A Decision Approach for Evaluation of Last Mile Delivery Methods: A Case Study in Istanbul

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Abstract: - The rapid increase in demand for e-commerce has changed and transformed the logistics sector and made the integration of sustainability criteria necessary. This study addresses the sustainable assessment of different transportation modes used for last-mile delivery in Istanbul, especially in the context of e-commerce. The aim is to analyze the environmental impacts of delivery vehicles, such as carbon emissions, energy consumption, and traffic density, in order to help decision makers make more sustainable choices. A comparison is made among bicycles, motorcycles, pickup trucks, and multimodal/hybrid vehicles, which are commonly used for last-mile delivery, by considering their environmental performances. In order to better manage uncertainties and subjective evaluations, the fuzzy multi-criteria decision-making method was chosen, allowing for a more realistic and accurate analysis of transportation alternatives.

Key-Words: - Fuzzy logic, last mile delivery, logistics sector, multi-criteria decision-making, TOPSIS

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1 Introduction

The importance of last-mile delivery in the logistics sector has increased with the rapid growth of e-commerce. This stage covers the process in which the product is delivered to the customer from the distribution center or the warehouse closest to the last point and is usually the most complex, costly and time-critical part of the entire logistics chain. The rise in consumer expectations towards speed, reliability and flexibility has directly linked the quality of last-mile delivery services to brand image and customer satisfaction [1,2].

Last-mile delivery is the most decisive stage that shapes the customer experience. When the customer receives the order on time and completely, their trust in the brand increases. Especially factors such as urban density, traffic, and the complexity of delivery addresses make this process difficult. Therefore, companies are trying to get ahead in the competition by developing innovative solutions such as shortening delivery times, providing route optimization, and offering flexible delivery options [1,3].

The demand for e-commerce and similar activities has increased and the logistics sector has become more necessary. The logistics sector has become more interested in sustainability due to the intensive use of vehicles. Therefore, a desire has arisen to improve the conditions in which vehicles carry products while they are on their way to delivery points and the goal of measuring them with criteria has emerged. However, there is very little research on multi-dimensional comparison of last-mile delivery methods in terms of sustainability and the establishment of a systematic decision-making model for these methods [2-4].

With the increasing demand for e-commerce and similar activities, the logistics sector has also undergone a major transformation. Due to the intensive use of vehicles, the sustainability evaluation of logistics processes has become even more important. This study focuses on the sustainability evaluation of different end-point delivery methods used in e-commerce deliveries in Istanbul. The study aims to compare transportation methods by considering criteria such as carbon emissions, energy consumption and environmental impacts.

The main purpose of this study is to determine more sustainable and environmentally friendly delivery alternatives by evaluating the environmental impacts of delivery vehicles used in the last-mile delivery process in Istanbul. The study aims to contribute to the adoption of sustainable practices by providing decision-makers (DMs) in the logistics sector with options to reduce carbon emissions and energy consumption.

In order to manage uncertainty and subjective evaluations in the study, fuzzy Multi-Criteria Decision Making (MCDM) method was used. This method offers a more flexible structure compared to classical decision-making methods and can quantify uncertainties between criteria [5]. In the study, the fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method [6] was used to rank the alternatives. The data sources used included environmental impact reports, technical data sets of transportation vehicles and statistical analysis tools. Modeling was performed with software tools and various verification steps were applied to increase the reliability of the results.

The study offers a unique perspective by considering logistics in the final delivery process in terms of environmental impacts, apart from traditional approaches focused solely on cost and customer satisfaction. Prioritizing factors such as carbon emissions, energy consumption and urban environmental pollution gives the study a scientific and sectoral difference. In addition, focusing on the local dynamics of a highly populated and traffic-intensive metropolis like Istanbul fills an important gap in the literature. The results of the study will make significant contributions to the development of sustainable logistics solutions in both academic and sectoral applications.

The remaining parts of the paper are organized as follows. The literature review part is presented in Section 2. Section 3 explains the application steps of fuzzy TOPSIS methodology. Section 4 outlines case study. Section 5 gives the obtained results. The final section presents concluding remarks and future research directions.

2 Literature Review

Last-mile delivery in the logistics sector has gained importance in recent years with sustainability and the development of the sector. When the studies on the subject are examined and combined with alternative delivery vehicles or delivery that provide sustainability, many results have emerged for our main topic, sustainable delivery to the last point. Studies on this subject are summarized in Table 1.

In some studies, four alternative delivery vehicles were used with different combinations, and in some studies, only one alternative delivery vehicle was used, and the alternative was selected by evaluating it based on many criteria. After the tests conducted during the selection of alternatives, evaluations were made based on the effects on costs, energy consumption, time saving and of course carbon emissions. Explanatory results were obtained in the measures taken to adapt to new challenges and regulations in the logistics sector. With the development of the e-commerce sector and the increase in demand from people, both developments are taking place and the possibility of encountering some disadvantageous situations arises.

Table 1: Studies conducted on last mile delivery for logistics sector

Year	Authors	Method	Application Area	Vehicle alternatives
2020	Švadlenka et al. [7]	Fuzzy MCDM	Czech Republic	Electric cargo bike Mobile parcel locker Autonomous delivery robot Drone Metro
2020	Nur et al. [8]	Fuzzy TOPSIS	-	Drone
2020	Caggiani et al. [9]	Fuzzy C-mean clustering	Vietnam	Electric vans Electric cargo bikes
2021	Wang et al. [10]	FAHP FWASPAS	Vietnam	-
2022	Garus et al. [11]	Fuzzy MCDM	Brazil	Truck Motorcycle Smart Lockers Drone
2022	Alves de Araújo et al. [12]	FAHP	Brazil	Electric vans Electric cargo bikes
2023	Castillo & Álvarez [13]	Multi-objective linear programming	Spain	Minibuses (electric, hydrogen and hybrid)
2023	Balassa et al. [14]	Discrete event simulation	-	Drone
2024	Yu et al. [15]	Discrete marine predators algorithm	-	Minivans Electric Tricycles
2024	Chen et al. [16]	Mixed-integer linear programming	-	Trucks Tricycles Drones
2025	Li et al. [17]	Agent-based simulation	China	Drone Electric bike
2025	Mokhtari-Moghadam et al. [18]	Multi-objective linear programming	-	Robot Drone Truck

Švadlenka et al. [7] discussed last-mile delivery in combination with cost, air pollution and difficulties in the logistics sector, and conducted the study in the Czech Republic using 20 criteria and 6 alternative delivery vehicles. A fuzzy multi-criteria decision-making approach was used in the study. According to the results of the actual study, the electric cargo bike proved to be the most suitable alternative in terms of cost, sustainability and industrial compatibility.

In the study conducted by Nur et al. [8], they addressed the last-mile delivery problem with a single alternative, only drones. Using the fuzzy TOPSIS method, 5 criteria were studied and a comparison was made by applying it to drones with different technical features. A sensitivity analysis was also conducted with the created scenarios and the application results were presented. It was determined that it is possible to work with smaller, short-range UAVs in urban areas, while it is appropriate to use longer-range UAVs in rural areas.

Caggiani et al. [9] discussed the distribution of electric van vehicles and electric cargo bikes in urban and traffic areas. They wanted to minimize costs using the C-mean fuzzy clustering method. Following the tests, the logistics companies concluded that they should focus more on zero-carbon policies in traffic areas.

Wang et al. [10] conducted a study to examine the sustainability performance of companies providing last-mile delivery services in Vietnam on the basis of 5 important criteria. Fuzzy MCDM, Fuzzy Analytical Hierarchy Processes (FAHP), and Fuzzy Weighted Overall Sum Product Assessment (FWASPAS) and triangular fuzzy number approaches were applied and concluded by tests with sensitivity analysis. The best company in terms of customer acquisition and compliance was identified and the results displayed.

In the study by Garus et al. [11], they focused on the sustainability part of last-mile delivery and integrated a multi-criteria decision analysis to perform a real case study. In their study, they proceeded through 6 different alternative vehicles, three of which were made up of similar but different vehicles, and three of which were made up of different distribution models involving robots. As a result of the study, it was observed that the alternatives using robots were more advantageous in terms of cost and environment. However, in this case, potential shortcomings in terms of safety and equality emerged in the section on social sustainability.

In the study conducted by Alves de Araújo et al. [12], they developed strategies to meet customer expectations for last-mile delivery and changes in delivery services and discussed them using the FAHP method. They conducted the study using 6 criteria and 5 distribution alternatives. The study was conducted in Brazil. They concluded that the last-mile delivery problem is more compatible with road transport, but the growth of the e-commerce sector can endanger the environment in urban areas by causing greenhouse gases.

In the study by Castillo and Álvarez [13], they investigated the improvement of vehicles in the delivery fleets of urban freight transport companies through actions to reduce the carbon footprint in line with legislation. The study aimed to reduce costs and greenhouse gas emissions. In Spain, an analysis was carried out on the fuel type of minibuses (electric, hydrogen and hybrid) using the multi-objective linear programming method on different scenarios. The study revealed that choosing electric or hydrogen-powered minibuses over natural gas-powered ones reduces carbon emissions and delivery costs.

In the study by Balassa et al. [14], they were conducted to test the service flexibility, time savings, carbon neutrality and energy consumption reduction of drones. By applying discrete-event simulation, its effect on last-mile delivery was examined, and it was observed that drone-based scenarios reduce carbon emissions and energy consumption.

Yu et al. [15] stated that when it comes to last mile delivery, not only customer satisfaction or cost is important, but also carbon emissions should be taken into account and reduced. They acted on 6 criteria in their study and conducted 6 tests with 2 common delivery vehicles. They achieved higher customer satisfaction, lower carbon emissions and lower costs compared to other methods with the method they used, the discrete sea hunter algorithm.

Chen et al. [16] argued that traditional delivery vehicles are not economical in the developing logistics sector with limited budgets and therefore it would be more economical to use multiple/hybrid fleets. They conducted their study using the mixed integer linear programming model, the improved multi-start wide neighborhood adaptive search algorithm and the ant colony algorithm. As a result, they suggested that the vehicle models themselves should be arranged to adapt to other vehicles and made suggestions for budget improvements.

In the study by Li et al. [17], the issue of last-mile delivery is addressed with a comparison of the drone and the electric bicycle. A multi-agent simulation model was used, and the study was carried out in China over an area of 12x12 km. According to the results obtained, although the greenhouse gas emissions of drones are higher than those of electric bicycles, given their life cycle and the fact that a drone makes 1 or 2 deliveries on each flight, the drone is more advantageous than the electric bicycle.

Mokhtari-Moghadam et al. [18] aims to automate last-mile delivery operations in the e-commerce sector by integrating robots and drones into trucks. It aims to reduce total distribution costs and increase customer satisfaction through versatile approaches. Experiments have shown that the robot-assisted model improves costs in dense regions. In addition, the drone-assisted model has proved effective in areas where distribution is high and demand low.

In summary, the last-mile delivery issue has been addressed in the studies conducted through sustainability and alternative delivery vehicles (electric bicycles, minivans, trucks, drones, robots, etc.) and studies have progressed in countries such as Vietnam, China, the Czech Republic, Spain, and Brazil according to many different criteria (self-copying, speed, customer satisfaction, delivery cost, energy consumption, etc.).

Therefore, this study is original because it is conducted in Istanbul and delivery time, distribution cost, carbon emission, waste amount, safe delivery, operational capacity, customer satisfaction criteria as well as bicycles, motorcycles, vans, multi-model delivery and alternative delivery vehicles are taken into consideration. By combining all these with a fuzzy MCDM approach, it aims to evaluate the vehicles according to the criteria and observe the results.

3 Fuzzy TOPSIS Methodology

TOPSIS, initially proposed by Hwang and Yoon [19], is a technique utilized for solving MCDM problems. TOPSIS technique chooses the best performing alternative, which possesses the shortest distance to the ideal solution, and the farthest distance to the anti-ideal solution. The proximity to the ideal solution provides maximization of the benefit and the minimization of the cost, while the distance to the ideal solution maximizes the cost and minimizes the benefit. Fuzzy TOPSIS methodology makes the extension of TOPSIS technique by providing fuzzy evaluations of criteria and alternatives to solve MCDM problems under imprecise environment.

The steps of application of the employed technique are listed as follows:

***Step* 1:** The criteria are indicated by conducting a literature review and using DMs' opinions. There are m alternatives referred $A_i = \{A_1, A_2, \ldots, A_m\}$, which are assessed under n criteria, $C_j = \{C_1, C_2, \ldots, C_n\}$.

***Step* 2:** Design the fuzzy decision matrix ($\widetilde{D}$) that refer to the assessment of alternatives regarding criteria and the weight matrix of criteria ($\widetilde{W}$) as

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} i = 1,2, \ldots, m; j = 1,2, \ldots, n. \quad (1)$$

$$\widetilde{W}_j = (\widetilde{w}_1, \widetilde{w}_2 \ldots, \widetilde{w}_n) \quad j = 1,2, \ldots, n. \quad (2)$$

where $\tilde{x}_{ij}$ and $\widetilde{w}_j$ can be denoted as $\tilde{x}_{ij} = \left(x_{ij}^1, x_{ij}^2, x_{ij}^3\right)$ and $\widetilde{w}_j = \left(w_j^1, w_j^2, w_j^3\right)$, respectively, in triangular fuzzy numbers.

***Step* 3:** The normalized fuzzy decision matrix $\tilde{R}$ is constructed as $\tilde{R} = \left[\tilde{r}_{ij}\right]_{mxn}$, $i = 1,2, \ldots, m; j = 1,2, \ldots, n$, where

$$\tilde{r}_{ij} = \begin{cases} \left(\dfrac{x_{ij}^1 - x_j^-}{x_j^* - x_j^-}, \dfrac{x_{ij}^2 - x_j^-}{x_j^* - x_j^-}, \dfrac{x_{ij}^3 - x_j^-}{x_j^* - x_j^-}\right), & x_j^* = \max_i x_{ij}^3, \quad j \in B_j \quad (3) \\ \left(\dfrac{x_j^* - x_{ij}^3}{x_j^* - x_j^-}, \dfrac{x_j^* - x_{ij}^2}{x_j^* - x_j^-}, \dfrac{x_j^* - x_{ij}^1}{x_j^* - x_j^-}\right), & x_j^- = \min_i x_{ij}^1, \quad j \in C_j \quad (4) \end{cases}$$

B_j denotes the set of benefit criteria for which the greater the performance value the more its preference, C_j denotes the set of cost criteria for which the greater the performance value the less its preference

***Step* 4:** Make the computation of the weighted normalized decision matrix, $\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn}$, as

$$\tilde{v}_{ij} = \tilde{r}_{ij}\widetilde{w}_j \quad (5)$$

Step 5: Make the definition of the ideal solution $(A^*) = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*)$, and the anti-ideal solution $(A^-) = (\tilde{v}_1, \tilde{v}_2, \ldots, \tilde{v}_n)$, where $\tilde{v}_j^* = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$ for $j = 1,2, \ldots, n$.

***Step* 6:** Calculate the distances from ideal and anti-ideal solutions (d_i^* and d_i^*, respectively) for each alternative A_i as

$$d_i^* = d(A_i, A^*) = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) \quad (6)$$

where

$$d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) = \sqrt{\frac{1}{3}\left[\left(v_{ij}^1 - v_j^{*1}\right)^2 + \left(v_{ij}^2 - v_j^{*2}\right)^2 + \left(v_{ij}^3 - v_j^{*3}\right)^2\right]} \quad (7)$$

and

$$d_i^- = d(A_i, A^-) = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \quad (8)$$

where

$$d(\tilde{v}_{ij}, \tilde{v}_j^-) = \sqrt{\frac{1}{3}\left[\left(v_{ij}^1 - v_j^{-1}\right)^2 + \left(v_{ij}^2 - v_j^{-2}\right)^2 + \left(v_{ij}^3 - v_j^{-3}\right)^2\right]} \quad (9)$$

Step 7: Make the calculation of the closeness coefficient *(CC_i)* of each alternative as follows:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, \quad i = 1,2,\ldots,m \quad (10)$$

Step 8: Reveal the outline of the alternatives regarding CC_i values in descending order. Determine the alternative with the highest CC_i as the best alternative.

4 Case Study

E-commerce, one of the fastest growing sectors in the developing world, has simultaneously expanded other sectors. The development of sectors such as manufacturing and logistics has brought new challenges and therefore new goals. The subject under consideration, last mile delivery, is one of the most important challenges in the logistics sector. For experimental and study data, information was collected through a survey by interviewing people working in the logistics sector and in this field. The data was obtained from people involved in the last mile delivery process in Istanbul and those working to support or contribute to this field. The reason for choosing Istanbul is that it has a very dense population, high interaction and challenges, and is one of the regions where the e-commerce sector is most frequently used.

As part of the study, a total of 7 evaluation criteria as in Table 2 were determined, including delivery time, distribution cost, carbon neutrality, waste quantity, safe delivery, operational capacity and customer satisfaction.

Table 2: Evaluation criteria

Criteria	Type	Definition
Delivery time [7,9,10]	Min	Speed of goods arrival
Distribution cost [8,10]	Min	Includes transport, labor, and administrative expenses
Carbon neutrality [7]	Min	Emission-free delivery
Waste quantity [7,8,10]	Min	Average volume of solid waste and harmful material emissions during operation and after lifecycle (e.g., tires and batteries)
Safe delivery [7,9]	Max	Safety of transported goods
Operational capacity [7,10]	Max	Expansion of operational capabilities
Customer satisfaction [7,10]	Max	Voice of the customer, adaptation to customer behavior

Some studies have already been carried out on these criteria, but the 7 criteria have not all been evaluated at the same time with the same alternatives. On the other hand, the 4 delivery vehicles to be evaluated in the study were determined as follows: bicycle, motorcycle, van, multi-model delivery.

Three of the DMs are academics between the ages of 40-60 working in the field of logistics, and the other six are people between the ages of 35-55 who are in managerial positions in a logistics company. All of the participants are located in Istanbul. In the first part of the questions asked, the participants were asked to evaluate their effects on the process of delivering products or orders to the person or institution that placed the order in terms of last mile delivery in terms of the 7 criteria determined at the beginning of the study (delivery time, delivery counter, carbon neutrality, waste amount, life safety, business capacity and customer satisfaction). In the second part of the survey, the relationship and effect of the alternatives with the weights were evaluated and the data to be used in the application part were obtained with these answers.

Multimodal delivery means using multiple alternative delivery methods simultaneously to deliver a delivery to the relevant person or location. 9 DMs that have all been working in logistics sector mention their opinions about the importance degrees of evaluation criteria along with the scores of alternatives according to the criteria using fuzzy scale in Fig. 1.

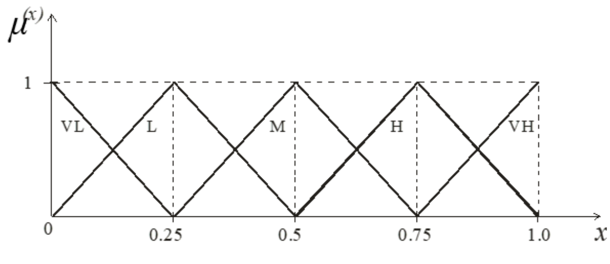

Figure 1: A linguistic term set where VL = (0, 0, 0.25), L = (0, 0.25, 0.5), M = (0.25, 0.5, 0.75), H = (0.5, 0.75, 1), VH = (0.75, 1, 1)

Averaged data related to evaluation of the last mile delivery methods are given in Table 3.

Table 3: Averaged fuzzy data related to evaluation of the last mile delivery methods

	Delivery time	Distribution cost	Carbon neutrality
Bicycle	(0.417,0.639,0.806)	(0.361,0.556,0.750)	(0.361,0.556,0.750)
Motocycle	(0.611,0.861,1.000)	(0.472,0.722,0.917)	(0.389,0.639,0.833)
Van	(0.417,0.667,0.833)	(0.472,0.722,0.861)	(0.306,0.528,0.722)
Multi modal delivery	(0.556,0.778,0.889)	(0.556,0.806,0.917)	(0.500,0.750,0.917)
	Waste quantity	Safe delivery	Operational capacity
Bicycle	(0.333,0.528,0.722)	(0.416,0.666,0.861)	(0.222,0.444,0.666)
Motocycle	(0.361,0.611,0.806)	(0.444,0.694,0.861)	(0.472,0.722,0.888)
Van	(0.250,0.472,0.694)	(0.555,0.805,0.972)	(0.611,0.861,0.972)
Multi modal delivery	(0.444,0.694,0.861)	(0.527,0.777,0.944)	(0.555,0.805,0.944)
	Customer satisfaction		
Bicycle	(0.361,0.583,0.777)		
Motocycle	(0.555,0.805,0.944)		
Van	(0.388,0.638,0.833)		
Multi modal delivery	(0.527,0.777,0.916)		

The average fuzzy importance of the criteria are given in Table 4.

Table 4: Importance of the criteria

Criteria	**Average fuzzy weight**
Delivery time	(0.694,0.944,1)
Distribution cost	(0.639,0.889,0.972)
Carbon neutrality	(0.361,0.556,0.75)
Waste quantity	(0.444,0.667,0.861)
Safe delivery	(0.722,0.972,1)
Operational capacity	(0.611,0.861,0.944)
Customer satisfaction	(0.722,0.972,1)

Ranking results of the alternatives are given in the following Table 5.

Table 5: Ranking results of the alternatives

	d_i^*	d_i^-	CC_i	Rank
Bicycle	4.4964	3.6124	0.4455	2
Motorcycle	4.5451	3.6006	0.4420	3
Van	4.0574	4.1521	0.5058	1
Multi modal delivery	4.5008	3.5598	0.4416	4

According to the results in Table 5, there are many reasons why vans, which are the closest vehicle to the ideal solution, are a logical choice. Vans can carry large quantities of products at the same time, as well as larger products. This saves both time and money. This efficiency will increase even more with studies such as route planning. It will be easier for this vehicle to ensure that products are delivered well protected for the right delivery.

In the scenario presented by the preferences and the situation, electric or more environmentally friendly minibuses will be preferred and sustainability will be contributed. In addition to all these, these comments can be made in line with the opinions of 9 experts. The fact that the experts work in different areas of the sector increases the reliability of the results of our study.

5 Results and Discussion

As a result of the Fuzzy TOPSIS analysis, alternatives such as bicycle (CC=0.4455), motorcycle (CC=0.4420) and multi-model delivery (CC=0.4416) are slightly further from the ideal than the van type vehicle, which shows that these options actually perform at similar levels in many criteria, but the van type vehicle offers a more dominant solution in some critical factors. While these vehicles offer advantages especially in terms of environmentally friendly approaches and low cost, according to expert evaluations, they are less preferred than van type vehicles due to their limitations in basic criteria such as operational efficiency, load capacity, resistance to weather conditions and safety.

Although vehicles such as bicycles and motorcycles offer advantages due to their easy access to narrow urban areas and low operating costs, they also have disadvantages such as limited transport volume, low product safety due to open transportation, and direct impact on adverse weather conditions. Especially in scenarios requiring multiple and large deliveries, the daily operational capacity of these vehicles decreases, delivery times may be extended, and customer satisfaction risks may arise.

Similarly, although multimodal distribution systems theoretically offer a sustainable structure, in practice they may receive lower scores from experts due to reasons such as the need for high coordination, increased implementation costs, and system complexity.

Therefore, according to expert opinions, it is natural that the van vehicle stands out as the vehicle closest to the ideal solution with its qualities such as delivery efficiency, capacity adequacy, protection against external conditions and operational flexibility. Although other alternatives seem advantageous in some respects, when the overall performance of the system is evaluated, the van emerges as a more balanced and sustainable option.

6 Conclusion

This study addresses the issue of sustainability—one of the most pressing and evolving challenges of our time—by examining it within the context of two highly dynamic and interdependent sectors: e-commerce and logistics. Conducted in Istanbul, the research offers an original contribution to the literature by focusing on the last-mile delivery problem. Four alternative delivery vehicles were evaluated across seven criteria, and the alternative closest to the ideal solution was identified through a structured analytical approach based on expert input.

The study provides several key contributions:

- *Economic impact:* Choosing the most efficient vehicle (the van) enhances operational capacity and customer satisfaction while creating economic added value.
- *Environmental impact:* Selecting the van reduces carbon emissions and energy consumption, promoting a greener logistics process and improving the environmental reputation of businesses.
- *Sustainability:* The proposed solution supports both economic and environmental sustainability over the long term.
- *Ethics and health:* It ensures fairer working conditions for employees by reducing workload imbalance and supports public health through lower emissions, minimizing ethical concerns through improved communication and process transparency.

Although the results indicate a solution that closely approximates the ideal, they remain theoretical and must be validated through practical implementation. Future research will focus on replicating the study in other major cities to compare results across different contexts, thereby enriching the literature and offering more generalizable insights for decision-makers. The inclusion of multidisciplinary expert perspectives strengthened the analysis and contributed to more reliable conclusions.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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