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Line Balancing Analysis Using Ranked Positional Weight and Region Approach Methods on Broad Plate Production Line

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Abstract

PT. Risa Implantama is a company engaged in the production of bone implants that focuses on the production of bone pins and screws. This company produces bone pins with various types and then markets the production results through distributors and also produces goods according to incoming orders, both from distributors and hospitals. Rapid advances in medical science and technology have significantly improved the quality and longevity of human life. The field of orthopedics in the world of medicine has also experienced technological advances in dealing with various cases in its field, one of which is bone fractures. Based on initial calculations, the line efficiency was 51.07%, then the balance delay was 48.93% and the idle time was 1.90 minutes. After processing the data using the ranked positional weight method for the line efficiency of the broad plate production process, the line efficiency results were 64.42%, then the balance delay was 35.58% and the idle time was 14.64 minutes. Furthermore, after data processing using the region approach method for the line efficiency of the broad plate production process, the line efficiency results were 54.47%, then for the balance delay of 45.53% and idle time of 14.64 minutes. Based on the calculation results, the Ranked Positional Weight (RPW) method is the optimal method in solving line balancing, because it has the highest Line Efficiency (LE) value and the lowest Balance Delay (BD).

Introduction

Manufacturing is a word derived from Latin, namely manus factus which means made by hand Sinulingga, 2009). In accordance with the definition of manufacturing, the science of manufacturing engineering studies the design of manufactured products and the design of their manufacturing processes and the management of their production systems (manufacturing systems) (Supriyanto, 2020; Hitomi, 2017; Eyers & Potter, 2017). According to Hidayat (2019) the word production comes from the word production, which in general can be interpreted as making or producing goods from various materials. Structural elements consist of: materials, labor, machinery and equipment, capital, energy and information. While functional elements consist of: supervision, planning, control and leadership related to organization and management (Suhardi, 2008; Nindie, 2022; Hammer et al., 2021).

In calculating and determining standard time, a bottom-up approach is taken, starting with measuring the basic time of a work element, then adjusting it to the work tempo (performance rating) and adding allowances such as relaxing, personal needs and anticipating delays (Wignjosoebroto, 2003). According to Saputra (2021), the measurement of downtime is the measurement of working time (active) using a stopwatch as the main tool. Sari (2020) stated

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that measuring time with a stopwatch (Stopwatch Time Study) is applied to both short-term work and repetitive work. The time required to carry out work elements generally varies slightly from cycle to cycle, even though some operators work at normal and uniform speeds for each element in different cycles (Pianda, 2018). According to Nasution in Cahyana (2015), cycle time is the time required to produce a product. Normal time aims to obtain time with average capability under reasonable conditions (Putra & Jakaria, 2020). Normal time is obtained by multiplying the cycle time of each operation by the existing allowance (Rachman et al., 2013; Kusuma & Firdaus, 2019). According to Cahyawati (2019) Performance Rating is a comparison of the operator's actual performance with a concept that has been defined in normal performance conditions. Allowance adjustment factors are divided into: allowance for personal needs, allowance to eliminate fatigue and allowance for obstacles. Takt Time (TT) is the time available to produce a good or service divided by the number of goods or services requested by customers within that time period (Luciano et al., 2021; Soliman, 2023; Bebersdorf & Huchzermeier, 2022).

According to Gaspersz (2004), Line balancing can be defined as balancing several work elements from an assembly line to work stations to streamline imbalances between machines or workers with the aim that the desired output can be met from the assembly line.The purpose of implementing line balancing in the production process is a balanced load on each work station with the desired production speed, the work station load is measured by the amount of time, the reduction in the number of work stations (Boysen et al., 2008; Asih, 2021; Prabowo, 2016; Widyasari, 2023).

The Ranked Positioned Weight (RPW) method can also be called the Helgeson-Birnie method (Tarigan & Ambarita, 2018; Achmadi et al., 2023). This method was developed in 1961 by Helgeson and Birnie at General Electric. The weight value of the ranking position is determined in each operation. The procedure is implemented to assign operations to work stations (Chang et al., 2022). According to Moonti (2022) the Region Approach (RA) method or regional approach method was developed by Bedworth and this method divides the precedence diagram into several regions vertically, and each region has no dependency between work operations (Aji & Widjajati, 2024).

PT. Risa Implantama has been established since December 17, 1993 with the vision and mission of fulfilling and developing domestic orthopedic implants and developing the potential of the nation itself to be able to compete competitively with foreign implant products. PT. Risa Implantama is a company engaged in the production of bone implants that focuses on the production of pens and screws for bones.

Methods

A quantitative experimental design has been used at PT Risa Implantama to conduct research that analyzes line balancing in broad plate production. Risa Implantama. The study evaluates the Ranked Positional Weight (RPW) and Region Approach (RA) line balancing techniques to identify the optimal approach for maximizing production efficiency while reducing balance delay problems. The study took place at PT. Risa Implantama. Risa Implantama operates in Jalan Medokan Sawah Timur No. 41, Surabaya 60295 throughout three months beginning August 2024 and ending in October 2024. The research gathered and studied data about production activities through its investigation of the broad plate production line in the division.

Various vital elements form the basis of the research analysis. Line efficiency and balance delay functions as the dependent factors to evaluate production line performance. The process efficiency depends on three independent elements: production capacity together with work element data and time data for all work elements. The researchers used different methods to achieve total data collection. Direct observations served to record the work sequencing along

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with cycle times along with operational limitations. Workflow challenges together with machine utilization methods were discovered through structured interviews conducted with supervisors and production workers. The Westinghouse performance rating method normalized the stopwatch-based time study results for determining standard work element timings. A review of production records was performed to track both monthly and annual production targets and monitor their performance trends.

The researcher uses systematic analytical steps based on the RPW and RA methods throughout the data evaluation process. During the pre-analysis phase the work elements received their relevant sequences through a precedence diagram. The measured cycle times of work elements served as input to calculate standard time through normal time adjustments with fatigue and other variable allowance factors. A precedence diagram served to accomplish implementation of the Ranked Positional Weight (RPW) methodology. A calculation of Ranked Positional Weight for each work element followed by descending innovative sorting process. The elements received their workstation assignments according to a plan which both reduced unnecessary waiting time and maintained a good performance balance. The line efficiency calculation used Total Work Content divided by Number of Workstations multiplied by Cycle Time and then multiplied by 100 while balance delay equalled 100% minus line efficiency. The computable metrics included Balance Delay (calculated as 100% - LE) alongside Idle Time (equal to (Number of Workstations × Cycle Time) - Total Work Content).

A precedence diagram served as the basis to execute the Region Approach (RA) method and determine work element dependencies. Independent work elements were established through region division on the diagram layout. The work elements allocation for workstations happened through a regional-based distribution system. The assessment of efficiency relied on calculations of line efficiency together with balance delay and idle time metrics in a way similar to RPW.

Multiple observation trials were conducted under different circumstances to validate the time study results. Computational checks occurred using software tools to confirm exactness when evaluating the performance of RPW and RA methods. Enforcement of ethical principles secured both the confidentiality of company data and the required approvals from PT during this research. The researcher collected data and interviewed staff members at the facility of PT Risa Implantama.

Results and Discussion

In conducting this research, some data are needed to support the solution of problems in line balancing. The data obtained are based on interviews with supervisors and workers in the field. The data required are data on the amount of production, work elements, time data for each work element, cycle time for each work element, and precedence diagram data. At PT. Risa Implantama, there are several products produced, namely:

Table 1.Company Production Data

Item Type	**Target**	**Demand**	**Production Quantity/Month**	**Production Quantity/Year**	**Percentage**
Semi *Tubular Plate*	1.550	1.500	90	1.080	69,6%
Narrow Plate	1.850	1.800	106	1.272	68,7%
Broad Plate	2.500	2.100	130	1.560	62,4%
Totally	**5.900**	**5.400**	**326**	**3.912**	

Source: Data Processing

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Table 2. Production Pprocess Time Data and Predecessor Operations

Work Station	Number	Process	Observation Time (Minutes)	Preliminary Task
Station 1	1	Wire Cutting	3 minute	-
	2	Hydraulic Press	2 minute 12 second	1
Station 2	3	Scrap Side Plate (Scrap Side Machine)	2 minute 42 second	2
	4	Slope Hole Milling	2 minute 30 second	3
Station 3	5	Finishing		
	A	Buffing	1 minute 54 second	4
	B	Surface Grinding	2 minute 12 second	A
	C	Hole Filing	1 minute 54 second	B
	D	Hole Polishing	1 minute 42 second	C
	E	Surface Polishing	8 minute 42 second	D
Station 4	6	Plate Cleaning (Manual) and QC	2 minute 42 second	E
	7	Plate Marking	2 minute 12 second	6
	8	Packing & Labeling	1,8 minute	7

Source: Data Processing

In the table above, the finishing process that takes too long causes a bottleneck, because if this manual milling machine is damaged, the production process will also stop. This is the reason why the production volume does not meet the company's target.

To find out the normal time, the adjustment factor value (p) must first be determined. This aims to normalize the working time obtained from employee work measurements when observed due to employee work speed, skill level, environment and others that change.

Table 3. Adjustment Factor Provisions

Factors	Class	Symbol	Adjustment
Skills	Good	C1	+0,06
Effort	Excelent	B1	+0,10
Working Conditions	Excelently	B	+0,04
Consistency	Excelent	B	+0,03
Totally			+0,23
Working Under Normal Conditions			+1,00
Adjustment Factors			+1,23

Source: Data Processing

From the table above, it is known that the P value with the Westinghouse method is 1.23 with details of 0.06 + 0.10 + 0.04 + 0.03 = 1.23. In calculating standard time or standard time, the allowance value must first be calculated. Allowance is the time for workers to interrupt the ongoing process due to unavoidable things. The time can be calculated by considering several aspects including the calculation of fatigue. Some allowances that are classified as fatigue are: energy expended, work attitude, work movements, eye fatigue, temperature conditions, atmospheric conditions and work environment conditions.

Table 4. Adjustment Factor Provisions

Number	Factors	Mark
1	Work Attitude : Standing for a Long Time	3%
2	Work Movement : Limited Movement	3%

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3	Eye Fatigue : Sore	4%
4	Temperature Condition : Too Hot	6%
5	Work Environment Condition : Noisy	3%
Totally		**19%**

Source: Data Processing

After knowing the value of the slack factor (P) and allowance, the next step is to calculate the normal time from the cycle time multiplied by the adjustment factor.

Table 5. Cycle Time, Normal Time and Initial Standard Time

Work Station	Number	Process	Cycle Time	Normal Time	Standard Time	Total Standard Time
Station 1	1	Wire Cutting	3	3.69	4,39	7,61
	2	Hydraulic Press	2,2	2.71	3,22	
Station 2	3	Scrap Side Plate (Scrap Side Machine)	2,7	3.32	3,95	7,61
	4	Slope Hole Milling	2,5	3.08	3,66	
Station 3	5	Finishing				24,00
	A	Buffing	1,9	2,34	2,78	
	B	Surface Grinding	2,2	2,71	3,22	
	C	Hole Filing	1,9	2,34	2,78	
	D	Hole Polishing	1,7	2,09	2,49	
	E	Surface Polishing	8,7	10,70	12,73	
Station 4	6	Plate Cleaning (Manual) and QC	2,7	3,32	3,95	9,81
	7	Plate Marking	2,20	2,71	3,22	
	8	Packing & Labeling	1,8	2,21	2,63	
Totally			**33,50**	**41,21**	**49,03**	**49,03**
Line Efficiency			**51,07%**			
Balance Delay			**48,93%**			
Idle Time			**1,90**			

Source: Data Processing

- LE $= \frac{49,03}{4 \ x \ 24} x \ 100\%$
- LE = 51,07%
- BD = 100% - 51,07% = 48,93%
- IT = n.Tc – Twc
- IT = 4 x 24,00 – 49,03
- IT = 46,97 Menit

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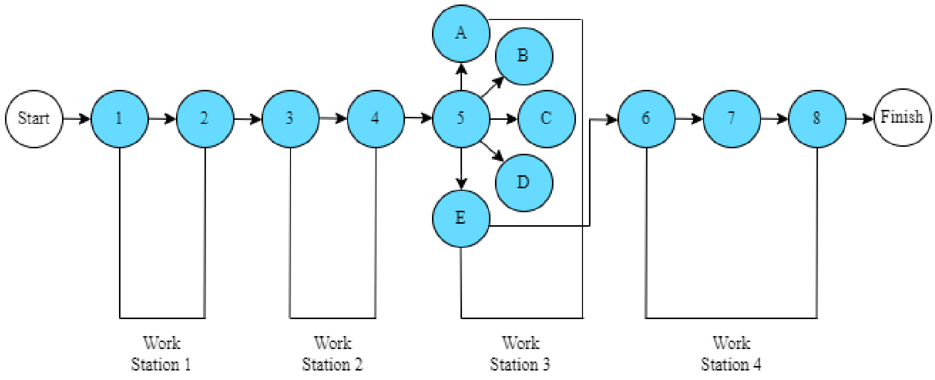

Figure 1. Initial Prcedence Diagram

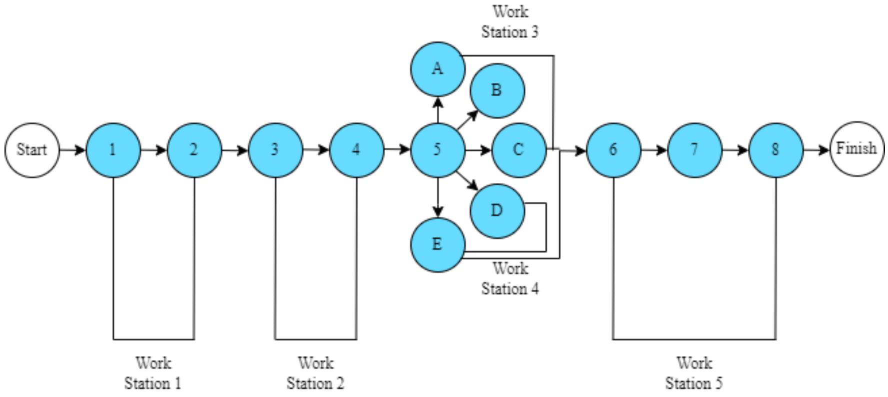

Figure 2. Prcedence Diagram RPW Method

Then there is the calculation using the Ranked Positional Weight (RPW) method. The initial step of this method is to create a precedence diagram according to the conditions in the field, then determine the position weight for each work element of an operation process, then sorted from the highest position weight value to the lowest position weight value.

Table 6. Cycle Time, Normal Time and Standard Time RPW Method

Number	Process	Standard Time	Weight	Rangking
1	Wire Cutting	4,39	49,03	1
2	Hydraulic Press	3,22	45,81	2
3	Scrap Side Plate (Scrap Side Machine)	3,95	41,86	3
4	Slope Hole Milling	3,66	38,20	4
5	Finishing			
A	Buffing	2,78	35,42	5
B	Surface Grinding	3,22	32,20	6
C	Hole Filing	2,78	29,42	7
D	Hole Polishing	2,49	26,93	8
E	Surface Polishing	12,73	14,20	9
6	Plate Cleaning (Manual) and QC	3,95	10,25	10
7	Plate Marking	3,22	7,03	11
8	Packing & Labeling	2,63	4,39	12
Totally		**49,03**		
Line Efficiency		**64,42%**		
Balance Delay		**35,58%**		
Idle Time		**14,64**		

Source: Data Processing

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$$LE = \frac{49,03}{5\ x\ 15,22}\ x\ 100\%$$

LE = 64,42%

BD = 100% - 64,42% = 35,28%

IT = n.Tc – Twc

IT = 5 x 15,22 – 49,03

IT = 27,07 Menit

In the Region Approach method, a regional approach is carried out by dividing work elements into regions or the same area for each work element that works in parallel. Therefore, a precedence diagram is needed for initial analysis before calculating the Region Approach method to determine the optimal work elements and work stations, here is a precedence diagram image :

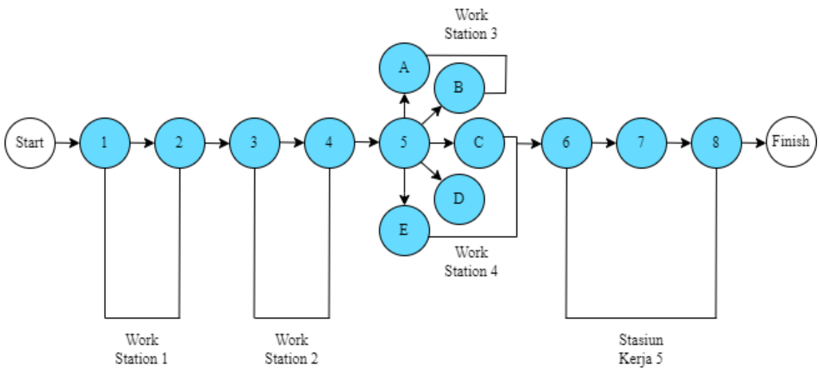

Figure 3. Prcedence Diagram RA Method

Table 7. Cycle Time, Normal Time and Standard Time RA Method

Work Station	Number	Process	Standard Time	Weight	Total Time (Minute)
Station 1	1	Wire Cutting	4,39	49,03	7,61
	2	Hydraulic Press	3,22	45,81	
Station 2	3	Scrap Side Plate (Scrap Side Machine)	3,95	41,86	7,61
	4	Slope Hole Milling	3,66	38,20	
Station 3	Finishing				
	A	Buffing	2,78	98,2	6,00
	B	Surface Grinding	3,22	35,42	
Station 4	C	Hole Filing	2,78	32,20	18,00
	D	Hole Polishing	2,49	29,42	
	E	Surface Polishing	12,73	26,93	
Station 5	6	Plate Cleaning (Manual) and QC	3,95	14,20	9,81
	7	Plate Marking	3,22	10,25	
	8	Packing & Labeling	2,63	7,03	
Totally			**49,03**		
Line Efficiency			**54,47%**		
Balance Delay			**45,53%**		
Idle Time			**14,64**		

Source: Data Processing

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$$LE = \frac{49,03}{5 \; x \; 18,00} x \; 100\%$$

LE = 54,47%

BD = 100% - 54,47% = 45,53%

IT = n.Tc – Twc

IT = 5 x 18,00 – 49,03

IT = 40,97 Menit

Conclusion

Based on data processing using two line balancing methods, namely ranked positional weight and region approach, it can be seen from the differences in the results of the broad plate production process before and after the application of the methods used. For the results of line efficiency, balance delay of the broad plate production process before data processing using the ranked positional weight and region approach methods, the line efficiency was 51.07%, then the balance delay was 48.93% and the idle time was 1.90 minutes. After data processing using the ranked positional weight method for the line efficiency of the broad plate production process, the line efficiency results were 64.42%, then for the balance delay of 35.58% and the idle time of 14.64 minutes. Furthermore, after data processing using the region approach method for the line efficiency of the broad plate production process, the line efficiency results were 54.47%, then for the balance delay of 45.53% and the idle time of 14.64 minutes. Based on the calculation results, the Ranked Positional Weight (RPW) method is the optimal method in solving line balancing, because it has the highest Line Efficiency (LE), the lowest Balance Delay (BD) and the lowest Idle Time (IT). The suggestion of this research for further data processing is to use software to help the calculation to be more valid, and to conduct research with different methods.

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