Warehouse Selection for Storage of Finished Goods

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ABSTRACT

In selecting a warehouse for storage of finished goods, from qualitative and quantitative data, aggregate value was obtained as a requirement to make choices and determine costs.

Keyword: logistic, warehouse, analysis hierarchy process (AHP)

Introduction

Currently, almost all manufacturing companies have a warehouse, which generally serves as a temporary storage of goods in each stage of the logistics process.

PT. Frisian Flag Indonesia (FFI) is a manufacturing company that produces healthy drinks such as powder and liquid milk with various other sub-products. In its operational activities, the FFI must always maintain the quality of the products it produces, especially the storage activities in the warehouse. The warehouse used for temporary storage of the products as well as a warehouse and distribution center is managed by PT. YCH Indonesia. In addition to insufficient storage location, FFI also pays attention to the hygiene or sterilization of the warehouse environment and facilities that will be used to store all the finished products. It is being considered because the nature of the products requires special treatment.

With the increasing number of new products, followed by the addition of product inventory in order to win the competition, FFI must be able to store the finished products in a larger scale at the central warehouse. However, due to the increase of additional inventory in the warehouse, FFI is looking for a new warehouse that can accommodate inventory with larger scale, better quality, and at a competitive cost.

Besides in Jakarta, FFI has other warehouses in other cities like in Surabaya, Semarang and Medan. It is aimed to make equal distributions of the product to be spread all over Indonesia. Of course, all the determinations and decisions on making warehousing services should be based on defined criteria.

This research used qualitative and quantitative data. Qualitative data is used for non-statistical analysis. Meanwhile, quantitative data is used for statistical analysis. It has primary and secondary data. The primary data is obtained directly from lo-

gistics managerss and the secondary data is obtained from other parties related to the research.

The measurement of the answer is based on Analytical Hierarchy Process method (AHP).

Analytical Hierarchy Process (AHP) is a systematic decision making method which was introduced by Thomas L. Saaty during 1971-1975 when he was in Wharton School. It is used if there are various criteria of the decision making. There are some principals that need to be understood from the AHP method, namely: decomposition, comperative judgment, synthesis of priority, dan logical consistensy.

Furthermore, AHP also has a special concern about the deviations of consistency in the pairwise comparison matrix. First, the decision makers make a scoring on the relative importance between two elements qualitatively of "vertical (ci)" element with "horizontal (cj)" element in the pairwise comparison matrix using the following formula: (Saaty, 1994).

Results and Disscusion

a. Rating the relative importance of two elements

$$a_{ij} = w_i / w_j \quad .....(1)$$

a = Pairwise Comparison matrix.

$c_i, c_j, ..., n$ = Elements (criteria) on pairwise comparison matrix of a level in a hierarchy.

$w_i, w_j, ..., w_n$ = The relative importance score between the two elements of the matrix of pairwise comparison based on the interpretation of paired comparisons (attachment IV appendix B.1)

After scoring the relative importance between elements, the inverse value is carried out to obtain the inverse score or reciprocal axiom, using the following formula:

b.Reciprocal axiom

$$a_{ij} = \frac{1}{a_{ij}} \quad .....(2)$$

a = Pairwise Comparison matrix

$c_i, c_j, ..., n$ = Elements (criteria) on pairwise comparison matrix of a level in a hierarchy. The scoring was performed to measure the consistency of the results of the relative importance between elements scoring quantitatively. The results of these scoring is said to be perfect or consistent if it satisfies the following formula:

c. Consistancy Scoring

$$aw = nw \text{ or } aw = zw \quad ....(3)$$

a = Pairwise Comparison matrix.

n or z = The total of relative importance between elements (ci, cj, ck, ..., n) scoring and the inverse value (reciprocal axiom) in each column of the Pairwise Comparison matrix or the Eigen values

w = priority score of pairwise comparison matrix.

This assessment was conducted to determine the validity of the priority score of pairwise comparison matrix. Thus obtained Zmax or Eigen value that meets the priority score in the pairwise comparison matrix. The consistency of the indicators measured

through the Consistency Index (CI) formulated as follow:

1. Counting the Consistensy Index value

$$CI = \frac{Z_{max} - n}{n - 1} \quad .....(4)$$

CI = *Consistensy Index.*

Z_{max} = the maximum Eigen value of the pairwise comparison matrix

n = the no of elements of pairwise comparison matrix

AHP measures the entire consistency value using the Consistency Ratio (CR) as defined:

2.Counting the Consistency Ratio (CR)

.....(5)

$$CR = \frac{\textit{Consistensy Index} \text{ (CI)}}{\textit{Random Consistensy Index *)}}$$

RI score is the score of the Random Index issued by Oarkridge Laboratory in the form shown in table 1. n is the number of criteria contained in the pairwise comparison matrix.

Determination of the Criteria of Each Warehouse Selection Priority

The decision makers should consider the following items before making the decision:

1. Warehouse's width; this is the first criteria should be considered.
2. Fasilities; assessed only on the availability of pallets owned by the suppliers and types of storage facilities on each alternative which are racking and stacking blocks (bulk)
3. cost; assessed from the rental and shipping costs from the factory to the warehouse as well as the cost per pallet.
4. Location; assessed from the distance and travel time between factories and warehouses

What being analyzed in this case is three warehouses with their own criteria, namely warehouse A, B, and C.

Table 2 is pairwise comparison matrix of the criteria of warehouse selection equiped with the relative importance score between elements and values of axioms Reciprocal based on the results of relative importance score between elements of decision makers value.

The table is the initial assessment done by comparing the vertical elements with horizontal elements.

1. Warehouse's width is more important than facilities so it is weighted 3.
2. Cost is more important than warehouse's width so it is weighted 3.
3. Warehouse's width is more important than location so it is weighted 5.
4. Cost is more important than facilities so it is weighted 5.
5. Facilities is more important than location so it is weighted 3.
6. Cost is more important than location so it is weighted 5.

The matrix gave result to the total value for each column that is Eigen value (Z) of the pairwise comparison matrix. Column that has the smallest Eigen value will be the highest priority score to the normalized matrix.

Table 3 refers to normalized matrix which was gained from the division of the pairwise comparison matrix and the Eigen value of each column. It shows the results of the perfect normalization calculations, as the total value of each column is 1.0000,

as well as the priority scores for each criterion

After getting the priority score, the next is to test the consistency of the results of relative importance score between elements by setting the value of Consistency Ratio (CR) through the following steps:

1. Counting the Eigen Vector Score.

$$Aw = Z_{max}.w$$

$$Aw = \begin{pmatrix} 1.0000 & 3.0000 & 0.3333 & 5.0000 \\ 0.3333 & 1.0000 & 0.2000 & 3.0000 \\ 3.0000 & 5.0000 & 1.0000 & 5.0000 \\ 0.2000 & 0.3333 & 0.2000 & 1.0000 \end{pmatrix} \begin{pmatrix} 0.2729 \\ 0.1276 \\ 0.5329 \\ 0.0667 \end{pmatrix}$$

$$= \begin{pmatrix} 1.1666 \\ 0.5251 \\ 2.3227 \\ 0.2703 \end{pmatrix}$$

$$Z_{max} = 1.1666 + 0.5251 + 2.3227 + 0.2703$$

$$= 4.2847$$

The Eigen values (Zmax) is 4.2847. It shows that each element (criterion) contains the priority score of the element.

2.Counting the Consistency Index (CI).

$$CI = \frac{Z_{max} - n}{n - 1} = \frac{4.2847 - 4}{4 - 1}$$

$$= 0.0949$$

3.Counting the Consistency Ratio (CR).

$$CR = \frac{CI}{RI} = \frac{0.0949}{0,90} = 0.1055$$

n is criteria compared. Based on table 1 RI score for n = 4 is 0.90

The CR value gained from the calculation above is 0.1055. Because CR ≤ 0.10 then, there is no need to do the assessment revision because the priority score of each alternative is consistent and valid

Determination of Alternative Priority toward Each Criterion

The comparison between alternative warehouses and warehouses' width criterion

The first criterion is to perform pairwise comparisons for each alternative of warehouse's width criterion. Filling the relative importance score of each alternative against the warehouse's width criterion is done by using the result of the interviews done to the logistics managers, as seen on table 4.

The table is the initial assessment done by comparing the vertical elements with horizontal elements.

a. Alternative Warehouse B is more important than alternative Warehouse A, so it is weighted 3.

b. Alternative Warehouse C is much more important than alternative Warehouse A so it is weighted 7.

c. Alternative Warehouse C is more important than alternative Warehouse B so it is weighted 5.

The matrix gave result to the total value for each column that is Eigen value (Z) of the pairwise comparison matrix of the warehouse's width. Next is to make the normalized matrix as shown in table 5.

Table 5 refers to normalized matrix which was gained from the division of the pairwise comparison matrix of warehouse's width criterion and the Eigen value of each column. It shows the results of the perfect normalization calculations, as the total value of each column is 1.0000. It also shows the priority scores for each column.

After getting the priority score, the next is to test the consistency of the relative importance assessment between elements by setting the value of Consistency Ratio (CR)

through the following steps:

a. Counting the Eigen vector.

$$Aw = Z_{max}.W$$

$$Aw = \begin{pmatrix} 1.0000 & 0.3333 & 0.1429 \\ 3.0000 & 1.0000 & 0.2000 \\ 7.0000 & 5.0000 & 1.0000 \end{pmatrix} \begin{pmatrix} 0.0833 \\ 0.1932 \\ 0.7235 \end{pmatrix}$$

$$= \begin{pmatrix} 0.2511 \\ 0.5878 \\ 2.2726 \end{pmatrix}$$

$$Z_{max} = 0.2511 + 0.5878 + 2.2726$$

$$= 3.1115$$

The Eigen values (Zmax) is 3.1115. It shows that each element (criterion) contains the priority score of the element.

b.Counting Consistensy Index (CI).

$$CI = \frac{Z_{max} - n}{n - 1} = \frac{3.1115 - 3}{3 - 1} = 0.0557$$

c.Counting the Consistensy Ratio (CR).

$$CR = \frac{CI}{RI} = \frac{0.0557}{0.58} = 0.0961$$

n is criteria compared. Based on table 1 RI score for n = 3 is 0.58

The CR value gained from the calculation above is 0.0961. Because CR ≤ 0.10 then, there is no need to do the assessment revision because the priority score of each alternative is consistent and valid.

The Comparison between Alternative Warehouses and Facilities Criterion

The next process is to perform pairwise comparisons for each alternative against the facilities criterion. Filling the relative importance score of each alternative against the facilities criterion is done by using the result of the interviews done to the logistics managers like the steps taken before as shown in the matrix of table 6.

The matrix gave result to the total value for each column that is Eigen value (Z) of the pairwise comparison matrix of the facilities. Next is to make the normalized matrix as shown in table 7.

Table 7 refers to normalized matrix which was gained from the division of the pairwise comparison matrix of facilities criterion and the Eigen value of each column. It shows the results of the perfect normalization calculations, as the total value of each column is 1.0000. It also shows the priority scores for each column

After getting the priority score, the next is to test the consistency of the relative importance assessment between elements by setting the value of Consistency Ratio (CR) through the following steps:

a.Counting the Eigen vector.

$$Aw = Z_{max}.w$$

$$Aw = \begin{pmatrix} 1.0000 & 2.0000 & 2.0000 \\ 0.5000 & 1.0000 & 2.0000 \\ 0.5000 & 0.5000 & 1.0000 \end{pmatrix} \begin{pmatrix} 0.4905 \\ 0.3119 \\ 0.1976 \end{pmatrix}$$

$$= \begin{pmatrix} 1.5095 \\ 0.9524 \\ 0.5988 \end{pmatrix}$$

$$Z_{max} = 1.5095 + 0.9524 + 0.5988 = 3.0607$$

The Eigen values (Zmax) result is 3.0607. It shows that each element (alternative) contains the priority score of the element.

b.Counting the Consistency Index (CI).

$$CI = \frac{Zmax - n}{n - 1} = \frac{3.0607 - 3}{3 - 1} = 0.0304$$

c.Counting the Consistency Ratio (CR).

$$CR = \frac{CI}{RI} = \frac{0.0304}{0.58} = 0.0523$$

Based on the above calculation, the CR val-

ue is 0.0523. Because CR ≤ 0.10 then, there is no need to do the assessment revision because the priority score of each alternative is consistent and valid.

The comparison between Alternative Warehouses and Cost Criterion

The next process is to perform pairwise comparisons for each alternative against the criteria of cost. Filling the relative importance score of each alternative against the Cost criterion is done by using the result of the interviews done to the logistics managers and resulted in the matrix of table 8:

The matrix gave result to the total value for each column that is Eigen value (Z) of the pairwise comparison matrix of the cost. Next is to make the normalized matrix as shown in table 9.

Table 9 refers to normalized matrix which was gained from the division of the pairwise comparison matrix of cost criterion and the Eigen value of each alternative.

After getting the priority score, the next is to test the consistency of the relative importance assessment between elements by setting the value of Consistency Ratio (CR) through the following steps:

a. Counting eigen vector value.

$$Aw = Z_{max} .w$$

$$Aw = \begin{pmatrix} 1.0000 & 5.0000 & 0.3333 \\ 0.2000 & 1.0000 & 0.1429 \\ 3.0000 & 7.0000 & 1.0000 \end{pmatrix} \begin{pmatrix} 0.2828 \\ 0.0738 \\ 0.6434 \end{pmatrix}$$

$$= \begin{pmatrix} 0.8662 \\ 0.2223 \\ 2.0083 \end{pmatrix}$$

$$Z_{max} = 0.8662 + 0.2223 + 2.0083 = 3.0967$$

The Eigen values (Zmax) result is 3.0967. It shows that each element (alternative) contains the priority score of the element

b.Counting the Consistency Index (CI).

$$CI = \frac{Zmax - n}{n - 1} = \frac{3.0967 - 3}{3 - 1} = 0.0484$$

c.Counting the Consistency Ratio (CR).

$$CR = \frac{CI}{RI} = \frac{0.0484}{0.58} = 0.0834$$

Based on the above calculation, the CR value is 0.0834. Because CR ≤ 0.10 then, there is no need to do the assessment revision because the priority score of each alternative is consistent and valid.

The Comparison between Alternative Warehouses and Location Criterion

Then, the process followed by pairwise comparisons for each alternative against the criterion of location using the result of the interviews to the logistics managers so we get a pairwise comparison matrix as seen on table 10.

The matrix gave result to the total value for each column that is Eigen value (Z) of the pairwise comparison matrix of the location. Next is to make the normalized matrix as shown in table 11.

Table 11 refers to normalized matrix which was gained from the division of the pairwise comparison matrix of location criterion and the Eigen value of each column. It shows the results of the perfect normalization calculations, as the total value of each column is 1.0000. It also shows the priority scores for each column.

After getting the priority score, the next is to test the consistency of the relative importance assessment between elements by setting the value of Consistency Ratio (CR) through the following steps:

a.Counting the Eigen Vector Score.

$$Aw = Z_{max} .w$$

$$Aw = \begin{pmatrix} 1.0000 & 5.0000 & 3.0000 \\ 0.2000 & 1.0000 & 0.3333 \\ 0.3333 & 3.0000 & 1.0000 \end{pmatrix} \begin{pmatrix} 0.6333 \\ 0.1062 \\ 0.2605 \end{pmatrix}$$

$$= \begin{pmatrix} 1.9456 \\ 0.3197 \\ 0.7901 \end{pmatrix}$$

$Z_{max} = 1.9456 + 0.3197 + 0.7901 = 3.0554$

The Eigen values (Zmax) result is 3.0554. It shows that each element (alternative) contains the priority score of the element

b.Counting the Consistency Index (CI).

$$CI = \frac{Zmax - n}{n - 1} = \frac{3.0554 - 3}{3 - 1} = 0.0277$$

c.Counting Consistency Ratio (CR).

$$CR = \frac{CI}{RI} = \frac{0.0277}{0.58} = 0.0477$$

Based on the above calculation, the CR value is 0.0477. Because CR ≤ 0.10 then, there is no need to do the assessment revision.

The determination of Alternative Warehouse based on the Highest Aggregate Score.

The last process in the calculation of Analytical Hierarchy Process (AHP) is to calculate the aggregate score of each alternative warehouse which was obtained by multiplying the priority score of each alternative on all criteria with a priority score of each criterion. The alternative warehouse that has the highest aggregate value is chosen as a reference in decision-making. Table 12 shows the aggregate scoring.

Conclusion

Warehouse C was selected as the storage of finished good at PT. Frisian Flag Indonesia as it has aggregate score twice bigger than others that is 0.5829. Its width is 27,900 m2. It has 44,682 pallet capacity. Besides, it has Racking and Block Stacking (Bulk) facility, because it is located in Cibitung or 28 km from the factory, so it takes only one and half hour to get there.

The cost that needs to be prepared by the company is Rp 1,413,036,625 as the delivery cost from the factory to the warehouse is Rp 1,300,000 and the cost per pallet is Rp 31,625.

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Appendices

Tabel. 1 Random Index (RI) Score

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Source: Sri Mulyono (2002)

Table 2 Pairwise Comparison Matrix of Warehouse Selection Criteria

Focus	Warehouse's width		Facilities		Cost		Location	
		4 digit decimal		4 digit decimal		4 digit decimal		4 digit decimal
Warehouse's width	1	1.0000	3	3.0000	1/3	0.3333	5	5.0000
Facilities	1/3*	0.3333	1	1.0000	1/5	0.2000	3	3.0000
Cost	3*	3.0000	5*	5.0000	1	1.0000	5	5.0000
Location	1/5*	0.2000	1/3*	0.3333	1/5*	0.2000	1	1.0000
Total		4.5333		9.3333		1.7333		14.000

Source: Processed interview result
*** = reverse score (axioms reciprocal)**

Table 3 Normalized Matrix

Focus	Warehouse's width	Facilities	Cost	Location	Priority Score
Warehouse's width	0.2206	0.3214	0.1923	0.3571	0.2729
Facilities	0.0735	0.1072	0.1154	0.2144	0.1276
Cost	0.6618	0.5357	0.5769	0.3571	0.5329
Location	0.0441	0.0357	0.1154	0.0714	0.0666
Total	1.0000	1.0000	1.0000	1.0000	1.0000

Source: Processed Interview result

Table 4 Warehouse's width Pairwise Comparison Matrix

Warehouse's width criterion	Warehouse A		Warehouse B		Warehouse C	
		4 digit decimal		4 digit decimal		4 digit decimal
Warehouse A	1	1.0000	1/3	0.3333	1/7	0.1429
Warehouse B	3*	3.0000	1	1,0000	1/5	0.2000
Warehouse C	7*	7.0000	5*	5.0000	1	1.0000
Total		11.0000		6.3333		1.3429

Source: Processed Interview result
*** = reverse score (axioms reciprocal)**

Table 5 Normalized Matrix

Warehouse's width criterion	Warehouse A	Warehouse B	Warehouse C	**Priority Score**
Warehouse A	0.0909	0.0526	0.1064	**0.0833**
Warehouse B	0.2727	0.1579	0.1489	**0.1932**
Warehouse C	0.6364	0.7895	0.7447	**0.7235**
Total	1.0000	1.0000	1.0000	**1.0000**

Source: Processed Interview result

Table 6 Facilities Pairwise Comparison Matrix

Warehouse's width criterion	Warehouse A		Warehouse B		Warehouse C	
		4 digit decimal		4 digit decimal		4 digit decimal
Warehouse A	1	1.0000	2	2.0000	2	2.0000
Warehouse B	1/2*	0.5000	1	1.0000	2	2.0000
Warehouse C	1/2*	0.5000	1/2*	0.5000	1	1.0000
Total		2.0000		3.5000		5.0000

Source: Processed Interview result
*** = reverse score (axioms reciprocal)**

Table 7 Matriks Normalized

Facilities Criterion	Warehouse A	Warehouse B	Warehouse C	Priority Score
Warehouse A	0.5000	0.5714	0.4000	0.4905
Warehouse B	0.2500	0.2857	0.4000	0.3119
Warehouse C	0.2500	0.1429	0.2000	0.1976
Total	1.0000	1.0000	1.0000	1.0000

Source: Processed Interview result

Table 8 Cost Pairwise Comparison Matrix

Warehouse's width criterion	Warehouse A		Warehouse B		Warehouse C	
		4 digit decimal		4 digit decimal		4 digit decimal
Warehouse A	1	1.0000	5	5.0000	1/3	0.3333
Warehouse B	1/5*	0.2000	1	1.0000	1/7	0.1429
Warehouse C	3*	3.0000	7*	7.0000	1	1.0000
Total		4.2000		13.0000		1.4762

Source: Processed Interview result
*** = reverse score (axioms reciprocal)**

Table 9 Normalized Matrix

Cost Criterion	Warehouse A	Warehouse B	Warehouse C	Priority Score
Warehouse A	0.2381	0.3846	0.2258	0.2828
Warehouse B	0.0476	0.0769	0.0968	0.0738
Warehouse C	0.7143	0.5385	0.6774	0.6434
Total	1.0000	1.0000	1.0000	1.0000

Source: Processed Interview result

Table 10 Location Pairwise Comparison Matrix

Warehouse's width criterion	Warehouse A		Warehouse B		Warehouse C	
		4 digit decimal		4 digit decimal		4 digit decimal
Warehouse A	1	1.0000	5	5.0000	3	3.0000
Warehouse B	1/5*	0.2000	1	1.0000	1/3	0.3333
Warehouse C	1/3*	0.3333	3*	3.0000	1	1.0000
Total		1.5333		9.0000		4.3333

Source: Processed Interview result
*** = reverse score (axioms reciprocal)**

Table 11 Normalized Matrix

Location Criterion	Warehouse A	Warehouse B	Warehouse C	Priority Score
Warehouse A	0.6522	0.5556	0.6923	0.6333
Warehouse B	0.1304	0.1111	0.0769	0.1062
Warehouse C	0.2174	0.3333	0.2308	0.2605
Total	1.0000	1.0000	1.0000	1.0000

Source: Processed Interview result

Table 22 Final Scoring of Each Alternative

	Warehouse's width	Facilities	Cost	Location	**Aggregate Value**
	0.2729	0.1276	0.5329	0.0667	
Warehouse A	0.0833	0.4905	0.2828	0.6333	**0.2783**
Warehouse B	0.,1932	0.3119	0.0738	0.1062	**0.1389**
Warehouse C	0.7235	0.1976	0.6434	0.2605	**0.5829**

Data source: processed by the writer