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Steel Pipe Warehouse Layout Optimization Using Integrated SLP and CORELAP: Optimalisasi Tata Letak Gudang Pipa Baja Menggunakan SLP dan CORELAP yang Terintegrasi

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Abstract

General Background: Manufacturing competitiveness depends partly on facility layouts that support efficient material flow and control material handling expenditure. **Specific Background:** The steel pipe warehouse has widely separated workstations, creating long movement distances and high daily material handling costs. **Knowledge Gap:** Previous studies cited in the article primarily compared material movement distances, whereas this study also incorporates overhead crane depreciation, maintenance, electricity, and operator cost components. **Aims:** The study redesigns the warehouse using Systematic Layout Planning (SLP) assisted by the Computerized Relationship Layout Planning (CORELAP) algorithm, based on existing layout data, facility areas, activity relationships, rectilinear distances, and material handling costs analyzed through ARC, ARD, TCR, and CORELAP. **Results:** The selected proposal reduced the layout value from 3,933 m^2 to 1,655 m^2, total material movement distance from 621.2 m to 233.4 m, and daily material handling cost from IDR 670,527.33 to IDR 192,241.82, producing daily savings of IDR 478,285.51. **Novelty:** The integrated SLP–CORELAP redesign evaluates both spatial movement and detailed overhead crane cost components rather than distance alone. **Implications:** The proposed arrangement provides a practical basis for shorter workstation travel and lower daily material handling expenditure, while future research should incorporate travel time between workstations.

Highlights:

- Workstation travel fell from 621.2 m to 233.4 m.
- Daily material-movement expenditure dropped by IDR 478,285.51.
- The proposed arrangement reduced the layout value from 3,933 m^2 to 1,655 m^2.

Keywords: Facility Layout, Systematic Layout Planning (SLP), CORELAP, Material Handling, Material Handling Cost.

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Introduction

The competitive manufacturing industry demands companies to improve operational efficiency, one of which is through good facility layout management. A suboptimal warehouse layout can lead to increased material movement distances, product buildup, and high material handling costs, thus impacting company productivity [1]. Therefore, facility layout design is an important factor in improving the smooth flow of materials and warehouse space utilization [2]. PT XYZ is a manufacturing company that produces various types of steel pipes. The problem that occurs in the company's warehouse is the position of several work stations that are far apart, resulting in a fairly large total material movement distance. This condition causes material handling activities to be less efficient and increases operational costs. The Systematic Layout Planning (SLP) method is a systematic approach in designing a facility layout through analyzing the proximity relationships between activities using Activity Relationship Charts (ARC) and Activity Relationship Diagrams (ARD) [3]. To obtain more objective layout alternatives, this study uses the Computerized Relationship Layout Planning (CORELAP) algorithm which compiles layouts based on the Total Closeness Rating (TCR) value. Unlike previous studies that only compared material movement distances, this study also includes material handling cost components based on overhead crane maintenance costs, electricity costs, and operator costs. The objective of this study is to generate a more optimal warehouse layout redesign and analyze its impact on reducing material movement distances and material handling costs.

Method

A. Warehouse

A warehouse is a facility used to store raw materials, semi-finished goods, and finished goods before distribution to customers [4]. In addition to storage, a warehouse also functions to support the smooth flow of materials, therefore, a layout that facilitates efficient storage, retrieval, and movement of materials is required [5].

B. Systematic Layout Planning

Systematic Layout Planning (SLP) is a facility layout design method developed systematically based on the proximity relationships between activities, space requirements, and material flow. Therefore, the SLP method is highly relevant for redesigning facility layouts, particularly in warehouse areas with high material flow complexity, thereby improving operational efficiency and overall system performance. This method produces more effective layout alternatives through the stages of developing Activity Relationship Charts (ARCs), Activity Relationship Diagrams (ARDs), and developing alternative layouts [6].

C. Distance Measurement

Measuring distances in material handling activities is a crucial aspect of facility layout design, as it directly impacts material movement efficiency, process time, and operational costs [7].

Rectilinear Distance

The Rectilinear method measures distance based on perpendicular paths or following the horizontal and vertical axes [8].

$$dij = |xi - xj| + |yi - yj| \tag{1}$$

D. Data Collection Sources

1. Primary Data

a. Observation

Data was collected through direct observation of the warehouse layout at PT XYZ.

b. Interviews

Data and information were obtained through interviews by asking questions related to the data being collected, and answers were obtained based on the company's current situation and conditions.

2. Secondary Data

The data used included the initial warehouse layout, work area or warehouse area data, workstation and activity area data, distances between activity areas, and material handling cost data, which served as the basis for analyzing and redesigning the warehouse facility layout.

E. Variable Identification and Definition

1. Dependent

The dependent variable is a variable that is influenced or affected by the presence of the independent variable. The dependent variables in this study are the proposed layout and the comparison of material handling costs.

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2. Independent

An independent variable is a variable that influences another variable or causes or causes a change in another variable. Independent variables include: initial block layout, distance between work activity areas, warehouse area, and material handling costs.

The flow of research steps that will be used to solve the problems in this research is as follows in Figure 1.

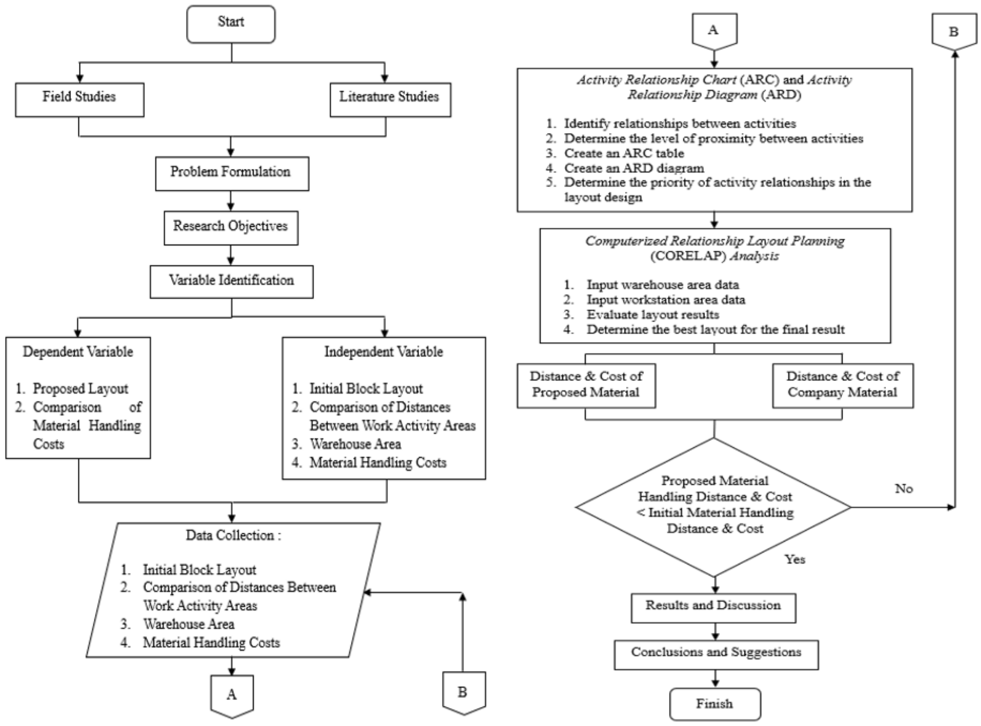

Figure 1. Flowchart

Result and Discusion

A. Data Collection

Data collection is a stage before entering data processing, data collection is obtained from direct field research, in addition, data collection is needed as basic material for processing in data processing.

1. Initial Layout Area

Table 1 below shows data obtained from PT XYZ regarding the initial layout area on the production floor

Table 1. Initial Layout Area

No	Work Stations	Length (m)	Width (m)	Area (m2)
A	Raw Material Storage	14	10	140
B1	Machine Work Station 1	50	6,5	325
B2	Machine Work Station 2	50	6,5	325
C1	Drain Board Work Station 1	5	4	20
C2	Drain Board Work Station 2	5	4	20
D	Pipe Sorting Work Station	12	5	60
E1	Finish Goods Storage 1	24	7	168
E2	Finish Goods Storage 2	24	7	168
E3	Finish Goods Storage 3	14	12	168
E4	Finish Goods Storage 4	14	12	168

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No	Work Stations	Length (m)	Width (m)	Area (m2)
F	Finish Bads Storage	12	3	36
G	Pipe Cutting Work Station	3	3	9
H	Pressgram Work Station	8	6	48

2. Coordinates Between Workstations in the Initial Layout

Coordinates between workstations in the initial layout are needed to redesign the layout and reduce the distance traveled, thereby increasing the effectiveness of the production process.

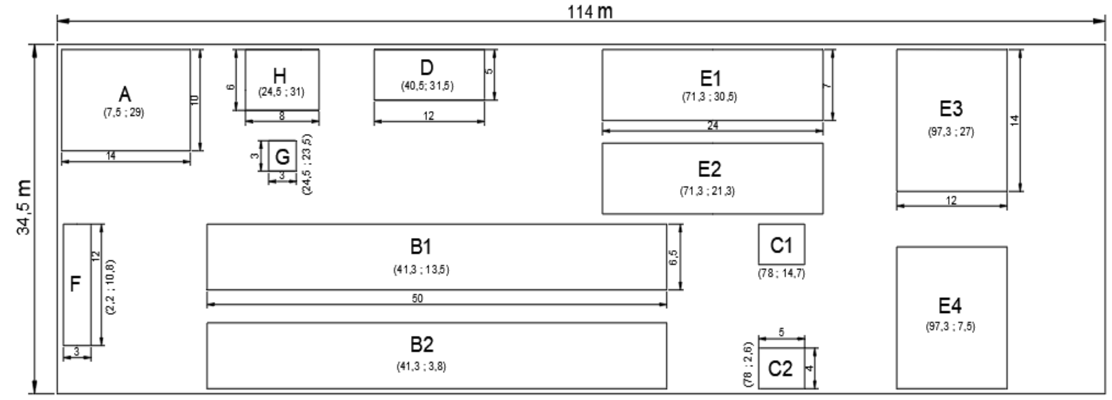

Figure 2. Initial Layout Map

Based on Figure 2 above, the following are the coordinates of the work station at PT XYZ:

Table 2. Coordinates Between Workstations in the Initial Layout

No	Work Stations	X (m)	Y (m)	Distance (m)
1	A	7,5	29	49,3
2	B1	41,3	13,5	59
3	B2	41,3	3,8	37,9
4	C1	78	14,7	37,9
5	C2	78	2,6	54,3
6	D	40,5	31,5	66,4
7	E1	71,3	30,5	31,8
8	E2	71,3	21,3	41
9	E3	97,3	27	61,3
10	E4	97,3	7,5	80,8
11	F	2,2	10,8	59
12	G	24,5	23,5	35
13	H	24,5	31	7,5

From the calculation results of the X coordinate point to the Y coordinate on the initial layout data of work station A to work station H using the rectilinear distance formula, the value of the midpoint meeting between work stations is obtained. For the steel pipe production process, there are 13 work station transfer movements, the distance between work stations for the initial layout is 621.2 meters.

3. Material Handling Costs

Material Handling Costs (OMH) are the costs incurred due to the movement of materials, either from one machine to another or from one department to another within a production system [9].

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Below are the costs incurred for company operations using an overhead crane to move steel pipes:
Purchase Cost: IDR 350,000,000
Economical Life: 20 Years
Working Hours: 26 days/month
Electricity Cost: IDR 2,513,118/month
Maintenance Cost: IDR 3,662,367/month
Operator Salary: IDR 9,800,000/month (2 Operators)

B. Data Processing

1. Activity Relationship Chart (ARC)

The Activity Relationship Chart (ARC) is an analytical tool in the SLP method used to determine the level of proximity between workstations based on the needs of activity relationships [10]. These relationships are expressed using codes A, E, I, O, U, and X, indicating the level of importance of proximity between areas as a basis for developing facility layouts [11].

Figure 3 below is the result of the activity relationship chart for processing data obtained at the company.

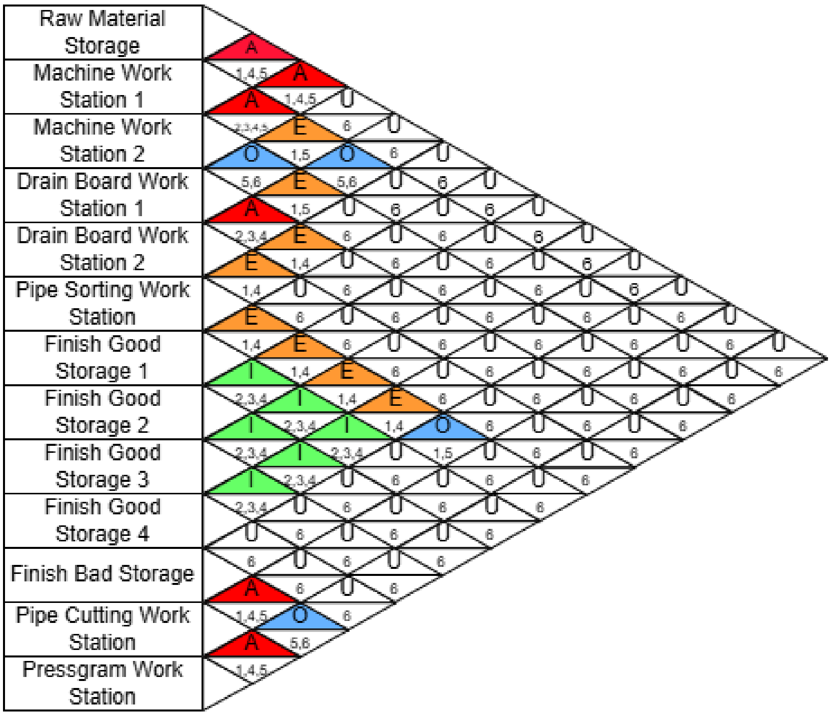

Figure 3. Activity Relationship Chart (ARC)

Table 3 below shows the definition of proximity codes obtained from the Activity Relationship Chart.

Table 3. Proximity Codes

Degree of Proximity	Description	Color Code	Code	Reason
Red	Absolutely Important	A	1	Sequential processes
Orange	Very Important	E	2	Uses the same space area
Green	Important	I	3	Has the same work function
Blue	Normal	O	4	Facilitates supervision
No Color	Not Important	U	5	Noisy, Dirty, and Dusty
Brown	Not Very Important	X	6	Unrelated processes

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2. Activity Relationship Diagram

The Activity Relationship Diagram (ARD) is a development of the ARC, depicting the proximity relationships between areas in diagram form, thus facilitating the process of developing a proposed layout [12]. This diagram shows the relative position of each department based on the priority level of activity proximity [13].

Figure 4 below is the result of an activity relationship diagram that has been processed from an activity relationship chart.

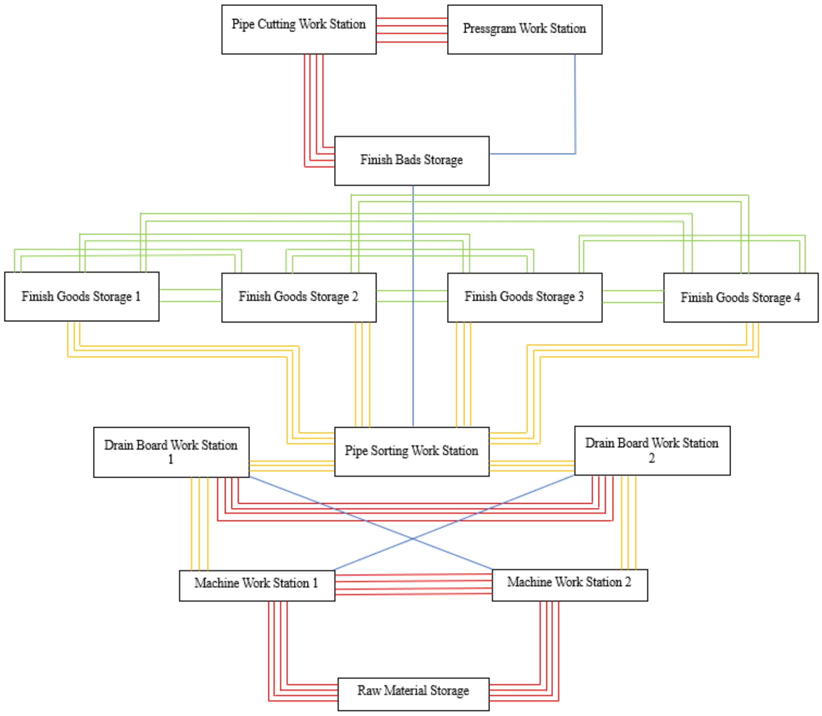

Figure 4. Activity Relationship Diagram (ARD)

2. Total Closeness Rating (TCR)

The Total Closeness Rating (TCR) is the total value obtained from the accumulated weighting of the closeness relationships of each department. The TCR value is used to determine the priority of area placement in the layout design process, with the department with the highest TCR value being placed first [14].

Table 4 below is the total closeness rating value from the data results taken from the previous diagram.

Table 4. *Total Closeness Rating*

To From	1	2	3	4	5	6	7	8	9	10	11	12	13	TCR
1		A	A	U	U	U	U	U	U	U	U	U	U	20
2	A		A	E	O	U	U	U	U	U	U	U	U	24
3	A	A		O	E	U	U	U	U	U	U	U	U	24
4	U	E	O		A	E	U	U	U	U	U	U	U	23
5	U	O	E	A		E	U	U	U	U	U	U	U	23
6	U	U	U	E	E		E	E	E	E	O	U	U	31
7	U	U	U	U	U	E		I	I	I	U	U	U	21
8	U	U	U	U	U	E	I		I	I	U	U	U	21
9	U	U	U	U	U	E	I	I		I	U	U	U	21
10	U	U	U	U	U	E	I	I	I		U	U	U	21

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11	U	U	U	U	U	O	U	U	U	U		A	O	18
12	U	U	U	U	U	U	U	U	U	U	A		A	20
13	U	U	U	U	U	U	U	U	U	U	O	A		17

3. Design Using CORELAP Software

CORELAP is a computer algorithm used to generate alternative layouts based on the proximity relationships between departments. This algorithm works by utilizing TCR values as the basis for department placement, thus producing a layout that is more objective and in accordance with the needs of activity relationships [15].

From the calculated layout results in Figure 5, it can be seen that there are 4 rows containing 13 departments. In the 1st row there is department H (pressgram work station); in the 2nd row there is department E4 (finish good 4 storage), department F (finish bad storage), and department G (pipe cutting work station); in the 3rd row there is department E2 (finish good 2 storage), department D (pipe sorting work station), department C1 (draining andang work station 1), and department B1 (machine work station 1); in the 4th row there is department E3 (finish good 3 storage), department E1 (finish good 1 storage), department C2 (draining andang work station 2), department B2 (machine work station 2), and department A (raw material storage). The method used is the western edge method, where the placement of departments starts from the top left side.

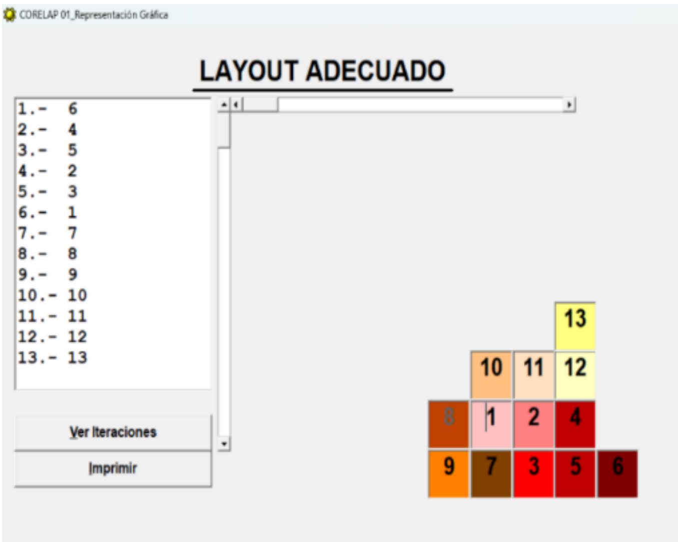

Figure 5. Software Running Results

4. Coordinates Between Workstations in the Proposed Layout

After processing the data in CORELAP software, a more efficient proposed map was obtained, as shown in Figure 6 below:

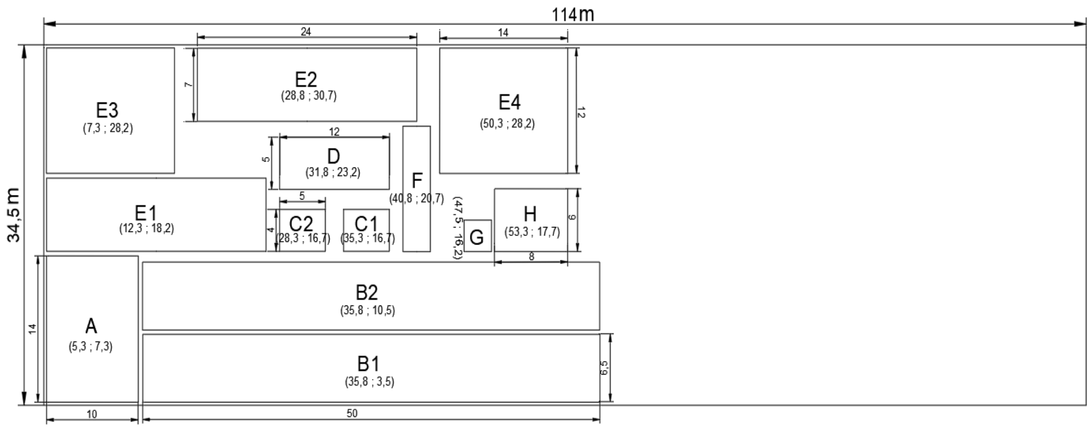

Figure 6. Proposed Layout Map

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Based on Figure 6 above, the following are the coordinates of the work station at PT XYZ:

Table 5. Proposed Layout Work Station Coordinates

No	Work Station	X (m)	Y (m)	Proposed Distance (m)	Initial Distance (m)	Distance Difference (m)
1	A	5,3	7,3	34,3	49,3	15
2	B1	35,8	3,5	33,7	59	25,3
3	B2	35,8	10,5	13,7	37,9	24,2
4	C1	35,3	16,7	13,7	37,9	24,2
5	C2	28,3	16,7	10	54,3	44,3
6	D	31,8	23,2	10	66,4	56,4
7	E1	12,3	18,2	24,5	31,8	7,3
8	E2	28,8	30,7	10,5	41	30,5
9	E3	7,3	28,2	29,5	61,3	31,8
10	E4	50,3	28,2	23,5	80,8	57,3
11	F	40,8	20,7	11,5	59	47,5
12	G	47,5	16,2	11,2	35	23,8
13	H	53,3	17,7	7,3	7,5	0,2

From the calculation results of the X coordinate point to the Y coordinate on the initial layout data of work station A to work station H using the rectilinear distance formula, the value of the midpoint meeting between work stations is obtained. From the comparison above, the distance in the proposed layout is 233.4 meters with a difference in the initial layout of 387.8 meters.

5. Comparison of Initial OMH Layout & Proposed Layout

After the initial layout data and the proposed layout are complete, the next process is to compare the total overhead crane operational costs with the costs required in the initial layout and the proposed layout by collecting data on the frequency of material handling movements per day, the distance between work stations, and calculations on the depreciation value of material handling, material handling maintenance costs, material handling electricity usage costs, material handling operator costs, total costs, and OMH obtained per meter.

a. Overhead Crane Handling Material Costs

Depreciation

$$\frac{\text{Material Handling Costs}}{\text{Economic Life x Operational Day}} = \text{Depreciation} \tag{2}$$

$$\frac{Rp.350.000.000}{20\ year\ x\ 312\ day} = Rp.56.089/day$$

Maintenance

$$\frac{Maintenance\ Cost}{Working\ Day} = Maintenance\ Cost/day \tag{3}$$

$$\frac{Rp.3.662.367}{26\ day} = Rp.140.860/day$$

Electricity Usage

$$\frac{\text{Electricity Usage Costs}}{Working\ Day} = \text{Electricity Usage Costs}/day \tag{4}$$

$$\frac{Rp.2.513.118}{26\ day} = Rp.96.658/day$$

Operator Costs

$$\frac{Operator\ Salary}{Working\ Day} = \text{Operator } Costs/day \tag{5}$$

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$$\frac{Rp.9.800.000}{26\ day} = Rp.376.923/day$$

Total Costs

$$\text{Depretiation + Maintenance + Electricity Usage + Operator = Total Cost} \quad (6)$$
$$\text{Rp. 56.089 + Rp. 140.860 + Rp. 96.658 + 376.923 = Rp. 670.531}$$

Distance per Day

$$\sum_{i=1}^{n=1\ldots,13}(Ji\ x\ Fi) \quad (7)$$
$$\text{(Distance A-B1 x Frequency A-B1) + ... + (Distance G-H x Frequency G-H)}$$
$$\text{(49,3 m x 1 time) + ... + (7,5 m x 1 time)}$$
$$= 2645{,}6\ \text{m}$$

OMH per Meter

$$\frac{\text{Total } Cost}{Distance\ per\ Day} = \text{OMH/meter} \quad (8)$$
$$\frac{RP.670.531}{2645{,}6\ m} = Rp.253{,}45$$

Table 6. OMH Initial Layout

From	To	Tool	Distance (m)	Frequency (time)	OMH/m (Rp)	Total OMH (Rp)
A	B1	*Overhead Crame*	49,3	1	253,45	12.495,09
A	B2	*Overhead Crame*	59	1	253,45	14.953,55
B1	C1	*Overhead Crame*	37,9	10	253,45	96.057,55
B2	C2	*Overhead Crame*	37,9	10	253,45	96.057,55
C1	D	*Overhead Crame*	54,3	10	253,45	137.623,35
C2	D	*Overhead Crame*	66,4	10	253,45	168.290,80
D	E1	*Overhead Crame*	31,8	2	253,45	16.119,42
D	E2	*Overhead Crame*	41	3	253,45	31.174,35
D	E3	*Overhead Crame*	61,3	2	253,45	31.072,97
D	E4	*Overhead Crame*	80,8	2	253,45	40.957,52
D	F	*Overhead Crame*	59	1	253,45	14.953,55
F	G	*Overhead Crame*	35	1	253,45	8.870,75
G	H	*Overhead Crame*	7,5	1	253,45	1.900,88
			Total			670.527,33

Table 6 above shows the total OMH in the initial layout which will then be processed into the proposed layout as in Table 7 below.

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Table 7. OMH Proposed Layout

From	To	Tool	Distance (m)	Frequency (time)	OMH/m (Rp)	Total OMH (Rp)
A	B1	*Overhead Crame*	34,3	1	253,45	8.693,34
A	B2	*Overhead Crame*	33,7	1	253,45	8.541,27
B1	C1	*Overhead Crame*	13,7	10	253,45	34.722,65
B2	C2	*Overhead Crame*	13,7	10	253,45	34.722,65
C1	D	*Overhead Crame*	10	10	253,45	25.345
C2	D	*Overhead Crame*	10	10	253,45	25.345
D	E1	*Overhead Crame*	24,5	2	253,45	12.419,05
D	E2	*Overhead Crame*	10,5	3	253,45	7.983,68
D	E3	*Overhead Crame*	29,5	2	253,45	14.953,55
D	E4	*Overhead Crame*	23,5	2	253,45	11.912,15
D	F	*Overhead Crame*	11,5	1	253,45	2.914,68
F	G	*Overhead Crame*	11,2	1	253,45	2.838,64
G	H	*Overhead Crame*	7,3	1	253,45	1.850,19
			Total			192.241,82

Calculation Formula :

$$\text{Total OMH} = \text{Distance x Frequency x OMH/m} \tag{9}$$

Based on table 6 and table 7 above, the calculation of OMH on the initial layout and the proposed layout by calculating the distance, frequency, and OMH per meter on the initial layout obtained the total value of OMH spent by PT XYZ in a day of Rp. 670,527.33 and for the total result of OMH spent in a day on the proposed layout of Rp. 192,241.82 with a difference in costs incurred of Rp. 478,285.51. Based on the output of the proposed layout, the impact obtained on PT XYZ is that the closer distance between work stations can be proven to reduce material handling costs and can speed up the production process.

Conclusion

Based on the research results at PT XYZ, it can be concluded that the application of the Systematic Layout Planning (SLP) method with the help of the CORELAP algorithm successfully produced a more optimal redesign of the warehouse layout at PT XYZ. The proposed layout was able to reduce the total material movement distance from 621.2 meters to 233.4 meters and reduce material handling costs from Rp670,527.33/day to Rp192,241.82/day. Thus, the SLP and CORELAP methods have proven effective in increasing the efficiency of the warehouse layout by reducing material movement distance and material handling costs. For further research, the proposed layout is recommended to consider the calculation of travel time between work stations.

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