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Implementation of Line Balancing to Increase the Productivity of the Box Aspect Production Process

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Abstract

In the manufacturing industry, the balance of the production trajectory is an important factor in increasing productivity and efficiency. In the production process at PT XYZ, there are problems with the balance of the production trajectory at the workstation, so it is necessary to determine the optimal production trajectory so that the load on the workstation can be evenly distributed and able to reduce idle time. The Ranked Positional Weight (RPW) and Region Approach (RA) methods were chosen in this study. The main bottleneck was found at the hole cutting stage, where tool limitations caused output differences between manual and machine processes. This imbalance resulted in idle time which affected the overall production efficiency. The analysis results show that the application of RPW and RA methods is able to improve trajectory efficiency by optimizing the number of work stations and reducing idle time. The analysis results state that the company can achieve a trajectory efficiency of 88.48% and reduce the balance delay from -16.67% to 15,73% and a smoothness index of 611,25%.

Introduction

Currently, the industrial world is experiencing increasingly rapid development, therefore companies are required to increase productivity in order to meet market demand. To face intense competition, companies must also create high efficiency and productivity (Liu et al., 2022; Leppänen et al., 2023; Tampi et al., 2022). Increasingly intense competition makes productivity not only a necessity, but also the main demand (Styawan et al., 2021; Carlin & Seabright, 2001). High production efficiency and productivity will be a positive value for companies and consumers in order to increase competitiveness. Of the many things that can affect efficiency and productivity, one of them is by paying attention to the balance of the production trajectory. Trajectory balance or line balancing aims to minimize idle time at each work station, so as to achieve high work efficiency at work stations (Fitri et al., 2022; Yılmaz, 2022; Prabowo, 2022).

PT XYZ, , manufactures ATCS (Area Traffic Control System). The box aspect is a box-shaped bar as a place to put traffic light components, starting from modules, wiring, and LED lights. In the production process, there is a trajectory bottleneck in the cutting hole section because it is done using the help of human labor (manual) as a result of the limited size cutting tools owned by the company (Naeem et al., 2022; Lunny, 2022; Ramalho et al., 2024). It can be seen that the cutting hole process is divided into 2 working methods, namely manually and automatically (using a machine). The difference in processing methods is caused by the lack of cutting tools, because the company only has a cutting tool with a diameter of 30 cm.

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Therefore, cutting with a diameter of 20 cm is still done manually. Because of the different ways of working, the output results in each size becoming unbalanced. This causes idle time so that it affects the overall production process (Habib et al., 2023; Cheng et al., 2022; Soori et al., 2023).

Based on this background, this research will discuss how to plan the work system at PT XYZ to optimize line balancing at work stations based on cycle time. The line balancing methods used are ranked positional weight and region approach. Ranked Position Weight is one of the heuristic methods proposed by Helgeson and Birnie as an approach to solving problems on line balancing and finding solutions quickly (Pulansari & Nugraha, 2023; Xu et al., 2023; Çelik & Arslankaya, 2023; Helal et al., 2024). Meanwhile, the Region Approach is a method that uses a technique that uses a work operation time sequencing technique based on a regional approach. This research aims to implement the balance of the aspect box production trajectory at PT XYZ by comparing the two methods. Later, the highest effectiveness that can be achieved on the trajectory balance using the ranked positional weight (RPW) method and the region approach will be selected. This research is expected to provide a better production trajectory than the current condition with a balanced workload and optimal use of existing production facilities.

Time Study

Time measurement is the work of observing and recording working times (Rahayu & Juhara, 2020). There are two categories of time measurement techniques, namely directly and indirectly. Direct measurements are taken at the place where the measurement is carried out such as the stopwatch and work sampling method. While indirect measurements are taken without having to be at the place of work (Pradana & Pulansari, 2021).

Line Balancing

Line balance is an important thing to do on a production line, because a balanced production line will streamline the use of company resources and reduce idle time (Gunawan & Wirawati, 2023). The ultimate goal of line balancing is to minimize idle time at each workstation, so as to achieve high work efficiency at workstations. Line balancing is the balancing of the assignment of task elements from an assembly line to workstations to minimize the number of workstations and minimize idle time at all stations (Pradesi et al., 2021; Álvarez-Miranda et al., 2021; Rasib et al., 2025; Zamzam & Elakkad, 2021).

Ranked Positional Weight (Helgeson – Birnie)

The Helgelson-Birnie / Ranked Positional Weight method was developed by W.B.Helgeson and D.P.Birnie. This method is better known as the Ranked Positional Weight system or RPW system (Amalia et al., 2021). Ranked Positional Weight (RPW) is a heuristic method. This method prioritizes the longest work element time. The work element will be prioritized first to be placed in another workstation that represents a lower element time. This process is done by giving a weight (rank). This weight is given to each work element with respect to the precedence diagram (Dasanti et al., 2020).

Region Approach

The Region Approach method was introduced by Kilbridge and Webster. This method is one of the line balancing methods and has been applied with success in solving a number of trajectory balance problems that occur in the manufacturing industry (Ivan T, 2022).

Methods

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This research was conducted at PT Adi Joyo Kusumo which is located in Porong District, Sidoarjo Regency, East Java. This research was conducted until the data was fulfilled. In this study there are independent variables and dependent variables, the independent variables in this study are production process time, number of work stations, number of work elements, and number of operators. While the dependent variable in this study is trajectory efficiency. Data collection techniques carried out in this field research by means of interviews and observations. At the interview stage, it was carried out together with the head of production. While the observation stage is carried out with documentation such as videos and photos. Observations were made during the normal production process. This research uses quantitative data analysis methods using the Ranked Positional Weight and Region Approach methods where an effective and efficient trajectory balance can be obtained.

Results and Discussion

After collecting data, we obtained data on the aspect box production process with 11 work stations and 14 work elements. Table 1 shows the sequence of the production process

Table 1. Production Process Sequence

No	Work Station	Work Element
1	Cutting Alumunium	Cutting Plate
2	Marking	Marking
3	Cutting	Cutting
		Cutting Hole
		Bending
4	Process Welding	Process Welding
5	Process Driling	Process Driling
6	Process Sanding	Process Sanding
7	QC	QC
8	Cleaning	Cleaning
9	Coloring	Powder Coating
10	Oven	Oven
11	Assembly	Assembly
12	QC	QC

Tabel 2. Time Measurement

Work Element	Observation Time (Second)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	62	62	66	65	63	61	61	63	63	60	59	64	59	59	60
2	50	55	53	55	53	51	50	51	51	53	52	51	51	50	51
3	114	113	105	112	113	110	106	111	107	109	106	111	110	106	108
4	140	131	135	136	137	132	136	134	132	133	137	134	132	130	134
5	110	105	99	107	105	106	104	111	99	101	102	99	100	104	108
6	282	293	284	283	282	281	280	284	283	284	285	292	295	289	294
7	121	124	123	123	120	120	122	124	121	118	121	120	123	119	120
8	146	134	151	146	151	139	141	143	145	150	138	139	143	152	140
9	70	67	70	68	69	71	65	68	67	69	70	68	68	71	68
10	60	63	61	63	65	60	63	62	63	62	60	63	62	60	61

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Work Element	Observation Time (Second)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11	60	65	62	64	63	65	65	61	59	61	60	58	58	62	61
12	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
13	290	295	293	289	290	288	289	293	290	293	298	289	292	292	296
14	85	82	95	86	81	84	85	92	91	89	86	84	86	87	91

Uniformity Test Calculation

In Table 3. There are uniformity test results for all work elements on the aspect box production trajectory. In the following table the data is uniform so we can proceed to the next step.

Tabel 3. Data Uniformity test Result

No	Work Element	Average	Standar Deviation	BKA	BKB	Description
1	Cutting Plate	61.80	2.21	66.22	57.38	Uniform
2	Marking	51.80	1.66	55.11	48.49	Uniform
3	Cutting	109.40	2.95	115.29	103.51	Uniform
4	Cutting Hole	134.20	2.68	139.56	128.84	Uniform
5	Bending	104.00	3.96	111.93	96.07	Uniform
6	Process Welding	286.07	5.09	296.25	275.88	Uniform
7	Process Driling	121.27	1.83	124.93	117.60	Uniform
8	Process Sanding	143.87	5.48	154.82	132.92	Uniform
9	QC	68.60	1.64	71.88	65.32	Uniform
10	Cleaning	61.87	1.51	64.88	58.86	Uniform
11	Powder Coating	61.60	2.41	66.43	56.77	Uniform
12	Oven	1200.00	0.00	1200.00	1200.00	Uniform
13	Assembly	291.80	2.91	297.62	285.98	Uniform
14	QC	86.93	3.92	94.77	79.10	Uniform

Calculation of Sufficiency Test

For the data sufficiency test, an accuracy level of 5% and a confidence level of 95% are used, so the data sufficiency test equation is the value of k = 2 and the value of s = 0.05.

$$N' = \left[\frac{k/s\sqrt{n\Sigma(xi^2) - (\Sigma xi)^2)}}{\Sigma xi}\right]^2$$

$$N' = \left[\frac{2/0{,}05\sqrt{210x(37795360) - (2138877504)}}{927}\right]^2$$

$$N' = 141{,}777$$

N = 210

Calculation of Cycle Time

The following is an example of calculating the results of cycle time on work element 1 obtained by:

$$W_{s1} \quad = \frac{\sum x}{N}$$

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$= \frac{62 + 62 + \cdots + 60}{15}$

$= \frac{927}{15} = 61.80\ second$

Calculation of Normal Time

After obtaining data on the production time of each work element, the next step is to calculate the normal time and standard production time. Previously, it was necessary to know the performance rating. The following is a table of the level of adjustment for making box aspects.

Table 4. Rating Performance

Work Station	Total Rating Performance
1	0.23
2	0.26
3	0.26
4	0.17
5	0.27
6	0.23
7	0.13
8	0.23
9	0.13
10	0.13
11	0.33
12	0.27

From the table, it can be calculated the normal time in the aluminum cutting process with the following equation:

$W_{n(1)} \quad = W_s\ x\ (1 + Rating\ Faktor)$

= 61.80 x (1+0.23)

= 76,01 second

Calculation of Standard Time

Before calculating the standard, it must first be known that allowances are used in calculating standard time so that workers can work properly because workers have the opportunity to do things that must be done for personal needs, relieve fatigue, and things that cannot be avoided so that the standard time obtained can be said to be data, complete work time and represent the observed work system. The following is the allowance for each work element:

Tabel 5. Allowance

Work Station	% Allowance
1	13
2	11.5
3	15
4	12.5
5	12.5
6	11.5
7	12.5
8	13
9	12.5
10	10.5
11	14

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12	12.5

Furthermore, the calculation of the standard time of the aluminum cutting process workstation can be done using the following equation:

$$W_{baku(1)} = W_{normal}\ x\ \frac{100\%}{100\% - \%Allowance}$$

$$= 76.01\ x\ \frac{100\%}{100\% - \%13}$$

= 87,37 second

Table 6. Recapitulation of Normal Time and Standard Time Calculations

Work Element	Cycle Time	Normal Time	Standardized Time
1	61.80	76.01	87.37
2	51.80	65.27	73.75
3	109.40	137.84	162.17
4	134.20	169.09	198.93
5	104	131.04	154.16
6	286.07	377.61	431.55
7	121.27	143.09	163.54
8	143.87	168.32	190.20
9	68.60	87.12	99.57
10	61.87	76.10	87.47
11	61.60	69.61	88.70
12	1200	1,356	1515.08
13	291.80	388.09	451.27
14	86.93	110.41	126.18

Initial Condition Calculation

The following is the calculation of initial condition line balancing performance parameters including workstation efficiency, line efficiency, idle time, balanced delay, and smoothness index.

Work Station Efficiency

$$Work\ Station\ Efficiency = \frac{Wbi}{Wb\ Max}\ x\ 100\%$$

$$= \frac{76.10}{1515,08}\ x\ 100\%$$

= 4,87 %

Line Efficiency

$$Line\ Efficiency = \frac{\sum_{i-1}^{k} STi}{(K)(CT)} x\ 100\%$$

$$= \frac{3829,9449}{(12)(1515,08)} x100\%$$

= 0,210%

Idle Time

$$Idle\ Time = nWb \max - Wbi$$

$$Idle\ Time_{(1)} = 12\ x\ 1515,08 - 87,37 = 18093,58$$

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The total idle time in the initial condition of the production trajectory is 214341,5751 seconds.

Balanced Delay

$$Balanced\ Delay = \frac{nC - \sum ti}{(nti)}\ x\ 100\%$$

$= \frac{12\ x\ 273{,}57 - 3829{,}94}{(12\ x\ 273{,}57)}\ x\ 100\% = -16{,}67\%$

Smoothness Index

$$Smoothness\ Index = \sqrt{\sum(TSImax - TSI)^2}$$

$= \sqrt{23423545{,}18}$

$= 4839{,}78\%$

Calculation of Ranked Positional Weight

Precedance Diagram of Initial Condition

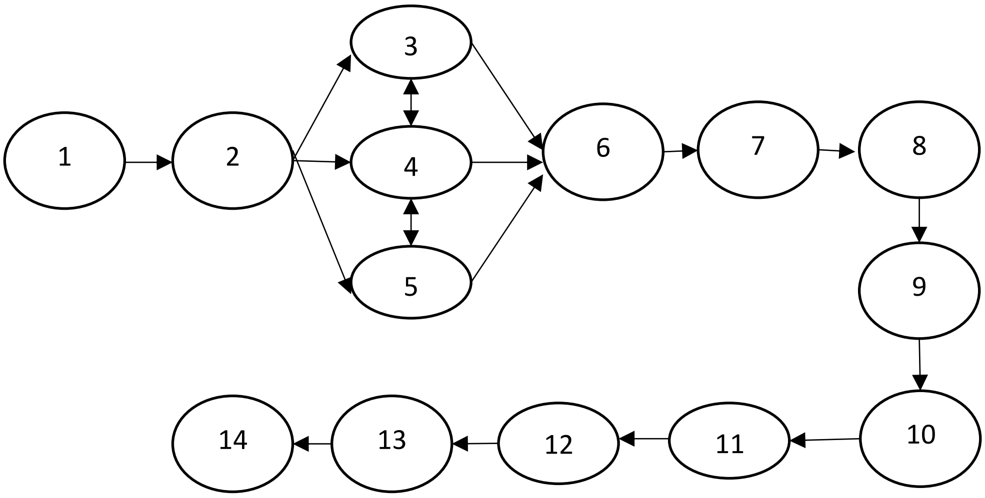

Figure 1. Precedance Diagram

Operation Weight Priority Ranking Based on Position Weight

Table 7. Operation Weight Priority

Work Operations	Predecessor Operation	Position Weight	Rank
A	B,C,D,E,F,G,H,I,J,K,L,M,N	3829.94	1
B	C,D,E,F,G,H,I,J,K,L,M,N	3742.57	2
C	D,E,F,G,H,I,J,K,L,M,N	3315.72	4
D	E,F,G,H,I,J,K,L,M,N	3352.48	3
E	F,G,H,I,J,K,L,M,N	3307.72	5
F	G,H,I,J,K,L,M,N	3153.55	6
G	H,I,J,K,L,M,N	2722.01	7
H	I,J,K,L,M,N	2558.46	8
I	J,K,L,M,N	2368.27	9
J	K,L,M,N	2268.70	10
K	L,M,N	2181.23	11
L	M,N	2092.53	12
M	N	577.44	13

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N	-	126.18	14

Number of work Station

Number of work Station $= \frac{Wbi}{Wb\ Max} = \frac{35596{,}86}{1515{,}08}$ = 2,53 rounded up to 3

Line Efficiency

$$Line\ Efficiency = \frac{\sum_{i-1}^{k} STi}{(K)(CT)} x\ 100\%$$

$= \frac{35596{,}86}{(3)(1515{,}08)} x100\%$

= 84,27%

Balanced Delay

$$Balanced\ Delay = \frac{nC - \sum ti}{(nti)}\ x\ 100\%$$

$= \frac{3\ x\ 1515{,}08 - 35596{,}86}{(\ 3\ x\ 1515{,}08)}\ x\ 100\%$

= 15,73%

Smoothness Index

$$Smoothness\ Index = \sqrt{\sum (TSImax - TSI)^2}$$

$= \sqrt{373627{,}30}$

= 611,25

Layout of Calculation Result of RPW Method

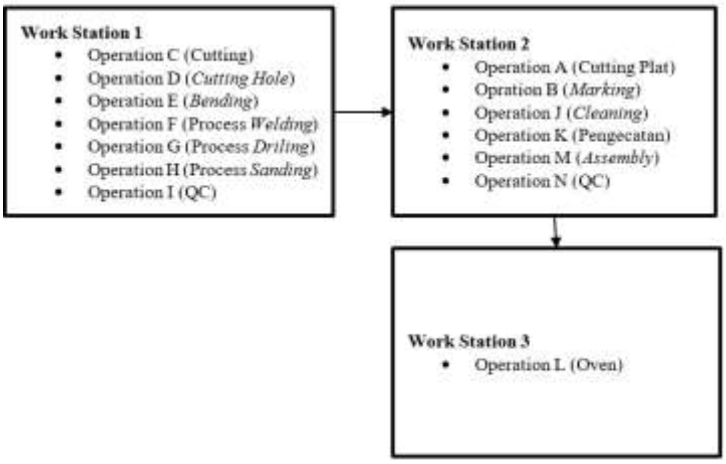

Figure 2. Layout of Calculation Result of RPW Method

Calculation of Metode Region Approach

Number of Work Station

Number of work Station $= \frac{Wbi}{Wb\ Max} = \frac{35596{,}86}{1515{,}08}$ = 2,53 rounded up to 3

Line Efficiency

$$Line\ Efficiency = \frac{\sum_{i-1}^{k} STi}{(K)(CT)} x\ 100\%$$

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$= \frac{35596,86}{(3)(1515,08)} x100\%$

= 84,27%

Balanced Delay

$$Balanced\ Delay = \frac{nC - \sum ti}{(nti)}\ x\ 100\%$$

$= \frac{3\ x\ 1515,08 - 35596,86}{(\ 3\ x\ 1515,08)}\ x\ 100\%$

= 15,73%

Smoothness Index

$$Smoothness\ Index = \sqrt{\sum (TSImax - TSI)^2}$$

$= \sqrt{373627,30}$

= 611,25

Layout of Calcualtion Result of RA Method

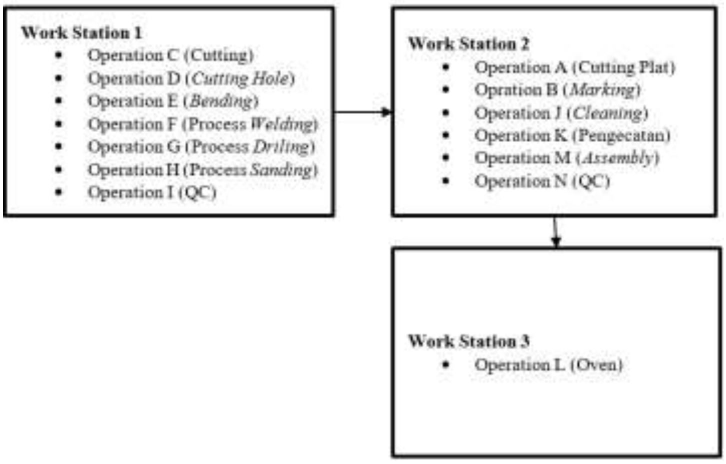

Figure 3. Layout of Calculation Result of RA Method

Table 8. Comparison Results Between Production Trajectory Performance Parameters

Potential Output	**Initial Conditions**	**Metode RPW**	**Metode RA**
Number of Work Stations	12	3	3
Line Efficiency	0,221%	84,26%	84,26%
Balance Delay	-16,67%	15,73%	15,73%
Smoothness Index	4839,79	611,25	611,25

From table 8 above, it can be concluded that both methods, namely the Ranked Positional Weight and Region Approach methods, can improve trajectory efficiency. Among the two methods, the calculation results between the two methods have the same value, which is divided into three work stations with a trajectory efficiency of 84.26%. This is a very positive impact compared to the initial condition which has a trajectory efficiency of close to 0%. The company can also reduce idle time during the production process. With the calculation of the minimum number of work stations, 3 work stations were obtained which were previously 12 work stations. This can affect the value of smooth production so that it experiences a very drastic decrease in value, from 4839.79 to 611.25. This can be shown through the smooth index value because the smaller the value, the better the line performance. Therefore, the

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Ranked Positional Weight and Region Approach methods will be chosen because they can improve the efficiency of the aspect box production line at PT XYZ.

Conclusion

It can be concluded that both methods, namely the Ranked Positional Weight and Region Approach methods, can improve trajectory efficiency. Among the two methods, the calculation results between the two methods have the same value, which is divided into three work stations with a trajectory efficiency of 84.26%. This is a very positive impact compared to the initial condition which has a trajectory efficiency of close to 0%. The company can also reduce idle time during the production process. With the calculation of the minimum number of work stations, 3 work stations were obtained which were previously 12 work stations. This can affect the value of smooth production so that it experiences a very drastic decrease in value, from 4839.79 to 611.25. This can be shown through the smooth index value because the smaller the value, the better the line performance. Therefore, the Ranked Positional Weight and Region Approach methods will be chosen because they can improve the efficiency of the aspect box production line at PT XYZ.

References

Álvarez-Miranda, E., Chace, S., & Pereira, J. (2021). Assembly line balancing with parallel workstations. *International Journal of Production Research*, *59*(21), 6486-6506. http://dx.doi.org/10.1080/00207543.2020.1818000

Amalia, A. N., Yudhanegara, D., & Gumelar, A. (2021). Pengukuran Keseimbangan Lintasan Produksi Sabuk Kopling Mobil. *Industrika: Jurnal Ilmiah Teknik Industri*, *5*(1), 25-30.

Carlin, W., & Seabright, P. (2001). The importance of competition in developing countries for productivity and innovation Background paper for World Development Report. *The Surveillance Studie s Centre*.

Çelik, M. T., & Arslankaya, S. (2023). Solution of the assembly line balancing problem using the rank positional weight method and Kilbridge and Wester heuristics method: An application in the cable industry. *Journal of Engineering Research*, *11*(3), 182-191. https://doi.org/10.1016/j.jer.2023.100082

Cheng, L., Tang, Q., Zhang, L., & Yu, C. (2022). Scheduling flexible manufacturing cell with no-idle flow-lines and job-shop via Q-learning-based genetic algorithm. *Computers & Industrial Engineering*, *169*, 108293. https://doi.org/10.1016/j.eswa.2025.128198

Dasanti, A. F., Jakdan, F., Dedy, & T.Santoso. (2020). Penerapan Konsep Line Balancing Untuk Mencapai Kerja Di PT GARMENT JAKARTA. *Bulletin of Applied Industrial Engineering Theory*, *1*(2), 2–7.

Fitri, M., Adelino, M. I., & Apuri, M. L. (2022). Analisis Line Balancing Untuk Meningkatkan Efisiensi Lintasan Produksi Perakitan. *Rang Teknik Journal*, *5*(2), 295–300. https://doi.org/10.31869/rtj.v5i2.3223

Gunawan, W., & Wirawati, M. (2023). Analisis Perbandingan Kriteria Line Balancing Dengan Menggunakan Metode Lcr Pada Automation Cell (Studi Kasus Di Pt. Unp). *Journal of Industrial Engineering & Management Research*, *4*(4), 95–107.

Habib, M. A., Rizvan, R., & Ahmed, S. (2023). Implementing lean manufacturing for improvement of operational performance in a labeling and packaging plant: A case study in Bangladesh. *Results in Engineering*, *17*, 100818. http://dx.doi.org/10.1016/j.rineng.2022.100818

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Helal, M., Nag, K., & Ozdemir, R. (2024). ON THE ASSEMBLY LINE BALANCING PROBLEM: A SIMPLIFIED PERSPECTIVE WITH THE PRECEDENCE MATRIX. *Journal of Applied Engineering and Technological Science*, *6*(1), 1-20. http://dx.doi.org/10.37385/jaets.v6i1.5597

Ivan T, J. A. S. (2022). *Analisis Line Balancing Menggunakan Metode Region Approach di PT. XYZ*. *03*(03), 49–60.

Leppänen, P., George, G., & Alexy, O. (2023). When do novel business models lead to high performance? A configurational approach to value drivers, competitive strategy, and firm environment. *Academy of management journal*, *66*(1), 164-194. http://dx.doi.org/10.5465/amj.2020.0969

Liu, Q., Qu, X., Wang, D., Abbas, J., & Mubeen, R. (2022). Product market competition and firm performance: business survival through innovation and entrepreneurial orientation amid COVID-19 financial crisis. *Frontiers in Psychology*, *12*, 790923. http://dx.doi.org/10.3389/fpsyg.2021.790923

Lunny, M. (2022). *Automation of NC Programming with Artificial Intelligence* (Doctoral dissertation, Massachusetts Institute of Technology).

Naeem, A., Pasha, R. A., & Muneeb, M. (2022). A novel milling fixture pallet system for production growth of alligator forceps: Design, manufacturing, and testing. *Results in Engineering*, *16*, 100668. http://dx.doi.org/10.1016/j.rineng.2022.100668

Prabowo, R. (2022). Line Balance Application to Achieve Optimum Work Efficiency at Work Station in PT. Pulsara Cempaka–Cigarette Factory at Tulungagung District, East Java. *JURNAL TEKNIK INDUSTRI*, *12*(3), 265-271. https://doi.org/10.25105/jti.v12i3.15659

Pradana, A. Y., & Pulansari, F. (2021). Analisis Pengukuran Waktu Kerja Dengan Stopwatch Time Study Untuk Meningkatkan Target Produksi Di Pt. Xyz. *Juminten*, *2*(1), 13–24. https://doi.org/10.33005/juminten.v2i1.217

Pradesi, J., Yaqin, N. A., & Yahya, R. (2021). Meningkatkan Efisiensi Lintasan Kerja Menggunakan Metode RPW dan Killbridge Western Di PT. Sango Ceramic Indonesia Improving Work Track Efficiency Using RPW and Killbridge Western Methods At PT. Sango Ceramic Indonesia. *Indonesian Journal of Science*, *2*(1), 20–27.

Pulansari, F., & Nugraha, I. (2023). Analysis of Line Balancing using Ranked Positional Weight (RPW), Largest Candidate Rule (LCR), and J-Wagon Methods in Crane Girder Production at PT MHE Demag Surabaya, Indonesia. *Technium*, *16*. https://doi.org/10.47577/technium.v16i.10008

Rahayu, M., & Juhara, S. (2020). Pengukuran Waktu Baku Perakitan Pena Dengan Menggunakan Waktu Jam Henti Saat Praktikum Analisa Perancangan Kerja. *Unistek*, *7*(2), 93–97. https://doi.org/10.33592/unistek.v7i2.650

Ramalho, P. M. S., Campilho, R. D. S. G., Silva, F. J. G., Pedroso, A. F. V., & Sales-Contini, R. C. M. (2024). Productivity improvement of control cable manufacturing machine for the automotive industry. *Mechanics Based Design of Structures and Machines*, *52*(12), 9717-9740. https://doi.org/10.1080/15397734.2024.2349903

Rasib, A. A., Abdullah, R., Wahyono, F. Z., & Ramli, M. (2025). Enhancing Manufacturing Efficiency: A Case Study On Automotive Assembly Line Balancing Techniques For Improving Production Capacity. *Journal of Engineering Science and Technology*, *20*(2), 427-441.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Soori, M., Arezoo, B., & Dastres, R. (2023). Optimization of energy consumption in industrial robots, a review. *Cognitive Robotics*, *3*, 142-157. https://doi.org/10.1016/j.cogr.2023.05.003

Styawan, D. A., Wahyudin, W., & Hamdani, H. (2021). Penerapan Line Balancing untuk Meningkatkan Proses Perakitan Control Panel di Line Service Part pada PT. Kawai Indonesia Plant 3. *Jurnal Serambi Engineering*, *6*(4). https://doi.org/10.32672/jse.v6i4.3520

Tampi, P. P., Nabella, S. D., & Sari, D. P. (2022). The influence of information technology users, employee empowerment, and work culture on employee performance at the Ministry of Law and Human Rights Regional Office of Riau Islands. *Enrichment: Journal of Management*, *12*(3), 1620-1628. https://doi.org/10.35335/enrichment.v12i3.628

Xu, S., Shavarani, S. M., Nejad, M. G., Vizvari, B., & Toghraie, D. (2023). A novel competitive exact approach to solve assembly line balancing problems based on lexicographic order of vectors. *Heliyon*, *9*(3). http://dx.doi.org/10.1016/j.heliyon.2023.e13925

Yılmaz, Ö. F. (2022). Tactical level strategies for multi-objective disassembly line balancing problem with multi-manned stations: an optimization model and solution approaches. *Annals of Operations Research*, *319*(2), 1793-1843. https://link.springer.com/article/10.1007/s10479-020-03902-3

Zamzam, N., & Elakkad, A. (2021). Time and space multi-manned assembly line balancing problem using genetic algorithm. *Journal of Industrial Engineering and Management (JIEM)*, *14*(4), 733-749. http://dx.doi.org/10.3926/jiem.3542

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