

Feasibility Analysis of Pipe Yard Facility Layout Redesign Using Systematic Layout Planning Method to Reduce Crane Material Handling Cost at PT Pertamina EP Tanjung Field

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ABSTRACT

The oil and gas industry requires a facility layout that supports smooth material flow and efficient use of handling equipment, particularly within storage areas. Suboptimal layouts lead to increased material transport distances, equipment operating times, and operational costs; this issue is particularly relevant to the pipe yard layout at PT Pertamina EP Tanjung Field. This study aims to analyze the feasibility of the existing layout and design a proposed pipe yard layout using the Systematic Layout Planning (SLP) method to reduce Material Handling Costs (MHC) associated with crane-based material transport. Data collection involved observation, interviews, and a literature review. The SLP process included material flow analysis, the creation of an Activity Relationship Chart and Activity Relationship Diagram, space requirement analysis, the development of a Space Relationship Diagram, and the formulation of a proposed layout. Analysis of the initial layout revealed a material transport distance of 5,240 meters, a crane usage time of 35 hours per month, and an MHC of IDR 63,359,999.9 per month. In contrast, the proposed SLP-based layout reduced the transport distance to 940 meters, lowered monthly crane usage to 29.2 hours, and decreased the monthly MHC to IDR 52,800,008.3. Consequently, the comparison between the initial and proposed layouts shows reductions of 4,300 meters in transport distance, 5.8 hours in crane usage time, and IDR 10,559,991.7 in monthly operational costs, representing a 16.6% increase in efficiency. Based on these evaluation results, the SLP method is deemed suitable for enhancing the operational efficiency of the pipe yard facility layout.

1. Introduction

PT Pertamina Hulu Indonesia operates in oil and natural gas exploration and production activities in Regional 3 Zone 9 Tanjung Field, commonly known as PT Pertamina EP Tanjung Field. To support its operations, the company manages several storage facilities, including a pipe yard used to store pipes and supporting components for exploration and production activities [1]. Unlike conventional warehouses, the pipe yard stores large and heavy materials that require cranes for lifting and movement. Therefore, the arrangement of storage areas, transportation routes, and facility relationships directly affects crane utilization and operational efficiency.

Facility layout planning plays an important role in improving space utilization, material flow, accessibility, and handling performance. An inefficient layout may increase movement distance, crane operating time, handling frequency, and operational cost [2]. In this context, Material Handling Cost (MHC) becomes an important indicator for evaluating the efficiency of the existing and proposed layouts [3].

Systematic Layout Planning (SLP) is a structured method for redesigning facilities based on activity relationships, material flow, space requirements, and alternative layout evaluation [4]. Previous studies have shown that SLP can reduce operational costs, material handling distances, and MHC [5][9]. However, most studies focus on manufacturing facilities and general warehouses, while research on pipe yards with crane-based handling systems in the oil and gas industry remains limited.

Based on this gap, this study aims to evaluate the feasibility of redesigning the pipe yard layout at PT Pertamina EP Tanjung Field using SLP. The analysis compares the existing and proposed layouts based on material movement distance, crane utilization time, and MHC to produce a more efficient layout recommendation.

2. Method

2.1 Type and Approach of Research

This study used a quantitative case study approach at the pipe yard facility of PT Pertamina EP Tanjung Field. The evaluation focused on material movement distance, crane utilization time, and Material Handling Cost (MHC), while considering facility relationships, material flow, space requirements, and operational performance [5], [6].

Systematic Layout Planning (SLP) was applied to redesign the layout through material flow analysis, Activity Relationship Chart (ARC), Activity Relationship Diagram (ARD), space adjustment, Space Relationship Diagram, and proposed layout evaluation. These stages combined quantitative factors, such as distance and cost, with qualitative activity relationships to improve layout efficiency [8], [10], [11], [14].

2.2 Object and Scope of Research

The research object was the pipe yard facility at PT Pertamina EP Tanjung Field, which stores pipes and supporting components for oil and gas operations. Because these materials are large and require specialized handling equipment, an appropriate facility arrangement is essential [15].

The study focused on facility layout, material flow, crane utilization, and Material Handling Cost (MHC). Performance was evaluated through technical aspects of space utilization, operational aspects of movement distance and crane time, and economic aspects of handling cost reduction [14], [16].

2.3 Data Collection Techniques

Data were collected through observations, interviews, documentation, and operational records covering facility dimensions, movement frequency, operating time, and crane utilization [5], [10]. The data were then analyzed using a From-To Chart to identify inefficient material flows and reduce unnecessary transportation [12].

2.4 Tools and Materials Used

SLP implementation used the From-To Chart, ARC, ARD, and Space Relationship Diagram to analyze material flow, facility closeness, and spatial relationships [12]. Movement efficiency was evaluated using actual crane routes because pipe yard handling follows defined operational pathways [13].

2.5 Research Procedures or Stages

The research procedure followed the systematic stages of SLP. The first stage involved analyzing the existing layout condition, including facility location, material storage arrangement, and current material flow. The second stage involved identifying relationships between facilities using ARC and ARD to determine the required proximity between operational areas [11], [12].

The third stage consisted of space requirement analysis by comparing available area with facility requirements. Space planning is an important stage in facility redesign because insufficient consideration of area requirements may reduce layout flexibility and operational effectiveness [14].

The fourth stage involved developing the proposed layout by considering material flow, facility relationships, available space, and practical limitations. Alternative layouts were evaluated based on their ability

to reduce material movement distance and improve handling efficiency. Previous studies have shown that SLP-based redesign can significantly reduce transportation distance and material handling costs in manufacturing and warehouse environments [6], [7], [8].

The final stage was the feasibility evaluation of the proposed layout. The initial and proposed layouts were compared based on material movement distance, crane utilization time, and Material Handling Cost (MHC). The layout with improved operational performance and lower handling costs was considered the recommended alternative.

2.6 Data Analysis Techniques

Data analysis was performed by comparing the existing layout performance with the proposed layout performance. The analysis focused on three main indicators: material movement distance, crane utilization time, and Material Handling Cost (MHC). Material handling efficiency is strongly influenced by facility arrangement because excessive movement distance directly increases handling time and operational costs [10], [7].

Material Handling Cost was calculated based on movement distance, handling frequency, and cost per unit distance. The MHC indicator is commonly used in facility layout evaluation because an efficient layout should minimize transportation activities while maintaining smooth material flow [7], [18].

The feasibility assessment was conducted by calculating the percentage reduction achieved after layout redesign. Similar evaluation approaches have been applied in previous SLP studies to measure improvements in facility efficiency through reductions in distance, handling activities, and operational costs [5], [7], [17].

3. Results and Discussion

3.1 Presentation of Research Results

3.1.1 Technical Analysis of the Existing Pipe Yard Layout Based on Space and Facilities

The existing layout was used as a baseline to evaluate facility utilization, movement distance, transfer frequency, and Material Handling Cost (MHC). The results were compared with the proposed layout to measure operational and cost improvements. The existing pipe yard layout is shown in Fig. 1.

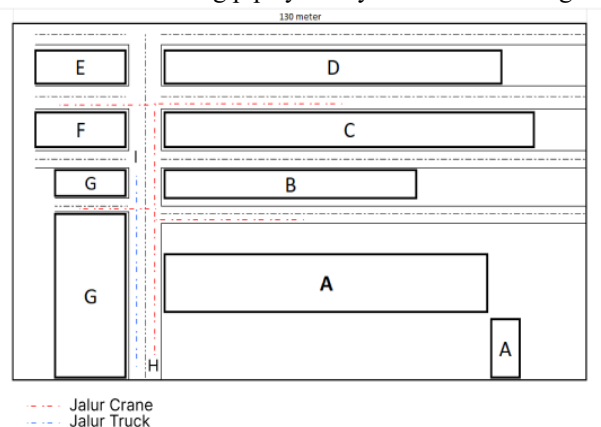


Fig. 1 The Existing Layout

Table. 1 Explanation of Existing Layout

No	Area	Explanation
1	A	Sucker Rod
2	B	Casing, Tubing, Line Pipe
3	C	Casing, Tubing, Line Pipe
4	D	Casing, Tubing, Line Pipe (Ex-Project)
5	E	Damaged Tubing, Consigned Goods
6	F	Consigned Casing and Ex-Project Goods
7	G	Line Pipe, Damaged Sucker Rod, Tubing, Steam Rack, Tubing Rack
8	H	Entrance and Exit
9	I	Parking Area

3.1.2 Operational Analysis Based on Material Movement Distance and Handling Time

Jarak Perpindahan Antar Lokasi (m)									
From/to	A	B	C	D	E	F	G	H	I
A		8	150	150	105	105	50	90	80
B	8		8	150	105	105	50	90	80
C	150	8		8	50	8	150	200	50
D	150	150	8		50	50	150	200	50
E	105	105	8	50		8	100	150	25
F	105	105	8	50	8		8	150	25
G	50	50	150	150	100	8		90	25
H	90	90	200	200	150	150	90		70
I	80	80	50	50	25	25	25	70	

Fig. 2 Material Movement Distance

Fig. 2 presents the From-To Matrix showing movement distances among nine locations (A–I). Each cell indicates the distance between locations, excluding diagonal cells because no transfer occurs within the same location. The longest distance is 200 m between locations C and H, while handling times are presented in Table 2.

Table. 2 Handling Time

No	From	To	Equipment	Distance (Meter)	Time (Minute)		Frequency	Distance Subtotal (Meter)	Time subtotal (Minutes)
				(J)	Move (P)	Load/Unload (L)		(J x F)	(P+L)x F
1	(A) Loading Pipe	(I) Truck	Crane	80	5	25	49	3920	1470
2	(B) Loading Pipe	(I) Truck	Crane	80	5	25	9	720	270
3	(C) Loading Pipe	(I) Truck	Crane	50	5	25	12	600	360
4	(D) Loading Pipe	(I) Truck	Crane	50	-	-	0	0	0
5	(E) Loading Pipe	(I) Truck	Crane	25	-	-	0	0	0
6	(F) Loading Pipe	(I) Truck	Crane	25	-	-	0	0	0
7	(G) Loading Pipe	(I) Truck	Crane	25	-	-	0	0	0
8	(I) Truck	(H) Exit	Truck	70	-	-	0	0	0
9	(H) Enter	(I) Parking Unload	Truck	70	-	-	0	0	0
10	(I) Unloading Pipe	(A) Yard	Crane	80	-	-	0	0	0
11	(I) Unloading Pipe	(B) Yard	Crane	80	-	-	0	0	0
12	(I) Unloading Pipe	(C) Yard	Crane	50	-	-	0	0	0
13	(I) Unloading Pipe	(D) Yard	Crane	50	-	-	0	0	0
14	(I) Unloading Pipe	(E) Yard	Crane	25	-	-	0	0	0
15	(I) Unloading Pipe	(F) Yard	Crane	25	-	-	0	0	0
16	(I) Unloading Pipe	(G) Yard	Crane	25	-	-	0	0	0
Total							70	5240	2100

3.1.3 Economic Analysis Based on Material Handling Costs

Based on the collected data, the calculation of crane material handling costs is as follows:

Rental Cost	: IDR 1,383,120,000/year/unit
	: IDR 115,260,000/months/unit
Economic Life	: 5 years
Number of Units	: 1 Unit
Working Time	: 176 hours/month
Diesel Fuel Price	: IDR 18,000/liter

1. Depreciation Cost

Since the crane used is a rental unit provided by a vendor, the depreciation cost is the responsibility of the crane owner.

2. Total Maintenance Cost

The crane used is a rental unit from a vendor; therefore, the maintenance cost is also borne by the crane owner.

3. Fuels Cost For Material Movement

Based on the collected information, the fuel consumption rate of the crane is 20 liters per hour. With a working time of 176 hours per month, the total diesel fuel consumption for one month of operation is 3,520 liters per unit. To calculate fuel usage, the total fuel consumption is divided by the total crane operating time during material movement. The calculation is as follows:

$$\text{Fuel consumption per hour} = \frac{\text{Fuel consumption}}{\text{Total operating time}} \quad (1)$$

$$\text{Fuel consumption per hour} = \frac{3520 \text{ liter}}{2100 \text{ minutes}} = \frac{3520 \text{ liter}}{35 \text{ hours}} = 100,57$$

The total fuel consumption cost is calculated as = 3.520 liter × IDR 18.000 × 1 unit = IDR 63.360.000 per month.

4. Material Handling Cost

$$\text{MHC} = \frac{\text{Fuel Costs}}{\text{Total operating time per month}} \quad (2)$$

$$\text{MHC} = \frac{\text{IDR } 63.360.000}{35 \text{ hours per month}}$$

$$\text{MHC} = \text{IDR } 1.810.285,71/\text{hours}$$

Table. 3 Initial Cost

No	From	To	Equipment	Time Subtotal (Minute)	Time Subtotal (Hour)	MHC/Hour	MHC
					(T)	(O)	(T x O)
1	(A) Loading Pipe	(I) Truck	Crane	1470	24,5	1.810.285,71	IDR 44.351.999,9
2	(B) Loading Pipe	(I) Truck	Crane	270	4,5	1.810.285,71	IDR 8.146.285,7
3	(C) Loading Pipe	(I) Truck	Crane	360	6	1.810.285,71	IDR 10.861.714,3
Total							IDR 63.359.999,9

The analysis shows that material movement from area (A) to area (I) contributes the highest MHC, reaching IDR 44,351,958 per month due to high crane utilization (1,470 minutes). The total Material Handling Cost (MHC) for material movement activities is IDR 63,359,999 per month.

3.1.4 Proposed Layout Planning Based on Operational Aspects

Based on the From-To Chart analysis, the material movement distance and handling time were calculated for each work-area relationship. The results are summarized in Table 4.5, which presents the total material movement distance in the existing *pipe yard* layout and identifies the routes with the highest contribution to material handling intensity.

Table. 4 From-To Chart Material Movement Based on Distance

Inter-location Movement Distance(m)											
From/to	A	B	C	D	E	F	G	H	I	J	K
A		60	0	70	10	30	75	10	30	20	80
B	60		70	0	30	10	75	10	30	80	20
C	0	70		60	50	60	5	30	10	70	100
D	70	0	60		50	45	5	30	10	100	70
E	10	30	50	50		0	80	10	40	20	60
F	30	10	60	45	0		80	10	40	60	20
G	75	75	5	5	80	80		60	25	95	95
H	10	10	30	30	10	10	60		25	55	55
I	30	30	10	10	40	40	25	25		85	85
J	20	80	70	100	20	60	95	55	85		130
K	80	20	100	70	60	20	95	55	85	130	

Table. 5 From-To Chart Material Movement Based on Time

Inter-location Movement Time (Minute)											
From/to	A	B	C	D	E	F	G	H	I	J	K
A		150	0	175	25	75	187,5	25	25	50	200
B	150		175	0	75	25	187,5	25	25	200	50
C	0	175		150	125	150	12,5	75	25	175	250
D	175	0	150		125	112,5	12,5	75	25	250	175
E	25	75	125	125		0	200	25	100	50	150
F	75	25	150	112,5	0		200	25	100	150	50
G	187,5	187,5	12,5	12,5	200	200		150	62,5	237,5	237,5
H	25	25	75	75	25	25	150		62,5	137,5	137,5
I	75	75	25	25	100	100	62,5	62,5		212,5	212,5
J	50	200	175	250	50	150	237,5	137,5	212,5		325
K	200	50	250	175	150	50	237,5	137,5	212,5	325	

3.1.5 Proposed Layout Planning Based on Technical Aspects

1. Activity Relation Chart

The ARC was developed to identify pipe utilization intensity across yard areas. The analysis shows that pipe yard A, B, and C have the highest utilization levels, with the highest pipe movement frequency occurring in areas A and B.

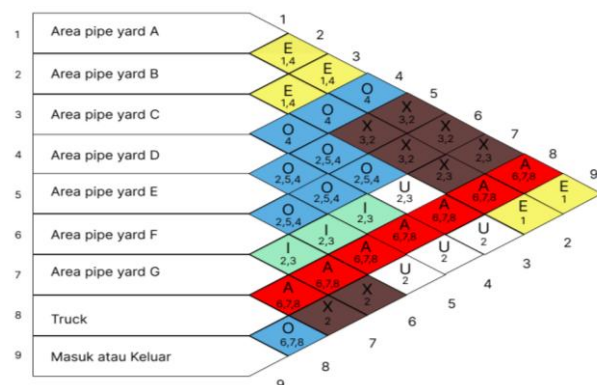


Fig. 3 Activity Relation Chart

Table. 6 Explanation of ARC

Code	Reason
1	Pipes with high usage requirements
2	Pipes with low usage requirements
3	Pipes no longer in use must be separated for sale or recycling
4	Pipes must be separated by type and size
5	Pipes requiring repair or refurbishment
6	Utilizing the same workforce
7	Involving the same activities
8	Using the same tools

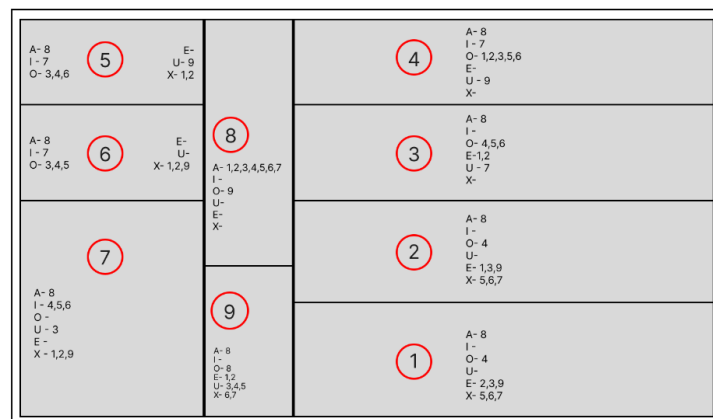
Based on the analysis of space relationships related to material handling activities, as shown in Figure 4.2, the space relationship table was developed as follows:

Table. 7 Degree of Room Proximity

No	Room	Proximity					
		A	E	I	O	U	X
1	Pipe yard area A	8	2,3,9	-	4	-	5,6,7
2	Pipe yard area B	8	1,3,9	-	4	-	5,6,7
3	Pipe yard area C	8	1,2	-	4,5,6	7	-
4	Pipe yard area D	8	-	7	1,2,3,5,6	9	-
5	Pipe yard area E	8	-	7	3,4,6	9	1,2
6	Pipe yard area F	8	-	7	3,4,5	-	1,2,9
7	Pipe yard area G	8	-	4,5,6	-	3	1,2,9
8	Truck	1,2,3,4,5,6,7	-	-	9	-	-
9	Enter or exit	-	1,2	-	8	3,4,5	6,7

2. Activity Relation Diagram

The proposed Activity Relationship Diagram (ARD) was developed based on the previously determined relationship table to systematically represent activity relationships according to their importance levels. The proposed ARD is presented in Fig. 4 and Fig. 5.

**Fig. 4** ARD of Initial Layout

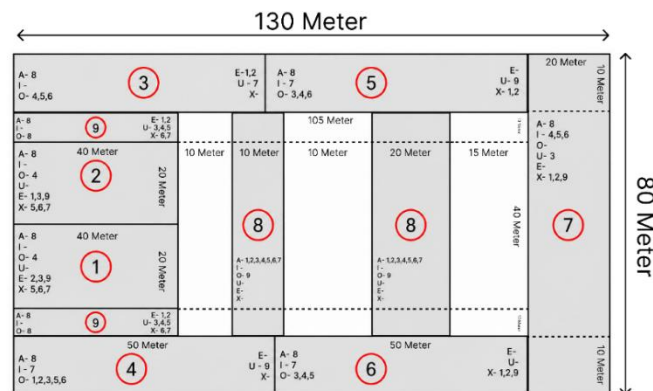


Fig. 5 ARD of Proposed Layout

Based on the proposed layout design, the material transfer distance and handling time were recalculated to evaluate the operational improvement achieved after the redesign process. The calculation considered the movement routes, material flow patterns, and operational activities within the *pipe yard* area. The obtained distance and time values were then used as performance indicators to compare the proposed layout with the existing condition. The detailed results of material transfer distance and time are presented in Table 8.

Table. 8 Proposed Material Transfer Distance and Time

No	From	To	Equipment	Distance (Meter)	Time (minutes)		Frequency (F)	Distance Subtotal (Meter)	Time Subtotal (Minute)
				(J)	Move (P)	Load/Unload (L)		(J x F)	(P+L)x F
1	(A) Loading Pipe	(I) Truck	Crane	10	0	25	49	490	1225
2	(B) Loading Pipe	(I) Truck	Crane	10	0	25	9	90	225
3	(C) Loading Pipe	(I) Truck	Crane	30	0	25	12	360	300
4	(D) Loading Pipe	(I) Truck	Crane	30	-	-	0	0	0
5	(E) Loading Pipe	(I) Truck	Crane	10	-	-	0	0	0
6	(F) Loading Pipe	(I) Truck	Crane	10	-	-	0	0	0
7	(G) Loading Pipe	(I) Truck	Crane	60	-	-	0	0	0
8	(I) Truck	(H) Exit	Truck	85	-	-	0	0	0
9	(H) Enter	(I) Parking Unload	Truck	55	-	-	0	0	0
10	(I) Unloading Pipe	(A) Yard	Crane	30	-	-	0	0	0
11	(I) Unloading Pipe	(B) Yard	Crane	10	-	-	0	0	0
12	(I) Unloading Pipe	(C) Yard	Crane	10	-	-	0	0	0
13	(I) Unloading Pipe	(D) Yard	Crane	10	-	-	0	0	0
14	(I) Unloading Pipe	(E) Yard	Crane	40	-	-	0	0	0
15	(I) Unloading Pipe	(F) Yard	Crane	40	-	-	0	0	0
16	(I) Unloading Pipe	(G) Yard	Crane	25	-	-	0	0	0
Total							70	940	1750

3.1.6 Proposed Cost Planning Based on Economic Aspects

After obtaining the data on distance, handling time, frequency, and other operational parameters, the next step was to calculate the costs associated with warehouse operations as follows:

1. Crane
 - Rental Cost : IDR 1,383,120,000/year/unit
: IDR 115,260,000/month/unit
 - Economic Life : 5 Years
 - Number of Units : 1 Unit
 - Working Time : 176 hours/month
 - Diesel Fuel Price : IDR 18,000/liter
- a. Depreciation Cost
Since the crane used in the operation is a rental unit provided by a vendor, the depreciation cost is the responsibility of the vendor as the crane owner.
- b. Total Maintenance Cost
The crane is rented from a vendor; therefore, the maintenance cost is also borne by the vendor.
- c. Fuel Cost for Material Movement
Based on the proposed material movement distance, the fuel consumption was calculated at 2,932.62 liters, obtained from the calculation of 100.57 liters/hour × 29.16 hours (equivalent to 1,750 minutes of operating time). With a diesel fuel price of IDR 18,000/liter, the total crane fuel consumption cost is:

$$2,933.33 \text{ liters} \times \text{IDR } 18,000 = \text{IDR } 52,800,000$$

- d. Material Handling Cost (MHC)
The Material Handling Cost (MHC) was calculated using the following equation:

$$\text{MHC} = \frac{\text{IDR } 52,800,000}{29,2 \text{ hours per month}}$$

$$\text{MHC} = \text{IDR } 1,810,286/\text{hours}$$

Based on the distance and time of displacement, this can be seen in Table 9 below.

Table. 9 Proposed Cost

No	From	To	Tools	Time Subtotal (Minute)	Time Subtotal (Hour)	MHC/Hour	MHC
					(T)	(O)	(T x O)
1	(A) Loading Pipe	(I) Truck	Crane	1225	20,4167	1.810.286	IDR 36.960.005,8
2	(B) Loading Pipe	(I) Truck	Crane	225	3,75	1.810.286	IDR 6.788.572,5
3	(C) Loading Pipe	(I) Truck	Crane	300	5	1.810.286	IDR 9.051.430,0
Total							IDR 52.800.008,3

Based on Table 9, the proposed layout provides more efficient material movement operations due to reduced transfer frequency and shorter crane operating time. In the initial layout condition, the total crane movement time reached 2,100 minutes (35 hours), resulting in a Material Handling Cost (MHC) of IDR 63,359,999.9. Meanwhile, the proposed layout reduced the total crane movement time to 1,750 minutes (29.2 hours), with an MHC of IDR 52,800,008.3. Therefore, the proposed layout generates a cost reduction of IDR 10,559,991.5, representing an efficiency improvement of approximately 16.6% compared with the initial layout.

3.2 Analysis of Findings

The analysis shows that the initial *pipe yard* layout generated inefficient material handling due to suboptimal facility arrangement and long movement routes. The highest contribution to Material Handling Cost (MHC) occurred in the movement from area A to area I, which was affected by high crane utilization intensity.

The implementation of the SLP method improved facility relationships through ARC and ARD analysis, allowing areas with high utilization and movement frequency to be positioned more effectively. The proposed layout reduced material movement distance from 5,240 meters to 940 meters and reduced handling time from 2,100 minutes to 1,750 minutes, indicating improved material flow efficiency.

3.3 Implications of the Results

The improvement in layout arrangement resulted in a reduction of MHC from IDR 63,359,999.9/month to IDR 52,800,008.3/month, providing cost savings of IDR 10,559,991.5/month or an efficiency improvement of approximately 16.6%.

These findings indicate that SLP can be effectively applied to *pipe yard* facilities to optimize existing resources, reduce crane utilization, and improve operational performance without additional equipment investment. The proposed layout provides practical benefits for PT Pertamina EP Tanjung Field as a reference for future facility improvement and supports more efficient material handling management.

3.4 Limitations of the Study

This study has several limitations that should be considered when interpreting the results. The analysis was conducted based on operational data from a single *pipe yard* facility at PT Pertamina EP Tanjung Field, so the proposed layout performance may vary when applied to other facilities with different operational characteristics, storage capacities, or material flow patterns. In addition, the evaluation focused on material movement distance, crane utilization time, and Material Handling Cost (MHC), while other factors such as future material demand variation, safety aspects, and long-term operational changes were not included. Further studies are recommended to incorporate simulation methods and dynamic operational scenarios to validate the proposed layout performance under different conditions.

4. Conclusion

This study successfully evaluated the feasibility of redesigning the *pipe yard* facility layout at PT Pertamina EP Tanjung Field using the Systematic Layout Planning (SLP) method. The existing layout showed inefficiencies in material handling activities, indicated by a total material movement distance of 5,240 meters, crane operating time of 2,100 minutes (35 hours), and Material Handling Cost (MHC) of IDR 63,359,999.9 per month. Through the implementation of SLP using From-To Chart, Activity Relationship Chart (ARC), Activity Relationship Diagram (ARD), and space relationship analysis, a proposed layout was developed by improving facility relationships and optimizing material flow.

The proposed layout reduced the total material movement distance to 940 meters and decreased crane operating time to 1,750 minutes (29.2 hours). The economic evaluation showed that the proposed layout reduced MHC to IDR 52,800,008.3 per month, resulting in cost savings of IDR 10,559,991.5 per month or an efficiency improvement of approximately 16.6% compared with the initial layout. These results indicate that the SLP method is feasible for improving operational efficiency in crane-based *pipe yard* facilities by reducing unnecessary material movement and optimizing existing resources. The proposed layout can serve as a reference for future facility improvement to support more effective material handling operations in the oil and gas industry.

Declarations

Author contribution. The contribution from first author : Miss Amanda Edifya Sana Putri: original draft, data collection, data analysis; Rachmasari Pramita Wardhani: Conceptualization , Review, Evaluation, Editing; Raden Andang Iskandar: Review, Analysis, Methodology.

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