Design of warehouse model with dedicated policy to minimize total travel costs: a case study in a construction workshop

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Abstract. Warehousing is one of the many important activities in a company. One of the important things in managing the warehouse is how to store finished or semi-finished goods, raw materials, spare parts, equipment, or other goods in the right location to minimize total travel costs inside the workshop. In a workshop construction company usually uses a raw material in a big size and the cost of moving a big size usually need a high cost also. Dedicated storage policy becomes an option to make a model where the material should be store inside the warehouse. A mathematical model as an Integer Linear Programming problem used to model the case problem. LINGO 17 used to solve the mathematical model in this research. The model can find the optimal solution in a fast time. The minimum total travel cost in this research resulted from LINGO is IDR 17,326,320,000. Minimizing warehouse operation cost will also minimize the total company operation cost, mean higher profit will be got by the company.

1. Introduction

There are so many functions of the warehouse; the main function is used as temporary storage for goods or warehousing, it seems like a non-value-added activity, but the warehouse can also be used for some value-added activity, likes product packaging process inside a warehouse [1]. As warehousing, the warehouse can store finished or semi-finished goods, raw materials, spare parts, equipment, or other goods that support the activities of a company. The warehouse needs to be managed properly, so it can minimize the search time for goods to reduce overall warehouse operating costs.

There are several policies in creating a warehouse layout that is used to store products, here five common policies: There are random storage policy, dedicated storage policy, cube-per-order-index policy, class-based storage policy, and shared storage policy [2]. Each policy has advantages and disadvantages; a designer needs to maximize the advantages of the policy when he creates a layout.

In a workshop construction company usually uses a raw material in a big size and the cost of moving a big size usually need a high cost also. When some big size materials are placed in the same place, the level of difficulty in selecting and moving material will be high because it will stack each other, so in this case, we need a dedicated place for each material. Dedicated storage policy becomes an option in this case. Two important points in warehouse management, there are a time for searching and handling material; and the location where the materials should be stored [3].

The purpose of this research is to create a warehouse layout that minimizes total travel costs. There are so many methods to get a good layout that minimizes total travel costs, including optimization [4], heuristic, or metaheuristic algorithm [5], simulation, and others. Some more complex systems will be easier when describing it in the simulation model [6]. In this research, we used a linear programming model to get an optimal layout. Lingo 17 used to solve the mathematical model in this research.
2. Methodology

This section explains the data collection, which is needed in this research. The method, which is used in this research, also explains in this section.

2.1. Data Collection

There is some data, which is needed, including existing warehouse layout, types of materials, materials space requirement, frequency trip of the materials, the distance between storage spaces inside the warehouse, and the cost of moving materials. The warehouse has 24 storage spaces, which is used to store materials; it also has two doors as I/O points. There are 14 types of materials, which need to store inside the warehouse, the storage spaces requirement and the frequency trips of materials are shown in Table 1. The distance between storage spaces inside the warehouse and the cost of moving materials are shown in Tables 2 and 3. The cost of moving material is collected from an interview with the company, including operation cost, worker's salary, the overhead of material handling and building, assurance, and taxes.

| Type of Material | n | Storage Spaces Requirement | Frequency Trips from I/O points |
|------------------|---|-----------------------------|-------------------------------|
|                  |   |                             | 1                             |
| Material-1       | 4 |                             | 13514                         |
| Material-2       | 2 |                             | 59                            |
| Material-3       | 1 |                             | 5                             |
| Material-4       | 1 |                             | 9647                          |
| Material-5       | 1 |                             | 43                            |
| Material-6       | 1 |                             | 15421                         |
| Material-7       | 4 |                             | 27                            |
| Material-8       | 1 |                             | 5                             |
| Material-9       | 4 |                             | 11                            |
| Material-10      | 1 |                             | 9                             |
| Material-11      | 1 |                             | 32                            |
| Material-12      | 1 |                             | 4                             |
| Material-13      | 1 |                             | 3                             |
| Material-14      | 1 |                             | 2                             |

Table 2. The distance (in meter) between storage spaces with I/O points

| I/O Point | Storage Space |
|-----------|---------------|
|           | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
| 1         | 6  | 6  | 6  | 6  | 12 | 12 | 12 | 12 | 18 | 18 | 18 | 18 |
| 2         | 36 | 36 | 36 | 36 | 30 | 30 | 30 | 30 | 24 | 24 | 24 | 24 |
2.2. Method
We use a linear mathematical model to minimize the total cost of moving material, which satisfies a dedicated storage policy [2]. Then we use LINGO solver version 17 to solve the model. Below the formula:

Minimize

\[
f(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[ \frac{\sum_{k=1}^{p} c_{ik} f_{ik} d_{kj}}{S_i} \right] x_{ij}
\]

Subject to

\[
\sum_{j=1}^{n} x_{ij} = S_i \quad i=1,2,...,m
\]
\[
\sum_{i=1}^{m} x_{ij} = 1 \quad j = 1,2 \ldots n
\]  
(3)

\[
x_{ij} = (1,0) \quad i=1,2 \ldots, m \quad j = 1,2 \ldots n
\]  
(4)

Parameters,
- \(C_{ik}\) Cost of moving material \(i\) through I/O point \(k\)
- \(f_{ik}\) Frequency trips of material \(i\) through I/O point \(k\)
- \(d_{kj}\) The distance of location \(j\) from I/O point \(k\)
- \(S_i\) Storage spaces required by material- \(i\)

Decision variable
\[
x_{ij} = \begin{cases} 
1 & \text{if material } i \text{ store in location } j \\
0 & \text{otherwise}
\end{cases}
\]

Eq. (1) presents the objective function of the model is to minimize the total cost of moving all material through I/O point \(k\) until \(p\). The Eq. (2) guarantees the spaces required by materials. The Eq. (3) is an assignment problem. It has integer values for the result.

3. Result & discussion
The formulation in this research is the PILP (Pure Integer Linear Program) Problem. Another research used MILP (Mixed Integer Linear Program) [7]. We used a computer with intel i3 processors and 12 GB of RAM to run the LINGO in global solver mode. Then we have the result in 1 second of time. The minimum total travel cost resulted from LINGO is IDR 17,326,320,000. A partial result of the LINGO shown in figures one and Table 4.

**Figure 1.** Summary of the LINGO
Table 4. The Lingo Result for Material's Storage Locations

| Type of Material | Storage Location   |
|------------------|--------------------|
| Material-1       | 1; 3; 5; 8         |
| Material-2       | 7; 10              |
| Material-3       | 23                 |
| Material-4       | 2                  |
| Material-5       | 9                  |
| Material-6       | 4                  |
| Material-7       | 11; 12; 15; 16     |
| Material-8       | 14                 |
| Material-9       | 17; 18; 19; 20     |
| Material-10      | 13                 |
| Material-11      | 6                  |
| Material-12      | 24                 |
| Material-13      | 22                 |
| Material-14      | 21                 |

4. Conclusion
The model can find the optimal solution in a fast time. This model is simple, but it can find the optimal solution; it also reliable for solving the real case with some assumptions. The minimum total travel cost in this research resulted from LINGO is IDR 17,326,320,000. Minimizing warehouse operation cost will also minimize the total company operation cost, mean higher profit will be got by the company.

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