Enhancing Line Efficiency Performance at Assembly Line using ECRS-Based Line Balancing Concept

Amalia Syaharani Ibnu[1)], Annisa Uswatun Khasanah[2)]

Department of Industrial Engineering, Faculty of Industrial Technology,
Universitas Islam Indonesia, Kaliurang Street km 14.5, Sleman
Daerah Istimewa Yogyakarta, 55584, Indonesia[1),2)]
E-Mail: annisa.uswatun@uii.ac.id[2)]

ABSTRACT

Recently, Indonesian textile and garment manufacturer has experienced a problem with shop floor production. The complexities in the manufacturing process led to many problems, such as inefficiency, and thus prevented the company from achieving its target. Even though the company has established an efficiency target of 80%, the production floor cannot realize it. Thus, this research aims to increase line efficiency to reach the company's target. At the beginning of the analysis, the efficiency of assembly line was only 51,68%. Since this value did not meet the company's target and was not satisfying, the concept of ECRS was applied. This research aims to simplify the method to provide better effect and process flow. Before applying the method, the fishbone diagrams were used. The factors of man, method, machine, and measurement were used to describe the root cause of the losses. Thus, after applying the concept of ECRS, the efficiency level increased to 81,54%, which met the company's target. The assembly line will run better and smoother with less possibility of bottlenecks if all of the workstations have a relatively balanced workload.

Keywords: Assembly Line Balancing (ALB); Line Efficiency; ECRS, Fishbone Diagram

1. Introduction

Industrial activities are inseparable from the global economy. Therefore, companies must create a business strategy to deal with a challenging business climate. Otherwise, the business is at risk of shutting down. Increasing domestic and international competition, coupled with relatively slow growth in Indonesian markets, have forced Indonesian apparel producers and retailers to pay close attention to changes in the market. Recently, Indonesian textile and garment manufacturer, PT XYZ, has confronted several problems related to overcapacity of production, global financial crisis, and multilateral and regional trade agreements. To become more competitive and profitable, PT. XYZ focused on achieving more incredible speed and efficiency. The tool and machinery play an essential role in each segment of textile. In a competitive market, the key determining factors of a company's success are on-time delivery and appropriate distribution. This issue becomes critical especially for the garment industry, which must always keep pace with style and fashion design changes. This is the problem faced by PT. XYZ, where changes must be made by involving complex processes. This condition often causes other problems such as delays in delivery, inefficiency preventing the company from meeting its targets, fewer outputs, and so on.

Australia was the country that placed the biggest order to PT XYZ. This company always tried to build a good relationship with its customers by constantly performing well and giving excellent service and quality, which became its vision and mission. This company maintained to have a solid financial support in order to improve the production technology and product quality. However, PT XYZ faced several problems on the production floor.

Nowadays, PT. XYZ has determined the target efficiency level of the production floor to be 80%. This target was set in order to push the production floor to reach the desired output within an hour and a day. Thus, it can prevent late shipments and maintain quality. However, the production floor mostly cannot meet the daily company target in all garment areas. This problem is mostly due to the sewing process as the last crucial process before finishing and shipping. This problem triggers several effects, such as late shipment that reduces buyers' loyalty or satisfaction. As mentioned in the agreement, in case of order delays, PT. XYZ should send its product using an airplane, which is undoubtedly costly and financially burdensome.

According to the condition mentioned earlier, the challenge for the PT. XYZ was to optimize the whole line production system. The key to improving the assembly line balancing performance is by recognizing the rooting (Nisphaphat & Ratanakuakangwan, 2016). First of all, the fishbone diagram was the appropriate method to analyze problems in the line production system. The root causes of the problem were analyzed based on factors of manpower or operator, methods, machine and measurement since this study was not only focused on the method but also focused on reducing operators. In addition, eliminating, combining, rearranging, and simplifying (ECRS) method was the most practical step to apply since the company integrated the procedure and arrangement of method and machine used. The purpose of the study was to improve the line efficiency of assembly line in the sewing area, and thus it can meet the company target of 80% and increase the output as well. It analyzed the production process based on work study principles and identified the bottleneck in the operation. This approach involved current production system analysis by collecting the cycle time of all operators in the production process, designing the production network, and identifying the bottleneck operation. After that, the ECRS method was proposed and implemented in the actual production line. This study was very important to solve the production shop floor problem and expand the understanding of the assembly line balancing issues that influence the production system.

2. Theoretical Framework

Assembly line balancing Assembly (ALB) lines are often used in the last step of production, in which the product's final assembly from previously manufactured parts is performed. An assembly line typically consists of several workstations, where each workstation is responsible for performing a specific set of tasks. The items move through the line from one workstation to the next according to their order and end up as finished products (Bukchin & Raviv, 2018). To maximize the efficiency of the line, the total assembly time has been divided as equal as possible, among the workstations. Since the assembly of each product consisted of indivisible elements (tasks), the problem of allocating the tasks to the stations became a combinatorial problem called the assembly line balancing problem (Limcharoen et al., 2007). Assembly line needs to be built effectively and efficiently and to distribute the same task among the workers and workstations to ensure that the production process meets the available time and capacity (Hui & Ng, 1999). Meanwhile, according to Nourmohammadi & Eskandari (2017), ALB functions as a design to assign properly the number of operators and machines in every process or work element to meet the desired production rate with zero ideal time. In brief, ALB aims to balance the workstations to reduce bottleneck and total processing by considering the process efficiency and increasing production rate.

Line Efficiency is the ratio of the total work time of the station divided by the cycle multiplied by the number of work stations (Baroto, 2002) or the number of work station efficiency divided by the number of work stations (Nasution, 1999). In this case, the Fishbone diagram (FB) is commonly named as the cause analysis and branches of analysis figure. The term is named after its master named, Kaoru Ishikawa, a Japanese management master who found out the root cause of the problems. It can also show the indicated relationship between the problems and the underlying causes, which are mostly used in qualitative analysis (Luo et al., 2007)(Xing, 2004). Once the problem is identified, the analysts can focus on reducing and eliminating the causes of the problem. Then, those causes are grouped into some key categories to ease the identification of sources and causes for any variations. Those categories included methods, manpower, machines, measurements, environment and materials.

On the other hand, ECRS is a simple approach to quickly and rapidly identify wastes and implement immediate improvements. This tool is impatient for long drawn out projects or long winded Kaizen events – since it is most appropriate for immediate and pointed Kaizen efforts. This tool supports Plan-Do-Check-Action (PDCA) and can be an important element in the PDCA mentoring and coaching process (Ongkunaruk & Wongsatit, 2014). The ECRS steps for continuous improvement consist of the following elements:

i. Elimination (E). In this step, it is important to identify the steps that can be quickly eliminated or reduced where possible to eliminate the details of work.
ii. Combination (C). When work cannot be eliminated, it is necessary to seek to combine them. Sometimes, the process or operation can be eliminated simultaneously by combining the whole processes into a single process.
iii. Rearrangement (R). Work can also be rearranged. Sometimes, it needs the rearrangement of resources, materials, man, or tools to ensure the smooth operation of the production process.
iv. Simplification (S). The simplification could be the combination of the above three steps to ease the manpower or the operator to perform their job. It could be done by combining the movements and operations before eliminating some waste.

Chueprasert & Ongkunaruk (2014) implemented the ECRS concept to increase productivity and efficiency in line process of milk manufactured in Thailand. The result showed that the line efficiency increased from 65.51% to the highest level of 88.33%. Macías-Jiménez et al. (2019) implemented 5W1H and ECRS techniques to improve productivity in food company. Bârsan & Codrea (2019) used the ECRS method to enhance a university's administrative process. Kelendar & Mohammed (2020) implemented ECRS in health sector to improve toolkit and minimize waste. Nisa et al. (2021) applied ECRS to improve the work system on a production line in a data storage manufacturing company in Indonesia. While, Suhardi et al. (2019) tried to minimize waste using lean manufacturing and ERCS principle in a furniture industry.

3. Research Method

3.1. Data Collection Methods

The research required primary and secondary data from interviews and direct observation. The interview involved asking informants open-ended questions. The interview was conducted in the sewing area by involving some managers and supervisors of the PPIC and Engineering department and the sewing operator. The most common problems that frequently occurred in this area were faced by the stakeholders, then lifted up becomes the problem that wants to be solved

For direct observation method, the direct stop-watch time study was used to calculate the cycle time for each element in every workstation in an assembly line. While observing and recording the time, an appraisal of the worker’s performance level is made to obtain the normal time for the task. The data are then used to compute the cycle time for each element in every workstation in assembly line.

3.2. Data Processing

In this study, there were some steps required in processing the data, as written below:

i. Calculating the line efficiency performance
In this first condition or initial model, the indicators of production system must be calculated, such as; cycle time, takt time, production capacity, production/head/hour, process time, and line efficiency. The equation for some calculations is as follows;

ii. Fishbone diagram
The result of line efficiency was then compared to the company's target. If it does not meet the company's target, there will be further analysis using fishbone diagram (by considering several factors: the method, man, machine, measurement, material, and environment).

iii. ECRS Method
In this step, some alternatives or solutions are considered by eliminating, combining, rearranging, and simplifying the process or the machine based on the most affected factors resulting from the fishbone diagram.

iv. Re-calculating the line efficiency performance using the updated cycle time.
The formula remains the same as the previous indicators and equation. The result is then compared to the company's target.

Table 1. Indicators used in assessing assembly line

	Description	Formula
Cycle time	Used to express the total manual work involved in a process, or part of a process	Production time + Waiting time for Production………(1)
Takt time	The maximum acceptable time to meet customer demand	Maximum cycle time x (100% + allowance)….(2)
Production capacity	The maximum output that can be produced in a business with available resources	Networking time x 60 sec / takt time…………….(3)
Production/ head/hour (PHH)	Production pieces are units business that are generated as an output.	Production capacity x 60 sec /total workstation x networking time ……(4)
Process time	the time used to actually work on the product spent on that workstation	Networking time x total workstation / production capacity……………(5)

While assessing the assembly line performance, some indicators were required as written in Table 1.

4. Results and Discussion

4.1. Calculation of Line Efficiency in Assembly Line Balancing

In the initial system, there were 27 workstations and operators in the assembly line area, which performed special jobs or work elements as showned in Table 2.

Table 2. Cycle Time of Initial Model

No	Work Station	Operator	Process	Work Element	Cycle Time	Total Cycle time in workstation
1	1	1	1	*Blabar* + *kepras* + *mancing* collar band	36,52	36,52
2	2	2	2	*Balik* collar (manual)	20,1	20,1
3	3	3	3	Stik leaf collar	49,98	49,98
4	4	4	4	Stik hexa s.cuff 5mm k/k	35,97	35,97
5	5	5	5	Put sleeve binding + potong k/k	44,5	44,5
6	6	6	6	Put tape split tempel k/k	14,99	14,99
7	7	7	7	Sort + brand label yoke	47	78
8			8	Sort + size label yoke	31	
9	8	8	9	Inspection	41	41
10	9	9	10	Joint collar	55,07	55,07
11	10	10	11	Stik middle collar	38,82	38,82
12	11	11	12	Joint armhole c.stitch k/k + tape	69,1	69,1
13	12	12	13	Stik armhole JR I + k/k + tape	62,53	62,53
14	13	13	14	sew waist front dart	112,8	112,8
15	14	14	15	sew laid on (kansai model)	90,4	126,64
16			16	sew laid on 2 motif	36,24	
17	15	15	17	Overlock waist dart	47,24	92
18			18	Waist back dart	45	
19	16	16	19	Pasang split	55	105
20			20	Joint cuff k/k	49,79	
21	17	17	21	Button hole (body)	42	42
22	18	18	22	Wrapped button	48,07	48,07
23	19	19	23	*Blabar* + stik back yoke(tape)	57,46	57,46
24	29	29	24	Joint shoulde r+ stik JR I + tape +sortir	50,8	50,8
25	21	21	25	*Blabar*+stik+joint collar+jepit piping	61,8	61,8
26	22	22	26	Put tape on shoder	62,44	62,44
27	23	23	27	*Blabar*+*kepras* side seam+sortir using tape	57	57
28	24	24	28	Stik side seam l/s + sortir	30,4	30,4
29	25	25	29	Put bottom tape klim	59,21	59,21
30	26	26	30	Bottom tape	64,55	64,55
31	27	27	31	Button sew + Wrapped button II	57,17	57,17
TOTAL CYCLE TIME					**1573,95**	**1573,95**

Thus, each workstation could accommodate more than one work element that also had a cycle time. The total cycle time was 1573,95 second accumulated from 27 workstations (with 27 operators), with 31 processes assembly to complete. Table 3 presents the calculation result to get line efficiency for the initial model.

Table 3. Line efficiency in initial model and company's target

	Initial Model	Company's target
Manpower/shift	27 operators	27 operators
Takt time	124,08 sec	82,5 sec
Total cycle time	1573,95 sec	1500 sec
Working hour/shift	460 minutes	460 minutes
Production capacity/shift	222,44 pieces	334 pieces
Production/head/hour	1,07 piece (s)	1,61 pieces
Process time Line efficiency	55,84 minutes 51,68%	37,2 minutes 80 %

Table 3 demonstrates that takt time was 124 sec from assembly line, which produced shirt. The upper limit of takt time had given a 10 % allowance, which showed the maximum time to produce a product (in unit) for each workstation. Then, the production capacity per shift was 222,44 pieces, meaning that Assembly Line could produce 222 pieces of shirt each day. This resulted in the production capacity calculation to know the PHH or production/head/hour, which was 1,07 pieces. It showed that the ability of one operator to finish the product within an hour was only one piece of shirt. The calculation of process time was derived from the production capacity of 55,84 minutes. This fact indicated that the assembly of 1-unit product (1 piece of shirt) needed for about 55,84 minutes. Thus, based on all calculation results, the line efficiency was 51,68 %. In other words, the efficiency in Assembly Line on output productivity was 51,68 %. Then, all results were compared to the company target of 80%, which means that the line efficiency did not meet the company's target.

4.2. Analysis of Fishbone Diagram

Knowing that the line efficiency failed to meet the company's target, the researcher conducted the next step of making the fishbone diagram to know the factors that caused the problems (Figure 1).

Each branch of the fishbone diagram represented the factors that contribute to line efficiency problem. In short, the categories of manpower, machine, and method were the most significant factor of failure of inefficiency of assembly line. This fishbone diagram can be further used to make decision about selecting the most appropriate method by considering those factors.

4.3. ECRS Concept

After mapping the root cause of the problem using the fishbone diagram, we can see that most of the problems were caused by technical activities such as the wrong method and the insufficient skill of the operator. Thus, the method will be improved using ECRS technique for building the proposed refinement. ECRS had four principles to reduce production time and optimize the whole process. It can be seen that the total reduction of cycle time was up to 165 second, resulting from the re-designing and applying the ECRS concept (elimination, combination, rearrangement, and simplification). The details of above proposed layout are summed up in Table 4.

4.4. Calculation of New Line Efficiency

Based on the new cycle time above, the takt time, production capacity, PHH, process time and assembly line efficiency must be recalculated. The result is depicted in Table 5.

Table 5 shows the performance of each model; initial and proposed model. The number of operators can be reduced to 24 operators in each workstation. It is a good result because the company can save the labor cost. The takt time was also reduced to 79,2 sec, meaning that the maximum acceptable time to meet the daily production target was reduced until 45 second. Then, the

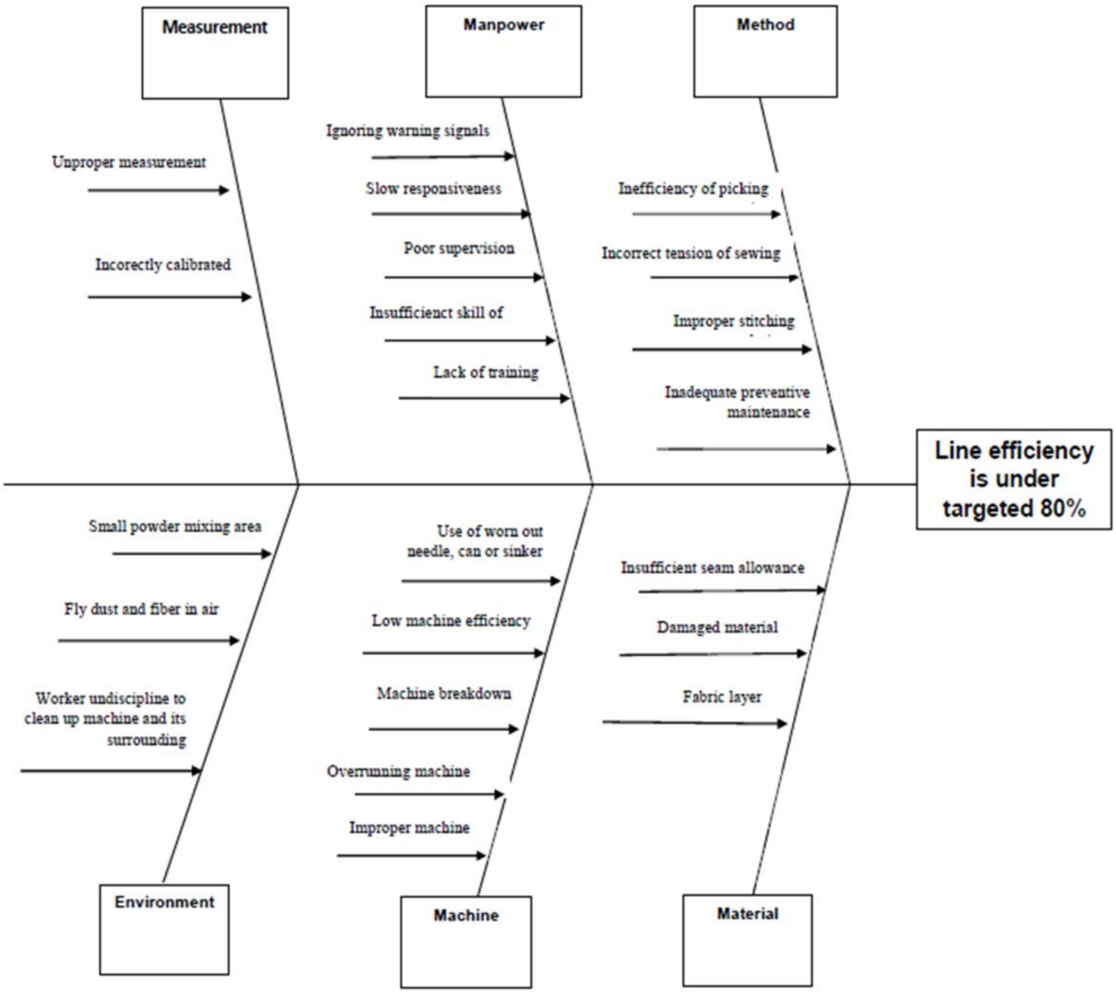

Figure 1: Fishbone Diagram

production capacity per shift was 348,48 pieces, meaning that Assembly Line could produce as many as 348,48 pieces or nearly 349 pieces of shirts each day. This production capacity was higher than the initial model, so the company could produce more products. Then, the PHH or production/head/hour was 1,89 pieces. It showed that the ability of one operator to finish the product within an hour was nearly 2 pieces of shirt. Production capacity was also derived from calculating process time and obtained 31,68 minutes. It showed that the assembly of 1-unit product (1 piece of shirt) took about 31,68 minutes. The time reduced from the initial model was up to 24 minutes. It means that the company can assemble 1 unit product earlier. These results led to the decreasing cycle time to 1408 second from 1573, which significantly impacted the efficiency, since it reduced up to 165 second. These also affected the takt time and process time. Both were strongly correlated, since the closer the processing time to takt time, the more efficient the assembly line. The assembly line will run better and smoother with the smaller possibility of bottlenecks if all of the work stations have a relatively balanced work load. In conclusion, it is possible to apply the ECRS method in the real production system since this method does not need a complex tool, has a more straightforward method (easy to operate), and has been proven effective in increasing the efficiency, as revealed by this study (Shirt style).

Table 4. Result of proposed action using ECRS method

ECRS Concept	Workstation	Process	Description	Proposed Refinement	Result
Eliminating and combining	8	9	Inspection	The operator did not check and inspect the result. Inspection and joint collar was done simultaneously in one workstation with the same operator. The new cycle time became 71,6 sec.	Workstation and process were reduced.
	9	10	Joint collar		Cycle time was reduced to 24,47 sec.
	7	7	Sorting and branding with label yoke	The operator sorted, selected and picked the brand label + size, and labelled items simultaneously in one mini-compartment. The new cycle time became 68 sec.	Process reduced
		8	Sorting and giving size label yoke		Cycle time was reduced to 10 sec
	17	21	Button hole (body)	The operator made buttonhole and wrapped the button in one workstation within one machine. The new cycle time became 70,07 sec.	Workstation and process were reduced.
	18	22	Wrapped button		Cycle time was reduced to 20 sec.
	23	27	Side seam and sorting using tape	The operator did side seam and sorting using tape and sticking it with side seam of long sleeve simultaneously in one machine. The new cycle time became 72 sec.	Workstation and process were reduced.
	24	28	Stick side seam l/s + sorting		Cycle time was reduced to 15,4 sec.
Rearrangement	14	15	Laid on sewing (kansai model)	The operator re-adjusting the clamping hole to become 9 cm. The new cycle time became 92,64 sec. Precise and match sewing-pattern. Cycle time was reduced to 34 sec.	
	22	26	Attaching tape to the shoulder	The press machine was set to a higher temperature and tape was easily sticked to fabric. Cycle time was reduced to 14,04 sec.	
Simplification	13	14	Front waits dart sewing	The operator sewed and followed the pattern sprightly using cartoon ruler. Cycle time was reduced to 41,1 sec.	
	20	24	Joint shoulder	The operator selected mode of reverse stitch lever in the machine, and the machine would sew in the reverse while the lever was pushed. Cycle time was reduced to 6 sec.	
Total reduction of cycle time					165 sec

Table 5. Comparison of line efficiency for both initial and proposed model.

	Proposed model	Initial model
Manpower/shift	24 operators	27 operators
Takt time	79,2 sec	124,08 sec
Total cycle time	1408,94 sec	1573,95 sec
Working hour/shift	460 minutes	460 minutes
Production capacity/shift	348,48 pieces	222,44 pieces
Production/head/hour	1,89 piece (s)	1,07 piece (s)
Process time Line efficiency	31,68 minutes 81,54 %	55,84 minutes 51,68%

5. Conclusion

Based on the above calculation and analysis in accordance to the research objective and formulation, it is possible to draw the following conclusions:

i. The value of line efficiency Assembly Line 11 Sewing-K2C in production line increased up to 81,54% from 51,68% after applying the ECRS method. This value was derived from the reduction of takt time, total cycle time, and process time. Thus, the performance of assembly line will run better and smoother with the smaller possibility of bottleneck if all of the work stations have relatively balanced work load.

ii. There are 4 strategies that is used in the proposed model based on ECRS concept, as written below:

   a. Eliminating and combining the inspection process with joint collar, sorting and branding label yoke with sorting and giving size of label yoke, button hole sewing with wrapped button, and side seam using tape with side seam of long sleeve.

b. Rearrangement of the process of laid on sewing (Kansai model) by re-adjusting the height of clamping hole and attaching tape to the shoulder by re-adjusting the higher temperature when ironing.

c. Simplifying the process of front waist dart sewing using cartoon-ruler and joint shoulder by selecting the mode of reverse stitch lever in the machine.

iii. This research is limited to the objective of only attaining efficiency of 80% by neglecting the external factors such as the economic aspects. This research results in some suggestions for the company after revealing the root cause behind the inefficiency of assembly line. On this basis, it is recommended for further research, that the company applies other methods of assembly line for balancing the condition of the production floor to gain the optimum output and tighter regulation. The company also needs to conduct preventive maintenance plan system against machine failure or breakdown.

References

Baroto, T. (2002). *Pengantar Teknik Industri*. Universitas Muhammadiyah Malang.

Bârsan, R. M., & Codrea, F.-M. (2019). Lean university: applying the ECRS method to improve an administrative process. *MATEC Web of Conferences*, *290*, 07003. https://doi.org/10.1051/matecconf/201929007003

Bukchin, Y., & Raviv, T. (2018). Constraint programming for solving various assembly line balancing problems. *Omega*, *78*, 57–68.

Hui, C., & Ng, S. (1999). A study of the effect of time variations for assembly line balancing in the clothing industry. *International Journal of Clothing Science and Technology*, *11*(4), 181–188.

Kelendar, H., & Mohammed, A. M. (2020). Lean And The Ecrs Principle: Developing A Framework To Minimise Waste In Healthcare Sectors. *International Journal of Public Health and Clinical Sciences*, *September*. https://doi.org/10.32827/ijphcs.7.3.98

Limcharoen, A., Wannarat, J., & Panich, V. (2007). The Application of Line Balancing Technique and Simulation Program to Increase Productivity in Hard Disk Drive Components. World Academy of Science. *Engineering and Technology International Journal of Computer and Information Engineerin*, *11*(9), 1074–1078.

Luo, Y., Huang, S., & Cao, S. (2007). Application of improved fishbone diagram in the operation management. *Industrial Engineering Journal*, *25*(2).

Macías-Jiménez, M. A., Romero-Conrado, A. R., Acosta-Fontalvo, L. C., & Coronado-Hernández, R. (2019). Application of Work Study to Process Improvement: Fruit Nectar Case. In *In: Saeed K., Chaki R., Janev V. (eds) Computer Information Systems and Industrial Management. CISIM 2019* (Vol. 11703). Springer.

Nasution, A. H. (1999). *Perancangan dan Pengendalian Produksi*. Jurusan Teknik Industri ITS.

Nisa, A. K., Hisjam, M., & Helmi, S. A. (2021). Improvement of Work Method with Eliminate, Combine, Re-arrange, and Simplify (ECRS) Concept in a Manufacturing Company: A Case Study. *IOP Conference Series: Materials Science and Engineering*, *1096*(1), 012016. https://doi.org/10.1088/1757-899x/1096/1/012016

Nisphaphat, N., & Ratanakuakangwan, S. (2016). Waste Reduction in Surface Treatment Process by Lean Six Sigma Approach. *IRO Transactions On*

Science And Technology, *1*(1), 35.

Nourmohammadi, A., & Eskandari, H. (2017). Assembly line design considering line balancing and part feedin. *Assembly Automation*, *37*(1), 135–143.

Ongkunaruk, P., & Wongsatit, W. (2014). An ECRS-based line balancing concept: a case study of a frozen chicken producer. *Business Process Manageent Journal*, *20*(5), 678–692.

Suhardi, B., Anisa, N., & Laksono, P. W. (2019). Minimizing waste using lean manufacturing and ECRS principle in Indonesian furniture industry. *Cogent Engineering*, *6*(1), 1–13. https://doi.org/10.1080/23311916.2019.1567019

Xing, W. (2004). QC Team Based Materials. *Beijing: China Society Press*.