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Cabin Assembly Balancing Line on Welding Using Ranked Positional Weight Method

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Abstract – **The Indonesian automotive industry has become an essential pillar in the country's manufacturing sector. As production capacity increases, problems will also increase, including disparities in the level of efficiency and productivity of each sub-sector of the manufacturing industry in Indonesia. This problem occurs due to the need for a good process path, such as the uneven distribution of work tasks machines in the work process so that it is possible to harm the company, so a solution is needed to increase the efficiency of the production line. This research aims to improve production efficiency, particularly concerning the use of electricity costs and operator wages on the cabin type S L assembly line, by applying the Ranked Positional Weight (RPW) method. The research phases include data collection, analysis, processing, and evaluation. Based on the SL-type cabin calculations using the RPW method, the track efficiency improved by 4.69% from the initial conditions, while the track effectiveness increased by 75.02% to 79.71%. Increased the production line efficiency has impacted on the decrease in production costs Rp. 13,827,249/month.**

Keywords: Computational efficiency, line balancing, line production, manufacturing, ranked positional weight

I. INTRODUCTION

In Indonesia, the manufacturing industry plays a crucial role in developing the country's economy. Besides that, it also has a vital role as a pusher and puller for various sectors. These sectors are the automotive, trade, tourism, and others. The automotive industry is one of the various industries in Indonesia that drive its economy because it bridges various other sectors such as rubber, steel, industrial, and other industries [1].

One of the activities carried out in the manufacturing industry is production planning, which plans what products to produce, what materials to use, and how long production will begin. A significant problem that often occurs in the planning process is the possibility of an imbalance (disparity) in the efficiency and productivity of each sub-sector from industry manufacturers in Indonesia, one of which is PT. Krama Yudha Ratu Motor (KRM) is a limited liability company that assembles of motorized vehicles and passengers [2].

The problems that occurred at PT. KRM, especially in the section welding assembly cabin type SL, still experienced inequality of work time at each workstation. Twenty-seven machines are operating to assemble the cabin used by 17 operators. The unequal distribution of work time at each workstation results in a buildup of work at one workstation at another workstation experiencing unemployment. The length of idle time caused by this inequality can cause losses to the company.

The line balancing method distributes several workers to each workstation associated with one production line, so there is no overlap between cycle time and work time [3],[4]. Helgeson and Birnie introduced the Ranked Positional Weight (RPW) technique in 1961 [5]. The heuristic method trajectory balance research is divided into three methods: RPW, Largest Candidate Rules (LCR), and Region Approach (RA). The RPW method combines the LCR and KWM methods [6]. The RPW method based on accelerated task completion time is a quick way to find solutions [7]. Based on previous research, in 2017, there was an increase in machine production using the RPW compared to 2 other heuristic methods on plastic production assembly lines box 260 with an efficiency value of 91.5%, while the method Large Candidate Rules (LCR) of 88.6% and method Region Approach (RA) of 88.6% [8]. Then, another study showing the RPW method obtained results with a cycle time of 10.88 seconds in 5 workstations, reducing the delay time by 56.25% from the initial conditions. in the soccer shoe industry [9].

This study aims to improve the efficiency of the production line, particularly in relation to the efficient use of electricity costs and operators' wages on the production of SL-type cabin assembly in PT KRM by implementing the Heavy RPW. The RPW is identifying failures in a production process and determining the weights of the production process [10]. Standard time calculations are usually the basis for research line balancing with the RPW method [11]. The RPW method was chosen because it has higher efficiency and lower idle time values, and its application is more straightforward, namely by weighing, sorting, and placing tasks into workstations.

II. METHODOLOGY

In general, this research has several flowchart diagrams of the research conducted. Figure 1 presents this flowchart.

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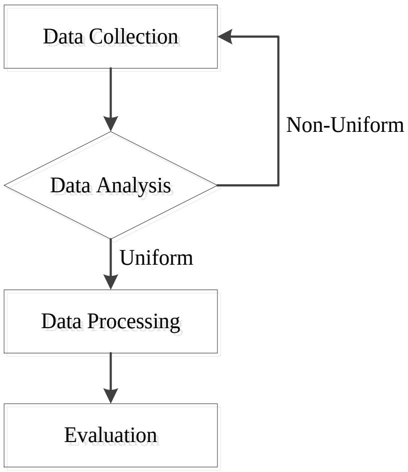

Figure 1. Flowchart diagrams

1. Data Collection

Data collection was carried out at PT.KRM in the section welding assembly cabin SL-type. Data was collected within one month by interviewing the manager, foreman, and operators. Retrieval of processing time data for each task on each machine was taken 30 observations, and then the average was taken from all tasks to use as runtime on each machine. The assembly process data obtained can be seen in Table 1.

Table 1. Assembly Process Time

No	Machine	Time (Second)
1	SSW1	212
2	SSW2	182
3	Front panel 1	158
4	Instrumen panel 1	131
5	Shield RH	140
6	Floor B assy	139
7	Shield LH	107
8	Mounting R/L	125
9	Real panel assy	149
10	Side frame RH	213
11	Front pilar RH	197
12	Bumper Assy	108
13	Front pilar LH	202
14	Side frame LH	204
15	Instrumen panel 2	116
16	Front panel 2	164
17	Cros member Fr floor	144
18	Floor A assy	135
19	Floor assy	322
20	Floor respot	254
21	Main body assy	465
22	Main body respot 1	374
23	Main body respot 2	398
24	Roof assy	180
25	Las CO2 + Brazzing	318
26	Door install	340
27	Repair in line	466
	Amount	5.943

2. Data Analysis

Data analysis was carried out by testing the uniformity of the assembly process data cabin obtained. The data processing phase can be performed if the data obtained is uniform. The data obtained can represent the data as a whole. This test is carried out by finding the average value for each task using equation 1, then calculating the standard deviation using Equation (2), and the subsequent calculation is looking for the Upper Control Limit (BKA) value using Equation (3) and looking for the Lower Control Limit (BKB) value with use Equation (4) [12].

$$\overline{X} = \sqrt{\frac{\sum xi}{N}} \quad (1)$$

where,

$\overline{X}$: Average value of the observation time for every activity

$\sum xi$: Sum of the observation of time each activity

N : Number of observations of each activity

$$\sigma = \sqrt{\frac{\Sigma\,(X_j - \underline{X})^2}{N-1}} \quad (2)$$

where,

X_j : Measurement time observed at every activity

$$BKA = \underline{x} + k\,\sigma \quad (3)$$

$$BKB = \underline{x} - k\,\sigma \quad (4)$$

where,

k : Constant value 95% confidence level

3. Data Processing

Data processing to find out the balance of the line is calculated by calculating the efficiency of the workstation using Equation (7), idle time is calculated using Equation (5), and the idle percentage of each workstation is calculated using Equation (6). The efficiency of the line and the percentage of idle time for the production line is calculated using Equation (8) and Equation (6). A Calculation to find out the minimum number of stations formed using Equation (9) [5], [13].

$$DT = K.ST_{max} - \sum_{k-1}^{k} Sti \quad (5)$$

where,

DT : Idle time

K : Number of workstations

ST_{max} : Greatest machine operating time

ST_i : Total assembly time

$$\%DT = \frac{DT}{K.ST_{max}} \text{ x } 100\% \quad (6)$$

where,

%DT : Idle time percentage

$$ESK = \frac{ST_k}{ST_{max}} \text{ x } 100\% \quad (7)$$

where,

ESK : Workstation efficiency

ST_k : Operating time for each station

$$LE = \frac{\sum_{k-1}^{k} ST_k}{K.CT} \text{ x } 100\% \quad (8)$$

where,

LE : Track efficiency

CT : Cycle time

$$K\ min = \frac{\sum_{k-1}^{k} Sti}{ST_{max}} \quad (9)$$

where:
K min : Minimum number of workstations

- *Calculates the efficiency of the current state.*

The efficiency of the current condition track is calculated to find out how much the efficiency of the track is currently being operated.

- *Calculating efficiency using the RPW method.*

The steps taken in calculating track balance using the Ranked Positional Weight method are as follows. The steps in the calculation can be seen in Figure 2 [14].

4. Evaluation

The RPW calculations are analyzed and compared with the track efficiency in the current conditions. This is done to see significant differences from these calculations so that conclusions can be drawn about whether or not the calculation results can be used. Evaluation is carried out through simulations made in the Python software display as a calculation processor and Matlab as a concise and visual display of results.

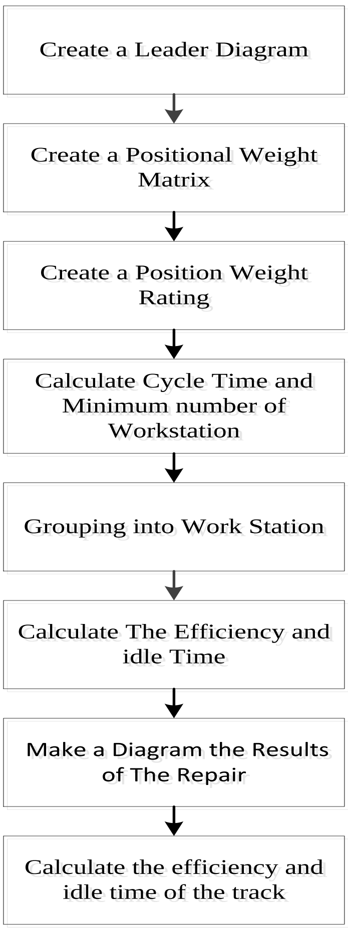

Figure 2. RPW method

III. RESULTS AND DISCUSSION

The results of calculating the efficiency of the production line currently running in the section Welding assembly cabin SL-type can be seen in Figure 3. Seventeen operators currently operate the assembly cabin.

Table 2. Current Path Efficiency

Track Efficiency Results in the Initial Conditions of PT. Krama Yudha Ratu Motor	
Percentage of track efficiency (%)	**Percentage of idle time (%)**
75.02	24.98

The efficiency of the current path on the assembly cabin type SL at PT. KRM of 75.02% and idle time of 24.98%. The following calculation is to calculate the assembly production line cabin SL type by using the RPW method.

The preliminary diagram on the assembly process cabin type SL at PT. KRM can be seen in Figure 4 to see the names of the machines in operation and Figure 5 to see the processing time for each machine. At the current state of the assembly, cabin SL-type is operated by seventeen operators. Each operator operates 1 to 3 machines.

Figure 3 is a preliminary diagram of the assembly process cabin SL-type, which explains the machines' names and the processing process's flow. Other information contained in Figure 3 is the number of machines operating in the assembly, as much as 27 engines. The time on each machine is presented in Figure 4. Processing time from the first to the last machine is presented in Figure 4.

Weighting is done by calculating the processing time from start to finish, starting from the first machine to the last machine. The weighting results will be shown in Table 3. Weighting on assembly cabin type SL is carried out from the first machine to the last, namely the 27th machine. The first weighting is carried out on the first machine, namely the Spot Welding Machines (SSW) 1 machine. Judging from the flow of work processes carried out after the first machine. This process will be continued from machines 9, 10, 11, and 12, which will then be continued on machine 21 to machine 27. The processing time on each machine that is passed by work starting from the SSW 1 engine is added up, and the result of this sum is the result of the weighting of the first machine, namely the SSW1 engine. The weighting process like this is carried out up to machine 27. Then, the ranking is carried out from the highest weighting result to with the lowest weighting result. The results of sorting the position weights on all machines can be seen in Table 4. The weighting results are sorted from the highest weighting results to the lowest weighting results. The highest weighting is on machine 8, which explains that the machine has the most extended process in the RPW method, where the position weight ranking results are used as a sequence in the time distribution at each workstation.

The cycle time in the calculation uses the most considerable time available on the assembly machine cabin SL type. The longest operating time on the machine was 27 of 466 seconds. Moreover, the minimum number of workstations formed is calculated by equation 9 as follows.

$$Kmin = \frac{\sum_{k-1}^{k} STi}{ST_{max}} = \frac{5943}{466} = 12{,}75 \sim 13 \text{ Workstation}$$

Table 3. Current Track Time

Position Weight		
Machine	**Position Weight (Seconds)**	**Time Each Machine (Seconds)**
1	3420	212
2	3129	182
3	2863	158
4	2952	131
5	3257	140
6	325	139
7	3224	107
8	3521	125
9	2690	149
10	2754	213
11	2951	197
12	1412	108
13	2947	202
14	2745	204
15	2821	116
16	2705	164
17	3396	144
18	3252	135
19	3117	322
20	2795	254
21	2541	465
22	2076	374
23	1702	398
24	1304	180
25	1124	318
26	806	340
27	466	466

Grouping machines into workstations using the RPW method on assembly cabin Type SL can be seen in Table 5. Table 5 results from grouping assembly machines cabin SL-type as a workstation. The grouping results using the RPW method have 16 groups, which describes that 16 operators can do assembly cabin SL type at PT KRM. The division of work time is carried out based on the order of weighting results. The weighting results have a high value, and then the machine enters the first workstation. It can be seen in Table 5 that the highest weighting results are found on machine 8, namely the R/L mounting machine, with a processing time of 125 seconds on this machine. The maximum time for each workstation is 466 seconds, so this first station can still receive other machines to maximize it.

Table 4. Sorting of Weight Results

Sorting of Weighting Results From Highest to Lowest Weight Value			
Order	**Position Weight (Seconds)**	**Machine TH-**	**Settlement Time**
1	3521	8	125
2	3420	1	212
3	3396	17	144
4	3257	5	140
5	3256	6	139
6	3252	18	135
7	3224	7	107
8	3129	2	182
9	3117	19	322
10	2952	4	131
11	2951	11	197
12	2974	13	202
13	2863	3	158
14	2821	15	116
15	2795	20	254
16	2794	10	213
17	2745	14	204
18	2705	16	164
19	2690	9	149
20	2541	21	465
21	2076	22	374
22	1702	23	398
23	1412	12	108
24	1304	24	180
25	1124	25	318
26	806	26	340
27	466	27	466

Table 5. Grouping Into Workstations

Grouping Machines into Workstations	
Workstation	**TH Machine**
1	(1, 8)
2	(6, 5, 17)
3	(2, 7, 18)
4	(4, 19)
5	(13, 11)
6	(15, 3)
7	(20)
8	(10, 14)
9	(16, 9)
10	(21)
11	(22)
12	(23)
13	(12, 24)
14	(25)
15	(26)
16	(27)

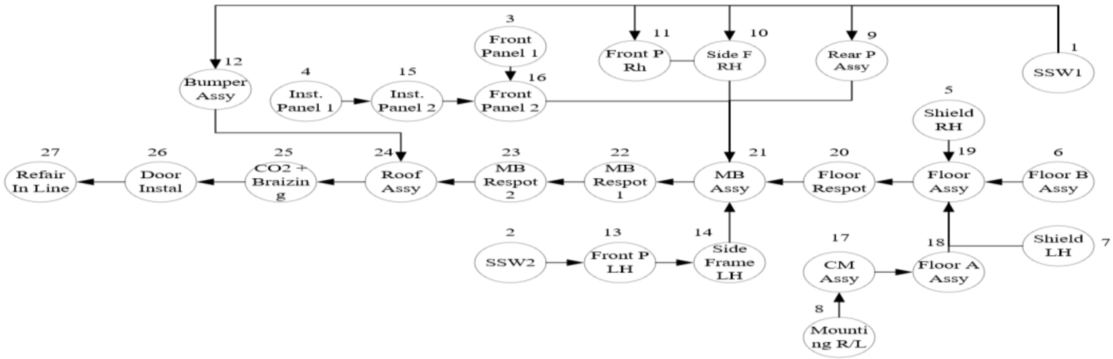

Figure 3. SL Type cabin assembly machine names

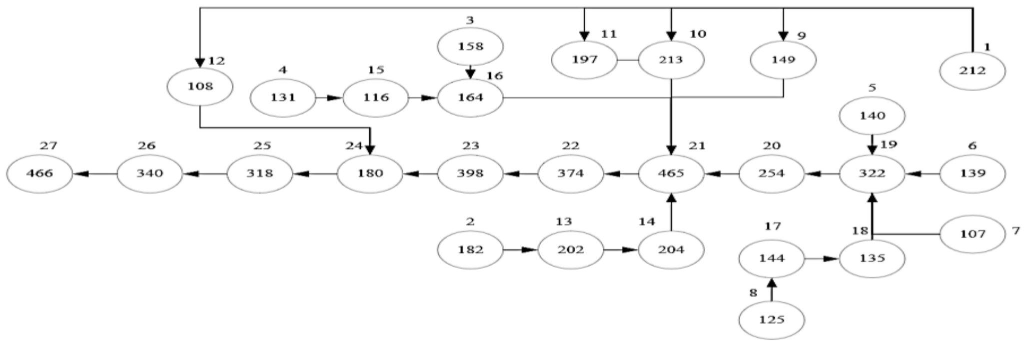

Figure 4. Machine assembly time cabin type SL

Looking back at Table 5, the second order of weighting results is machine 1, which is the SSW1 machine with a processing time of 212 seconds on this machine. With the addition of the SSW1 machine at the first workstation, the combined time is 337 seconds. The maximum time at each workstation is 466 seconds, and at the first station, two machines have joined together with a total time of 337 seconds, so the first workstation still needs to be improved by 129 seconds. Next, we will look at the third order of the weighting results in table 7, namely engine 17, which is the engine *member* assy with processing time on this machine is 144 seconds. The first station has a time shortage of 129 seconds and the third order of weighting has a processing time of 144 seconds. If combined at the first workstation, the time at the first workstation will exceed the maximum time. Therefore, the first station can only be filled with machines on first and second position weight ranking, namely the engine *mounting* R/L and SSW 1 engine with a combined time of 337 seconds. Subsequent grouping is carried out in the same process until all machines are realized at all workstations. The workstation formed is then calculated for the efficiency of the workstation. The efficiency of each workstation can be seen in Table 6. The workstation efficiency result formed using the RPW method. The efficiency of the first workstation is 72.32%, indicating that there is still idle time at this first workstation, which can be seen in Table 7. the idle time found at each workstation formed using the RPW method. The first workstation has an idle time of 129 seconds, and this is due to time sharing in the RPW method must pay attention to the ranking of position weight results so that this first workstation cannot be optimized even though there are still machines that can fill idle time at this first workstation. The workstation with no idle time is at the last workstation, namely workstation 16 with an in-line repair machine, and the processing time on this machine is 466 seconds.

Table 6. Workstation Efficiency

Efficiency of Each Working Station in the RPW Method		
Operator	**Workstation Completion Time (Seconds)**	**Workstation Efficiency (%)**
1	337	72.32
2	423	90.77
3	424	90.99
4	453	97.21
5	399	85.62
6	274	58.80
7	254	54.51
8	417	89.48
9	313	67.17
10	465	99.79
11	374	80.26
12	398	85.41
13	288	61.80
14	318	68.24
15	340	72.96
16	466	100.00

Table 7. Workstation Idle Time

Operator Idle Time On RPW Method			
Operator	**Workstation Completion Time (Seconds)**	**Idle Time (Seconds)**	**Percentage (%)**
1	337	129	27.68
2	423	43	9.23
3	424	42	9.01
4	453	13	2.79
5	399	67	14.38
6	274	192	41.20
7	254	212	45.49
8	417	49	10.52
9	313	153	32.83
10	465	1	0.21
11	374	92	19.74
12	398	68	14.59
13	288	178	38.20
14	318	148	31.76
15	340	126	27.04
16	466	0	0.00

A preliminary diagram of the assembly process cabin type SL was remade based on the workstation results that were formed while still paying attention to the flow of the assembly process. A preliminary diagram using the RPW method can be seen in Figure 5. Each machine joined to one workstation is made as close as possible so that the operator does not waste time switching machines. Each workstation is marked with one color. The color information for each workstation can be seen in Figure 6.

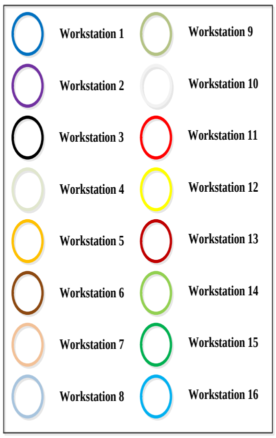

Figure 6. Information color preliminary diagram using RPW method

The 16 colors that describe the workstations in the predecessor diagram were formed using the RPW method. The following calculation is to find the efficiency of the production line cabin SL-type using the RPW method. The efficiency of the production line using the RPW method can be seen in Table 8.

Table 8. Method Trajectory Efficiency *Ranked Positional Weight* (RPW)

Track Efficiency Results Using the RPW method	
Percentage of Track Efficiency (%)	**Percentage of Idle Time (%)**
79.71	20.29

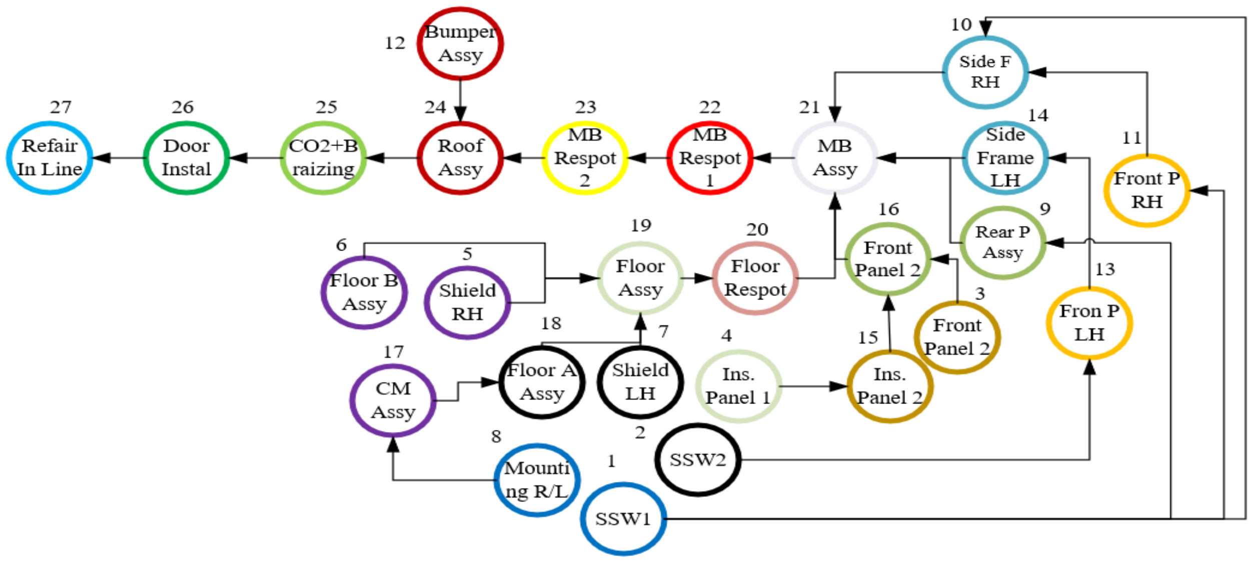

Figure 5. Preliminary diagram using the RPW method

Calculation results using the RPW method obtained a tracking efficiency of 79.71% and idle time of 20.29%. Calculations using this method slightly increase track efficiency from the conditions currently operated by the company, which is 4.69%. Routing efficiency calculation results with RPW can be converted to calculate the efficiency of electricity consumption on SL cabin assembly. The operator's and electricity fees issued by the company for the production of SL Cabin Assembly amounted to Rp.199.916.125,- a month with 27 machines working for two shifts per day and operated by 17 operators. The efficiency result obtained from RPW by reducing operators to 16 operators, thereby reducing costs by Rp. 13,827,249/ month.

IV. CONCLUSION

Based on the results of calculation simulations using RPW methode, the efficiency of the production line has increased by 4.69%, from the initial line efficiency of 75.02% to 79.71%, and the assembly line idle time cabin type SL decreased from 24.96% to 20.29%. Then there is the efficiency of the cost of electricity use and the operator's wages due to the increased efficiency and can reduce 1operator so there is a cost reduction of Rp. 13,827,249/month.

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