Reducing Work Overtime in Production Line by Comparing Two Heuristic Line Balancing Method: Case Study of Beam Comp Stering Hanger at PT. Metindo Era Sakti

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Abstract. Production line is a set of sequential operation that support refinery process product from raw material to end process into finish product. However, due to the operations have different time process to finish an item/part, it caused unbalance processing time in certain work station in a production line. This problem increases overtime to work station with heavy load tasks, in the contrary to work station with low load tasks results idle workers. Overtime is definitely cost to organization. PT. Metindo Era Sakti has overtime as their issue. To balance the process time in work stations, line balancing method is one of option to the problem. Line Balancing uses to reduce overtime by increasing production line efficiency, reducing delay time, and decreasing worker idle time [8]. By using Rank Positioned Weight (RPW) and Largest Candidate Rules (LCR) and comparing those methods was proven that production line efficiency increased by 85.63%, delay time decreased by 14.37%, and reduced idle time by 3.77 minutes. Therefore, while reducing overtime, PT. Metindo Era Sakti enable to minimize overtime cost by Rp. 4.092.000 each year.

1. Introduction
Development of manufacturing industry extremely tremendous forced many organizations to keep innovate and develop their technology, product, and service. Once they survived in changing global trend, they can win the global competition and market. Therefore, organizations ought to be able to manage their tactical and operational as effective and efficient as possible in order to minimize cost and time which lead to optimum production level and increasing companies profit [5].

In a production planning, scheduling and managing each production line is significant. This ensure each work station runs smoothly, has same workload, and no bottleneck. If each production line and its workstation did not plan well, it caused unbalance production line due to difference production speed. Therefore, in a certain work station had bottleneck as a result of material/part that accumulate in certain point. Production line is placing production area into work station where each operation is arranged chronologically and material flows continuously [10]. Production line is a track that places production facilities as machines, instruments and tools closer to each other chronologically in order to support production process in same production speed [1].
Issues regarding balance of production line are often times happened in assembly process rather than in producing process (changes raw material into half finish good, no assembly process needed). A balance production line is a flexible production line which mean while producing goods, the process can be divided into several work station with short processing time and balance the workload so there are no work stations that finish earlier or later than any other stations along production line [1][6][12].

Research done by [7] show by using line balancing method for could improve the line efficiency up to 30% and reduce bottleneck and idle time by 5% so each work station in production line was more balance. Another research done by Purnamasari & Sidhi [4] by using Ranked Positional Weight and Largest Candidate Rules resulting in production line efficiency to 81%.

Unbalanace production line also a big problem to PT. Metindo Era Sakti. Metindo Era Sakti is a company that produce component of automotive under Astra Ototapart Group, PT Metindo Era Sakti expanded their business into motorcycle part/components production. Nowadays, PT. Metindo Era Sakti produce a part named part Beam Comp Stering Hanger with series number 61310-T8N-T003 which is part for product named HPM 2XP [2]. In the table 1.1 show demand of this part has inclining trend. The data is collected from PT. Metindo Era Sakti.

| Plant 1 | Model | October | November | December | January |
|---------|-------|---------|----------|----------|---------|
| 2XP     | 3060  | 2220    | 4620     | 5100     |
| 2MG     | 510   | 510     | 0        | 300      |
| 2SK     | 522   | 1560    | 1134     | 1134     |

| Plant 2 | Model | October | November | December | January |
|---------|-------|---------|----------|----------|---------|
| 2WF     | 1620  | 1140    | 1920     | 960      |
| 2SJ     | 1140  | 2580    | 3060     | 2040     |
| 2MD     | 2520  | 4620    | 0        | 2640     |
| 2CF     | 5640  | 4740    | 4800     | 3000     |

2XP production line has 6 work station (WS). After doing pre-observation the Current situation in 2XP production line was show that average processing time for each 6 stations was unbalance when they are produce part beam comp stering hanger. There was bottleneck in WS 2 and WS 6. See fig 1.1. It means that once bottleneck happen in work station can have big impact along whole production cycle. Once the bottleneck occurred, the workers need to solve the bottleneck, get to target production therefor they worked overtime. This overtime cost to PT. Metindo Era Sakti and such a concern to the board of high management.

![Fig. 1.1 Material flow and processing time in each WS](image)

In order to overcome the overtime issue, this research help to give a solution to minimize it by using line balancing method as this method proven can be helped to unbalance production line to become more balance and efficient. The research aims to rearrange working element and tasks in each work
station, therefore workload can be spread equally in certain output level so overtime can be reduce or best eliminated.

2. Method
This research is using several line balancing method and comparing it to find the best solution. The method used are Rank Positional Weight Method (RPW) and Largest Candidate Rule Method (LCR).

2.1 Rank Positional Weight Method
One approach that is commonly used to balance production line is a method developed by Helgesson and Birnie called Rank Positional Weight. This approach uses addition of certain time from operation/tasks that is controlled in a work station. It emphasizes to count the working element that has the latest time as priority to be done first in that WS than follow by another working element that has shorter time [10]. This is the sequence to prepare calculation using RPW method [10]:

a. Make precedence diagram for each process in WS
b. Define Positional Weight for each working element which related to its shorter-longer time. The longer working element has the bigger weight.
   
   \[
   \text{Weight (RPW)} = \text{Operation time}_t + \text{Operation time}_{t+1}
   \]

c. Make rank for each working element based on weight from the previous step. Working element that has highest weight is the highest rank.
d. Calculate cycle time.
e. Choose working element that has highest weight and allocate to work station then calculate the takt time. The time in WS should be lesser than takt time.
f. If allocation of working element made WS time > takt time, then the rest of this number (Takt time subtract WS time) is filled with time allocation of working element that has biggest weight and the addition did not make the WS time > takt time.

2.2 Largest Candidate Rule Method (LCR)
The advantage of LCR method that is easier to be implemented however the result from LCR calculation needs trial and error to fine optimum combination of working element arrangement then allocate it into working station. But when a lot and complex working element involved in one WS, then this method automatically used to put the working station in an order based on largest operation time to smaller operation time [10]. Therefore, the sequence of this method as follow:

a. Draw the precedence diagram of the current WS
b. Put in order each working Element from the longest time to shortest time.

   c. Working element at the first WS is taken from the first order. Working element can be change or placed to another WS when if the number of working element is over the cycle time.
   d. Continue the second step until all the working element to be placed in each WS and the total time of WS < takt time.

2.3 Research Sequence
The following flowchart is the sequence of doing the research. It consists of several step as follow:

1. Theoretical & Observation Study
2. Identification of Problem
3. Define Research Objective
4. Emphasize Research Scope
5. Collect Data
6. Tabulate Data
7. Calculate existing condition
8. Computation using RPW LCR
9. Define the indicator needed to choose the best solution
10. Compare Line Balancing Method calculation result

Fig. 2.1 Research Sequence
### 3. Result

#### 3.1 Working Element of Each Work Station

In the table below show list of working element in production line in order to produce part beam comp stering hanger.

| Work Station | No. | Working Element | Number of Operator |
|--------------|-----|-----------------|--------------------|
| **Main Assy** 1 | 1 | Push Button push bottom 1 | |
| | 2 | Take part (SAS-1A thensett. on Jig Assy) | |
| | 3 | Take part (77196-T7A-3000) Then sett. on Jig Assy | |
| | 4 | Take part (61311-T8N-T000-H1) Then sett. on Jig Assy | |
| | 5 | Press button push bottom 2 | |
| | 6 | Take part (SAS-5A) then sett. on Jig Assy | |
| | 7 | Take part (SAS-4) then sett. on Jig Assy | |
| | 8 | Take part (SAS-3) then sett. on Jig Assy | |
| | 9 | Press button push bottom 3 | 1 |
| | 10 | Press button push bottom 4 | |
| | 11 | Take part (61312-T8N-T000-H1) Then sett. on Jig Assy | |
| | 12 | Press button push bottom 5, 6, & 7 | |
| | 13 | Hit part uses rubber hammer to fix position | |
| | 14 | Do process Assy Welding as 20 Portion with pushing push bottom button with two hands | |
| | 15 | Press button push bottom "UNCLAMP" | |
| | 16 | Take out part from Jig and put it on sutter part | |
| **Main Assy** 2 | 17 | Take part (SAS-2A) then sett. on Jig Assy | |
| | 18 | Take part (SAS-6) Then sett. on Jig Assy | |
| | 19 | Press button push bottom 1 | |
| | 20 | Take part (77167-T7A-3000) then sett. on Jig Assy | |
| | 21 | Take part (Main Assy 1) then sett. on Jig Assy | |
| | 22 | Press button push bottom 2 | |
| | 23 | Press button push bottom 3 | |
| | 24 | Take part (SAS-5B) then sett. on Jig Assy | |
| | 25 | Take part (77181-T5A-3000) then sett. on Jig Assy | |
| | 26 | Take part (77175-T7A-3000) then sett. on Jig Assy | |
| | 27 | Press button push bottom 4 | |
| | 28 | Press button push bottom 5 | |
| | 29 | Hit part uses rubber hammer | |
| | 30 | Do process Assy Welding as many as 31 portion with pushing button push bottom with two hands | |
| | 31 | Press button push bottom 6 "UNCLAMP" | |
| | 32 | Take out part from Jig and put it on sutter part | |

| Work Station | No. | Working Element | Number of Operator |
|--------------|-----|-----------------|--------------------|
| | 33 | Press button push bottom 1 | |
| | 34 | Take part (MAIN ASSY 2) then sett. on Jig Assy | |
| | 35 | Press button push bottom 2 | |
| | 36 | Take part (77168-T7A-3000) then sett. on Jig Assy | |
| | 37 | Take part (SAS-2B) then sett. on Jig Assy | |
| | 38 | Take part (SAS-1B) then sett. on Jig | 1 |
39 Press button puss bottom 3
40 Press button puss bottom 4
41 Hit part uses rubber hammer
42 Do process Assy Welding as many as 15 portion with pushing button puss bottom with two hands
43 Press button puss bottom 5 "UNCLAMP"
44 Take out part from Jig and put it on pallet standard

| Working Station | No. | Working Element | Number of Operator |
|-----------------|-----|----------------|--------------------|
| Main Assy 4     | 45  | Press button puss bottom 1 | |

46 Take part (77197-T7A-3000) then sett. on Jig Assy
47 Take part (SAS-5C) then sett. on Jig Assy
48 Take part (MAIN ASSY 3) then sett. on Jig Assy
49 Press button puss bottom 2
50 Take part (77142-T7A-3000) then sett. on Jig Assy
51 Take part (77166-T7A-3000) then sett. on Jig Assy
52 Take part (61362-T8N-T000-H1) then sett. on Jig Assy
53 Press button puss bottom 3
54 Press button puss bottom 4
55 Press button puss bottom 5
56 Hit part uses rubber hammer
57 Do process Assy Welding sebanyak 19 portion with pushing button puss bottom with two hands
58 Press button puss bottom 6 "UNCLAMP"
59 Take out part from Jig and put it on pallet standard

| Working Station | No. | Working Element | Number of Operator |
|-----------------|-----|----------------|--------------------|
| Instal Bolt     | 60  | Take part hasil proses Jig 4/4, then put on Jig | |
|                 | 61  | Move Lever Pneumatic 1 into position "CLAMP". | |
|                 | 62  | Take part (46597-T7A-9500) and sett. on Jig | |
|                 | 63  | Move Lever Pneumatic 2 into position "CLAMP" | |
|                 | 64  | Take bolt M-8 (90104-TF0-0030) then insert it into hole part (46597-T7A-9500) and turn it to the right using hand then strengthen it with screw driver pneumatic | |
|                 | 65  | Take part (77370-T7A-0000) and sett. on Jig | |
|                 | 66  | Take bolt M-6 (90140-TF0-0000) then insert it into hole part (77370-T7A-0000) and insert it into hole part kanan menggunakan tangan, then turn menggunakan screw driver pneumatic | |
|                 | 67  | Take part (77375-T7A-0000) and sett. on Jig | |
|                 | 68  | Take bolt M-6 (90140-TF0-0000) then insert it into hole part (77375-T7A-0000) and turn it to the right using hand then strengthen it with screw driver pneumatic | |
|                 | 69  | Take Nut 90310-SMA-0030 (2 Pcs) and put on part | |
|                 | 70  | Take out part from Jig, and put it on pallet standard | |

| Working Station | No. | Working Element | Number of Operator |
|-----------------|-----|----------------|--------------------|
| Check           | 71  | Put part from instal bolt on Jig | |
|                 | 72  | Insert pin Datum 2 ke part, turn “CLAMP X” | |
|                 | 73  | Insert pin Datum 3, “PIN LOCKED” | |
|                 | 74  | Clamp part by turning “CLAMP Y” | |
|                 | 75  | Place swing-swing into position checking, insert pin part as order | |
|                 | 76  | Free all pin and swing from part | |
|                 | 77  | Take off from Jig, place it in area wip next process | |
3.2 Define Cycle Time, Normal Time, and Standard Time

In the table 3.2 shows the collected data regarding working time for each work station in order to complete the set of working element. The measurement was taken 10 times and the data was being tested using statistical method. The raw data is as follow:

| No. | Work Station  | Work Time (in Second) |
|-----|---------------|-----------------------|
| 1   | Main Assy 1   | 115                   |
|     |               | 116.04                |
|     |               | 115.95                |
|     |               | 115.63                |
|     |               | 116.03                |
|     |               | 115.96                |
|     |               | 115.51                |
|     |               | 116.07                |
|     |               | 116.02                |
|     |               | 116.12                |
| 2   | Main Assy 2   | 121.44                |
|     |               | 122.00                |
|     |               | 121.80                |
|     |               | 121.65                |
|     |               | 121.70                |
|     |               | 121.85                |
|     |               | 121.98                |
|     |               | 121.53                |
|     |               | 121.91                |
|     |               | 122.11                |
| 3   | Main Assy 3   | 107.00                |
|     |               | 107.61                |
|     |               | 107.84                |
|     |               | 107.55                |
|     |               | 107.65                |
|     |               | 107.46                |
|     |               | 107.61                |
|     |               | 107.88                |
|     |               | 107.73                |
|     |               | 107.59                |
| 4   | Main Assy 4   | 114.00                |
|     |               | 114.51                |
|     |               | 114.97                |
|     |               | 115.11                |
|     |               | 114.40                |
|     |               | 114.71                |
|     |               | 115.05                |
|     |               | 114.63                |
|     |               | 114.78                |
|     |               | 115.03                |
| 5   | Instal Bolt  | 107.00                |
|     |               | 107.77                |
|     |               | 107.66                |
|     |               | 107.70                |
|     |               | 107.48                |
|     |               | 107.75                |
|     |               | 107.77                |
|     |               | 107.73                |
|     |               | 107.52                |
|     |               | 107.81                |
| 6   | Checki ng    | 161.0                 |
|     |               | 161.5                 |
|     |               | 161.7                 |
|     |               | 161.6                 |
|     |               | 161.5                 |
|     |               | 161.2                 |
|     |               | 161.5                 |
|     |               | 161.5                 |
|     |               | 161.7                 |

3.2.1 Cycle Time

Cycle time is average observation time for certain task which is used to calculate Normal Time. The equation to calculate cycle time is as follow and the result shows in table 3.3.

$$ W_s = \frac{\sum X_i}{n} $$

Where:

- $W_s$ = Cycle Time
- $X_i$ = Data Measure
- $n$ = Times Collected data

| N   | Working Time (Minute) |
|-----|-----------------------|
|     | S1 (X1)  | S2 (X2)  | S3 (X3)  | S4 (X4)  | S5 (X5)  | S6 (X6)  |
| 1   | 1.917    | 2.024    | 1.783    | 1.783    | 2.683    | 2.683    |
| 2   | 1.934    | 2.033    | 1.794    | 1.796    | 2.692    | 2.692    |
| 3   | 1.933    | 2.030    | 1.797    | 1.794    | 2.695    | 2.695    |
Table 3.3 Cycle Time Result (continue)

| N   | S1 (X1) | S2 (X2) | S3 (X3) | S4 (X4) | S5 (X5) | S6 (X6) |
|-----|---------|---------|---------|---------|---------|---------|
| 4   | 1.927   | 2.028   | 1.793   | 1.795   | 2.693   | 2.693   |
| 5   | 1.934   | 2.028   | 1.794   | 1.791   | 2.688   | 2.688   |
| 6   | 1.933   | 2.031   | 1.791   | 1.796   | 2.695   | 2.695   |
| 7   | 1.925   | 2.033   | 1.794   | 1.796   | 2.687   | 2.687   |
| 8   | 1.933   | 2.026   | 1.798   | 1.796   | 2.692   | 2.692   |
| 9   | 1.934   | 2.032   | 1.796   | 1.792   | 2.692   | 2.692   |
| 10  | 1.935   | 2.035   | 1.793   | 1.797   | 2.695   | 2.695   |
| Total| 19.3   | 20.30   | 17.9     | 17.9     | 26.9     | 26.9     |
| Ws  | 1.93   | 2.030   | 1.79   | 1.91   | 1.79   | 2.69   |

3.2.2 Normal Time
In order to calculate normal time, adjustment factor while doing certain working element is added. This adjustment factor is defined according to personal skill of the operator while doing certain tasks. It converts to time and added to normal time. The list of adjustment factor that identified to be added to Normal Time is shown in table 3.4. The factor defined below is using Westinghouse Method.

Table 3.4 Adjustment Factor identified for Beam Comp Stering Hanger production

| Factor                        | Level     | Icon | Value |
|-------------------------------|-----------|------|-------|
| (Skill) “Operator well Trained” | Excellent | (B1) | + 0.11|
| (Effort) “Hardwork”          | Excellent | (B1) | + 0.10|
| Environment (Condition) “good” | Good      | (C)  | + 0.02|
| Konsistensi (Consistency) “on time” | Good | (C)  | + 0.01|
| Total                         |           |      | + 0.24|
| Therefore                     |           |      | (P) = 1 + 0.24 = 1.24 |

The equation to calculate normal time is:

\[ W_n = W_s \times P \]  \hspace{1cm} (2)

Where:
- \( W_n \): Normal Time
- \( W_s \): Working Time
- \( P \): Adjustment Factor
Table 3.5 Normal Time

| Work Station | Ws (minute) | Wn (minute) |
|--------------|-------------|-------------|
| 1            | 1.93        | 2.40        |
| 2            | 2.030       | 2.52        |
| 3            | 1.79        | 2.22        |
| 4            | 1.91        | 2.37        |
| 5            | 1.79        | 2.22        |
| 6            | 2.69        | 3.34        |
| **Total**    | **12.14**   | **15.07**   |
| **Average**  | **2.023**   | **2.52**    |

3.2.3 Standard Time

After the calculation of cycle time and Normal Time, the calculation of Standard time is possible. Standard Time is the best time or the worst time to complete a task according to existing condition. The allowance factor is classified into three which is for personal activity (such as eating, peeing, etc), reduce fatigue and unavoidable obstacle (such as talking between workers). The list of factors is chosen below used factors defined by Sutalaksana [9].

Table 3.6 Allowance Factor of Comp Beam Stering Hanger Production

| Allowance Factor          | Existing Condition Level | Allowance % | Ref | Judgement |
|---------------------------|--------------------------|-------------|-----|-----------|
| Power used                | Very Low                 | 6,0 – 7,5   | 6   |           |
| Work Position             | Stand                    | 1,0 – 2,5   | 2   |           |
| Work Possible Motion      | Difficult                | 0,0 – 5,0   | 3   |           |
| Eye Fatigue               | Continues sight          | 6,0 – 7,5   | 7   |           |
| Work Environment Temperature | Normal                  | 7,5 – 12    | 10  |           |
| Atmosphere                | Not good                 | 5,0 - 10    | 7   |           |
| Environment               | Noisy, unclean           | 5,0 – 15    | 12  |           |
| Sub Total                 |                          | 47          |     |           |
| Personal Need             | Man                      | 0 – 2,5     | 2   |           |
| **Total Allowance**       |                          | 49          |     |           |

Equation below is calculated takt time.

\[ Wb = Wn + (1 + i) \]  \hspace{1cm} (3)

Keterangan:

Ws = Average Cycle Time
After defining average cycle time, adjustment factor, and allowance, therefore standard time of come beam steering hanger can be calculated. Table 3.6 below shows average standard time for each work station.

Table 3.7 Standard Time for Each Work Station for production Beam Comp Stering Hanger

| Work Station | Ws (Min) | Wn (Min) | Wb (Min) |
|--------------|----------|----------|----------|
| 1            | 1.93     | 2.40     | 3.57     |
| 2            | 2.030    | 2.52     | 3.75     |
| 3            | 1.79     | 2.22     | 3.31     |
| 4            | 1.91     | 2.37     | 3.53     |
| 5            | 1.79     | 2.22     | 3.31     |
| 6            | 2.69     | 3.34     | 4.98     |
| Total        | 12.14    | 15.07    | 22.45    |
| Average      | 2.023    | 2.52     | 3.74     |

3.2.4 Defining Line Efficiency, Balance Delay, and Idle Time Existing Condition

According to Malave [3] in order to get maximum balance production line, it is required that a production line should minimize idle time and minimize balance delay, therefore, the efficiency of the line could be increased.

Defining Efficiency

Based on Sutalaksana [9] calculation of efficiency is following the equation:

\[
Efficiency = \frac{\text{Total time}}{N \times TT_{max}} \times 100\% \tag{4}
\]

Where:

- \( N \) = Number of WS
- \( TT_{max} \) = Largest standard time

Therefore:

\[
\frac{22.45}{6 \times 4.98} \times 100\% = 75.13\% 
\]

Defining Balance Delay

Balance delay is a ratio between idle time and available time. The equation to calculate balance delay is following:

\[
D = \frac{(N \cdot S_m) - \sum_{i=1}^{m} S_i}{(N \cdot S_m)} \times 100\% \tag{5}
\]

Where:

- \( D \) = Balance Delay
- \( N \) = Number of WS
- \( S_m \) = Largest time in WS

Therefore:

\[
\frac{6 \times 4.98 - 22.45}{6 \times 4.98} \times 100\% = 24.87\% 
\]

Defining Idle Time
Idle time is the difference between cycle time and working time of a work station. Idle time can be calculated with the equation below:

\[ \text{Idle Time} = ((N \times Tc) - Twc) \]  

(6)

Where:
- \( N \) = Number of WS
- \( Tc \) = Largest (Cycle Time)
- \( Twc \) = Total Cycle Time

Therefore:
\[ d = ((n \times Tc) - Twc) = 6 \times 4.98 - 22.45 = 7.43 \text{ minute} \]

3.2.5 Comparison between Takt Time and Standard Timme in each Work Station

Number of effective work time in PT. Metindo Era Sakti is 8 hours/day. Takt time is effective time work/demand each day. Production target is 126 unit/day. Therefore:

\[ \text{Takt Time} = \frac{480 \text{ Min}}{126 \text{ unit/day}} = 3.8 \text{ min/unit} \]

Takt Time of Beam Comp Stering Hanger production is 3.8 minute per unit, it means 3.8 minute is the maximum limit on finishing working element at each work station. Target production increase to 135 unit/day, means there is change in takt time as follow:

\[ \text{Takt Time} = \frac{480 \text{ min}}{135 \text{ unit/hr}} = 3.5 \text{ min/unit} \]

3.2.6 Line Balancing Using Rank Positional Weight Method (RPW)

The first step on applying this method is weighted in chronological order with accumulating work time for each working element since beginning of process until completed. The longest time will be placed first in the WS 1. The result of this ordering can be seen in table 3.7 below.

| Working Element | Weight | Position Weight | Working Element | Weight | Position Weight | Working Element | Weight | Position Weight |
|-----------------|--------|-----------------|-----------------|--------|-----------------|-----------------|--------|-----------------|
| 1               | 1.88   | 1346.93         | 28              | 1.85   | 1084.02         | 52              | 5.31   | 660.66          |
| 2               | 7.41   | 1345.05         | 29              | 20.94  | 1082.17         | 21              | 7.44   | 655.35          |
| 3               | 7.23   | 1337.64         | 30              | 136.64 | 1061.23         | 53              | 1.85   | 647.91          |
| 4               | 7.29   | 1330.41         | 31              | 1.78   | 924.59          | 54              | 1.88   | 646.06          |
| 5               | 1.85   | 1323.12         | 32              | 10.23  | 922.81          | 55              | 1.78   | 644.18          |
| 6               | 9.96   | 1321.27         | 33              | 1.90   | 912.58          | 56              | 15.21  | 642.4           |
| 7               | 7.34   | 1311.31         | 34              | 10.13  | 910.68          | 57              | 136.37 | 627.19          |
| 8               | 7.37   | 1303.97         | 6               | 7.21   | 900.55          | 58              | 1.91   | 490.82          |
| 9               | 1.90   | 1296.6          | 35              | 1.85   | 893.34          | 59              | 12.96  | 488.91          |
| 10              | 1.87   | 1294.7          | 36              | 6.43   | 891.49          | 60              | 39.00  | 475.95          |
| 11              | 7.43   | 1292.83         | 62              | 11.24  | 885.06          | 61              | 8.86   | 436.95          |
| 12              | 2.17   | 1285.4          | 37              | 6.05   | 873.82          | 63              | 9.45   | 428.09          |
| 13              | 14.83  | 1283.23         | 38              | 5.73   | 867.77          | 64              | 11.78  | 418.64          |
| 14              | 123.29 | 1268.4          | 39              | 1.82   | 862.04          | 66              | 11.66  | 406.86          |
| 15              | 2.72   | 1145.11         | 40              | 1.79   | 860.22          | 67              | 10.12  | 395.2           |
| 16              | 12.22  | 1142.39         | 41              | 25.44  | 858.43          | 68              | 11.87  | 385.08          |
| 17              | 5.70   | 1130.17         | 42              | 117.87 | 832.99          | 69              | 11.67  | 373.21          |
In order to find the best combination of working element and its best order, several attempts have been done by trial and error until there are no possible position to be changed. The attempts result is placed the work station and combine it with time in total to finish should be less than 3.5 minute. In the table 3.8 show the combination done after several attempts.

Table 3.9 Classification of Working Element into Work Station Using RPW

| Attempt | WS I   | WS II  | WS III | WS IV  | WS V   | WS VI  |
|---------|--------|--------|--------|--------|--------|--------|
| 1       | 1-2-3-4-5-6-7-18-9-10-11-12-13-14-15-16 | 17-8-19-20-21-22-23-24-25-26-27-28-29-30-31-32 | 33-34-6-36-62-21-38-39-40-41-42-43-44 | 45-46-47-48-49-50-51-52-37-53-54-55-56-57-58-59 | 60-61-63-64-65-66-67-68-69-72-73-74-70 | 71-75-76-77 |
| Less < 3.5 | 3.64 min | 3.64 min | 3.64 min | 3.63 min | 3.56 | 4.37 |
| 2       | 1-2-3-4-24-5-6-5-7-18-9-10-11-12-13-14-15-16 | 11-18-19-20-22-23-4-26-27-28-29-30-31-32 | 33-34-6-35-36-62-38-39-40-41-42-43-44 | 45-46-47-48-49-50-51-52-37-53-54-55-56-57-58-59 | 60-61-63-64-66-67-25-21-52-68-69-73-74-70 | 71-72-75-76-77 |
| Less > 3.5 | 3.56 Min | 3.52 Min | 3.52 Min | 3.54 Min | 3.58 Min | 4.68 Min |

Efficiency

\[
EL_1 = \frac{T_{wc}}{n \times T_c} \times 100\% = \frac{22.45}{6 \times 4.37} \times 100\% = 85.63\%.
\]

\[
EL_2 = \frac{T_{wc}}{n \times T_c} \times 100\% = \frac{22.45}{6 \times 4.68} \times 100\% = 79.95\%.
\]

Balance Delay

\[
BD_1 = \frac{n \times T_c - T_{wc}}{n \times T_c} \times 100\% = \frac{6 \times 4.37 - 22.45}{6 \times 4.37} \times 100\% = 14.37\%.
\]

\[
BD_2 = \frac{n \times T_c - T_{wc}}{n \times T_c} \times 100\% = \frac{6 \times 4.68 - 22.45}{6 \times 4.68} \times 100\% = 20.05\%.
\]

Idle Time

\[
IT_1 = ((n \times T_c) - T_{wc}) = ((6 \times 4.37) - 22.45) = 3.77 \text{ min}
\]

\[
IT_2 = ((n \times T_c) - T_{wc}) = ((6 \times 4.68) - 22.45) = 5.63 \text{ min}
\]
3.2.7 Line Balancing Using Largest Candidate Rules Method (LCR)

To calculate using LCR, the precedence constraint should be made firstly. This is made in order to understand the process sequences and its predecessor. In the table 3.8 below shows the process is placed consecutively.

**Table 3.10 Precedence Constraint of Beam Comp Stering Hanger**

| Working Element | Number of Predecessor | Predecessor | Time |
|-----------------|-----------------------|-------------|------|
| 1               | 0                     | -           | 1.88 |
| 2               | 1                     | 1           | 7.41 |
| 3               | 2                     | 2           | 7.23 |
| 4               | 3                     | 3           | 7.29 |
| 5               | 4                     | 4           | 1.85 |
| 6               | 5                     | 5           | 7.21 |
| 7               | 6                     | 6           | 7.34 |
| 8               | 7                     | 7           | 7.37 |
| 9               | 8                     | 8           | 1.90 |
| 10              | 9                     | 9           | 1.87 |
| 11              | 10                    | 10          | 7.43 |
| 12              | 11                    | 11          | 2.17 |
| 13              | 12                    | 12          | 14.83|
| 14              | 13                    | 13          | 123.29|
| 15              | 14                    | 14          | 2.72 |
| 16              | 15                    | 15          | 12.22|
| 17              | 16                    | 16          | 5.70 |
| 18              | 17                    | 17          | 6.79 |
| 19              | 18                    | 18          | 1.77 |
| 20              | 19                    | 19          | 6.49 |
| 21              | 20                    | 20          | 7.44 |
| 22              | 21                    | 21          | 1.86 |
| 23              | 22                    | 22          | 1.82 |
| 24              | 23                    | 23          | 6.45 |
| 25              | 24                    | 24          | 6.82 |
| 26              | 25                    | 25          | 6.61 |
| 27              | 26                    | 26          | 1.84 |
| 28              | 27                    | 27          | 1.85 |
| 29              | 28                    | 28          | 20.94|
| 30              | 29                    | 29          | 136.64|
| 31              | 30                    | 30          | 1.78 |
| 32              | 31                    | 31          | 10.23|
| 33              | 32                    | 32          | 1.90 |
| 34              | 33                    | 33          | 10.13|
| 35              | 34                    | 34          | 1.85 |
| 36              | 35                    | 35          | 6.43 |
| 37              | 36                    | 36          | 6.05 |
| Working Element | Number of Predecessor | Predecessor | Time   |
|-----------------|-----------------------|-------------|--------|
| 38              | 37                    | 37          | 5.73   |
| 39              | 38                    | 38          | 1.82   |
| 40              | 39                    | 39          | 1.79   |
| 41              | 40                    | 40          | 25.44  |
| 42              | 41                    | 41          | 117.87 |
| 43              | 42                    | 42          | 1.88   |
| 44              | 43                    | 43          | 17.90  |
| 45              | 44                    | 44          | 1.80   |
| 46              | 45                    | 45          | 5.37   |
| 47              | 46                    | 46          | 5.50   |
| 48              | 47                    | 47          | 9.27   |
| 49              | 48                    | 48          | 1.82   |
| 50              | 49                    | 49          | 5.42   |
| 51              | 50                    | 50          | 5.50   |
| 52              | 51                    | 51          | 5.31   |
| 53              | 52                    | 52          | 1.85   |
| 54              | 53                    | 53          | 1.88   |
| 55              | 54                    | 54          | 1.78   |
| 56              | 55                    | 55          | 15.21  |
| 57              | 56                    | 56          | 136.37 |
| 58              | 57                    | 57          | 1.91   |
| 59              | 58                    | 58          | 12.96  |
| 60              | 59                    | 59          | 39.00  |
| 61              | 60                    | 60          | 8.86   |
| 62              | 61                    | 61          | 11.24  |
| 63              | 62                    | 62          | 9.45   |
| 64              | 63                    | 63          | 11.78  |
| 65              | 64                    | 64          | 9.96   |
| 66              | 65                    | 65          | 11.66  |
| 67              | 66                    | 66          | 10.12  |
| 68              | 67                    | 67          | 11.87  |
| 69              | 68                    | 68          | 11.67  |
| 70              | 69                    | 69          | 63.22  |
| 71              | 70                    | 70          | 6.04   |
| 72              | 71                    | 71          | 18.32  |
| 73              | 72                    | 72          | 8.18   |
| 74              | 73                    | 73          | 9.58   |
| 75              | 74                    | 74          | 207.65 |
| 76              | 75                    | 75          | 38.03  |
| 77              | 76                    | 76          | 10.52  |

After defining precedence constraint, the next step is placed the working element which has the highest number of work time firstly then followed by other working element that shorter time. The first attempt
is done in the following table 3.9. Next step is classified all the working element in table 3.9 into work stations. However, the placing of the longest time working element in each station cannot precede on its predecessor. It can be shown in table 3.10.

### Table 3.11 Working Element is Placing in Order Based On LCR Rule 1st Attempt

| Working Element | Time  | Working Element | Time  | Working Element | Time  | Working Element | Time  |
|-----------------|-------|-----------------|-------|-----------------|-------|-----------------|-------|
| 75              | 207.65| 62              | 11.24 | 18              | 6.79  | 54              | 1.88  |
| 30              | 136.64| 77              | 10.52 | 26              | 6.61  | 43              | 1.88  |
| 57              | 136.37| 32              | 10.23 | 20              | 6.49  | 10              | 1.87  |
| 14              | 123.29| 34              | 10.13 | 24              | 6.45  | 22              | 1.86  |
| 42              | 117.87| 67              | 10.12 | 36              | 6.43  | 5               | 1.85  |
| 70              | 63.22 | 65              | 9.96  | 37              | 6.05  | 53              | 1.85  |
| 60              | 39.00 | 74              | 9.58  | 71              | 6.04  | 28              | 1.85  |
| 76              | 38.03 | 63              | 9.45  | 38              | 5.73  | 35              | 1.85  |
| 29              | 20.94 | 48              | 9.27  | 17              | 5.70  | 27              | 1.84  |
| 41              | 25.44 | 61              | 8.86  | 47              | 5.50  | 23              | 1.82  |
| 72              | 18.32 | 73              | 8.18  | 51              | 5.50  | 39              | 1.82  |
| 44              | 17.90 | 21              | 7.44  | 50              | 5.42  | 49              | 1.82  |
| 56              | 15.21 | 11              | 7.43  | 46              | 5.37  | 45              | 1.80  |
| 13              | 14.83 | 2               | 7.41  | 52              | 5.31  | 40              | 1.79  |
| 59              | 12.96 | 8               | 7.37  | 15              | 2.72  | 55              | 1.78  |
| 16              | 12.22 | 7               | 7.34  | 12              | 2.17  | 31              | 1.78  |
| 68              | 11.87 | 4               | 7.29  | 58              | 1.91  | 19              | 1.77  |
| 64              | 11.78 | 3               | 7.23  | 9               | 1.90  |                 |       |
| 69              | 11.67 | 6               | 7.21  | 33              | 1.90  |                 |       |
| 66              | 11.66 | 25              | 6.82  | 1               | 1.88  |                 |       |

### Table 3.12 Classification of Each Working Element into Work Station Using LCR

| Attempt | WS I       | WS II      | WS III     | WS IV      | WS V       | WS VI      |
|---------|------------|------------|------------|------------|------------|------------|
| 1       | 14-13-16-65-11-12-2-8-7-4-3-15-12-9-1-10-5 | 30-29-32-25-18-26-20-24-17-22-28-27-23-31-19 | 42-41-44-62-34-6-36-37-38-33-43-35-39-40 | 57-56-59-48-21-47-51-50-46-52-58-54-53-49-45-55 | 70-60-72-68-64-69-66-67-74-63-61 | 75-76-77-73-71 |
| Less < 3,5 | 3.61 min   | 3.63 min   | 3.62 min   | 3.66 min   | 3.43 min   | 4.51 min   |
| 2       | 14-13-16-65-11-2-25-7-4-3-15-12-9-1-10-5 | 30-29-32-18-26-20-24-36-17-22-28-27-23-31-19 | 42-41-44-62-34-6-8-47-38-33-43-35-39-40 | 57-56-59-48-37-21-51-50-46-52-58-54-53-49-45-55 | 70-60-72-68-64-69-66-67-63-61-73 | 75-76-77-74-71 |
| Less > 3,5 | 3.6 Min    | 3.62 Min   | 3.52 Min   | 3.67 Min   | 3.4 Min    | 4.53 Min   |

##
Efficiency
\[
\begin{align*}
EL_1 &= \frac{T_{wc}}{n \times T_c} \times 100\% = \frac{22.45}{6 \times 4.51} \times 100\% = 82.96\%
\end{align*}
\]
\[
\begin{align*}
EL_2 &= \frac{T_{wc}}{n \times T_c} \times 100\% = \frac{22.45}{6 \times 4.53} \times 100\% = 82.60\%
\end{align*}
\]
Balance Delay
\[
\begin{align*}
BD_1 &= \frac{n \times T_c - T_{wc}}{n \times T_c} \times 100\% = \frac{6 \times 4.51 - 22.45}{6 \times 4.51} \times 100\% = 17.04\%
\end{align*}
\]
\[
\begin{align*}
BD_2 &= \frac{n \times T_c - T_{wc}}{n \times T_c} \times 100\% = \frac{6 \times 4.53 - 22.45}{6 \times 4.53} \times 100\% = 17.40\%
\end{align*}
\]
Idle Time
\[
\begin{align*}
IT_1 &= ((n \times T_c) - T_{wc}) = ((6 \times 4.51) - 22.45) = 4.61 \text{ min}
\end{align*}
\]
\[
\begin{align*}
IT_2 &= ((n \times T_c) - T_{wc}) = ((6 \times 4.53) - 22.45) = 4.73 \text{ min}
\end{align*}
\]
Classification of each working element into work station should consider precedence constraint and takt time that has been set. It means beside giving priority to working element that has longest work time, there should not be working element that precede previous possible process.

4. Analysis

4.1 Comparison Line Balancing Methods

According to previous research done by Purnamasari (2015) using RPW helped to increase efficiency up to 50%, reduce balance delay up to 12%. In her case study showed that impacted to production output which increased 37 ton/month, from 400 ton/month to 437 ton/month. Ghutukade & Suresh (2013) emphasized with the help of RPW synchronized the overall work station.

This research also shows the same result. RPW and LCR indeed helped to rearrange the working element into better sequence therefore accelerate the process of finishing the product. In the table 4.2 shows comparison of three main indicators which is line efficiency, balance delay, and idle time between existing condition and improvement the production line using RPW and LCR Method.

| Table 4.1 Existing Condition |
|-------------------------------|
| Method | Criteria   | Result |
|-------|------------|--------|
| Existing Condition | Line Efficiency | 75.13% |
|       | Balance Delay | 24.87% |
|       | Idle Time (min) | 7.43 |

| Table 4.2 Comparison between RPW & LCR |
|--------------------------------------|
| Method                      | Criteria        | Attempt 1 | Attempt 2 |
|-----------------------------|-----------------|-----------|-----------|
| Ranked Positional Weight (RPW) | Line Efficiency | 85.63%    | 79.95%    |
|                             | Balance Delay   | 14.37%    | 20.05%    |
|                             | Idle Time (min) | 3.77      | 5.63      |
| Largest Candidate Rules (LCR) | Line Efficiency | 82.96%    | 82.60%    |
|                             | Balance Delay   | 17.04%    | 17.40%    |
|                             | Idle Time (min) | 4.61      | 4.73      |
From the comparison table 4.2 it can be shown the best solution to improve the existing condition is using RPW method with result on 1st attempt. Line efficiency increases to 10.5%, balance delay reduces up to 10.5%, and idle time decreases around 3.66 min.

4.2 Calculation the overtime cost

The main aim of the research is to calculate the overtime cost before and after the improvement. This cost immediately reduces the profit of the company. The calculation is summarized in table 4.2 and table 4.3 below. The target production of the company is mentioned to be 126 pcs. After the improvement of the work station it improve up to 135 pcs/day.

| Work Days | Production/day | Production/month | Production/year |
|-----------|----------------|-----------------|-----------------|
| Before    | 22             | 126 pcs         | 704 pcs         | 8448 pcs       |
| After     | 22             | 135 pcs         | 748 pcs         | 8976 pcs       |

Table 4.3 Production target changes before-after the implementation of RPW

| Hours/year | Total Cost/year |
|------------|-----------------|
| Before     | 528 Hour Rp. 69.696.000 |
| After      | 497 Hour Rp. 65.604.000 |

Therefore By arranging working element in existing condition of work station using RPW is proven to reduce overtime by 31 hours which cost Rp. 4.092.000

5. Conclusion

Overtime is one indicator shows that something is going on in production line. Production Line might not work properly so daily production target cannot be fulfilled. In PT Metindo Era Sakti, there are always be a time where overtime happened, and the company want to reduce it lost by overtime. Overtime often happened on line of Beam Comp Stering hanger production. By Using Line balancing method so called Rank Positional Weight helped to rearrange working element of each workstation. Before the implementation of RPW, time to finish in each work station is unbalance therefore resulting certain idle time in certain WS. However, after implementation, efficiency increased 10.5%, Balance delay decreased 10.5%. This reduction effected to reduced overtime almost 31 hours which cost Rp. 4.092.000. If this reduction can be done for another production line, more impact on increasing total profit. This opportunity surely benefited to company.

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