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APPLICATION OF FUZZY C MEANS AND TOPSIS IN WAREHOUSE SELECTION AT PT WARUNG ISLAMI BOGOR

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Abstract

PT Warung Islami Bogor needs a warehouse to store goods that come from suppliers. Currently, the selection of warehouses is still done manually and is subjective. It is feared that this will lead to inaccuracies in renting the warehouse. So an application is needed to assist companies in choosing a warehouse. The fuzzy C-Means method can be used to classify warehouse data based on the characteristics of each group. After obtaining the next group is to make a rating of each group. One method that can be used is the TOPSIS method. The TOPSIS method can be applied to this application to rank the data warehouses that have been grouped. In the selection of this warehouse, there are several criteria. The criteria used are price, building area, distance from the head office (HO), parking area, and number of floors. The calculation process is done by dividing the warehouse data into several groups and ranking them to obtain the best recommendations. This application uses the PHP programming language with the Laravel framework—testing using a black box. Fuzzy C-Means and TOPSIS calculations show that Warehouse CCC is the best warehouse in Cluster 1 with a value of 0.797, and the Warehouse in Front of Gas Station Villa Bogor Indah is the best in Cluster 2 with a value of 0.613.

Keywords: Cluster, Warehouse, Fuzzy C-Means, TOPSIS

Abstrak

PT Warung Islami Bogor membutuhkan sebuah gudang untuk menyimpan barang yang datang dari pemasok. Saat ini pemilihan gudang masih dilakukan secara manual dan bersifat subjektif. Hal ini dikhawatirkan akan menimbulkan ketidaktepatan dalam memilih gudang yang akan disewa. Sehingga dibutuhkan aplikasi untuk membantu perusahaan dalam memilih gudang. Metode Fuzzy C-Means dapat dilakukan untuk mengelompokkan data gudang berdasarkan karakteristik per tiap kelompok. Setelah didapatkan kelompok selanjutnya yaitu membuat peringkat dari tiap kelompok. Salah satu metode dapat digunakan adalah metode TOPSIS. Metode TOPSIS dapat diterapkan pada aplikasi ini untuk membuat peringkat dari data gudang yang sudah dikelompokkan. Pada pemilihan gudang ini ada beberapa kriteria. Adapun kriteria yang digunakan yaitu harga, luas bangunan, jarak dari head office (HO), luas parkir, dan jumlah lantai. Proses perhitungannya yaitu dengan cara membagi data gudang menjadi beberapa kelompok kemudian merangkingnya untuk memperoleh rekomendasi terbaik. Aplikasi ini dibangun menggunakan bahasa pemrograman PHP dengan framework Laravel. Pengujian menggunakan blackbox. Dari hasil perhitungan Fuzzy C-Means dan TOPSIS didapatkan bahwa Gudang CCC adalah gudang terbaik di kluster 1 dengan nilai 0.797 dan Gudang Depan Pom Bensin Villa Bogor Indah adalah gudang terbaik di kluster 2 dengan nilai 0.613.

Kata kunci: Cluster, Gudang, Fuzzy C-Means, TOPSIS

INTRODUCTION

PT Warung Islami Bogor is one of the developing companies in Indonesia with a business that focuses on the trading sector of industrial packaging products. Starting from an idea to help fellow business people/producers find it challenging to get product packaging with plastic bottles to cover their production needs, in 2012, PT Warung Islami Bogor pioneered the company from a shop in Bogor to become a national company that continues to grow. PT Warung Islami Bogor specializes in distributing plastic bottle product packaging with a distribution network that spreads throughout Indonesia through traditional and modern digital and internet-based channels. In its

distribution, PT Warung Islami Bogor requires warehouses to accommodate goods coming from suppliers, and these goods will be sent back to stores owned by PT Warung Islami Bogor, scattered in various cities in Indonesia.

A warehouse is a place or building used to hoard, and store goods, either in the form of raw materials, work in process, or finished products (R. Widowati & Septiawan, 2021). Inside the warehouse are essential components of the modern supply chain. The supply chain involves activities in various stages: sourcing, production, and distribution of goods, from handling raw materials and works in progress to finished products. A warehouse is part of a company's logistics system, which stores products and provides information regarding the status and condition of materials/supplies stored in the warehouse so that this information is always up-to-date and easily accessible to anyone concerned (D. Widowati & Ningtiyas, 2022).

Selection of the current warehouse without using a specific calculation method. The General Affairs (GA) staff conducts a field survey and records the warehouse data into a memorandum, then gives the memo to the GA Supervisor, and the GA Supervisor forwards it to the Operations Manager for discussion with the board of directors. The selection of warehouses is only based on the needs criteria at that time, for example, only based on price or building area. Warehouse selection must be compared one by one with warehouse data that has been recorded, and the selection is subjective. To optimize the warehouse selection process, the fuzzy method is an alternative that can be used to group warehouse data.

First of all, the data must be grouped using fuzzy clustering. Fuzzy clustering is a technique for determining optimal clusters in a vector space based on the standard Euclidian form for the distance between vectors. Several data clustering algorithms exist, including Fuzzy C-Means (Nugraha & Riyandari, 2020). Fuzzy C-Means (FCM) is a data clustering technique in which the existence of each data point in a cluster is determined by the degree of membership (Sanusi, Zaky, & Afni, 2020). The basic concept of FCM is to determine the cluster center that will mark each cluster's average location. With this method, the cluster center and membership degree are always repaired repeatedly so that it can be seen that the cluster center will move toward the correct location (Hidayat, Nazir, Candra, Sanjaya, & Syafria, 2023; Ningtyas, Nasution, & Syaripuddin, 2022). The FCM method allows dividing part of the data into two or more groups, comparing an object that divides into group members based on the division level (Adifia, Ulinnuha, & Khaulasari, 2023). FCM also has high accuracy and fast computation time (Rohmah & Saputro, 2020).

After the data is grouped, the data must be ranked. There are several data ranking methods, one of which is TOPSIS. TOPSIS is a concept in which the best-chosen alternative has the shortest distance from the positive ideal solution and the longest from the negative ideal solution (Nasution & Hanum, 2020; Syafi'ie, Tursina, & Yulianti, 2019). This method is widely used in the MCDM concept to solve practical decision problems, and this is because the concept is simple and easy to understand, computationally efficient, and can measure the relative performance of decision alternatives in a simple mathematical form (Sembiring & Hasugian, 2021).

After the data is ranked, the data will be presented by the manager to the management for consideration. To simplify this, we need an accurate system to make decision-making correctly.

In this study, four previous studies will be used to support the research that will be carried out. The first study was written by Giovan Meidy Susanto et al. with the title Android Smartphone Selection Reference System Using the Fuzzy C-Means and TOPSIS Methods in 2020. This study discusses the Fuzzy C-Means and TOPSIS algorithms to provide references for selected Android smartphones. The results of the Fuzzy C-Means and TOPSIS calculations can group Android smartphones into three clusters, then testing is carried out using White-Box Testing, and the results are that all functions in the software can run properly. The weakness of this system is that it does not discuss lifestyle needs in choosing Android(Susanto, Kosasi, David, Gat, & Kuway, 2020). The second study was written by Erlita Faridatul Himah and Raden Sulaiman, titled Implementing Fuzzy C-Means and TOPSIS Methods in Evaluating the Financial Performance of Banking Companies in Indonesia Based on Financial Ratios for 2021. This study discusses financial performance in the banking sector, which needs to be evaluated for company performance. Banking in Indonesia is based on financial ratios to determine a company's financial condition. The results of the discussion above are cluster rankings using the Fuzzy C-Means and TOPSIS methods. In calculating company performance evaluations using the Fuzzy C-Means and TOPSIS methods, a displacement index is obtained: the average number of companies in an inappropriate classification of 1.23 and the error rate of 25.65% (Himah & Sulaiman, 2021).

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The third study was written by Yuliadarnita et al. titled Management of Distribution of Assistance for SMEs Cooperative Office Using the FCM and TOPSIS Methods in 2023. this study discusses the management of aid distribution so that it can be given accurately. Fuzzy C-Means is used to classify eligible and ineligible recipients, and TOPSIS is used to sort by turnover and the number of employees. The results of calculations using Fuzzy C-Means and TOPSIS show that SMEs in Bedeng Bata deserve assistance (Yuliadarnita, Dwi Wardana, & Toyib, 2023). Christian Sri Kusuma Aditya wrote the fourth study titled Selection of Representative Sentences with the Integration of Fuzzy C-Means Clustering and TOPSIS (FCM-TOPSIS) for Document Summarization in 2020. In this study, discussing text documents is a much-needed source of information, but document collections in large numbers can hurt users who need a relatively long time to sort. A summary is needed for the essence without changing the context of information from a text document. The discussion above shows that this study integrates Fuzzy C-Means with the TOPSIS method to get summary results from text documents (Christian S. K. Aditya, 2021).

What this research has in common with previous research is the method used, namely Fuzzy C-Means and TOPSIS, and what distinguishes this research from previous research is the research object, namely the selection of warehouses with price criteria, building area, distance from HO, parking area, and floors.

RESEARCH METHODS

The research method applied is by conducting interviews and direct observation of PT Warung Islami Bogor. More details can be seen in Figure 1.

Time and Place of Research

This research starts from March 2022 to June 2022 at PT Warung Islami Bogor.

Research Target / Subject

In this research, the target/subject is the HRD Manager, and then the interview stages are carried out in the information of variables, criteria, and alternatives.

Procedure

The research method is described in Figure 1. The analysis begins with the stages of observation, interviews, and literature application. Furthermore, the design is carried out using UML. The next stage is coding using the PHP programming language with the Laravel framework. Other applications are the Google Chrome application as a browser, MySQL as a database development application, and Apache as a web server. The testing phase is carried out using a black box to test the suitability of the application with the functionality or functional capabilities of the system. The Fuzzy C-Means algorithm generates calculation clusters, and the TOPSIS algorithm generates recommendation values.

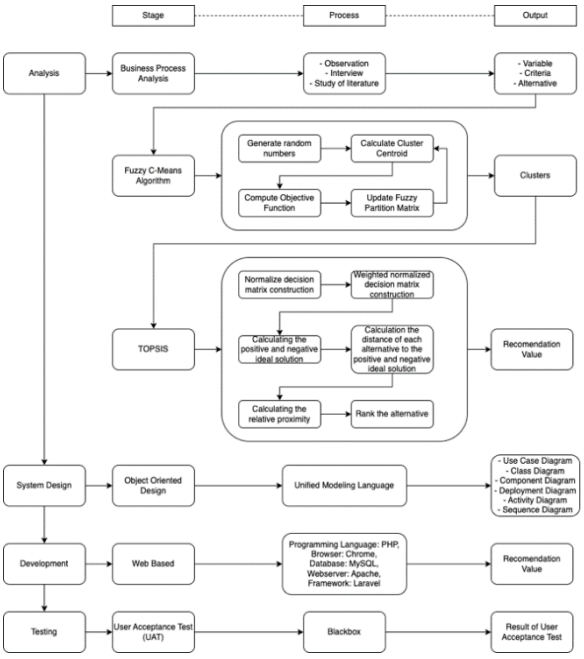

Figure 1. Research Methods

Data, Instruments, and Data Collection Techniques

The data used in this research is warehouse data at PT Warung Islami Bogor. Warehouse data can be seen in Table 1.

Table 1. Warehouse Data

No	Code	Variable
1	W1	Warehouse in Front of Gas Station Villa Bogor Indah
2	W2	Warehouse in Front of Puri Nirwana
3	W3	Warehouse KM 36
4	W4	Warehouse 88
5	W5	Warehouse Welding Workshop
6	W6	Warehouse CCC
7	W7	Warehouse PT. Grasindo
8	W8	Warehouse Kacang Garuda
9	W9	Warehouse Kedung Halang
10	W10	Warehouse PT. Nugratama Dayamitra
11	W11	Warehouse Nurdhin
12	W12	Warehouse Hj. Nasrul

The criteria used for this research can be seen in Table 2, and details can be seen in Table 3.

Table 2. Criteria Data

No	Code	Variable
1	C1	Price
2	C2	Building Area
3	C3	Distance from HO
4	C4	Parking Area
5	C5	Floor

Table 3. Details of the criteria data

No	Ware house	C1 (month/year)	C2 (m^2)	C3 (km)	C4 (m^2)	C5
1	W1	200	500	3,3	150	2
2	W2	200	300	1,5	150	2
3	W3	355	600	11,9	300	2
4	W4	460	1500	2,8	500	1
5	W5	180	300	2,8	150	1
6	W6	279	1200	3,3	500	2
7	W7	653	1600	3,2	150	1
8	W8	921	1650	0,8	400	1
9	W9	406	720	11,1	360	2
10	W10	868	1800	10,1	500	1
11	W11	607	600	12,7	700	1
12	W12	962	1400	15,2	546	1

Data analysis technique with Fuzzy C-Means

The first stage is Warehouse Data Grouping Using Fuzzy C-Means.

1. Input data to be clustered X is a matrix of size n x m (n = number of data samples, m = attributes of each data). X_{ij} = sample data i ($i = 1,2,\dots,n$), attribute j ($j = 1,2,\dots,m$).
2. Define:
   a. Number of cluster = $\boldsymbol{c}$;
   b. Power = $\boldsymbol{w}$;
   c. Maximum Iteration = MaxIter;
   d. The smallest expected error = $\boldsymbol{\varepsilon}$;
   e. Initial objective function $P_0 = 0$;
   f. Initial iteration = $t = 1$;
3. Generate random numbers μ_{ik}, $i = 1,2,\dots,n$; $k = 1,2,\dots,c$; as the elements of the initial partition matrix U.
   Count the sum of each column (attribute):
   $\boldsymbol{Q_j} = \sum_{k=1}^{c} \mu_{ik}$ ..... (1)
   with $j = 1,2,\dots,m$.
   Calculate:
   $\mu_{ik} = \frac{\mu_{ik}}{Q_j}$ ..... (2)
4. Compute the cluster center k: V_{kj}, with $k = 1,2,\dots,c$; and $j = 1,2,\dots,m$.

$$\boldsymbol{V_{kj}} = \frac{\sum_{i=1}^{n}((\mu_{ik})^{w} * X_{ij})}{\sum_{i=1}^{n}(\mu_{ik})^{w}} \quad \text{..... (3)}$$

5. Compute the objective function on iteration t, P_t.

$$\boldsymbol{P_t} = \sum_{i=1}^{n}\sum_{k=1}^{c}\left(\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right](\mu_{ik})^{w}\right) \quad \text{... (4)}$$

6. Compute the change in the partition matrix:

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}} \quad \text{..... (5)}$$

   with: $i = 1,2,\dots,n$; and $k = 1,2,\dots,c$.
7. Check stop condition:
   If: $(|P_t - P_t - 1| < \varepsilon)$ or $(t > MaxIter)$ then stop;
   If not: $t = t + 1$, repeat step 4.

Data analysis technique with TOPSIS

The next step is to rank using the TOPSIS.

1. Create a normalized decision matrix;
2. Create a weighted normalized decision matrix;
3. Determine the positive ideal solution matrix & negative ideal solution matrix;
4. Determine the distance between the value of each alternative with the positive ideal solution matrix & negative ideal solution matrix;
5. Determine the preference value for each alternative.

RESULTS AND DISCUSSION

Warehouse Data Grouping Using Fuzzy C-Means

The first stage is Warehouse Data Grouping Using Fuzzy C-Means.

1. Input warehouse data to be clustered based on Table 3 in the form of x_{ij} matrix as follows:

$$\begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \dots & \dots & \dots & \dots & \dots \\ x_{111} & x_{112} & x_{113} & x_{114} & x_{115} \\ x_{121} & x_{122} & x_{123} & x_{124} & x_{125} \end{bmatrix}$$

   – i is warehouse data amounting to 12 (n=12)
   – j is criterion data amounting to 5 (m=5)
2. Initialization :
   a. Number of cluster = 2;
   b. Power = 2;
   c. Maximum iteration = 100;
   d. The smallest expected error = 10^{-2};
   e. Initial objective function = 0;
   f. Initial iteration = 1;

3. Generate random numbers (μ_{ik})
How to calculate the initial μ_{ik} Matrix:
a. Generate the random value of the partition matrix

$$\begin{bmatrix} \mu_{11} & \mu_{12} \\ \cdots & \cdots \\ \cdots & \cdots \\ \cdots & \cdots \\ \mu_{111} & \mu_{112} \\ \mu_{121} & \mu_{122} \end{bmatrix}$$

b. Calculate the number of each line (attribute)

$$\begin{bmatrix} 0{,}316 & 0{,}765 \\ \cdots & \cdots \\ \cdots & \cdots \\ \cdots & \cdots \\ 0{,}912 & 0{,}179 \\ 0{,}365 & 0{,}727 \end{bmatrix} \rightarrow \begin{matrix} 1{,}081 \\ \cdots \\ \cdots \\ \cdots \\ \cdots \\ \cdots \end{matrix}$$

Contoh baris ke 1 :
$\mu_{i1} + \mu_{i2} = Q_j$
$0{,}316 + 0{,}765 = 1{,}081$

c. Calculate the matrix element. μ_{ik}
– $\frac{\mu_{i1}}{Q_j} = \mu_{i1}$

$\frac{0{,}316}{1{,}081} = 0{,}292$

– $\frac{\mu_{i1}}{Q_j} = \mu_{i1}$

$\frac{0{,}765}{1{,}081} = 0{,}708$

Q_j Is the number of degrees of membership in line = 1: $0{,}292 + 0{,}708 = 1$
So that the value of the first-row initial partition matrix is obtained: 0,292 0,708 Thus, for rows 2 to 12, the initial partition matrix is obtained in Table 4.

Table 4. Initial $\boldsymbol{\mu_{ik}}$ matrix

$\boldsymbol{\mu_{i1}}$	$\boldsymbol{\mu_{i2}}$
0,292	0,708
0,125	0,875
0,620	0,380
0,514	0,486
0,112	0,888
0,921	0,079
0,205	0,795
0,545	0,455
0,129	0,871
0,410	0,590
0,836	0,164
0,334	0,666

4. Calculate cluster centroid (v_{kj})
For the first cluster center:
Is known $\mu_{11}^2 = (0{,}292)^2 = 0{,}085$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}(\mu_{i1})^w = 2{,}944$

Calculate the first warehouse value for the 1st criterion :
$\mu_{11}^2 \times x_{11} = (0{,}292)^2 \times 200 = 17{,}034$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}((\mu_{i1})^w \times x_{i1}) = 1502{,}124$

Calculate the first warehouse value for the 2nd criterion :
$\mu_{11}^2 \times x_{12} = (0{,}292)^2 \times 500 = 42{,}584$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}((\mu_{i1})^w \times x_{i2}) = 3142{,}911$

Calculate the first warehouse value for the 3rd criterion :
$\mu_{11}^2 \times x_{13} = (0{,}292)^2 \times 3{,}3 = 0{,}281$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}((\mu_{i1})^w \times x_{i3}) = 21{,}273$

Calculate the first warehouse value for the 4th criterion :
$\mu_{11}^2 \times x_{14} = (0{,}292)^2 \times 150 = 12{,}775$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}((\mu_{i1})^w \times x_{i4}) = 1453{,}435$

Calculate the first warehouse value for the 5th criterion :
$\mu_{11}^2 \times x_{15} = (0{,}292)^2 \times 2 = 0{,}170$, and so on until the warehouse to 12
So that $\sum_{i=1}^{n}((\mu_{i1})^w \times x_{i5}) = 4{,}293$

Calculate the central value for the 1st cluster :
$V_{11} = 510{,}301$
$V_{12} = 1067{,}708$
$V_{13} = 7{,}227$
$V_{14} = 493{,}760$
$V_{15} = 1{,}458$

And so on for the 2nd cluster center, so the cluster center is obtained in Table 5.

Table 5. 1st Iteration Cluster Center

$\boldsymbol{V_{kj}}$	$\boldsymbol{x_{i1}}$	$\boldsymbol{x_{i2}}$	$\boldsymbol{x_{i3}}$	$\boldsymbol{x_{i4}}$	$\boldsymbol{x_{i5}}$
Cluster 1	510,301	1067,708	7,227	493,760	1,458
Cluster 2	455,540	890,706	5,889	279,577	1,448

5. Compute Objective Function
For the 1st cluster, calculate the 1st warehouse value for the 1st criterion. So the objective function is obtained in Table 6.

Table 6. 1st Iteration Objective Function

$\left[\sum_{j=1}^{m}(x_{ij} - V_{kj})^2\right](\mu_{i1}^w)$	$\left[\sum_{j=1}^{m}(x_{ij} - V_{kj})^2\right](\mu_{i2}^w)$
45715,076	117726,384
12551,624	330051,563
107755,691	13737,417
50103,957	99067,354
10194,818	348477,762
60226,013	1104,689
17662,799	353573,876
153477,066	167159,649
2496,727	28886,814
111846,019	363532,067
189050,165	7669,505
35392,487	260336,977

6. Calculate the new partition (μ_{ik}) matrix
How to calculate the new U partition matrix :

Table 7. 1st Iteration Partition μ_{ik} Matrix

$\left[\sum_{j=1}^{m}(x_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}$	$\left[\sum_{j=1}^{m}(x_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}$	$\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(x_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}$
0,00000186	0,00000426	0,00000612
0,00000124	0,00000232	0,00000356
0,00000357	0,00001052	0,00001408
0,00000528	0,00000238	0,00000766
0,00000122	0,00000226	0,00000349
0,00001407	0,00000570	0,00001977
0,00000237	0,00000179	0,00000416
0,00000194	0,00000124	0,00000317
0,00000668	0,00002625	0,00003293
0,00000151	0,00000096	0,00000246
0,00000369	0,00000352	0,00000721
0,00000315	0,00000170	0,00000486

7. Check the stop condition.
$|P_t - P_0| = |2887796{,}499 - 0|$
$= 2887796{,}499$

In 1st iteration, the conditions have not been met because ($|P_t - P_0| > \varepsilon$), and ($t < MaxIter$), then the process continues to 2nd iteration until the conditions are met. The process stops at the 10th iteration because of the condition. ($|P_t - P_t - 1| < \varepsilon$) Has been met. In other experiments, different cluster positions may be obtained due to the random initial initialization of the partition matrix, but this does not affect the final result.

In the 10th iteration, the cluster center and the new μ_{ik} Matrix is obtained in Table 8:

Table 8. 10th Iteration Cluster Center

V_{kj}	x_{i1}	x_{i2}	x_{i3}	x_{i4}	x_{i5}
Cluster 1	739,094	1554,222	6,214	427,274	1,074
Cluster 2	307,721	521,034	6,791	284,492	1,715

From Table 8, the following information is obtained:

a. Cluster 1 contains warehouse data which has a price of around IDR 739,094,000; an average building area of 1,554.222 m^2; the distance from HO is about 6,214 km; an average parking area of 427,274 m^2; and an average of 1 floor. This cluster is a cluster with a higher price but with a larger building area.
b. Cluster 2 contains warehouse data which has a price of around IDR 307,721,000; an average building area of 521,034 m^2; the distance from HO is about 6,791 km; an average parking area of 284,492 m^2; and an average of 2 floors. This cluster has a lower price but a smaller building area.

Table 9. New μ_{ik} matrix

No	Ware house	The degree of data membership in the cluster		The most significant degree of membership in the cluster
		1	2	
1	W1	0,020	0,980	2
2	W2	0,039	0,961	2
3	W3	0,008	0,992	2
4	W4	0,923	0,077	1
5	W5	0,041	0,959	2
6	W6	0,597	0,403	1
7	W7	0,938	0,062	1
8	W8	0,975	0,025	1
9	W9	0,063	0,937	2
10	W10	0,960	0,040	1
11	W11	0,211	0,789	2
12	W12	0,935	0,065	1

The new μ_{ik} The matrix table shows the degree of membership of the data warehouse in each cluster. The most significant degree of membership shows the highest tendency of the data warehouse to become a member of the cluster. From Table 9, the following information is obtained :

a. Based on the largest membership in Cluster 1, there are 6 data warehouses in Cluster 1, namely the warehouse: **4, 6, 7, 8, 10, dan 12**.
b. Based on the most significant degree of membership in cluster 2, there are 6 data warehouses in cluster 2, namely the warehouse **1, 2, 3, 5, 9, dan 11**.

Warehouse Data Ranking Using TOPSIS

After the data is grouped, the data must be ranked.

1. Create a normalized decision matrix.

Table 10. Warehouse Data Cluster 1

No	Ware house	C1	C2	C3	C4	C5
1	W4	460	1500	2,8	500	1
2	W6	279	1200	3,3	500	2
3	W7	653	1600	3,2	150	1
4	W8	921	1650	0,8	400	1
5	W10	868	1800	10,1	500	1
6	W12	962	1400	15,2	546	1

Table 11. Warehouse Data Cluster 2

No	Ware house	C1	C2	C3	C4	C5
1	W1	200	500	3,3	150	2
2	W2	200	300	1,5	150	2
3	W3	355	600	11,9	300	2
4	W5	180	300	2,8	150	1
5	W9	406	720	11,1	360	2
6	W11	607	600	12,7	700	1

For cluster 1
Calculate the first warehouse value for the 1st criterion: $x_{11}{}^2 = 460^2 = 211.600$
Calculate the first warehouse value for the 2nd criterion: $x_{11}{}^2 = 279^2 = 77.841$
Calculate the first warehouse value for the 3rd criterion: $x_{11}{}^2 = 653^2 = 426.409$
Calculate the first warehouse value for the 4th criterion: $x_{11}{}^2 = 921^2 = 848.241$
Calculate the first warehouse value for the 5th criterion: $x_{11}{}^2 = 868^2 = 753.424$
Calculate the first warehouse value for the 6th criterion: $x_{11}{}^2 = 962^2 = 925.444$

$\sum_{i=1}^{m} x_{ij}{}^2 = 3.242.959$
$r_{11} = 0{,}255$
And so on until the sixth warehouse. To obtain a normalized decision matrix, in Table 12.

Table 12. Normalized Decision Matrix Cluster 1

No	Ware house	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
1	W4	0,255	0,398	0,147	0,451	0,333
2	W6	0,155	0,319	0,173	0,451	0,667
3	W7	0,363	0,425	0,168	0,135	0,333
4	W8	0,511	0,438	0,042	0,361	0,333
5	W10	0,482	0,478	0,530	0,451	0,333
6	W12	0,534	0,372	0,798	0,492	0,333

In the same way for the second cluster, so that in the second cluster, a normalized decision matrix is obtained. Table 13.

Table 13. Normalized Decision Matrix Cluster 2

No	Ware house	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
1	W1	0,228	0,387	0,156	0,170	0,471
2	W2	0,228	0,232	0,071	0,170	0,471
3	W3	0,404	0,465	0,563	0,340	0,471
4	W5	0,205	0,232	0,132	0,170	0,236
5	W9	0,462	0,557	0,525	0,408	0,471
6	W11	0,691	0,465	0,601	0,794	0,236

2. Create a weighted normalized decision matrix. The weight to be used is based on Table 3
Calculate normalized weights :
$w_{ij} = 4+3+2+2+2$
$= 13$

Calculate the normalized weight for the 1st criterion:
$w_1 = 4 \div 13 = 0{,}308$
And so on until the 5th criterion

Calculate the first warehouse value :
$y_{11} = w_1 \times r_{11}$
$= 0{,}308 \times 0{,}255$
$= 0{,}079$
And so on until the sixth warehouse.

So we get a weighted normalized decision matrix in Table 14.

Table 14. Weighted Normalized Decision Matrix Cluster 1

No	Ware house	y_{ij}	y_{ij}	y_{ij}	y_{ij}	y_{ij}
1	W4	0,079	0,092	0,023	0,069	0,051
2	W6	0,048	0,074	0,027	0,069	0,103
3	W7	0,112	0,098	0,026	0,021	0,051
4	W8	0,157	0,101	0,006	0,055	0,051
5	W10	0,148	0,110	0,082	0,069	0,051
6	W12	0,164	0,086	0,123	0,076	0,051

In the same way, for the second cluster, so that in the second cluster a weighted normalized decision matrix is obtained in Table 15.

Table 15. Weighted Normalized Decision Matrix Cluster 2

No	Ware house	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
1	W1	0,070	0,089	0,024	0,026	0,073
2	W2	0,070	0,054	0,011	0,026	0,073
3	W3	0,124	0,107	0,087	0,052	0,073
4	W5	0,063	0,054	0,020	0,026	0,036
5	W9	0,142	0,129	0,081	0,063	0,073
6	W11	0,213	0,107	0,092	0,122	0,036

3. Determine the positive ideal solution matrix & negative ideal solution matrix.

If the criterion is a benefit, the most significant value is calculated by calculating the positive ideal solution matrix. If the criterion is cost, then the

smallest value is taken. The result of the negative ideal solution matrix is taken as the smallest value if the criterion is beneficial. If the criterion is cost, then the most significant value is taken. So we get the matrix of positive and negative ideal solutions in Table 16.

Table 16. Matrix of Positive and Negative Ideal Solutions Cluster 1

y_j^+	0,048	0,110	0,006	0,076	0,103
y_j^-	0,164	0,074	0,123	0,021	0,051

In the same way, in the second cluster, so that in the second cluster the positive and negative ideal solution matrices are obtained in Table 17.

Table 17. Matrix of Positive and Negative Ideal Solutions Cluster 2

y_j^+	0,063	0,129	0,011	0,122	0,073
y_j^-	0,213	0,054	0,092	0,026	0,036

4. Determine the distance between the value of each warehouse with the positive ideal solution matrix & negative ideal solution matrix.

Calculate the distance between the values of each warehouse and the positive ideal solution matrix for the first warehouse :

$D_1^+ = 0{,}065$. And so on until the sixth warehouse.

Calculate the distance between the values of each warehouse and the negative ideal solution matrix for the first warehouse:

$D_1^- = 0{,}142$

And so on until the sixth warehouse. To get the distance between warehouses, here can be seen in the matrix of positive and negative ideal solutions in Table 18.

Table 18. Warehouse Distance with Positive and Negative Ideal Solution Matrix Cluster 1

No	Warehouse	D_i^+	D_i^-
1	W4	0,065	0,142
2	W6	0,042	0,167
3	W7	0,101	0,113
4	W8	0,123	0,125
5	W10	0,136	0,075
6	W12	0,174	0,056

In the same way for the second cluster, so that in the second cluster, the distance between the warehouse and the positive and negative ideal solution matrices is obtained in Table 19.

Table 19. Warehouse Distance with Positive and Negative Ideal Solution Matrix Cluster 2

No	Warehouse	D_i^+	D_i^-
1	W1	0,105	0,166
2	W2	0,122	0,168
3	W3	0,122	0,113
4	W5	0,127	0,166
5	W9	0,121	0,116
6	W11	0,175	0,110

5. Determine the preference value for each alternative

For the 1st warehouse :

$$V_1 = \frac{0{,}142}{0{,}065+0{,}142} = 0{,}686$$

And so on until the sixth warehouse. So that the preference value is obtained which can be seen in Table 20.

Table 20. Preference Value Cluster 1

No	Warehouse	V_i
1	W4	0,686
2	W6	0,797
3	W7	0,528
4	W8	0,503
5	W10	0,357
6	W12	0,244

In the same way as the second cluster, the second cluster gets the preference value in Table 21.

Table 21. Preference Value Cluster 2

No	Warehouse	V_i
1	W1	0,613
2	W2	0,579
3	W3	0,481
4	W5	0,566
5	W9	0,489
6	W11	0,385

6. Based on the order of choice, the warehouse with the best preference value is the best. These results can be seen in Table 22.

Table 22. Final Results Ranking Cluster 1

No	Warehouse	V_i
1	W6	0,797
2	W4	0,686
3	W7	0,528
4	W8	0,503
5	W10	0,357
6	W12	0,244

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Accredited rank 4 (SINTA 4), excerpts from the decision of the DITJEN DIKTIRISTEK No. 230/E/KPT/2023

Table 23. Final Results Ranking Cluster 2

No	Warehouse	V_i
1	W1	0,613
2	W2	0,579
3	W5	0,566
4	W9	0,489
5	W3	0,481
6	W11	0,385

In Table 23, it can be explained that the recommended warehouse data for cluster 1 is the CCC Warehouse, with the highest value of 0.797. And for cluster 2, namely the warehouse in front of the Villa Bogor gas station, with a value of 0.613.

System Implementation

Figure 2-5 is the result of the display of the warehouse selection application. Figures 2 and 3 show the criteria and warehouse data, while Figures 4 and 5 are the calculation process pages.

1. Criteria Data

No	Kode	Nama	Atribut	Bobot
1	C1	Harga (Juta/tahun)	Cost	4
2	C2	Luas Bangunan (m2)	Benefit	3
3	C3	Jarak dari HO (KM)	Cost	2
4	C4	Luas Parkir (m2)	Benefit	2
5	C5	Lantai	Benefit	2

Figure 2. Criteria Data

2. Warehouse Data

No	Nama	Harga (Juta/tahun)	Luas Bangunan (m2)	Jarak dari HO (KM)	Luas Parkir (m2)	Lantai
1	Depan Pom Bensin Villa Bogor Indah	200.00	500.00	3.30	150.00	2.00
2	Depan Puri Nirwana / Samping Gudang Alfa	200.00	300.00	1.50	150.00	2.00
3	Komplek Pergudangan KM 36	355.00	600.00	11.90	300.00	2.00
4	Gudang 88	460.00	1500.00	2.80	500.00	1.00
5	Bengkel LAS	180.00	300.00	2.80	150.00	1.00
6	GUDANG CCC	279.00	1200.00	3.30	500.00	2.00
7	PT. GRASINDO	653.00	1600.00	3.20	150.00	1.00
8	Gudang Kacang Garuda	921.00	1650.00	0.80	400.00	1.00
9	Komplek Pergudangan KEDUNG HALANG	406.00	720.00	11.10	360.00	2.00
10	PT. Nugratama Dayamitra	868.00	1800.00	10.10	500.00	1.00
11	Gudang Nurdhin	607.00	600.00	12.70	700.00	1.00
12	Gudang Hj. Nasrul	962.00	1400.00	15.20	546.00	1.00

Figure 3. Warehouse Data

3. Calculation Process

Data Gudang		Data Kriteria				
No	Nama	Harga (Juta/tahun)	Luas Bangunan (m2)	Jarak dari HO (KM)	Luas Parkir (m2)	Lantai
1	Depan Pom Bensin Villa Bogor Indah	200.00	500.00	3.30	150.00	2.00
2	Depan Puri Nirwana / Samping Gudang Alfa	200.00	300.00	1.50	150.00	2.00
3	Komplek Pergudangan KM 36	355.00	600.00	11.90	300.00	2.00
4	Gudang 88	460.00	1500.00	2.80	500.00	1.00
5	Bengkel LAS	180.00	300.00	2.80	150.00	1.00
6	GUDANG CCC	279.00	1200.00	3.30	500.00	2.00
7	PT. GRASINDO	653.00	1600.00	3.20	150.00	1.00
8	Gudang Kacang Garuda	921.00	1650.00	0.80	400.00	1.00
9	Komplek Pergudangan KEDUNG HALANG	406.00	720.00	11.10	360.00	2.00
10	PT. Nugratama Dayamitra	868.00	1800.00	10.10	500.00	1.00
11	Gudang Nurdhin	607.00	600.00	12.70	700.00	1.00
12	Gudang Hj. Nasrul	962.00	1400.00	15.20	546.00	1.00
Keterangan Atribut		Cost	Benefit	Cost	Benefit	Benefit
Bobot		4	3	2	2	2

Figure 4. Calculation Process

4. Calculation Result Detail Page

Cluster 1

Ranking	Nama Gudang	Harga (Juta/tahun)	Luas Bangunan (m2)	Jarak dari HO (KM)	Luas Parkir (m2)	Lantai	Derajat Keanggotaan		Nilai TOPSIS
							Cluster 1	Cluster 2	
1	GUDANG CCC	279.00	1200.00	3.30	500.00	2.00	0.5974575976172	0.4025424023828	0.7972334796136
2	Gudang 88	460.00	1500.00	2.80	500.00	1.00	0.9226920310422	0.0773079689577	0.6855431271232
3	PT. GRASINDO	653.00	1600.00	3.20	150.00	1.00	0.9377488760094	0.0622511239905	0.5275439179846
4	Gudang Kacang Garuda	921.00	1650.00	0.80	400.00	1.00	0.9747892133427	0.0252107866577	0.5031608544678
5	PT. Nugratama Dayamitra	868.00	1800.00	10.10	500.00	1.00	0.9603894190096	0.0396105809903	0.3565754361765
6	Gudang Hj. Nasrul	962.00	1400.00	15.20	546.00	1.00	0.9353990601365	0.0646009398634	0.2440419655200
Pusat Cluster		739.09	1,554.22	6.21	427.27	1.07	Detail FCM		Detail TOPSIS

Gudang yang direkomendasikan untuk Cluster 1 yaitu **GUDANG CCC** dengan nilai **0,797**

Cluster 2

Ranking	Nama Gudang	Harga (Juta/tahun)	Luas Bangunan (m2)	Jarak dari HO (KM)	Luas Parkir (m2)	Lantai	Derajat Keanggotaan		Nilai TOPSIS
							Cluster 1	Cluster 2	
1	Depan Pom Bensin Villa Bogor Indah	200.00	500.00	3.30	150.00	2.00	0.019977284027342	0.9800227159726	0.6131955038869
2	Depan Puri Nirwana / Samping Gudang Alfa	200.00	300.00	1.50	150.00	2.00	0.038914820890094	0.9610851791099	0.5794674547507
3	Bengkel LAS	180.00	300.00	2.80	150.00	1.00	0.040703910961161	0.9592960893884	0.5656512596824
4	Komplek Pergudangan KEDUNG HALANG	406.00	720.00	11.10	360.00	2.00	0.063443087775507	0.9365569122244	0.4885381018806
5	Komplek Pergudangan KM 36	355.00	600.00	11.90	300.00	2.00	0.008067791597756	0.9919322084022	0.4807237645771
6	Gudang Nurdhin	607.00	600.00	12.70	700.00	1.00	0.211257760516981	0.7887423944802	0.3852175017134
Pusat Cluster		307.72	521.03	6.79	284.49	1.71	Detail FCM		Detail TOPSIS

Gudang yang direkomendasikan untuk Cluster 2 yaitu **Depan Pom Bensin Villa Bogor Indah** dengan nilai **0,613**

Figure 5. Calculation Result Detail Page

CONCLUSIONS AND SUGGESTIONS

Conclusion

The conclusion that can be drawn from this research is that this application can group warehouse data into two clusters. With the characteristics of the first cluster, the price is higher but with a larger building area, and the characteristics of the second cluster are cheaper but with a smaller building area. The results of grouping data must be ranked to obtain recommended data warehouses. The warehouse selection application can run according to the needs desired by the company and has been implemented at PT Warung Islami Bogor.

Suggestion

Thanks to the newly added warehouse data import capability, companies no longer need to manually enter warehouse data into the system. Meanwhile, the Subtractive Clustering with Fuzzy C-Means algorithm is used to increase speed.

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