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Warehouse Relayout Design with Weighted Distance Method to Minimize Time Travel

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Abstract

Global competition between companies is becoming increasingly stringent, resulting in companies having to understand their customers better. Customers no longer only need quality products, but also need excellent and timely service. To meet the desires of these consumers, the company must create an effective and efficient work system. PT IJS is a warehouse engaged in logistics services in the Perak area of Surabaya. One of the services provided by PT IJS is bonded warehouse logistic services. A bounded warehouse owned is currently not able to provide maximum service because there are still many late deliveries that do not send goods to the port, and there is a closing time that is detrimental to the customer. The length of the delivery process is due to several factors, one of which is a less effective warehouse layout. Travel time is the time required for a vehicle to carry out activities loading goods PT. IJS from arrival to exit the warehouse. The method weighted distance is a mathematical model used to evaluate the layout based on proximity factors. The design of the layout design by using the technique weighted distance produces an alternative layout that shows calculation travel time a shorter.

Keywords: Relayout; travel time; weighted distance.

1. Introduction

Competition in the business world is now increasingly stringent, and every effort is required to carry out business activities effectively and efficiently. In a factory, effective and efficient can be seen through various aspects, including material storage systems. For example, the warehouse of raw materials, the availability of raw materials at the right time, and the right amount can affect the smooth production process. (Hidayat, 2012). The role of warehouses in the supply chain is currently quite important, especially in terms of cost and services customer needs. Goods stored in warehouses can be raw materials, semi-finished products, spare parts, or finished goods. Company performance will be influenced by the level of productivity and warehousing services (Sujana et al., 2014)

A right layout arrangement will also have many strategic impacts because it determines the competitiveness of the company are: including capacity, process, flexibility, cost, quality of the work environment, contact with customers, and company image (Liana, 2017).

Facility layout planning includes determining the location of manufacturing systems and facility planning, which consists of the design of facilities, layout, and handling of materials that support production activities in a warehouse. The layout is a significant foundation in the industrial world. Plant layout or facility layout can be defined as the procedure for managing factory facilities to support the smooth production process (Johan and Suhada, 2018).

In the logistics system, service companies often require a long time for the movement one location to another is defined as travel time, which impacts the process is hampered supply chain and cause losses. Travel time within a warehouse can occur due to several factors, one of which is the warehouse layout implemented by the warehouse has not been effective because the layout is applied conditionally. This causes the duration of the process of loading goods in the warehouse. Delivery processes that are scheduled are often late. PT IJS serves a variety of logistics activities for companies that require export-import shipping services. One of the services provided by PT IJS is bonded warehouse rental services. One of the customers who use these services is a manufacturing warehouse that processes cocoa beans and produces various kinds of products in the form of cocoa powder. The Bounded Warehouse system owned by PT IJS is closely related to customs, where all activities carried out in bonded areas must follow all applicable regulations, one of which is the timeliness of delivery and speed of service.

A bounded warehouse owned by PT IJS is currently not able to provide maximum services because there are often too many late deliveries that do not send goods to the port, and there is a closing time that is detrimental to the customer. One of the factors causing the delay in the delivery process is the warehouse's layout, which is considered ineffective because it still maintains the warehouse's layout since the warehouse's inception. There needs to be a change in warehouse layout given the increasing number of goods loading activities within the warehouse every day

2. Literature Review

2.1 Layout Facility of Company

Layout Facility can be defined as an activity to plan or arrange an industry's facilities optimally, which includes labor, transportation equipment, production department, raw material storage warehouse, finished material warehouse, and all supporting facilities following the best structural design which consists of this facility. Storage of an item placed on a shelf in accordance with the categories of each product, the goods mixed in the bin can be minimized and other benefits that can reduce lost sales and increase revenue with the FNS (Fast moving, Non-moving and Slow-moving) analysis method in order to determine storage allocation (Arumsari, 2015). Facility design is the activity of evaluating, analyzing, conceptualizing and realizing a system for the manufacture of goods and services, in other words, an arrangement where physical resources are used to make products. Research conducted of Rahman et al., (2018) aims to minimize material handling costs by using the class-based storage method used to determine the layout of equipment and documents in the warehouse capable of reducing the distance of material handling to minimize material handling costs.

The warehouse's layout can be defined as the procedure for regulating facilities- warehouse facilities by optimally utilizing the area to support the smooth production process. Arrangement of factory layout can improve production efficiency and effectiveness so that the planned production capacity and quality can be achieved with the most economical level of cost. The factory layout is a procedure for managing factory facilities by optimally utilizing the area to support the smooth production process (Hidayat, 2012). The layout of the plant is one of the main aspects of the industrial world because it is closely related to the way factory facilities are managed. Optimal factory layout settings will contribute to the smooth operation of all plant operations. This means that a good factory layout can place various facilities and physical equipment on a regular basis to support the work running productively (Zhenyuan et al., 2011). Layout arrangement in a company is one of the strategies used to be able to compete because layout is an important decision that must be made to achieve the efficiency of the long-term operation of a company. A good layout arrangement will result in time, energy, and cost-efficiency can be achieved. Good corporate layout design that can shorten distances and minimize material handling costs to provide greater profits to the warehouse. Weighted distance method can be used to determine the layout of the room that is interrelated with a load distance that is smaller than the initial layout, and this method produces several layout options that can be selected by considering the smallest load distance (Liana, 2017).

2.2 Travel Time

Travel Time from a road section is one of the references that can be used in planning a trip. Estimated travel time information is beneficial for road users to choose travel routes that can make it easier to get to the destination. For this reason, a reliable travel time estimate is needed (Haqqi, 2017). The travel time estimation method can be estimated by direct surveys in the field and can also be obtained from travel time modeling. The average speed of time is the average speed of all vehicles that pass a point from the road during a certain period. The travel time estimation method provides information to determine the traffic flow conditions on the highway. Travel time can be estimated by measuring directly called the direct method or by measuring traffic variables such as speed, occupancy and flow to estimate travel time. Travel time can be done directly or indirectly. The Direct Method measures travel time using vehicle probes, records at toll stations, collecting tracking for cell-phones, and many other technologies. The indirect method of travel time uses the required traffic volume, speed, and occupancy in a point sensor (Cheng et al., 2019).

The travel time measurement model used in this study is the Instantaneous Model which is included in the indirect methods and part of theoretical techniques. Instantaneous Model is a method of estimating travel time that uses local speed data collected from each link at the time k. The travel time for each link is calculated as the length of the link divided by the average speed at the upstream and downstream links, with the following formulation:

$$t(i, k) = 2li/(v(i,k) + v(ib,k)) \quad (1)$$

With:

Li = Link length (km)

v (a, k) = Speed upstream of link i at time k (km/hour)

v (ib, k) = Speed downstream of link i at time k (km/hour)
t (i, k) = Travel Time

2.3 Weighted Distance Method

The weighted-distance method is a mathematical model used to evaluate the layout based on proximity factors. The application of this method can be made using Euclidean distance or rectilinear distance. Euclidean distance is the distance measured straight between the center of one facility and the center of another facility. Euclidean distance measurement systems are often used because they are easier to understand and easy to use (Muslim and Ilmaniati, 2018). Examples of applications in several conveyor models, as well as transportation and distribution networks (Pratiwi et al., 2012). Calculate the rectilinear distance between i and j as follows

$$dij = \sqrt{[(x2-x1)^2 + (y2-y1)^2]} \quad (2)$$

$$dij = |xa| + |yb| \quad (3)$$

Rectilinear distance is measured along the path using a line perpendicular to one another. An example is a material that moves along a rectangular aisle in a factory (Ekoanindiyo and Wedana, 2012).

3. Methods

The problem-solving step in this research is to design an alternative layout with the weighted distance method and compare the results of the calculation of his travel timeline with the initial layout.

3.1 Data Collection

A framework is structured to provide direction in researching to facilitate in determining the steps to achieve goals. In this study, the main objective is to minimize travel time service within the warehouse by rearranging the warehouse's layout using the weighted distance method approach.

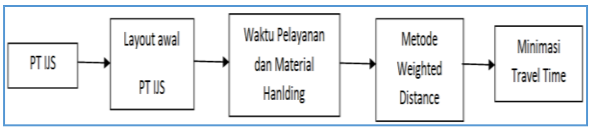

Figure 1. Framework for IJS

Data needed in this research are as warehouse data (profile, location, scope, initial warehouse layout), schedule data and amount of loading, the data flow of delivery activities within the warehouse, data frequency and flow of activities loading goods and data processing time of activities loading goods.

After the data has been collected, data processing is carried out by calculating the travel time required based on the initial layout. Then use the weighted distance method approach to determine the proposed warehouse layout and calculate travel time based on the proposed layout. The final step is to compare travel time between initial layout and travel time calculation using the proposed layout. The method used to solve one problem formulation is the Weighted Distance Method. The method used consists of several artistry sequences, which are: first warehouse information likely initial warehouse layout and warehouse layout, data on warehouse space and facilities, travel time data at the initial layout, and Frequency of flow and movement of goods. Second, material handling flow, namely data flow patterns of materials at PT IJS and activity relationships with the degree of closeness between rooms. Third, the proximity matrix is an activity, which is a table that gives a relative measure of the importance of each pair of spaces that are located close together. Fourth, the availability of space is a facility data contained in the room to obtain the required area data. Fifth, the design of new layouts by developing a block plan considers the frequency of material handling and the proximity matrix of the activity of each space and method Evaluation, the comparison between the initial layout and the new layout with the results that can minimize travel time.

4. Results

4.1 Warehouse information

PT IJS is a service warehouse engaged in logistics. PT IJS serves several logistical activities in the Surabaya area and surrounding areas. PT IJS is supported by various transportation facilities and equipment that are complete and new Figure 2. For logistics activities, PT IJS serves a variety of activities, the main ones being container depots and bonded warehouse rentals (PLB). The following is the initial layout of PT IJS that is directly related to the loading of goods.

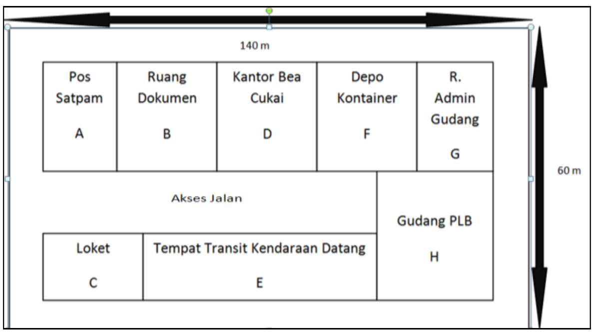

Figure 2. The initial layout of the PT IJS Warehouse

4.2 Process Flow Activity Loading

Duration of the activity, which is used as a research reference, is the result of the average length of loading process for 20 working days in July 2019 the following is the observation result data for the length of time for processing activities in each department.

Table 2. Data Processing Time for Goods Loading

No	Location	Activities	Executing	Length of Process
1	A	Licensing and Checking Process Vehicle License Letter	and Container Driver	5 Minutes
2	B	Making Customs Document	Admin Customs	30 minutes
3	C	Picking up queue stuffing numbers and checking document	Admin Counter	10 minutes
4	D	Legalization process Documents and taking customs seals	Customs officers	10 minutes
5	E	Waiting place to be ready to be called stuffing according to the order number	Security guard	1 hour
6	F	Picking up a container which will be used according to the	Operator Reachtruck waypoint	5minute
7	G	Making travel document and finalizing the document	warehouse Admin	30 minutes
8	H	Process stuffing	Warehouse Officers	1 hour
	Total time once stuffing activity			3 hours 30 minutes

Table 2. Travel Time Data Between Departments

From Travel time to department (s)								
	A	B	C	D	E	F	G	H
A	-	60	60	120	120	180	240	250
B		-	60	60	60	120	180	190
C			-	120	120	180	250	260
D				-	60	60	120	130
E					-	100	130	120
F						-	60	70
G							-	60
H								-

To find out the travel time needed to reach department one to another department then carried out observation and measurement of travel time in the field. Travel time between locations is obtained from the average time required by an officer of each department to travel from one department to another. The travel time data above is used as a reference for determining travel time for each move between departments in the initial layout and layout. Table 2 describes the flow process between departments at PT IJS with the required travel time from one department to another based on the current layout.

4.3 Proximity Matrix

Table 3. Proximity Matrix between Department

Interaction between spaces								
	A	B	C	D	E	F	G	H
A	-	2	4	1	3	2	2	2
B		-	2	5	1	2	5	3
C			-	2	4	3	3	2
D				-	1	2	3	2
E					-	4	3	4
F						-	2	4
G							-	5
H								-

Table 4. Degree of Proximity, Weight, and Description of Proximity

No	Degree of Proximity	Weights	Descriptions of reasons
1	The absolute need to be brought closer	5	There is a flow of essential documents and joint contact
2	Essential to be brought closer	4	Frequently transferring documents and contacts together
3	Fair/ordinary	3	There are contacts and documents moving
4	Not important brought together	2	Rarely make contact together
5	Not desired to be brought closer	1	There is no transfer of documents and joint contact

Based on the analysis of the proximity matrix above, information can be obtained as follows:

1) The Departments that must be placed close together, namely departments B and G, B and D, G, and H.
2) Departments that should not be brought closer to are departments A and D, B, and E.
3) Departments that can be closer are departments A and C, C and E, E with F with H.

4) Departments that do not need to be closer are departments A to B, F, G, H. Department B with C, F. Department C with D, H. Department D with F, H. Department F with G.
5) For the proximity of other departments, the yellow proximity matrix is optional; that is, it can be moved or not moved.
6) Note from PT IJS that for department H, the central warehouse must not be moved because the facilities and structure of the building are permanent and cannot be moved.

4.4 Arrange Plan Alternative and Layout

Block plan is a design that is used to arrange a department block or space by showing the placement of each of these rooms. Based on the information on the availability of space that has been obtained from observations and considering the proximity matrix between departments, a block plan can be prepared as a more natural reference to determine the proposed layout. The compilation of the current block plan based on the current layout is figure 4.

<table>
<tr><td>A</td><td>B</td><td>D</td><td>F</td><td>G</td></tr>
<tr><td>C</td><td colspan="3">E</td><td>H</td></tr>
</table>

Figure 4. Block Plan Based Layout Initial

Based on current block plan and matrix proximity it can be arranged proposed block plan first with the record department H or warehouse must not be moved as in the prior information and taking into account the conclusions 1 and 2 in the matrix proximity, i.e.:

1. Ministry to be placed adjacent, namely departments A and C, C and E, E with F with H.
2. Departments that should not be approached are departments A with B, F, G, H. Departments B with C, F. Departments C with D, H. with D with F, H. Departments F with G.

The above considerations are implemented in the first proposed block plan as figure 5.

<table>
<tr><td>A</td><td>D</td><td>B</td><td>G</td><td>F</td></tr>
<tr><td>C</td><td colspan="3">E</td><td>H</td></tr>
</table>

Figure 5. Proposed Block Plan

The next step is to design the proposed block plan into a proposal layout according to the department's needs and the availability of available space. Based on the needs of each space, the first proposal layout can be arranged based on the proposed block plan.

4.5 Method Evaluation

Determine whether the proposed block plan is acceptable or not, we evaluate the method weighted distance by measuring rectilinear distance (d) and weighting distance (wd). To calculate rectilinear distance using the following formula:

$$dij = |xa| + |yb| \text{ multiplying the} \quad (4)$$

while the weighting distance (wd) is obtained by distance (d) by the proximity factor (wd). So we get the formula of distance weighting or weighted distance as follows:

$$wd = (d) * (w) \quad (5)$$

based on the formula above, we obtain the value (wd) for each relationship between departments as table 5.

Table 5. Results of Calculation of Weighted Distance

Spaces	Proximity factor, (w)	Current Block Plan		Proposed Block Plan I	
		Distance (d)	Wd score	Distance (d)	Wd Score
A,B	2	1	2	2	4
A,C	4	1	4	1	4
A,D	1	2	2	1	1
A,E	3	2	6	2	6
A,F	2	3	6	4	8
A,G	2	4	8	3	6
A,H	2	5	10	5	10
B,C	2	1	2	3	6
B,D	5	1	5	1	5
B,E	1	1	1	1	1
B,F	2	2	4	2	4
B,G	5	3	15	1	5
B,H	3	4	12	3	9
C,D	2	3	6	1	2
C,E	4	2	8	2	8
C,F	3	3	9	4	12
C,G	3	4	12	3	9
C,H	2	4	8	2	4
D,E	1	1	1	1	1
D,F	2	1	2	3	6
D,G	3	2	6	2	6
D,H	2	3	6	4	8
E,F	4	2	8	3	12
E,G	3	3	9	2	6
E,H	4	3	12	3	12
F,G	2	1	2	1	2
F,H	4	1	4	1	4
G,H	5	1	5	1	5
Total Load Distance (LD)			175		166

Based on the results of calculations and analysis weighted distance for each relationship between departments, the value Load distance for the current block plan is LD = 175 while for the proposed block plan, value obtained Load Distance of LD = 166 is. From this value, it can be concluded that the first proposed block plan is acceptable because the LD value of the proposed block plan is smaller when compared to the LD Current block plan. A load distance smaller value indicates the efficiency obtained because the workload during the activity will be lower because the distance between departments that are interrelated is closer and the distance of departments that are not related farther

5. Discussion

Find out the travel time minimization that occurs in alternative layouts, and it is necessary to calculate the travel time for the initial layout. Because travel time is the total time in stuffing activities, the definition of travel time is the accumulation of the travel time and duration of the activities in each department, so the above formula can be derived as follows:

T total = T process + T travel time (6)

With, T Process (1,2)

= (2X (1,2))/(v (1) + v (2)) (7)

T (1,2) = (2D (1,2))/(v (1) + v (2))

+ T travel time (8)

with V (1) = X1/t1 , V (2) = X2/t2 (9)

a complete formula forobtained travel time is:

T (1,2) = (2D (1,2))/(X1/t1+X2/t2)

+ T travel time (10)

with:
T t = travel time total(s)
T p = activity processing time (s)
T travel timetravel = time between departments (s)
D = Distance between departments (m)
V(1) = Process activity speed in department 1 (m / s)
V(2) = Process activity speed in department 1 (m / s)
X1 = length of department room (1)
X2 = length of department room (2)
t1 = processing time of activities dementement (1)
t2 = processing time of department activities (2)

Based on the formula above, the calculation results can be obtained travel time according to the flow of stuffing activities for the initial layout at PT IJS. The result of the calculation of travel time at the initial layout is T = 2002 second, and then these results are compared with the travel time at an alternative layout. In the alternative layout, there is a change in travel time due to the transfer of department B with department F that moves position or location, calculated the total travel time on the alternative layout using the same formula.

Table 6. Data of Travel Time

D 1	D 2	D(1,2) (m)	X(1) (m)	X(2) (m)	t(1) (s)	t(2) (s)
A	C	1	25	15	300	600
C	E	2	15	75	600	3600
E	F	2	75	35	3600	300
F	H	1	35	50	300	3600
G	H	1	20	50	1800	3600
H	G	1	50	20	3600	1800
G	B	3	20	30	1800	1800
B	D	1	30	30	1800	600
D	G	2	30	20	600	1800
G	C	4	20	15	1800	600
C	A	1	15	25	600	300
Total		19	335	365	16800	18600

Table 7. Calculation of Travel Time Layout

V(1) (m/s)	V(2) (m/s)	T(1,2) (s)	T (1,2) (s)	T(1,2) (s)
0,0833	0,0250	18	60	78
0,0250	0,0208	87	120	207
0,0208	0,1167	29	100	129
0,1167	0,0139	15	70	85
0,0111	0,0139	80	60	140
0,0139	0,0111	80	60	140
0,0111	0,0167	216	180	396
0,0167	0,0500	30	60	90
0,0500	0,0111	65	120	185
0,0111	0,0250	222	250	472
0,0250	0,0833	18	60	78
0,3847	0,3875	862	1140	2002

And the calculation results for alternative travel time are obtained in table 8. Based on the calculation results travel time above, the value obtained travel time on the alternative layout is T = 1667 seconds. From these results, when compared to the travel time at the initial layout, T = 2002 a larger second so that the minimization obtained travel time of 335 seconds is an alternative layout is applied

Table 8. Calculation of Time Alternative Layout

V (1) (m / s)	V (2) (m / s)	T (1,2) P (s)	T (1,2) t (s)	T (1.2) total (s)
0,0833	0,0250	18	60	78
0,0250	0,0208	87	120	207
0,0208	0,1167	44	130	174
0,1167	0,0139	15	60	75
0,0111	0,0139	80	70	150
0,0139	0,0111	80	70	150
0,0111	0,0167	72	60	132
0,0167	0,0500	30	60	90
0,0500	0,0111	65	120	185
0,0111	0,0250	166	180	346
0,0250	0,0833	18	60	78
0,3847	0,3875	677	990	1667

6. Conclusions

Based on the results of data processing and discussion, this study produced an alternative layout proposal for PT IJS that could maximize the loading of goods within the warehouse. Calculation of travel time at the initial layout of T = 2002 second while the alternative layout produces a value of T = 1667 second, this shows that the alternative layout of the proposal succeeded in minimizing travel time. Then it can be suggested to PT IJS to use an alternative layout in this study to rearrange the layout of the warehouse. Further research is needed regarding the use of the weighted distance method to minimize the cost of material handling in the warehouse. Calculation of travel time is still rarely used in determining the length of time a service company and needed regarding the minimization of travel time in determining service time.

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