Warehouse Layout Designing of Slab Using Dedicated Storage and Particle Swarm Optimization

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Abstract— Warehouse is a supporting facility and has the important role in the production system. Goods warehouse arrangement is an activity based on related/rationale reason. There are several policies in random storage, fixed or dedicated storage, and class-based storage. We conducted this study in XYZ Company which the main business is producing steel. In this research, dedicated storage and particle swarm optimization will be used in the layout design of slab raw material warehouse to obtain the best layout to minimize material handling cost. Based on the result of the research, particle swarm optimization method gives the best layout result with the least material handling cost compared to the existing layout and layout using dedicated storage method.

1. Introduction
A warehouse is one of supporting and an important part of a production system. Good conditions and arrangements in the warehouse are expected to avoid corporate losses and minimize the costs incurred and speed up operations and services at the warehouse. Storage process can be performed by different storage policies. The most used and preferred policies can be given as randomized storage policy, the dedicated storage policy, and class-based storage policy. The randomized storage policy is performed by the allocation of the storage location based on the available space at the time of the storage job. Storage decision is left to the operator in another word. A dedicated storage policy determines a particular predetermined location for each product to be stored. A class-based storage policy is a common and shared policy between randomized and dedicated policies. It divides goods into classes based on some criteria and each class is assigned a block of storage locations. This policy can be called as ABC zoning [1]. Hot Strip Mill (HSM) is one of XYZ which produces the hot rolled coil with the raw material of slab steel. In the period 2016-2017. XYZ has to order raw material of slab steel as much as 2,777,089 tons, in 2018. PT. XYZ plans to increase its production capacity so as to support its new warehouse to store raw material of slab steel bar. PT. XYZ has been doing soil dredging which will be used as outer warehouse 04 to store 20 types of grades and length groups of raw materials of different slabs with 83,070.12 m2.

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Currently, outer warehouse 04 has no specific rules applied to arrange the placement and preparation of raw material steel slabs (slab). As there is rules, the raw material storage is arbitrary. In order to have an efficient warehouse layout which saves storage space, has short material handling distance and low material handling costs, the method of dedicated storage and particle swarm optimization (PSO) are applied to obtain the best layout.

The dedicated storage method of compiling the product is based on the comparison of the activity of each product to the required space required by the product and then obtained the order of products from the largest to the decimated. Whereas, A particle swarm optimization (PSO) algorithm as a metaheuristic algorithm was developed for determining the optimal layout.

2. Literature Review

2.1. Warehouse

The function of a production warehouse is to store raw materials, work-in-process and finished products, associated with a manufacturing and/or assembly process. Raw materials and finished products may be stored for long periods. This occurs for example when the procurement batch of incoming parts is much larger than the production batch, or when the production batch exceeds the customer order quantity of finished products [2]. The warehouse design is a complex task because of the interaction and relationships between each of the activities in warehouses [3]. The warehouse plays a role in supporting a company's supply chain success. The mission of warehouse is to effectively ship product in any configuration to the next step in the supply chain without damaging or altering the product's basic form. Numerous steps must be accomplished and hence there are key warehousing opportunities to address. Doing that will optimize the methods used to achieve the mission. If the warehouse cannot process orders quickly, effectively, and accurately. Then a company's supply chain optimization efforts will suffer. All warehousing opportunities, including improving order picking operations, utilizing cross-docking, increasing productivity, utilizing space and increasing value-added services [4].

2.2. Storage Policy

Storage process can be performed by different storage policies. The most used and preferred policies can be given as randomized storage policy, a dedicated storage policy, and class-based storage policy.

Randomized Storage Policy: The randomized storage policy is performed by the allocation of the storage location based on the available space at the time of the storage job. Storage decision is left to the operator in another word. With a pure randomized storage system each unit of particular product is equally likely to be retrieved when retrieval operation is performed; likewise, each empty storage slot is equally likely to be selected for a storage operation is performed.

Dedicated Storage Policy: With dedicated storage policy a particular set of storage slots or location is assigned to the specific product; hence, a number of slots equal to the maximum inventory level for the product must be provided. The Warehouse layout problem considered involves the assignment of products to storage locations in the warehouse. One of the advantages of dedicated storage is the data-handling efficiency due to the fixed addressing of storage items [5]. In order to minimize the total expected distance travelled the following approach is taken. [4]

\[ \sum_{i=1}^{q} \sum_{j=1}^{n} \frac{D}{S_j} \]

The following notation is used:

- \( q \) = number of storage locations
- \( n \) = number of products
Sj = number of storage locations required for product j

Tj = number of trips in/out of storage for product j. that is, the throughput of product j

An approach is presented for determining the optimum dedicated storage; rectilinear travel is assumed. The rectilinear travel can be formulated as follows:

\[ d_{ij} = |x_i - x_j| + |y_i - y_j| \]  

The following notation is used:

- \( d_{ij} \): distance Traveled
- \( x_i \): coordinate x for point 1
- \( x_j \): coordinate y for I/O
- \( y_i \): coordinate x for point 1
- \( y_j \): coordinate y for I/O

**Class-Based Storage Policy:** A class-based storage policy is a common and shared policy between randomized and dedicated policies. It divides goods into classes based on some criteria and each class is assigned a block of storage locations. This policy can be called as ABC zoning [1]. Each class is then assigned to a dedicated area of the warehouse. Storage within an area is random. The advantage of this policy is that fast moving products can be stored close to the depot while the flexibility and high storage space utilization of random storage are applicable [6].

### 2.3. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a stochastic optimization technique and also a population-based search algorithm first proposed by Eberhart and Kennedy (1995). It is a population-based search method that is inspired by the social behavior of organisms such as bird flocking or fish schooling. A brief and complete survey on PSO mechanism, technique, and application is provided by Kennedy and Eberhart (2001) [7].

Each particle has got a velocity, a memory, and informants. The positions and the velocity of the first population of particles are generated randomly. To decide to move, the particle needs four pieces of information: her actual velocity, her best performance and the best performance of her neighbors. It is based on three parameters \( w \), \( c_1 \), and \( c_2 \) which allow them respectively either to follow its own path, retrace his steps, or follow the best neighbor [8].

In PSO, each particle included by social structure keeps in mind its best position and uses this as a factor affecting its speed. A particle gains speed toward its individual best position considering with how far away from that point. It also shows the same behavior for the global best position. In other words, while it is scanning the surface, it is affected by the global best position and adjusts its own speed. In the situation of that, it is far from the global best position, there will be a higher change in its speed and direction [1].

Each individual (particle)’s speed changes according to the formula:

\[ V_{t+1} = wV_t + c_1r_1(p_t - x_t) + c_2r_2(g_t - x_t) \]  

The following notation is used:

- \( V_{t+1} \): velocity of particle i. area j on t+1th iteration
- \( V_t \): velocity of particle i. area j on t-1th iteration
- \( w \): inertia weight pada iterasi t-1
xtij : position value of particle i. area j on tth iteration
xt-1ij : position value of particle i. area j on t-1th iteration
pt-1ij : personal best of particle i. area j on t-1th iteration
gt-1j : global best of particle i. area j on t-1th iteration
c1 , c2 : cognitive and social parameter
r1 , r2 : random uniform [0, 1]

Inertia value of the equation changes on each iteration. This change is based on the logic of decreasing from the value determined to a minimum value according to inertia function. The objective is to converge the created speed by diminishing on the further iterations; hence more similar results can be obtained.

Inertia function is obtained as follows:

\[ w_t = w_{t-1} \times \alpha \]  

(4)

The following notation is used:

- \( w_t \) : inertia weight tth iteration
- \( w_{t-1} \) : inertia weight t-1th iteration
- \( \alpha \) : decrement factor

Positions of the particles change by speeds as shown in Eq. (5)

\[ x_{tij} = x_{t-1ij} + v_{tij} \]  

(5)

3. Research method

In this section, the stage in problem-solving is described in the following flowchart.

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Figure 1. Flow Chart of Dedicated Storage Method
In proposal 2 layout of outer warehouse 04 is utilizing particle swarm optimization method. The problem-solving path using the particle swarm optimization method is as shown in Figure 2. The PSO method for designing the outer warehouse layout 04 is implemented using MATLAB software. The parameters used are the population (swarm size) of 50 particles. Maximum generation is 1000 Cognitive parameters (c1) and social parameters (c2) are 2 and inertia weight (w) of 0.9.

4. Results
The following is the results obtained on proposals 1 and 2 of the outer warehouse layout 04 using dedicated storage and particle swarm optimization methods

![Flow Chart of Particle Swarm Optimization Method](image)

**Figure 2.** Flow Chart of Particle Swarm Optimization Method

4.1 Dedicated Storage
Layout placement using dedicated storage method is based on the comparison between throughput with space requirement every type of slab.
Table 1. Ranking of throughput over space requirement

| No. | Slab  | Space Requirement | Throughput | T/S  |
|-----|-------|--------------------|------------|------|
| 1   | F1.1  | 4                  | 24         | 6    |
| 2   | G.1   | 2                  | 4          | 2    |
| 3   | J.1   | 4                  | 7          | 1.75 |
| 4   | D1.3  | 88                 | 151        | 1.715909 |
| 5   | C.1   | 71                 | 117        | 1.647887 |
| 6   | A.3   | 46                 | 74         | 1.608696 |
| 7   | F1.3  | 120                | 156        | 1.3  |
| 8   | J.3   | 20                 | 26         | 1.3  |
| 9   | A.1   | 73                 | 91         | 1.246575 |
| 10  | K.1   | 18                 | 22         | 1.222222 |
| 11  | M1.3  | 78                 | 93         | 1.192308 |
| 12  | H2.3  | 64                 | 76         | 1.1875 |
| 13  | D.3   | 57                 | 60         | 1.052632 |
| 14  | K.3   | 91                 | 88         | 0.967033 |
| 15  | C.3   | 429                | 396        | 0.923077 |
| 16  | G1.3  | 46                 | 42         | 0.913043 |
| 17  | H.3   | 72                 | 65         | 0.902778 |
| 18  | M1.1  | 51                 | 46         | 0.901961 |
| 19  | D1.1  | 48                 | 41         | 0.854167 |
| 20  | G.3   | 711                | 539        | 0.758087 |

The outer warehouse layout 04 is designed based on the result of the throughput ratio and the space requirement from the largest to the smallest and closest to the outer door of the warehouse 04. The following is the layout of proposal 1 outsourced warehouse 04 using the dedicated storage method. The design of the second proposal of warehouse layout is using the particle swarm optimization method which requires several steps, such as preparing the total distance input matrix for each slab. determines parameters for particle swarm optimization algorithm. The results obtained from MATLAB as shown in Figure 3.

```matlab
ans =
Columns 1 through 8
1000   5  2  19  11  12 4  14
Columns 9 through 16
1  18  7  10 20  6  3  16
Columns 17 through 22
13  17  9  8  18  24198
My PSO program took 6.082945 seconds to run.
```

**Figure 3. Output Particle Swarm Optimization**
Based on the Figure above, we obtained the sequence of location based on the best objective fitness value should be placed close to the outer door of the output 04 or the entrance of the HSM warehouse location are: 5 – 2 – 19 – 11 – 12 – 4 – 14 – 1 – 15 – 7 – 10 – 20 – 6 – 3 – 16 – 13 – 17 – 9 – 8 – 18 with the types : K.3 – F1.1 – F1.3 – K.1 – H.3 – J.3 – C.1 – D1.1 – M1.3 – G.1 – D1.3 – J.1 – A.1 – H2.3 – C.3 – G1.3 – G.3 – M1.1 – A.3 – D.3. The objective fitness value for each of generation is shown in Figure 4.

![Graph showing objective fitness value vs generation](image)

**Figure 4.** Objective Fitness Every Generation of PSO

### 4.2 Total Distance Travelled

The calculation of distance travelled using the rectilinear method. That distance is measured along the path by using a perpendicular (orthogonal) line with each other. Here is the distance of each area trip to the input point on the existing layout:

| From | X    | Y    | To  | X    | Y    | Distance (m) |
|------|------|------|-----|------|------|--------------|
| Input | WH.04| 0    | 286.70 | 625.89 | 26.54 | 886.048      |
|      | 0    | 286.70 | A.1  | 625.89 | 25.40 | 838.188      |
|      | 0    | 286.70 | A.3  | 576.89 | 25.40 | 838.188      |
|      | 0    | 286.70 | C.1  | 531.39 | 26.45 | 791.638      |
|      | 0    | 286.70 | C.3  | 368.56 | 27.24 | 628.015      |
|      | 0    | 286.70 | D.3  | 224.55 | 27.50 | 483.746      |
|      | 0    | 286.70 | D1.1 | 93.00  | 91.60 | 288.098      |
|      | 0    | 286.70 | D1.3 | 359.74 | 53.10 | 593.334      |
|      | 0    | 286.70 | F1.1 | 370.54 | 52.20 | 605.031      |
|      | 0    | 286.70 | F1.3 | 328.04 | 58.50 | 556.236      |
|      | 0    | 286.70 | G.1  | 285.54 | 50.10 | 522.130      |
|      | 0    | 286.70 | G.3  | 124.34 | 54.46 | 356.580      |
|      | 0    | 286.70 | G1.3 | 513.89 | 54.45 | 746.140      |
|      | 0    | 286.70 | H.3  | 60.50  | 91.60 | 255.598      |
| From | X   | Y   | To  | X   | Y   | Distance (m) |
|------|-----|-----|-----|-----|-----|--------------|
| A.1  | 625.89 | 26.54 | 659.39 | 0.00 | 60.041 |
| A.3  | 576.89 | 25.40 | 659.39 | 0.00 | 107.901 |
| C.1  | 531.39 | 26.45 | 659.39 | 0.00 | 154.451 |
| C.3  | 368.56 | 27.24 | 659.39 | 0.00 | 318.074 |
| D.3  | 224.55 | 27.50 | 659.39 | 0.00 | 462.343 |
| D1.1 | 93.00  | 91.60 | 659.39 | 0.00 | 657.991 |
| D1.3 | 359.74 | 53.10 | 659.39 | 0.00 | 352.755 |
| F1.1 | 370.54 | 52.20 | 659.39 | 0.00 | 341.058 |
| F1.3 | 328.04 | 58.50 | 659.39 | 0.00 | 389.853 |
| G.1  | 285.54 | 50.10 | Output WH 04 | 659.39 | 0.00 | 423.959 |
| G.3  | 124.34 | 54.46 | 659.39 | 0.00 | 589.509 |
| G1.3 | 513.89 | 54.45 | 659.39 | 0.00 | 199.949 |
| H.3  | 60.50  | 91.60 | 659.39 | 0.00 | 690.491 |
| H2.3 | 660.55 | 30.17 | 659.39 | 0.00 | 31.329 |
| J.1  | 278.54 | 52.20 | 659.39 | 0.00 | 433.059 |
| J.3  | 68.38  | 50.25 | 659.39 | 0.00 | 641.267 |
| K.1  | 669.89 | 54.45 | 659.39 | 0.00 | 64.949 |
| K.3  | 624.38 | 53.40 | 659.39 | 0.00 | 88.414 |
| M1.1 | 565.89 | 54.45 | 659.39 | 0.00 | 147.951 |
| M1.3 | 56.50  | 102.76 | 659.39 | 0.00 | 705.654 |
| **TOTAL** | | | | | | **6861** |

**Table 4.** Total distance each area to output point in based on PSO algorithm

| From | X   | Y   | To  | X   | Y   | Distance (m) |
|------|-----|-----|-----|-----|-----|--------------|
| A.1  | 533.39 | 4.20 | 659.39 | 0.00 | 130.201 |
| A.3  | 570.89 | 25.40 | 659.39 | 0.00 | 113.900 |
| C.1  | 683.77 | 20.52 | 659.39 | 0.00 | 44.895 |
| C.3  | 315.54 | 27.50 | Output WH 04 | 659.39 | 0.00 | 371.356 |
| D.3  | 559.89 | 53.40 | WH.04 | 659.39 | 0.00 | 152.901 |
| D1.1 | 263.39 | 4.20 | 659.39 | 0.00 | 400.201 |
| D1.3 | 622.89 | 26.45 | 659.39 | 0.00 | 62.950 |
| F1.1 | 651.89 | 4.20 | 659.39 | 0.00 | 11.701 |
### 4.3 Material Handling Cost

The calculation for the total cost of material handling for an existing condition.

| From | To | Distance (m) | Freq. | MH | Cost | Total Cost (IDR) |
|------|----|--------------|-------|----|------|------------------|
| A.1  | WH.0 | 60.041      | 41    | 659.39 | 0.00 | 2.893.365       |
| A.3  |     | 107.901     | 31    | 659.39 | 0.00 | 3.931.473       |
| C.1  |     | 154.451     | 55    | 659.39 | 0.00 | 9.984.401       |
| C.3  |     | 318.074     | 213   | 659.39 | 0.00 | 79.630.173      |
| D.3  |     | 462.343     | 29    | 659.39 | 0.00 | 15.759.118      |
| D1.1 |     | 657.991     | 3     | 659.39 | 0.00 | 2.320.124       |
| D1.3 |     | 352.755     | 61    | 659.39 | 0.00 | 25.291.393      |
| F1.1 |     | 341.058     | 4     | 659.39 | 0.00 | 1.603.460       |
| F1.3 |     | 389.853     | 76    | 659.39 | 0.00 | 34.824.475      |
| G.1  | WH.0 | 423.959     | 1     | 659.39 | 0.00 | 171.142.125     |
| G.3  |     | 589.509     | 247   | 659.39 | 0.00 | 4.935.248       |
| G1.3 |     | 433.059     | 2     | 659.39 | 0.00 | 1.017.998       |
| H.3  |     | 690.491     | 32    | 659.39 | 0.00 | 25.970.358      |
| H2.3 |     | 31.329      | 19    | 659.39 | 0.00 | 699.621         |
| J.1  |     | 433.059     | 2     | 659.39 | 0.00 | 1.017.998       |
| J.3  |     | 641.267     | 10    | 659.39 | 0.00 | 7.537.171       |
| K.1  |     | 64.949      | 6     | 659.39 | 0.00 | 458.032         |
| K.3  |     | 88.414      | 40    | 659.39 | 0.00 | 4.156.729       |
| M1.1 |     | 147.951     | 23    | 659.39 | 0.00 | 3.999.597       |
| M1.3 |     | 705.654     | 23    | 659.39 | 0.00 | 9.076.091       |
| TOTAL|     |             |       |       |      | **3826.006**    |
4.4 Space Efficiency

The calculation of storage space efficiency is

\[
\text{Percent of Efficiency} = \frac{\text{Total Block Area}}{\text{area of space}} \times 100\%
\]

Based on the above calculation obtained the percentage of storage space efficiency on the existing outer warehouse layout 04 is 46.704%. The following is a calculation of the area of each slab area in the proposed layout 1 outside warehouse 04.

| Table 6. Space Efficiency of First Alternative Layout |
|-----------------------------------------------|
| Area | I     | II   | III | IV   | Total Area |
|------|-------|------|-----|------|------------|
| A.1  | 1041.6| 0    | 0   | 0    | 1041.6   |
| A.3  | 655.2 | 0    | 0   | 0    | 655.2    |
| C.1  | 737.111907 | 273 | 0   | 0    | 1010.111907 |
| C.3  | 4641  | 0    | 0   | 0    | 4641     |
| D.3  | 764.396325 | 0  | 0   | 0    | 764.396325 |
| D1.1 | 655.2 | 0    | 0   | 0    | 655.2    |
| D1.3 | 1228.511907 | 0  | 0   | 0    | 1228.511907 |
| F1.1 | 58.8  | 0    | 0   | 0    | 58.8     |
| F1.3 | 1719.9| 0    | 0   | 0    | 1719.9   |
| G.1  | 29.4  | 0    | 0   | 0    | 29.4     |
| G.3  | 4368.74991 | 3003 | 2457 | 9828.74991 |
| G1.3 | 655.2 | 0    | 0   | 0    | 655.2    |
| H.3  | 1092  | 0    | 0   | 0    | 1092     |
| H2.3 | 873.6 | 0    | 0   | 0    | 873.6    |
| J.1  | 58.8  | 0    | 0   | 0    | 58.8     |
| J.3  | 323.4 | 0    | 0   | 0    | 323.4    |
| K.1  | 245.7 | 0    | 0   | 0    | 245.7    |
| K.3  | 491.4 | 764.4 | 0  | 1255.8       |
| M1.1 | 737.1 | 0    | 0   | 0    | 737.1    |
| M1.3 | 1083.6| 0    | 0   | 0    | 1083.6   |
| Total |     |     |     |     | 27958.07 |

5. Analysis and discussion

The total distance obtained in layout proposal 1 using dedicated storage method is 18992.036 m with material handling cost IDR. 340.062.757, the percentage of storage space efficiency obtained in a layout by using dedicated storage method is 46.685%. Placement of all types of slab using particle swarm optimization method based on the best solution search process in the form of moving material handling distance with parameters that have been determined. The sequence generated in the best solution (global best) will serve as a sequence on the placement of the slab in the layout. The first sequence of the slab will be placed at the location which has the smallest distance that is close to the outer warehouse output door 04. The total distance obtained in the layout using the particle swarm optimization method is 18955.780 m with material handling cost of IDR. 334.217.964 and the percentage of storage space efficiency of 48.189%. In the existing layout. The distance obtained is
18945.092 m which is the smallest distance. However, material handling cost is IDR 415,729,255. Thus, the best layout in this research is the proposed 2 layout using particle swarm optimization method because it produces the lowest material handling cost.

6. Conclusion

The best layout in this research is the layout of proposal 2 using particle swarm optimization method because it produces the lowest material handling cost that is IDR 334,217,964.

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