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# REDESIGNING WAREHOUSE LAYOUT BASED ON WAREHOUSE MANAGEMENT SYSTEM POLICY TO MINIMIZE MATERIAL HANDLING COST

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**ABSTRACT**

*The purpose of this research is to propose a solution that minimizes fuel consumption and the average travel distance, and at the same time, maximizes the utilization of forklift usage in the biggest glass manufacturer in Indonesia. The methods are by using Class-Based Storage, Dedicated Storage, and simulation. We simulate 18 scenarios for various assignment policies, the arrival probabilities of entities, and the number of available forklifts. The best scenario is obtained by using Dedicated Storage with a combination of one storage forklift and one delivery forklift.*

**Key words:** Warehouse Management System, Class-Based Storage, Dedicated Storage, Performance Management

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## 1. INTRODUCTION

One of many indicators to measure the performance of an organization is the ability to fulfill orders. To increase customer satisfaction, all units in the company must be integrated to carry out manufacturing, sales, delivery, and warehousing (Corina et al., 2013). Productivity enhancement can be achieved by reducing the picking time and material handling cost, while optimizing the space utilization (Richard, 2014).

The company's warehouse consists of four areas, namely, A, B, C, and SS. The product enters the warehouse starting from the transit area and is delivered and stored in the available locations. When the order arrives, the operator checks and then delivers the product. There are five forklifts in use: three for delivery, one for storage, and the remains for stock keeping. Initially, the company uses the storage randomly. As a result, some problems such as the dispersedly and nonuniform stock arise. In addition, the product is hard to find taking more time for picking and dispatching and is also stored in the warehouse for too long. Material handling cost is also higher, and the forklifts utilization is low as shown in Table 1.

**Table 1**. The Forklift Utilization Data for January until March of 2018.

| Forklift No | Average hour/month | Utilization (%) |
|---|---|---|
| 1 | 168.00 | 23.33 |
| 2 | 153.67 | 21.34 |
| 3 | 167.33 | 23.24 |
| 4 | 236.33 | 32.82 |
| 5 | 214.67 | 29.81 |

Cimino, Longo, and Mirabelli (2010) and Kostrzewski (2016) had studied the warehouse management systems by using simulation. Ouhoud, Guezzen, and Sari (2016) studied the caseby a class-based storage method. For the study of the warehouse management system, Peixoto et al. (2016) also utilized the class-based storage with simulation. Fumi, Scarabotti, and Schiraldi (2013) proposed a dedicated storage method for warehouse management.

## 2. RESEARCH METHODOLOGY

The primary data are resources's speed and time, and the secondary data are the carry-in-product, delivery product, average stock, and etc. We evaluate two warehouse management systems, namely, class-based storage and dedicated storage methods. We begin the research by observing the warehouse to identify and define the performance objectives. And then, we collect the required data, and test them for adequacy and uniformity. When the data meet the criteria, we proceed with the distribution test to the data by using Minitab. Finally, we build, test, and verify the model in ProModel. As for the validation, we perform tests by using $t$- and chi-squares-statistics for two samples.

From the validated model, we measure the performance for material handling cost, travel distance, and resources utilization. The performance is also measured on the revised model, which implements various improvement scenarios.

## 3. DISCUSSION AND ANALYSIS

For building the model, we require the data of the arrivals, forklifts time, operator time, and forklift speed. In Table 2, $P(x)$ denotes the Poisson distribution of the entity arrival time. The value $x$ denotes the average value of each incoming entity. Table 3 shows the time and speed for each resource movement and their probability distributions. Three probability distributions, namely, $L(x, y)$, $N(x, y)$, and $P(x)$ for the lognormal, normal, and Poisson distributions, respectively. Variable $x$ denotes the mean and y denotes the standard deviation.

**Table 2**. Entity and Arrival for ProModel

| No | Entity | First Location | Probability of the Arrival | Frequency (day) |
|---|---|---|---|---|
| 1 | CL | Inspection Location | $P(222.656)$ | 1 |
| 2 | CE | Inspection Location | $P(70.7556)$ | 1 |
| 3 | DL | Warehouse Office | $P(169.578)$ | 1 |
| 4 | DE | Warehouse Office | $P(64.0111)$ | 1 |

**Table 3**. Resources with Path Network and Motion for ProModel

| No. | Resources | Unit | Path Network | Motion |
|---|---|---|---|---|
| 1 | Forklift Storage | 1 | Transit Area - Storage | Empty: $L(159.06,31.296)$ mpm |
| | | | | Full: $L(147.12,18.93)$ mpm |
| | | | | Pickup: $N(38.14,7.67)$ seconds |
| | | | | Deposit: $N(44.8,9.883)$ seconds |
| 2 | Forklift Delivery | 2 | Storage -Loading Deck | Empty: $L(105,30.894)$ mpm |
| | | | | Full: $L(152.04,19.112)$ mpm |
| | | | | Pickup: $N(58.85,15.63)$ seconds |
| | | | | Deposit: $P(56.2667)$ seconds |
| 3 | Inspection Operator | 1 | None | $N(20.24,3.114)$ |
| 4 | Office Employee | 1 | None | $L(64.38,5.802)$ |
| 5 | Join Operator | 1 | None | $N(11.2,4.625)$ |

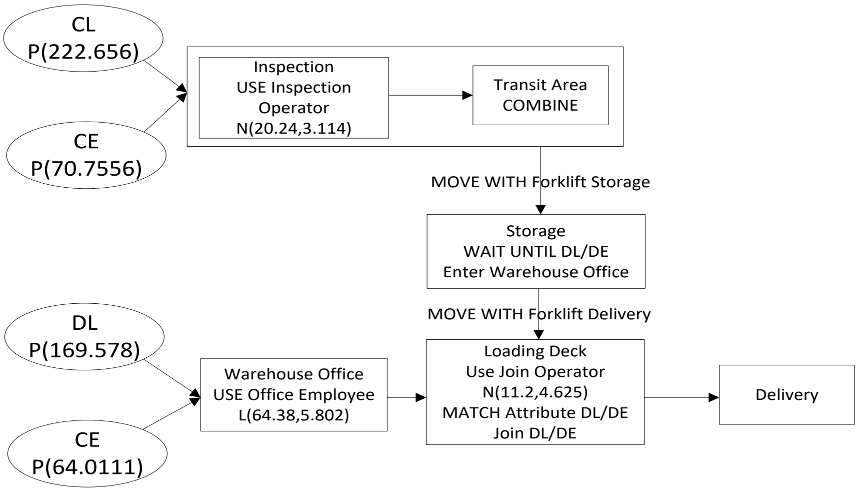


**Figure 1**. Entity Flow Diagram Based on Real Situation

Figure 1 shows the entity flow diagram of the simulation model. The simulation starts with the arrival of CL and CE to the inspection location. The inspection operator performs the task at a rate following the normal distribution $N(20.24,3.114)$. Then, the entity moves to the transit area but in the same location for combination according to the capacity of each forklift. The entity is brought by the storage forklift to the storage. The entity then waits until for DL and DE with the same attribute entering the warehouse office. When DL and DE enter the office, a worker does the documentation for $L(64.38,5.802)$. CL or CE meet DL and DE at the loading deck to be matched and then the operator joins them for N(11.2,4.625). The joined entity goes to the delivery and finally leave the system.

# 4. MODEL VERIFICATION AND VALIDATION

Table 4 shows that the $p$-value of the two-sample $t$-test and two sample variances are higher than 0.05. This describes that mean and variance of the model are able to represent the real situation.

**Table 4**.Validation

| Arrival | $t$-test | $\chi^2$-test ($F$) | $\chi^2$-test (Levene) |
|---|---|---|---|
| CL | 0.063 | 0.912 | 0.449 |
| CE | 0.940 | 0.924 | 0.833 |
| DL | 0.439 | 0.076 | 0.053 |
| DE | 0.991 | 0.347 | 0.509 |

### 4.1. The Case of Class-Based Storage

The allocation of the products starts with the measurement of movement frequency, whether it is carry in or delivery and determine the allocation of the product. Table 5 shows the allocation for each product in the warehouse. The column 'Class' is filled with A for sum of the percentage until 80%, B for sum of the percentage until 15%, and C for the rest 5%. The column 'Allocation' filled according to the class of each product, for CL can only fill location A and B, and CE can only fill location B and C.

**Table 5**. Product Allocation based on Class-Based Storage Policy

| Symbol | Movement Frequency | Percentage | Class | Allocation |
|---|---|---|---|---|
| CL4 | 1506.5 | 23.06 | A | A01 |
| CL3 | 826.3 | 12.65 | A | A01 |
| CL6 | 559.5 | 8.57 | A | B01 |
| CL10 | 436.5 | 6.68 | A | B01 |
| CE1 | 400.0 | 6.12 | A | C01 |
| CE7 | 358.0 | 5.48 | A | C01 |
| CL12 | 352.5 | 5.40 | A | A02 |
| CE4 | 296.0 | 4.53 | A | B02 |
| CE6 | 207.0 | 3.17 | A | B02 |
| CE3 | 205.0 | 3.14 | A | C02 |
| CE9 | 175.0 | 2.68 | B | B03 |
| CE8 | 165.0 | 2.53 | B | B03 |
| CL8 | 163.0 | 2.50 | B | A04 |
| CE10 | 129.5 | 1.98 | B | C03 |
| CL15 | 117.0 | 1.79 | B | B04 |
| CE2 | 99.0 | 1.52 | B | C04 |
| CL16 | 90.0 | 1.38 | B | A05 |
| CL1 | 88.0 | 1.35 | C | A06 |
| CE5 | 64.0 | 0.98 | C | C05 |
| CL11 | 61.3 | 0.94 | C | A06 |
| CL14 | 52.5 | 0.80 | C | A07 |
| CL9 | 48.9 | 0.75 | C | A07 |
| CL5 | 47.0 | 0.72 | C | B07 |
| CL2 | 39.2 | 0.60 | C | B07 |
| CL7 | 26.0 | 0.40 | C | B08 |
| CL13 | 19.5 | 0.30 | C | B08 |
| Total | 6532.2 | 100.00 | | |

### 4.2. The Case of Dedicated Storage

Allocation product starts with measurement of throughput for carry in and delivery, calculate the space requirement and determine the allocation of the product.

**Table 6.** Product Allocation based on Dedicated Storage Policy

| Symbol | T/S | Allocation |
|---|---|---|
| CL3 | 309.364 | A01 |
| CL4 | 188.374 | A01 |
| CL6 | 112.719 | A01 |
| CL1 | 87.111 | A01 |
| CE7 | 71.203 | B01 |
| CL8 | 63.360 | A01 |
| CE1 | 62.222 | B01 |
| CL10 | 47.882 | A01 |
| CE3 | 47.015 | B01 |
| CE8 | 42.805 | B01 |
| CL12 | 41.744 | A02 |
| CE6 | 40.685 | B01 |
| CL2 | 38.080 | A02 |
| CE4 | 34.748 | C01 |
| CE2 | 34.000 | C01 |

| Symbol | T/S | Allocation |
|---|---|---|
| CE9 | 33.188 | C01 |
| CE10 | 32.857 | C01 |
| CL14 | 30.684 | A02 |
| CL15 | 28.125 | A02 |
| CL16 | 26.649 | A02 |
| CL11 | 19.914 | A02 |
| CL5 | 19.577 | A02 |
| CL9 | 14.614 | A02 |
| CL7 | 13.011 | B02 |
| CE5 | 12.243 | C01 |
| CL13 | 11.028 | B02 |

Table 6 shows the allocation of the product based on T/S value. Products with the highest T/S value will be allocated to the most convenient place.

## 4.3. The Proposed Model Simulation

Table 7 shows the combination of the proposed scenarios from two warehouse management system policy, arrival, and number of forklifts. Table 8 contained the information of travel distance, forklift utilization, and fuel consumption cost from the scenarios and the real model. The first analysis is to determine the best warehouse management system policy between the two proposed model and one real model. The dedicated storage policy gives the lowest travel distance of 8.3 meters each day and the class-based storage gives 13.1 meters. Meanwhile, the real model gives 36.9 meters of travel distance. In this case, the dedicated storage policy is the best policy. The combination of one storage forklift and one delivery forklift gives the highest utilization. It can be concluded that one storage forklift and one delivery forklift is the best combination. The combination of one storage forklift and one delivery forklift still gives the best combination, because if the fixed cost of the forklifts is included, then the second combination with one storage forklift and two delivery forklifts will be higher in material handling cost compared with the first combination with one storage forklift and one delivery forklift.

**Table 7**. Proposed Model Scenarios

| No | Policy | Arrival | Forklift Storage | Forklift Delivery | Scenarios Code |
|---|---|---|---|---|---|
| 1 | Class Based Storage | High | 1 | 1 | CBSH11 |
| 2 | | | 1 | 2 | CBSH12 |
| 3 | | | 2 | 1 | CBSH21 |
| 4 | | Normal | 1 | 1 | CBSN11 |
| 5 | | | 1 | 2 | CBSN12 |
| 6 | | | 2 | 1 | CBSN21 |
| 7 | | Low | 1 | 1 | CBSL11 |
| 8 | | | 1 | 2 | CBSL12 |
| 9 | | | 2 | 1 | CBSL21 |
| 10 | Dedicated Storage | High | 1 | 1 | DCSH11 |
| 11 | | | 1 | 2 | DCSH12 |
| 12 | | | 2 | 1 | DCSH21 |
| 13 | | Normal | 1 | 1 | DCSN11 |
| 14 | | | 1 | 2 | DCSN12 |
| 15 | | | 2 | 1 | DCSN21 |
| 16 | | Low | 1 | 1 | DCSL11 |
| 17 | | | 1 | 2 | DCSL12 |
| 18 | | | 2 | 1 | DCSL21 |
| 19 | Real Model | Normal | 1 | 2 | None |

**Table 8**. Simulation Results

| Scenarios Code | Travel Distance (meters) | F.Storage Utilization (%) | F.Delivery Utilization (%) | Fuel Consumption Cost (IDR) |
|---|---|---|---|---|
| CBSH11 | 16330 | 20.91 | 21.29 | 255576.0424 |
| CBSH12 | 15625 | 20.28 | 10.08 | 244985.4176 |
| CBSH21 | 17165 | 10.11 | 23.17 | 262781.1396 |
| CBSN11 | 12594 | 16.18 | 5.59 | 193831.0444 |
| CBSN12 | 13469 | 16.53 | 8.16 | 198985.0408 |
| CBSN21 | 13286 | 8.05 | 17.75 | 204964.7264 |
| CBSL11 | 9956 | 12.48 | 11.88 | 147560.1484 |
| CBSL12 | 9455 | 11.84 | 5.59 | 139404.1964 |
| CBSL21 | 10101 | 6.03 | 12.82 | 150654.9688 |
| DCSH11 | 10496 | 17.76 | 20.55 | 232024.7216 |
| DCSH12 | 10274 | 17.79 | 10.08 | 227870.0312 |
| DCSH21 | 10654 | 10.11 | 21.34 | 233724.5512 |
| DCSN11 | 8392 | 14.22 | 16.11 | 183678.4992 |
| DCSN12 | 8093 | 14.18 | 8.16 | 178811.1724 |
| DCSN21 | 8661 | 8.05 | 17.11 | 188422.6792 |
| DCSL11 | 5991 | 10.40 | 11.03 | 129764.4264 |
| DCSL12 | 5794 | 10.50 | 5.59 | 130271.1452 |
| DCSL21 | 6270 | 6.03 | 12.11 | 135201.0548 |
| Real Model | 36900 | 27.29 | 11.77 | 307844.7932 |

## 5. CONCLUSION AND SUGGESTION

The fuel consumption of the real model is IDR 307.944, with total of 39.900 meters travel distance and 19.53% of forklift utilization, the scenarios of proposed model are shown by table 14. The optimal number of forklifts used by considering the utilization is one storage forklift and one delivery forklift, but if the consideration is the cost, then the optimal number of forklifts used is one storage forklift and two delivery forklifts. It applies to all of the arrival scenarios whether it is high, normal, or low. Based on the propose model and performance management measurement, the Dedicated Storage policy is chosen with the total of fuel consumption is IDR 181.882 with total of 8.293 meters of travel distance and 15,01% of forklift utilization.

Company can apply dedicated storage policy and use only one storage forklift to deposit products and one delivery forklift to pick up finished goods. There might be additions for future research objects, such as packaging types and quality.

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