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BALANCE ANALYSIS OF WATER DISPENSER ASSEMBLY LINE USING RANKED POSITIONAL WEIGHT, REGION APPROACH, AND LARGEST CANDIDATE RULE METHODS AT PT. XYZ

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ABSTRACT

PT. XYZis one of the largest electronic goods manufacturers in Indonesia, producing various electronic products, including water dispensers. Based on the performance graph over the past six months, the efficiency rate of the assembly line was below the company's standard, and several workstations experienced bottlenecks. Therefore, an analysis of the water dispenser assembly line balancing was conducted to meet the company's performance standards. To support this analysis, data sufficiency testing, data uniformity testing, and standard time calculations in the assembly process were performed. The line balancing was then analyzed using the Ranked Positional Weight, Region Approach, and Largest Candidate Rule methods. The results showed that the actual line efficiency reached 121.41%, with a balance delay of -21.41%, indicating a significant number of bottleneck workstations, initially totaling 14. After analysis using the three methods, line efficiency increased to 80.9%, and balance delay improved to 19.1%. Regarding the smoothness index, the Ranked Positional Weight and Largest Candidate Rule methods yielded 145.715 seconds, while the Region Approach produced 145.790 seconds, with an increased total of 21 workstations. Furthermore, a simulation using Arena software and a Paired Samples T-Test yielded a significance value of 0.317, confirming that the simulation model passed verification and validation.
Keywords: *Bottleneck, Line Balancing, Water Dispenser*

1. Introduction

Productivity plays a crucial role in the manufacturing industry, enabling companies to remain competitive and sustainable in the market. This drives both service and manufacturing providers to compete in operating efficiently. Inefficiency in a process can be attributed to discrepancies in planning and setup at workstations. To address this issue, line balancing is required.

PT. XYZIndonesia is one of the largest electronic goods manufacturers in Indonesia, producing various electronic products, including water dispensers. In the business unit (BU) dedicated to water dispensers, the activities involve assembly for the installation of the hot tank component on the inside and several checks such as leak checks, electrical checks, and refill timer checks.

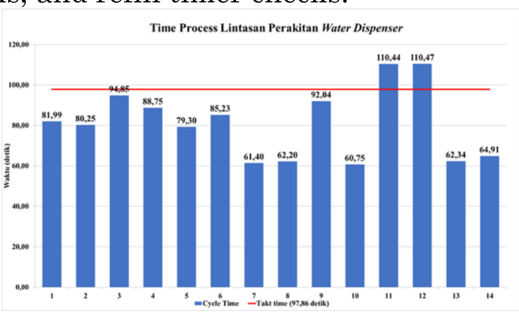

Figure 1. Graph of Actual Condition of Assembly Line
(Source: Company Data, 2023)

https://doi.org/10.33005/wj.v18i1.176 semnasti.telkomuniversity.ac.id semnasti@telkomuniversity.ac.id

Based on the graph above, it can be observed that there are 14 operators performing different activities, and there is a takt time of 97.86 seconds, which is determined by dividing the company's net working time divided by the quantity of production per day. Takt time is the time required to produce one unit of product-based customer demand speed (Wignjosoebroto, 2003). From the graph, it can be seen that several operations experience bottlenecks (exceeding the operation cycle time), and many operators are idle due to their activities being less frequent compared to other operators, which affect work productivity in generating production output.

The company aims to balance the workload of each operator on a single assembly line, so that the targets set by the company can be achieved, reaching the company's line efficiency standard of 85%. Below is the recapitulation of the company's line efficiency percentage over the past 6 months.

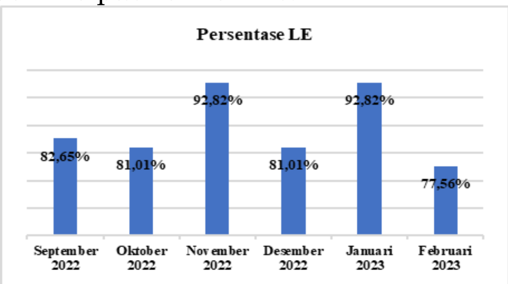

Figure II. Graph of Line Efficiency Percentage
(Source: Company Data, 2023)

Based on the above diagram, during the past six months, the percentage of line efficiency obtained during the water dispenser assembly process shows that more of them did not meet the company's efficiency standards. Work measurement is a method for determining the standard time required to complete an activity (Wignjosoebroto, 2003). Work measurement involves the use of a stopwatch to measure the processing time conducted by the operators.

After that, a line balancing process was conducted in the water dispenser business unit. Line balancing is a method used to equalize the distribution of several operation items from the assembly line to work stations to minimize the total idle time across all workstations at a specific efficiency level (Boysen, 2007). The Ranked Positional Weight (RPW) method is a technique that distributes work elements based on priority weight positions at each workstation to minimize them as much as possible (Baroto, 2006). The Region Approach (RA) prioritizes work elements for each workstation based on the precedence diagram sequence (Jaggi, et al., 2015). Then, the third method Largest Candidate Rule (LCR) approaches by merging operation processes with the largest process time (Yudha, et al., 2017).

Based on the description, the research objective is to determine improvement recommendations to enhance the efficiency of the water dispenser assembly line.

2. Research Methodology

2.1. Data Type and Source

Primary data is data obtained directly by researchers in the field. Primary data that has been collected by researchers in conducting this research include (Hasan, 2002):

The data is obtained from the results of observing the takt time at each workstation, documenting every conducted by the operators, calculating the cycle time of each operator at the workstation using a stopwatch, and conducting interviews with the factory engineering department regarding activities or operations that can or cannot be allocated to other operators, as well as the company's efficiency standards.

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Secondary data is sourced from journal references and information sources related to the research, such as production data for the past year year and working instructions.

2.2. Research Flowchart

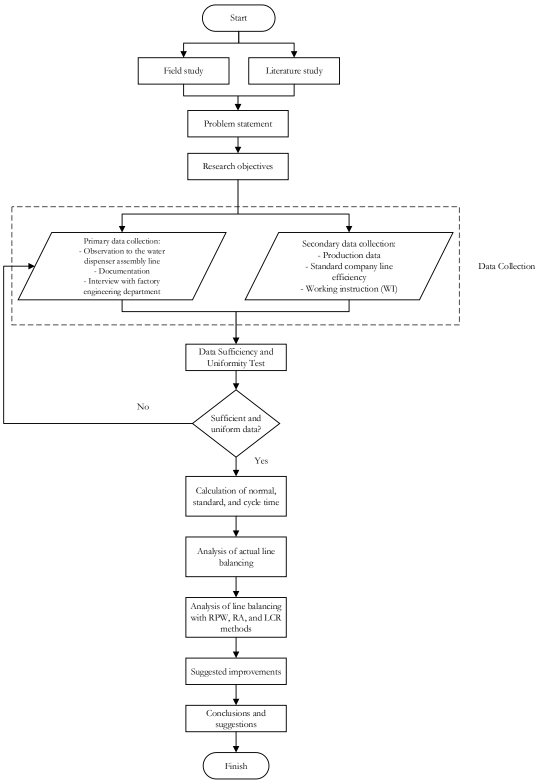

Figure III. Research Flowchart
(Source: Data Processing, 2023)

3. Findings and Discussions

3.1. Findings

3.1.1 Assembly Process Flow of Water Dispenser

The following is the process flow of the water dispenser assembly:

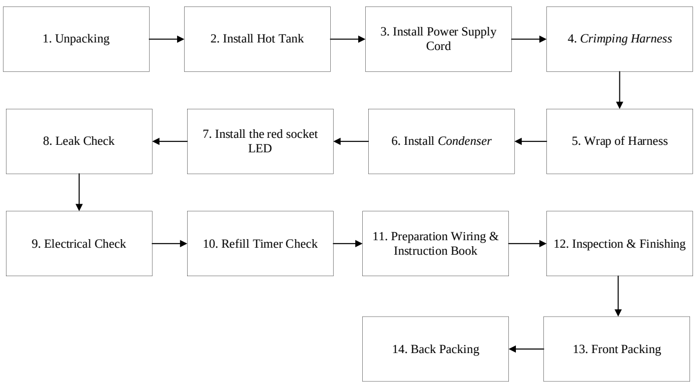

Figure IV. Assembly Flow of Water Dispenser
(Source: Data Processing, 2023)

3.1.2 Description of Work Elements

Table I. Description data of Work elements

OP	Description of work element	Predecessor
1	Put the pallet on the conveyor	-
2	Attach series number label	-
3	Marking strip	1
4	Lift the product onto the roller conveyor	3
5	Cut the strapping band	4
6	Open carton box	5
7	Open condenser screw & top cover	6
8	Install the tube binding on the socket harness top cover	7
9	Install hot tank	8
10	Plug in the power supply cord	9
11	Attach PS Cord with fixing block	10
12	Tie the hose pipe with tube binding	11
13	Attach the red and blue harness	12
14	Open the top cover, hang it on the side	13
15	Twist harness of blue & brown	14
16	Clamp harness of blue & brown	15
17	Wrap the harness with wire sleeve	16
18	Cut the overflow tube	17
19	Cut the overflow tube & place it on the cold tank cover	18

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OP	Description of work element	Predecessor
20	Replace the condenser with the screw	19
21	Straighten the hose pipe	20
22	Install the red socket LED	21
23	Tie the red socket LED with tube binding	22
24	Install the stopper jig on the exhaust tube	23
25	Open the cold tank cover	24
26	Take leak tester & apply alcohol on seal ring	25
27	Install the leak tester on the cold tank tightly	26
28	Loose leak tester & stopper jig	27
29	Install PS Cord, claws & electric check stage 1	28
30	Close the safety door & electric check stage 2	29
31	Open the safety door, loose claws & PS Cord, slide out the chassis	30
32	Install cold tank cover gasket & PS Cord	31
33	Install overflow/exhaust tube	32
34	Close the top power & loose the PS Cord	33
35	Install screws on top cover & condenser	34
36	Return of boc & bearing spareparts	35

OP	Description of work element	Predecessor
37	Tie the PS Cord behind the condenser	36
38	Preparation of wiring & instruction book	37
39	Install wiring & label name, input instruction book	38
40	Install the label switch	39
41	Tidy up dryer, capillary, condenser pipe	40
42	Check the faucet tube hole	41
43	Cleaning the chassis	42
44	Slide chassis axles	43
45	Attach the sheet cover to the chassis axle	44
46	Install plastic cover	45
47	Scan product barcode	46
48	Take the corner cushion	47
49	Attach carton label & global code	48
50	Take carton box & slide chassis axles	49
51	Install the front corner cushion	50
52	Install carton box & rear corner cushion	51
53	Tape OPP 50 to the carton box	52
54	Tie strapping band	53
55	Move it to the finish good area	54

(Source: Data Processing, 2023)

3.2. Discussion

3.2.1 Data Sufficiency Test

Based on the result of the data sufficiency test conducted using Microsoft Excel, the observation time data on the water dispenser has an N' value that is smaller than the N (5) value. Therefore, the data of all operators has a sufficient number of samples.

3.2.2. Data Uniformity Test

Based on the calculation results, the water dispenser cycle time data has uniform data. Because, the data is within the upper and lower control limits. So, the data can be processed.

3.2.3 Calculation of Standard Time

The following is an example of calculating the cycle time of the 1st operation:

$$\mathbf{CT} = \frac{\sum x_i}{n} \quad (1)$$

$$\mathbf{CT_1} = \frac{7{,}19+7{,}15+7{,}20+7{,}23+7{,}35}{5} = \frac{36{,}12}{5} = 7{,}22$$

A. Rating Factor

$$= \textit{Operator normal rating} + \textit{performance rating} \quad (2)$$

$= 1 + (0{,}08+0{,}05+0{,}02+0{,}03)$

$= 1{,}18$

B. Normal Time

$$= \textit{Cycle time} \times \textit{Rating factor} \quad (3)$$

$= 7{,}22 \times 1{,}18$

$= 8{,}52$

C. Standard Time

$$= \textit{Normal time} \times \frac{100}{100-\textit{Allowance}} \quad (4)$$

$= 8{,}52 \times \frac{100}{100-18}$

$= 10{,}40$

D. Calculation of Minimum number of Ws (Workstation)

Table II. Supporting Data of Water Dispenser

Month/year	12
Shift/day	1
Working hours/shift	9
Working days/month	22
Demand	70766

(Source: Data Collection, 2023)

E. Cycle time of Workstation

$$= \frac{(\textit{Working days} \times \textit{Working hours})}{\textit{Total Demand}} \quad (5)$$

$= \frac{244 \times 28380}{70766}$

$= \frac{6924720}{70766} = 97{,}85$ second

F. Minimum number of Workstations

$$= \frac{Total\ process\ time}{Cycle\ time\ of\ workstation} \quad (6)$$

$$= \frac{1663{,}26}{97{,}85} = 16{,}998 \approx 17$$

3.2.4 Line Balancing of Actual Condition

A. Actual Precedence Diagram

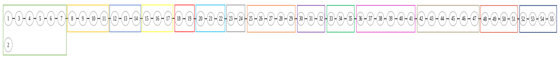

Figure V. Precedence Diagram of Actual Condition
(Source: Data Processing, 2023)

Based on the result of grouping work elements in the current condition, a precedence diagram consisting of 14 workstations is obtaineds. These workstations result from the grouping of work elements with the condition that the cumulative processing time of the work elements is equal to or less than the predetermined workstation cycle time, which is 97,85 seconds.

B. Calculation of Actual LB Evaluation

Table III. Result of Actual LB Evaluation

Ws	OP	ST	IT	SI	WE
I	1,2,3,4,5,6,7	117,82	-19,97	398,92	120,41%
II	8,9,10,11	116,02	-18,17	330,08	118,57%
III	12,13,14	146,09	-48,24	2326,76	149,30%
IV	15,16,17	136,24	-38,39	1473,55	139,23%
V	18,19	117,62	-19,77	390,67	120,20%
VI	20,21,22	116,61	-18,76	351,83	119,17%
VII	23,24	90,17	7,68	58,93	92,15%
VIII	25,26,27,28, 29	95,79	2,06	4,25	97,89%
IX	30,31,32	138,70	-40,85	1669,03	141,75%
X	33,34,35	89,75	8,10	65,59	91,72%
XI	36,37,38,39, 40,41	162,12	-64,27	4130,81	165,68%
XII	42,43,44,45, 46,47	149,47	-51,62	2664,47	152,75%
XIII	48,49,50,51	90,36	7,49	56,08	92,35%
XIV	52,53,54,55	96,51	1,34	1,80	98,63%
Total		**1663,26**	**-293,36**	**13922,76**	**1699,81%**
Line Efficiency					121,41%
Balance Delay					-21,41%
Smoothness Index					117,995

(Source: Data Processing, 2023)

Information:
Ws = Workstation
OP = Operation
ST = Station time
IT = Idle time
SI = Smoothing index
WF = Workstation of efficiency

Based on the calculation result of Table 3, it is obtained that the evaluation of the balance of the assembly line in actual conditions results in a line efficiency value of 121,41% and balance delay of -21,41%. In addition, there is a smoothness index that shows the relative smoothness of a trajectory. The more the smoothness index value approaches 0, the more balance an assembly line can be said to be. In actual conditions, the smoothness index is obtained at 117,995 seconds.

3.2.5 Line Balancing of RPW & LCR Methods

A. Precedence Diagram of RPW & LCR

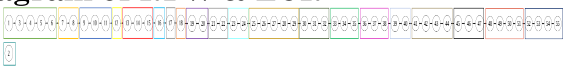

Figure IV. Precedence Diagram of RPW & LCR
(Source: Data Processing, 2023)

The following are the result of grouping workstations using the RPW & LCR methods, where work elements that have the opportunity to be combined into one workstation are arranged based on standard time equal to or not exceeding the cycle time of the workstation, expect for operations that have become isolated or isolated workstations that cannot be separated, namely the electrical check workstation.

B. Calculation of LB Evaluation

Table VI. Result of RPW and LCR Method LB Evaluation

Ws	OP	ST	IT	SI	WE
I	2	16,24	81,61	6659,59	16,6%
II	1,3,4,5,6	70,69	27,16	737,57	72,2%
III	7,8	51,18	46,67	2178,51	52,3%
IV	9,10,11	95,73	2,12	4,49	97,8%
V	12	83,92	13,93	193,98	85,8%
VI	13,14,15	71,94	25,91	671,33	73,5%
VII	16	93,87	3,98	15,80	95,9%
VIII	17	32,59	65,26	4259,35	33,3%
IX	18	88,28	9,57	91,55	90,2%
X	19,20	48,37	49,48	2448,54	49,4%
XI	21,22	97,57	0,28	0,08	99,7%
XII	23,24	90,17	7,68	58,93	92,2%
XIII	25,26,27,28,29	95,79	2,06	4,25	97,9%
XIV	30,31,32	138,70	-40,85	1669,03	141,8%
XV	33,34,35	89,75	8,10	65,59	91,7%
XVI	36,37,38	59,86	37,99	1442,89	61,2%
XVII	39,40	77,19	20,66	426,72	78,9%
XVIII	41,42,43,44	90,64	7,21	52,03	92,6%
XIX	45,46,47	83,90	13,95	194,73	85,7%
XX	48,49,50,51	90,36	7,49	56,08	92,3%
XXI	52,53,54,55	96,51	1,34	1,80	98,6%
Total		**1663,26**	**391,59**	**21232,82**	**1699,8%**
Line Efficiency					80,9%
Balance Delay					19,1%
Smoothness Index					145,715

(Source: Data Processing, 2023)

Based on the calculation result of Table 4, it is obtained that the evaluation of the assembly line balance using the RPW & LCR method results in a line efficiency value of 80,9% and a balance delay of 19,1% which shows a previous increase of -21,41% in actual conditions. Then, a smoothness index of 145,715 seconds was obtained.

3.2.6 Line Balancing of RA Methods

A. Precedence Diagram of RA

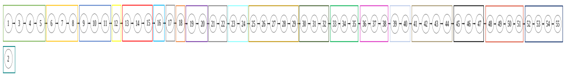

Figure VII. Precedence Diagram of RA
(Source: Data Processing, 2023)

B. Calculation of LB Evaluation

Table V. Result of RA Method LB Evaluation

Ws	OP	ST	IT	SI	WE
I	2	16,24	81,61	6659,59	16,6%
II	1,3,4,5	50,63	47,22	2229,56	51,7%
III	6,7,8	71,24	26,61	708,33	72,8%
IV	9,10,11	95,73	2,12	4,49	97,8%
V	12	83,92	13,93	193,98	85,8%
VI	13,14,15	71,94	25,91	671,33	73,5%
VII	16	93,87	3,98	15,80	95,9%
VIII	17	32,59	65,26	4259,35	33,3%
IX	18	88,28	9,57	91,55	90,2%
X	19,20	48,37	49,48	2448,54	49,4%
XI	21,22	97,57	0,28	0,08	99,7%
XII	23,24	90,17	7,68	58,93	92,2%
XIII	25,26,27,28,29	95,79	2,06	4,25	97,9%
XIV	30,31,32	138,70	-40,85	1669,03	141,8%
XV	33,34,35	89,75	8,10	65,59	91,7%
XVI	36,37,38	59,86	37,99	1442,89	61,2%
XVII	39,40	77,19	20,66	426,72	78,9%
XVIII	41,42,43,44	90,64	7,21	52,03	92,6%

Ws	OP	ST	IT	SI	WE
XIX	45,46,47	83,90	13,95	194,73	85,7%
XX	48,49,50,51	90,36	7,49	56,08	92,3%
XXI	52,53,54,55	96,51	1,34	1,80	98,6%
Total		**1663,26**	**391,59**	**21254,64**	**1699,8%**
Line Efficiency					80,9%
Balance Delay					19,1%
Smoothness Index					145,79

(Source: Data Processing, 2023)

Based on the calculation result of Table 5, it is obtained that the evaluation of the assembly line balance using the RA method results in a line efficiency value of 80,9%, a balance delay of 19,1% and a smoothness index of 145,790 seconds was obtained.

3.3 Proposed Improvements

Table VI. Recapitulation of Line Balancing Calculation Results

	LE	BD	SI	Ws
Actual	121,41%	-21,41%	117,995	14
RPW	80,9%	19,1%	145,715	21
RA	80,9%	19,1%	145,790	21
LCR	80,9%	19,1%	145,715	21

(Source: Data Processing, 2023)

Based on the analysis results of the three methods above, the selected methods are RPW and LCR with a line efficiency value of 80,9% and a smoothness index of 145,715 seconds with a proposed improvement that can be given to the company is to add the number of workstations or operators from 14 operators to 21 operators or workstations.

3.4 Model Simulations

The following below is a model layout of the proposed water dispenser assembly process using Arena simulation.

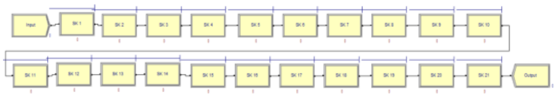

Figure VIII. Layout of the Proposed Simulation Model
(Source: Data Processing, 2023)

To find out the replication needed in the proposed simulation model, it is necessary to replicated it 11 times. The following are the output results of the proposed simulation of 11 replications which can be seen in Tabel 7.

Table VII. Proposed Simulation Output

Replication to-	Proposed Simulation Output
1	5352
2	5393
3	5366
4	5381
5	5346
6	5331
7	5327
8	5346
9	5331
10	5376
11	5372

(Source: Data Processing, 2023)

3.5 Replication Calculation

A. Calculating standard deviation

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \underline{x})^2}{n-1}} \quad (7)$$

$$s = \sqrt{\frac{(5054{,}73)^2}{11-1}} = 1598{,}44$$

B. Calculating *Half Width (hw)*

$$\boldsymbol{hw} = \frac{\left(t_{n-1\frac{\propto}{2}}\right) x s}{\sqrt{n}} \quad (8)$$

Keterangan:

$n = 11,\ n - 1 = 10$

$\alpha = 0{,}05,\ \frac{\alpha}{2} = 0{,}025$

$t_{n-1,\frac{\propto}{2}} = t_{10,0{,}025} = 2{,}228$ (value obtained from the T table with alpha 0,05)

$$hw = \frac{(2{,}228) x\ (1598{,}44)}{\sqrt{11}} = 1073{,}77$$

C. Calculating the number of replications

$$n' = \left[\frac{\left(z\frac{\propto}{2}\right) x\ s}{e}\right]^2 \quad (9)$$

$$n' = \left[\frac{(1{,}96)\ x\ 1598{,}44}{1073{,}77}\right]^2 = 8{,}513$$

Based on the replication calculations that have been obtained, it shows that the calculation results amount to 8,513 replications. Since the number of replications performed is 11 times, it is sufficient.

3.6 Performance Test

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Simulasi	.144	11	.200*	.937	11	.488

Figure IX. Validation Results of Normality Test
(Source: Data Processing, 2023)

If the Sig. or significance value or p-value of the Kolmogorov-Smirnov or Shapiro-Wilk test is greater than alpha (α=0,05), it can be concluded that the proposed simulation output has a normal distribution. Therefore, a performance test can be conducted the different between actual production and the proposed simulation output.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Produksi - Simulasi	1076.81818	2208.46376	665.87688	-406.84796	2560.48432	1.617	10	.137

Figure X. Validation Results of *Paired Samples T-Test*
(Source: Data Processing, 2023)

Based on Figure 10. there is a significant value (sig. 2-failed) of 0,137. This significant value is greater than α which is 0,05 so that h_0 is accepted. Meanwhile, the value of T table with a percentage of error of 5% obtained is 2,228, then T count < T table so that h_0 is accepted. Thus, it can be concluded that there is no difference between the average actual output and the average proposed simulation output, so that the simulation model can be said to pass verification and validation.

4. Conclusion and Suggestions

The result of this research is to be able to increase efficiency in the water dispenser assembly line using the Ranked Positional Weight, Region Approach, and Largest Candidate Rule methods by adding 21 work station which were previously only 14 work stations, so that the idle time of each work station is reduced expect for isolated work stations. This can be seen from the increase in balance delay from -21,41% to 19,1%, then line efficiency of 80,9% and smoothness index of 145,715 seconds. As for suggestions for future research, researchers can use other line balancing methods to strengthen similar research.

Acknowledgement

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