

## Line Balancing in Mountain Sandal Production Using the Ranked Positional Weight (RPW) and Largest Candidate Rule (LCR) Methods

Novella Renota\* and Putu Eka Dewi Karunia Wati

Department of Industrial Engineering, Universitas 17 Agustus  
1945, Surabaya, Indonesia

\*1412200226@surel.untag-sby.ac.id

### OPEN ACCESS

**Citation:** Novella Renota and Putu Eka Dewi Karunia Wati. 2026. Line Balancing in Mountain Sandal Production Using the Ranked Positional Weight (RPW) and Largest Candidate Rule (LCR) Methods. *Journal of Research and Technology* Vol. 12 No. 1 Juni 2026: Page 111–123.

### Abstract

In small and medium manufacturing, uneven workloads between production stations often slow down the entire process and waste valuable working time. This study addresses that problem at UD XYZ, a mountain sandal manufacturer where the production line was divided into six workstations with highly unbalanced station time, ranging from just 11,03 second to 55,52 seconds. As a result, line efficiency was only 62,17%, meaning nearly 37,83% of available production capacity went unused. Two heuristic line balancing methods, Ranking Positional Weight (RPW) and Largest Candidate Rule (LCR), were used to reassign 18 work elements into a better-organized set of workstations. Both methods successfully reduced the number of workstations from six to five and raised line efficiency to 94,83%, while lowering balance delay from 37,83% to 5,17%. However, RPW produced a smoother workload distribution with a smoothness index of 6,21 seconds, compared to 7,13 seconds for LCR. Making RPW the recommended approach. The new line configuration also increased daily production capacity from 454 to 579 pairs per day.

**Keywords:** Line Balancing, Ranked Positional Weight, Largest Candidate Rule, Production Efficiency, Heuristic Method.

### Abstrak

Ketidakseimbangan beban kerja antar stasiun menjadi salah satu hambatan umum dalam sistem produksi manufaktur skala kecil dan menengah. Kondisi ini tidak hanya menimbulkan penumpukan produk di titik-titik tertentu, tetapi juga menyebabkan waktu menganggur yang berdampak langsung pada rendahnya produktivitas keseluruhan lini produksi. Penelitian ini mengkaji permasalahan tersebut di UD XYZ, sebuah produsen sandal gunung yang lintasan produksinya terdiri dari enam stasiun kerja dengan rentang waktu stasiun sangat bervariasi, mulai dari 11,03 detik pada stasiun pengerolan hingga 55,52 detik pada stasiun pengemasan. Kondisi ini menghasilkan efisiensi lintasan hanya sebesar 62,17% dengan balance delay mencapai 37,83%. Untuk

*mengatasi ketimpangan tersebut, dua metode heuristik penyeimbangan lintasan diterapkan, yaitu Ranked Positional Weight (RPW) dan Largest Candidate Rule (LCR). Kedua metode ini berhasil merampingkan jumlah stasiun kerja dari enam menjadi lima dan mendorong efisiensi lintasan naik menjadi 94,83% dengan balance delay yang turun signifikan ke angka 5,17%. Perbedaan di antara keduanya terletak pada nilai smoothness index, RPW menghasilkan 6,21 detik sementara LCR sebesar 7,13 detik, menjadikan RPW sebagai pilihan yang lebih unggul dalam pemerataan beban kerja. kapasitas produksi harian pun meningkat dari 454 menjadi 579 pasang per hari, sehingga memenuhi target produksi harian.*

**Keywords:** *Keseimbangan Lintasan, Ranked Positional Weight, Largest Candidate Rule, Efisiensi Produksi, Metode Heuristik.*

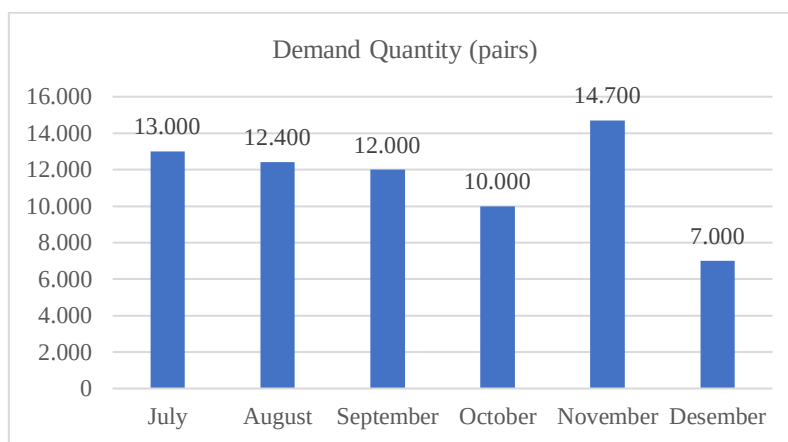
## 1. Introduction

The competitiveness of manufacturing industries largely depends on a company's ability to maintain a consistent production flow. When workloads across stations are not proportionally distributed, product accumulation and idle time emerge at certain points along the line [1]. This condition indirectly hampers process smoothness and lowers the output capacity that could otherwise be achieved [2].

UD XYZ is a mountain sandal manufacturer located in Waru, Sidoarjo, East Java, operating under a combined make-to-order and make-to-stock system. Its production line consists of six workstations covering 18 work elements, ranging from insole screen printing to final packaging. Initial measurements revealed highly variable standard station times: station 1 required 46.38 seconds, station 2 needed 35.68 seconds, station 3 took 31.94 seconds, station 4 only 11.03 seconds, station 5 reached 26.55 seconds, and station 6 was the heaviest at 55.52 seconds, confirming a clear imbalance along the existing production line. Such an imbalanced line, as found at UD XYZ, is not a new phenomenon in the manufacturing industry. When the facility layout no longer matches the actual process flow, idle time and product accumulation at certain points become unavoidable. Murnawan and Wati [3] demonstrated that realigning the production space configuration with the true process flow can reduce waste and increase overall output capacity.

Demand data over the past six months (July–December 2025) in Figure 1, recorded a total of 69,100 pairs of sandals, with monthly fluctuations ranging from 7,000 to 14,700 pairs. To anticipate this variation, the company set a production target of 15,000 pairs per month, equivalent to 577 pairs per day. With 25,200 seconds of productive working time available per day, the cycle time required to reach the daily target is 43.68 seconds per pair. However, the initial line condition showed a line efficiency of only 62.17% and a balance delay of 37.83%, indicating substantial room for improvement.

Heuristic line-balancing methods have proven effective in resolving line-imbalance problems across various industries. Mumtaz et al. [4] found that LCR raised line efficiency from 46.40% to 77.33% in a garment production line. Karmawan et al. [5] reported that RPW outperformed other methods with an efficiency of 90.27%, followed by LCR at 84.25%. Poncotoyo et al. [6] similarly recorded an RPW efficiency of 95.70% compared with 94.94% for LCR, while [7] applied heuristic line-balancing methods to a footwear production line to minimize idle time, resulting in a significant efficiency improvement. This consistency across prior studies forms the basis for selecting both methods in the present research. Accordingly, this study aims to identify the processing speed of each workstation, design a new line-balancing configuration using the RPW and LCR methods, compare line performance before and after balancing, and evaluate the production capacity achievable after improvement.



Source: UD XYZ

Figure 1. UD XYZ Demand Chart

## 2. Method

This research was conducted at UD XYZ from February to May 2026 through direct observation and work-time measurement using a stopwatch. Each work element was observed 10 times to obtain representative data. The data-processing procedure covers the following stages.

### 2.1 Time Data Measurement and Validation

Observation times were collected using a stopwatch, with 10 repetitions per element. A uniformity test was performed using the upper control limit (UCL) and lower control limit (LCL) to ensure no observed data deviated significantly from the population mean [8]. The control limits were calculated using the following equations:

$$\sigma = \sqrt{\frac{\sum (xi - \bar{x})^2}{N-1}} \quad (1)$$

$$BKA = \bar{x} + k\sigma ; BKB = \bar{x} - k\sigma \quad (2)$$

description:

$\sigma$  = time standard deviation

$x_i$  = i-th data point  
 $\bar{x}$  = mean value of observations  
 $N$  = number of observations  
 $k$  = constant (confidence level coefficient)  
 $UCL$  = upper control limit  
 $LCL$  = lower control limit

Data is considered uniform if all observed values fall between the UCL and LCL.

Meanwhile, the data adequacy test was conducted to determine whether the observed data was sufficient or required additional measurement [9]. The test uses the  $N'$  formula at a 95% confidence level and 5% degree of precision, with data considered adequate when  $N' \leq N$ .

$$N' = \left[ \frac{\frac{k}{s} \sqrt{N(\Sigma x^2) - (\Sigma x)^2}}{\Sigma x} \right]^2 \quad (3)$$

description:

$N'$  = minimum number of observations required  
 $k$  = confidence level coefficient  
 $s$  = degree of precision  
 $x$  = observed data

## 2.2 Standard Time Calculation

Standard time is calculated based on the average cycle time adjusted with a rating factor (Westinghouse method) and an allowance, using the following equation:

$$W_b = W_n \times \frac{100\%}{100\% - \text{allowance}} \quad (4)$$

Given that sandal production at UD XYZ is still performed manually, causing variation in the speed of each operator, the rating factor was determined based on four Westinghouse assessment aspects: skill (the operator's proficiency and smoothness of movement), effort (the level of genuine exertion during work), condition (the working environment at the time of measurement), and consistency (the stability of completion time across cycles). These four aspects were converted into adjustment values using the Westinghouse performance-rating table and summed to obtain the total rating factor. The allowance was established from three standard leeway components: personal allowance for personal needs, fatigue allowance for recovery from physical strain caused by repetitive movements such as stitching and gluing, and delay allowance for unavoidable obstacles such as waiting for materials or adjusting tool positions. These three components were combined into a single total allowance value used in the standard-time equation above, so that the resulting standard time remains representative of realistic working conditions even when performed by operators with varying skill levels.

## 2.3 Cycle Time Calculation

Cycle time is obtained by dividing the available working time by the production target, and can be calculated using equation (5).

$$\text{Cycle time} = \frac{\text{available working time}}{\text{production target per period}} \quad (5)$$

## 2.4 Workstation Calculation

Determining the number of new workstations establishes how many stations are ideally required along the production line. This value is obtained by dividing the total element time by the cycle time set as the production rate.

$$\text{workstations} = \frac{\text{total time}}{\text{cycle time}} \quad (6)$$

## 2.5 Ranked Positional Weight (RPW) Method

The RPW method works by calculating the positional weight of each work element, which is obtained by adding the time of that element to the total time of all elements that follow it in the precedence diagram. The element with the highest positional weight is assigned to a station first, provided the total station time does not exceed the cycle time. The steps are as follows [10]:

1. Construct the precedence diagram based on the sequence of elements.
2. Calculate the positional weight of each element.
3. Rank the elements from the highest to the lowest positional weight.
4. Assign elements to stations sequentially as long as the total station time is below the CT and the precedence constraint is satisfied.

## 2.6 Largest Candidate Rule (LCR) Method

The LCR method prioritizes the assignment of work elements based on operation time from largest to smallest, while still observing the sequence constraints in the precedence diagram. This approach builds a predecessor (P) and follower (F) matrix from the precedence diagram. A free element (one whose predecessors have all been assigned) with the largest operation time is prioritized for assignment to the station currently being formed, until its cycle-time capacity is reached [10]. The steps are as follows:

1. Calculate the desired cycle time.
2. Construct the predecessor (P) and follower (F) operation matrices for each operation based on the precedence diagram.
3. Identify rows in the predecessor (P) matrix consisting entirely of zeros, and assign the largest work element if more than one row has all elements equal to zero.
4. Identify the corresponding element number in the follower (F) matrix row that matches the element already assigned.
5. Continue assigning work elements to the workstation, provided the total operation time does not exceed the cycle time.

## 2.7 Line Performance Measures

Line performance evaluation was carried out using the following indicators [11]:

 Line Efficiency

$$\text{EL} = \frac{\sum_{i=1}^k ST_i}{(K)(WS)} \times 100\% \quad (7)$$

#### ✚ Balance delay

$$BD = \frac{(K)(WS) - \sum_{i=1}^k ti}{(K)(WS)} \times 100\% \quad (8)$$

#### ✚ Smoothness index

$$SI = \sqrt{\sum_{i=1}^k (ST maks - STi)^2} \quad (9)$$

description:

STi = time of station i

K = number of workstations

WS = cycle time

STmax = maximum station time

### 3. Result and Discussion

#### 3.1 Precedence Diagram

The precedence diagram was constructed to illustrate the dependency sequence among the 18 work elements identified during the time-measurement stage, ranging from the sole gloss removal element to the placing-into-packaging-plastic element. This diagram maps out which elements must be completed first as a prerequisite for the next element to begin, allowing the relationships among work elements to be visualized as a network of nodes and connecting lines. Constructing the precedence diagram serves as the primary reference for calculating positional weights in the RPW method and determining free elements in the LCR method, since both methods require clear sequencing information so that the resulting station groupings do not violate the actual production sequence on the UD XYZ shop floor. Figure 2 presents the precedence diagram used as the basis for data processing in this study.

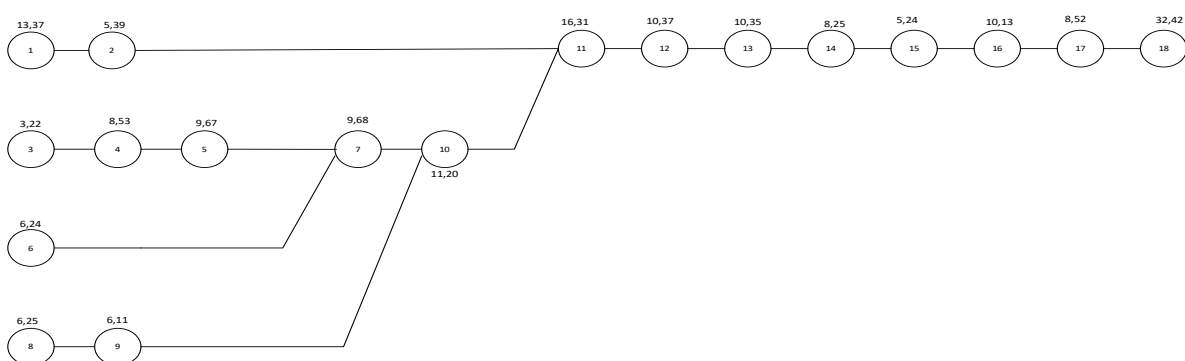


Figure 2. Precedence Diagram

#### 3.2 Data Uniformity and Adequacy Test

All 18 work elements were tested for data uniformity using the upper and lower control limits at a 95% confidence level. The calculated UCL and LCL values for each work element are presented in the table below.

Table 1. Data Uniformity Test Results for Each Work Element

| No | Work Element Description                         | Mean  | S    | UCL   | LCL   | Remarks |
|----|--------------------------------------------------|-------|------|-------|-------|---------|
| 1  | Sole Gloss Removal                               | 13,37 | 0,15 | 13,67 | 13,07 | Uniform |
| 2  | Primer Application                               | 5,39  | 0,03 | 5,45  | 5,34  | Uniform |
| 3  | Insole Screen Printing                           | 3,22  | 0,01 | 3,24  | 3,20  | Uniform |
| 4  | Sandal Shape Cutting                             | 8,53  | 0,28 | 9,09  | 7,98  | Uniform |
| 5  | Sandal Die-Cutting                               | 9,67  | 0,19 | 10,04 | 9,29  | Uniform |
| 6  | Large Brand Label Stitching on Upper Sole        | 6,24  | 0,04 | 6,31  | 6,17  | Uniform |
| 7  | Upper and Middle Sole Assembly                   | 9,68  | 0,30 | 10,27 | 9,08  | Uniform |
| 8  | Sandal Strap Stitching                           | 6,25  | 0,03 | 6,32  | 6,18  | Uniform |
| 9  | Small Brand Label Stitching and Rivet Attachment | 6,11  | 0,03 | 6,18  | 6,06  | Uniform |
| 10 | Strap Attachment                                 | 11,20 | 0,11 | 11,42 | 10,98 | Uniform |
| 11 | Outsole Attachment                               | 16,31 | 0,14 | 16,58 | 16,03 | Uniform |
| 12 | Rolling                                          | 10,37 | 0,31 | 10,98 | 9,76  | Uniform |
| 13 | Sandal Edge Sanding                              | 10,35 | 0,08 | 10,51 | 10,19 | Uniform |
| 14 | Trimming Excess Material on Sandal Sides         | 8,25  | 0,02 | 8,30  | 8,20  | Uniform |
| 15 | Hangtag Attachment                               | 5,24  | 0,02 | 5,28  | 5,20  | Uniform |
| 16 | QC                                               | 10,13 | 0,04 | 10,20 | 10,06 | Uniform |
| 17 | Placing into Packing Net                         | 8,52  | 0,32 | 9,17  | 7,88  | Uniform |
| 18 | Placing into Packaging Plastic                   | 32,42 | 0,40 | 33,22 | 31,62 | Uniform |

Source: Processed Data, 2026

The test results show that no observed value exceeded the control limits, so all data was declared uniform. Subsequently, the data adequacy test using the  $N'$  formula confirmed that the number of observations performed ( $N = 10$ ) exceeded the  $N'$  value for every work element, meaning the collected data was sufficient to represent the actual process population. The calculated  $N$  and  $N'$  values for each work element are summarized in the table below.

Table 2. Data Adequacy Test Results for Each Work Element

| No | Work Element Description                         | N  | N'   | Remarks                  |
|----|--------------------------------------------------|----|------|--------------------------|
| 1  | Sole Gloss Removal                               | 10 | 0,18 | $N' < N$ , Data Adequate |
| 2  | Primer Application                               | 10 | 0,04 | $N' < N$ , Data Adequate |
| 3  | Insole Screen Printing                           | 10 | 0,02 | $N' < N$ , Data Adequate |
| 4  | Sandal Shape Cutting                             | 10 | 1,51 | $N' < N$ , Data Adequate |
| 5  | Sandal Die-Cutting                               | 10 | 0,54 | $N' < N$ , Data Adequate |
| 6  | Large Brand Label Stitching on Upper Sole        | 10 | 0,05 | $N' < N$ , Data Adequate |
| 7  | Upper and Middle Sole Assembly                   | 10 | 0,03 | $N' < N$ , Data Adequate |
| 8  | Sandal Strap Stitching                           | 10 | 1,37 | $N' < N$ , Data Adequate |
| 9  | Small Brand Label Stitching and Rivet Attachment | 10 | 0,04 | $N' < N$ , Data Adequate |
| 10 | Strap Attachment                                 | 10 | 0,14 | $N' < N$ , Data Adequate |
| 11 | Outsole Attachment                               | 10 | 0,10 | $N' < N$ , Data Adequate |
| 12 | Rolling                                          | 10 | 1,26 | $N' < N$ , Data Adequate |
| 13 | Sandal Edge Sanding                              | 10 | 0,09 | $N' < N$ , Data Adequate |
| 14 | Trimming Excess Material on Sandal Sides         | 10 | 0,01 | $N' < N$ , Data Adequate |

|    |                                |    |      |                       |
|----|--------------------------------|----|------|-----------------------|
| 15 | Hangtag Attachment             | 10 | 0,02 | N' < N, Data Adequate |
| 16 | QC                             | 10 | 0,02 | N' < N, Data Adequate |
| 17 | Placing into Packing Net       | 10 | 2,06 | N' < N, Data Adequate |
| 18 | Placing into Packaging Plastic | 10 | 0,22 | N' < N, Data Adequate |

Source: Processed Data, 2026

With both tests satisfied, the collected observation-time data can be considered representative of the actual work-process population at UD XYZ

### 3.3 Standard Time

After the data was declared uniform and adequate, the standard time was calculated for each work element by accounting for the rating factor and allowance. The standard time calculation results for all elements are presented in Table 3.

**Table 3. Standard Time**

| No | Work Element Description                         | Ws<br>(seconds) | Wn<br>(seconds) | Wb<br>(seconds) |
|----|--------------------------------------------------|-----------------|-----------------|-----------------|
| 1  | Sole Gloss Removal                               | 13,37           | 14,57           | 15,50           |
| 2  | Primer Application                               | 5,39            | 5,88            | 6,25            |
| 3  | Insole Screen Printing                           | 3,22            | 3,57            | 3,85            |
| 4  | Sandal Shape Cutting                             | 8,53            | 9,05            | 9,75            |
| 5  | Sandal Die-Cutting                               | 9,67            | 10,24           | 11,02           |
| 6  | Large Brand Label Stitching on Upper Sole        | 6,24            | 7,42            | 8,16            |
| 7  | Upper and Middle Sole Assembly                   | 9,68            | 10,84           | 11,53           |
| 8  | Sandal Strap Stitching                           | 6,25            | 7,44            | 8,17            |
| 9  | Small Brand Label Stitching and Rivet Attachment | 6,11            | 7,27            | 7,82            |
| 10 | Strap Attachment                                 | 11,20           | 11,76           | 12,51           |
| 11 | Outsole Attachment                               | 16,31           | 18,26           | 19,43           |
| 12 | Rolling                                          | 10,37           | 10,37           | 11,03           |
| 13 | Sandal Edge Sanding                              | 10,35           | 10,97           | 11,67           |
| 14 | Trimming Excess Material on Sandal Sides         | 8,25            | 8,75            | 9,30            |
| 15 | Hangtag Attachment                               | 5,24            | 5,24            | 5,58            |
| 16 | QC                                               | 10,13           | 11,25           | 11,96           |
| 17 | Placing into Packing Net                         | 8,52            | 8,52            | 9,07            |
| 18 | Placing into Packaging Plastic                   | 32,42           | 32,42           | 34,49           |

Source: UD XYZ

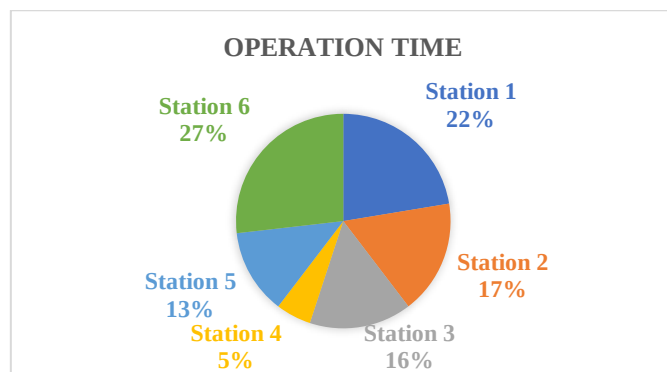
### 3.4 Actual Line Condition

**Table 4. Time Data and Work Elements**

| Workstation | No | Work Element Description                  | Element<br>Time (s) | Total Station<br>Time (s) |
|-------------|----|-------------------------------------------|---------------------|---------------------------|
| 1           | 1  | Sole Gloss Removal                        | 15,50               | 46,38                     |
|             | 2  | Primer Application                        | 6,25                |                           |
|             | 3  | Insole Screen Printing                    | 3,85                |                           |
|             | 4  | Sandal Shape Cutting                      | 9,75                |                           |
|             | 5  | Sandal Die-Cutting                        | 11,02               |                           |
| 2           | 6  | Large Brand Label Stitching on Upper Sole | 8,16                | 35,68                     |
|             | 7  | Upper and Middle Sole Assembly            | 11,53               |                           |
|             | 8  | Sandal Strap Stitching                    | 8,17                |                           |

|   |    |                                                  |       |       |
|---|----|--------------------------------------------------|-------|-------|
|   | 9  | Small Brand Label Stitching and Rivet Attachment | 7,82  |       |
| 3 | 10 | Strap Attachment                                 | 12,51 | 31,94 |
|   | 11 | Outsole Attachment                               | 19,43 |       |
| 4 | 12 | Rolling                                          | 11,03 | 11,03 |
|   | 13 | Sandal Edge Sanding                              | 11,67 |       |
| 5 | 14 | Trimming Excess Material on Sandal Sides         | 9,30  | 26,55 |
|   | 15 | Hangtag Attachment                               | 5,58  |       |
|   | 16 | QC                                               | 11,96 |       |
| 6 | 17 | Placing into Packing Net                         | 9,07  | 55,52 |
|   | 18 | Placing into Packaging Plastic                   | 34,49 |       |

Source: Processed Data, 2026



Source: Processed Data, 2026

Figure 3. Time Distribution of the Actual Condition

The figure above presents the proportion of time for each workstation relative to the total line time under the actual condition. The visualization shows that Station 6 dominates with 27% of the total line time, far exceeding the other stations. In contrast, Station 4 accounts for only 5%, a stark difference that provides clear evidence of the imbalance in the existing production line.

Table 4. Actual Line Condition

|              | Number of Workstations | Line Efficiency | Balance Delay | Smoothness Index |
|--------------|------------------------|-----------------|---------------|------------------|
| Initial Line | 6                      | 62,17%          | 37,83%        | 62,06            |

Source: Processed Data, 2026

This condition directly resulted in a low line efficiency of only 62.17% and a balance delay of 37.83%. The high balance delay value indicates a considerable imbalance between workstations. The smoothness index also reached 62.06 seconds; the larger the smoothness index value, the greater the imbalance in workload distribution along the line.

### 3.5 Application of the Ranked Positional Weight (RPW) Method

Positional weight calculation was performed by tracing the precedence diagram forward. The element with the highest weight is element 3 (Insole Screen Printing) at 161.20 seconds, while the lowest weight belongs to element 18 (Placing into Packaging Plastic) at 34.49

seconds. Based on this priority order, the 18 elements were successfully allocated into five workstations. The grouping results are presented in the table below.

Table 6. RPW Method Grouping Results

| Workstation | Work Elements  | Operation Time | Line Efficiency |
|-------------|----------------|----------------|-----------------|
| 1           | 3, 4, 5, 6, 8  | 40,95          | 93,76%          |
| 2           | 7, 1, 9, 2     | 41,11          | 94,11%          |
| 3           | 10, 11, 12     | 42,97          | 98,37%          |
| 4           | 13, 14, 15, 16 | 38,52          | 88,18%          |
| 5           | 17, 18         | 43,56          | 99,72%          |

Source: Processed Data, 2026

The RPW method produced a considerably more balanced line configuration than the initial condition, yielding a line efficiency of 94.83%, a balance delay of 5.17%, and a smoothness index of 6.21 seconds. This reflects that nearly all available time was utilized productively and that the workload imbalance across stations was successfully minimized.

### 3.6 Application of the Largest Candidate Rule (LCR) Method

The application of LCR began with constructing the predecessor (P) and follower (F) matrices from the same precedence diagram. At each station-formation stage, the free element (all of whose predecessors had already been assigned) with the largest operation time was prioritized for assignment first. Using this approach, the 18 elements were likewise successfully distributed into five workstations, yielding a line efficiency of 94.83% and a balance delay of 5.17%, with an LCR smoothness index of 7.13 seconds. The results of applying the Largest Candidate Rule (LCR) method are as follows.

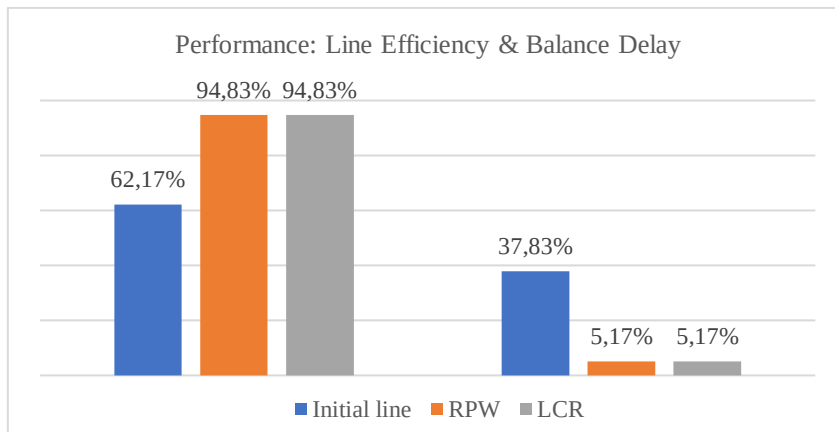
Table 7. LCR Method Grouping Results

| Workstation | Work Elements  | Operation Time | Line Efficiency |
|-------------|----------------|----------------|-----------------|
| 1           | 1, 8, 6, 9, 3  | 43,51          | 99,60%          |
| 2           | 4, 5, 7, 2     | 38,56          | 88,27%          |
| 3           | 10, 11, 12     | 42,97          | 98,37%          |
| 4           | 13, 14, 15, 16 | 38,52          | 88,18%          |
| 5           | 17, 18         | 43,56          | 99,72%          |

Source: Processed Data, 2026

### 3.7 Comparison of the Two Methods' Results

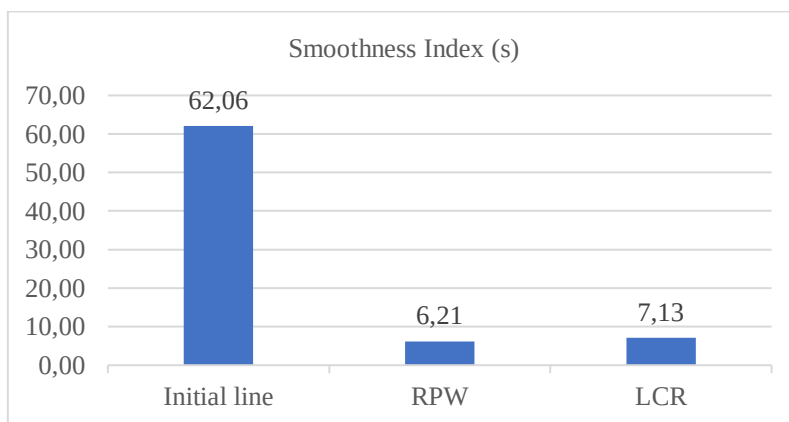
A comprehensive comparison between the initial condition and both methods is presented in the Figure 4. The chart in Figure 4 shows a comparison of two lines performance indicators, line efficiency and balance delay, between the initial condition and the balancing results using the RPW and LCR methods. Before improvement, the line operated at an efficiency of only 62.17% with a balance delay as high as 37.83%, meaning roughly one-third of production capacity was wasted as idle time. After balancing was applied, both methods produced identical line efficiency and balance delay values, raising efficiency to 94.83% while reducing the balance delay to just 5.17%.



Source: Processed Data, 2026

Figure 4. Line Performance Comparison

The smoothness index value reflects how evenly the workload is distributed along the line; the smaller the value, the more balanced the production flow. In the initial condition, a value of 62.06 seconds illustrated a very large workload imbalance between stations. After balancing, the RPW method produced a value of 6.21 seconds, smaller than LCR's 7.13 seconds, indicating that RPW achieves a more even workload distribution across stations and a smoother production flow. RPW is therefore recommended as the line-balancing design to be implemented.



Source: Processed Data, 2026

Figure 5. Smoothness Index Comparison

### 3.8 New Line Production Capacity

After the line was redesigned using the RPW method, the longest station time (the capacity-determining factor) decreased from 55.52 seconds to 43.56 seconds. The achievable daily production capacity increased to:

$$\text{New Capacity} = \frac{25.200 \text{ seconds}}{43,56 \text{ seconds/pairs}} = 579 \text{ pairs/day} \quad (10)$$

#### 4. Conclusion

Improved through the application of heuristic methods. The initial condition with six workstations produced a line efficiency of only 62.17% and a smoothness index of 62.06 seconds, reflecting substantial capacity waste. After balancing, both the RPW and LCR methods successfully reduced the number of workstations to five and increased line efficiency to 94.83% with a balance delay of only 5.17%. RPW proved superior with a smoothness index of 6.21 seconds compared with LCR's 7.13 seconds, and is therefore recommended as the implementation solution. The production capacity of the new line reaches 579 pairs per day, exceeding the company's target of 577 pairs per day.

This study focuses on the production-line balancing aspect and has not examined the readiness of raw-material supply capacity from suppliers or the capacity of supporting machines (such as press and sewing machines) to keep pace with the new production speed, so the potential for new bottlenecks in the raw-material warehouse or post-production process cannot be fully ruled out. In addition, merging 18 work elements into 5 new workstations may increase the workload at some stations, yet the readiness of physical layout and operator multi-skilling under this new configuration has not been directly tested in the field. Based on these limitations, further research is recommended to directly measure raw-material supply capacity from suppliers and the throughput of supporting machines, so that increased line output does not create new bottlenecks upstream or downstream of the production process. Further study on the readiness of physical workstation layout and the operator multi-skilling training required under the new line configuration is also needed so that the RPW design can be implemented optimally in the field. A simulation or stochastic modelling approach may also be considered in future research to accommodate the variability in manual work time between operators, in order to produce a line-balancing design that is more robust to actual field conditions.

#### REFERENCES

- [1] A. Basuki and A. D. Cahyani, "Heuristic Line Balancing Method for Solving Bottleneck Problems on Production Lines," vol. 13, no. 3, pp. 317-323, 2020.
- [2] A. Bima and M. Siti, "Production Line Balancing Analysis to Reduce Waiting Time in Chair Production (Case Study: UD XYZ)," *J. Tek. Ind.*, 2025.
- [3] H. Murnawan and P. E. D. K. Wati, "Redesign of Facilities and Production Space to Increase Production Output," vol. 19, no. 2, pp. 157-165, 2018.
- [4] J. Mumtaz, C. Alvina, and P. Hapsari, "Line Balancing Analysis on the C-9 Sewing Production Line Using Heuristic Methods (Case Study: PT Sari Warna Asli Garment)," 2025.
- [5] M. I. P. Karmawan, F. Pulansari, and D. S. Donoriyanto, "Line Balancing Analysis Using the Largest Candidate Rule, Kilbridge and Wester Method, and Ranked Positional Weight Methods," vol. 01, no. 01, pp. 43-54, 2020.
- [6] W. Poncotoyo, S. Mardhiani, R. Puspita, M. F. Zain, and S. A. Sholihah, "Application of Line Balancing Methods Using the Ranked Positional Weight, Regional Approach, and Largest Candidate Rule Approaches," vol. 2, no. 1, pp. 32-38, 2022.
- [7] H. F. Permatasari, *Line Balancing Analysis Using Heuristic Methods to Minimize Idle Time on the Closing Line at a Footwear Company*. Universitas Brawijaya (Undergraduate Thesis), 2016.

- [8] S. Wignjosoebroto, *Ergonomics: Motion and Time Study*, 1st ed. Surabaya: Guna Widya, 2006.
- [9] I. Z. Sitalaksana, R. Anggawisastra, and J. H. Tjakraatmadja, "Work Methods Engineering," Institut Teknologi Bandung, Bandung, 1979.
- [10] A. H. Nasution and Y. Prasetyawan, *Production Planning and Control*, 1st ed. Yogyakarta: Graha Ilmu, 2008.
- [11] Santoso and R. M. Heryanto, *Production Planning and Control 1*. Bandung: Alfabeta, 2017