Analysis of the Application of Line Balancing the Ranked Position Weighted Method in the ROBOCHOP-β Production Process

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Abstract. This research uses data from the production process of Robochop beta version, beta.1 version, and beta.2 version. The Robochop beta version is a prototype robot used to create the Robochop beta.1 and beta.2 versions. Robochop beta.1 and beta.2 were produced as part of the Integrated Design practice implementation, which was based on the guidelines obtained after the National Meeting at the National BKSTI Workshop on August 27, 2019, in Central Java, Indonesia, specifically concerning the implementation of the Integrated Design practical work [1]. Since there is always a desire to improve the implementation going forward—with the mindset that, like any production process, it requires a system based on continuous improvement—this study is conducted, particularly in determining the number of effective workstations with the same number of production workers, using the ranked position weighted method for line balancing.

Keywords: Line balancing, Ranked Position Weight, Production Process, ROBOCHOP-β

1 Introduction

Industrial Engineering, according to the Institute of Industrial and Systems Engineers [2], is defined as: "Industrial Engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy." BKSTI has elaborated the definition and all related aspects of this field of knowledge, known as Industrial Engineering, as stated in the IEBoK (Industrial Engineering Body of Knowledge) into eight (8) groups of courses [3]. The material presented in this research is primarily from Course Group (5) Industrial Engineering Science and Course Group (7) Industrial Engineering Design, while according to the classification [2], it belongs to Group (1) Work Design and Measurement, (12) Design and Manufacturing Engineering, and (13) Related Topics: (13.1) Product Design and Development, (13.2) System Design and Engineering.

The Production Systems Laboratory is one of the laboratories at the Universitas Katolik Darma Cendika Surabaya. This laboratory produces a product called ROBOCHOP, and a prototype of this product was created by Purba [4] under the name ROBOCHOP. The Robocop is a product in the shape of a vehicle equipped with a sensor to guide its movement (shown in images 1 and 2). The sensor in the Robocop is a photodiode sensor, allowing the Robocop to move forward following its path or track that is black or dark in color. The Robocop uses a 9V battery as its power source. However, programming the control system (control) for the Robocop's movement requires the assistance of Arduino software [5].

Six students (referred to as operators in this paper) are part of the production team for Robocop, and they will work together to create Robocop. Similarly, another team of six operators collaborates to create Robochop. Each station is operated by one operator, and each station has different tasks according to the operator's expertise. Initially, the stations used were S-A-B-I-U-C, where S stands for the sensor station for assembling the SENSOR, A stands for the Arduino station, B for the BODY (acrylic), I for the INTEGRATION of the results from stations S, A, and B. The U station represents the TEST station, where the product from the INTEGRATION station is tested. The output from the U-Test station is a robot product without a cover, which is then added in the C-COVER station [6]. These stations later evolved into the following based on the process function: Cutting Station, Assembly Station, Programming/Coding Station, Testing/Quality Control Station, and Packaging Station. However, there are still some idle stations, which can negatively impact the production process. For example, while some operators are busy with tasks, others remain idle. If this were a company, it could lead to increased costs due to unnecessary wage payments, implying that profits could be maximized if the number of workers were more appropriately assigned, matching their tasks and the time needed to complete the Robocop product. One approach to address this issue is by applying the Line Balancing method.

A production line is the arrangement of work areas where operations are arranged consecutively and materials move continuously through interconnected operations. Based on the characteristics of the production process, the production line is divided into two [7]:

1. Fabrication Line, which consists of operations aimed at forming or altering the shape of the workpiece.
2. Assembly Line, which consists of operations where assembly tasks are carried out at several workstations and combined into an assembly or subassembly.

Line balancing is the assignment of tasks to workstations in a production line in such a way as to minimize idle time at the slowest operation in the line [7], [8], [9], [10]. Heuristic line balancing methods are divided into five: Moddie Young method, Kilbridge-Wester Heuristics, Hoffmans or Precedence Matrix method, Immediate Update First Fit method, and the Helgeson-Birnie method, commonly known as the Rank Positional Weight (RPW) method [11], [12]. The RPW method has proven to be more efficient than other methods for determining work elements at workstations because it allows the calculation of the cycle time and the number of workstations required for a production line, which is not achievable with the other four heuristic methods [11], [12]. Therefore, this research uses the RPW method in the development of the production line balancing.

Table 1. Production Process Activities

Station Code	Station Name	Work Elements
A	Cutting	- Design of top casing mold - Cutting casing material - Drilling material - Design of workpiece mold - Cutting acrylic - Drilling acrylic - Acrylic sanding process
B	Assembly	- Installation of free wheel - Installation of DC motor - Installation of motor driver - Assembly of sensor - Installation of sensor - Installation of 6 cm spacer - Installation of Arduino - Installation of switch - Installation of battery case and battery - Installation of top casing
C	Coding	- Transfer program to Arduino
D	Testing	- Checking cable installation - RoboChop test run
E	Packing	- Packing of RoboChop

This table outlines each station, the tasks associated with that station, and how they contribute to the overall production of the RoboChop unit. The production steps are categorized into cutting, assembly, coding, testing, and packing, ensuring that all components are handled efficiently.

2 Methodology

This line balancing design research was conducted through several stages, including problem identification, goal determination, data collection, data analysis, and drawing conclusions. The problem and goal determination were explained in the introduction above. The data collected was based on observations during the practical sessions and the resulting reports, with the workers at each station being those with average skill levels (from October to December 2019).

The data obtained was then analyzed using the Ranked Positional Weight (RPW) technique, which follows the procedure as outlined in [7]:

1. Select the task with the highest positional weight and assign it to the first workstation.
2. Calculate the unused time for that workstation by subtracting the cumulative time of all tasks assigned to that station from the cycle time.
3. Select the task with the next highest positional weight and attempt to place it at that workstation, after performing the following checks:
   a. Check the list of tasks already assigned. If the predecessor task has already been placed, precedence will not be violated. Proceed to the next step.
   b. If the predecessor task has not been assigned, proceed to step 4.
   c. Compare the task time with the unused time. If the task time is less than the unused time at the workstation, assign the task and recalculate the unused time.
4. Continue selecting, checking, and assigning tasks, as long as one of the following conditions is met: All tasks have been assigned, or there are no more unassigned tasks that can meet the precedence or time requirements.
5. Assign the task with the highest positional weight (the total time of the task plus the time of any following tasks) that has not yet been assigned to the second workstation and repeat the process as above.
6. Continue assigning tasks until all tasks have been assigned.
7. The RPW procedure [7] can be summarized in four stages as follows [10]:
   a. Determine the precedence diagram, which helps in determining the positional weight of each task based on the operation time, from the beginning of the process to the remaining process time.
   b. Determine the cycle time based on the longest standard time.
   c. Determine the minimum number of workstations (theoretical minimum criteria).
   d. Determine the ranking of each work element based on positional weight.
   e. Determine the grouping of workstations, so that the production line achieves balance, efficiency, balance delay, and smoothness index, ensuring production line balance.

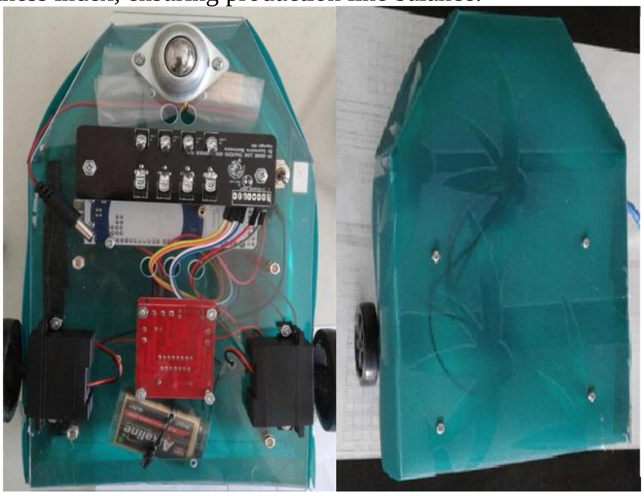

Figure 1. Robochop

3 Results and Discussion

The RPW line balancing technique is used to minimize employee idle time by dividing tasks across multiple workstations. The illustration of production levels in a production system environment, as shown in Figure 2, demonstrates how raw materials, already available, are processed through workstations to produce the product, with the precedence diagram shown in Figure 3. The Robocop production process map is shown in Table 1, and the activities/process operations from the precedence diagram (Figure 2) are shown in Figure 4. Data for production planning over the next three periods can be seen in Table 2, and the process time for each unit of Robocop product completion is shown in Table 3.

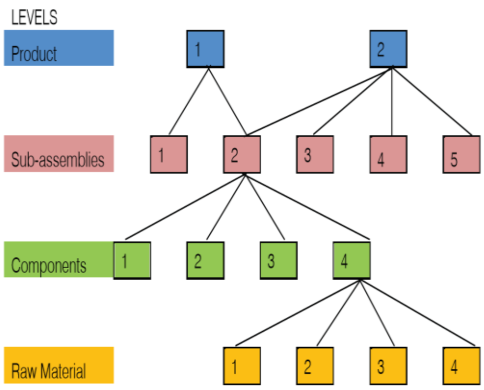

Figure 2. Typical Illustration of Production Levels in a Production System Environment [13]

This illustration depicts the processes within a production system environment in a tiered manner, starting from raw materials passing through various workstations until they become finished products. The diagram highlights the workflow from start to finish, emphasizing the transformation stages of materials at each workstation to achieve the desired final output.

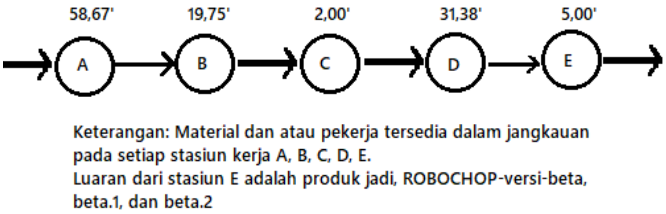

Figure 3. Initial Precedence Diagram of the Robochop-Beta Production Line (processed data, 2020)

This precedence diagram represents the sequence of operations in the initial production line for Robochop-Beta. It outlines the hierarchical flow of tasks and dependencies among workstations, ensuring that each process follows the required operational precedence.

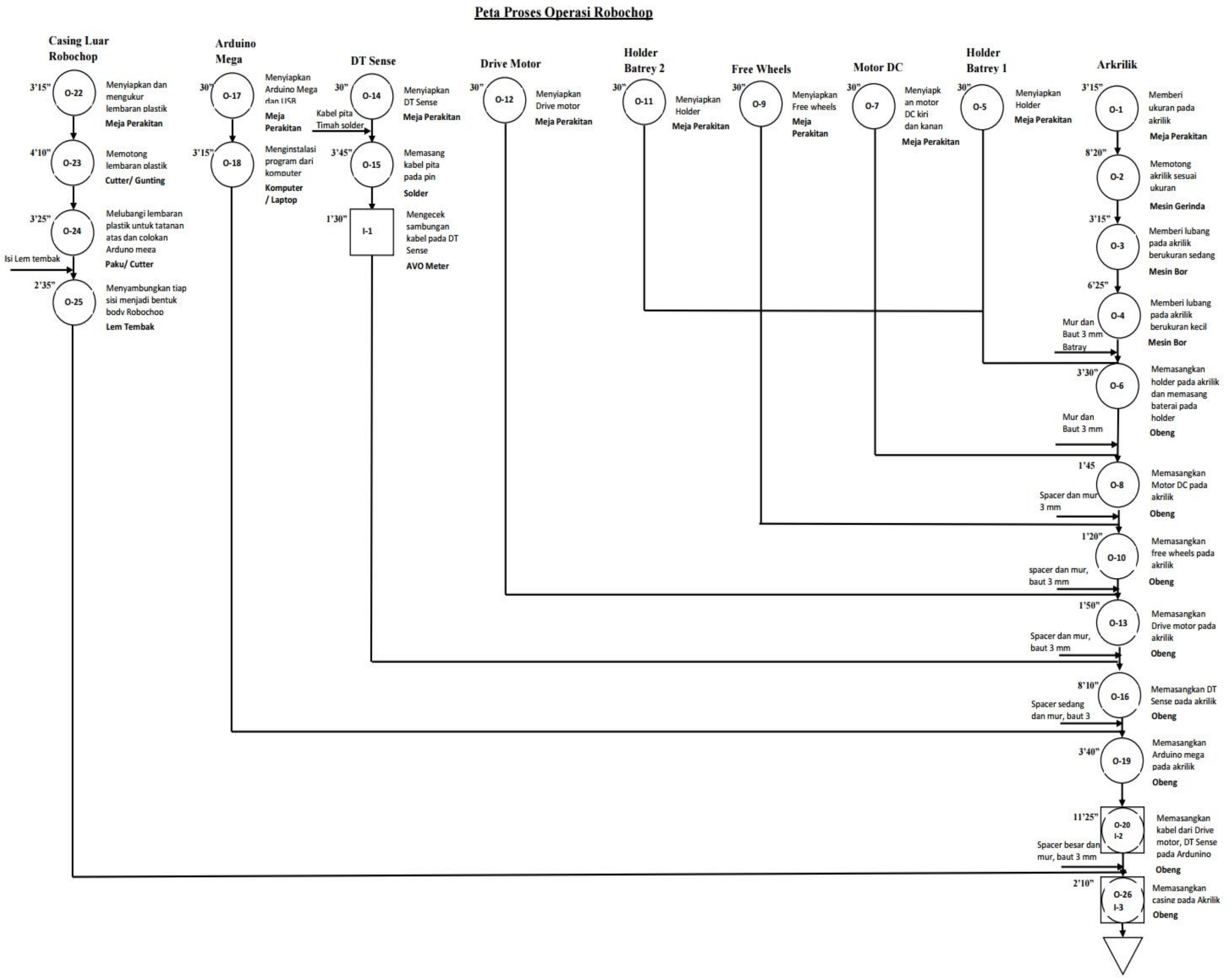

Figure 4. Operation Process Chart for Robochop Beta Version Production (processed data, 2020)

The chart represents the sequence and details of operations performed at each stage of the Robochop Beta Version production. It outlines the tasks from raw material preparation to final packaging, providing insights into workflow efficiency and task distribution.

Table 2. Production Plan for Three Months

Period	Demand (products)
Month 1	10
Month 2	10
Month 3	10
Total	**30**

This table shows the planned demand for the RoboChop product over the next three months, with a total of 30 products to be produced during this period.

Table 3. Production Process Time for Each Workstation

Workstation Code	Process Time (Minutes)	Predecessor Code
A	58.67	-

Workstation Code	Process Time (Minutes)	Predecessor Code
B	19.75	A
C	2.00	B
D	31.38	C
E	5.00	D
Total	**116.80**	

Explanation:

1. This table shows the time required to complete the process at each workstation (A, B, C, D, E) in minutes.
2. The Predecessor Code indicates which workstation must be completed first before starting the next workstation.
3. The total process time for all workstations is 116.80 minutes.

After determining the process time for each workstation, the next step is to calculate the cycle time. It is assumed in this study that the product demand over the next three months is 30 units, with 75 working days and 8 hours of work per day, resulting in a cycle time of 1200 minutes per product.

The positional weight matrix is shown in Table 4, while the sequence of work operations, prioritized by the longest operation time, is shown in Table 5.

Table 4. Positional Weight Matrix

Predecessor Operations	Follower Operations					Sum (Minutes)
	A	B	C	D	E	
A	-	19,75	2	31,38	5	63,13
B	0	-	2	31,38	5	43,38
C	0	0	-	31,38	5	41,38
D	0	0	0	-	5	10
E	0	0	0	0	-	5

Table 5. Sequence of Operations from Longest to Shortest Time

No	Predecessor Operation	Duration (minutes)
1	A	63.13
2	B	43.38
3	C	41.38
4	D	10.00
5	E	5.00

This table lists the operations based on the longest time, with operation A taking the longest time at 63.13 minutes, followed by B, C, D, and E in descending order.

The total production process time is 63.13 minutes, rounded up to 64 minutes. The cycle time is the longest time of all process operations, rounded to 59 minutes (from 58.67), derived from field data (average observation and report times).

After determining the total process time and cycle time, the next step is to calculate the minimum number of workstations required, as shown in Table 6. This table also shows the grouping of workstations B, C, D, and E. Based on the calculations in Table 6, the production process efficiency, calculated using the RPW method, is derived. Based on the established line, the Robocop version beta production process requires only 2 workstations. Therefore, the production capacity is determined by calculating the takt time over the next three months. The takt time here is 1200 minutes per product. The RPW method can be used for the next three months as the production quantity matches the production capacity, meaning employees do not need to work overtime or increase their working hours.

Table 6. Workstation Efficiency Based on the RPW Method

Workstation	Operation	Station Speed (Minutes)	Idle (Minutes)	Efficiency (%)
A	A	58.67	0.33	99%
B	B, C, D, and E	19.75 + 2 + 31.38 + 5 = 58.13	0.87	98%

1. **Workstation A:**

    a. **Operation**: Task A (cutting) has a total operation time of 58.67 minutes.
    b. **Station Speed (Minutes)**: 58.67 minutes are used for the operation.
    c. **Idle Time (Minutes)**: The workstation has 0.33 minutes of idle time.
    d. **Efficiency**: The efficiency is calculated as (Operation Time/(Operation Time+Idle Time))×100, giving 99% efficiency, which is very high.

2. **Workstation B:**

    a. **Operation**: Tasks B, C, D, and E have operation times of 19.75 minutes, 2 minutes, 31.38 minutes, and 5 minutes, respectively. The total time for these tasks is 58.13 minutes.
    b. **Station Speed (Minutes)**: 58.13 minutes are required to complete all tasks at this station.
    c. **Idle Time (Minutes)**: There is 0.87 minutes of idle time.
    d. **Efficiency**: Efficiency here is calculated similarly, yielding 98% efficiency.

This table indicates that both workstations (A and B) have very high efficiency rates, with minimal idle time. The RPW method helps balance the work across stations and reduce wasted time, leading to efficient production.

The calculations for line efficiency (%), balance delay (%), and smoothness index are as follows [9]: line efficiency = 116.8 / (2 x 59) = 98.98%; balance delay = 100% - line efficiency = 1.02%; and the smoothness index is calculated as $\sqrt{(59-5867)^2+(59-5813)^2} = 0{,}9305\ menit.$

The findings of this study align with previous research on the use of the RPW line balancing technique [13], as affirmed in the following excerpt:

"From the study of assembly line balancing, it is found that assembly lines are flow-line production systems, where a series of workstations, on which interchangeable parts are added to a product. The product is moved from one workstation to another through the line, and is complete when it leaves the last workstation. Ultimately, we need to assign the workstations in such a way that the predetermined goal is achieved. This can be done by minimizing the number of workstations and maximizing the production rate, as studied in the literature survey".

4 Conclusion

Based on the analysis results of the conducted research, the following conclusions can be drawn: From the process identification results, it was found that station A (Cutting) has the longest time of 59 minutes, and this time was used as the cycle time for this study. Employees working on the production of the Robochop do not need to extend their working hours or work overtime, as the production demand is equal to the production capacity. Furthermore, the three parameters of line balancing based on the RPW method are considered to be sufficiently effective.

Recommendation

After conducting the line balancing study on this process, the following recommendations are given for improvement to the laboratory team: the concerned parties should regularly calculate the line balancing, as the amount of demand received will impact the production process within the system.

5 References

[1]. A. Ma’ruf, Rencana Pembelajaran Semester Praktikum Terintegrasi Teknik Industri. Badan Kerja Sama Penyelenggara Pendidikan Tinggi Teknik Industri Indonesia (BKSTI), 2019.

[2]. M. Steffen, D. May, and J. Deuse, "The Industrial Engineering Laboratory," no. January, pp. 1–10, 2012, doi: 10.1109/educon.2012.6201098.

[3]. T. K. BKSTI, Kurikulum Inti BKSTI Input-Output Based Education. Badan Kerja Sama Penyelenggara Pendidikan Tinggi Teknik Industri Indonesia (BKSTI), 2019.

[4]. L. P. Purba, R. S. A. Laurence, and A. Cristian, "Upcoming Industry 4 . 0 : Development of ROBOCHOP with Embeded Control System to Strengthen Creative Industries in Surabaya," Int. J. Latest Eng. Manag. Res., vol. 05, no. 02, pp. 13–18, 2020.

[5]. Arduino, "Arduino 1.8.5." arduino.cc, [Online]. Available: https://www.arduino.cc/.

[6]. L. P. Purba, L. M. C. Wulandari, and A. Bellanov, Modul Praktikum Perancangan Terintegrasi. Surabaya: Program Studi Teknik Industri FT UKDC, 2019.

[7]. A. T. Panudju, B. S. Panulisan, and E. Fajriati, "Analisis Penerapan Konsep Penyeimbangan Lini (Line Balancing) Dengan Metode Ranked Position Weight (Rpw) Pada Sistem Produksi Penyamakan Kulit Di Pt . Tong," J. Integr. Sist. Ind., vol. 5, no. 2, pp. 70–80, 2018.

[8]. H. H. Azwir and H. W. Pratomo, "Implementasi Line Balancing untuk Peningkatan Efisiensi di Line Welding Studi Kasus: PT X," J. Rekayasa Sist. Ind., vol. 6, no. 1, p. 57, 2017, doi:

[9]. B. Kho, "Pengertian Line Balancing (Keseimbangan Lini) dan Cara Menggunakannya." https://ilmumanajemenindustri.com/pengertian-line-balancing-keseimbangan-lini-cara-menggunakannya/ (accessed May 04, 2020).[1] A. Ma'ruf, Rencana Pembelajaran Semester Praktikum Terintegrasi Teknik Industri. Badan Kerja Sama Penyelenggara Pendidikan Tinggi Teknik Industri Indonesia (BKSTI), 2019.

[10]. A. Balancing, "Assembly-Line Balancing," pp. 1–11, 2015.

[11]. S. T. Ghutukade and Dr. Suresh M. Sawant, "Use of Ranked Position Weighted Method for," Int. J. Adv. Eng. Res. Stud., pp. 5–7, 2013.

[12]. K. B. Chavare and P. A. M. Mulla, "Application of Ranked Position Weighted (RPW) Method for Assembly Line Balancing," Int. J. Res. Appl. Sci. Eng. Technol., vol. 3, no. VI, pp. 254–262, 2015, [Online]. Available: www.ijraset.com.

[13]. N. Kumar and D. Mahto, "Assembly Line Balancing: A Review of Fevelopments and Trends in Approach to Industrial Application," Glob. J. Res. Eng., vol. 13, no. 2, pp. 807–811, 2013.