IOP Conf. Series: Materials Science and Engineering **453** (2018) 012049 doi:10.1088/1757-899X/453/1/012049

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%.

Unbalance production line also a big problem to PT. Metindo Era Sakti. Metindo Era Sakti is a company that produce component of automotive under Astra *Otopart 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.

Tabel 1.1. Demand of HPM recorded from October 2016 – January 2017 (Unit)

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

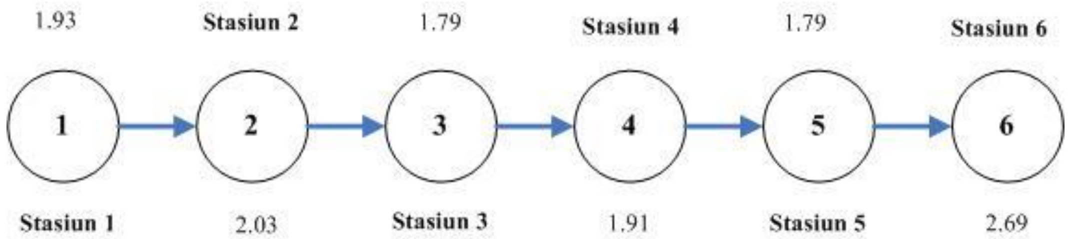

Fig. 1.1 Material flow and processing time in each WS

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.
   Weight (RPW) = Operation $time_x$ + Operation $time_{x+1}$
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 substract 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

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9. Define the indicator needed to chooses the best solution
10. Compare Line Balancing Method calculation result

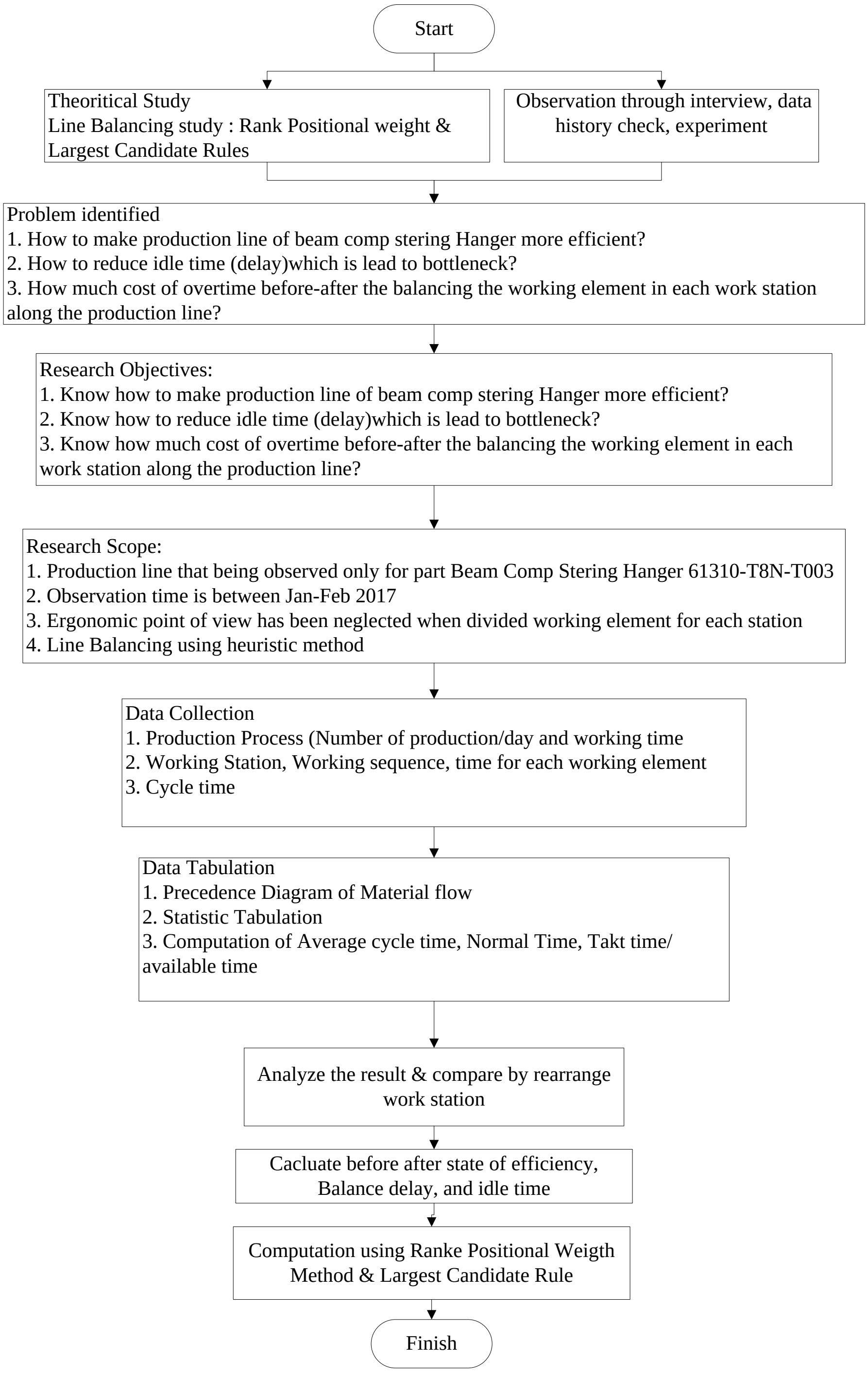

Fig. 2.1 Research Sequence

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.

Table 3.1 List of Working Element in Current State at each Work Station

Work Station	**No.**	Working Element	Number of Operator
***Main Assy* 1**	1	Push Button *puss bottom* 1	1
	2	Take *part* (SAS-1A then *sett*. 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 *puss 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 *puss bottom* 3	
	10	Press button *puss bottom* 4	
	11	Take *part* (61312-T8N-T000-H1) Then *sett.* on Jig Assy	
	12	Press button *puss bottom* 5, 6, & 7	
	13	Hit *part* uses rubber hammer to *fix position*	
	14	Do process *Assy Welding* as 20 *Portion* with pushing puss bottom button with two hands	
	15	Press button *puss bottom "UNCLAMP"*	
	16	Take out *part* from *Jig* and put it on *sutter part*	
Work Station	**No.**	**Working Element**	**Number of Operator**
***Main Assy* 2**	17	Take *part* (SAS-2A) then *sett*. on *Jig Assy*	1
	18	Take *part* (SAS-6) Then *sett*. on *Jig Assy*	
	19	Press button *puss 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 *puss bottom* 2	
	23	Press button *puss 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 *puss bottom* 4	
	28	Press button *puss bottom* 5	
	29	Hit *part* uses rubber hammer	
	30	Do process *Assy Welding* as many as 31 *portion* with pushing button *puss bottom* with two hands	
	31	Press button *puss 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 *puss bottom* 1	
	34	Take *part* (*MAIN ASSY* 2) then *sett.* on *Jig Assy*	
	35	Press button *puss 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*	

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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 I 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:

Table 3.2 Working Time Data Collection based on Observation

No.	**Work Station**	**Work Time (in Second)**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
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	*Checking*	161.0	161.5	161.7	161.6	161.3	161.7	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.

$$Ws = \frac{\sum Xi}{n} \quad (1)$$

Where:

Ws = Cycle Time
Xi = Data Measure
n = Times Collected daa

Table 3.3 Cycle Time Result

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	Working Time (minute)					
	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
Environmen (*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:

$$Wn = Ws \times P \qquad (2)$$

Where:
Wn: Normal Time
Ws: 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.

$$Wb = Wn + (1 + i) \quad (3)$$

Keterangan:

Ws = Average Cycle Time

Wn = Normal Time
Wb = Standard Time
P = Adjustment Factor
%Allowance = %Allowance

After defining average cycle time, adjustment factor, and allowance, therefore standard time of come beam stering 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:

$$Efficiency = \frac{Total\ time}{N\ x\ TT\ max}\ x\ 100\% \quad (4)$$

Where:
N = Number of WS
$TTmax$ = Largest standard time
Therefore : = $\frac{22.45}{6\ x\ 4.98}$ x100% = 75,13%

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

$$D = \frac{(N\ .\ S_m) - \sum_{i=1}^{n} S_i}{(N\ .\ S_m)} x100\% \quad (5)$$

D = *Balance Delay*
N = Number of WS
S_m = Largest time in WS

Therefore: $\frac{6\ x\ 4.98 - 22.45}{6\ x\ 4.98}$ x 100% = 24,87%

Defining Idle Time

Idle time is difference between cycle time and working time of Work station. Idle time can be calculated with the equation below:

$$Idle\ Time = ((N\ x\ Tc\ ) - Twc) \quad (6)$$

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

Therefore: $d = ((n\ x\ Tc) - Twc) = 6\ x\ 4.98 - 22.45$ = 7.43 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:

$$Takt\ Time = \frac{480\ Min}{126\ unit/day} = 3{,}8 \text{ min/unit}$$

Takt Time of *Beam Comp Stering Hanger* production is 3,8 menit 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:

$$Takt\ Time = \frac{480\ menit}{135\ unit/hari} = 3{,}5 \text{ menit/unit}$$

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.

Table 3.8 Weighted Result of Each Working Element Using RPW

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

18	6.79	1124.47	43	1.88	715.12	72	18.32	361.54
19	1.77	1117.68	44	17.9	713.24	73	8.18	343.22
20	6.49	1115.91	45	1.80	695.34	74	9.58	335.04
22	1.86	1109.42	46	5.37	693.54	70	63.22	325.46
23	1.82	1107.56	47	5.50	688.17	71	6.04	262.24
24	6.45	1105.74	48	9.27	682.67	75	207.65	256.2
25	6.82	1099.29	49	1.82	673.4	76	38.03	48.55
26	6.61	1092.47	50	5.42	671.58	77	10.52	10.52
27	1.84	1085.86	51	5.50	666.16			

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	3,6 min	3,64 min	3,64 min	3,63 min	3,56	4,37
2	1-2-3-4-24-5-65-7-18-9-10-17-12-13-14-15-16	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	45-46-47-48-49-50-51-37-53-54-55-56-57-58-59	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

$$EL_1 = \frac{Twc}{n\ x\ Tc}\ x\ 100\% = \frac{22.45}{6\ x\ 4.37}\ x\ 100\% = 85.63\%.$$

$$EL_2 = \frac{Twc}{n\ x\ Tc}\ x\ 100\% = \frac{22.45}{6\ x\ 4.68}\ x\ 100\% = 79.95\%.$$

Balance Delay

$$BD_1 = \frac{n\ x\ Tc - Twc}{n\ x\ Tc}\ x\ 100\% = \frac{6\ x\ 4.37 - 22.45}{6\ x\ 4.37}\ x\ 100\% = 14.37\%$$

$$BD_2 = \frac{n\ x\ Tc - Twc}{n\ x\ Tc}\ x\ 100\% = \frac{6\ x\ 4.68 - 22.45}{6\ x\ 4.68}\ x\ 100\% = 20.05\%$$

Idle Time

$$IT_1 = ((n\ x\ Tc) - Twc) = ((6\ x\ 4.37) - 22.45) = 3.77\ min$$

$$IT_2 = ((n\ x\ Tc) - Twc) = ((6\ x\ 4.68) - 22.45) = 5.63\ min$$

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

38	37	37	5.73
39	38	38	1.82
40	39	39	1.79
41	40	40	25.44
Working Element	**Number of *Predecessor***	***Predecessor***	**Time**
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	14-13-16-65-11-2-8-7-4-3-15-12-9-1-10-5	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

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Efficiency

$EL_1 = \frac{Twc}{n \ x \ Tc} \ x \ 100\% = \frac{22.45}{6 \ x \ 4.51} \ x \ 100\% = 82.96\%.$

$EL_2 = \frac{Twc}{n \ x \ Tc} \ x \ 100\% = \frac{22.45}{6 \ x \ 4.53} \ x \ 100\% = 82.60\%.$

Balance Delay

$BD_1 = \frac{n \ x \ Tc - Twc}{n \ x \ Tc} \ x \ 100\% = \frac{6 \ x \ 4.51 - 22.45}{6 \ x \ 4.51} \ x \ 100\% = 17.04\%$

$BD_2 = \frac{n \ x \ Tc - Twc}{n \ x \ Tc} \ x \ 100\% = \frac{6 \ x \ 4.53 - 22.45}{6 \ x \ 4.53} \ x \ 100\% = 17.40\%$

Idle Time

$IT_1 = ((n \ x \ Tc) - Twc) = ((6 \ x \ 4.51) - 22.45) = 4.61$ min

$IT_2 = ((n \ x \ Tc) - Twc) = ((6 \ x \ 4.53) - 22.45) = 4.73$ min

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 to10,5%, 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.

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

	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 4.4 Difference Total Production Time include Overtime Before After RPW Calculation

	Hours/year	Total Cost/year
Before	528 Hour	Rp. 69.696.000
After	497 Hour	Rp. 65.604.000
Efficiency	31 Hour	Rp. 4.092.000

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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