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A Multi-Criteria Decision Making for Postal Item Delivery Optimization from an Operational Perspective

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Abstract. Pos Indonesia already has a distribution model, which includes vehicle routing and scheduling. The innovation that can compete with various logistics services is essential through improve services and exceed consumer expectations for delivery speed and accuracy. The Postal Processing Centres Bandung 40400 is responsible for deliveries; it has a specific route and number of trucks assigned to delivery in line with a specified zone system. In order to remain competitive with other providers, innovation in optimizing existing routes is required. This study aims to propose a Multi-Criteria Decision Making model with an Analytical Hierarchy Process and The Technique for Order of Preference by Similarity to Ideal Solution and Monte Carlo Simulation to optimize route path by selecting delivery centres that give the best performance based on four criteria: product express types, demand, distance, and the number of postal bags. The Multi-Criteria Decision Making method is implemented to adapt the choice of operational managers in determining the priority of delivery centres based on company policies. Analytical Hierarchy Process implements the weighted criteria and The Technique for Order of Preference by Similarity to Ideal Solution to determine the priority ranking based on the dataset. Monte Carlo then simulates the solution set. This simulation model shows the priority of distribution centres concerning current routes to assist operational managers in forecasting future delivery patterns based on available datasets. The delivery centre Cikeruh, Cikutra, Lembang, and Majalaya are the four delivery centres with the highest-ranking priority, suggesting that these four are given priority for the next delivery plans related to route, vehicle, and time constraints. A comprehensive dataset is required to optimize the model.

Keywords: MCDM, AHP, TOPSIS, Monte Carlo Simulation, Postal Item Delivery

INTRODUCTION

The postal service is a network activity comprised of postal outlets or franchised counters, and it is classified as a network industry due to the network effect created by the delivery service, which begins with the collection of the postal items and ends with the receipt of the postal items by the final recipient [1]. Reducing transportation costs can increase company profits, streamline the distribution system, and utilize company-owned transportation modes. The Postal Processing Center (PPC) Bandung 40400 is responsible for planning, organizing, implementing, and controlling, as well as for the effective and efficient implementation of the collecting, processing, transporting, delivery, and reporting policies in its work area, which is mainly in Bandung area. Pos Indonesia's distribution uses a zoning system, explicitly dividing the tertiary network's delivery area into several delivery areas [2]. As a result, adjacent areas are served by distinct modes of transport. Therefore, it is essential to determine a more efficient distribution route with the least total mileage. Determining the shortest route between post offices and DC within a given area is the most effective method of lowering total postal service costs [3]. In addressing the challenge, Pos Indonesia must consider two factors: the zoning system, which can be profitable in some cases, and the distribution

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pattern, which is regulated by the internal fleet and predetermined routes. Pos Indonesia also adheres to the less than truckload policy for greater flexibility [4]. In detail, we will discuss several considerations, including how the zoning system can affect routing optimization via the MCDM method. The following sections comprise the document. Section 2 reviews prior studies on the MCDM method utilizing the AHP and TOPSIS process. Section 3 shows details the methods performed in this research by describing the experimental phase. Section 4 covers the implementation model to the dataset from Pos Indonesia's delivery history. The operational manager determines the criteria weightage for AHP and TOPSIS to yield the DC ranking priority set that will eventually be simulated using MCS. Finally, section 5 discusses some findings and future research.

LITERATURE REVIEW

Multi-Criteria Decision Making

Most logistics network design problems have been implementing MCDM, mathematical modelling, and network optimization, among the numerous techniques available under the umbrella of analytical methods. MCDM incorporates various methodologies and algorithms, and several research publications in network design and facility placement are accessible. For example, [5] focused on network design in the relief of supply chain area disasters and offered an integrated methodology that combines geographic information system technology with fuzzy AHP. MCDM in logistics and supply chain management includes supplier and third-party logistics provider selection. Numerous studies have demonstrated that MCDM techniques such as AHP and TOPSIS are effective methods for assisting in complex decision-making in these fields. However, it has not been demonstrated how to combine MCDM techniques in route optimization with implementing simulation techniques involving operational managers to determine the weight criteria on DC performance. Table 1 summarizes different MCDM processes and their associated implementation criteria based on some of the literature provided by [6]. The review demonstrates that the AHP-TOPSIS technique is the best suitable for addressing the issues presented in this research.

TABLE 1. MCDM Processes

MCDM process	Advantage	Disadvantage	Application
AHP	Simple to comprehend, well-suited to a limited amount of criteria and choices [7].	This technic is not relevant when the number of criteria or options is excessive.	Corporate policy, supply chain strategy, and location selection [7].
TOPSIS	It applies to a wide variety of areas and can manage a large number of variables and criteria [8].	It is ineffective if the number of criteria or options is too small. [9].	Supply chain and logistics, energy, human factor, health and safety, and environment [8].

Simulation

Computer simulation has also been extensively employed to address network design issues and supply chain policy formulation. The primary benefit of simulation is that it enables the dynamic performance of the supply chain to be evaluated in virtual settings, minimizing the financial and economic risks associated with direct real-world implementations [10]. Numerous research groups have employed simulation tools to aid decision-making about supply chain architecture, particularly in scenarios with logistic uncertainty [11]. [12] Also recommended adopting a simulation-based optimization strategy to tackle supply chain network design difficulties to reduce the total predicted cost. [13] They use the MCS to reduce fixed costs associated with delivery centres location, inventory expenses, including safety stocks, and ordering and shipping costs over the whole supply network. [14] This study outlined Pos Indonesia's supply network design issues.

RESEARCH METHOD

While the MCDM technique is capable of determining the choices that will be utilized to optimize the existing route, the AHP and TOPSIS methods are also considered in light of the issues at hand. AHP and TOPSIS are utilized to simplify the numerical difficulties by the following procedure:

- Step 1: incorporates expert input—the operations manager input the criteria weight.
- Step 2: performing the AHP technique, which generates criteria from DC based on the weight of the AHP method's criterion.
- Step 3: the TOPSIS technique will process the AHP result and yield a set of DC ranking priorities.
- Step 4: the DC ranking priority transforms the data into the format required and performing MCS. Compared to the route determination in the PPC zoning system, the simulation results will indicate the DC ranking priority, which will subsequently be assigned as DC priority in the existing route.

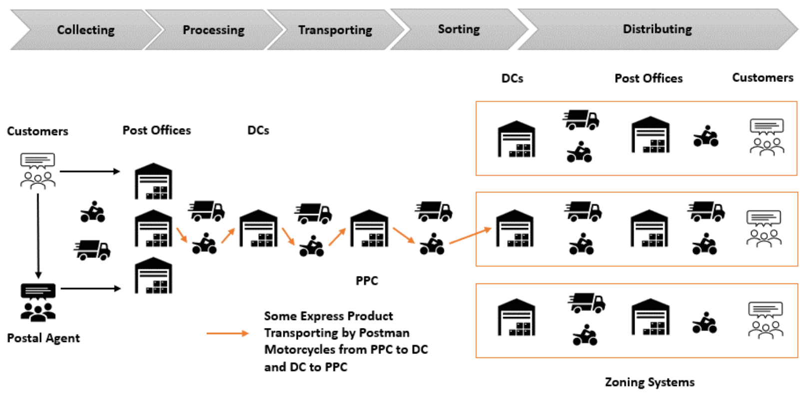

FIGURE 1. Pos Indonesia distribution network and zoning system

Problem Identification

Pos Indonesia has developed its distribution network with the hub and spoke model, PPC as the hub, and the spokes are the nearby post offices, as shown in Figure 1. The DC will dispatch a vehicle at the designated time to pick up the mail and packages from post offices. A sorting process is then conducted in the origin and destination PPC before delivering the items to each DC and the customers. This study focuses on distributing the tertiary network between PPC and DC, which operates a nationwide network serving various businesses and consumers. A PPC is dedicated to serving densely populated urban areas, usually consisting of several DCs, and Post Offices. Pos Indonesia has previously established a distribution scenario based on a zone-based system. Specific schedules and vehicles serve each DC in a particular area. PPC Bandung 40400 consists of 13 DC and several district post offices that provide six vehicles, seven days a week and two times a day. The types of vehicles used are relatively homogeneous, with an average capacity of 1,500 kilograms. Provide two dropships at 06.00 WIB and 10.00 WIB. This study gathers three months database, including products, destinations, demand, weight, and shipping date. Data collected from September to December 2020 was 19,850 records. The zone system constraint utilizes by the operational manager as input into AHP criteria and TOPSIS to reflect the DC ranking priority.

MCDM Processes

The MCDM technique was chosen based on Table 1 by the following features of the issues encountered. The issue is binary by definition. That is, each criterion is either better or worse than the others. There is no such thing as a middle ground. The fuzzy model is no longer an issue. Manager input through the survey shows that the AHP and TOPSIS methods are the most appropriate to resolve the associated issues. The following four criteria were established after analyzing the data set and evaluating the DC performance for ranking priority. Postal bag: the number of postal bags is delivered. Demand: the number of kilos delivered to a DC. Distance: the distance between PPC and DC and between DCs is measured in kilometres. Express products: items with express features. The AHP technique is implemented to determine the weight of the given criteria, and the weight of each criterion will determine DC's ranking priority.

Monte Carlo Simulation

Simulation is a quantitative technique for evaluating alternative courses of action that entails developing a system model and then repeating the process by connecting a series of tests to forecast the system's features over time. To investigate how the existing system would respond to these changes in a model and replicate the existing system's response. Simulation is a suitable alternative for the mathematical assessment of a model in circumstances when mathematical convenience is not flexible. Steps in the Monte Carlo Simulation technique: Step 1: Establish a probability distribution for the critical variables. Step 2: To create a cumulative probability distribution for each variable. Step 3: Assign each variable a random number interval. Step 4: Generating random numbers. Step 5: Simulating a series of tests.

IMPLEMENTATION

Performing AHP

The initial step in using the AHP method is to define the criteria based on the dataset's historical delivery data. The establishment of criteria is shown in the following: 1 as equal importance, 3 moderate importance, 5 strong importance, 7 very strong importance, 9 extreme importance, 2-4-6-8 to express intermediate values. These equations are now used to generate the normalized pairwise matrix. First, a survey is performed to determine the criterion's significance level. Following that, the criteria are compared pairwise. Following that, formulae (1) is used to generate a normalized pairwise comparison matrix.

$$N_{ij} = \frac{C_{ij}}{\sum_i^n C_{ij}} \quad (1) \qquad\qquad W_i = \frac{\sum_i^n N_i}{n} \quad (2)$$

Rows and columns are denoted by i and j, accordingly. Nij is the pairwise equation's normalized form. i and j may be any value between 1 and 4 since there are four requirements. Following that, the weighting of the chosen criterion was determined. To confirm that the following formulae 2. Here i as a column. Where i = 1,2,3,4, and n is the number of criteria that have been chosen. Ni is the value of the normalized matrix. Wi denotes the weight of the criterion. Likewise, alternate weight is calculated in the same manner. Alternative weight is denoted by the symbol Ai. Then a score is calculated, and the option with the highest score is chosen.

$$score = \sum W_i * A_i \quad (3) \qquad\qquad WS_i = C_i \, x \, W_i \quad (4)$$

After determining the weighted sum value, the ratio of the weighted sum to the criterion weight is computed using the following formulaer 4. WSi denotes the weighted sum value for the i criteria. Ci and Wi denote the element of pairwise comparison and the weight of criteria, respectively.

$$R_i = \frac{W\,S_i}{W_i} \quad (5) \qquad\qquad \lambda_{max} = \frac{\sum_i^n R_i}{n} \quad (6)$$

The CI denotes the consistency index, the CR denotes the consistency ratio, and the RI is the random consistency index. λmax denotes the eigenvalue's maximum value. It is a fundamental tenet of AHP. The random index is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (7) \qquad CR = \frac{CI}{RI} \ (8)$$

Now, a normalized pairwise matrix is constructed using these formulae. First, the survey determines the relative significance of the selected criteria. Then, pairwise comparisons of the criteria are performed. Following that, a normalized pairwise comparison matrix is constructed using the formula 1.

TABLE 2. Eigen value yields for criteria

No	Criteria	Description	Eigenvalue
1	Postal bag	Sum of postal bag do deliver	0.0727
2	Demand	Amount of weight	0.1623
3	Distance	Distance from PPC to DC and DC to DC	0.2679
4	Express product	Amount of weight of express product	0.4971

The number of criteria used in this study is four, and the random index is 0.9. By performing the AHP procedure, the eigenvalues as shown in Table 2. Then TOPSIS method implements to calculate the DC ranking priority based on the provided dataset.

Performing TOPSIS

TOPSIS utilize to find the optimal DC ranking priority. The following formulae are required. After entering the actual values, they are normalized using the equation:

$$\overline{X_{ij}} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{m} X_{ij}^{2}}} \qquad (9) \qquad V_{ij} = \overline{X_{ij}}\; x\; W_j \qquad (10)$$

The normalized element is denoted by $\overline{X_{ij}}$. J denotes the column count; in this instance, j=1, 2, 3. And X_{ij} denotes the non-normalized member in the matrix mentioned earlier. Then, using the following equation, the weighted normalized matrix is determined at formulae 10. Here, W_j denotes the weight of the criterion. The criterion's weight has already been established in the preceding section, particularly the section on AHP computation. V_{ij} is the normalized weighted matrix element. Then the euclidian distances between the ideal best and worst values are calculated, and the formula is given below:

$$S_i^{+} = \sqrt{\sum (V_{ij} - V_j^{+})^\wedge 2} \qquad (11) \qquad S_i^{-} = \sqrt{\sum (V_{ij} - V_j^{-})^\wedge 2} \qquad (12)$$

Here, S^{+} and S^{-} denote the Euclidian distance between the ideal best and worst values. The performance score is then calculated. The alternative with the highest performance score is chosen. The following equation implements to calculate the performance score:

$$p^{ij} = \frac{S_{+}^{-}}{S_i^{+} + S_i^{-}} \qquad (13)$$

According to the TOPSIS method, figure 2 below shows the DC ranking priority based on those analyzed criteria before.

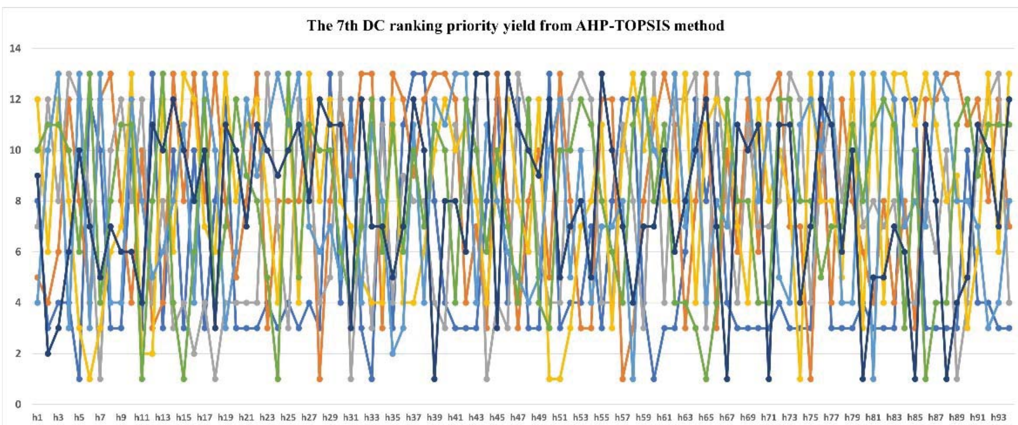

FIGURE 2. DC ranking yield from AHP-TOPSIS method

4.3 Result and Discussion

Additional data adjustment is needed, depending on the data generated by AHP-TOPSIS. The DC Ranking table is converted into a matrix that shows the frequency with which a DC occupies the ranking based on the specified criteria to perform MCS. Based on 94 delivery records in the dataset, the following matrix shows a DC's frequency ranking. The simulation error proportional to the number of iterations can be predicted using the MCS approach. The total error is determined using the formula: $= \frac{3\,\sigma}{\sqrt{N}}$, σ is the standard deviation of the random variable, and N is the number of iterations. The standard deviation σ is calculated based on the entire population, using the formula: $\sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{N}}$ yields $\sigma = 3.74318928$. The desired absolute error value is less than 2%, and then this value is obtained using the formula: $\varepsilon = \frac{\bar{x}}{\left(\frac{1}{0{,}02}\right)}$ yields ε = 0.14 As a result, the number of iterations required to obtain results with an error of less than 2% is as follows: $N = \left(\frac{3\ x\ \sigma}{\varepsilon}\right)^2 = 6.434$. The average value = 7.68 is known from the iteration results, compared to the iteration sequence with the Object DC range between 85–105 and 106–126, as shown in Table 3.

TABLE 3. Random Number and Simulation yields

Object Delivery Centres		Average	Freq.	DD	DK	Tag Number	MCS	ODCSIM
1	21	4.90	103	0.08	0.08	0-8	51	7.476190
22	42	10.71	225	0.18	0.27	9-27	79	8.285714
43	63	5.29	111	0.09	0.36	28-36	4	4.904762
64	84	7.43	156	0.13	0.49	37-49	15	10.71429
85	105	7.48	157	0.13	0.62	50-62	19	10.71429
106	126	7.76	163	0.13	0.75	63-75	35	5.285714
127	147	8.29	174	0.14	0.89	76-89	26	10.71429
148	168	6.05	133	0.11	1.00	90-100	44	7428571

Referring to the results of AHP – TOPSIS, the following DC ranking priorities. Essentially, the simulation implements determining the DC's performance level based on the criteria specified when running the AHP and TOPSIS methods. Monte Carlo Simulation determines which DCs have a certain level of importance based on the provided history dataset. As a result of the previous calculation, it is clear that several DCs have a ranking and frequency that indicates their importance in operational managers' delivery planning considerations. As a result of the simulation results, it is clear that several DC perform well in terms of the four criteria. DC Cikeruh, DC Cikutra, DC Lembang, and DC Majalaya are the highes DC performance rankings.

TABLE 4. DC Priority based on PPC Zoning System

Route	Route Flow	DC Priority
Route-6	PPC --> DC Cikeruh --> DC Majalaya --> PPC	DC CK Cikeruh
Route-5	PPC --> DC Ujung Berung --> DC Cikeruh --> PPC	DC CK Cikeruh
Route-1	PPC --> DC Situ Saeur --> DC Asia Afrika --> PPC	DC AA Asia Afrika
Route-2	PPC --> DC Dayeuhkolot --> DC Katapang --> DC Soreang --> PPC	DC KTP Soreang
Route-3	PPC --> DC Cikutra --> DC Lembang --> PPC	DC CA Cikutra
Route-4	PPC --> DC Cipedes --> DC Padalarang --> DC Cimahi --> DC Cimahi --> PPC	DC PDL Padalarang

Prioritization of DC rankings generated by AHP-TOPSIS-MCS compared to the current route, as shown in Table 4, it is clear that the four DCs generated by the simulation become priority routes based on the specified criteria. This prediction means that some of these DC have a certain level of importance in expressing product and demand capacity, which operational managers can use to plan routes, schedules, and vehicles to prioritize postal item delivery.

CONCLUSIONS

The simulation results provide an overview for operational managers to make extra informed decisions based on historical data from three months' worth of shipments. If the dataset is more extensive by the period, predictions can be generated to meet the needs of operational delivery planning; simulations can be used to demonstrate peak sessions and demand at each DC, allowing the number of transport vehicles to be allocated to priority routes.

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