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Optimization of Last-Mile Delivery Alternatives Using the Fuzzy FARE and ADAM Multi-Criteria Decision-Making Methods

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Abstract: The increasing demand for efficient and sustainable last-mile delivery solutions has presented a significant challenge in the evolving landscape of e-commerce logistics. To address this issue, a systematic evaluation and prioritization of six alternative delivery methods—namely, home delivery, workplace delivery, delivery to a neighbor or acquaintance, staffed pickup points, unstaffed (automated) pickup points, and third-party drop-off locations—has been conducted. These alternatives have been assessed against a comprehensive set of criteria, including delivery time flexibility, accessibility, cost-efficiency, security, speed of service, and ease of product return. To capture the nuanced preferences and subjective judgements of stakeholders, the Fuzzy Factor Relationship (FARE) method has been employed to determine the relative importance of each criterion through a structured fuzzy logic framework. Subsequently, the Aggregated Decision-Making (ADAM) method has been applied to rank the delivery alternatives, integrating evaluations from key stakeholder groups—consumers, retailers, and logistics service providers. The findings reveal that unstaffed pickup points, particularly those leveraging automated systems, represent the most balanced and sustainable solution, offering superior performance in terms of cost-effectiveness, user accessibility, and operational flexibility. In contrast, while home delivery continues to be favored for its convenience, it remains constrained by elevated operational costs and limited scheduling flexibility. The methodological integration of Fuzzy FARE and ADAM ensures a robust and transparent decision-support mechanism that accounts for both qualitative and quantitative factors. These insights are expected to guide strategic decision-making in last-mile logistics (LML), contributing to service quality enhancement, operational cost reduction, and the advancement of environmentally responsible delivery systems. This evaluation framework offers practical relevance to e-commerce platforms, third-party logistics providers, and urban mobility planners seeking to implement scalable and customer-centric delivery models in complex urban environments.

Keywords: Logistics; Last-mile delivery; E-commerce; FARE; ADAM; MCDM

1 Introduction

The habits of consumer society are changing under the influence of various factors. The adoption of digital technologies has reduced the need for physical presence in stores [1]. Technological innovations, such as smartphones, the internet, and e-commerce, have drastically transformed the way consumers purchase and use products and services [2]. Changes in demographic patterns, such as the rise of single-person households, also affect consumption habits [1]. The COVID-19 pandemic has had a significant additional impact on the transformation of consumer behavior [2].

The continuously growing volume of e-commerce, which recorded an increase of approximately 8.6% in 2024 compared to 2023 [3], has led to a rise in the number of packages that need to be delivered daily, particularly in large urban areas [1]. LML is becoming a key factor in shaping customer experience, influencing their satisfaction and loyalty. An increasing number of delivery vehicles is required to address this segment of the logistics chain, contributing to congestion and negative impacts on health, the environment, and safety [4]. Transparency is becoming a crucial factor, as customers demand accurate and up-to-date information about the status of their shipments, with the ability to track and redirect deliveries according to their needs. Delivery speed is another critical requirement, with customers expecting same-day or even same-hour deliveries, placing additional pressure on logistics operations. There is also a growing need for consolidation, where multiple shipments are combined into a single delivery to optimize the process and reduce inefficiencies. Consequently, it is not surprising that numerous innovative concepts have emerged in recent years. Examples include drone deliveries, small autonomous robots, electric vehicles, trunk deliveries to parked cars, combined freight distribution using public and private vehicles, the implementation of micro-consolidation centers, and more [1].

Today, customers expect greater flexibility in the delivery process, including the option to pick up their shipments at alternative locations such as Pick Up Drop Off (PUDO) points and parcel lockers, which are increasingly replacing traditional home delivery, making it a premium service. PUDO points allow customers to collect or drop off their shipments at locations that are not official post offices, such as retail stores or specialized depots. Parcel lockers, on the other hand, enable fully automated deliveries, allowing customers to retrieve their shipments at any time without waiting for a courier. These solutions not only enhance flexibility but also reduce costs and average delivery times, making them advantageous for meeting the growing demand for efficient and customer-oriented services in the e-commerce era.

The aim of this study is to determine the most optimal delivery model from the destination perspective, taking into account all relevant alternatives and criteria. It is important to note that the problem is addressed as a general case, considering all types of goods, customer requirements, and other relevant factors.

Following the introduction, the second chapter is dedicated to a literature review. The third chapter provides a detailed description of the problem to be solved, analyzing specific delivery points as alternatives, their impact on customers and service providers, and the criteria defining the success of each alternative, as well as their advantages and disadvantages from the perspective of stakeholders. The fifth chapter focuses on solving the defined problem through the application of a specified methodology. Finally, concluding considerations are presented.

2 Literature Review

E-commerce involves the buying and selling of goods, services, and information through a network (a computer network, including the internet). It differs from traditional commerce in that an e-retailer simultaneously acts as both a seller and a distribution center, the choice of the seller's location is much more flexible, consumers connect to the store virtually, and goods are most often delivered to them. E-commerce has significantly transformed the role of logistics in the supply chain, requiring different solutions for order fulfillment, distribution channels, and operations management. Increased demand and consumer expectations have necessitated the optimization of delivery processes and the adaptation of LML to new market requirements [5].

The last mile is the segment of the supply chain that extends from the final distribution center to the recipient's chosen destination [6]. Tadić and Veljović [7] highlight the evolution of terms describing LML, including last mile(s) delivery, final delivery, home delivery, residential delivery, door-to-door delivery, doorstep delivery, consumer direct service delivery, B2C e-commerce delivery, and extended supply chain. Some of these terms are more prevalent in the literature (e.g., last mile delivery, final delivery, B2C e-commerce delivery), while others are more commonly used in the market (e.g., doorstep delivery) [7]. Alongside the term last mile delivery, home delivery is dominant in both literature and market usage.

LML is often described as one of the most expensive, inefficient, and environmentally burdensome segments of the supply chain, contributing to an increase in freight vehicles, traffic accidents, congestion, and stress [8]. It is crucial for customer satisfaction, as it encompasses all activities occurring just before goods reach the consumer [9]. LML faces a dual challenge: it must meet the demands of globalized trade while complying with environmental standards [4]. Some studies estimate that LML accounts for between 13% and 75% of total supply chain costs, depending on various factors such as demand density, time windows, congestion, delivery fragmentation, and shipment size and homogeneity [6].

The main factors that hinder process optimization and increase costs include [10]:

Unconsolidated deliveries: Proper consolidation of deliveries among different online retailers has not been established. Customers order products from various websites and receive separate deliveries, which extends waiting times. Additionally, even though deliveries for different customers from the same e-retailer could be consolidated, they often occur through multiple separate trips, increasing logistics costs.

High rate of failed deliveries: The main reasons for failed deliveries are the absence of the recipient or an incorrect address. Each failed delivery requires additional attempts, raising costs. To mitigate these expenses, some companies require customers to collect undelivered packages from designated locations, which may cause additional inconvenience for consumers.

Low utilization of key logistics resources: In e-commerce, shipments are generally smaller. The current delivery process requires couriers to park their vehicles, unload packages, and deliver them to designated locations using staircases, elevators, etc. This process can lead to additional delays. Inefficiencies increase when consolidation and coordination are lacking, resulting in suboptimal utilization of resources such as time, labor, etc. Innovation is a key factor in transitioning from current LML system configurations to more sustainable models, where researchers and practitioners work together to enhance efficiency and reduce externalities [4]. The sustainability of LML is assessed from economic, environmental, and social perspectives, with a particular focus on emissions, energy consumption, product quality, cost efficiency, and employee and customer satisfaction [8]. Innovative, sustainable solutions include advanced vehicle technologies, collaborative and cooperative urban logistics, route optimization, and transportation management improvements. To identify the most suitable solution, various delivery models are being developed based on the destination aspect, such as pickup and delivery points, drop-off companies, etc. Selecting the most optimal model is a critical and complex task, best approached using Multi-Criteria Decision-Making (MCDM) methods.

MCDM aims to determine the best alternative by considering multiple criteria in the selection process. MCDM includes numerous tools and methods applicable across various fields [11]. It consists of two major subfields: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM) [12]. The MCDM analysis process consists of three steps [12]:

Step 1: Identifying relevant criteria and alternatives based on existing theory and practice.

Step 2: Assigning numerical values to criteria to indicate their relative importance, weight, and to quantify the impact of alternatives on the criteria.

Step 3: Applying a formal mathematical procedure to analyze numerical values and determine the ranking (prioritization) of alternatives.

An alternative is considered the subject of decision-making. More precisely, an alternative is a potential solution to a decision-making problem when there is interest either in its implementation or in its evaluation. Criteria serve as the means for assessing and comparing alternatives, derived from clearly defined objectives and created based on one or more related attributes associated with the alternatives [13].

For the selected criteria to be valid, they must meet specific conditions: completeness, coherence, non-redundancy, comprehensibility, and acceptability. Additionally, each criterion is assigned a nature, which can be either minimization or maximization.

Since each criterion can have a different significance in the final outcome, determining criterion weights is crucial for properly guiding the decision-making process. This allows decision-makers to better express priorities and align solutions with specific objectives, thereby achieving greater accuracy and relevance in selecting alternatives. In most MCDM methods, criterion weights and the preferential outcomes of alternatives on those criteria are gathered under the assumption that criteria are mutually independent [14]. The mathematical models used for determining weights are classified into three categories: subjective (expert assessments), objective (statistical approaches), and integrated methods (a combination of the previous two) [15].

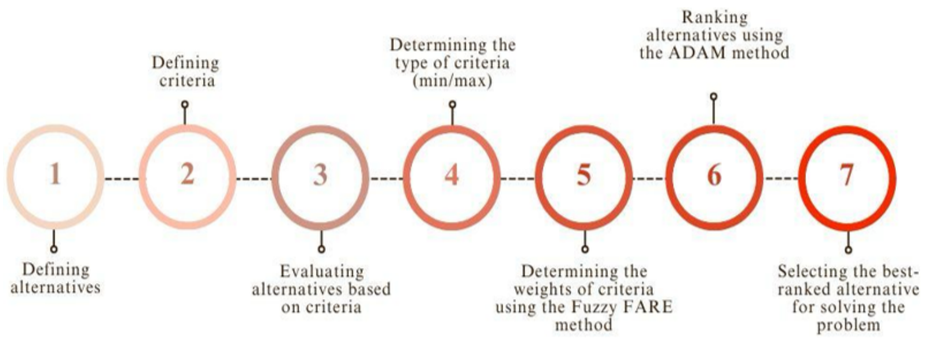

Figure 1. Methodology for solving a MCDM problem

The application of the MCDM method to solve the previously described problem follows a seven-step process (Figure 1):

Defining alternatives: This involves identifying potential solutions to the problem.

Defining criteria: This involves identifying the tools for evaluating alternatives.

Evaluating alternatives based on criteria: The process of evaluating each alternative according to the defined criteria to determine which solution best meets the decision-making objectives. This includes assigning appropriate values to each criterion for every alternative.

Determining the type of criteria (max/min): This refers to determining whether the goal for each criterion is maximization or minimization. If the criterion is a maximization (max) criterion, the goal is to achieve the highest possible value, while for a minimization (min) criterion, the goal is to achieve the lowest possible value.

Determining the weights of criteria using the Fuzzy FARE method: The Fuzzy FARE method uses fuzzy logic to handle uncertainties and subjectivity in evaluating criteria [16]. It allows subjective assessments from decision-makers to be taken into account and converted into numerical values for quantitative analysis. The Fuzzy FARE method is implemented in six stages:

Phase 1 – Identifying the criteria to be evaluated:

$$K = \{K_j \mid j = 1, \ldots, n\} \tag{1}$$

where, n is the number of identified criteria.

Phase 2 - Converting linguistic evaluations into triangular fuzzy numbers (TFN) using scales. These scales define the lower, middle, and upper values (l, m, u) for each linguistic evaluation.

Phase 3 - Creating the criteria evaluation matrix $\tilde{K}$:

Decision-makers evaluate the relative importance of criteria in relation to each other using linguistic expressions. These linguistic evaluations are then converted into TFNs using predefined scales. In the criteria evaluation matrix:

$$\widetilde{K} = \left[\tilde{k}_{ij}\right]_{nxn} \tag{2}$$

$$\tilde{k}_{ij} = (l, m, u) \tag{3}$$

This represents the evaluation of the importance of criteria in relation to criterion j, where l, m, and u are the lower, middle, and upper values of the TFNs.

For the formation of the criteria evaluation matrix $\tilde{K}$, the following holds:

$$\tilde{k}_{ji} = -\tilde{k}_{ij} \tag{4}$$

The evaluation is considered consistent if:

$$\sum_{j=1}^{n} u = -\sum_{j=1}^{n} l \tag{5}$$

Phase 4 - Obtaining the potential impact of the criteria $\tilde{P}$:

$$\tilde{P} = H \times (n-1) \tag{6}$$

Phase 5– Obtaining the total impact (importance) of the criteria:

$$\tilde{P}_j = \sum_{j=1}^{n} \tilde{k}_{ij}, \forall j = 1, \ldots, n, \quad j \neq i \tag{7}$$

Phase 6– Obtaining the final fuzzy weights of the criteria W:

$$W = \tilde{P}_j / \tilde{P}_H, \forall j = 1, \ldots, n \tag{8}$$

where, $\tilde{P}_H$ is the total potential importance of the criteria obtained as:

$$\tilde{P}_H = \left(\min_j l^{\tilde{P}jr}, mean_j m^{\tilde{P}jr}, \max_j u^{\tilde{P}_j r}\right) \tag{9}$$

where, $\tilde{P}_j^r$ is the actual total impact of criterion j, obtained as the sum of the potential impact and the criterion's potential:

$$\tilde{P}_j^r = \tilde{P}_J + \widetilde{P}, \forall j = 1, \ldots, n \tag{10}$$

Ranking alternatives using ADAM method: This method transforms the evaluation of alternatives into vector magnitudes and then utilizes angular coordinates to represent the relative weights and performance of criteria. Based on these data, the ADAM method calculates the volume of complex polyhedra, which represent the alternatives, to rank and select the best options. This method enables decision-making based on clear and quantitative evaluations of different options according to defined criteria [17]. The ADAM method is implemented through six phases [17].

Phase 1 - Defining the Decision Matrix E:

The decision matrix E contains elements e_q, which represent the evaluations of alternatives q in relation to criteria j. The vectors corresponding to these evaluations represent magnitudes:

$$E = [e_{qj}]_{mxn} \tag{11}$$

where, m is the total number of alternatives, and n is the total number of criteria.

Phase 2 - Defining the Sorted Decision Matrix S:

The sorted matrix S contains elements s_{qj}, which represent the sorted evaluations e_{qj} in descending order according to the importance (weight) of the criteria:

$$S = [s_{qj}]_{mxn} \tag{12}$$

Phase 3 - Defining the Normalized Sorted Matrix N:

The elements of the normalized sorted matrix N are the normalized evaluations n_{qj}, which are obtained as:

$$n_{qj} = \begin{cases} \frac{s_{qj}}{\max_q S_{qj}}, & zaj \in B \\ \frac{\min_q S_{qj}}{s_{qj}}, & zaj \in C \end{cases} \tag{13}$$

where, B is the set of maximization criteria, and C is the set of minimization criteria.

Phase 4 - Determining the Coordinates (x, y, z) of Reference (R_{qj}) and Weighted Reference (P_{qj}) Points that Define the Complex Polyhedron.

The coordinates are determined as follows:

$$X_{qj} = n_{qj} \times \sin\alpha_j, \forall j = 1, \ldots, n; \forall q = 1, \ldots, m \tag{14}$$

$$Y_{qj} = n_{qj} \times \cos\alpha_j, \forall j = 1, \ldots, n; \forall q = 1, \ldots, m \tag{15}$$

$$z_{qj} = \begin{cases} 0, & \text{za } R_{q_j} \\ w_j, & \text{za } R_{q_j} \end{cases}, \quad \forall j = 1, \ldots, n; \forall q = 1, \ldots, m \tag{16}$$

where, α_j is the angle that determines the direction of the vector defining the alternative's value, calculated as:

$$\alpha_j = (j-1)\frac{90°}{n-1}, \forall j = 1, \ldots, n \tag{17}$$

Phase 5 - Determining the volumes of complex polyhedra V_q^C as the sum of the volumes of the constituent pyramids using the following equation:

$$V_q^C = \sum_{k=1}^{n-1} Vk, \forall q = 1, \ldots, m \tag{18}$$

where, V_k is the volume of a pyramid calculated using the following equation:

$$V_k = \frac{1}{3} B_k \times h_k, \forall k = 1, \ldots, (n-1) \tag{19}$$

where, B_k is the base area of the pyramid, defined by the reference and weighted reference points of two consecutive criteria, obtained using the following equation:

$$B_k = \mathrm{c}_k \times a_k + \frac{a_k \times (b_k - c_k)}{2} \tag{20}$$

where, a_k is the Euclidean distance between the reference points of two consecutive criteria, calculated as:

$$a_k = \sqrt{(x_{j+1} - x_j)^2 + (y_{j+1} - y_j)^2} \tag{21}$$

where, b_k and c_k are the magnitudes of the vectors corresponding to the weights of two consecutive criteria, i.e.:

$$b_k = Z_j \tag{22}$$

$$C_k = z_{j+1} \tag{23}$$

where, h_k is the height of the pyramid, measured from the defined base to the pyramid's apex located at the coordinate origin O, and is obtained using the following equation:

$$h_k = \frac{2\sqrt{s_k\,(S_k - a_k)\,(s_k - d_k)\,(s_k - e_k)}}{a_k} \tag{24}$$

where, s_k is the semi perimeter of the triangle defined by the $\boldsymbol{x}$ and $\boldsymbol{y}$ coordinates of two consecutive criteria and the coordinate origin, calculated as:

$$s_k = \frac{a_k + d_k + e_k}{2} \tag{25}$$

where, d_k and e_k are the Euclidean distances of the reference points of two consecutive criteria from the coordinate origin, obtained as:

$$d_k = \sqrt{x_j^2 + y_j^2} \tag{26}$$

$$e_k = \sqrt{x_{j+1}^2 + y_{j+1}^2} \tag{27}$$

Phase 6 - Ranking alternatives based on the descending values of the volumes of complex Polyhedra $V_q^C(q = 1, \ldots, m)$. The best alternative is the one with the largest volume.

Selection of the best alternative: This represents the final stage of decision-making, in which the alternative that best meets the objectives and conditions is chosen based on the evaluations of the alternatives according to the criteria. This process takes into account all relevant criteria and the results of their evaluation to select the optimal option.

3 Solution to the Problem

The application of the previously described methods will enable the selection of the optimal delivery method for the last mile. Various alternatives and criteria have been selected as input parameters for the model. The alternatives include different delivery implementation models from the perspective of the destination. The decision about the delivery destination can be made by the seller or the buyer.

Home delivery (A1) is the most significant and most commonly applied model for last-mile implementation, involving direct delivery of goods to the customer's address. The characteristics of home delivery affect service levels, demand, customer satisfaction, efficiency, costs, and profitability for the delivery organizer, as well as the environment in which these processes occur [7, 18].

Delivery to the customer's workplace (A2) is also a commonly applied model. Since a large number of users spend a significant amount of time at their workplaces, these locations are often convenient for delivering goods.

Deliveries to the address of a neighbor, friend, or relative (A3) are also applied, most often as an alternative destination in cases where the customer is not home at the time the shipment is to be picked up.

Delivery to attended CDPs (A4) is a concept increasingly adopted by both e-retailers and courier, express, and parcel services. Attended CDPs are dedicated facilities for delivery and pickup, staffed with personnel, or locations where this is not the primary activity, such as post offices, gas stations, garages, supermarkets, bakeries, etc.

Delivery to unattended CDPs (A5) is even more widely implemented than the previously mentioned model. It typically involves automated stations/parcel lockers located in public, high-traffic areas, transportation hubs, etc. Unlike the previous model, where delivery or pickup times are limited by operating hours, goods at unattended CDPs can usually be collected at any time, although they require investment costs.

Delivery to drop-off companies (A6) refers to delivery to companies that provide parcel or shipment collection services at specialized locations, where they are further processed and forwarded to their final destination.

The criteria for evaluating the previously mentioned alternatives have been selected to ensure that all stakeholders—in this case, sellers, delivery providers, and buyers—can assess the chosen alternatives in a way that reflects their specific needs and expectations, thereby ensuring a fair and comprehensive evaluation. The selected criteria are presented below.

The delivery execution time window (C1) refers to the specific timeframe within which a delivery can be completed. It may cover entire days or specific time periods, such as deliveries only after 4 PM. It is crucial for buyers to be informed about these timeframes so they can plan the receipt of their orders and be assured of when to expect delivery. On the other hand, sellers must be aware of the time windows during which buyers can receive goods to enable delivery providers to effectively plan, organize, and execute the delivery process.

Availability (C2) relates to the ease of access to delivery services for all stakeholders, including buyers, sellers, and delivery providers. This includes the geographical reach of the service, operating hours, and specific conditions under which the service is available. For example, if delivery is only available in certain parts of the city or within specific timeframes, overall availability is reduced. Greater availability allows more users to access the service, which is essential for sellers aiming to reach a broader customer base.

Flexibility (C3) refers to the ability of delivery services to adapt to the varying needs and preferences of users, as well as the expectations of sellers and delivery providers. It includes the possibility of changing the delivery time and location, as well as adapting to specific customer requests. For instance, if a buyer wishes to reschedule the delivery date or send a package to an alternative address, flexibility ensures easier adjustments.

Costs (C4) refer to the total expenses associated with the delivery service, including delivery fees, additional charges, and any costs that may arise during the process. It is important to consider costs not only for buyers but also for sellers. Additionally, there are investment costs that are particularly significant for delivery providers; however, these will not be addressed in this paper.

Delivery speed (C5) refers to the time required for a package to reach the buyer after the order has been placed. Delivery speed can significantly impact customer satisfaction and influence their decision to make repeat purchases. Moreover, both sellers and delivery providers benefit from fast delivery, as it can increase efficiency and reduce storage costs. Safety and security (C6) pertain to the level of protection against product damage or loss. This also includes the security of customer data during online transactions. All stakeholders have an interest in ensuring that their products and information remain protected throughout the entire process.

Ease of product returns (C7) is another important criterion. E-commerce, in particular, faces high return rates, as customers often lack complete knowledge of a product's characteristics before purchasing [19]. The costs associated with handling returned products, including bridging the "last mile" for a second time, can easily undermine the economic viability of online retail channels [20, 21]. Ease of returns refers to the simplicity and efficiency of the return process for products that customers are dissatisfied with or that arrive damaged [22]. This includes the clarity of return procedures, the speed of return processing, and communication between the buyer, seller, and delivery provider. A smoother return process can enhance customer trust in the seller, which may positively influence their purchasing decisions.

The selected alternatives will be evaluated based on the chosen criteria. Since the alternatives are assessed qualitatively, their values are converted into quantitative measures using a scale defined in Table 1. All criteria are defined as maximization criteria, meaning that a score of 5 represents the most favorable rating.

Table 1. Conversion of qualitative ratings into quantitative values

Qualitative Value of the Alternative	**Very Poor**	**Poor**	**Good**	**Very Good**	**Excellent**
Quantitative Value of the Alternative	1	2	3	4	5

The alternatives are evaluated for each criterion from the perspective of the three stakeholders: the seller, the delivery provider, and the buyer. The final rating of the alternative according to each criterion is obtained as the average of the ratings given. The final ratings of the alternatives according to the criteria are presented in Table 2.

Table 2. Values of alternatives according to criteria (decision table)

	C1	C2	C3	C4	C5	C6	C7
A1	2.00	1.67	1.33	1.67	1.67	5.00	4.00
A2	3.33	2.67	2.67	2.67	3.33	5.00	4.00
A3	3.67	3.33	3.33	3.00	3.00	3.67	2.67
A4	4.00	3.67	4.00	3.67	4.00	4.00	4.00
A5	5.00	4.00	5.00	5.00	5.00	2.00	2.00
A6	4.00	3.33	2.67	3.00	3.33	3.00	3.00
Type of Criterion	max	max	max	max	max	max	max

For the previously selected criteria, their weights are determined using the fuzzy FARE method. This approach assesses the relative importance of criteria through pairwise comparisons and the use of linguistic expressions. These linguistic assessments are then converted into TFNs using the scale presented in Table 3. Criteria are compared with each other, and their interrelationships are evaluated using the Fuzzy FARE scale. The assigned ratings for the mutual importance of the criteria are presented in Table 4.

Table 3. Fuzzy FARE scale [17]

Linguistic Value	TFN	Numeric Value
Extremely low	(1, 1, 2)	1
Very low	(1, 2, 3)	2
Low	(2, 3, 4)	3
Moderately low	(3, 4, 5)	4
Medium	(4, 5, 6)	5
Moderately high	(5, 6, 7)	6
High	(6, 7, 8)	7
Very high	(7, 8, 9)	8
Extremely high	(8, 9, 10)	9

Table 4. Evaluation matrix of criteria

	C1			C2			C3			C4			C5			C6			C7		
C1				7	8	9	1	1	2	1	2	3	5	6	7	3	4	5	3	4	5
C2	1/9	1/8	1/7				8	9	10	7	8	9	5	6	7	4	5	6	5	6	7
C3	1/2	1/1	1/1	1/10	1/9	1/8				2	3	4	3	4	5	3	4	5	6	7	8
C4	1/3	1/2	1/1	1/9	1/8	1/7	1/4	1/3	1/2				5	6	7	3	4	5	5	6	7
C5	1/7	1/6	1/5	1/7	1/6	1/5	1/5	1/4	1/3	1/7	1/6	1/5				2	3	4	5	6	7
C6	1/5	1/4	1/3	1/6	1/5	1/4	1/5	1/4	1/3	1/5	1/4	1/3	1/4	1/3	1/2				6	7	8
C7	1/5	1/4	1/3	1/7	1/6	1/5	1/8	1/7	1/6	1/7	1/6	1/5	1/7	1/6	1/5	1/8	1/7	1/6			

Table 5. Weight of criteria

	Pj			Pjr			wj			Weight of Criteria
C1	20.00	25.00	31.00	68.00	79.00	91.00	0.69	1.12	1.86	1.173527323
C2	29.11	34.13	39.14	77.11	88.13	99.14	0.78	1.25	2.03	1.303114555
C3	14.60	19.11	23.13	62.60	73.11	83.13	0.63	1.04	1.70	1.081770484
C4	13.69	16.96	20.64	61.69	70.96	80.64	0.62	1.01	1.65	1.051376168
C5	7.63	9.75	11.93	55.63	53.75	71.93	0.56	0.91	1.47	0.943146021
C6	7.02	8.28	9.75	55.02	62.28	69.75	0.55	0.89	1.43	0.920768584
C7	0.88	1.04	1.27	48.88	55.04	61.27	0.49	0.78	1.25	0.812815863
	92.93	114.26	136.86	48.88	70.32	99.14				

The evaluation matrix for the criteria, created after applying the fuzzy FARE method, yielded criterion weights as shown in Table 5. The weights range between 0.81 and 1.30. The most significant criterion is availability (C2), while the least significant is ease of return (C7).

In order to select the best alternative from the previously chosen ones, the ADAM method was applied, with its theoretical basis presented in Chapter 3. Software for the ADAM method was used to obtain the results. After entering the necessary input parameters, the software determines the ranking of alternatives. The obtained ranking of alternatives is presented in Table 6.

Table 6. Alternative ranking

Alternative	Volume	Rank
A1	0.147622632	6
A2	0.267287237	3
A3	0.252653645	4
A4	0.356544475	2
A5	0.429311777	1
A6	0.242376064	5

The best alternative identified is the fifth one, i.e., delivery to CDPs without staff. The solution obtained by applying the ADAM method may vary if the preferences of the criteria or the ratings of alternatives according to those criteria change. Since all ratings are based on subjective evaluation on a qualitative scale, different approaches or perspectives of stakeholders can affect the ranking of alternatives. For example, if the priorities of one of the stakeholders change, or if the ratings according to the criteria are adjusted, it may lead to a different choice of the optimal alternative. Therefore, it is important to regularly reevaluate and update the criteria and ratings to ensure that the solution remains relevant and aligned with the needs of all participants.

The application of the ADAM software enabled the visualization of alternatives (Figure 2). They are presented as a three-dimensional geometric body. The visualization allows for quick analysis of results and identification of the best alternatives. It also helps in understanding how changes in the weights of criteria affect the ranking.

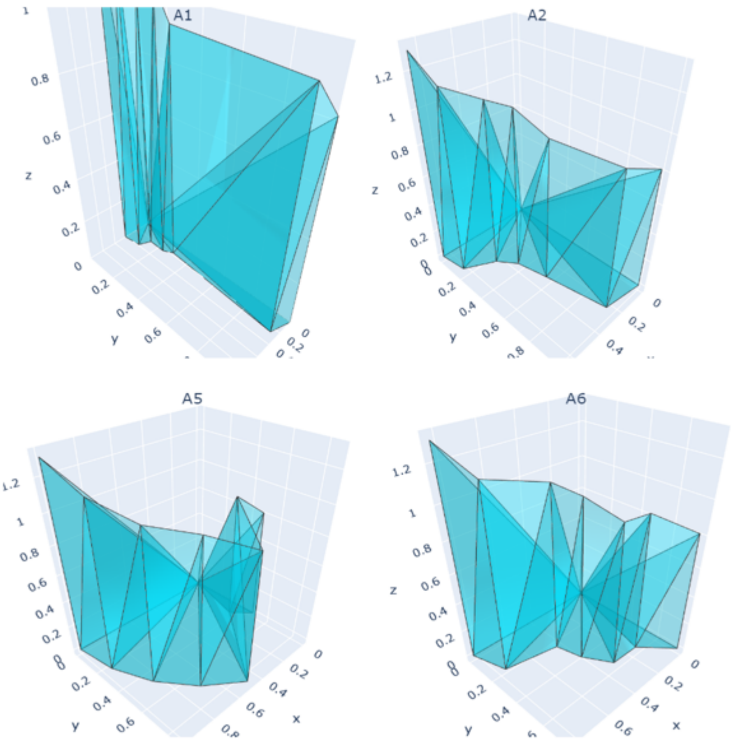

Figure 2. Alternatives represented as geometric bodies

4 Conclusions

Last mile logistics is a critical component of modern supply chains, ensuring efficient product distribution directly to end users. Its importance stems from the need for fast and reliable services, especially in the context of ubiquitous e-commerce, where customers expect to receive their orders as quickly as possible. In this area, there are various delivery models from the perspective of the final point, which are used to meet specific user needs. For example, home delivery and delivery to the workplace allow users to receive packages without making their own effort or generating flows. On the other hand, options such as delivery to neighbors or friends, as well as delivery to CDPs or drop-off companies, provide greater flexibility in terms of delivery time and goods collection. These diverse delivery models not only enable users to choose the option that suits them best but also help optimize the process and reduce costs.

For selecting the best delivery model, this paper utilized a combination of the fuzzy FARE and ADAM methods. The first method was used to determine the weights of the criteria, and the second for ranking the alternatives. The analysis results showed that the best alternative was delivery to CDPs without staff.

The solution obtained by applying the ADAM method may vary if the preferences of the criteria or the ratings of alternatives according to those criteria change. Since all ratings are based on subjective evaluation on a qualitative scale, different approaches or perspectives of stakeholders can affect the final ranking.

It is important to note that this paper addresses the problem in a general context. The decision on the choice of delivery destination depends on various circumstances, such as the type of goods, customer requirements (e.g., delivery speed or security), vendor/shipper preferences, etc. Therefore, future research should apply the model to specific companies, types of goods, etc. Also, while the problem in this paper covers directly involved stakeholders, it does not include those indirectly related (management, natural, and social environment). The model should be extended to include the missing stakeholders.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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