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Line Balancing Analysis Using Ranked Positional Weight and Region Approach Method in Nail Production

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Abstract

At the moment industrial development, there is open competition on a national and international scale, the manufacturing and service industry sectors are developing very quickly. To create good, quality products and efficiency, the company must have a good track balance. As is the case in nail production. CV. XYZ is a company engaged in manufacturing. This company is located in the city of Sidoarjo, East Java. The aim of this research is to improve the balance of the work station trajectory of the nail production process at CV. XYZ. The method used in this research is the Region Approach and ranked positional weight. The best method chosen for this problem is the Region Approach method, because this method has the greatest line efficiency (68.17%), the smallest balance delay (31.83%), and the smallest smoothes index (100.63), so this method was chosen as the best method and can improve line balancing conditions in the company. The increase in line efficiency from 54.68% using the company method to 68.17% using the Region Approach method can occur due to a reduction in the number of work stations from 5 work stations as well as a decrease in the number of smoothing indexes from 168.20 to 100.63. which indicates that there is an increase in balance between work stations.

Introduction

In the current industrial development, there is open competition on a national and international scale, the manufacturing and service industrial sectors are developing very rapidly. To create good, quality and efficient products, companies must have a good balance(Siregar.et al, 2017). CV. XYZ is a company engaged in manufacturing. This company is located on East Java. CV XYZ is a company that produces nails, among the types of nails produced include wooden nails, thumbtacks and concrete nails in various sizes. This company produces various types of nails, capable of producing a total of 5 - 10 tons per day according to market demand. The nail production process in this company begins with preparing the tools and materials, followed by pulling the wire from the roll which is then inserted into the nail making machine (Schlegel, 2023), the process of forming the nail head, cutting the wire nail to form a pointed tip, then the nail that has been formed comes out of the machine followed by the cleaning process and polishing, and at the final stage the nails are packed.

In the period from January to December 2023, market demand increased, but in several periods the production level was unable to meet the demand, so it was necessary to increase production efficiency by increasing the balance of the nail production line in the company (Zhang et al., 2020). In every production process activity, balance must be maintained between work stations, because in the case at CV XYZ it was found that there was a bottleneck

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at the polishing station which was the result of a jam in the previous process, namely the machining process. To achieve production efficiency, the bottleneck process must be minimized, one way is by balancing the number of operators and the speed of the existing machines. By aligning the number of operators and machines, production efficiency can increase and the quantity produced can be increased (Morgan et al., 2021).

In realizing track balancing at CV XYZ, a transformation process towards sustainability is needed which will face several obstacles that need to be eliminated or reduced. Therefore, path balance analysis is very necessary to plan and control a production process flow. This can be realized by carrying out line balancing analysis using the Regional Approach method and ranking position weights. By using this method the company can evaluate its production trajectory and improve the production trajectory with the aim of maximizing work efficiency in order to increase production output and also minimize production trajectory imbalances (Tang & Meng, 2021). The method used in this case is the Regional Approach and ranking position weights. With this analysis, it is hoped that the company can eliminate or reduce all trajectory imbalances that exist in the process in an effort to increase production at CV XYZ.

Work Measurement

Work measurement is a systematic and continuous process for assessing the success and failure of implementing activities in accordance with the programs, policies, targets and objectives that have been set in realizing the vision and mission of one organizational/work unit (Purnomo, 2004). This measurement of working time will relate to efforts to reduce the standard time needed to complete a job. Standard time is the time that is reasonably required by a normal worker to complete a job carried out in the best work system (Iftikar, 2006). According to Saputra (2021) increasing efficiency and effectiveness in a work system is absolutely related to the working time used in production. The purpose of measuring this time is to obtain various kinds of work system designs so that the best work design can be obtained. Measuring working time (Time Study) is an activity to determine the time needed by an operator or employee to complete work activities under normal conditions and tempo.

Standard Time

Sutalaksana (2006) stated that calculating standard output is the next step after measuring working time and testing the uniformity and adequacy of data in order to obtain suitability for operator productivity levels. To obtain standard output, the following steps can be taken:

Cycle Time

Cycle time is the amount of time required to complete one unit of production, starting from standard materials processed at the workplace and finishing.

$W\,cycle = \frac{\Sigma Xt}{N}$ ……………………………………………………………………..*(2.1) cycle time*

Normal Time

Normal time is defined as the completion time of work completed by workers under reasonable conditions and average ability.

$W\,normal = W\,cycle \times P$ …………………….……………………………... (2.2) *Normal time*

Standard Time

The standard is the amount of time that must be taken by workers who comply requirements to complete a specific task, working at that level sustainable, using methods, tools and equipment, raw materials, and existing workplace arrangements

$W\,standard = W\,normal \times \frac{100\%}{100\% - \%allowance}$ …………..…………………….(2.3) *standard time*

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Performance Ratting

Sutalaksana (2006) said that in making adjustments (Performance Rating) we try to normalize working time obtained from measuring employee work when observed due to changes in employee work speed, skill level, environment and so on. Adjustment factors are analyzed based on observations before the research takes place and are subjective depending on the research, but at least efforts are made to be close to reality.

Line Balancing

Line balancing is the balancing of resources given in each production line to a group of people or machines that carry out sequential tasks in assembling a product, so that high work efficiency is achieved at each work station (Mujahidulloh & Bakhtiar, 2021). Trajectory balance is a balance in the process of placing work at each work station so that it has the same cycle time and no idle time to achieve high work efficiency (Moonti et al, 2022). In the manufacturing industry, line balancing can help increase productivity, reduce production costs and improve product quality (Budi et al., 2023). Baroto (2002) stated that there are several terms commonly used in line balancing as follows:

Work Station

A location on an assembly or product manufacturing line where work is completed either manually or automatically. Minimum number of workstations K > 1.

$n\ min = \frac{\sum Te}{TT}$ ……………………………………………………………………(2.4) *work station*

***Takt Time* (TT)**

Takt Time can be defined as the maximum time allowed for producing a product to meet demand

$TT = \frac{Ta}{D}$ ……………………………………………………………………………..(2.5) *Takt Time*

Idle Time

Idle Time is the difference between station time and working station time.

$IT = (n.Tc - Twc)$ ……………………………………………………………………(2.6) *Idle Time*

Line Efficiency

Work station efficiency is the ratio of the total work station time to the relationship between cycle time and the number of work stations, expressed as a percentage.

$LE = \frac{Twc}{n.Tc} x\ 100\%$ ....(2.7) *Line Efficiency*

Balance Delay

Is a comparison between idle time and cycle time the number of work stations, or in other words the sum between balance delay and line efficiency is equal to one

$BD = \frac{n.Tc - Twc}{n.Tc} x\ 100\%$ ....(2.8) *Balance Delay*

Smoothness Index

Smoothness Index (SI) is an index that indicates how balanced a production trajectory is. The value SI = 0 is the value of perfect track balance.

$SI = \sqrt{\sum(Tsi_{Maks} - Tsi)}$ ……………………………………….(2.9) *Smoothness Index*

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Region Approach Method

The Region Approach method was introduced by Kilbridge and Webster. This method is one of the line balancing methods that has been applied successfully in solving a number of line balancing problems that occur in the manufacturing industry (Tjioewinata & Saifuddin, 2022). This method is a regional approach in production operation time sequencing techniques. The areas are the division of production operations based on the precedence diagram (Herlambang, 2021)

Rangked Positional Weight Method

Ranked Position Weight is a heuristic calculation method proposed by two leading figures, namely Helgeson and Birnie, as an approach to solving problems in line balance and finding solutions quickly. This method assigns work elements to stations optimally by taking into account the priority relationship and processing time of all work (Hapid & Supriyadi, 2021).

Methods

Research with the title " *Line Balancing Analysis Using Ranked Positional Weight (RPW) and Region Approach (RA) Method In Nail Production At CV. XYZ*" was carried out at CV.on East Java in February 2024 until completion or observation data fulfilled. There are steps that must be taken to get the desired results namely problem identification, data collection, data processing, results analysis and conclusion. The data collection stage is a way to obtain data required in data processing. Data was obtained by direct observation at field and also interviews with parties related to the company. Some of the data needed to support this research are as follows: (1) Production capacity data; (2) Available work element data; (3) Time data for each work element; (4) Production process flow diagram data.

Data processing was carried out using the *Ranked Positional Weight* and *Region Approach* methods. The Ranked Positional Weight method provides details about the balance of the production trajectory using a position weighting system in the production process, this will have an effect on increasing the efficiency of nail production in one production cycle, while the Region Approach method is a line balancing method based on work operation time sequencing techniques based on a regional approach.

Results and Discussion

The following is data on the observation time of the nail making process at CV XYZ is:

Table 1. Collection of Nail Production Data at CV.XYZ

Work element	Time (Second)										Average	Minutes
	1	2	3	4	5	6	7	8	9	10		
Transferring wirerods with forklifts	168,2	176,4	169,6	172,4	173,7	165,4	169,4	164,8	170,1	169,2	169,92	2,83
Wire drawing process	4440,4	4270,6	4262	4350,3	4280,6	4328,5	4320,4	4160,9	4530,1	4320,4	4326,42	72,11
Jagang wirerod placement	18,44	20,25	19,25	21,44	20,56	22,32	21,58	22,04	20,43	19,87	20,62	0,34
warehouse relocation	55,46	63,36	52,45	62	63,53	57,42	58,24	62,31	64,43	56,36	59,56	0,99
Wirerod weighing	53,23	51,45	56,56	47,32	55,35	53,43	55,35	53,47	52,34	49,34	52,78	0,88
wirerod removal	63,2	60,6	59,8	62,4	60,8	58,4	59,6	60,7	61,2	59,6	60,63	1,01
Wirerod insertion in the machine	30,35	32,45	32,35	31,45	28,95	29,87	30,42	31,57	30,06	29,65	30,71	0,51
Nail making process	4230	4228	4560	4328	4267	4348	4360	4260	4340	4365	4328,60	72,14
Nail storage in drum	42,25	45,38	44,2	41,28	42,54	43,62	42,54	41,28	42,87	44,35	43,03	0,72
Drum shifting	126,2	112,8	120,62	118,7	124,5	119,3	121,82	122	116,8	122,3	120,50	2,01
Drum weighing	75,3	79,2	78,4	74,9	78,7	77,89	78,5	79,3	78,8	78,4	48,83	1,30
Transfer of drums by carriage	52,46	54,48	53,48	52,49	55,68	51,8	52,38	56,12	52,8	54,3	53,60	0,89
Providing polish and wood chips	1156,2	1232,5	1142,6	1211,8	1132,4	1128,4	1214,2	1187,6	1214,5	1184,3	47,77	19,67

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Installation of drum cover nut bolts	205,4	243,2	210,6	230,2	228,2	236,1	245,2	228,9	234,2	241,2	230,32	3,84
Polishing procces	3980,2	4120,4	3876,9	4118,4	4218,2	4341,6	3864,9	3984,2	4012,8	3874,6	4039,22	67,32
Moving the drum with a forklift	124,8	138,6	142,4	135,6	140,7	138,2	142,3	134,8	126,98	132,6	135,70	2,26
Packaging and Quality Control	2168,2	2180,6	2380,2	2261,4	2314,2	2350,4	2320,2	2138,4	2241,2	2654,2	2300,90	38,35
warehouse storage	1123,2	1224,2	1322,1	1284,4	1314,8	1342,5	1278,5	1296,2	1253,2	1368,5	1280,76	21,35

Source : CV.XYZ

Precedence Diagram

The following is a precedence diagram of the nail making process.

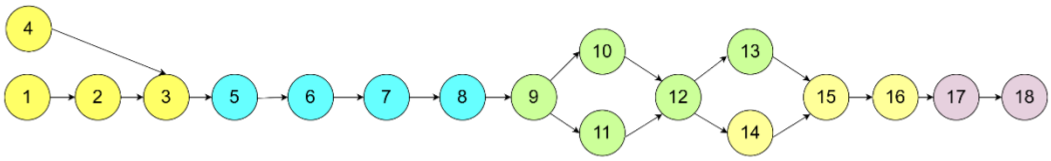

Figure 2. Precedence Diagram

Data Sufficiency Test

The following is the formula used in the data adequacy test, namely:

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\,(\Sigma x^2) - (\Sigma} \quad 2}{\Sigma x}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Data Suffienciency Test}$$

In the process of Transferring wirerods with forklifts, the n' value is obtained as follows:

$$n' = \left[\frac{\frac{2}{0{,}05}\sqrt{(10x\ 288841{,}02\ ) - (1699{,}20)^2}}{1699{,}20}\right]^{\mathbf{2}}$$

n’ = 0,626

based on these calculations can be seen that all work elements have met the assumption of data adequacy. This is because the results of calculating the actual number of observations must be taken (n’) ≤ n. So the data is said to be sufficient.

Data Uniformity Test

After testing the adequacy of the data and all the data is sufficient, then a data uniformity test can be carried out. Based on the values in table 4.2 to calculate the BKA and BKB values, the following calculations are obtained:

Average

$$\overline{X} = \frac{\Sigma x}{N} = = \frac{1699{,}20}{10} = 169{,}2$$

Standard Deviation

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N-1}} \quad = \sqrt{\frac{(168{,}2 - 169{,}92)^2 + (176{,}4 - 169{,}92)^2 + \cdots + (169{,}2 - 169{,}92)^2}{10-1}} = 3{,}54$$

Upper Control Limit (UCL) and Lower Control Limit (LCL)

BKA $= \bar{X} + k.\ \sigma$

$= 169{,}92 + (2 \text{ x } 3{,}54)$

$= 177{,}01$ second

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CL = $\bar{X}$ = 169,92 second

BKB = $\bar{X}$ - k. σ

= 169,92- (2 x 3,54)

= 162,83 second

After obtaining the results of calculations and data diversity tests, a control chart can be created for the Transferring wirerods with forklifts as follows:

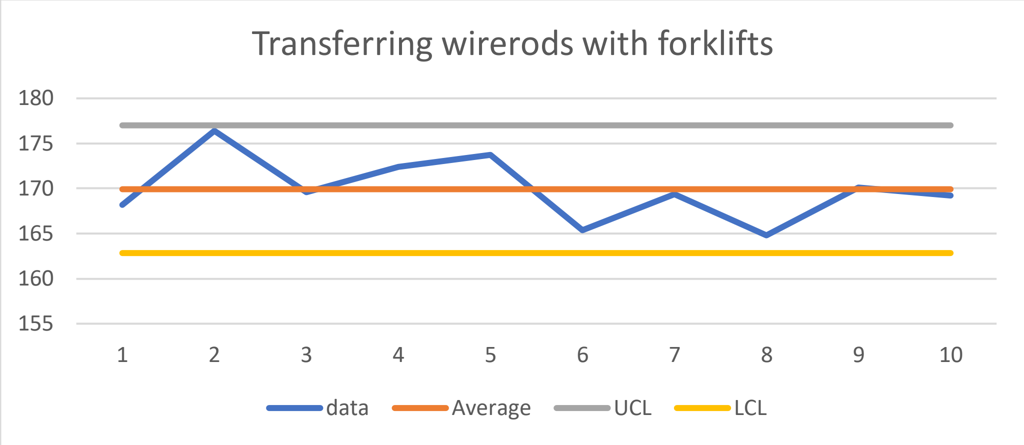

Figure 3. Control Chart of the Transferring wirerods with forklifts

Standard Time

The following is the normal time calculation for the work elements for Transferring wirerods with forklifts as follows:

Cycle Time = $\frac{\Sigma x}{N}$ = $\frac{1699,2}{10}$ = 169,92 second

Normal Time = WS x P

= 169,92 x (1 + *Performance Ratting*)

= 169,92 x (1+0,21) = 205,6 detik/unit

Standard Time = Normal Time x $\frac{100\%}{100\% - \text{allowance}\,\%}$

= 205,6 x $\frac{100\%}{100\% - 12\%}$= 232,33 second

Table 2. Standard Time

Work Element	Standard Time (Minutes)
Transferring wirerods with forklifts	3,87
Wire drawing process	98,59
Jagang wirerod placement	0,41
warehouse relocation	1,36
Wirerod weighing	1,10
wirerod removal	1,27
Wirerod insertion in the machine	0,58
Nail making process	106,79
Nail storage in drum	0,83
Drum shifting	2,52
Drum weighing	1,63
Transfer of drums by carriage	1,12

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Providing polish and wood chips	22,23
Installation of drum cover nut bolts	4,81
Polishing procces	84,44
Moving the drum with a forklift	2,84
Packaging and Quality Control	52,43
warehouse storage	29,19

Based on the results of the above calculations, it can be analyzed that the standard time is a benchmark in the standard completion in one nail production cycle at CV XYZ. Standard time is also set as standard time in comparative production efficiency in standard time has taken into account various conditions that become obstacles in production such as leeway and speed such as performance rating.

Line Balancing

Total Processing Time

Total process time is the total standard time for each work element in nail production.

Twc $= 3{,}87 + 98{,}59 + 0{,}41 + \cdots + 29{,}19$ = 416,02 minutes

Production Rate

Rp $= \frac{production\ capacity}{Operation\ Time}$

$= \frac{60}{24x7}$

= 0,36 Box 27kg/hour

Time Cycle

Tc $= \frac{60\ E}{Rp}$

$= \frac{60\ (0{,}92)}{0{,}36}$

= 154,56 minutes

Time Service

Ts $= Tc - Tr$

$= 154{,}56 - 2$

$= 152{,}56 \approx 153$ menit

Minimum Workstation

W^{min} $= (Minimum\ Integer \geq \frac{Twc}{Tc})$

$= (Minimum\ Integer \geq \frac{416{,}02}{154{,}56})$

$= 2{,}69 \approx 3\ Workstation$

Company data

The initial condition of the company is the balance condition of the production path that is currently being implemented by the company in the nail production line. The company applies work station assignments for component processing (one work station for one component processing).

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Table 3. Company in the nail production line

Company	Line Efficiency	Balance Delay	Smoothness
	54,54%	45,46%	168,2

The following is the flow of the nail production process at the CV.XYZ company:

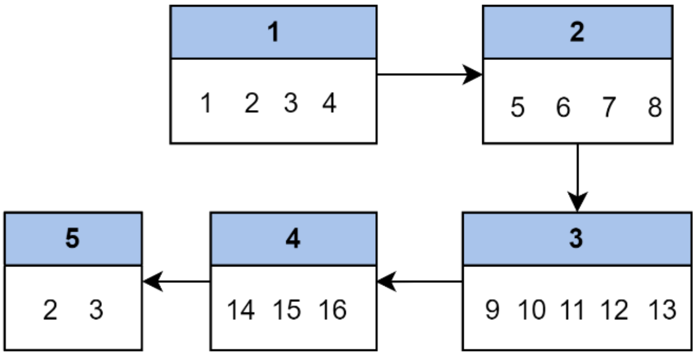

Figure 4. Work Flow Nail Production

Ranked Positional Weight Method

The ranked positional weight method is a method that applies the positional weight principle in its work.

Create position relationships between work elements

Operasi Terdahulu	Operasi pengikut																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	-1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	-1	-1	0	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	-1	-1	-1	-1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
6	-1	-1	-1	-1	-1	0	1	1	1	1	1	1	1	1	1	1	1	1
7	-1	-1	-1	-1	-1	-1	0	1	1	1	1	1	1	1	1	1	1	1
8	-1	-1	-1	-1	-1	-1	-1	0	1	1	1	1	1	1	1	1	1	1
9	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1	1	1	1	1	1	1	1
10	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	1	1	1	1	1	1	1
11	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1	1	1	1	1	1
12	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1	1	1	1	1
13	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	1	1	1	1
14	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1	1	1
15	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1	1
16	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1	1
17	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	1
18	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0

Figure 5. Posution relationships

Determine the position weight of each work element

Table 4. Position Weight

Work Element	Position Weight RPW	Work Element	Position Weight RPW
1	414,66	10	199,58
2	410,79	11	198,69
3	312,20	12	197,06
4	313,56	13	191,13
5	311,79	14	173,71
6	310,69	15	168,90

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7	309,42	16	84,46
8	308,84	17	81,62
9	202,05	18	29,19

Determine the sequence of work elements based on the RPW position weight

Table 5. work elements based on the RPW position weight

Work Element	*Position Weigh RPW*	Ranking	Work Element	*Position Weigh RPW*	Ranking
1	414,66	1	10	199,58	10
2	410,79	2	11	198,69	11
4	313,56	3	12	197,06	12
3	312,20	4	14	191,13	13
5	311,79	5	13	173,71	14
6	310,69	6	15	168,90	15
7	309,42	7	16	84,46	16
8	308,84	8	17	81,62	17
9	202,05	9	18	29,19	18

Assignment of work elements to work stations based on largest to smallest weight

Table 6. work elements to work stations based on largest to smallest weight

Work station	Work elements	Time (minutes)	Time Work station	Time service	Idle time	Efficiency work station
1	1	3,872	107,18	152,56	45,38	70,25
	2	98,592				
	3	0,408				
	4	1,357				
	5	1,103				
	6	1,267				
	7	0,578				
2	8	106,794	139,94	152,56	12,62	91,73
	9	0,835				
	10	2,519				
	11	1,63				
	12	1,120				
	13	22,23				
	14	4,815				
3	15	84,440	139,71	152,56	12,85	91,58
	16	2,837				
	17	52,434				
4	18	29,186	29,19	152,56	123,37	19,13

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Work Flow Diagram

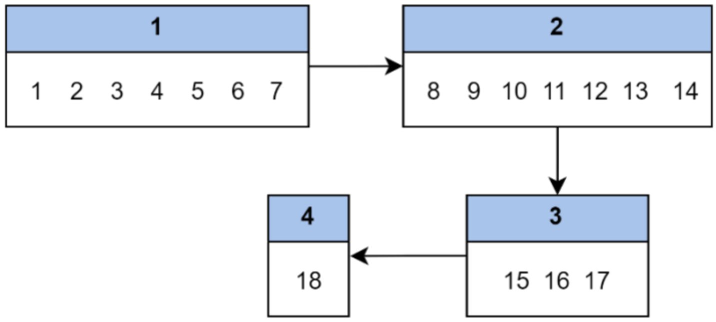

Figure 6. Work Flow Ranked Positional Weight Method

Line Efficiency

$$\textit{Line efficiency} = \frac{\sum STi}{K.Tsmaks} \text{ x } 100\% = \frac{416{,}02}{(4 \; x \; 152{,}56)} \text{ x } 100\% = 68{,}17\%$$

Balanced Delay

$$\textit{Balanced Delay} = \frac{K.Tsmaks - \sum Sti}{(K.Tsmaks)} \; x \; 100\% = \frac{4 \; x \; 152{,}56 - 416{,}02}{(4 \; x \; 152{,}56)} \; x \; 100\% = 31{,}83\%$$

Smoothes index

$$\textit{Smoothes index} = \sqrt{\sum (Tsmaks - Tsi)^2}$$

$$\sqrt{(45{,}38)^2 + (34{,}56)^2 + (12{,}85)^2 + (123{,}37)^2} = 132{,}68$$

Region Approach Method

In this method, a regional approach is carried out by dividing work elements into the same regions or regions for each work element that works in parallel

Grouping work elements into several regions from left to right

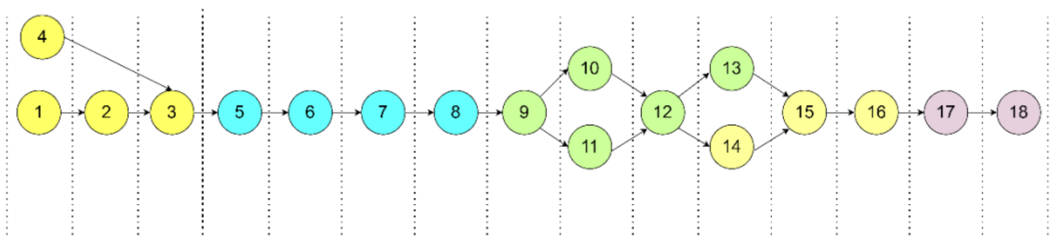

Figure 6. Precedence Diagram

Table 7. Assignment of each work element to a work station based on division region

Work station	Work elements	Time (minutes)	Time Work station	Time service	Idle time	Efficiency work station
1	1	3,872	107,18	152,56	45,38	70,25
	2	98,592				
	3	0,408				
	4	1,357				
	5	1,103				
	6	1,267				
	7	0,578				
2	8	106,794	112,90	152,56	39,66	74,00
	9	0,835				

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	10	2,519				
	11	1,63				
	12	1,120				
3	13	22,23	114,32	152,56	38,24	74,94
	14	4,815				
	15	84,440				
	16	2,837				
4	17	52,434	81,62	152,56	70,94	53,50
	18	29,186				

***Workflow* Procces**

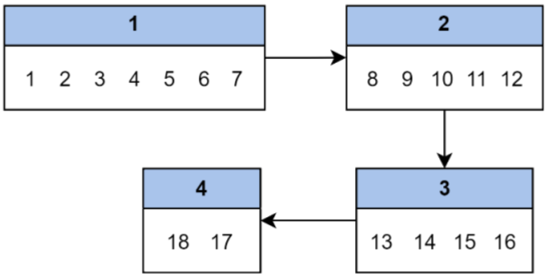

Figure 7. Work Flow Diagram

Line Efficiency

$$Line\ efficiency = \frac{\sum STi}{K.Tsmaks} \text{ x } 100\% = \frac{416{,}02}{(4\ x\ 152{,}56)} \text{ x } 100\% = 68{,}17\%$$

Balanced Delay

$$Balanced\ Delay = \frac{K.Tsmaks - \sum Sti}{(K.Tsmaks)}\ x\ 100\% = \frac{4\ x\ 152{,}56 - 416{,}02}{(4\ x\ 152{,}56)}\ x\ 100\% = 31{,}83\%$$

Smoothes index

$$Smoothes\ index = \sqrt{\sum(Tsmaks - Tsi)^2}$$

$$\sqrt{(45{,}38)^2 + (34{,}56)^2 + (12{,}85)^2 + (123{,}37)^2} = 100{,}63$$

From this research, the results were obtained from direct observation of the nail production process at CV.XYZ. The production process for making nails has 5 work elements. The nail production process has a total processing time of 185116.61 minutes, with a processing time of 8 hours per day with 24 days per month, resulting in a production speed of 0.92 units/hour. Has a minimum number of workstations of 3 workstations and has a service time at each station of 152.56 minutes. Based on the line balancing analysis that has been carried out, the best method chosen for this problem is the Region Approach method, because this method has the largest line efficiency (68.17%), the smallest balance delay (31.83%), and the smallest smoothes index (100 ,63), So this method was chosen as the best method and can improve line balancing conditions in the company. The increase in line efficiency from 54.68% using the company method to 68.17% using the Region Approach method can occur due to a reduction in the number of work stations from 5 work stations as well as a decrease in the number of smoothing indexes from 168.20 to 100.63. which indicates that there is an increase in balance between work stations.

Conclusion

From the results of this research it can be concluded that in the nail production process at CV.XYZ there are 5 work stations with 18 work elements, namely; with Line Efficiency

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results of 54.54%, Balance Delay of 45.46%, and Smoothness Index of 168.20. As for the influence of these two methods, based on the line balancing analysis that has been carried out, the best method chosen for this problem is the Region Approach method, because this method has the greatest line efficiency (68.17%), the smallest balance delay (31.83%) , and the smallest smoothes index (100.63), so this method was chosen as the best method and can improve line balancing conditions in the company. The increase in line efficiency from 54.68% using the company method to 68.17% using the Region Approach method can occur due to a reduction in the number of work stations from 5 work stations as well as a decrease in the number of smoothing indexes from 168.20 to 100.63. which indicates that there is an increase in balance between work stations

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