the results of the study, there was an increase in the daily production of gear A (0.86%) and gear B (1.12%). From this merger, the company was able to optimize manpower and cut production WIP storage areas.

**Keywords:** Production process; Waste, Machining line; Combining process

### 1. Introduction

Companies are required to set the right strategy to win the competition in the era of globalization. To support this strategy, it can be done through efficiency and productivity by defining the right production system [1-5]. For example, in a manufacturing company that produces components for motor vehicles, the production system available within the company is very important. If the demand for production is high, or there is a demand for new products, an effective system must be considered so that there are no delays. Production planning will influence the production scheduling process. Scheduling is a measurement tool for aggregate planning. Production scheduling in the industrial world, both the manufacturing industry and the agro industry has an important role as a form of decision making [6]. Some of the aspects affected by the production process include cost, productivity, profitability, manpower and equipment. To produce the best output and maximize production results, a lean manufacturing approach can be used. In principle, lean focuses on eliminating waste and reducing Non-Value Added activities in the process, while at the same time maximizing activities that provide Value Added to the final product in accordance with customer demand [3, 7, 8].

A manufacturing company involved in the manufacture of automotive components (Gear & Shaft) conducts research on the production line. From the analysis results found several problems, namely in the production process of Gear A and Gear B there are many points in the process that do not provide added value, the difference in cycle time of each production process causes WIP between machining process and inefficient operator performance. The idea proposed by the production department is that several line processes on the machining line become one track [9]. This idea is believed to increase the effectiveness and productivity of line machines. Non-value-added activities will be reduced or eliminated, storage and manpower will be optimized. With this idea, it is hoped that all problems will be solved and the production process can be more controlled. The basic objective of this research is how companies can increase production volumes through optimization and efficiency of human resources [10]. This goal will be achieved if with this merger the company can eliminate waste, increase productivity and production efficiency [8]. This study only discusses process liner merging on special line machining of gear A and gear B. The data used are data layout, cycle time, and operators involved in the work before and after track merging.

## 2. Methodology

Total Productive Maintenance (TPM) is an approach that is in line with the Lean Manufacturing philosophy. This approach is the most effective method of significantly increasing a company's productivity through the elimination of waste, including any activities, processes or investments that do not add value to a product [1]. The lean approach is expected to reduce waste from the production process and minimize costs [11, 12]. Lean can identify time in each production activity to improve productivity and quality [13]. Cycle time is important for companies to increase profitability and competitiveness by eliminating waste [14, 15]. In an effort to improve productivity and quality, workstation balance in the production process is a common problem in the Manufacturing Industry. Problems of late delivery, long queues, and high inventory in the process, improper use are fundamental problems that often occur in the industry resulting in increased overall production costs [6]. Small to large scale production processes require adjustment of production flow by going through different processes according to the process speed [16]. Reasons for the implementation of the TPM include; improve machine reliability and capacity; fulfillment in providing continuity of production processes; job safety; preventive measures; support the fulfillment of customer demands; reduce the causes of failure; good engine control; and process improvements [17, 18].

The data of this study was taken from one of the line machining machine manufacturing companies located in West Java - Indonesia. Research data collection methods were conducted in several ways, namely through observations, interviews, and literature study. Observations are made by making direct observations of the study object to ensure the conformity of the data listed on the line with the actual results of the work in line machining. The data collected in the observations included data on machine cycle time, available time, idle time, production volume, number of employees, and WIP volume. To complete and make data adjustments, interviews were conducted with leaders and several operators in line machining. The data collected is in the form of a resume from the data obtained and the detailed data obtained becomes the confidential data of the company. This study discusses the productivity of the production process of the manufacturing industry, so that the data format is appropriate to the method used. Interviews conducted on online operators cover the activities of online operators in carrying out their work in each process. The analysis in this study is aimed at processing time and the number of products processed. In this study, the efficiency of processing time is the main point and improvements to the production process method resulting in operator demand and labor costs are alternative improvements. The processing time used is the average obtained from several online operators in each process. To support this research, a library study was conducted by reading some literature, scholarly essays and other library materials related to this research. The data obtained are then processed and the results are analyzed until finally conclusions are obtained.

## 3. Results

In a manufacturing company, the production process is grouped into several production process lines when production demand continues to increase, companies are asked to make continuous increases so that large amounts of demand do not hinder production scheduling [19, 20]. One of the points targeted for improvement is waste in the production process. Since most of the activity is in the field of machining, the company conducts a study on the waste that arises in the flow of the production process in the machining lines. In the machining line, there are 2 types of products with high demand every month, namely gear A and gear B. Research is done by identifying the waste that arises in the machining process of these two products. The following is the production process flow for gear A and gear B before combining the process lines (Figure 1).

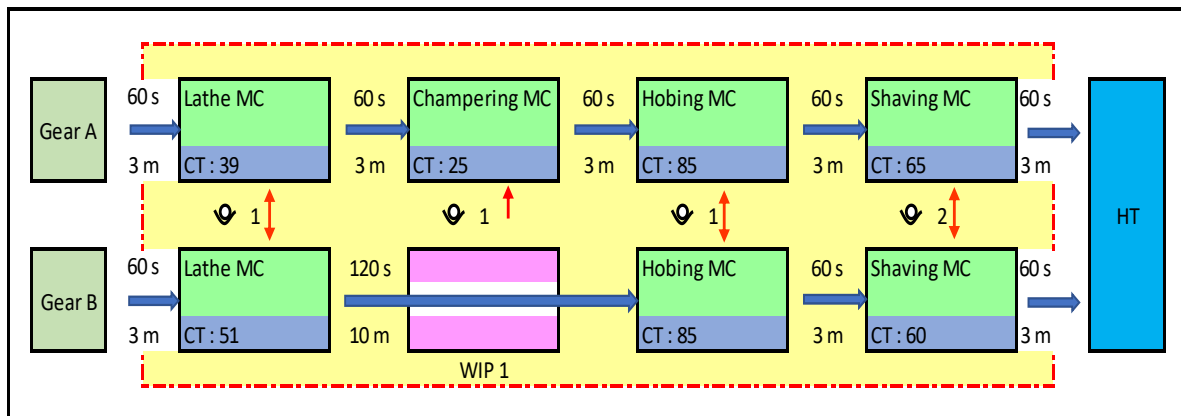


Figure 1. Initial machining lines layout

From the picture above, it can be seen that in the production process of gear A and gear B, there are several process strips with different machine rotation times. Time differences tend to cause wastage in the production process. The research was furthered by collecting data on the activities of machines and operators involved in the production. The following is data on machines and operators activity in each process line before making improvements.

a. Operator and Machine Activity in lathe MC

Base on Table 1, total idle time operator per day is 14880. Since there are 3 shifts on the lathe line, the inactive time for each operator is  $14880/3 = 4960$  s.

Base on Table 2, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

**Table 1.** Lathe MC operator activity

| <b>Lathe Operator (1 Person/Shift)</b>                        |     |               |           |     |               |           |           |
|---|-----|---------------|-----------|-----|---------------|-----------|-----------|
| <b>Operator Activity / Day (7 hours x 3 shift = 75.600 s)</b> |     |               |           |     |               |           |           |
| Activity  | Qty | MC L1         |           | Qty | MC L2         |           | Total (s) |
|   |     | Time Unit (s) | Total (s) |     | Time Unit (s) | Total (s) |           |
| Take material   | 6   | 60            | 360       | 6   | 60            | 360       |           |
| Loading   | 9   | 900           | 8100      | 7   | 900           | 6300      |           |
| Setting   | 3   | 1800          | 5400      | 3   | 1800          | 5400      |           |
| Inspection  | 9   | 300           | 2700      | 9   | 300           | 2700      |           |
| Tool Changes  | 3   | 600           | 1800      | 2   | 600           | 1200      |           |
| Unloading   | 3   | 4200          | 12600     | 3   | 4200          | 12600     |           |
| Transfer to next line   | 8   | 60            | 480       | 6   | 120           | 720       |           |
| Total activity  |     |               |           |     |               | 60720     |           |
| Idle  |     |               |           |     |               | 14880     |           |

**Table 2.** Lathe MC machine activity

| <b>Lathe MC</b>   |       |     |       |     |  |
|-------------------|-------|-----|-------|-----|--|
|                   | MC L1 |     | MC L2 |     |  |
| Available Times   | 75600 | s   | 75600 | s   |  |
| Setting           | 5400  | s   | 5400  | s   |  |
| Tool Changes      | 1800  | s   | 1200  | s   |  |
| Operation Times   | 68400 | s   | 69000 | s   |  |
| MC Productivity   | 90%   |     | 91%   |     |  |
| Cycle time        | 39    | s   | 51    | s   |  |
| Available Product | 1754  | Pcs | 1353  | Pcs |  |

b. Operator and Machine Activity in Chamfering MC

Base on Table 3, total idle time operator per day is 21120. Since there are 2 shifts, the inactive time for each operator is  $21120/2 = 10560$  s.

Base on Table 4, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

**Table 3.** Chamfering MC operator activity

| <b>Chamfering Operator (1 Person/Shift)</b>                   |     |               |           |
|---|-----|---------------|-----------|
| <b>Operator Activity / Day (7 hours x 2 shift = 50.400 s)</b> |     |               |           |
| Activity  | Qty | MC C1         |           |
|   |     | Time Unit (s) | Total (s) |
| Take material   | 9   | 900           | 8100      |
| Loading   | 3   | 600           | 1800      |
| Setting   | 9   | 300           | 2700      |
| Tool Changes  | 1   | 3600          | 3600      |
| Unloading   | 3   | 4200          | 12600     |
| Transfer to next line   | 8   | 60            | 480       |
| Total activity  |     |               | 29280     |
| Idle  |     |               | 21120     |

**Table 4.** Chamfering MC machine activity

| <b>Chamfering MC C1</b> |       |     |
|-------------------------|-------|-----|
| Available Times         | 50400 | s   |
| Setting                 | 1800  | s   |
| Tool Changes            | 3600  | s   |
| Operation Times         | 45000 | s   |
| MC Productivity         | 89%   |     |
| Cycle time              | 25    | s   |
| Available Product       | 1800  | Pcs |
| Parts after Lathe       | 1754  | Pcs |
| Processing Times        | 43846 | s   |
| Idle                    | 1154  | s   |

## c. Operator and Machine Activity in Hobbing MC

Base on Table 5, total idle time operator per day is 19320. Since there are 3 shifts, the inactive time for each operator is  $19320/3 = 6440$  s.

Base on Table 6, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

**Table 5.** Hobbing MC operator activity

| <b>Hobbing Operator (1 Person/Shift)</b>                      |       |               |           |       |               |           |
|---|-------|---------------|-----------|-------|---------------|-----------|
| <b>Operator Activity / Day (7 hours x 3 shift = 75.600 s)</b> |       |               |           |       |               |           |
| Activity  | MC H1 |               |           | MC H2 |               |           |
|   | Qty   | Time Unit (s) | Total (s) | Qty   | Time Unit (s) | Total (s) |
| Loading   | 3     | 4000          | 12000     | 3     | 4000          | 12000     |
| Setting   | 3     | 1800          | 5400      | 3     | 1800          | 5400      |
| Inspection  | 9     | 300           | 2700      | 9     | 300           | 2700      |
| Tool Changes  | 1     | 1800          | 1800      | 1     | 1800          | 1800      |
| Unloading   | 3     | 2000          | 6000      | 3     | 2000          | 6000      |
| Transfer to next line   | 4     | 60            | 240       | 4     | 60            | 240       |
| Total activity  |       |               |           |       | 56280         |           |
| Idle  |       |               |           |       | 19320         |           |

**Table 6.** Hobbing MC machine activity

| <b>Hobbing MC</b> |       |     |       |     |  |
|-------------------|-------|-----|-------|-----|--|
|                   | MC H1 |     | MC H2 |     |  |
| Available Times   | 75600 | s   | 75600 | s   |  |
| Setting           | 5400  | s   | 5400  | s   |  |
| Tool Changes      | 1800  | s   | 1800  | s   |  |
| Operation Times   | 68400 | s   | 68400 | s   |  |
| MC Productivity   | 90%   |     | 90%   |     |  |
| Cycle time        | 85    | s   | 85    | Pcs |  |
| Available Product | 805   | Pcs | 805   | Pcs |  |

## d. Operator and Machine Activity in Shaving MC

**Table 7.** Shaving MC operator activity

| <b>Shaving Operator (1 Person/Shift)</b>                      |       |               |           |       |               |           |
|---|-------|---------------|-----------|-------|---------------|-----------|
| <b>Operator Activity / Day (7 hours x 3 shift = 75.600 s)</b> |       |               |           |       |               |           |
| Activity  | MC S1 |               |           | MC S2 |               |           |
|   | Qty   | Time Unit (s) | Total (s) | Qty   | Time Unit (s) | Total (s) |
| Loading   | 12    | 1200          | 14400     | 12    | 1200          | 14400     |
| Setting   | 3     | 1800          | 5400      | 3     | 1800          | 5400      |
| Inspection  | 9     | 1800          | 16200     | 9     | 1800          | 16200     |
| Tool Changes  | 1     | 1800          | 1800      | 3     | 1800          | 5400      |
| Unloading   | 12    | 2000          | 24000     | 12    | 2000          | 24000     |
| Transfer to next line   | 4     | 60            | 240       | 4     | 60            | 240       |
| Total activity  |       |               |           |       | 127680        |           |
| Idle  |       |               |           |       | 23520         |           |

Base on Table 7, total idle time operator per day is 23520. Since there are 3 shifts and 2 operators per day, the inactive time for each operator is  $23520/6 = 3920$  s.

**Table 8.** Shaving MC machine activity

| Shaving MC          |       |     |       |     |  |
|---------------------|-------|-----|-------|-----|--|
| MC S1               | MC S1 |     | MC S2 |     |  |
| Available Times     | 75600 | s   | 75600 | s   |  |
| Setting             | 5400  | s   | 5400  | s   |  |
| Tool Changes        | 1800  | s   | 1800  | s   |  |
| Operation Times     | 68400 | s   | 68400 | s   |  |
| MC Productivity     | 90%   |     | 90%   |     |  |
| Cycle time          | 65    | s   | 60    | s   |  |
| Available Product   | 1052  | Pcs | 1140  | Pcs |  |
| Parts after Hobbing | 805   | Pcs | 805   | Pcs |  |
| Processing Times    | 52325 | s   | 48300 | s   |  |
| Idle                | 16075 | s   | 20100 | s   |  |

Base on Table 8, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

Results of the observations made above, it can be seen the points that result in wastage that affect the cost of the company. The following is the identification data on the process lines of gear A and gear B.

**Table 9.** Identification of machining process gear A per day

| MC    | Available Time (s) | Processing Time (s) | CT | Capacity (pcs) | In (pcs) | Out (pcs) | Idle (s) | WIP (pcs) |
|-------|--------------------|---------------------|----|----------------|----------|-----------|----------|-----------|
| MC L1 | 75600              | 68400               | 39 | 1754           |          | 1754      | -        | -         |
| MC C1 | 50400              | 45000               | 25 | 1800           | 1754     | 1754      | 43846    | -         |
| MC H1 | 75600              | 68400               | 85 | 805            | 1754     | 805       |          | 949       |
| MC S1 | 75600              | 68400               | 65 | 1052           | 805      | 805       | 16075    | 949       |

Base on Table 9, process of gear A there are 2 units waiting machines (chamfer MC and shaving MC) and there is WIP before the hobbing and shaving process.

**Table 10.** Identification of machining process gear B per day

| MC    | Available Time (s) | Processing Time (s) | CT | Capacity (pcs) | In (pcs) | Out (pcs) | Idle (s) | WIP (pcs) |
|-------|--------------------|---------------------|----|----------------|----------|-----------|----------|-----------|
| MC L2 | 75600              | 69000               | 51 | 1353           |          | 1353      | -        | -         |
| MC H2 | 75600              | 68400               | 85 | 805            | 1353     | 805       | -        | 548       |
| MC S2 | 75600              | 68400               | 60 | 1140           | 805      | 805       | 20100    | 548       |

Base on Table 10, process of gear A there are 1 unit waiting machines (shaving MC) and there is WIP before the hobbing and shaving process.

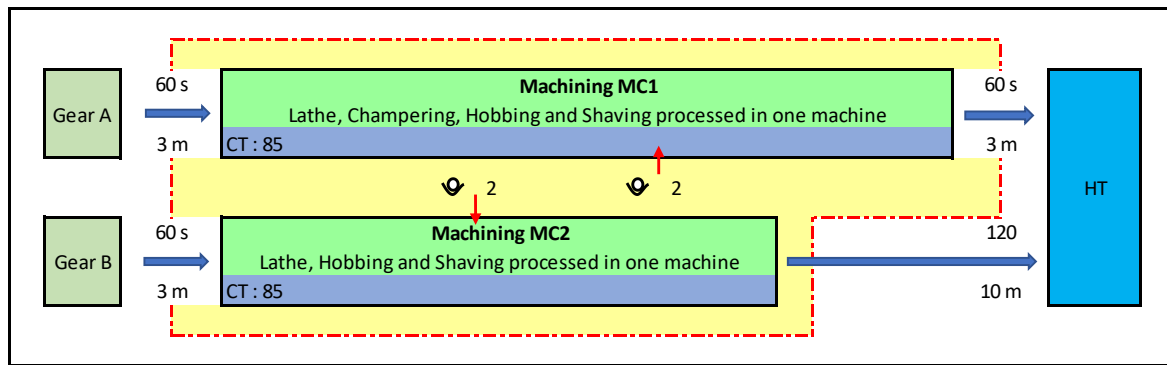
Base on Table 11, it can be seen that the standby time (idle time operator) of the chamfering machine is more than on other machines. Conclusion above three data, it can be seen that there are several points that can be improved, namely in the area of WIP, operator and waiting times. Improvements are made by combining process lines into one machining process line. The following is the production process flow of product A and product B after combining the line process (Figure 2).

**Table 11.** Data of operator for machining process gear A and gear B

| OP    | Per Shift | Shift | Sub total | Idle per Line (s) | Idle per Operator (s) |
|-------|-----------|-------|-----------|-------------------|-----------------------|
| MC L  | 1         | 3     | 3         | 14880             | 4960                  |
| MC C  | 1         | 2     | 2         | 21120             | 10560                 |
| MC H  | 1         | 3     | 3         | 19320             | 6440                  |
| MC S  | 2         | 3     | 6         | 23520             | 3920                  |
| Total |           |       | 14        | 78840             |                       |

#### 4. Discussion

Next, we take data on machine activity and machine operators in the new machining lines as in previous data collection. Operator and machine activity data on the new machining line are as follows in Figure 2.



**Figure 2.** Machining line layout after combining line process

a. Operator and Machine Activity Machining gear A

Base on Table 12, total idle time operator per day is 27960. Since there are 3 shifts and 2 operators per day, the inactive time for each operator is  $27960/6 = 4660$  s.

Base on Table 13, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

**Table 12.** Operator activity machining MC gear A

| <b>Machining Operator Gear A (2 Person/Shift)</b>             |     |               |           |
|---|-----|---------------|-----------|
| <b>Operator Activity / Day (7 hours x 3 shift = 75.600 s)</b> |     |               |           |
| Activity  | Qty | Time Unit (s) | Total (s) |
| Take materials  | 5   | 60            | 300       |
| Loading   | 9   | 900           | 8100      |
| Setting   | 3   | 1200          | 3600      |
| Inspection  | 9   | 3600          | 32400     |
| Tool Changes  | 1   | 3000          | 3000      |
| Unloading   | 18  | 4200          | 75600     |
| Transfer to the next line                                     | 4   | 60            | 240       |
| Total Activity  |     |               | 123240    |
| Idle  |     |               | 27960     |

**Table 13.** Operator activity machining MC gear A

| <b>Machining MC Gear A</b> |        |     |
|----------------------------|--------|-----|
| Available Times            | 75600  | s   |
| Setting                    | 3600   | s   |
| Tool Changes               | 3000   | s   |
| Operation Times            | 69000  | s   |
| MC Productivity            | 91.27% |     |
| Available Product          | 812    | Pcs |

b. Operator and Machine Activity Machining gear B

**Table 14.** Operator activity machining MC gear B

| <b>Machining Operator Gear B (2 Person/Shift)</b>               |     |               |           |
|---|-----|---------------|-----------|
| <b>Operator Activities / Day (7 hours x 3 shift = 75.600 s)</b> |     |               |           |
| Activity  | Qty | Time Unit (s) | Total (s) |
| Take materials  | 5   | 60            | 300       |
| Loading   | 9   | 900           | 8100      |
| Setting   | 3   | 1200          | 3600      |
| Inspection  | 9   | 3600          | 32400     |
| Tool Changes  | 1   | 2800          | 2800      |
| Unloading   | 18  | 4200          | 75600     |
| Transfer to the next line                                       | 4   | 60            | 240       |
| Total Activity  |     |               | 123040    |
| Idle  |     |               | 28160     |

Base on Table 14, total idle time operator per day is 28160. Since there are 3 shifts and 2 operators per day, the inactive time for each operator is  $28160/6 = 4693s$ .

**Table 15.** Operator activity machining MC gear A

| <b>Machining MC Gear B</b> |        |     |
|----------------------------|--------|-----|
| Available Times            | 75600  | s   |
| Setting                    | 3600   | s   |
| Tool Changes               | 2800   | s   |
| Operation Times            | 69200  | s   |
| MC Productivity            | 91.53% |     |
| Available Product          | 814    | Pcs |

Base on Table 15, operation times is the result of the calculation of available times minus lost times (setting and tool changes). Machine Productivity is the result of calculating the operation times divided by the available times.

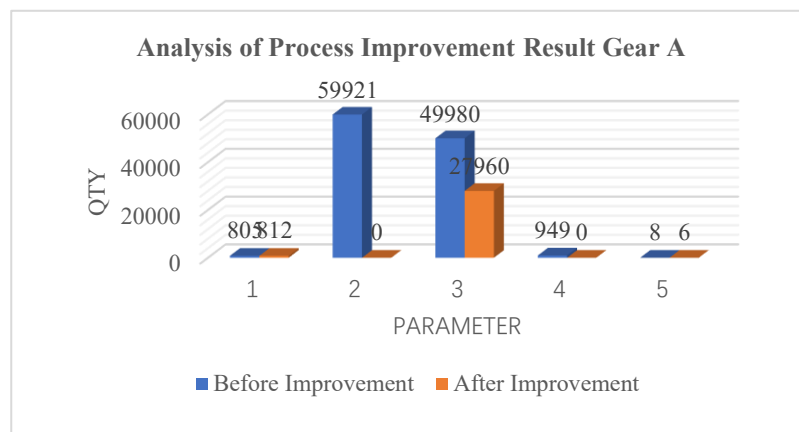
On machining gear A and machining gear B, there is a change in the quantity of produce due to the change in the faster machine setting time so that the productivity of the machine also increases. The next step is to analyze the data before with the data after the improvement. The comparative analysis data obtained from this study are arranged in the following tables (Tables 16 and 17) and graphs (Figures 3 and 4):

c. Effectiveness Comparison Data on Machining Process Gear A

Base on Table 16, production process of Gear A shows that idle time of machine is eliminated and idle time of manpower has been reduced by 44.06%. Furthermore, WIP is disappears and the number of workers is reduced from 8 manpower to 6 manpower.

**Table 16.** Effectiveness comparison data gear A

| No | Parameter             | <b>Gear A</b> |        |              |        |
|----|-----------------------|---------------|--------|--------------|--------|
|    |                       | <b>Before</b> |        | <b>After</b> |        |
| 1  | Output                | 805           | Pcs    | 812          | Pcs    |
| 2  | Idle times of machine | 59921         | s      | 0            | s      |
| 3  | Idle time of manpower | 49980         | s      | 27960        | s      |
| 4  | WIP                   | 949           | Pcs    | 0            | Pcs    |
| 5  | Qty manpower          | 8             | Person | 6            | Person |

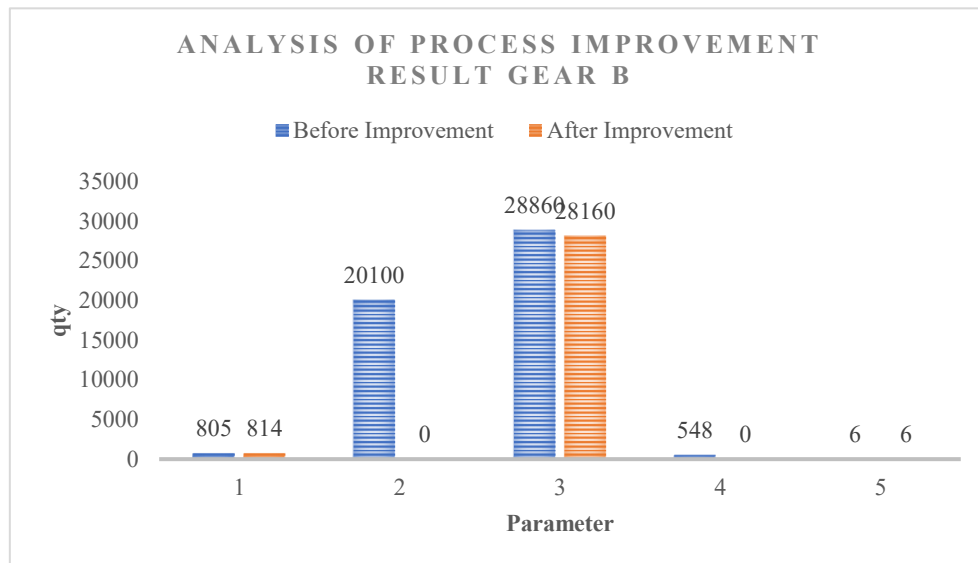


**Figure 3.** Effectiveness comparison chart gear A

d. Effectiveness Comparison Data on Machining Process Gear B

**Table 17.** Effectiveness comparison data gear B

| No | Parameter             | <b>Gear B</b> |        |              |        |
|----|-----------------------|---------------|--------|--------------|--------|
|    |                       | <b>Before</b> |        | <b>After</b> |        |
| 1  | Output                | 805           | Pcs    | 814          | Pcs    |
| 2  | Idle times of machine | 20100         | s      | 0            | s      |
| 3  | Idle time of manpower | 28860         | s      | 28160        | s      |
| 4  | WIP                   | 548           | Pcs    | 0            | Pcs    |
| 5  | Qty manpower          | 6             | Person | 6            | Person |



**Figure 4.** Effectiveness comparison chart gear B

Base on Table 17, production process of Gear A shows that idle time of machine is eliminated, idle time of manpower has been reduced by 2,42% and WIP is disappears.

## 5. Conclusions

Based on the results of the study, it can be concluded that the incorporation of these process lines is very influential on the effectiveness and productivity of production. The merger has successfully made changes to the effectiveness of production, use of area and manpower. In terms of productivity, there was an increase in daily production of gear A from 805 to 812 (up 0.86%) and gear B from 805 to 814 (up 1.12%). then with this change the company can also optimize the use of operators from a total of 14 people to 12 people (for 3 shifts). With this process line process also the company can use the area used for WIP goods so that the control process is easier, and the process flow is more organized. The mathematical model used is a standard calculation used to determine each activity time of each process. The Manufacturing Process of Gear A and Gear B cannot be combined due to machine limitations and the dimensions of each Gear. The results of this study will be used as input in determining production planning in the company.

## Data Availability

Not applicable.

## Conflicts of Interest

The authors declare no conflict of interest.

## References

- [1] M. J. A. Pinto and J. V. Mendes, "Operational practices of lean manufacturing: Potentiating environmental improvements," *J. Ind. Eng. Manag.*, vol. 10, no. 4, pp. 550-580, 2017. <http://dx.doi.org/10.3926/jiem.2268>.
- [2] A. Sanders, C. Elangeswaran, and J. Wulfsberg, "Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing," *J. Ind. Eng. Manag.*, vol. 9, no. 3, pp. 811-833, 2016. <http://dx.doi.org/10.3926/jiem.1940>.
- [3] J. Kaneku-Orbegozo, J. Martinez-Palomino, F. Sotelo-Raffo, and E. Ramos-Palomino, "Applying Lean Manufacturing Principles to reduce waste and improve process in a manufacturer: A research study in Peru," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 689, no. 1, 2019. <http://dx.doi.org/10.1088/1757-899X/689/1/012020>.
- [4] A. Ariffien and D. Rosminingsih, "Lean manufacturing approach to minimize waste production parts STN Wfx000 RIB at the prismatic medium machine 2 in PT X," *Int. Rev. Manag. Mark.*, vol. 6, no. S8, pp. 310-314, 2016.



- [5] Z. Cekerevac, Z. Dvorak, and L. Prigoda, "Lean manufacturing vs COVID-19," *MEST J.*, vol. 10, no. 1, pp. 1-11, 2022. <http://dx.doi.org/10.12709/mest.10.10.01.01>.
- [6] F. E. K. O. Putra, Z. F. Ikatrinasari, and H. H. Purba, "Waste analysis and lean manufacturing development in heavy equipment component industry," *Int J. Mech. Prod. Eng. Res. Dev.*, vol. 10, no. 3, pp. 14233-14242, 2020.
- [7] F. H. Awan, D. Liu, K. Jamil, S. Mustafa, M. Atif, R. F. Gul, and G. Y. Qin, "Mediating role of green supply chain management between lean manufacturing practices and sustainable performance," *Front. Psychol.*, vol. 12, pp. 1-11, 2022. <http://doi.org/10.3389/fpsyg.2021.810504>.
- [8] R. Nagaich, "Lean concept implementation practices in small and medium scale pharmaceutical industry- a case study," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 10, no. 1, pp. 213-220, 2022. <http://dx.doi.org/10.22214/ijraset.2022.39811>.
- [9] S. Neha, M. G. Singh, K. Simran, and G. Pramod, "Lean manufacturing tool and techniques in process industry," *Int. J. Sci. Res. Rev.*, vol. 2, no. 1, pp. 54-63, 2013.
- [10] A. Dixit, V. Dave, and A. P. Singh, "Lean manufacturing: An approach for waste elimination," *Int. J. Eng. Res.*, vol. 4, no. 4, pp. 532-536, 2015. <http://dx.doi.org/10.17577/IJERTV4IS040817>.
- [11] K. A. El-Namrouty, "Seven wastes elimination targeted by lean manufacturing case study "Gaza Strip Manufacturing Firms"," *Int. J. Econ. Financ. Manag. Sci.*, vol. 1, no. 2, pp. 68-68, 2013. <http://dx.doi.org/10.11648/j.ijefm.20130102.12>.
- [12] J. P. Womack and D. T. Jones, "Lean thinking-Banish waste and create wealth in your corporation," *J. Oper. Res. Soc.*, vol. 48, no. 11, pp. 1148-1148, 1997. <http://dx.doi.org/10.1038/sj.jors.2600967>.
- [13] P. Puvanasvaran, H. Megat, T. S. Hong, M. M. Razali, and H. A. Magid, "Lean process management implementation through enhanced problem solving capabilities," *J. Ind. Eng. Manag.*, vol. 3, no. 3, pp. 447-493, 2010. <http://dx.doi.org/10.3926/jiem.2010.v3n3>.
- [14] W. M. Goriwondo, S. Mhlanga, and A. Marecha, "Use of the value stream mapping tool for waste reduction in manufacturing case study for bread manufacturing in zimbabwe," In Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia, January 22-24, 2011, pp. 236-241.
- [15] S. Nallusamy and M. A. Adil Ahamed, "Implementation of lean tools in an automotive industry for productivity enhancement - a case study," *Int. J. Eng. Res. Africa*, vol. 29, pp. 175-185, 2017. <http://dx.doi.org/10.4028/www.scientific.net/jera.29.175>.
- [16] N. Vamsi Krishna Jasti and A. Sharma, "Lean manufacturing implementation using value stream mapping as a tool," *Int. J. Lean Six Sigma*, vol. 5, no. 1, pp. 89-116, 2014. <http://dx.doi.org/10.1108/ijlss-04-2012-0002>.
- [17] S. Nallusamy and G. Majumdar, "Enhancement of overall equipment effectiveness using total productive maintenance in a manufacturing industry," *Int. J. Performability Eng.*, vol. 13, no. 2, pp. 173-188, 2017. <http://dx.doi.org/10.23940/ijpe.17.02.p7.173188>.
- [18] K. Antosz, A. T. Productive, and M. Tpm, "TPM in large enterprises: Study results," *Int Scholarly Sci. Res. Innov.*, vol. 7, no. 10, pp. 2101-2108, 2013.
- [19] F. Maroofi, "Performing lean manufacturing system in small and medium enterprises," *Int. J. Acad. Res. Account., Financ. Manag. Sci.*, vol. 2, no. 3, pp. 156-163, 2012.
- [20] A. M. Herzallah, L. Gutiérrez-Gutiérrez, and J. F. Munoz Rosas, "Total quality management practices, competitive strategies and financial performance: The case of the Palestinian industrial SMEs," *Total Qual. Manag. Bus. Excell.*, vol. 25, no. 5-6, pp. 635-649, 2014. <http://dx.doi.org/10.1080/14783363.2013.824714>.