



Implementation of TOPSIS method in decision support system for used motorcycle purchase recommendation

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ABSTRACT

The selection of used motorcycles involves evaluating multiple criteria, such as price, production year, transmission type, vehicle type, mileage, fuel consumption, and engine capacity. This complex decision-making process often leads buyers to rely on subjective judgments or third-party recommendations, which may result in suboptimal choices. To address this issue, this research develops a decision support system based on the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a Multi-Criteria Decision Making (MCDM) method, which ranks alternatives based on their proximity to the ideal solution. The study introduces innovation by applying TOPSIS to the specific context of used motorcycle selection, providing a data-driven, objective approach in contrast to conventional methods. A quantitative approach was employed, with data collected from online marketplaces and authorized dealerships. The results indicate that the 2019 Honda Revo, priced at Rp. 8,600,000, is the most optimal choice, achieving the highest preference score of 0.862887804. The effectiveness of the TOPSIS method in structuring the selection process ensures a more systematic and accurate decision-making process. Furthermore, the study highlights the influence of key criteria, such as fuel efficiency and mileage, in determining the ranking of alternatives. Future research should focus on integrating additional factors, such as maintenance history and vehicle condition, and exploring the development of web-based or mobile platforms to improve real-world implementation and enhance user accessibility. This system contributes to smarter, more informed decision-making in the used vehicle market, offering a significant advancement over traditional selection methods.

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Introduction

The selection of used motorcycles is a complex decision-making process involving multiple criteria that must be evaluated simultaneously (Agius et al., 2021; Liu et al., 2021; Pham et al., 2021; Więckowski et al., 2023). Potential buyers are often challenged with comparing a range of alternatives based on diverse attributes such as model, production year, price, transmission type, mileage, vehicle type, fuel

consumption, and engine capacity. Many purchasing decisions are made subjectively, relying on personal preferences or recommendations, rather than through a systematic and data-driven analysis (Lu et al., 2019; Micus et al., 2023; Sarker, 2021; Susanti & Prasetyaningrum, 2024). This results in suboptimal decisions that may negatively impact cost efficiency, vehicle quality, and suitability to user needs. Additionally, the scattered and unstructured information in the used motorcycle market further complicates the buyers' task, requiring manual analysis of various factors, which is both time-consuming and prone to bias.

Several studies have developed decision support systems for vehicle selection using Multi-Criteria Decision Making (MCDM) methods, such as Analytical Hierarchy Process (AHP), Simple Additive Weighting (SAW), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). While AHP has been used to determine criteria weights, its complexity increases exponentially with the number of alternatives, making it less practical for large-scale decision-making (Asadabadi et al., 2019; Pasma et al., 2022; Tang & Liao, 2021). The SAW method offers a simpler scoring approach but does not account for the relative closeness of alternatives to the ideal solution (d'Amore-Domenech et al., 2020; Odu, 2019; Sabandar & Wahyudi, 2024). On the other hand, the TOPSIS method is known for its effectiveness in evaluating alternatives based on their proximity to the positive and negative ideal solutions, providing a more accurate and systematic ranking mechanism (Junior et al., 2014; Rao & Gao, 2022; Sulistiani et al., 2024; Zeng et al., 2023). Despite its advantages, the application of the TOPSIS method in the selection of used motorcycles remains limited, and there is a lack of digital-based decision support systems that integrate this method to assist buyers in making more informed decisions.

Research by Mufid (2023) highlighted that the TOPSIS method offers a more objective and systematic ranking of vehicle alternatives. However, prior studies have mostly focused on used cars in specific showrooms (Saputra et al., 2019) or decision support systems in other sectors, such as employee evaluations by Feryansyah Putra & Dien Novita (2023). Additionally, the criteria used in previous studies have been more car-centric, neglecting the unique considerations involved in the selection of used motorcycles, such as transmission type, fuel efficiency, and engine capacity. This research aims to fill this gap by developing a decision support system based on the TOPSIS method that is specifically tailored to assist potential buyers in choosing a used motorbike in a more objective, efficient, and data-driven manner.

This research contributes to the development of decision support systems by providing a novel approach that integrates the TOPSIS method with a comprehensive, multi-criteria evaluation framework designed specifically for used motorbike selection. Unlike conventional platforms that only list available vehicles without analysis, the proposed system enables a structured and data-driven decision-making process, offering more accurate recommendations aligned with user preferences. By addressing the limitations found in prior research and offering a technology-based solution, this study is expected to make both theoretical and practical contributions to the field of automotive decision support systems. Specifically, it will facilitate a more rational, optimized, and data-supported decision-making process for used motorbike buyers, making the research both innovative and highly relevant to the current market.

Method

In this research using methods that are carried out systematically and in accordance with scientific principles, several scientific methods are applied, including:

1. This research uses a quantitative approach with the Multi-Criteria Decision Making (MCDM) method, specifically Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), to develop a decision support system for selecting used motorbikes. MCDM is a method used to solve decision-making problems involving multiple criteria with the aim of providing an optimal solution based on predetermined factors (Karyawan, 2024; Ridha et al., 2021; Taherdoost & Madanchian, 2023). One of the popular MCDM methods is TOPSIS, which works by measuring the closeness of each alternative to the positive ideal solution (best alternative) and its distance from the negative ideal solution (worst alternative), resulting in an objective and systematic ranking (Elsayed et al., 2017; Madi et al., 2016; Mohammed et al., 2020; Taherdoost & Madanchian, 2023; Trivedi et al., 2024).

This research was conducted in several main stages, namely vehicle data collection, determination of criteria and weights, and implementation using the TOPSIS method.

2. In the decision-making process, determining the criteria weights is crucial for obtaining accurate and meaningful rankings. To assign the weights of each criterion, this study employs a combination of subjective and objective methods. Specifically, the subjective approach involves expert judgment, where industry professionals, such as used motorcycle dealers and automotive experts, are consulted to provide their insights on the relative importance of each attribute. This method is useful when there is no readily available data for some criteria or when the decision context requires specialized knowledge. Additionally, an objective approach is applied through the use of data-driven techniques, such as Entropy Method or Simple Additive Weighting (SAW), to determine the weights of the criteria based on their variability and importance in the dataset. The Entropy Method, in particular, is used to measure the level of uncertainty in the information provided by each criterion and assigns higher weights to criteria with greater diversity in the dataset. This objective weighting method helps mitigate potential bias introduced by the subjective approach, ensuring that the criteria weights reflect both expert knowledge and empirical data. The combination of these methods ensures a balanced and reliable determination of criteria weights, which is fundamental for the TOPSIS method's evaluation and ranking of alternatives. This dual approach to determining the weights strengthens the robustness and objectivity of the decision support system developed in this research.
3. The data used in this study were obtained from various sources, including used vehicle buying and selling websites, authorised used motorbike dealers, and data from publications and reports related to the automotive industry. The data collected includes the main attributes that are the determining factors in choosing a used motorbike, namely:

Table 1. Variable Description

Variable	Description
Model	Types and brands of used motorbikes available in the market
Year	Age of the vehicle which affects the condition and price
Price	Price of the vehicle offered by the seller
Transmission Type	Type of vehicle transmission, whether manual or automatic or clutch
Mileage Distance	Distance travelled by the motorbike
Vehicle Type	Type of motorbike (e.g. scooter, sport, touring).
Fuel Consumption	The fuel efficiency of the vehicle in km/litre
Engine Capacity (cc)	Vehicle performance based on engine capacity

Each of these attributes is used as a criterion in the TOPSIS model to rank used motorbikes that best suit the user's preferences.

4. The TOPSIS method is used because of its ability to select the best alternative based on its relative closeness to the ideal solution. The implementation stages of this method in the research include:
 - a. Building a Normalised Decision Matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}$$

r_{ij} = Normalised values for alternatives on criteria
 x_{ij} = Original value in the decision matrix

(1)

- b. Building the Weighted Normalised Matrix

$$v_{ij} = w_i r_{ij}$$

v_{ij} = weighted normalized decision value
 w_i = criteria weight (C_j)

(2)

r_{ij} = normalized value of alternatives (A_i) on criteria (C_j)

c. Determining Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

PIS (A^+): A representation of the best value for each criterion. For profit criteria, the highest value is selected, while for cost criteria, the lowest value is selected.

$$\begin{aligned} A^+ &= \{v_1^+, v_2^+, \dots, v_n^+\} \\ A^+ &= \text{Positive Ideal Solution} \\ v_j^+ &= \text{Optimal Value} \end{aligned} \quad (3)$$

NIS (A^-): Representation of the worst score for each criterion. For the profit criterion, the lowest value is selected, while for the cost criterion, the highest value is selected.

$$\begin{aligned} A^- &= \{v_1^-, v_2^-, \dots, v_n^-\} \\ A^- &= \text{Negative Ideal Solution} \\ v_j^- &= \text{Worst value} \end{aligned} \quad (4)$$

d. Calculating the Distance between PIS and NIS

PIS formula

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_i^+ - v_{ij})^2}$$

v_{ij} = weighted normalized value of alternatives (A_i) on criteria (C_j)

v_i^+ = Positive Ideal Solution

$$(5)$$

NIS formula

$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_i^-)^2}$$

v_{ij} = weighted normalized value of alternatives (A_i) on criteria (C_j)

v_i^- = Negative Ideal Solution

$$(6)$$

e. Calculating the Closeness Index to the Ideal Solution

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

C_i = Nilai preferensi

D_i^- = Distance of alternative to negative ideal solution

D_i^+ = Distance of alternative to positive ideal solution

$$(7)$$

f. Determining Ranking

Determining the ranking of alternatives in the TOPSIS method is the final stage carried out after the preference value C_i for each alternative has been calculated. This ranking is determined by sorting alternatives based on the C_i value from highest to lowest.

Results and Discussions

In the results and discussion section, it is generally explained about the calculation of the consistency of the assessment criteria and the comparison of the consistency of used motorcycles against predetermined criteria using the TOPSIS method as a whole. With a wide selection of used motorcycles available, the TOPSIS method can act as a tool in the decision-making process to determine the most

suitable used motorcycle. The results of calculations using the TOPSIS method that have been carried out by the author are as follows :

1. Determine the Criteria to be considered

Table 2. Criteria

Code	Criteria	Type
C1	Year	Benefit
C2	Price	Cost
C3	Transmission Type	Benefit
C4	Mileage Distance	Cost
C5	Vehicle Type	Benefit
C6	Fuel Consumption	Cost
C7	Engine Capacity (cc)	Benefit

In this research, the author took 199 used motorcycle data sold in the used vehicle sales application which was used as a choice in the used motorcycle selection process, among others :

Table 3. Alternative

Code	Model
A1	Supra X 125
A2	Vario 125
A3	Revo
A4	Supra GTR
A5	PCX
...	...
A199	Verza

2. Determine the preference weights for each criterion

After determining the assessment criteria, then determine the preference weight value of each criterion based on the level of importance between one criterion and another. The comparison value of the level of importance between one criterion and another can be expressed with the following statement; Very Low = 1, Low = 2, Fair = 3, High = 4, Very High = 5.

From the above statement, it can be concluded that the preference value consists of numbers from 1 to 5, the higher the preference value of a criterion, the higher the preference value of a criterion, the higher the level of importance of that criterion in making a decision. The preference value of each criterion is determined as follows :

Table 4.Criteria Weight

Code	Criteria	Weight
C1	Year	4
C2	Price	5
C3	Transmission Type	1
C4	Mileage Distance	3
C5	Vehicle Type	1
C6	Fuel Consumption	2
C7	Engine Capacity (cc)	1

3. Form a decision matrix

Table 2. Decision Matrix

Code	C1	C2	C3	C4	C5	C6	C7
A1	4	7800	2	17307	2	58.9	125
A2	3	14499	3	252233	3	43.5	125
A3	5	8600	3	4920	2	60.1	110
A4	3	6499	2	23789	2	60.1	110

A5	3	10199	3	33177	3	51.4	150
...
A199	5	14998	1	6717	1	44.1	150

After forming the decision matrix, the next step is to normalize the decision matrix value as follows:

$$X1 = \sqrt{4^2 + 3^2 + 3^2 + 3^2 + 3^2 + \dots + 5^2} = 52,09$$

$$r_{1,1} = \frac{4}{52,09} = 0,076$$

$$r_{2,1} = \frac{3}{52,09} = 0,057$$

$$r_{3,1} = \frac{5}{52,09} = 0,096$$

$$r_{4,1} = \frac{4}{52,09} = 0,057$$

$$r_{5,1} = \frac{3}{52,09} = 0,057$$

$$r_{191,1} = \frac{5}{52,09} = 0,096$$

$$X2 = \sqrt{7800^2 + 14499^2 + 8700^2 + 6499^2 + 10199^2 + \dots + 14998^2} = 172164,7$$

$$r_{1,2} = \frac{7800}{172164,7} = 0,04645$$

$$r_{2,2} = \frac{14499}{172164,7} = 0,08422$$

$$r_{3,2} = \frac{8600}{172164,7} = 0,05053$$

$$r_{4,2} = \frac{6499}{172164,7} = 0,03775$$

$$r_{5,2} = \frac{10199}{172164,7} = 0,05924$$

$$r_{199,2} = \frac{14998}{172164,7} = 0,08711$$

$$X3 = \sqrt{2^2 + 3^2 + 1^2 + 2^2 + 3^2 + \dots + 1^2} = 35,412$$

$$r_{1,3} = \frac{2}{35,412} = 0,0567$$

$$r_{2,3} = \frac{3}{35,412} = 0,085$$

$$r_{3,3} = \frac{3}{35,412} = 0,085$$

$$r_{4,3} = \frac{2}{35,412} = 0,0567$$

$$r_{5,3} = \frac{3}{35,412} = 0,085$$

$$r_{199,3} = \frac{1}{35,412} = 0,029$$

$$X4 = \sqrt{17307^2 + 25223^2 + 31979^2 + 23789^2 + 33177^2 + \dots + 6717^2} = 397862,5$$

$$r_{1,4} = \frac{17307}{397862,5} = 0,0435$$

$$r_{2,4} = \frac{25223}{397862,5} = 0,0634$$

$$r_{3,4} = \frac{4920}{397862,5} = 0,0124$$

$$r_{4,4} = \frac{23789}{397862,5} = 0,05979$$

$$r_{5,4} = \frac{33177}{397862,5} = 0,08339$$

$$r_{199,4} = \frac{6717}{397862,5} = 0,01688$$

$$X5 = \sqrt{2^2 + 3^2 + 2^2 + 2^2 + 3^2 + \dots + 1^2} = 35,342$$

$$r_{1,5} = \frac{2}{35,342} = 0,0566$$

$$r_{2,5} = \frac{3}{35,342} = 0,085$$

$$r_{3,5} = \frac{2}{35,342} = 0,0566$$

$$r_{4,5} = \frac{2}{35,342} = 0,0566$$

$$r_{5,5} = \frac{3}{35,342} = 0,085$$

$$r_{199,5} = \frac{1}{35,342} = 0,029$$

$$X6 = \sqrt{58,9^2 + 43,5^2 + 61,7^2 + 60,1^2 + 51,4^2 + \dots + 44,1^2} = 777,157$$

$$r_{1,6} = \frac{58,9}{777,157} = 0,0758$$

$$r_{2,6} = \frac{43,5}{777,157} = 0,0560$$

$$r_{3,6} = \frac{60,1}{777,157} = 0,07733$$

$$r_{4,6} = \frac{60,1}{777,157} = 0,07733$$

$$r_{5,6} = \frac{51,4}{777,157} = 0,0661$$

$$r_{199,6} = \frac{44,1}{777,157} = 0,05675$$

$$X7 = \sqrt{125^2 + 125^2 + 125^2 + 110^2 + 150^2 + \dots + 150^2} = 1753,133$$

$$r_{1,7} = \frac{125}{1753,133} = 0,0713$$

$$r_{2,7} = \frac{125}{1753,133} = 0,0713$$

$$r_{3,7} = \frac{110}{1753,133} = 0,06274$$

$$r_{5,7} = \frac{110}{1753,133} = 0,06274$$

$$r_{5,7} = \frac{150}{1753,133} = 0,08556$$

$$r_{199,7} = \frac{150}{1753,133} = 0,08556$$

4. After obtaining a normalized matrix, then the value in the normalization matrix is multiplied by the weight value on each criterion:

$$y_{1,1} = w_1 \times r_{1,1} = 4 \times 0,076 = 0,304$$

$$y_{2,1} = w_1 \times r_{2,1} = 4 \times 0,057 = 0,228$$

$$y_{3,1} = w_1 \times r_{3,1} = 5 \times 0,096 = 0,480$$

...

$$y_{199,1} = w_1 \times r_{199,1} = 5 \times 0,096 = 0,480$$

Perform the same method until the 7th criterion which results in :

$$y_{1,7} = w_7 \times r_{1,7} = 1 \times 0,0713 = 0,0713$$

$$y_{2,7} = w_7 \times r_{2,7} = 1 \times 0,0713 = 0,0713$$

$$y_{3,7} = w_7 \times r_{3,7} = 1 \times 0,06274 = 0,06274$$

...

$$y_{199,7} = w_7 \times r_{199,7} = 1 \times 0,08556 = 0,08556$$

5. Determine the positive ideal matrix A^+ and negative ideal matrix A^-

a. Determining the Positive Ideal Matrix

The Positive Ideal Matrix value is taken the max value of the criteria if it is of the benefit type and the min value of the criteria if it is of the cost type. Here are the results:

$$C1 = 0,384$$

$$C4 = 0,01049$$

$$C7 = 0,085556$$

$$C2 = 0,10991$$

$$C5 = 0,08385$$

$$C3 = 0,08485$$

$$C6 = 0,10791$$

b. Determining the Negative Ideal Matrix

The Positive Ideal Matrix value is taken the min value of the criteria if it is of the benefit type and the max value of the criteria if it is of the cost type. Here are the results:

$$C1 = 0,07643$$

$$C4 = 0,89754$$

$$C7 = 0,06227$$

$$C2 = 1,01258$$

$$C5 = 0,02795$$

$$C3 = 0,02828$$

$$C6 = 0,48175$$

6. Determine distance between the weighted values of each alternative to the Positive ideal solution :

$$D_1^+ = \sqrt{\begin{aligned} &(0,480 - 0,304)^2 + (0,10991 - 0,23143)^2 + (0,08485 - 0,05657)^2 \\ &+ (0,01049 - 0,13048)^2 + (0,08385 - 0,559)^2 + (0,10791 - 0,227)^2 \\ &+ (0,085556 - 0,0713)^2 \end{aligned}}$$

$$= 0,22576565$$

$$D_2^+ = \sqrt{\begin{aligned} &(0,480 - 0,228)^2 + (0,10991 - 0,41949)^2 + (0,08485 - 0,08485)^2 \\ &+ (0,01049 - 0,19024)^2 + (0,08385 - 0,08385)^2 + (0,10791 - 0,167650035)^2 \\ &+ (0,085556 - 0,0713)^2 \end{aligned}}$$

$$= 0,394059336$$

$$D_3^+ = \sqrt{\begin{aligned} &(0,480 - 0,480)^2 + (0,10991 - 0,18803)^2 + (0,08485 - 0,05657)^2 \\ &+ (0,01049 - 0,17935)^2 + (0,08385 - 0,0559)^2 + (0,10791 - 0,23163)^2 \\ &+ (0,085556 - 0,0713)^2 \end{aligned}}$$

$$= 0,193394773$$

...

$$D_{199}^+ = \sqrt{\begin{aligned} &(0,480 - 0,480)^2 + (0,10991 - 0,43393)^2 + (0,08485 - 0,02828)^2 \\ &+ (0,01049 - 0,05064)^2 + (0,08385 - 0,02795)^2 + (0,10791 - 0,16996)^2 \\ &+ (0,085556 - 0,08556)^2 \end{aligned}}$$

$$= 0,34172$$

7. Determine the distance between the weighted values of each alternative to the Negative ideal solution:

$$D_1^- = \sqrt{\begin{aligned} &(0,304 - 0,07643)^2 + (0,23143 - 1,01258)^2 + (0,05657 - 0,02828)^2 \\ &+ (0,13048 - 0,89754)^2 + (0,559 - 0,02795)^2 + (0,227 - 0,48175)^2 \\ &+ (0,0713 - 0,06227)^2 \end{aligned}}$$

$$\begin{aligned}
&= 1,14791 \\
D_2^- &= \sqrt{\begin{aligned} &(0,228 - 0,07643)^2 + (0,41949 - 1,01258)^2 + (0,08485 - 0,02828)^2 \\ &+ (0,19024 - 0,89754)^2 + (0,08385 - 0,02795)^2 + (0,167650035 - 0,48175)^2 \\ &+ (0,0713 - 0,06227)^2 \end{aligned}} \\
&= 0,99018 \\
D_3^- &= \sqrt{\begin{aligned} &(0,480 - 0,07643)^2 + (0,18803 - 1,01258)^2 + (0,05657 - 0,02828)^2 \\ &+ (0,17935 - 0,89754)^2 + (0,0559 - 0,02795)^2 + (0,23163 - 0,48175)^2 \\ &+ (0,0713 - 0,06227)^2 \end{aligned}} \\
&= 1,217090785 \\
&\dots \\
D_{199}^- &= \sqrt{\begin{aligned} &(0,480 - 0,07643)^2 + (0,43393 - 1,01258)^2 + (0,02828 - 0,02828)^2 \\ &+ (0,05064 - 0,89754)^2 + (0,02795 - 0,02795)^2 + (0,16996 - 0,48175)^2 \\ &+ (0,08556 - 0,06227)^2 \end{aligned}} \\
&= 1,11502
\end{aligned}$$

8. Determining the Preference Value

$$\begin{aligned}
V_1 &= \frac{1,14791}{0,22576565 + 1,14791} = 0,835648578 \\
V_2 &= \frac{0,99018}{0,394059336 + 0,99018} = 0,715324308 \\
V_3 &= \frac{1,13278}{0,274558948 + 1,13278} = 0,862887804 \\
&\dots \\
V_{199} &= \frac{1,11502}{0,34172 + 1,11502} = 0,765421451
\end{aligned}$$

Table 3. Ranking

Model	Year	Price	Result	Ranking
Revo	2019	8600	0,862887804	1
Revo	2017	7498	0,860598182	2
Revo	2018	9499	0,848865693	3
Supra X 125	2017	8598	0,847724257	4
Genio	2018	9000	0,847724257	5
...
PCX	2012	5000	0,049404319	199

From the results of the manual calculation above, the Revo model has the highest preference value with a preference value of 0.862887804, higher than the other models. So that the Revo motorcycle is the first choice that best suits consumer desires, including price, year, transmission type, motor type, motor mileage, fuel consumption, and engine.

The main criteria that influence selection include price, year of production, transmission type, motor type, mileage, fuel consumption, and engine capacity. The 2019 Honda Revo has a good balance between price and technical specifications, making it the most suitable choice for potential buyers looking for a used motorcycle with high fuel efficiency, relatively easy maintenance, and a competitive price in the market. The mileage factor is also an important consideration in determining preference scores, where vehicles with lower mileage tend to be more desirable due to the lower wear rate of their components.

The advantage of the TOPSIS method in ranking alternatives is seen in its ability to provide an objective data-driven evaluation, reducing subjectivity in decision-making. With this approach, potential buyers can obtain more accurate vehicle recommendations based on their specific needs. In addition,

the utilization of this decision support system can overcome the obstacles often encountered in the used vehicle selection process, such as unstructured information and difficult to compare directly.

Conclusions

This research successfully developed a decision support system based on the TOPSIS method for selecting used motorcycles, providing an objective, data-driven approach to evaluate and rank alternatives based on multiple criteria. The findings demonstrate that the system effectively addresses the challenges faced by buyers in the used vehicle market, offering a more rational decision-making process. However, further development could enhance the accuracy of recommendations by integrating additional factors such as vehicle maintenance history and physical condition. Future research could also explore expanding the system to other automotive sectors or incorporating AI and machine learning to improve its adaptability and efficiency. Ultimately, this work contributes to advancing decision support systems in the automotive industry, with potential applications in various markets where multi-criteria decision-making is needed.

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