Application of line balancing using the heuristic method to equalize the production line at PT. Bogatama Marinusa Makassar

Ahmad Sawal and Ainun Jariah Hamzah
Agro Industrial Engineering, Polytechnic of ATI Makassar, Makassar, 90211, Indonesia
Email: sawal@atim.ac.id

Abstract. PT. Bogatama Marinusa is one of the fishery industry sectors located in South Sulawesi that moves in shrimp processing and frosting as pioneer of fishery industry in southern Sulawesi. PT. Bogatama Marinusa certainly wants the planned production target to be achieved as expected, where every day the company processes raw materials with the capacity of approximately 575 kg for *vannamei* shrimp and 425 kg for *black tiger* shrimp. At deheading work station (shrimp head separation) and sortation area (sorting) materials buildup occurs in the production flow (bottle neck) which results an idle time to other work stations. With the existence of these problems, it is necessary to do production line balancing in order to minimize idle time and be able to balance the production lines so that the works carried out effectively and efficiently. The method used for overcoming the production line imbalance is by applying line balancing, namely the heuristic method, which is calculation using Regional Approach (RA) and Ranked Positional Weight (RPW) methods. Line efficiency (LE) increased by 83.33%, smoothing index (SI) decreased by 160.90, balance delay (BD) decreased by 16.66%, and idle time (IT) decreased by 264 minutes, and production capacity could be increase to 1,022 kg means that the results are far better than the current conditions.

1. Introduction
1.1. Background
The current development of the food industry demanding companies to keep survive and develop. Companies that are able to survive and develop well can certainly increase competitive advantage in the industrial world. Therefore, companies must have effective management operations in determining the number of workers and the balance of work seen from the efficiency of production process time so wasting of time and costs can be avoided which can harm the company in achieving expected level of production [1].

PT. Bogatama Marinusa is one of the fishery industry sectors located in South Sulawesi that moves in shrimp processing and frosting as pioneer of fishery industry in southern Sulawesi. The raw materials used are *vannamei* shrimp (white shrimp) and black tiger shrimp (tiger shrimp).

PT. Bogatama Marinusa aim to achieve every planned production target as expected, every day the company processes raw materials with a capacity of approximately 575 kg for *vannamei* shrimp and 425 kg for *black tiger* shrimp to keep up the demand. However, the processed production capacity reaches 1 ton per day resulting a buildup on the production flow (bottle neck) specifically in some work stations, one of which is deheading area and sortation area while the other work stations are idle, this is a big challenge for the company to create more efficient and effective production process. The balance
of production line is important to note because it will affect the smoothness of the production process including balancing the assignment of several work stations and minimizing the total waiting time (idle time) to obtain a smooth production flow in order to produce targeted output, labor and equipment in reducing production cycle times which will provide substantial savings to the production costs [2]. Production lines in the deheading department (cut shrimp head) and sorting areas have obstacles caused by the production process which is done manually with minimal use of the machine. Human capability limitation in sorting process become one cause of the build-up factor and long waiting time, to overcome these obstacles it is necessary to do the research to the work station especially on deheading area and sortation area to minimize buildup and waiting time.

1.2. Matter Formulation
Based on the background described above, the formulation of the problem in this study is how to balance the production line using the heuristic method in the form of calculations using the Regional Approach (RA) and Ranked Positional Weight (RPW) methods?

1.3. Research Purposes
Based on the matter formulation, the purpose of this study is to determine the balance of the production line using the heuristic method in the form of calculations using the Regional Approach (RA) and Ranked Positional Weight (RPW) methods.

2. Methods
Data obtained from the results of the study are processed and analyzed by applying Line Balancing with calculations using the Regional Approach (RA) method and Ranked Positional Weight (RPW) which is a method to solve the problem of determining the optimal number of work stations. To solve the problem of production line, the steps that must be done are as follows: [3,4]

2.1. Data Adequacy Test
Testing the adequacy of data is needed to ensure that the data collected is objective enough, below are the formulation:

\[ N' = \frac{k/s\sqrt{\sum(x-x)^2}}{\sum x} \]  \hspace{1cm} (2.1)

2.2. Data uniformity test
To ensure that the data gathered comes from the same system, it is very necessary to test the data uniformity. Therefore we need to test the uniformity of data to separate data which has different characteristics.

\[ \sigma = \sqrt{\frac{\sum(x-x)^2}{N-1}} \]  \hspace{1cm} (2.2)

\[ BKA = \bar{X} + K \cdot \sigma \]  \hspace{1cm} (2.3)

\[ BKB = \bar{X} + K \cdot \sigma \]  \hspace{1cm} (2.4)

2.3. Creating Precedence Diagram
Precedence diagram which is a graphical description of the sequence of work operations, as well as dependence on other work operations that aim to facilitate the control and planning of related activities.

2.4. Determine the work station (work station)
Work station (work station) is a place where track carried out. After determining the cycle time, then determine the minimum number of work stations that will be formed using the following equation
2.5. Calculating Cycle Time (CT)
Cycle time is time needed to make one product unit in a work station. Determination of cycle time done by taking prime factorization from the total time element of the company’s work. In designing the production line balance for a certain number of production, the cycle time must be equal or greater than the largest operating time which is the cause of bottle neck.

\[ ST_{\text{max}} \leq CT \leq \sum ti \]  

(2.6)

2.6. Calculating Production Capacity
Calculating production capacity is needed to find out how much production capacity in one production line for one production cycle.

\[ \text{Capacity} = \frac{\text{Daily Production Time}}{\text{Cycle Time}} \]  

(2.7)

2.7. Calculate Line Efficiency (LE)
Line efficiency is the ratio of the total work station time divided by the cycle time multiplied by the work station. A good production path has a high track efficiency value which indicates that all work stations have a closer time to the specified cycle time. So it can be said that the higher the value of track efficiency, the track will become better.

\[ LE = \frac{\sum_{i=1}^{K} ST_i}{(K)(CT)} \]  

(2.8)

2.8. Calculate Smoothing Index (SI)
Smoothing index is an index that has a relative smoothness of the balancing from production line. A good production path has a smoothing index value that is close to zero. In other words the smaller the smoothing index value the better

\[ SI = \sqrt{\sum_{i=1}^{K} (ST_{\text{max}} - ST_i)} \]  

(2.9)

2.9. Calculate Balance Delay (BD)
Balance delay is a measure of trajectory inefficiency resulting from actual idle time due to less than perfect allocation between work stations. A good production line has a balance delay value close to zero, which means that the idle time is small for all work stations. The smaller the balance delay, the better a production line.

\[ BD = \frac{(K \times CT) - \sum i ti}{(K)(CT)} \]  

(2.10)

2.10. Idle Time (IT)
Idle time is the difference between cycle time (CT) and station time (ST). The idle time occurs in each work station. Idle time occurs when the processing time on a work station is smaller than the cycle time.

\[ IT = K (CT) - \sum ST \]  

(2.11)
3. Results and Discussion

3.1. Data Collection Results

Based on the results of direct observation in the production section for the initial process of PT. Bogatama Marinusa Makassar, namely in department receiving, deheading, sortation area, and chillroom, the data for operating elements of work time were obtained. Data collection carried out is the process time data from each work element with 18 observations by averaging the time to get the accuracy results. Then the data processing time on the track can be seen in Table 1 below.

| Table 1. Description of Work Station Operations |
|------------------------------------------------|
| Operation | Description | Predecessor Event | Station Time (Minutes) |
|-----------|-------------|-------------------|-----------------------|
| A         | Unloading of vannamei shrimp | -     | 50        |
| B         | Unloading of black tiger shrimp | -     | 48        |
| C         | Pre-washing of vannamei shrimp | A     | 52        |
| D         | Pre-washing of black tiger shrimp | B     | 55        |
| E         | Weighing 1 (head on) vannamei | C     | 34        |
| F         | Weighing 1 (head on) black tiger | D     | 28        |
| G         | Deheading (shrimp head cutting) | E, F  | 230       |
| H         | Washing 1 | G     | 64        |
| I         | Weighing 2 (head less) vannamei | H     | 37        |
| J         | Weighing 2 (head less) black tiger | H     | 39        |
| K         | Sortation of vannamei shrimp | I     | 258       |
| L         | Sortation of black tiger shrimp | J     | 260       |
| M         | Washing 2 | K, L  | 53        |
| N         | Weighing 3 (head less) vannamei | M     | 48        |
| O         | Weighing 3 (head less) black tiger | M     | 38        |
| P         | Storage in chill room (Temporary Storage) | N, O  | 26        |
| Total     |             |       | 1,320     |

(Source: Data processing, 2019)

3.2. Data Processing

3.2.1. Data Adequacy Test. Based on data that has been observed at PT. Bogatama Marinusa, can be seen in table 1, then the adequacy of the observation data will be tested, there are two factors that are used to determine the test of data adequacy, namely the level of confidence and degree of accuracy. In this study used a confidence level of 95% = 2 and a degree of accuracy of 10% = 0.1.

| Table 2. Recapitulation of the data adequacy test |
|-----------------------------------------------|
| No | Operation | N | N'  | Information |
|----|-----------|---|-----|-------------|
| 1  | A         | 18| 13,77| Adequate   |
| 2  | B         | 18| 11,38| Adequate   |
| 3  | C         | 18| 7,95 | Adequate   |
| 4  | D         | 18| 3,65 | Adequate   |
| 5  | E         | 18| 3,42 | Adequate   |
| 6  | F         | 18| 15,58| Adequate   |
| 7  | G         | 18| 4,04 | Adequate   |
| 8  | H         | 18| 17,66| Adequate   |
| 9  | I         | 18| 4,51 | Adequate   |
| 10 | J         | 18| 15,39| Adequate   |
| 11 | K         | 18| 2,27 | Adequate   |
| 12 | L         | 18| 2,02 | Adequate   |
| 13 | M         | 18| 0,88 | Adequate   |
3.2.2. Data Uniformity Test. Based on data that has been observed at PT. Bogatama Marinusa, can be seen in table 1, then the uniformity of the observation data will be tested, this uniformity test is done with the aim of identifying the existence of data that deviates significantly from the actual average due to data which has too large or too small amount. From the data tested, the control limit will be obtained, namely the Upper Control Limit (BKA) and Lower Control Limit (BKB). In this study using 95% of confidence level = 2 and uniformity of data being tested using Minitab software.

Table 3. Recapitulation of data uniformity tests

| No | Operation | x  | Deviation Standard | K  | BKA  | BKB  | Information |
|----|-----------|----|--------------------|----|------|------|-------------|
| 1  | A         | 50 | 9.54               | 2  | 69.08| 30.92| Even        |
| 2  | B         | 48 | 8.33               | 2  | 64.66| 31.34| Even        |
| 3  | C         | 52 | 7.54               | 2  | 67.08| 36.92| Even        |
| 4  | D         | 55 | 5.37               | 2  | 65.74| 44.26| Even        |
| 5  | E         | 34 | 3.23               | 2  | 40.46| 27.54| Even        |
| 6  | F         | 28 | 5.68               | 2  | 39.36| 16.64| Even        |
| 7  | G         | 230| 23.81              | 2  | 277.62| 182.38| Even        |
| 8  | H         | 64 | 13.91              | 2  | 91.82| 36.18| Even        |
| 9  | I         | 37 | 4.04               | 2  | 45.08| 28.92| Even        |
| 10 | J         | 39 | 7.87               | 2  | 54.74| 23.26| Even        |
| 11 | K         | 258| 20.01              | 2  | 298.02| 217.98| Even        |
| 12 | L         | 260| 19.02              | 2  | 298.04| 221.96| Even        |
| 13 | M         | 53 | 2.56               | 2  | 58.12| 47.88| Even        |
| 14 | N         | 48 | 8.07               | 2  | 64.14| 31.86| Even        |
| 15 | O         | 38 | 8.28               | 2  | 54.56| 21.44| Even        |
| 16 | P         | 26 | 5.46               | 2  | 36.92| 15.08| Even        |

(Source: Data processing, 2019)

3.2.3. Describes the Precedence Diagram. Based on table 1, precedence diagram will be made, the following is a precedence diagram (Figure 1) based on a description of the department's operational receiving area (receipt of raw materials), deheading area (cut shrimp head), sorting area, and chilling room (temporary storage).

Figure 1. Precedence diagram

3.2.4. Line Balancing Analysis in Actual (Initial) Conditions. Based on the picture 1 precedence diagram above, the working elements of the initial conditions can be seen in table 4 where there are 10 work stations, can be seen the work load at stations 4 and 7 is the maximum load that is on the current production trajectory as for operating time can be seen in table 4 as follows:
Table 4. Work station initial conditions

| Working Station | Element | Station Time (ST) (Minutes) |
|-----------------|---------|-----------------------------|
| I               | A, B    | 98                          |
| II              | C, D    | 107                         |
| III             | E, F    | 62                          |
| IV              | G       | 230                         |
| V               | H       | 64                          |
| VI              | I, J    | 76                          |
| VII             | K, L    | 518                         |
| VIII            | M       | 53                          |
| IX              | N, O    | 86                          |
| X               | P       | 26                          |
| Total           |         | 1,320                       |

Line efisiensi (LE) 25.48%
Smoothing Index (SI) 1,297.14
Balance Delay (BD) 74.51%
Idle Time (IT) 3.860 minutes
Production capacity 0.521 Ton (521.23 kg)
(Source: Data processing, 2019)

3.2.5. Analysis for Proposed Conditions Using The Regional Approach (RA) Method

1. Calculating CT determination (cycle time)
   Determining the cycle time is obtained from the prime number of the total work station time, the cycle time must be greater or equal to the maximum time of the work station. Prime numbers for total work station time 1,320 minutes are 2, 3, 4, 5, 6, 8, 10, 11, 12, 15, 20, 22, 24, 30, 33, 40, 44, 55, 60, 66, 88, 110, 120, 132, 165, 220, 264, 330, 440, 660, 1,320 then the possible alternative time for cycles (CT) are 264, 330, 440, 660, 1,320 because the value is out of 260 minutes which is the biggest work station time. The value of the cycle time (CT) chosen is factorization 264. Where the provisions can be seen in equation (2.6) as for the determination of the cycle time (CT) can be seen as follows. Where:

\[ ST_{\text{max}}: 260 \text{ minutes} \]
\[ CT: 264 \text{ minutes} \]
\[ \sum t_i: 1,320 \text{ minutes} \]
Settlement:
\[ ST_{\text{max}} \leq CT \leq \sum t_i \]
\[ 260 \leq 264 \leq 1,320 \]
Value of CT = 264 is obtained

2. Alternative Improvement of Track Balance using The Regional Approach (RA) Method
   Based on the picture 1 precedence diagram above, the merging of work elements of repair conditions using the regional approach (RA) method for alternative can be seen in table 5, among others as follows:

Table 5. Alternative experiments

| Station | Element | ST | CT - STi | (STmax - STi)\text{2} |
|---------|---------|----|----------|-----------------------|
| I       | A,B,C,D,E | 239 | 25 | 441 |
| II      | F, G    | 258 | 6  | 4  |
| III     | L       | 260 | 4  | 0  |
| IV      | K       | 258 | 6  | 4  |
| V       | H,J,I,N,O | 226 | 38 | 1.156 |
| VI      | M, P    | 79  | 185 | 32.761 |
| Total   |         | 1,320 | 264 | 34.366 |
3.2.6 Line Balancing Calculations for Proposed Conditions using Ranked Positional Weight (RPW) Method

1. Calculating CT Determination (cycle time)
Determining the cycle time is obtained from the prime number of the total work station time, the cycle time must be greater or equal to the maximum time of the work station. Prime numbers for total work station time 1,320 minutes are 2, 3, 4, 5, 6, 8, 10, 11, 12, 15, 20, 22, 24, 30, 33, 40, 44, 55, 60, 66, 88, 110, 120, 132, 165, 220, 264, 330, 440, 660, 1,320 then the possible alternative time for cycles (CT) are 264, 330, 440, 660, 1,320 because the value is out of 260 minutes which is the biggest work station time. So that the value of the cycle time (CT) chosen is factorization 264. Where the provisions can be seen in equation (2.6) as for the determination of the cycle time (CT) can be seen as follows.

Where:

\[ \text{ST}_{\text{max}}: 260 \text{ minutes} \]
\[ \text{CT}: 264 \text{ minutes} \]
\[ \sum t_i: 1,320 \text{ minutes} \]

Settlement:
\[ \text{ST}_{\text{max}} \leq \text{CT} \leq \sum t_i \]
\[ 260 \leq 264 \leq 1,320 \]

Value of CT = 264 is obtained

2. Alternative Repair of Track Balance by Using The Ranked Positional Weight (RPW) Method
Based on the figure 1. precedence diagram above, the merging of the working elements of the repair condition by using the ranked positional weight (RPW) method for alternative 2 can be seen in table 4.14, among others as follows:

Table 6. Alternative experiments

| Station | Element | ST | CT - STi | (ST_{\text{max}} - STi)2 |
|---------|---------|----|----------|-----------------------------|
| I       | A,B,C,D,F | 233 | 31 | 961 |
| II      | E, G    | 264 | 0  | 0  |
| III     | H,I     | 140 | 124 | 15,376 |
| IV      | L       | 260 | 4  | 16 |
| V       | K       | 258 | 6  | 36 |
| VI      | M,N,O,P | 165 | 99 | 9,801 |
| Total   |         | 1,320 | 264 | 26,190 |

Line Efficiency (LE) 83.33 %
Smoothing Index (SI) 170.75
Balance Delay (BD) 16.66 %
Idle Time (IT) 264 minutes

(Source: Data processing, 2019)

3.3. Proposed Improvements
Based on the previous discussion, it is known that the proposed improvement using the alternative positional weight (RPW) method calculation 3 has the best results so that the researchers propose to improve the production trajectory based on the results as many as 6 work stations. The following is a picture of the proposed improvement in the production line at PT. Bogatama Marinusa can be seen in figure 2 below:
From the results of the proposed improvement by balancing the production line based on the Ranked Positional Weight (RPW) method carried out by combining work elements so the company can move or assign workers to a process that lacks workforce, namely at the work station deheading area (cutting of shrimp head) and station work sortation area (sorting). If after the transfer of labor has been carried out and it turns out that there is an excess of labor in each process and there is no process or station that has a shortage, labor elimination or reduction of this can occur due to employees in the deheading area (cutting of shrimp head) is a non-daily employee, but of course this can provide cost savings to the company.

4. Conclusion
Based on observations made at PT. Bogatama Marinusa Makassar is known for the current condition of having 10 work stations divided into 16 work elements by having a line efficiency level (LE) of 25.48%, smoothing index (SI) with a number of 1,297.14, balance delay (BD) with a number 74, 51%, idle itime (IT) 3,860 minutes and only able to process raw materials as much as 521.23 kg.

5. Suggestions
Based on the conclusions from the calculation results, the company needs to apply the Ranked Positional Weight (RPW) method to determine the ideal work station in order to minimize idle time and eliminate obstacles then provide smooth production processes in the receiving area, deheading area (cutting head shrimp), sorting area, and cillroom (temporary storage warehouse).

References
[1] Gaspersz V 2004 Production planning and inventory control (Jakarta: PT Gramedia Pustaka Umum)
[2] Lamatinulu 2011 Sistem Operasi (Makassar: Cahaya Baliputra)
[3] Wignjosebroto S 2003 Pengantar teknik dan manajemen industri (Surabaya: Guna Widya)
[4] Suryadi 1996 Pengantar Teknik Industri (Jakarta: Publisher Gunadarma)