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# Multi-Criteria Decision Support System for Best Warehouse Performance Selection Using Combined Compromise Solution Method

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**Abstract**−Selecting the best performing warehouse is a strategic step in supporting the efficiency of the supply chain and distribution of goods. This research aims to design a multi-criterion-based decision support system in evaluating and determining the best warehouse using the Combined Compromise Solution (CoCoSo) method. This method was chosen for its ability to combine the strength of weighted average approaches and relative compromises between alternatives, resulting in more balanced and objective decisions. This research involves eight warehouse alternatives that are assessed based on a number of relevant performance criteria. The process starts from problem identification, determination of criteria, data collection, normalization, weighting, to the application of the CoCoSo method. The final results showed that Warehouse C obtained the highest score of 4.8155, followed by Warehouse E and Warehouse A, indicating that the three warehouses had the best performance. These findings are expected to be a reference in strategic decision-making related to warehousing management as well as the basis for the development of a data-based performance evaluation system.

**Keywords:** Decision Support System, CoCoSo, Warehouse Evaluation, Multi-Criteria, Combined Compromise

## 1. INTRODUCING

Warehouses play a strategic role in modern supply and logistics chains as a hub for consolidation, storage, and distribution of goods that connect the various stages in the material flow, from suppliers to end consumers. In an era of global competition that demands speed and efficiency, warehouse functions are no longer limited to storage facilities, but have evolved into a key element in ensuring smooth operations and achieving customer service targets. Effective warehouse management can speed up the delivery cycle, reduce logistics costs, and improve order fulfillment accuracy[1], [2]. In addition, the integration of the warehouse with advanced information technology and logistics management systems allows for real-time monitoring of inventory, faster processing, and more responsive distribution planning to market demand dynamics. Therefore, optimal warehouse performance is an important indicator of overall supply chain success, while supporting the achievement of the company's strategic goals in terms of cost efficiency, customer satisfaction, and competitive advantage[3], [4].

Evaluation of warehouse performance is a very important aspect in improving operational efficiency and company competitiveness in the logistics industry[5], [6]. A well-managed warehouse not only serves as a storage place for goods, but also as a hub that affects the speed, accuracy, and cost of distribution. By conducting regular performance evaluations, companies can identify areas that need improvement, such as more efficient inventory management, reduced processing time, optimization of space usage, or improved accuracy in order fulfillment. This evaluation also helps in reducing operational costs that can arise due to errors in warehouse management, such as overstocking, stockout, or shipping errors. In addition, optimal warehouse performance contributes directly to increased customer satisfaction through faster and more accurate delivery. In the context of increasingly fierce global competition, companies that can maximize the efficiency of their warehouses will have a significant competitive advantage, both in terms of cost, speed, and quality of services offered. Therefore, warehouse performance evaluation is a crucial step to create a supply chain that is more responsive and adaptive to market needs[7], [8].

Complexity in decision-making arises when there are many criteria that must be considered in the evaluation of an alternative or problem-solving[9]–[11]. In the context of warehouse optimization, for example, logistics managers are faced with a variety of interrelated factors, such as operational costs, storage capacity, speed of picking and shipping goods, inventory accuracy levels, and quality of customer service. Each of these criteria has a different weight and impact on the overall performance of the warehouse, and there is often a trade-off between one criterion and another. For example, increasing storage capacity can risk increasing operational costs or reducing the efficiency of picking goods. In addition, external factors such as changes in market demand and fluctuations in raw material prices must also be taken into account in decision-making. Therefore, decision management that involves many criteria becomes very complicated, requiring in-depth analysis and a systematic approach to find the optimal solution. In the face of this complexity, a multicriteria method-based decision support system (MCDM) is very useful because it is able to evaluate and prioritize criteria objectively, thus helping decision-makers in making more precise and informed decisions[12], [13].

The application of a multicriterion-based decision support system (MCDSS) to select the best warehouse performance is an effective solution in dealing with the complexity of warehouse performance evaluation. This system allows for more objective decision-making by considering various relevant criteria in the assessment of warehouse performance, such as operational costs, delivery time, inventory accuracy level, space utilization, and customer satisfaction. In the process, MCDSS integrates various multicriteria methods such as AHP, TOPSIS, or other combined methods to provide a more structured and systematic ranking or recommendation. The implementation of MCDSS allows logistics managers to evaluate and compare warehouse alternatives more precisely, based on the priority and weight of

each criterion[14], [15]. For example, if the company prioritizes cost efficiency, then the operational cost criteria will be given greater weight in the assessment process. Conversely, if shipping speed and inventory accuracy take precedence, those criteria will gain higher weight. Thus, MCDSS helps in choosing a warehouse that is not only the best in one aspect, but also balanced in meeting the various operational needs of the company. With the ability to adjust weights according to market conditions or changes in company strategy, MCDSS provides flexibility in more adaptive and responsive decision-making[16]. Therefore, the application of MCDSS in selecting the best warehouse not only increases the efficiency and effectiveness of decisions, but also helps companies in achieving a sustainable competitive advantage in the supply chain and logistics. In the context of selecting the best warehouse, CoCoSo enables more effective decision-making by combining information from various evaluation criteria, such as operational costs, delivery speeds, inventory accuracy, and space utilization. The process begins with the normalization of the data, followed by the identification of ideal solutions and negative solutions, which aims to measure the distance between the existing alternatives and the two solutions. The CoCoSo then calculates the combined compromise value for each alternative based on this distance, providing a rating that reflects how well an alternative meets the predetermined criteria.

Applying the Combined Compromise Solution (CoCoSo) method as the best alternative selection approach in a multicriteria-based decision support system provides significant advantages in decision-making involving many conflicting criteria[17]–[19]. CoCoSo is a method that combines the strengths of various compromise approaches in order to find a balanced and optimal solution, taking into account diverse and complex criteria. The advantage of the CoCoSo method lies in its ability to handle various types of criteria, both benefit and cost. Thus, CoCoSo not only considers the criteria separately, but is also able to combine them to achieve the most optimal solution based on the overall relevant criteria. This method also has flexibility in adjusting the weight of criteria, which allows companies to adapt decision-making according to changing market conditions or internal strategies. The implementation of the CoCoSo method in selecting the best warehouse can provide more measurable and data-driven decisions, reduce subjectivity, and increase efficiency in selecting alternatives[20]–[22]. The CoCoSo method provides a more comprehensive and adaptive solution in the selection of the best warehouse to support the company's strategic goals.

The purpose of this research is to apply a multicriterion-based decision support system in the selection of the best warehouse in the supply chain and logistics. The contribution of this research is expected to make several important contributions both in the development of science and in practice in the logistics industry. Theoretically, this study enriches the literature by developing the application of the CoCoSo method in the context of warehouse performance evaluation, which is still rarely applied. This research also provides a deeper understanding of the use of combined compromise methods for decision-making in multicriteria decision support systems.

## 2. RESEARCH METHODOLOGY

### 2.1 Research Stages

The research stage generally includes systematic steps taken to answer research problems or questions. The benefit of the research stage is the importance of each systematic step in the research process to ensure that the research objectives can be achieved effectively and efficiently. In addition, the benefit of the research stage also lies in its ability to facilitate the process of evaluation, replication, and further research development, thereby strengthening scientific contributions in certain scientific fields. The stages of the research conducted are shown in figure 1.

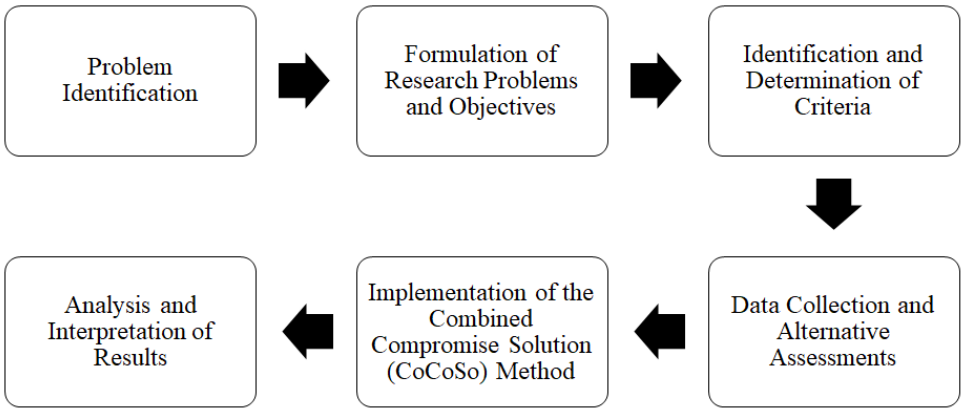


**Figure 1.** Research Stages

The research stages of Figure 1 begin by identifying problems in selecting the best warehouse performance, where decision-making often involves many conflicting criteria. This problem has become complex and requires the right approach in decision-making. Furthermore, the formulation of the problem was carried out by formulating the core question of the research: how to develop a decision support system based on the CoCoSo method to objectively and accurately assess and determine the best warehouse performance. The aim of the research was to build an effective MC-

DSS framework for this issue. The identification and criteria determination stage involves identifying relevant and important criteria to evaluate warehouse performance, both from the results of literature studies and interviews with logistics experts. Each criterion will be used in a multi-criteria evaluation process. Data collection and alternatives were collected from several warehouse alternatives through observations, questionnaires, and historical data of the company. Each alternative will be evaluated based on predetermined criteria, using a specific numerical scale. The CoCoSo method is applied to integrate the preference values of all alternatives to the criteria, in order to produce a final ranking of the warehouse performance. This process involves normalization, compromise aggregation, and distance calculation of the common ideal solution. The results of the application of the method are analyzed to evaluate the effectiveness of the decision support system, as well as identify the best performing warehouse alternatives.

### 2.2 Combined Compromise Solution (CoCoSo) Method

The Combined Compromise Solution (CoCoSo) method is one of the approaches in multi-criteria decision-making (MCDM) designed to combine the advantages of several compromise concepts in one integrated evaluation framework. The CoCoSo method integrates the principles of linear aggregation methods and ratio-based methods to assess alternatives based on their proximity to the ideal solution. The scoring process involves normalizing the data, calculating preference scores through three main formulas—weighted amounts, power-weighted scores, and relative composite values that are then combined into a single final value to rank each alternative. This method is known for its ability to handle the complexity of decision-making involving many criteria as well as its flexibility in various application contexts.
The stages of the CoCoSo method are the preparation of a decision matrix which contains the performance value of each alternative to each criterion made using the equation.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{n1} \\ \vdots & \ddots & \vdots \\ x_{1m} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Decision matrix normalization is the process of converting the data in the decision matrix into a uniform scale, so that each value can be directly compared even if the unit or units are different calculated using the following equation.

$$r_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (2)$$

$$r_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (3)$$

The next step is to calculate the values Si (Positive Ideal Solution) and Pi (Negative Ideal Solution). Si and Pi are ideal solutions used to compare alternatives in decision-making. The value of a positive ideal solution and a negative ideal solution can use the equation.

$$S_i = \sum_{j=1}^{n} (W_j r_{ij}) \quad (4)$$

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j} \quad (5)$$

The calculation of the relative weights of all alternatives uses the aggregation calculation technique. In this process, there are 3 stages of calculation of assessment scores that will produce relative weight. The relative weight equation can be seen below.

$$K_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m} (P_i + S_i)} \quad (6)$$

$$K_{ib} = \frac{S_i}{min\, S_i} + \frac{P_i}{min\, P_i} \quad (7)$$

$$K_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{(\lambda\, max\, S_i + (1-\lambda)\, max\, P_i)} \quad (8)$$

The last stage is to calculate the total value of each alternative using the following equation.

$$K_i = (k_{ia} k_{ib} k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}) \quad (9)$$

The CoCoSo method is particularly suitable for use when decision-making requires a combination of additive (additional) and multiplicative (multiplication) approaches to consider the impact of the criteria as a whole.

## 3. RESULT AND DISCUSSION

Multi-criteria decision support system for best warehouse performance selection using combined compromise solution method is an approach to selecting the best performing warehouse using a multi-criteria decision support system (DSS). The system is designed to handle the complexity of warehouse selection involving various criteria, such as operational

efficiency, delivery speed, stock accuracy, operational costs, and logistics flexibility. In this system, the CoCoSo method is applied to integrate various conflicting criteria and produce a comprehensive solution. The CoCoSo method combines the principles of aggregation based on addition and multiplication to calculate the preference value of each warehouse alternative. The process begins with compiling a decision matrix that contains the values of each alternative to the set criteria, followed by normalization and weighting of these values. Furthermore, the preference score is calculated using three main scores, namely sum weighted, product weighted, and aggregated assessment score which are then combined to produce the final score used to determine the warehouse ranking. Thus, this system assists logistics managers or related parties in selecting the best warehouse objectively and data-driven, while considering various aspects that are important in logistics operations.

### 3.1 Problem Identification

The first stage in this study is problem identification, which aims to reveal the challenges or issues faced in the selection of the best-performing warehouse. In the world of logistics, the selection of an optimal warehouse involves many conflicting criteria, such as shipping speed, stock accuracy, operational costs, and flexibility. The problem that must be solved is how to evaluate and select the best-performing warehouse based on these criteria objectively and systematically.

### 3.2 Formulation of Research Problems and Objectives

At this stage, the problems that have been identified will be further formulated in the form of clear and focused research questions. The research objectives are then determined, which can be in the form of developing a decision support system based on the Combined Compromise Solution (CoCoSo) method to determine the warehouse with the best performance based on predetermined criteria.

### 3.3 Identification and Determination of Criteria

At this stage, steps are taken to identify and establish relevant criteria for warehouse performance evaluation. These criteria can include aspects such as operational efficiency, delivery speed, cost, inventory management accuracy, and logistics flexibility. The determination of these criteria is important to ensure that all important aspects of warehouse operations are considered in decision-making. Typically, criteria are determined based on relevant literature and input from practitioners in the field of logistics. The description of the criteria data is shown in Table 1.

**Table 1.** Criteria Data

| Criteria Name | Criteria Type | Weighting Criteria | Description |
|---|---|---|---|
| Operational Efficiency | Benefit | 0.25 | Assess the extent to which the warehouse can operate at minimal cost and high speed. |
| Delivery Speed | Benefit | 0.2 | Assess the time it takes to ship goods from the warehouse to the customer. |
| Operating Costs | Cost | 0.25 | Assess the extent to which the warehouse can maintain stock of goods according to inventory data. |
| Inventory Management Accuracy | Benefit | 0.2 | Assess the costs incurred to run warehouse operations. |
| Logistics Flexibility | Benefit | 0.1 | Assess the ability of warehouses to adapt to changing demands, including varying handling capacities. |

### 3.4 Data Collection and Alternative Assessments

The next stage is the collection of the data needed to assess existing warehouse alternatives. This data can be obtained through direct observation, company reports, interviews with related parties, or surveys of warehouse managers. Once the data is collected, each warehouse alternative is assessed based on the criteria that have been established in the previous stage. This assessment is carried out using a numerical scale or descriptive-based assessment. The assessment data obtained in this study is shown in table 2.

**Table 2.** Assessment Data

| Alternative Name | Operational Efficiency | Delivery Speed | Operating Costs | Inventory Management Accuracy | Logistics Flexibility |
|---|---|---|---|---|---|
| Warehouse A | 85 | 90 | 88 | 75 | 80 |
| Warehouse B | 80 | 75 | 90 | 70 | 85 |
| Warehouse C | 90 | 95 | 85 | 80 | 90 |
| Warehouse D | 75 | 80 | 80 | 65 | 70 |
| Warehouse E | 88 | 85 | 92 | 78 | 82 |
| Warehouse F | 82 | 80 | 85 | 72 | 75 |
| Warehouse G | 80 | 70 | 80 | 65 | 88 |
| Warehouse H | 78 | 80 | 77 | 83 | 80 |

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This assessment is carried out using a numerical scale with values between 1 and 100, which will then be used in the CoCoSo method.

### 3.5 Implementation of the Combined Compromise Solution (CoCoSo) Method

The implementation of the CoCoSo method is applied to evaluate warehouse alternatives based on the data that has been collected and the criteria determined. This process involves normalizing the data, weighting criteria, and calculating the preference score for each alternative using three main formulas: weighted summation score, weighted multiplication-based score, and aggregate score. The results of these calculations are combined to produce a final score that shows the level of preference of each alternative to the ideal solution. The highest-scoring alternatives are considered the best-performing warehouses.

The stages of the CoCoSo method are the preparation of a decision matrix which contains the performance value of each alternative to each criterion made using the equation (1).

$$X = \begin{bmatrix} 85 & 90 & 88 & 75 & 80 \\ 80 & 75 & 90 & 70 & 85 \\ 90 & 95 & 85 & 80 & 90 \\ 75 & 80 & 80 & 65 & 70 \\ 88 & 85 & 92 & 78 & 82 \\ 82 & 80 & 85 & 72 & 75 \\ 80 & 70 & 80 & 65 & 80 \\ 78 & 80 & 77 & 83 & 88 \end{bmatrix}$$

Decision matrix normalization is the process of converting the data in the decision matrix into a uniform scale, so that each value can be compared directly even though the unit or several units are different which is calculated using equation (2) for the benefit criterion and equation (3) for the cost criterion.

$$r_{11} = \frac{x_{11} - \min x_{11,18}}{\max x_{11,18} - \min x_{11,18}} = \frac{85 - 90}{90 - 75} = \frac{5}{15} = 0.6667$$

Table 3 is the result of the overall calculation of the normalization value of the decision matrix that has been calculated for each alternative based on the existing criteria.

**Table 3.** Normalization Value of the Decision Matrix

| Alternative Name | Operational Efficiency | Delivery Speed | Operating Costs | Inventory Management Accuracy | Logistics Flexibility |
|---|---|---|---|---|---|
| Warehouse A | 0.6667 | 0.8000 | 0.7333 | 0.5556 | 0.5000 |
| Warehouse B | 0.3333 | 0.2000 | 0.8667 | 0.2778 | 0.7500 |
| Warehouse C | 1.0000 | 1.0000 | 0.5333 | 0.8333 | 1.0000 |
| Warehouse D | 0.0000 | 0.4000 | 0.2000 | 0.0000 | 0.0000 |
| Warehouse E | 0.8667 | 0.6000 | 1.0000 | 0.7222 | 0.6000 |
| Warehouse F | 0.4667 | 0.4000 | 0.5333 | 0.3889 | 0.2500 |
| Warehouse G | 0.3333 | 0.0000 | 0.2000 | 0.0000 | 0.9000 |
| Warehouse H | 0.2000 | 0.4000 | 0.0000 | 1.0000 | 0.5000 |

The next step is to calculate the values Si (Positive Ideal Solution) and Pi (Negative Ideal Solution). Si and Pi are ideal solutions used to compare alternatives in decision-making. The value of a positive ideal solution and a negative ideal solution can use the equation (4) and (5).

$$S_1 = (0.25 * 0.6667) + (0.2 * 0.8000) + (0.25 * 0.7333) + (0.2 * 0.5556) + (0.1 * 0.5000)$$

$$S_1 = 0.6711$$

$$P_1 = (0.6667^{0.25}) + (0.8000^{0.2}) + (0.7333^{0.25}) + (0.5556^{0.2}) + (0.5000^{0.1})$$

$$P_1 = 4.6075$$

Table 4 is the result of the calculation of the overall value of the positive ideal solution and negative ideal solution that has been calculated for each alternative based on all existing criteria.

**Table 4.** Positive Ideal Solution and Negative Ideal Solution

| Alternative Name | Positive Ideal Solution | Negative Ideal Solution |
|---|---|---|
| Warehouse A | 0.6711 | 4.6075 |
| Warehouse B | 0.4706 | 4.1951 |
| Warehouse C | 0.8500 | 4.8188 |
| Warehouse D | 0.1300 | 1.5013 |

| Alternative Name | Positive Ideal Solution | Negative Ideal Solution |
|---|---|---|
| Warehouse E | 0.7911 | 4.7549 |
| Warehouse F | 0.4328 | 4.2121 |
| Warehouse G | 0.2233 | 2.4181 |
| Warehouse H | 0.3800 | 3.4343 |

The of all alternatives uses the aggregation calculation technique. In this process, there are 3 stages of calculation of the assessment score which will produce a relative weight calculated using equations (6), (7), and (8), the results of the calculation are shown in Table 5.

**Table 5.** Relative Weight Calculation

| Alternative Name | $K_{ia}$ | $K_{ib}$ | $K_{ic}$ |
|---|---|---|---|
| Warehouse A | 0.1558 | 8.2314 | 0.9312 |
| Warehouse B | 0.1377 | 6.4140 | 0.8230 |
| Warehouse C | 0.1673 | 9.7482 | 1.0000 |
| Warehouse D | 0.0481 | 2.0000 | 0.2878 |
| Warehouse E | 0.1636 | 9.2527 | 0.9783 |
| Warehouse F | 0.1371 | 6.1347 | 0.8194 |
| Warehouse G | 0.0779 | 3.3286 | 0.4660 |
| Warehouse H | 0.1125 | 5.2107 | 0.6729 |

The last stage is to calculate the total value of each alternative using the following equation (9), the results of the calculation are shown in Table 6.

**Table 6.** Total Value of Each Alternative

| Alternative Name | Total Value |
|---|---|
| Warehouse A | 4.1669 |
| Warehouse B | 3.3573 |
| Warehouse C | 4.8155 |
| Warehouse D | 1.0812 |
| Warehouse E | 4.6048 |
| Warehouse F | 3.2469 |
| Warehouse G | 1.7853 |
| Warehouse H | 2.7322 |

The final result of the CoCoSo method is the result of evaluation based on predetermined criteria. The alternative with the highest final value of the CoCoSo method calculation results is considered the best alternative or the optimal compromise solution, because it has gone through a multi-criteria assessment process that considers various aspects in a balanced manner.

### 3.6 Analysis and Interpretation of Results

Analysis and interpretation of results is the final stage in the decision-making process using the Combined Compromise Solution (CoCoSo) method. At this stage, an analysis was carried out on the results of the final value calculation of each alternative based on a decision matrix that had been normalized and weighted. These values reflect the level of performance of each alternative in meeting all predetermined criteria. The highest-rated alternative is considered the best choice because it has the most optimal compromise among all the alternatives. Next, the meaning of the resulting rankings is interpreted, including the reasons why one alternative has a higher or lower value than another. The results of the alternative ranking are shown in Figure 2.

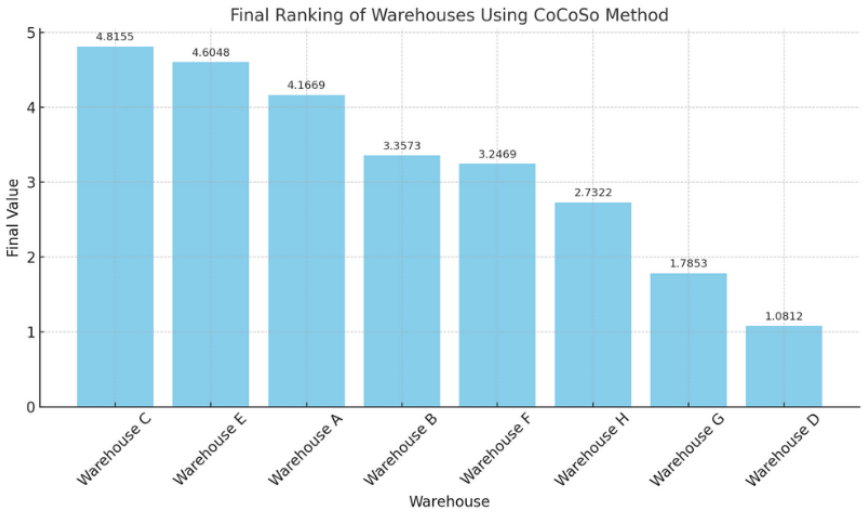


**Figure 2.** Research Stages

The final ranking results from Figure 2, it can be seen that Warehouse C occupies the highest position with a final value of 4.8155, showing that this warehouse has the best performance compared to other alternatives according to the evaluation of the CoCoSo method. In second place is Warehouse E with a value of 4.6048, followed by Warehouse A which recorded a value of 4.1669, indicating that the three warehouses are the best alternatives in the selection of warehouse performance. Meanwhile, Warehouse B and Warehouse F performed quite well with values of 3.3573 and 3.2469 respectively, but were still below the top three. Warehouse H, Warehouse G, and Warehouse D occupy the bottom positions with relatively low values, respectively, 2.7322, 1.7853, and 1.0812, indicating the need for evaluation and improvement in their operational performance. Overall, these results provide a clear picture of which warehouse alternatives are the most viable to choose and which ones need improvement in order to be better competitive in the future.

## 4. CONCLUSION

The implementation of the Combined Compromise Solution (CoCoSo) method in a multicriterion-based decision support system provides an effective solution in the selection of the best warehouse in the supply chain and logistics. This method is able to handle the complexity of the evaluation by considering various conflicting criteria, such as operational costs, delivery speed, inventory accuracy, and space utilization, to produce more objective and measurable decisions. The study also underscores the importance of sensitivity analysis to changes in the weight of criteria, which provides flexibility and adaptability in decision-making as market conditions or company strategies change. The final results of the ranking that Warehouse C occupies the highest position with a final value of 4.8155, showing that this warehouse has the best performance compared to other alternatives according to the evaluation of the CoCoSo method. In second place is Warehouse E with a value of 4.6048, followed by Warehouse A which recorded a value of 4.1669, indicating that the three warehouses are the best alternatives in the selection of warehouse performance. The main contribution of this study is the implementation of the CoCoSo method which enriches the scientific literature in the field of multicriteria decision support systems, especially in the context of logistics and warehouse management. In practical terms, this study provides guidance for logistics companies in selecting the optimal warehouse, which in turn can improve supply chain efficiency, reduce operational costs, and increase customer satisfaction. Thus, this research provides a solid basis for further development in the use of multicriteria methods in logistics decision-making and opens up opportunities for innovation in warehouse management systems in various industries.

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