Productivity Improvement of Motorcycle Headlight Assembly through Line Balancing Using Simulation Modeling: A Case Study

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Abstract

The purpose of this paper is to increase the efficiency of the production of motorcycle headlights by balancing the assembly line in order to achieve maximum utilization of manpower. Since the motorcycle headlight assembly in question is a new production line, this research can be seen as providing a supportive approach to achieving work full efficiency. It was observed that improvements can be made to the arrangements of the various elements that form the production line. Therefore, the reseachers proposed a solution that incorporates production line balancing and improvements of work techniques. Simulation with the Arena program is used to analyze the results of the current working conditions and these are compared to the various alternative strategies proposed. The results show that the proposed improvements can help to increase the productivity of motorcycle headlight production line (production cycle time reduced by 25.51 % and production capacity increased by 28.36 % compared to the current situation) and involve more efficient use of manpower (the utilization of manpower increased by 13.33 % compared to the exisitng situation). Moreover, this research and the proposed improvements point to further research aimed at better meeting the monthly demands for product of customer.

Keywords: Motorcycle headlight; line balancing; work improvement; simulation
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1. Introduction

The Thai automotive industry is likely to expand further as the domestic economy and the global economy improve. Motor vehicle production has been continuously increasing, and this has stimulated the automotive parts industry to develop and grow in accordance with the directions of the automobile and motorcycle production industries. The parts that continue to be in demand are mechanical parts such as car frames and bodies, suspensions, car accessories and lighting systems, all of which are expected to continue to increase in demand. The company involved in this case study is one of the companies that produce automotive lighting equipment for a large automotive distribution company. At present, the company studied in this research, which produces automotive lighting devices, has problems that relate to insufficient labor resources when demand for product is high. This case study of the motorcycle headlight assembly line found that as the motorcycle

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headlight parts were new models, there was no development plan for the assembly line. Furthermore, the research showed that even when the current line setup operates at maximum capacity, the level of production is still less than the maximum demand of customers. It was also found that the main problem of this assembly process is an improper balancing of the production line. Notably, the company had a policy to reduce the use of employees in this production process from 6 people to 5 people. Therefore, the aim of this research, which is concerned with the flow process and working charts of the motorcycle headlight assembly line, is to improve the production efficiency of the line.

Line balancing is about equalizing the workload or assigning working operations to workstations across all operations along the production line in order to remove bottlenecks and excess capacity [1]. Assembly line balancing was first proposed in Helgeson and Birnie [2]. The various techniques of line balancing, which vary according to specific aspects of the manufacturing process, have been widely used and applied for many years [3, 4]. Manufacturing throughput is dependent on the length of time each task requires on the line. With so many different and potentially conflicting requirements on the system, the outcomes of line balancing processes can be difficult to predict. Factors such as the rapid rate of and uncertainty that occur in each process, interactions among employees, and the different transfer times between workstations make it difficult to optimize. Although analytical methods can be used, there are limitations due to the dynamic nature of the system [5, 6]. Therefore, a simulation model is an easier way to create a model that can identify problems and bottlenecks in the real system, and thus facilitate better production efficiency, resource usage, and time usage [7, 8]. In this work, simulation was used to analyze the current system and propose and study an optimized alternative before implementation in the real system, thus minimizing risk, error, and uncertainty [7]. Simulation techniques have been widely used for development and decision-making support in many fields, such as manufacturing, transportation, production distribution, banking and health care [9]. The advantages of simulation were found to be reasonableness, provability and output comparison. It gives a re-configurable assembly line the flexibility needed to improve the throughput of the assembly line and working cells while reducing the need for manpower. These outcomes can all help the enterprise to meet growing customer demand. In addition, more effective techniques of work can reduce wasted time, increase production efficiency and facilitate smooth production levels [1]. Therefore, the important criteria to do with motorcycle headlight production in this paper are whether or not assembly line output meets the demands of the customers, and how employees are being utilized. To realize this approach, various combinations of work improvement, line balancing and simulation technique are applied to the assembly line to increase the efficiency of the motorcycle headlight assembly line. The proposed model 1 is a line balancing technique (LB model) and the proposed model 2 involves eliminating unnecessary work and work technique improvements (LB+Work Improvement model). Moreover, the results of the research can not only improve the system studied; they can also be implemented on a bigger scale in larger industrial situations.

2. Materials and Methods

2.1 Analysis of production process flow

A study of work and data collection using an operations chart shows that there are work sequences and division of 22 sub-tasks, and the details of each step is shown in Figure 1.

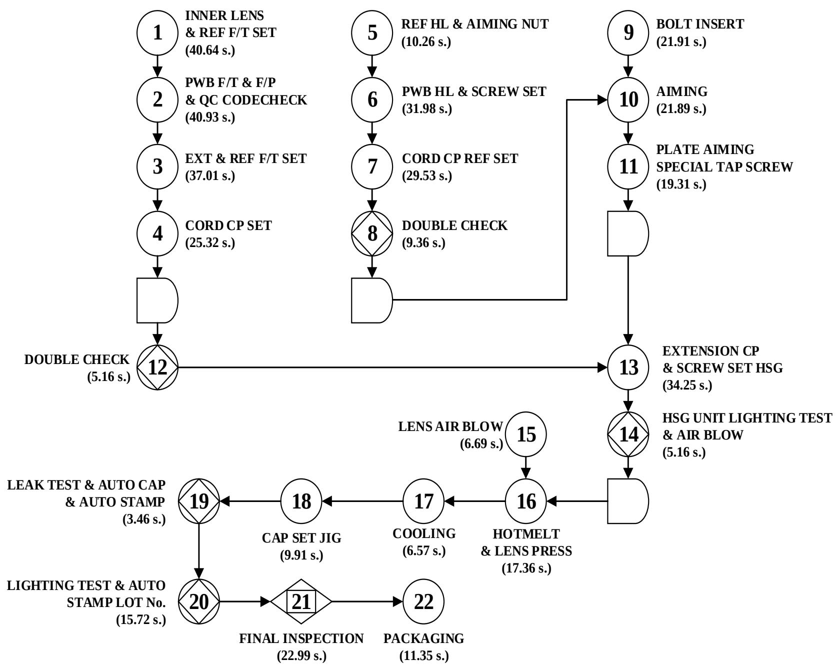

Figure 1. The flow process of the motorcycle headlight assembly line

Under present working conditions, it is found that there are production plans in the case of using 6 employees and 5 employees (the latter being part of a plan to reduce resources). The working diagram of the production process in both cases is shown in Figures 2 and 3, respectively.

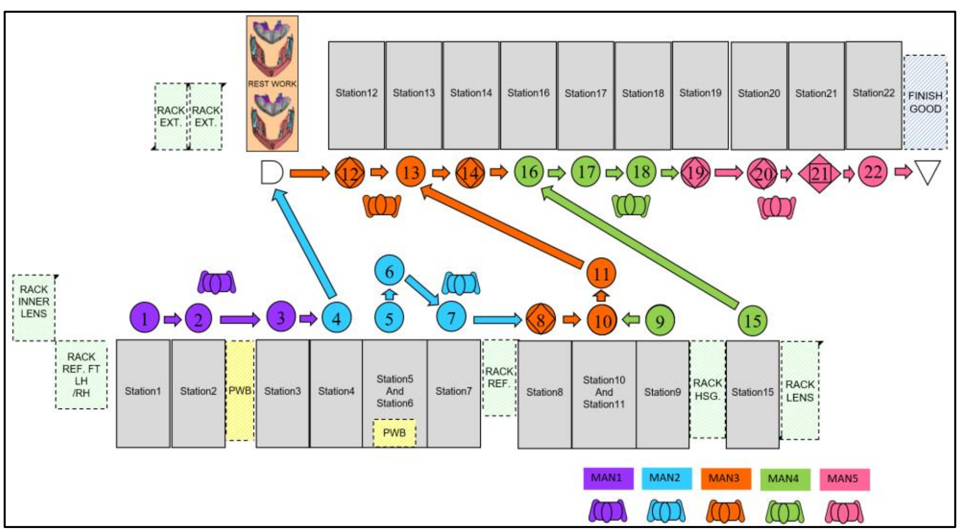

Figure 2. The operation of the motorcycle headlight assembly while operating with 5 people

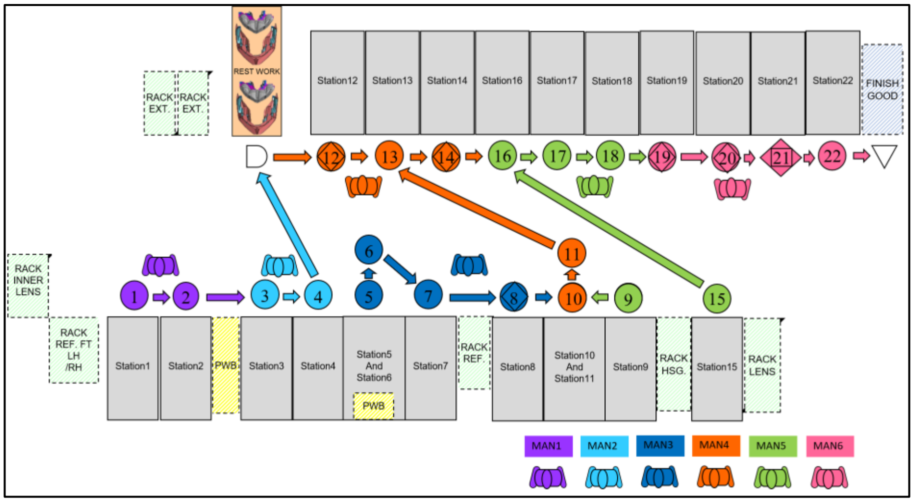

Figure 3. The operation of the motorcycle headlight assembly while operating with 6 people

2.2 Analysis of causes of problems and solutions

The analysis of the causes of the problems and the solutions to the problems is based on the why-why analysis principles. These can summarize the causes of the problems and the solutions, and are shown in Table 1. The root cause of the problem consists in the skill of the staff because it is a new production line. The solution is to train employees to be fluent in their positions. In addition, the utilization and the working order are not consistent with the alignment of the machines. The solution is to line balance and adjust the workstation positions along the production line.

Table 1. The why-why analysis

Problem/Why?	Why?	Answer	Solution
1) Skill of the staff	Why do employees not have expertise in their work?	This is a new production line.	Training of employees
2) Some staff are not working at full utilization	Why are employees not working at full utility?	Work assignments are not balanced.	Line Balancing
	Can the workload be balanced?	Yes, but it must comply with the work order conditions	
3) The work order does not correspond to the alignment of the machine.	Why is it not consistent?	The formatting of the layout in the production line and the work order are unbalanced.	Re-position the production line
	Can the workload be balanced?	Yes, but it must comply with the work order conditions	Line Balancing

2.2.1 Product demand quantity and takt time

Table 2 shows a list of quantity of orders in units per month. The quantity of product demand is used to calculate the takt time (takt time = net working time /number of work pieces needed) according to the customer's requirements. The company has 21 working hours per month and 20 h per day (net working time = (20x3600)x21 = 1,512,000 s).

Table 2. Product demand quantity (pieces/month) and takt time (second per piece)

Month	Demand quantity	Takt time	Month	Demand quantity	Takt time
1	12,876	117.43	7	16,086	93.99
2	20,839	72.56	8	14,790	102.23
3	17,653	85.65	9	17,102	88.41
4	15,944	94.83	10	15,928	94.93
5	14,534	104.03	11	15,062	100.39
6	14,420	104.85			

2.2.2 Cycle time

From the analysis of data on current production work, a summary has been prepared that shows the workload of each person assigned and the cycle time of work of each person in the production of one workpiece in the case of 5 employees per line (Figure 4), and for 6 people employees per line (Figure 5). The figures also show the workload utilization of the production line.

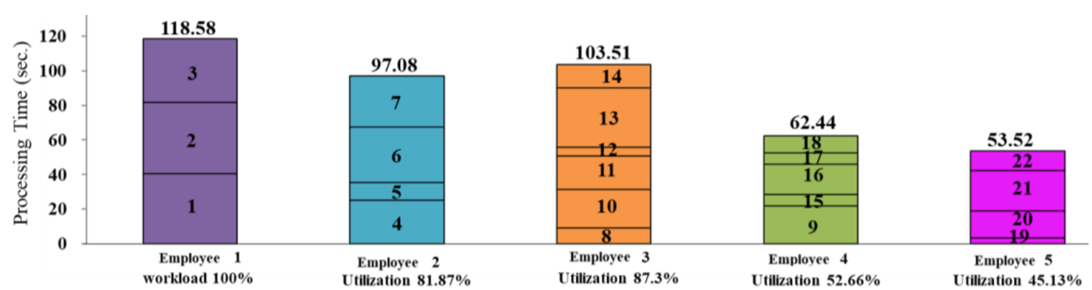

Figure 4. Workload in the case of having 5 production line staff

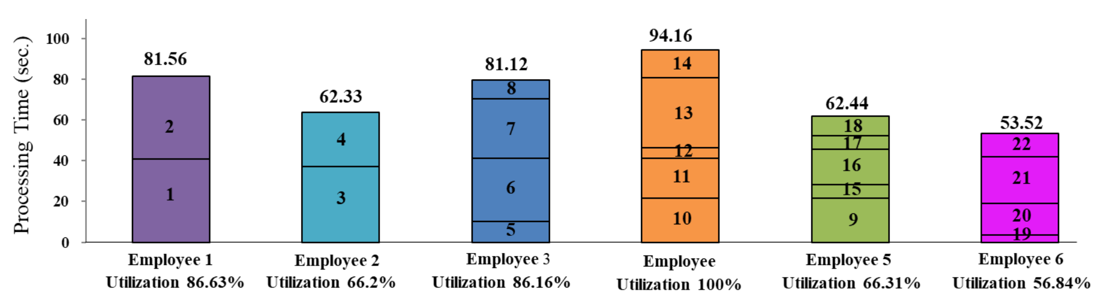

Figure 5. Workload in the case of having 6 production line staff

2.3 Production improvement

2.3.1 Line balancing technique (LB model)

In this research, we balance the production line with the rank positional weight method [10], which includes a network of all 22 sub-tasks, as shown in Figure 6.

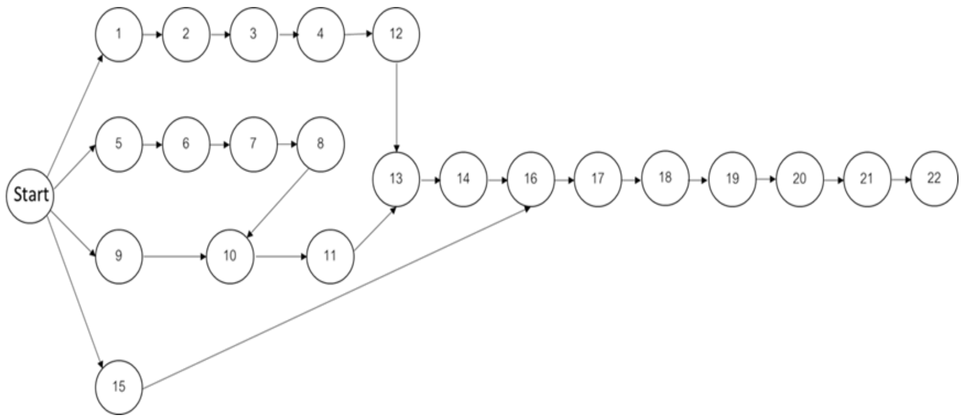

Figure 6. The network of all 22 sub-tasks

The conditions of production are sub-tasks between pairs 3 and 4, pairs 5 and 6, pairs 13 and 14, and pairs 18 and 19, which are tasks that need to be done on the same machine. In addition, the inspection tasks in steps 8 and 12 cannot use the same workers that work in steps 7 and 4, respectively. A summary of the assigned workload utilization of the production line after line balancing is detailed in Figures 7 and 8.

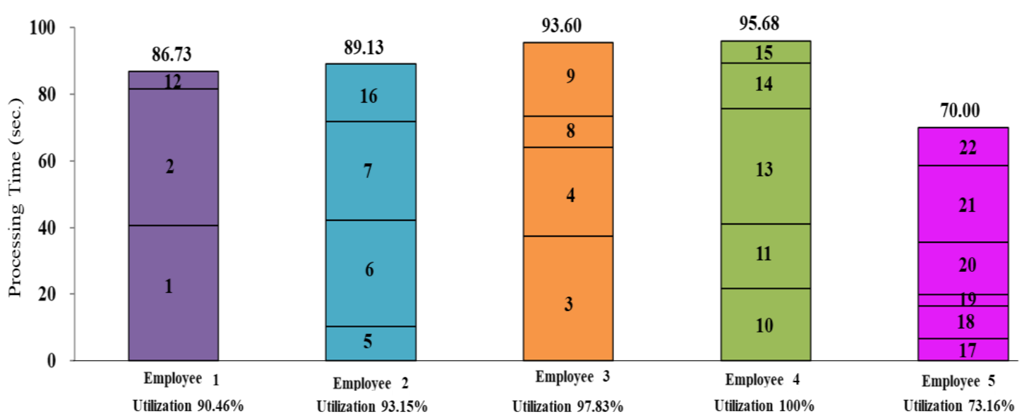

Figure 7. Workload in the case of having 5 employees after balancing the production line

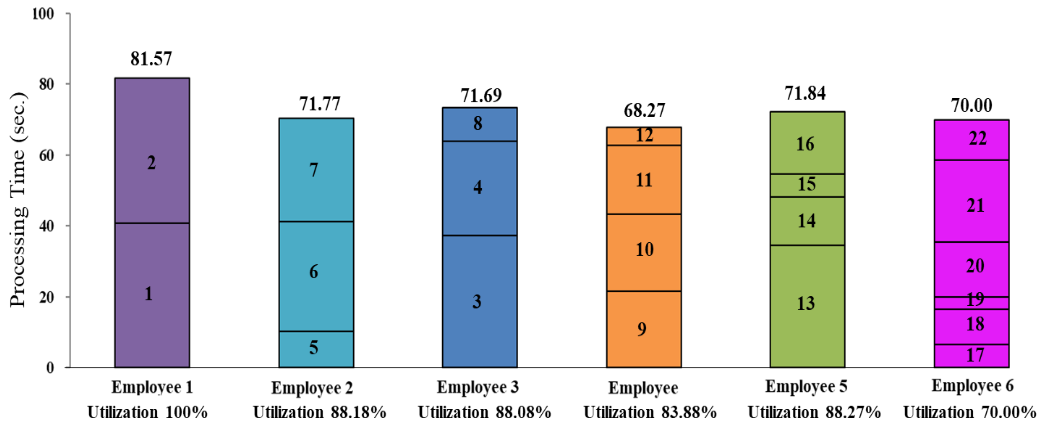

Figure 8. Workload in the case of having 6 employees after balancing the production line

After balancing the production line, the position of the workload has changed. The layout and placement of machines in the new production process are critical and must be in line with the new work order. Furthermore, the layout and placement of machines must be adjusted under the constraints of the production line space and the possibilities of relocating each machine. A updated flowchart that reflects the balancing is shown in Figures 9 and 10, respectively.

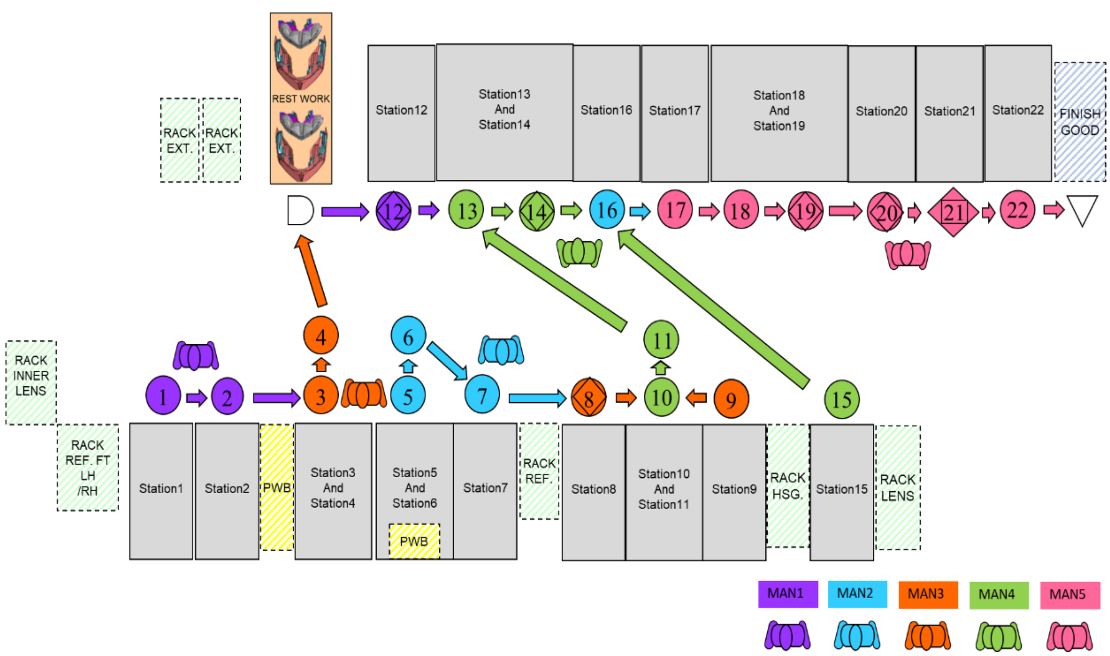

Figure 9. Workflow after balancing the production line with 5 people working

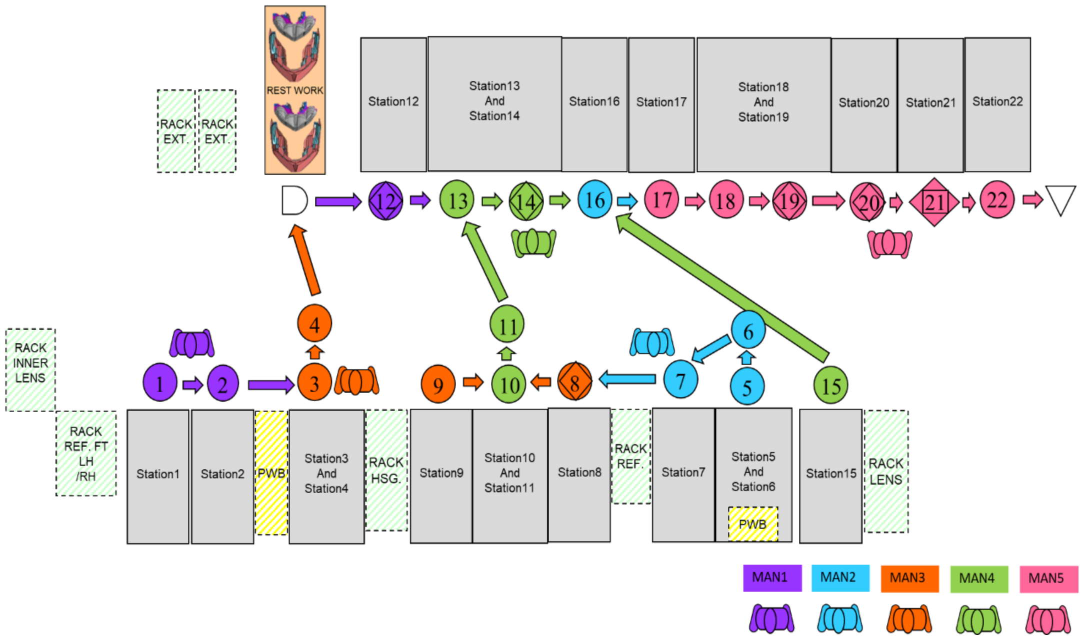

Figure 10. Workflow after balancing the production line with 6 people working

2.3.2 Eliminating unnecessary work with work improvement techniques (LB+work improvement model)

The analysis of the current process reveals that the 1st sub-task is a task that prepares parts from the previous production line. The application of ECRS technique (Eliminate, Combine, Rearrange, Simplify) eliminates this sub-task from the process, reducing the total time to 40.64 s. After cutting the 1st sub-task from the process, the effects of rebalancing the production line for both 5 and 6 employees on the assigned workload utilization of the production line is detailed in Figures 11 and 12, respectively.

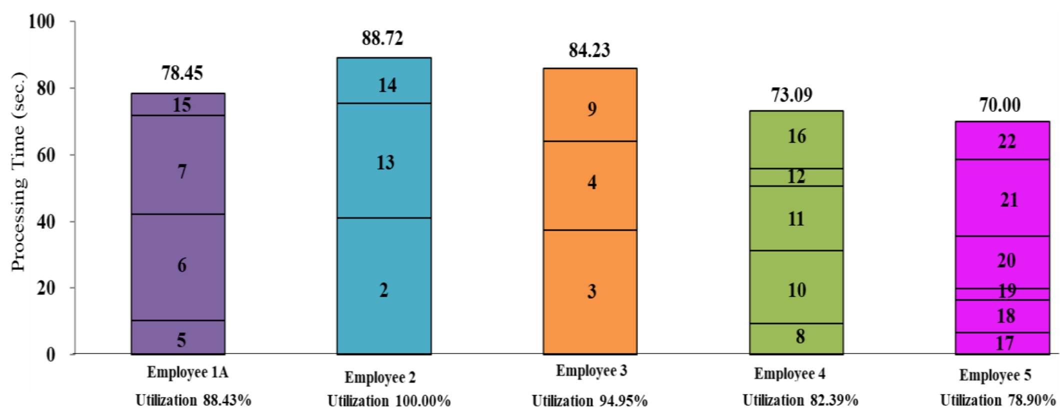

Figure 11. Workload in case of having 5 staff members after line balancing and work improvement

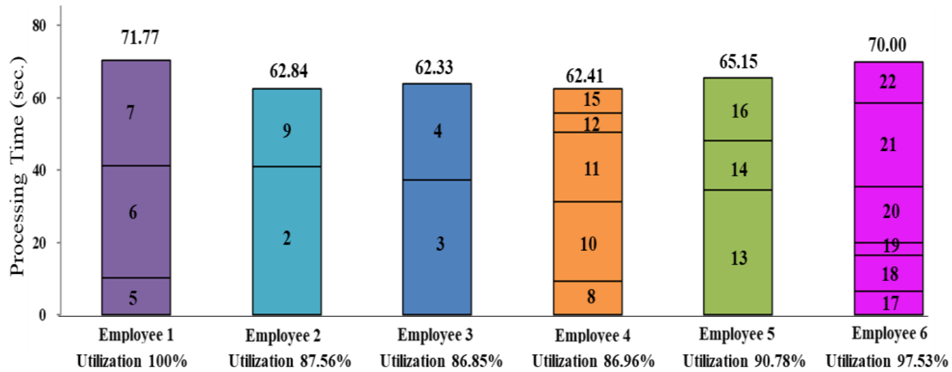

Figure 12. Workload in case of having 6 staff members after line balancing and work improvement

2.4 Simulation model

The study of the process flow of the system and the collection of the necessary information enables the development of the current workflow model using the Arena program. The systematic diagram (Figure 13) that shows the entities that are fed into the system through each process is clear and most consistent with the actual situation. The model that was developed (represented in Figure 14) mimics the actual production process. Data obtained from the model's processing, when analyzed, supports the uncertainty of the real situation. The system of interest in this study consists in the important components as shown in Table 3. The working time data for each workstation is analyzed for distribution with the input analyzer in the Arena program. Hypothesis testing is performed using the chi-square test at the 95% confidence interval. The p-value is greater than 0.05, causing all data used in the test to have probability distributions that can be used to represent the data in the simulation. The distribution of time in the motorcycle front lamp assembly line of each workstation is shown in Table 4.

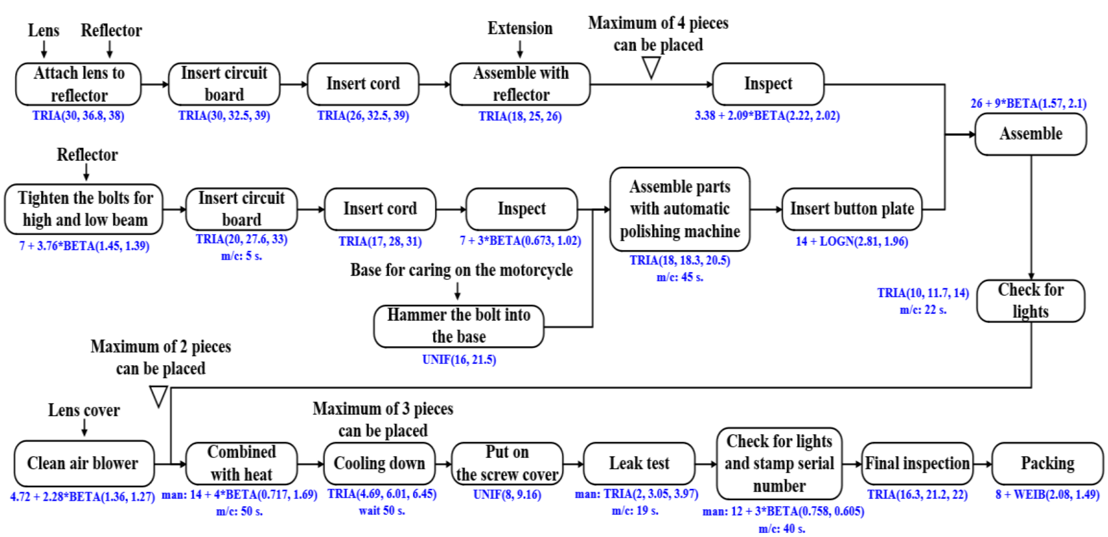

Figure 13. Systematic diagram

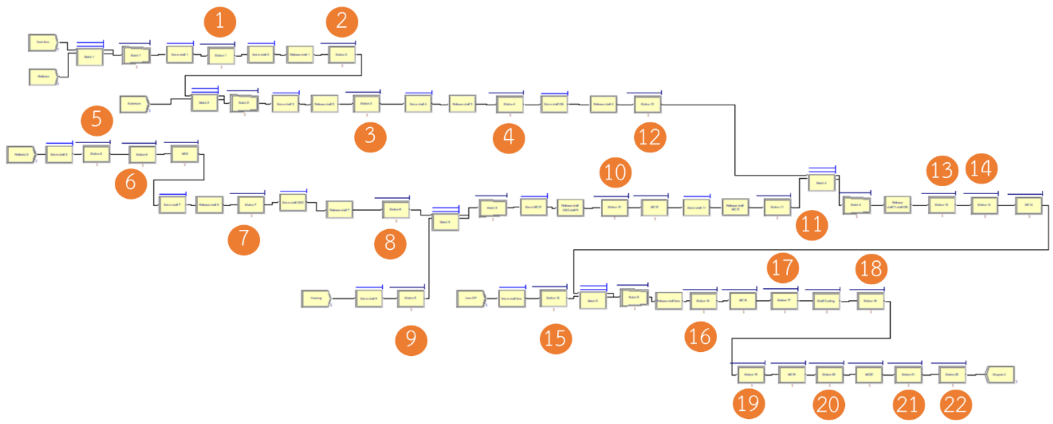

Figure 14. Simulation model

Table 3. Details of system components of the simulation model

Components	Details
Entity	The object of interest that flows into the system is the motorcycle headlight component.
Resource	Resources used in activities such as employees, machinery, etc.
Activity	Operations that occur at a certain time, such as assembly, etc.
Variable	System status indicators such as assembly time, etc.
Event	Activities that result in and change the status of variables such as entering the assembly line or ending the assembly, etc.

Table 4. Distribution of time (s) of each workstation

St.	Expression	St.	Expression	St.	Expression
1	TRIA(30,36.8,38)	9	UNIF(16,21.5)	17	TRIA(4.69,6.01,6.45)
2	TRIA(30,35.8,41)	10	TRIA(18,18.3,20.5)	18	UNIF(8,9.16)
3	TRIA(26,32.5,39)	11	14+LOGN(2.81,1.96)	19	TRIA(2,3.05,3.97)
4	TRIA(18,25,26)	12	3.38+2.09*BETA(2.22,2.02)	20	12+3*BETA(0.758, 0.605)
5	7+3.76*BETA(1.45,1.39)	13	26+9*BETA(1.57,2.1)	21	TRIA(16.3,21.2,22)
6	TRIA(20,29.2,33)	14	TRIA(10,11.7,14)	22	8+WEIB(2.08,1.49)
7	TRIA(17,28,31)	15	4.72+2.28*BETA(1.36,1.27)		
8	7+3*BETA(0.673,1.02)	16	14+4*BETA(0.717,1.69)		

Note: St. = Station

2.4.1 Model verification

In this step, the standard time of work is examined for the accuracy of the simulation model by comparing the workload utilization in the real system with the workload utilization from the simulation model in the cases of 5 and 6 employees as shown in Table 5. The results show that average workload utilization in both cases (5 and 6 persons) for real system and simulation model were not significantly different (between 0-0.37%).

Table 5. Comparison of workload utilization

Number of workers	Workload utilization in real system (%)		Workload utilization of model (%)		Percentage difference (%)	
	5 persons	6 persons	5 persons	6 persons	5 persons	6 persons
1	100.00	86.63	100	87	0.00	0.37
2	81.87	66.20	82	66	0.13	0.20
3	87.30	86.16	87	86	0.30	0.16
4	52.66	100.00	53	100	0.34	0.00
5	45.13	66.31	45	66	0.13	0.31
6	-	56.84	-	57	-	0.16

2.4.2 Model validation

This section examines the suitability of the model to check whether the computer model can replace the real system. The values obtained from the computer model, such as the number of products produced daily, must be close to the actual values and have a half width not more than 5% of the current actual data. Therefore, it can be concluded that the computer model can represent the current system. The first step in verifying the suitability of the model is to specify the information used to configure the run setup. The values from the current work system data are determined by using the average time in the system of 5 employees in a day with 20 working hours per day. According to the operating period considered, the average quantity of work produced is 606 pieces per day. The model is considered to be appropriate by requiring a half width deviation of not more than 5% (confidence interval value 95) of the current actual data. Therefore, the number of workpieces resulting from the model must be in the range of 606±30.3 pieces. The model examination has been performed in 20 replications in order to find the average amount of work produced each day. The result shows that the average number of workpieces produced each day is equal to 606.15, which is only +0.15 pieces different from the actual system which is less than the specified half width (±30.3 pieces). Moreover, the model was validated against the real system by comparing the average number of products produced by using t-test for statistic validation, and it was found that the p-value is 0.83, greater than 0.05. Therefore, in this paper, it is found that the simulation model can represent the current system by specifying number of replications to be 20 cycles.

3. Results and Discussion

The improvement of a motorcycle headlight production line using the production line balancing method following analysis of the current working methods via Arena simulation program was studied. The generated model was run for 20 replications, in the cases of 5 and 6 employees, and the results are summarized in Figures 15 and 16. It can be seen that the application of production line balancing and task improvement (by the elimination of the first sub-task), followed by re-balancing of the line, results in a higher average utility cost of employee. Each employee is given a more balanced workload, resulting in a balanced production line and reduced production cycle time. Similarly, the modifications help to increase productivity in production. The analysis of the ability to respond to customer product demand using demand data from the past 11 months of the company was compared with the results of the capacity analysis obtained from the model, both in the case of improvements by balancing production lines and improving work by eliminating unnecessary sub-tasks. As noted, the model was run through 20 replications, and importantly each cycle was of the actual operating time of the company. The case study covers 21 days per working month. The production capacity per month for various cases is shown in Table 6.

Figure 15. Comparison of workload utilization

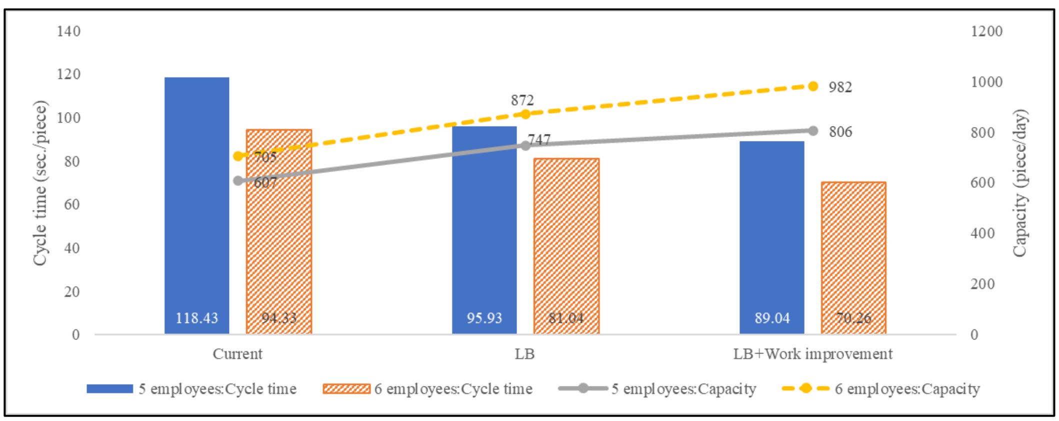

Figure 16. Comparison of production cycle time and capacity

Table 6. Production capacity per month

Instance	**Current system**		**LB**		**B + Work improvement**	
#Employees	5	6	5	6	5	6
Capacity (pieces/month)	12,755	16,059	15,709	18,325	16,985	20,630

The production capacity data (pieces / month) for each case is compared with the demand for the products in each month, in the cases of both 5 and 6 employees. Figure 17 shows that the proposed improvement results in a positive trend of production that better corresponds to the customers' product requirements than does current, which is not covered by the 11-month case of using 5 employees and covering 8 months from 11 months in the case of using 6 employees. In the latter part of the improvement, by balancing the production line in the case of using 5 employees, it was found that the demand can be covered for up to 5 months from 11 months, and in the case of using 6 employees covering 10 months from 11 months. The improvement of work by eliminating unnecessary work in conjunction with production line balancing shows that in the case of using 5 employees, the demand will be covered for up to 7 months from 11 months and in the case of using 6 employees, it is covered for 10 months from 11 months. Both types of improvement guidelines in the case of using 6 employees can meet almost all needs. There is only the 2nd month that may not yet be able to respond to the demand. Additional information from the company suggested that the 2nd month is the beginning of the production line. This new product therefore has more demand than usual, which, after that month, will return to normal at an average of 15,931 pieces / month. Therefore, it can be demonstrated that the proposed improvement approach can lead to a comprehensive case study to meet the needs of each month.

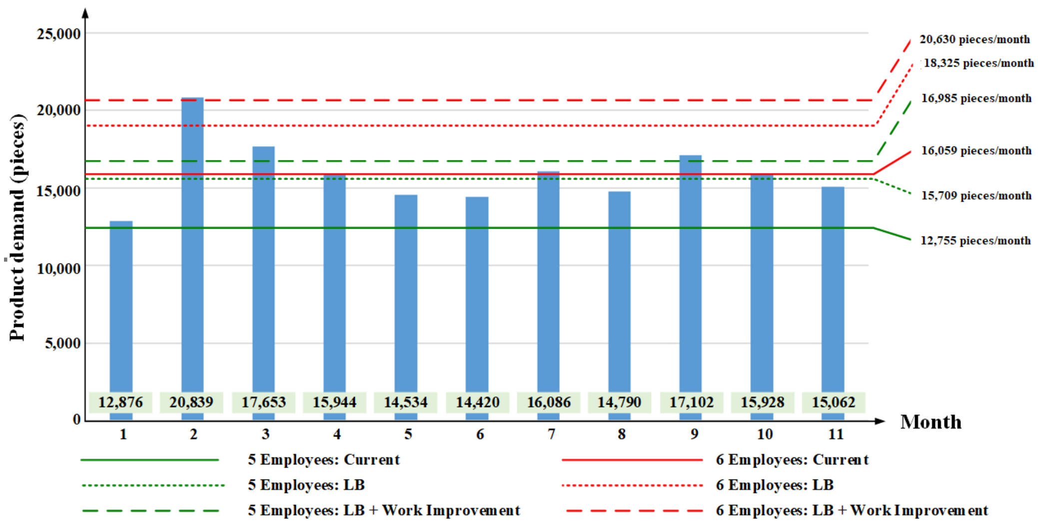

Figure 17. Comparison of production capacity and product demand after improvement

4. Conclusions

The results show that the current operation in the case of using 5 production line employees is still unable to respond to demand and can only respond to demand for 8 months from 11 months in the case of using 6 production line employees. Therefore, in order to increase the efficiency of the motorcycle headlight production line and to allocate the most efficient use of manpower, two solutions are proposed as follows: The application of line balancing found that when using 5 workers in a production line, there was a production cycle of 95.93 seconds per piece which is a reduction of 18.99% compared to the current situation. Production capacity increased to 747 pieces per day, which is an increase of 23.06% compared to the current situation. The utilization of the production line is 91.2%, which is 17.6% increase on the current situation and in the case of using 6 production line employees, the production cycle time is 81.04 seconds per piece, which represents a reduction of 14.08% on the current situation. Production capacity increased to 872 pieces per day, which is an increase of 13.99 % compared to the current situation. The utilization of the production line is 88.17%, which represents an 11% increase compared to the current situation. Addition, in the case of improving production line efficiency by using work improvement, it was found that when 5 workers were used in the production line, there was a production cycle of 89.04 seconds per piece, which is a reduction of 24.81% from the current situation. Production capacity increased to 806 pieces per day, an increase of 32.78% compared to current. The utilization of the production line is 88.6%, which is a 15% increase over current. Furthermore, in the case of 6 production line employees, the production cycle time is 70.26 seconds per piece, a reduction of 25.51 % from the current situation. Production capacity increased to 982 pieces per day, which is an increase of 28.36 % over current. The utilization of the production line is 90.5 %, a 13.33 % increase compared to the current situation. Furthermore, further studies may consider ways to further improve the efficiency of the work, and included here could be improved tools or the supply of support equipment to ease the work and shorten the production cycle time. Finally, as the demand for each period is unstable, further studies may be conducted in order to better understand instabilities and variations in product demand and thus better match workload and customer demand.

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