Redesigning The Facility Layout With Systematic Layout Planning Method and Lean Manufacturing Approach On The Production Floor At PT. Baruna Trayindo Jaya

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Abstract

PT. Baruna Trayindo Jaya is a manufacturing company engaged in producing or manufacturing cable tray, cable support system, and pole pipe. PT. Baruna Trayindo Jaya still has wasted on its production floor and does not yet have effectiveness for production. Researchers conducted observations in the field and processed the data using systematic layout planning (SLP) methods to redesign the facility layout and lean manufacturing approach to minimize waste on the production floor. The data selected to be processed through OPC with the number of operations and the long duration of time is cable ladder products. Data processing using FPC, OPC, routing sheet, FTC, MPPC, ARC, ATBD, ARD, AAD, and flow process materials for alternative layouts and adjustment factor determination, looseness determination, and current value stream mapping to minimize waste. After processing the data, two alternate layouts are generated with different production distances and times. Alternate layout one is selected compared to alternate layout two because it has a shorter distance and production time. The implementation of both methods can reduce distance reduction by 56.56% and time reduction by 10.07% on alternative layout 1 of the initial layout.

Keywords
Facility Layout, Systematic Layout Planning, Lean Manufacturing

1. Introduction
The industry is a business or activity to process raw materials or half materials into finished goods with added value. Industrial products are not only in the form of goods but also in the form of services. Types of industries there are various kinds such as the fishing industry, mining industry, automotive industry, and others. In a production process, the layout is one of the most critical components in a company's sustainability and effectiveness and efficient production process.
PT. Baruna Trayindo Jaya is a manufacturing company engaged in producing or manufacturing cable trays, cable support systems, and pole pipes. There is backtracking during the production process, especially in the punching and bending process. Besides, there is a waste of transportation when finishing products because in PT. Baruna Trayindo Jaya, finishing is done hot-dip galvanize process done by factory partners. Layout or layout on PT. Baruna Trayindo Jaya still does not have effectiveness for its production, so an optimal production layout design is required. Therefore, it is necessary to redesign the layout of facilities and waste analysis for PT. Baruna Trayindo Jaya can increase production effectiveness. Redesigning the facility layout using the Systematic Layout Planning (SLP) method and waste analysis using the lean manufacturing method.

1.1 Objectives
The purpose of this research is to identify waste that occurs in PT. Baruna Trayindo Jaya proposed changes to the layout for the production floor at PT. Baruna Trayindo Jaya and identified the occurrence of backtracking in the production process at PT. Baruna Trayindo Jaya.

2. Literature Review
Systematic layout planning (SLP) is an organized way to conduct layout planning, consisting of a phasing framework, procedure pattern, and a set of conventions to identify, assess, and visualize the elements and areas involved in layout planning [1]. The sequence of systematic layout planning procedures is as follows [2]:
1. Data Collection and Activities

At this early stage, data obtained information related to work drawings, assembly charts, part lists, bill of materials, route sheets, operation/flowchart, and others.
2. Material Flow Analysis
Analysis of material flow (flow of material analysis) will be related to quantitative measurement analysis efforts for any movement of material movement between departments or operational activities.
3. Flow Process Chart
At this stage, obtained data describing all activities, productive activities (operations and inspections), and unproductive (transportation, waiting, and saving).
4. Operation Process Chart
Describes the process steps that raw materials will experience regarding the sequences of operations and inspections from the initial stage to the finished product or component. It contains the information needed to analyze the time, material, place, tools, and machinery used.
5. Multi-Product Process Chart (MPPC)
The multi-product process chart shows the production linkage between the constituent components. MPPC is also used to analyze the flow or flow of materials in a series of production processes.
6. Routing Sheet
This stage contains tabulations of the steps covered in producing specific components and the necessary details of related matters. Production sequencing becomes the backbone of production activities, which is the recollection of all data developed by process engineers and essential communication tools between product engineers and production people.
7. From To Chart (FTC)
From to chart or trip frequency or travel chart is a conventional technique commonly used for planning factory layout and moving goods in a production process.
8. Activity Relationship Analysis
Measuring inter-departmental activities is one of the most important elements in the layout of facilities[3]. It is important to evaluate alternative rules; an activity relationship must be established. The relationship of activity can be found in quantitative and qualitative ways. Quantitative measures can include sheets per hour, motion shifts per day, or pounds per week.
9. Activity Relationship Diagram (ARD)
Activity Relationship Diagram (ARD) is a diagram of the relationship between activities (department or machine) based on the priority level of proximity, so it is expected that the cost of handling is minimum.
10. Area Allocation Diagram (AAD)
Area Allocation Diagram (AAD) is a continuation of ARD where in ARD is known conclusions of importance between activities, so activities must be close to other activities and vice versa. The relationship between activities affects the level of closeness between the layout of the activity.
11. Selection and Evaluation of Alternative Layouts
It is a step used to decide on the proposed layout design that must be selected or applied. The decision on alternative layout selection based on distance and time compared with an existing layout
Lean manufacturing is an ongoing effort to eliminate waste and increase the value-added of products (goods and services) to provide value to customers (customer value) [4]. Waste is categorized into seven categories, namely, [5]:
1. Waste of waiting, waiting time is a waste (e.g., waiting for material to come).
2. Waste of overproduction, making more products than customer demand is a waste.
3. Waste of overprocessing, a process that is more than the customer wants, is waste.
4. Waste of defect, reject, or repair is a waste that can be directly seen.
5. Waste of motion, Unnecessary movement, and not ergonomics, so adding process time is a waste.
6. Waste of inventory, the more inventory is stored, the more waste occurs.
7. Waste of transportation, waste caused by irregular transportation.

Time study is a measuring work technique by collecting data based on the time needed to complete a job. The time study method is used to calculate the standard time value of a job [6]. The following are the stages of the time study conducted:
1. Cycle Time
Cycle time is the time it takes to create one product unit on one workstation. The cycle time is calculated using the following equation:

$$Ws = \frac{\Sigma xi}{N} \tag{1}$$

Description:
Ws = Cycle Time
Xi = Measurement Data
N = Number of Observations Made
2. Normal Time

Normal time is an element of work operation that shows that a well-qualified worker will work to complete the work at a normal working tempo[8]. The following equation can calculate the normal time:

$$Wn = Ws \times (1 + p) \tag{2}$$

Description:
Wn = Normal Time
Ws = Cycle Time
p = Adjustment Factor

3. Default Time

The default time is when a normal worker reasonably takes to complete a job performed in the best working system. The following equation can calculate the default time:

$$Wb = Wn \times (1 + L) \tag{3}$$

Description:
Wb = Standard Time
Wn = Normal Time
L = Allowance

3. Methods

Research begins with field studies and literature and literature studies. Furthermore, identify problems based on field studies that have been done. The determination of research objectives is based on the problem that occurs. Then set the boundaries of research. The next stage is data collection. The data collected are the size of the production floor area, the overall factory size, the size of the machinery and equipment, the amount of production per year, and each production process's cycle time. Then the data is processed by taking into account the distance and time during the production process. Generated design layout or new alternatives and minimize waste that occurs. Then make conclusions and suggestions for the research.

4. Data Collection

4.1 Initial Layout

The initial layout of the production floor of PT Baruna Trayindo Jaya can be seen in Figure 1.

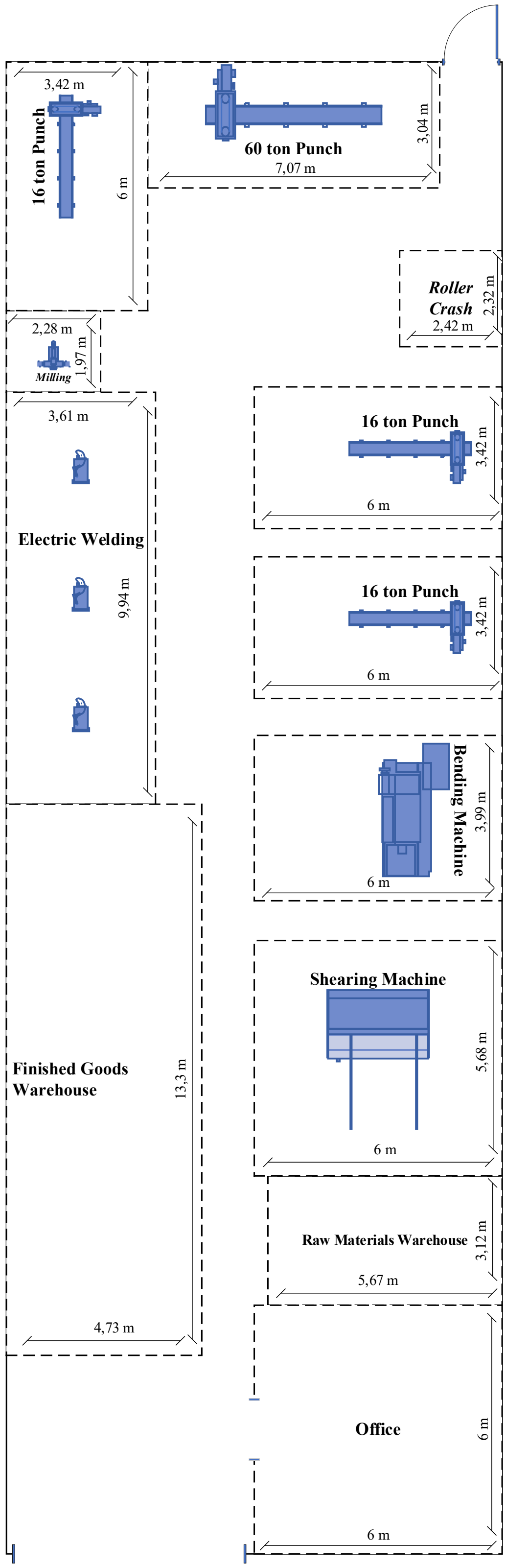

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Figure 1. Initial Layout

4.2 Floor Area

Based on data collection on the production floor of PT. Baruna Trayindo Jaya, researchers obtained data on the area of production floor is 432 m^2. The following is the floor area data of each process based on the initial layout of PT. Baruna Trayindo Jaya as follows.

Table 1. Floor Area Before Re-Layout

Work Area/Station	Total	Dimensions		Area (m^2)
		P (m)	L (m)	
Raw Materials Warehouse	1	5,67	3,12	17,69
Shearing Machine	1	6	5,68	34,08
Bending Machine	1	6	3,99	23,94
Punching 16 ton Machine	3	6	3,42	20,52
Roller Crash Machine	1	2,48	2,32	5,75
Punching 60 ton Machine	1	7,07	3,04	21,49
Milling Machine	1	2,28	1,97	4,49
Welding Machine	1	9,94	3,61	35,88
Finished Goods Warehouse	1	13,3	4,73	62,909
Office Area	-			36
Other areas	-			169,251
Total				432

4.3 Production Flow

The flow of the cable tray and ladder production process in PT Baruna Trayindo Jaya can be seen below.

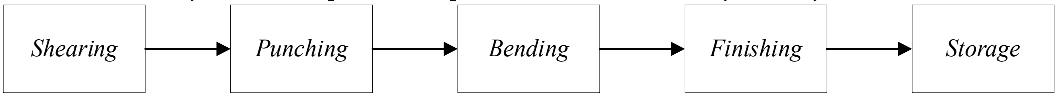

Figure 2. Cable Tray Production Flow

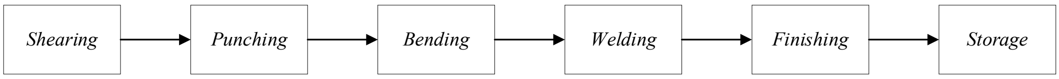

Figure 3. Cable Ladder Production Flow

5. Results and Discussion

5.1 Flow Process Chart

A flow process chart (FPC) is used to determine the work process in PT production. Baruna Trayindo Jaya. Here is the Flow Process Chart (FPC) cable ladder.

Table 2. Cable Ladder FPC

Flow Process Chart								
SUMMARY							Occupation : Cable Ladder Making	
ACTIVITIES	ACTUAL		SUGGESTION		DIFFERENT		Chart No. : 002	
	AMOUNT	TIME	AMOUNT	TIME	AMOUNT	TIME	Man ☐	Materials ☑
○ OPERATION	11	438					Actual ☑	Suggestion ☐
□ INSPECTION	5	52					Mapped by : Dino Ramadhan	
⇨ TRANSPORTATION	6	98					Date mapped : 25 October 2020	
D WAITING	0	0						
▽ STORAGE	1	5						
TOTAL	23	593						

DESCRIPTION OF ACTIVITIES	SYMBOL ○	□	⇨	D	▽	DISTANCE (m)	AMOUNT	TIME (minutes)
Collection of raw materials			●			1	11	2
Raw materials measured using a meter	●					0	11	18
Putting plates on the shearing machine	●					1	11	1
Doing shearing process for side rail and rung	●					0	11	16
Examination of plate cutting results		●				0	11	6
The plate is carried to the punching machine to be used as a rung and to the bending machine for side rail			●			5	11	4
Measurement with meter for rung	●					0	11	9
Putting plates on punching machine for rung	●					1	11	2
Doing process punching for rung	●					0	11	14
Examination of punching results for rung		●				0	11	4
The result of the punching process plate is brought to the bending machine			●			5	11	8
Measurement with meter for rung and side rail	●					0	11	25
Melakukan plat pada mesin bending	●					1	11	6
Putting plates on bending machine	●					0	11	35
Bending result check		●				0	11	12
Rung and side rail taken to electric welding machine			●			5	11	4
Perform the welding process	●					0	11	12
Welding process check		●				0	11	20
Cable ladder brought to the finishing place			●			25000	11	40
Melakukan proses finishing	●					0	11	300
Doing the finishing process		●				0	11	10
Cable ladder taken to finished goods warehouse			●			25000	11	40
Cable ladder stored in a finished goods warehouse					●	0	11	5

5.2 Operation Process Chart

Operation process chart (OPC) is used to find out the production process on products in PT. Baruna Trayindo Jaya. Operation Process Chart (OPC) cable ladder products can be seen below.

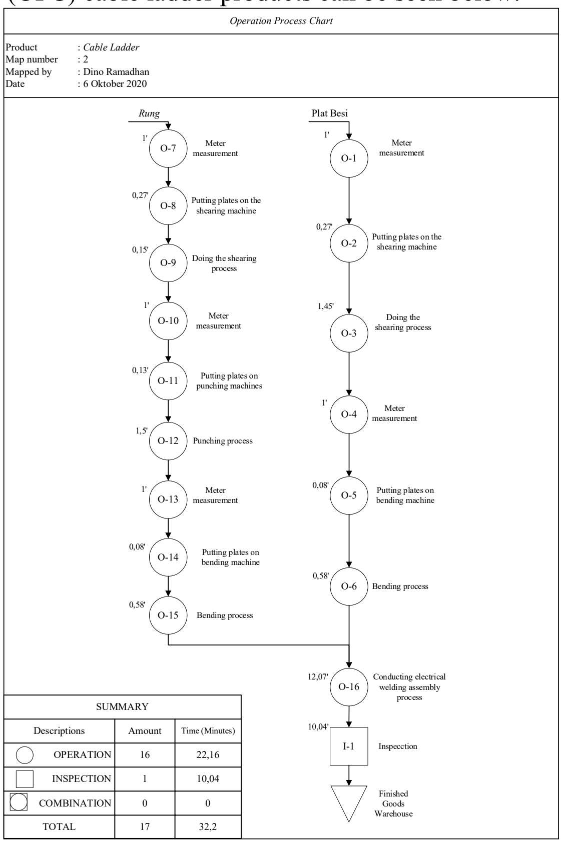

Figure 4. Cable Ladder OPC

5.3 Routing Sheet

The routing Sheet for cable ladder products can be seen in Table 3.

Table 3. Routing Sheet

Operation	Operation Name	Machine/ Tools	Default Time (minute)	Machine Set Up Time (minutes)	Scrap (%)	Number requested (units)	Number prepared (units)	Reability (%)	Number After Reliability (units)	Efficiency (%)	Number After Efficiency (units)	Theoretical Machine Capacity (unit)	Number of Theoretical Machines (units)
Iron Plate													
O-1	Meter measurement	Hand	1	1	0	13,285	13,285	95	13,984	90	15,538	2638,000	0,006
O-2	Putting plates on the shearing machine	Hand	0,27	1	1	13,152	13,285	90	14,761	90	16,401	9770,370	0,002
O-3	Shearing process	Shearing Machine	1,45	5	4	12,626	13,152	90	14,614	90	16,237	1813,793	0,009
O-4	Meter measurement	Tangan	1	1	0	12,626	12,626	95	13,291	90	14,768	2638,000	0,006
O-5	Putting plates on bending machine	Hand	0,08	1	1	12,500	12,626	90	14,029	90	15,588	32975,000	0,000
O-6	Bending process	Bending Machine	0,58	5	4	12	12,500	90	13,889	90	15,432	4534,483	0,003
Rung													
O-7	Meter measurement	Hand	1	1	0	13,488	13,488	95	14,198	90	15,776	2638,000	0,006
O-8	Putting plates on the shearing machine	Hand	0,27	1	1	13,353	13,488	90	14,987	90	16,652	9770,370	0,002
O-9	Shearing process	Shearing Machine	0,15	5	4	12,819	13,353	90	14,837	90	16,485	17533,333	0,001
O-10	Meter measurement	Hand	1	1	0	12,819	12,819	95	13,494	90	14,993	2638,000	0,006
O-11	Putting plates on punching machines	Hand	0,13	1	1	12,691	12,819	90	14,243	90	15,826	20292,308	0,001
O-12	Punching process	Punching Machine	1,5	5	4	12,183	12,691	90	14,101	90	15,668	1753,333	0,009
O-13	Meter measurement	Hand	1	1	0	12,183	12,183	95	12,824	90	14,249	2638,000	0,005
O-14	Putting plates on bending machine	Hand	0,08	1	1	12,061	12,183	90	13,537	90	15,041	32975,000	0,000
O-15	Bending process	Bending Machine	0,58	5	4	12	12,061	90	13,402	90	14,891	4534,483	0,003
Electrical Welding Assembly													
O-16	Electrical welding assembly	Welding Machine	12,07	5	5	11	11,579	90	12,865	90	14,295	217,896	0,066

5.4 From To Chart

Based on Table 9, it generates From To Chart (FTC) can be seen in Table 4.

Table 4. FTC

From \ To	a	b	c	d	e	f	Total
a		128					128
b			79	103 206			285
c				75			75
d					122		122
e						24	24
f							0
Total	0	128	79	281	122	24	634

From To Chart Inflow can be seen in Table 5.

Table 5. FTC Inflow

From \ To	a	b	c	d	e	f	Total
a		1					1
b			1	0,37			1
c				0,27			0,27
d					1		1
e						1	1
f							0
Total	0	1	1	0,27	1	1	4,27

From To Chart Inflow can be seen in Table 6.

Table 6. FTC Outflow

From \ To	a	b	c	d	e	f	Total
a		0,45					0,45
b			1,05	0,84			1,05
c				0,61			0,61
d					5,08		5,08
e						0	0
f							0
Total	0	0,45	1,05	0,61	5,08	0	7,20

5.5 Activity Relationship Chart

Activity Relationship Chart (ARC) is based on the From-To Chart Inflow that has been created. ARC can be seen in Figure 5.

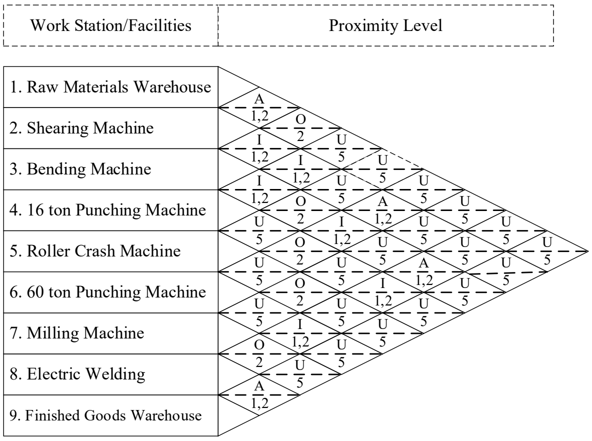

Figure 5. ARC

5.6 Activity Relationship Diagram

Activity Relationship Diagram (ARD) 1 is based on ARC, shown in Figure 6.

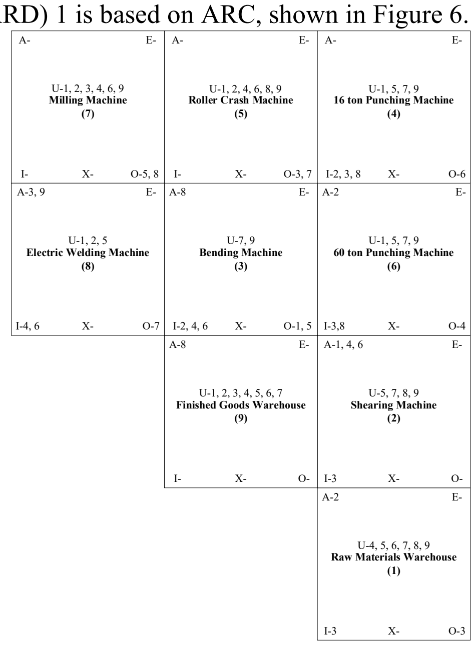

Figure 6. ARD 1

Activity Relationship Diagram (ARD) 2 can be seen in Figure 7.

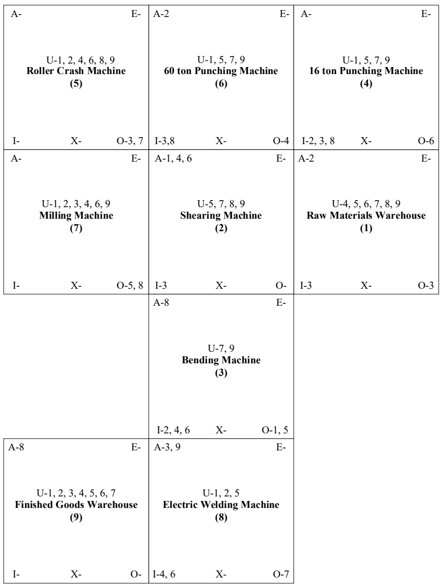

Figure 7. ARD 2

5.7 Area Allocation Diagram

The Area Allocation Diagram (AAD) is created based on ARD. AAD 1 can be seen in Figure 8.

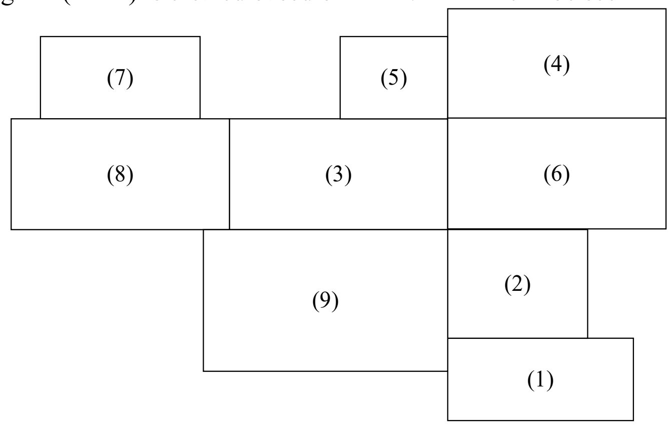

Figure 8. AAD 1

AAD 2 can be seen in Figure 9.

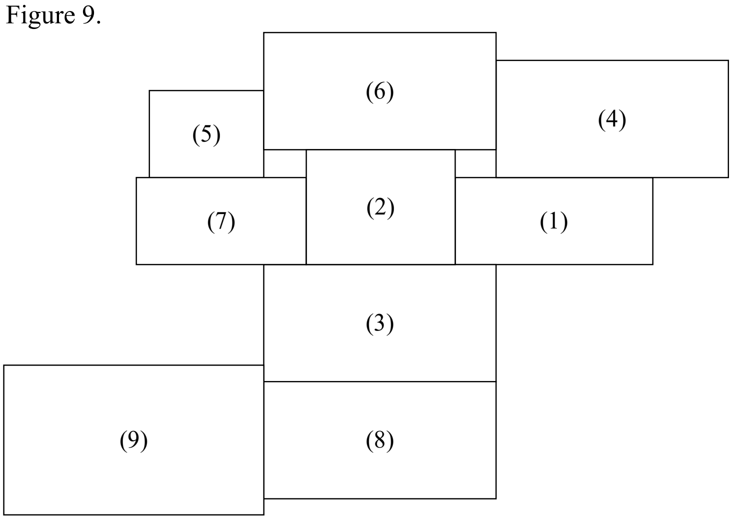

Figure 9. AAD 2

5.8 Process Activity Mapping

Each activity in the cable ladder production process is described in detail and recorded. Process activity mapping of cable ladder products can be seen in Table 7.

Table 7. Process Activity Mapping

Process	Activity Description	Machine/Tools	Distance (m)	Time (sec)	Number of Workers	O	I	T	D	S
Shearing	To the raw material warehouse	Hand	1	60	1					
	Search for raw materials		0	60	1					
	Bringing raw materials to the shearing area		1	30	1					
	Taking the meter for shearing		1	60	1					
	Take measurements	Meter	0	60	2					
	Powering the shearing machine	Hand	0	300	1					
	Placing the plate on the shearing machine		1	16,2	2					
	Shearing process	Shearing Machine	0	87	2					
	Quality check process	Hand	0	300	1					
Punching	Picking up shearing results	Hand	22,5	240	2					
	Take measurements	Meter	0	60	1					
	Turning on the punching machine	Hand	0	300	1					
	Putting materials on punching machines		1	7,8	2					
	Punching process	Punching Machine	0	90	2					
	Quality check process	Hand	0	300	1					
	Bringing punching results that don't pass to the rework table		1	120	2					
	Put punching results to the table		1	45	2					
	Bringing punching results to bending		18,5	180	2					
Bending	Take punching results	Hand	1	30	2					
	Picking up shearing results		5,13	120	1					
	Take measurements	Meter	0	60	1					
	Turn on the bending machine	Hand	0	300	1					
	Placing material on bending machine		1	4,8	2					
	Bending process	Bending Machine	0	34,8	2					
	Put bending results to the table	Hand	1	60	2					
	Bringing bending results to welding		10,5	150	2					
Welding	Retrieving bending results	Hand	1	45	1					
	Placing materials in the welding area		1	30	2					
	Powering an electric welding machine		0	300	1					
	Welding process	Electrical Welder	0	724,2	3					
	Quality check process	Hand	0	300	1					
	Bringing products to the finished goods warehouse		10	300	3					
Storage	Storage of cable ladder products	Hand	10	240	2					
Total			88,63	5014,8		22	3	7	0	1

Descriptions:
O = *Operation*, I = *Inspection*, T = *Transportation*, D = *Delay*, S = *Storage*

5.9 Waste Analysis

The waste analysis is done by clarifying all production process activities into three categories, namely Value Added (VA), Non-Value Added (NVA), and Necessary Non-Value Added (NNVA). Waste analysis that occurred on the production floor of PT. Baruna Trayindo Jaya can be seen in Table 8.

Table 8. Waste Analysis

Process	Activity Description	VA/NVA/ NNVA	T	I	M	W	O	O	D
Shearing	To the raw material warehouse	NNVA	■						
	Search for raw materials	NVA				■			
	Bringing raw materials to the shearing area	NNVA	■						
	Taking the meter for shearing	NNVA			■				
	Take measurements	NNVA			■				
	Powering the shearing machine	NNVA			■				
	Placing the plate on the shearing machine	NNVA			■				
	Shearing process	VA							
	Quality check process	NNVA				■			
Punching	Picking up shearing results	NNVA	■						
	Take measurements	NNVA			■				
	Turning on the punching machine	NNVA			■				
	Putting materials on punching machines	NNVA			■				
	Punching process	VA							
	Quality check process	NNVA				■			
	Bringing punching results that don't pass to the rework table	NNVA							■
	Put punching results to the table	NNVA			■				
	Bringing punching results to bending	NNVA	■						
Bending	Take punching results	NNVA	■						
	Picking up shearing results	NNVA	■						
	Take measurements	NNVA			■				
	Turn on the bending machine	NNVA			■				
	Placing material on bending machine	NNVA			■				
	Bending process	VA							
	Put bending results to the table	NNVA	■						
	Bringing bending results to welding	NNVA	■						
Welding	Retrieving bending results	NNVA	■						
	Placing materials in the welding area	NNVA			■				
	Powering an electric welding machine	NNVA			■				
	Welding process	VA							
	Quality check process	NNVA				■			
	Bringing products to the finished goods warehouse	NNVA	■						
Storage	Storage of cable ladder products	NVA		■					
Total			10	1	13	4	0	0	1

Descriptions:
T = *Transportation*, I = *Inventory*, M = *Motion*, W = *Waiting*, O = *Overproduction*, O = *Overprocessing*, D = *Defect*

5.10 Alternative Layout

Alternate layouts are selected based on shorter distances and times compared to the original layout. Alternative layouts can be seen in Figure 10.

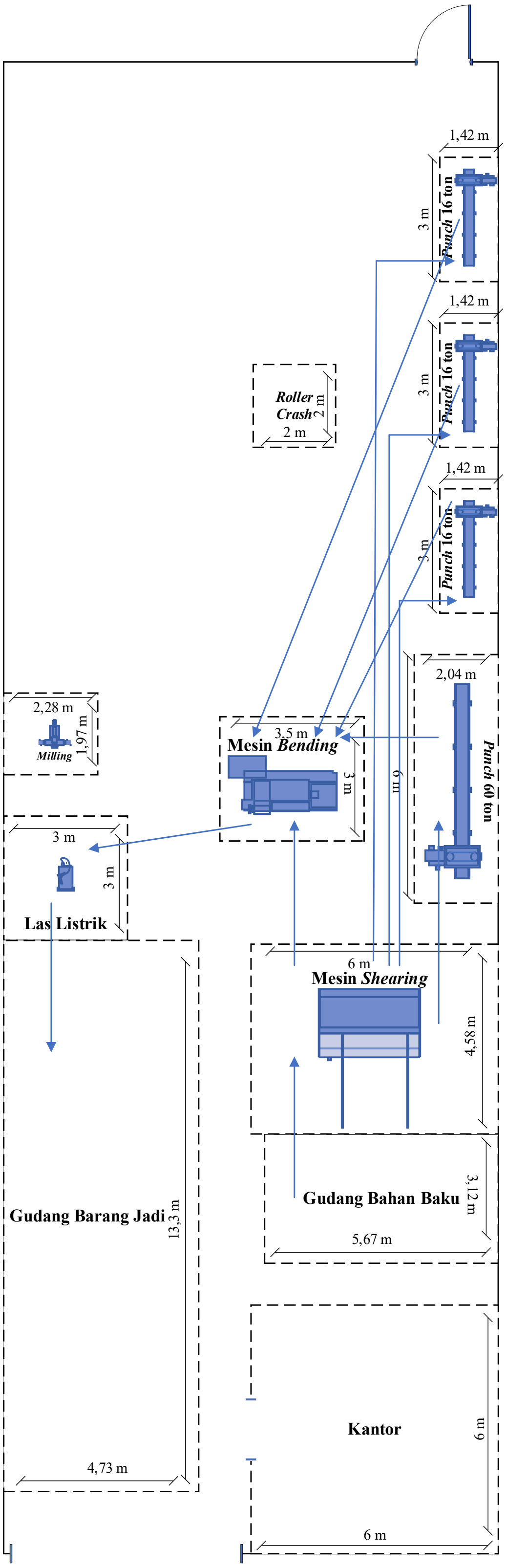

Figure 10. Alternative Layout

Analysis of distance and time based on an alternative layout can be seen in Table 9.

Table 9. Alternative Layout Distance and Time Analysis

Process	Activity Description	Machine/ Tools	Jarak (m)	Waktu (dtk)	Jumlah Pekerja	O	I	T	D	S
Shearing	To the raw material warehouse	Hand	1	15	1					
	Search for raw materials		0	30	1					
	Bringing raw materials to the shearing area		1	30	1					
	Taking the meter for shearing		1	10	1					
	Take measurements	Meter	0	60	2					
	Powering the shearing machine	Hand	0	300	1					
	Placing the plate on the shearing machine		1	16,2	2					
	Shearing process	Shearing Machine	0	87	2					
	Quality check process	Hand	0	300	1					
Punching	Picking up shearing results	Hand	5,6	180	2					
	Take measurements	Meter	0	60	1					
	Turning on the punching machine	Hand	0	300	1					
	Putting materials on punching machines		1	7,8	2					
	Punching process	Punching Machine	0	90	2					
	Quality check process	Hand	0	300	1					
	Bringing punching results that don't pass to the rework table		1	120	2					
	Put punching results to the table		1	45	2					
	Bringing punching results to bending		2,8	90	2					
Bending	Take punching results	Hand	1	30	2					
	Picking up shearing results		4,9	150	1					
	Take measurements	Meter	0	60	1					
	Turn on the bending machine	Hand	0	300	1					
	Placing material on bending machine		1	4,8	2					
	Bending process	Bending Machine	0	34,8	2					
	Put bending results to the table	Hand	1	45	2					
	Bringing bending results to welding		5,2	160	2					
Welding	Retrieving bending results	Hand	1	30	1					
	Placing materials in the welding area		1	30	2					
	Powering an electric welding machine		0	300	1					
	Welding process	Electrical Welder	0	724,2	3					
	Quality check process	Hand	0	300	1					
	Bringing products to the finished goods warehouse		3	90	3					
Storage	Storage of cable ladder products	Hand	5	210	2					
Total			38,5	4509,8		25	4	8	0	2

Descriptions:
O = *Operation*, I = *Inspection*, T = *Transportation*, D = *Delay*, S = *Storage*

The proposed alternative layout produces a shorter distance and cycle time operator than the initial layout of 38.5 m and 4509.8 s. The following compares the alternate layout's distance and time with the initial layout shown in Table 10.

Table 10. Layout Distance and Time Comparison

	Current Layout	**Alternative Layout**
Operator Distance	88,63 m	38,5 m
Distance Reduction		**-56,56%**
Cycle Time	5014,8 s	4509,8 s
Time Reduction		**-10,07%**

Alternate layouts are tested and simulated using ProModel software to find out the final result or better output. The simulation can be seen in Figure 11.

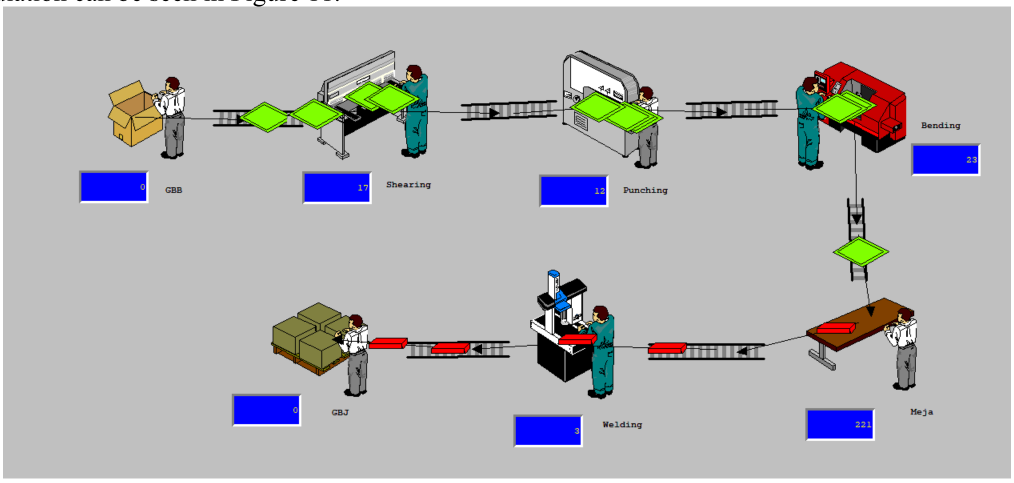

Figure 11. Simulation

The results of the simulation of alternative designs can be seen in Figure 12.

Scoreboard

Name	Total Exits	Average Time In System (Min)	Average Time In Operation (Min)	Average Cost
Plat Besi	428,00	55,10	51,01	0,00
Cable Ladder	200,00	150,87	13,50	0,00

Figure 12. Result of The Simulation of Alternative Design

6. Conclusion

Research results on applying systematic layout planning methods obtained alternative proposed layouts that can be applied to increase production effectiveness. The lean manufacturing method can minimize waste that occurs mostly in waste of motion and waste of transportation. The layout chosen from the application of both methods is the proposed layout 1(one) because it has a distance operator of 38.5 m with a distance reduction of 56.56% and cycle time of 4509.8 s with a time reduction of 10.07% to the initial layout.

References

Muther and Hales. *Systematic Layout Planning*. USA: Management & Industrial Research Publications, 2015.

Gozali, L., Widodo, L., Nasution, S. R., & Lim, N. "Planning the New Factory Layout of PT. Hartekprima Listrindo using Systematic Layout Planning (SLP) Method." *IOP Conference Series: Materials Science and Engineering*, vol. 847, no. 1, p. 012001. IOP Publishing.

Bagaskara, K. B., Gozali, L., & Widodo, L. "Redesign Layout Planning of Raw Material Area and Production Area Using Systematic Layout Planning (SLP) Methods (Case Study of CV Oto Boga Jaya)." *IOP Conference Series: Materials Science and Engineering*, vol. 852, no. 1, p. 012122. IOP Publishing.

Gaspersz, Vincent. *Lean Six Sigma*. Jakarta: Gramedia Pustaka Utama, 2007.

Ohno, Tai'ichi. *The Toyota Production System*. Diss. Monterey Institute of International Studies, 1987.

Pawiro, S. *Optimalisasi Produktivitas Tenaga Kerja dalam Proyek Konstruksi*. Skripsi, Manado: Teknik Sipil, Fakultas Teknik, Universitas Sam Ratulangi, 2015.

Purnomo, H. *Pengantar Teknik Industri*. Yogyakarta: Graha Ilmu, 2003.

Wignjosoebroto, Sritomo. *Teknik Tata Cara dan Pengukuran Kerja*. Jakarta: PT. Guna Widya, 1992.

Sutalaksana, Iftikar Z., A. Ruhana, dan H. T. John. *Analisa dan Perancangan Sistem Kerja*. Bandung: Institut Teknologi Bandung, 2006.

Biographies

Dino Ramadhan is an undergraduate student at Tarumanagara University majoring in Industrial Engineering. He is active in the organizations. He once did an internship at PT. Lelco Trindo Nusantara in the Quality Control Division and conduct research on the layout of facilities or factories at PT. Baruna Trayindo Jaya to get a Bachelor's degree.

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Lamto Widodo is a lecturer at Tarumanagara University Jakarta since 1994, joining the Mechanical Engineering Department.; he is involved as a team for the Industrial Engineering Department opening in 2004-2005. He was starting in 2005 as a lecturer in the Industrial Engineering Department. Obtained a Bachelor's degree at the Sepuluh Nopember Institute of Technology Surabaya (ITS), then completed a Master's degree at the University of Indonesia (UI) and graduated with the title Dr. at the Bogor Agricultural Institute (IPB). He is engaged in research and publication in Product Design and Ergonomics, Production Systems, and Engineering Economics and teaches at many universities in Jakarta. He has published nearly 30 publications in the field of Industrial Engineering research both nationally and internationally. Active in various professional organizations, especially in the field of Ergonomics (IEA), and active in the organization of the Indonesian Industrial Engineering Higher Education Cooperation Agency (BKSTI).

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Frans Jusuf Daywin was born in Makasar, Indonesia on 24th November 1942. is a lecturer in the Department of Agricultural Engineering at Faculty of Agricultural Technology Bogor Agricultural University since 1964 conducted teaching, research, and extension work in the field of farm power and machinery and become a professor in Internal Combustion Engine and Farm Power directing and supervising undergraduate and graduate students thesis and dissertation and retired as a professor in 2007. In 1994 up to present as a professor in Internal Combustion Engine and Farm Power at Mechanical Engineering Program Study and Industrial Engineering Program Study Universitas Tarumanagara, directing and supervising undergraduate student's theses in Agricultural Engineering and Food Engineering Desain. In 2016 up to present teaching undergraduate courses of the introduction of concept technology, research methodology, and seminar, writing a scientific paper and scientific communication, and directing and supervising undergraduate student's theses in Industrial Engineering Program Study at the Faculty of Engineering Universitas Tarumanagara. He got his Ir degree in Agricultural Engineering, Bogor Agricultural University Indonesia in 1966, and finished the Master of Science in Agricultural Engineering at the University of Philippines, Los Banos, the Philippines 1981, and got the Doctor in Agricultural Engineering, Bogor Agricultural University Indonesia in 1991. He joined 4-month farm machinery training at ISEKI CO, AOTS, Japan in 1969 and 14 days agricultural engineering training at IRRI, Los Banos the Philippines, in March 1980. He received the honors "SATYA LANCANA KARYA SATYA XXX TAHUN" from the President of the Republic of Indonesia, April 22nd, 2006, and received appreciation as Team Jury from the Government of Indonesia Minister of Industry in Industry Start-Up 2008. He did several research and survey in the field of farm machinery, farm mechanization, agricultural engineering feasibility study in-field performance and cost analysis, land clearing and soil preparation in secondary forest and alang-alang field farm 1966 up to 1998. Up till now he is still doing research in designing food processing engineering in agriculture products. Up to the present he already elaborated as a conceptor of about 20 Indonesia National Standard (SNI) in the field of machinery and equipment. He joins the Professional Societies as a member: Indonesia Society of Agricultural Engineers (PERTETA); Indonesia Society of Engineers (PII); member of BKM-PII, and member of Majelis Penilai Insinyur Profesional BKM-PII.

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