Evaluation on Production Flow Using Line Balancing Method to Increase the Production Capacity of Spun Pile at PT. Adhi Persada Beton Plant Mojokerto - East Java

Andika Okayana
Civil Engineering Department, Faculty of Engineering Universitas Indonesia
Kampus UI, Depok, 16424, Indonesia
andika.okayana@ui.ac.id

Abstract

Infrastructure development for Gresik Smelter Project requires a substantial amount of precast spun piles. The current factory capacity of 50 piles/day does not meet the minimum project's daily needs of 80 piles/day. The current production line still shows an imbalance output on each existing work station, which caused a numerous problems such as delays, bottle necks and ineffective production flows leading to a reduction in production capacity. This study is conducted using the Line Balancing method, Process Activity Mapping and Root Cause Analysis. Using this method, you can find out the existing conditions of each work station, understand the production flows and identify waste by grouping the stages of the production process into activities that are Value Added, Non Value Added and Necessary but Non Value Added. The Takt Time value needed is 15 minutes/unit, the results of this study indicate there are 4 work stations with Station Time above Takt time and have an NVA value of 14.71%. After analyzing and improving the 5 research variables the NVA value can be reduced to 4.58% and the overall Station Time has a value under 15 minutes/unit resulting on the fulfillment the target of 80 piles/day.

Keywords
Balancing, Upgrades, Capacity, Production, Precast

1. Introduction
In Indonesia, the world of precast is currently growing rapidly. Every company is competing in developing and speeding up the construction time through precast. One thing that needs to be considered in precast production is that, it is required to be fast, précised and efficient. PT. Adhi Persada Beton is precast manufactured company where one of it's plant is located in Mojokerto, East Java. The company is currently supporting the construction of smelter for PT. Freeport Indonesia by supplying concrete Spun Pile. The minimum capacity to fulfilled this project's requirement is 80 piles/day. However, the previous record shows that the average capacity of this plant was only at <50 piles/day. Based on the above issue, Mojokerto plant faced on the potential of not being able to supply the concrete spun pile as per project's capacity requirement. In terms of timeline, there will be a potential setback from the original contract's period of 12 months to 18 months. As for the contract volume, there will be a potential reduction of values as much as 33% from the original contract's volume. To avoid these from happening, it is necessary to evaluate the production flow to observe and locate which part of the process that brings about the bottleneck that needs to be improved

1.1 Objectives
Tabel I. Capacity Comparison For Each Work Station clearly shows that the output produced by each work station has quite a significant variations. There are a few work stations with capacity below 50 unit/day whilst other work station might produced up to 170 unit/day. So it is essential to balance the capacity of each work stations using the Line Balancing method. The definition of Line Balancing according to two experts is as follows: (1) Balance is the similarity of output or yield or overall production on each sequence of production lines (Buffa Elwood 1983). (2) Line balance aims to obtain a smooth flow of production in order to gain high utility of facilities, labor and equipment through balancing work time between work stations (Herjanto 1999). This research will identify what causes this imbalance and will evaluate how to balance the production line to achieve a capacity of 80 piles/day. The concept of line balancing is aimed at minimizing total idle in the production process (Biegel 1981). In accordance to the goal of

Line balancing, namely balancing the tasks of work elements from assembly lines to work stations so as to minimize the number of work stations and the idle time on each work stations to increase production output. In balancing tasks, the time requirement per unit of product produced specified for each task so as to obtain a smooth flow of production lines in order to obtain high utility of available facilities, man power, and equipment.

Table I. Capacity Comparison For Each Work Station

Process	Capacity		
	Existing	Plan	Deviation
Cutting	67	80	-13
Heading	112	80	32
Cage Forming	87	80	7
Setting Joint Plate	95	80	15
Setting Moulding	53	80	-27
Pouring	47	80	-33
Stressing	170	80	90
Spinning (2 Unit)	90	80	10
Steam (5 Unit)	82	80	2
Demoulding	63	80	-17

2. Literature Review

Line Balancing

Line balancing defined as a group of people or machine that carried out a sequential tasks in assembling a product given to each resource in a balanced way on each production paths. Thus, high work efficiency on all respective work station can be achieved. The function of Line Balancing is to create a balanced trajectory. The main objective of trajectory balancing is to maximize the speed at each work station, so that high work efficiency is achieved (Bagaskara 2017). This study is conducted using Helgeson Bernie line balancing method or Ranked Positional Weight (RPW), This approach uses a way of summing up the time of controlled operations in a work station with certain operations which are referred to as positional weights.

According to Gaspersz (2004), there are 10 steps of solving Line Balancing problems which are: (1) Identify individual tasks of activities to be performed. (2) Determine the time for each tasks to be done. (3) Establish precedence constraints, anything related to each tasks. (4) Determine the output from the assembly line. (5) Determine the total time available to produce the output. (6) Calculating the required cycle time for example the time between the completion of the product required for the completion of the desired output within the tolerance limit of time (allowed time limit). (7) Assign tasks to workers and/or machines. (8) Determine the minimum number of work stations needed to produce the desired output. (9) Assess the effectiveness and efficiency of the solution. (10) Looking for innovations for continuous process improvement. Data processing begins with creating and compiling supporting data, namely:

Takt Time

Takt time can be defined as the time needed to produce one unit of product based on the speed of customer demand. (Wignjosoebroto, 2003). If the production time and production target have been determined, then the takt time can be generated from the quotient of production time and production target. In designing a balanced production line for a certain amount of production, the cycle time must be equal to or less than the effective working hours per day divided by the amount of production per day, which is mathematically expressed as follows:

$$Takt\ time \leq \frac{P}{Q}. \tag{1}$$

Description:
P : Effective working hours per day
Q : The number of production per day

Precedence Diagram

A graphical description of the work operation sequences, as well as dependencies of one work operation to another. The purpose is to facilitate the control and planning of the activities involved in it.

Line efficiency (LE)

Ratio of the total time at the work station divided by the cycle time multiplied by the number of work stations. Systematically are as follows:

$$LE = \frac{\sum_{i=t}^{K} \mathrm{STi}}{(K)(CT)}\ x\ 100\% \tag{2}$$

Description :
STi : Station time from station 1
K : The amount of work station
CT : Cycle time

Smoothes index (SI)

Index that shows the relative smoothness from balancing a particular assembly line. Systematically are as follows:

$$SI = \sqrt{\sum_{i=1}^{K}(STi\ max - STi)^2} \tag{3}$$

3. Methods

This research uses the case study method where according to Yin (2013), this method is the right strategy to used in research that uses how or why research questions, the little amount of time the researcher has to control the events studied, and the focus of the research is phenomena contemporary, to track contemporary events. On this method, researchers focus on the research's design and implementation. The research instruments used in this study were surveys and hystorical as well as archival analysis. Surveys were conducted to collect data through direct observation and interviews with experts. Interviews with a list of questions prepared to gain information from respondents shall be valid and reliable. Historical research was conducted by tracking backwards the certain event in the present to look for the factors that causes that specific event to occur. This method can be done through experimental study or surveys. Meanwhile, archival analysis was performed to determine the factors that influence the accuracy of conceptual cost estimation. Archival analysis is also used as a supporting element in the discussion of each research questions.

Time Study

An attempt to determine the length of time required by an operator to complete a job. (Wignjosoebroto, 1995: 340). The role of timing for a job is very essential in production systems such as incentive wage systems, work and machine scheduling, factory layout settings, budgeting and so on (Sutalaksana et al. 2006). Broadly speaking, time measurement consists of two types, namely: (1) Direct time measurement, a measurement made at the place where the work is carried out. Example: measurement using a stopwatch and work sampling. (2) Indirect time measurement, a calculation of work time without being at the place where the work is carried out. Direct observations have been conducted from the period of 11 to 16 July 2022. Cycle time data were collected by direct measurements as much as 30 times. The data adequacy was analyzed as follows:

Standard Deviation

It is the most widely used measurement for distribution. Standard deviation can be calculated using the following formula:

$$S = \sqrt{\frac{\sum \mathrm{T2}\ - (\sum \mathrm{Ti})^2 / N}{N-1}} \tag{4}$$

Distribution Uniformity

The formula used to calculate the interval value is as follows:

$$I_m = 2\ x\ t_{0.95}\ x \frac{s}{\sqrt{(N)}} \tag{5}$$

Description:
Im : Interval occurs
N : The amount of data measurement

Minimum Samples

The formula used to calculate the amount of sample needed is as follows :

$$N' = \frac{4(t^2)(s)^2}{(I)^2} \quad (6)$$

Description:
N' : The amount of sample needed
s : Standard deviation
t : The value of t price index (95%)
I : Plan intervals

4. Data Collection

Tabel 2. Resume Of Data Samples Adequacy

No	Process	Time	Summary		
			S	I	N
	Cutting				
1	PC Bar Installment	7,16	31,61	19,62	6,25
2	Cutting Bar Process	0,51	0,32	0,20	0,12
	Heading	-			
3	Cutting - Heading transport	0,82	4,90	3,04	11,08
4	Heading process	0,23	0,51	0,31	1,48
	Caging Forming	-			
5	PC Wire installment	22,55	117,63	73,02	8,74
6	Heading Installment	5,73	37,16	23,07	13,49
7	Cage forming process	4,36	14,17	8,80	3,40
	Setting Joint Plate	-			
8	Delay on OH gantry queue	24,73	238,82	148,25	29,95
9	Transporting the Forming result	1,99	9,70	6,02	7,60
10	Joint Plate installment	5,42	31,01	19,25	10,52
	Setting Moulding	-			
11	Delay on OH gantry queue	30,65	249,78	155,05	21,33
12	Transporting moulding from trolley	1,18	10,47	6,50	24,86
13	Transferring the caging of joint plate	1,28	3,97	2,46	3,03
14	Setting moulding process	11,14	28,62	17,77	2,12
15	Transferring moulding to pouring location	1,38	11,49	7,13	22,12
	Pouring	-			
16	Transporting moulding from trolley	2,02	15,37	9,54	18,57
17	Delay on BP Loading	3,80	27,50	17,07	16,82
18	Pouring process	11,12	39,88	24,76	4,13
19	Transferring moulding for closing	0,66	5,22	3,24	19,69
20	Moulding cleansing and closing	6,60	25,40	15,77	4,76
21	Moulding transferring for stressing	1,14	5,45	3,38	7,15
	Stressing	-			
22	Shifting moulding to stressing location	0,99	4,75	2,95	7,25
23	Setting the moulding to stressing machine	2,11	4,41	2,74	1,40
24	Stressing process till release	3,94	20,89	12,97	9,04
	Spinning	-			
25	Transfeering moulding from line 1 to line 2	1,45	3,87	2,40	2,28
26	Handling moulding to spinning location	1,20	7,32	4,54	11,92
27	Spinning process	13,68	59,68	37,05	6,11
28	Disposing spinning waste	2,23	13,51	8,39	11,73
29	Transferring moulding to steam tub	1,56	6,72	4,17	5,86
	Steam	-			
30	Filling the steam tub till it's full	96,51	537,54	333,68	9,96
31	Steaming tube 1	330.00			
32	Transferring moulding to demouylding area	2,45	9,71	6,03	5,02
	Demoulding	-			
33	Delay on OH gantry queue	32,74	215,15	133,55	13,87
34	Demoulding	22,13	126,38	78,45	10,48
35	Transferring product to stockyard	2,50	10,45	6,49	5,61

Based on Table 2, the resume of samples adequacy shows a value below 30. thus, the current data samples are sufficient

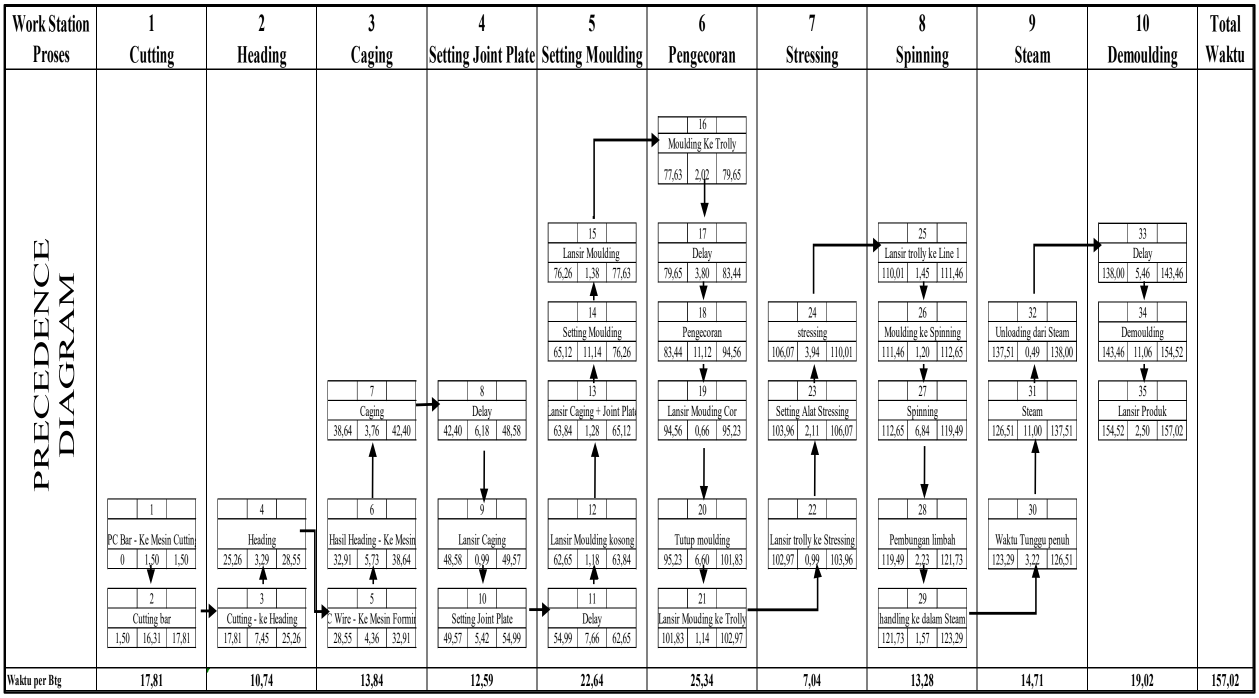

Figure 1. Precedence Diagram Line Production Spun Pile (Initial Condition)

Proses Activity Mapping (PAM)

Process Activity Mapping (PAM), one of the VALSAT tool that helps to understand the production flow and identify waste by grouping the stages of the production process into activities which are Value Added (VA), Non Value Added (NVA) dan Necessary but Non Value Added (NNVA).

Tabel 3. Process Activity Mapping (PAM) On Spun Pile Production

No	Process	Time/ Unit	Activities				
			O	T	I	S	D
1	Cutting	17,81	17,81	-	-	-	-
2	Heading	10,74	7,45	3,29	-	-	-
3	Caging Forming	13,84	13,84	-	-	-	-
4	Setting J.Plate	12,59	5,42	0,99	-	-	6,18
5	Set. Moulding	22,64	11,14	3,84	-	-	7,66
6	Pouring	25,34	17,72	3,83	-	-	3,80
7	Stressing	7,04	6,04	0,99	-	-	-
8	Spinning	13,28	9,07	4,21	-	-	-
9	Steam	14,71	14,22	0,49	-	-	-
10	Demoulding	19,02	11,06	2,50	-	-	5,46
	Total Time	157,02	113,77	20,15	-	-	23,10
	PAM		VA	NNVA		NVA	
	Percentage		72,46%	12,83%		14,71%	

Based on the table above, the current existing production line has an activity percentage of Value Added (VA) as much as 72.46%, Necessary but Non Value Added (NNVA) as much as 12.83% and Non Value Added (NVA) as much as 14.71%. This indicates there are still a considerable amount of unnecessary activities.

5. Results and Discussion

5.1 Takt Time

To achieve the production capacity of 80 piles/day, its is necessary to calculate the Takt Time value. As per SOP of PT. Adhi Persada Beton, the working hours is set to 20 hours. The takt time can be calculated as below:

P : Effective working hours : 1200 Minute / day
Q : Daily production : 80 piles / hari
Thus,

$$Takt\ time \leq \frac{1200}{80} = 15 \text{ mnt/unit}$$

Based on the calculation above, the takt time for each work station is 15 minutes/unit.

5.2 Survey Data Processing

Furthemore, to find out the current condition of spun pile production line, an analysis of the survey results is carried out using the time study method, grouping according to each work stations and compared to the takt time calculation. The collected data is then averaged with the following results:

Tabel 4. Data Comparison Of Takt Time And Station Time Of Work Station

No	Work Station	Element	Station Time (ST)	Takt Time (TT)	Deviation (ST-TT)
1	Cutting	1, 2	17,81	15,00	2,81
2	Heading	3,4	10,74	15,00	-4,26
3	Forming	5, 6,7	13,84	15,00	-1,16
4	Setting J. Plate	8,9,10	12,59	15,00	-2,41
5	Set. Moulding	11,12,13,14,15	22,64	15,00	7,64
6	Pouring	16,17,18,19,20,21	25,34	15,00	10,34
7	Stressing	22,23,24	7,04	15,00	-7,96
8	Spinning	25,26,27,28,29	13,28	15,00	-1,72
9	Steam	30,31,32	14,71	15,00	-0,29
10	Demoulding	33,34,35	19,02	15,00	4,02
	TOTAL		**157,02**	**150,00**	**-7,02**

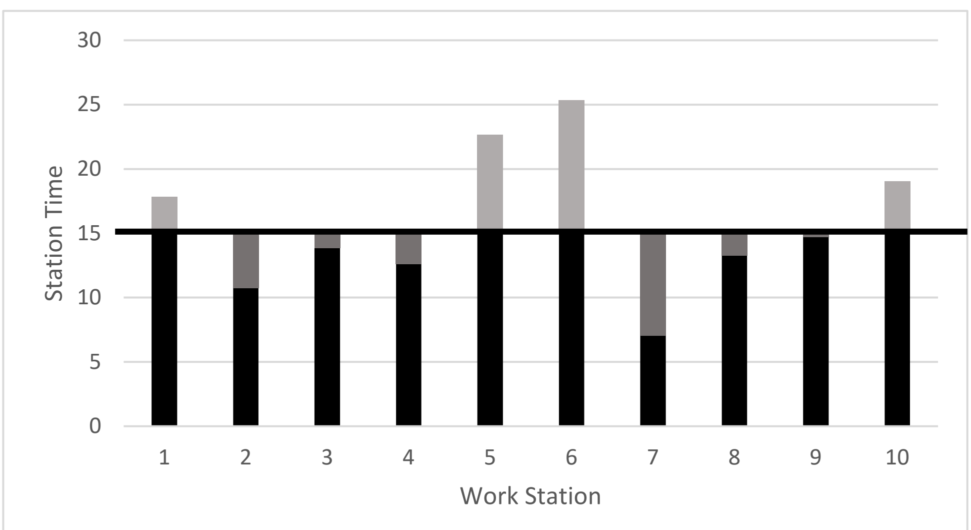

Figure 2. Graph comparison of station time and takt time

In Table IV, the comparison data of takt time and station time shows there are 4 Work Stations with ST value > dari TT value. Namely: Cutting, Setting Moulding, Pouring and Demoulding. Hencefroth, it necessary to analyze and look for the main reason on why these 4 Work Stations have Station Time (ST) values that exceed it's Takt Time values.

5.3 Root Cause Analysis (RCA)

According to Jucan (2005), RCA (Root Cause Analysis) is a methodology to identify and correcting functional causes. RCA method is very useful to analyze system failure of unexpected situation, how and why it is happening. The implementation process of RCA method is carried out direct discussion with experts and production team to find the problems suggest improvements which outlined on the fishbone diagram below:

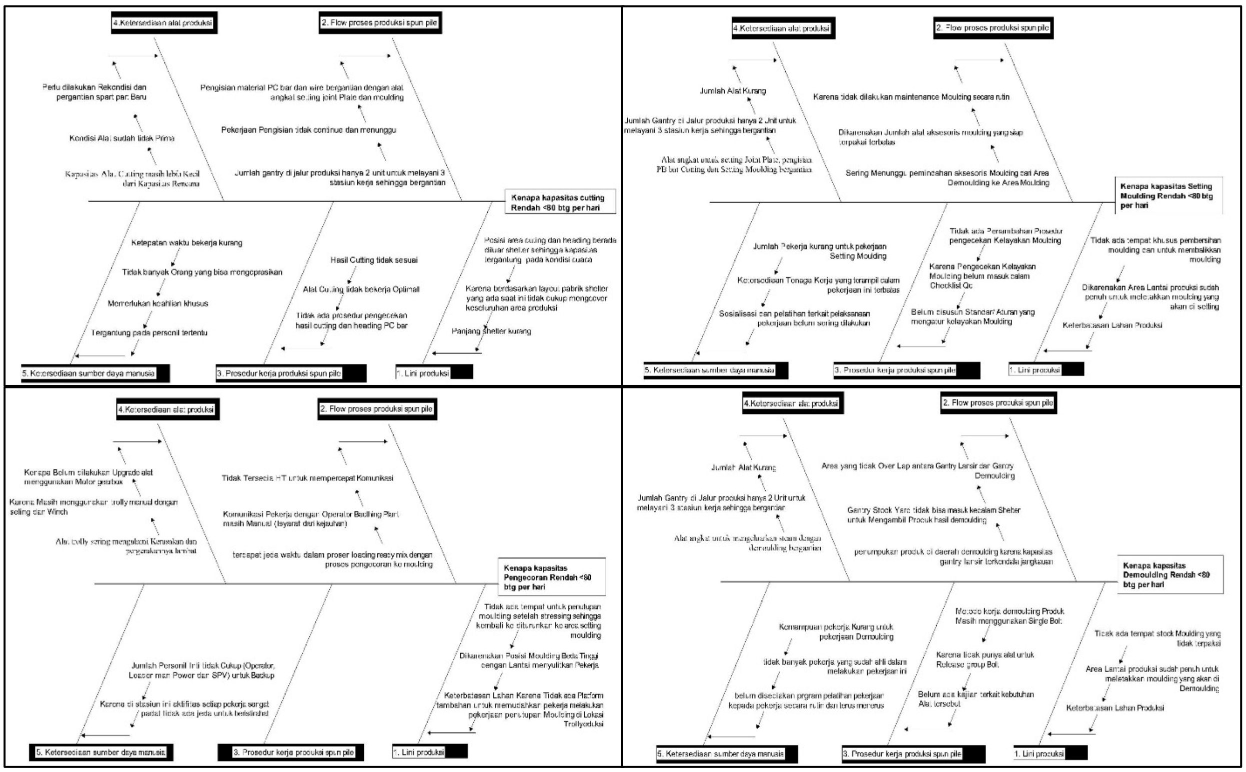

Figure 3. Fish Bone Diagram

The identification results of the problems and recommendations using Root Cause Analysis showed that for the exisiting production process for production line variable (X1), several production area were located outside the shelter (limited working area). For variable Flow (X2), there are opposite flows during spun pile production. The shortage of gantry causing several delays on prodution, the amount of unused moulding (broken or needs to be repaired) and the communication between work station which still hold manually. For Working Procedure variable (X3), several process are yet to be coverd in company's SOP. Namely, procedure for cutting process and demoulding method using single bolt. For equipment availability variable (X4) shows that the capacity of cutting machine is still above takt time, the shortage amount of portal gantr and trolleys that undergo several continues breakdown. For the availability of manpower variable (X5), the accuracy of working hours, staffing availability, insufficient number of core and backup personnel and manpower gap skills especially on demoulding process.

Based on the interviews with experts and the results of the data processing research. These are the points recommended for each variables. For (X1), there shall be an additional shelter or additional working area, relayout on moulding arrangement and additional moulding closing platforms. For (X2), there shall be a new gantry addition, a periodic moulding repair, providing handy talky or other communication device and additional trolley or trailer. For (X3), develop a new SOP for cutting process, mouldng checking and demoulding release procedure. For (X4), it is necessary to upgrade the cutting machine, adding new gantry and modified the trolleys. For (X5), to socialized the rules of working hours, introducing rewards and punishment system, coaching and training, and adding new personnel and backups.

5.4 Condition of Production Line after Improvement

Based on the review and recommendation of the 5 variables, it is decided to add an additional lifting equipment (gantry) on Setting Moulding and Demoulding work stations to avoid potential delays and to change the production flow on the Pouring work station by reducing activities element and diverting that element through Stressing working station.:

Tabe 5. Comparison Of Station Time And Takt Time After Repair

No	Work Station	Element	Station Time (ST)	Takt Time (TT)	Deviation (CT-TT)
1	Cutting	1, 2	14,55	15,00	-0,45
2	Heading	3,4	10,74	15,00	-4,26
3	Forming		13,84	15,00	-1,16
4	Setting J. Plate	8,9,10	12,59	15,00	-2,41
5	Setting Moulding	11,12,13,14	14,98	15,00	-0,02
6	Pouring	15,16,17	14,13	15,00	-0,87
7	Stressing	18,19,20	12,64	15,00	-2,36
8	Spinning	21,22,23,24,25	13,28	15,00	-1,72
9	Steam	26,27,28	14,71	15,00	-0,29
10	Demoulding	29,30	13,56	15,00	-1,44
	TOTAL		**135,03**	**150,00**	**-14,98**

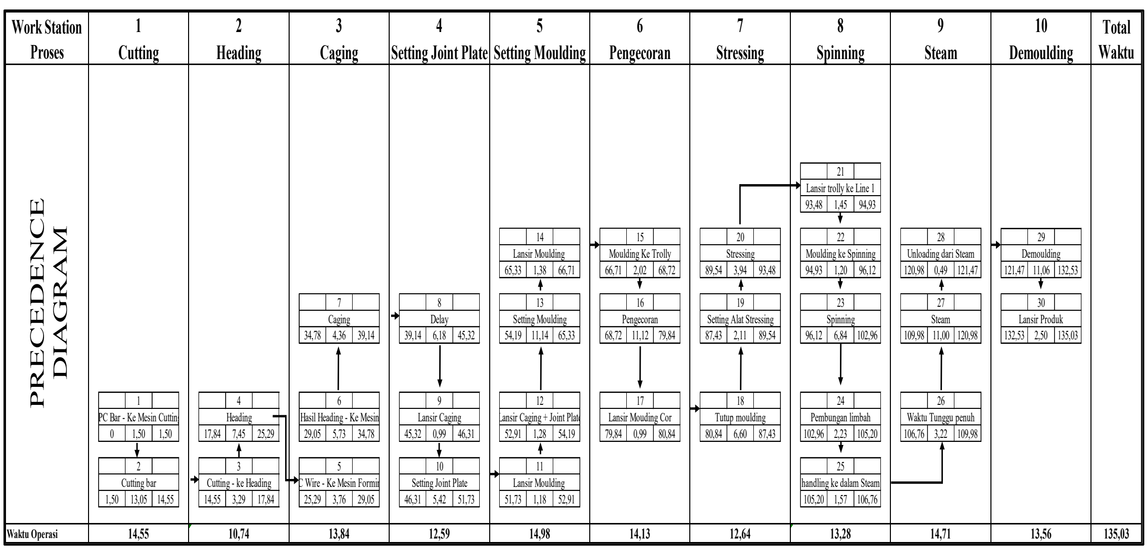

Figure 4. Precedence Diagram Line Production Spun Pile (Condition After Improvement)

In Figure 4. Precedence Diagram of the Production Line Spun Pile Conditions After Improvement shows an increase in performance on the production line, namely that all work stations already have a Station Time under the specified Tatk Time, which is <15 minutes/unit. The results of the improvements are poured back into the Process Activity Mapping (PAM) to find out the conditions of the changes that have occurred as follows Based on Table VI. the production process after improvement has an activity percentage of (VA) as much as 76.68%, (NNVA) as much as 18.74% and (NVA) of 4.58%. this shows that the value of unnecessary activities is much smaller than the initial conditions

Table 6. Process Activity Mapping (PAM) Spun Pile After Improvement

No	**Process**	**Time/Unit**	**Activities**				
			O	**T**	**I**	**S**	**D**
1	Cutting	14,55	14,55	-	-	-	-
2	Heading	10,74	7,45	3,29	-	-	-
3	Caging Forming	13,84	10,09	3,76	-	-	-
4	Setting J.Plate	12,59	5,42	0,99	-	-	6,18
5	Setting Moulding	14,98	11,14	3,84	-	-	-
6	Pouring	14,13	11,12	3,01	-	-	-
7	Stressing	12,64	12,64	-	-	-	-
8	Spinning	13,28	9,07	4,21	-	-	-
9	Steam	14,71	11,00	3,71	-	-	-
10	Demoulding	13,56	11,06	2,50	-	-	-
	Total Waktu	**135,03**	**103,54**	**25,31**	**-**	**-**	**6,18**
	PAM		**VA**	**NNVA**		**NVA**	
	Prosentase		**76,68%**	**18,74%**		**4,58%**	

Tabel 7. Line Balancing Variables

No	Indicators	Unit	Existing	After	Deviation
1	Operation Time	minute/product	157,02	135,03	21,99
2	Work Station	unit	10	10	-
3	Number of Element	unit	35	30	5
4	Line Efficiency	Percent	-	90%	-
5	Smoothes Index		16,76	6,07	10,7
6	Product Output	unit/day	50	80	30

The condition after the repair is then calculated using line balancing formulas with the following results:

The estimated costs incurred to carry out the recommendations according to this research are as follows:

Table 8. Estimation Of Improvement Cost

No	**Description**	**Total Price**
1	Over Head Gantry 2 Unit	Rp 2.986.480.000,00
2	Shelter	Rp 300.000.000,00
3	Cutting Reconditioning	Rp 50.000.000,00
4	Moulding Lid Platform	Rp 25.000.000,00
5	Handy Talky	Rp 25.000.000,00
	Total (A)	**Rp 3.386.480.000,00**

In terms of investment feasibility it also shows that the recommendations given have NPV and IRR values that are feasible to work on according to the following table:

Table 9. Analysis On Investment Feasibility

URAIAN			**TOTAL**	**2022**	**2022**	**2023**
Revenue	*100,0%*		66.161.838.600		13.232.367.720	52.929.470.880
COSG	*-90,0%*		(59.545.654.740)		(11.909.130.948)	(47.636.523.792)
Depreciation	*-5,1%*		(3.386.480.000)		(615.723.636)	(2.770.756.364)
Interest	*-0,6%*		(372.512.800)	(372.512.800)		
Earning Before Tax (EBT)	4,32%		2.857.191.060	(372.512.800)	707.513.136	2.522.190.724
CASH FLOW						
Earning After Tax (EAT)			2.857.191.060	(372.512.800)	707.513.136	2.522.190.724
Depreciation (+)			3.386.480.000		615.723.636	2.770.756.364
Capital Expenditure (Capex)			(3.386.480.000)	(3.386.480.000)		
NET CASH FLOW	4,32%		2.857.191.060	(3.758.992.800)	1.323.236.772	5.292.947.088

PRESENT VALUE				(3.758.992.800)	1.323.236.772	4.768.420.800
NPV > 0			**2.332.664.772**	**Feasible**		
IRR > WACC + 3%			**37,56%**	**Feasible**		
PI > 1			**2**	**Feasible**		
PP < Investment Age (Year)			**1,5**	**Feasible**		

6. Conclusion

The results of observation and data processing using the line balancing method show that there are currently 4 work stations on existing production process with station time exceeding 15 minutes/unit Takt Time, namely cutting, setting molding, casting and demoulding. Results from PAM and RCA analysis showed that the existing production line has a total operating time of 157.02 minutes, the value of activity time that has no added value (NVA)/delay is 17.71% due to problems with the 5 observed variables.

The recommendations given were able to make the overall station time goes below the takt time of <15 minutes/unit, operating time to 135.03 minutes and reducing the NVA value to 4.58%. The results of the Line Efficiency (LE) calculation are 90.02% and the Smooth index (SI) value is 6.07. Thus, according to the calculation of production capacity, it is capable of producing a capacity of 80 piles/day as per planned output. The results of the Investment Feasibility Analysis also show that the improvement is feasible.

References

Herjanto, E., Manajemen Produksi&Operasi. Jakarta: Grasindo,1999.
Biegel, John E.; Production Control: A Quantitative Approach; 2nd Edition, 1981
Bagaskara, D., "Line Balancing Aggregate Line Di PT. Mercedes-Benz Indonesia Divisi Assembly Commercial Vehicle Department Tipe OH1526." Universitas Mercu Buana,2017
Gaspersz, V., Production Planning and Inventory Control, Cetakan Keempat. Jakarta: PT. Gramedia Pustaka Utama,2004
Sutalaksana, I. Z., Anggawisastra, R., & Tjakraatmadja, J. H. (2006). Teknik perancangan sistem kerja. Bandung: ITB Bandung.
Wignjosoebroto, S. (1995). Ergonomi, Studi Gerak Dan Waktu. Teknik Analisis Untuk Peningkatan Produktivitas kerja, Edisi Pertama. Jakarta: PT. Guna Widya
Wignjosoebroto, S., Pengantar Teknik dan Manajemen Industri. Surabaya: PT. Guna Widya,2003
Yin, R. K., Case study research: Design and methods (4th Ed.). Canadian Journal of Action Research, 69-71,2013

Andika Okayana is a Master student in the Civil Engineering Department, Universitas Indonesia, Depok, Indonesia. He completed his bachelor in Civil Engineering Department, state Gadjah Mada University (UGM), Yogyakarta, Indonesia. Currently he is working at PT Adhi Karya (persero) Tbk, as Regional Coordinator. His research is currently being carried out in one of the factories where he works for the completion of a Masters Degree