IDEAL LOCATION SELECTION FOR CONTACTLESS PARCEL PICK-UP POINTS

Tutku Tuncalı Yaman
Faculty of Business Administration
Department of Management Information Systems
Marmara University
Istanbul, Turkey
tutku.tuncali@marmara.edu.tr

Serdar Yaylalı
Institute of Social Sciences
International Trade and Logistics Management Program
Yeditepe University
Istanbul, Turkey
yaylali@groupv4.com

ABSTRACT

The post-Covid era has witnessed the adoption of various new habits in our daily lives, particularly in relation to the ubiquitous e-commerce platforms that have become essential for urban populations. The surge in e-commerce activities and the intensified volume in delivery of packages during the pandemic sparked innovative ideas. This study explores one such creative concept: parcel pick-up points. We conducted a pioneering research endeavor to determine the optimal locations for these pick-up points in Istanbul, Turkey. Our methodology employed a novel hybrid approach, combining the Spherical Fuzzy Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The evaluation of criteria importance was facilitated by a literature review and experienced high-level managers in the cargo industry, who determined the criteria weights using the Spherical Fuzzy AHP method. Subsequently, the TOPSIS method was employed to identify the most ideal locations, leading to the selection of Kadikoy, Umraniye, and Atasehir. This study provides valuable insights into the selection of the optimal locations for parcel pick-up points in Istanbul, Turkey, which can inform policymakers, e-commerce companies, and logistics stakeholders. The proposed hybrid approach demonstrates the integration of modern smart technologies with fuzzy decision-making techniques, offering a robust framework for decision support in the field of e-commerce logistics. Future research can further explore the implementation and effectiveness of these pick-up points to enhance the efficiency and convenience of last-mile deliveries in urban areas.

Keywords: parcel pick-up points; location selection; spherical fuzzy AHP; TOPSIS

1. Introduction

In recent years, notable progress has been made in computer systems, robot software, and internet technologies, leading to substantial advancements across various domains. Particularly in the aftermath of the Covid-19 pandemic, electronic purchasing has become an indispensable activity, particularly for urban dwellers. The surge in e-commerce activity and the intensified volume in delivery of packages to consumers during the pandemic spurred novel concepts in this field. With the integration of contemporary intelligent technologies into these developments, numerous prospects have emerged for entrepreneurs and enterprises to explore. One such innovative concept is the adoption of Parcel Pick-up Points (PPP), which has swiftly gained traction in Europe, and it is anticipated that its usage will soon experience a rapid surge in Turkey (Yıldıztekin, 2021).

The delivery of e-commerce parcels, commonly referred to as cargo, typically consists of small-sized shipments. Couriers, following predetermined distribution routes, can deliver these packages to a limited number of addresses, typically ranging from 30 to 40 per day. However, the daily volume of shipments handled by e-commerce companies has surpassed the range of 40,000 to 50,000 packages. Considering the scale of such intensive delivery operations, involving thousands of vehicles and couriers, it has become evident that the associated delivery costs are substantial, necessitating the exploration of alternative solutions (Parcelbox, 2022).

An emerging solution, prompted by the surge in e-commerce utilization and the subsequent rise in cargo transportation, involves the consolidation of parcels at designated locations accessible to consumers, instead of individually delivering packages to specific addresses within particular districts. Under this system, consumers can conveniently collect their packages by visiting these designated locations and using a password provided to them via SMS messages. However, the implementation of this system has encountered challenges related to the operational costs associated with employing staff throughout the day to manage the parcels, as well as the high rental fees for the premises. Consequently, the widespread adoption of this solution has been limited thus far (Editorial, 2022).

Another solution that has gained traction globally is the utilization of automated cargo cabins strategically positioned at various points within cities, operating without human intervention. This rapidly expanding system involves distributor companies depositing packages in secure, user-friendly compartments installed at locations such as gas stations, parking areas, subways, shopping malls, bus stops, train stations, and terminals. Consumers can conveniently access these compartments in close proximity to their desired locations and retrieve their packages independently. These compartments, often known by names like Cargomatic, Cargobox, Parcelbox, and Packegebox, hold the packages until their owners arrive and input the corresponding lock code. Each interaction within the system is meticulously tracked online. Furthermore, these compartments also serve as convenient return points for packages being sent back to the distributor (Rovlocker, 2022).

These modular units have significantly expanded the scope of their applications. Since each unit can be customized for a specific company, it is also feasible for multiple companies to share the same unit based on their respective needs. These units, designed to minimize delivery errors, mitigate product damage, and reduce costs, are rapidly gaining popularity, particularly in major urban centers. Additionally, in areas where electrical infrastructure is limited, these units can operate autonomously using built-in solar panels, ensuring uninterrupted functionality (Yıldıztekin, 2021).

The PPP service, akin to the Automatic Teller Machine (ATM) services offered by banks (Zeydan & Kayserili, 2019), presents similar solutions in the logistics sector. When cargo companies, operating exclusively during working hours, are unable to reach end-users at their residences, the courier must return the packages to the cargo branch, resulting in failed deliveries. In such cases, PPP serves as an alternative solution. With PPP, transactions can be swiftly and securely conducted 24/7, without the need for personnel. This not only saves fuel but also enables round-the-clock operation, making it an advantageous solution for cargo and e-commerce companies while supporting environmentally friendly logistics trends. It is anticipated that PPPs will soon become physically present in nearly every neighborhood, particularly in large cities, offering numerous benefits to customers, like ATMs (Albayrak, 2019). The study conducted by Min and Melachrinoudis (2002) on the selection of commercial banking facilities in heterogeneous centers can be referenced to guide the appropriate location selection for PPPs.

In response to the ongoing pandemic, online shopping platforms have continuously introduced innovative shipping solutions through e-commerce applications to ensure customer satisfaction. These solutions, such as contactless delivery and customizable container options, provide customers with convenience and flexibility in receiving their products according to their preferences. By implementing "contactless delivery," customers can receive their products anywhere and at any time. These shipping innovations also offer advantages for freight companies, as the growing volume of e-commerce puts strain on their operations, particularly during periods of price reductions. Additionally, these solutions help alleviate transportation congestion (Zheng et al., 2020).

Considering the additional functionalities of PPP, the following aspects warrant evaluation:

- Parcel delivery with payment
- Sending parcels in prepaid packages
- Payment of postal checks
- Ticket printing (as an additional module)
- Cash machine (as an additional module)
- Digital state agenda point
- Support for public health initiatives
- Operating as a company branch open 24/7
- Accepting both cash and credit card transactions
- Possessing security certification
- Utilizing both barcode and RFID parcel identification systems.

The eco-friendly PPP service offers customers a comprehensive delivery network that goes beyond traditional shipping services by introducing a new delivery model.

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Customers seeking flexibility in selecting delivery points can choose their preferred pickup location for their orders. Once the order arrives at the designated delivery point, customers can conveniently retrieve it at a date and time of their choosing. This innovative delivery model also stands out for its environmentally friendly features. By eliminating direct deliveries, this solution reduces vehicle emissions and minimizes the carbon footprint. The following advantages of the PPP services can be highlighted (Parcelbox, 2022):

- Reduces shipping costs and enhances profit margins.
- Provides convenient 24-hour pickup options without requiring staff presence.
- Promotes public health through contactless pickup, aligning with the current health concerns.
- Offers a visually appealing solution that aligns with corporate branding.
- Boasts high-quality mechanical design.
- Allows for extensibility with a central unit (column).
- Demonstrates modularity by accommodating more central/user communication units per locker block and facilitating combinations of columns with lockers.
- Facilitates easy integration with overarching postal systems.

Figure 1 Example of parcel pick-up point (Parcelbox, 2022)

The objective of this study is to establish a systematic framework aligned with the installation goals of PPPs and to determine the most suitable locations for their implementation. As pioneering research in cargo vending machines, this study aims to pave the way for further investigations, enabling the private sector to make informed decisions regarding pinpoint location selection. Such research will assist professionals in identifying optimal location choices for similar solutions. Previous studies conducted in China have explored the location selection of PPPs, utilizing new technologies and software to support the sector's development and provide simplicity for e-commerce companies, cargo companies, and end-users (Liu et al., 2021; Zheng et al., 2021; Sajid et al., 2021). Similar objectives were identified in the work of Moslem and Pilla (2023), focusing on the problem of parcel locker location selection in Dublin, Ireland. The study specifically considered the following five criteria: reliability, accessibility, traffic and operation, security, and environmental impact. The inherent nature of the operation renders the reliability and environmental impact of PPPs evident (Mangiaracina et al., 2019; González-Varona et al., 2020; Kilibarda et al., 2020; Lagorio & Pinto, 2020; Tsai & Tiwasing, 2021). In another study by Yalcin Kavus et al. (2023), which addressed the same issue within Istanbul, the examination was limited to the alternative PPP locations

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specifically in Istanbul's Beşiktaş district. The article reexamined six primary and 31 sub-criteria during the evaluation phase, acknowledging that many of these criteria may be interrelated. It is recognized that, in such cases, employing a preliminary Analytical Network Process (ANP) analysis and/or utilizing the Analytic Hierarchy Process (AHP), which assesses criteria in a hierarchical fashion, would likely yield more dependable results (Sipahi & Timor, 2010). However, none of the proposed solutions were favored in the presented resolution. Nevertheless, extensive academic research employing contemporary methodologies tailored to the Turkish context is necessary, given the promising potential of PPPs as a contemporary solution to a novel problem. The principal contribution of this study lies in proactively addressing this gap by applying a hybrid and robust fuzzy methodology, encompassing the most densely populated city in Turkey. According to the most recent Statista report (2023) on the distribution of e-commerce orders in Turkey for the year 2021 (Fig. 2), Istanbul accounted for over 30% of the total share, surpassing all other cities.

In this research, we conducted a pilot study on the optimal location selection of PPPs using a novel and hybrid fuzzy multi-criteria decision-making (MCDM) approach, specifically a hybrid of the Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodologies.

To address the limitations of previous studies, our article concentrated on five prospective districts situated within the boundaries of Istanbul, specifically Atasehir, Besiktas, Kadikoy, Umraniye, and Sisli, encompassing both the European and Asian sides of the city. The criteria for evaluating location selection were derived from the pertinent literature, incorporating practices observed in various related location selection examples (Goli et al., 2010; Roig-Tierno et al., 2013; Syahputra et al., 2020; Yildiz et al., 2020; Simić et al., 2021; Krstić et al., 2021) and specifically in parcel locker location selection (Lagorio & Pinto, 2020; Yalcin Kavus et al., 2023; Moslem & Pilla, 2023). To ascertain the criteria weights, seasoned managers in the cargo industry evaluated the criteria within the framework of the SF-AHP. Subsequently, TOPSIS was employed to pinpoint the optimal districts in the vicinity of Istanbul. According to the outcomes, Kadikoy, Umraniye, and Atasehir emerged as the three most suitable districts for the implementation of PPPs.

The subsequent sections of this article provide essential information on the MCDM techniques employed, the research design, the obtained results, discussions, and future directions for research.

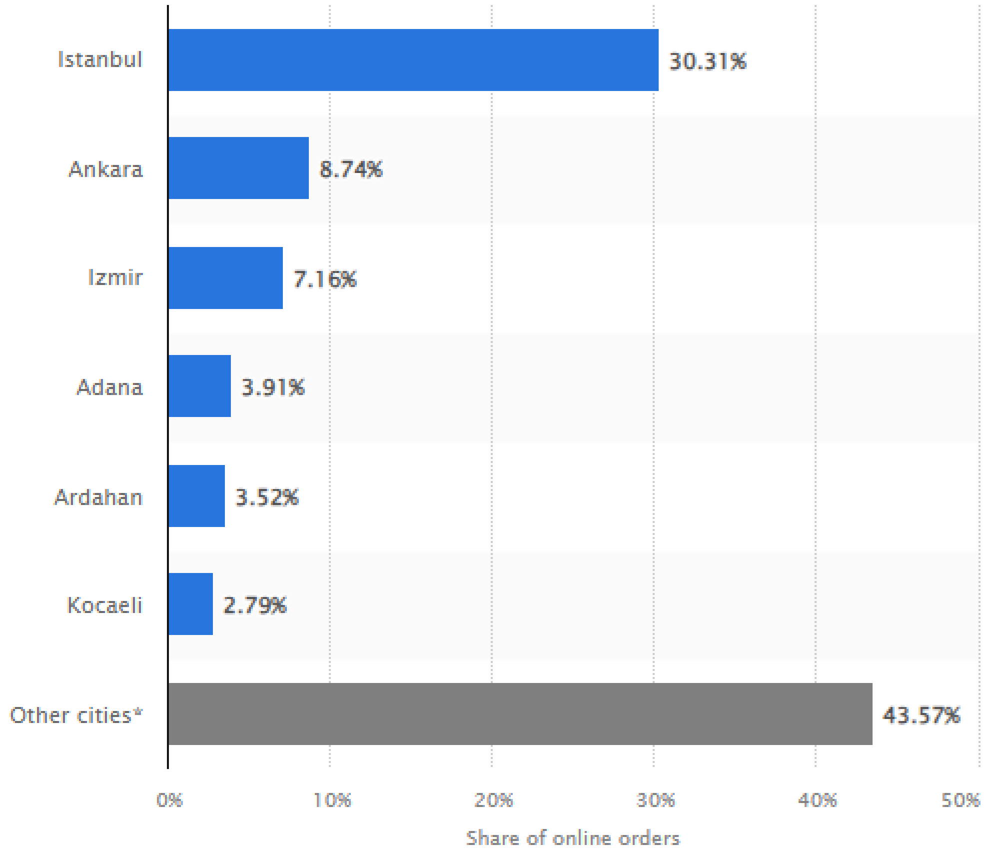

Figure 2 Distribution of e-commerce orders in Turkey in 2021, by city (Statista, 2023)

2. Materials and methods

This research was conducted to help decision-makers analyze the most suitable potential location for the PPP location selection by using an integration of SF-AHP and TOPSIS (Parkhan et al., 2018). General information about both techniques is given below.

2.1 Spherical Fuzzy AHP

The Analytic Hierarchy Process (AHP), developed by Saaty (1977), is a widely used multi-criteria decision-making method that enables the comparison of multiple alternatives based on specified criteria. It is a preferred approach by decision makers when dealing with complex problems. The AHP employs a hierarchical framework to represent the multi-dimensional nature of the problem, illustrating the relationships between the main objectives, criteria, sub-criteria, and alternatives. By estimating the relative importance of the criteria and sub-criteria, the AHP reduces the problem's complexity, allowing decision makers to prioritize the criteria and select the best alternative. The opinions of experienced individuals, as well as the preferences of company executives and subject matter experts, are considered during the calculations to make the final selection.

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The application of the AHP with Spherical Fuzzy Sets (SFS), as examined by Parkhan et al. (2018) and applied to the TOPSIS method, is relatively new in the literature. A SFS can be viewed as a three-dimensional fuzzy set that extends the intuitionistic, Pythagorean, and Neutrosophic Fuzzy Sets to handle uncertainty in the linguistic evaluations provided by decision makers. The membership functions of SFS encompass truthiness (membership: $\mu_{\tilde{S}}$), falsity (non-membership: $\nu_{\tilde{S}}$), and indeterminacy (hesitancy: $\pi_{\tilde{S}}$) parameters, whose squared sums range between 0 and 1. Some basic information about SFS is presented in the following references (Kutlu Gündoğdu & Kahraman, 2019; Mathew et al., 2021; Dogan, 2021; Kutlu Gündoğdu & Kahraman, 2020). The same references should be consulted for a comprehensive overview of the fundamental operations of SFSs outlined below.

$\boldsymbol{\tilde{S}}$ is a SFS of $\boldsymbol{U}$, the universe of discourse which is given by

$$\tilde{S} = \{\langle u, (\mu_{\tilde{S}}(u), \nu_{\tilde{S}}(u), \pi_{\tilde{S}}(u))\rangle | u \in U\} \quad (1)$$

where $\mu_{\tilde{S}}, \nu_{\tilde{S}}, \pi_{\tilde{S}} : U \to [0,1]; 0 \le \mu_{\tilde{S}}^2(u) + \nu_{\tilde{S}}^2(u) + \pi_{\tilde{S}}^2(u) \le 1$

For each $u \in U$, $\mu_{\tilde{S}}(u), \nu_{\tilde{S}}(u)$ and $\pi_{\tilde{S}}(u)$ represent the membership, non-membership, and hesitancy degrees respectively. Some fundamental operations for two SFS like $\tilde{A}_S = \left(\mu_{\tilde{A}_S}, \nu_{\tilde{A}_S}, \pi_{\tilde{A}_S}\right)$ and $\tilde{B}_S = \left(\mu_{\tilde{B}_S}, \nu_{\tilde{B}_S}, \pi_{\tilde{B}_S}\right)$ are detailed below.

Addition of $\tilde{A}_S$ and $\tilde{B}_S$: $(\tilde{A}_S \oplus \tilde{B}_S)$

$$\begin{aligned}&(\tilde{A}_S \oplus \tilde{B}_S)\\ &= \left\{\sqrt{\left(\mu_{\tilde{A}_S}^2 + \mu_{\tilde{B}_S}^2 - \mu_{\tilde{A}_S}^2\mu_{\tilde{B}_S}^2\right)}, \nu_{\tilde{A}_S}\nu_{\tilde{B}_S}, \sqrt{\left(1-\mu_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1-\mu_{\tilde{A}_S}^2\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2}\right\}\end{aligned} \quad (2)$$

Multiplication of $\tilde{A}_S$ and $\tilde{B}_S$: $(\tilde{A}_S \otimes \tilde{B}_S)$

$$\begin{aligned}&(\tilde{A}_S \otimes \tilde{B}_S)\\ &= \left\{\mu_{\tilde{A}_S}\mu_{\tilde{B}_S}, \sqrt{\left(\nu_{\tilde{A}_S}^2 + \nu_{\tilde{B}_S}^2 - \nu_{\tilde{A}_S}^2\nu_{\tilde{B}_S}^2\right)}, \sqrt{\left(1-\nu_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1-\nu_{\tilde{A}_S}^2\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2}\right\}\end{aligned} \quad (3)$$

A scalar (λ) is the power of $\tilde{A}_S$ where $\lambda > 0$: ${\tilde{A}_S}^{\lambda}$

$${\tilde{A}_S}^{\lambda} = \left\{\mu_{\tilde{A}_S}^{\lambda}, \sqrt{1-\left(1-\nu_{\tilde{A}_S}^2\right)^{\lambda}}, \sqrt{\left(1-\nu_{\tilde{A}_S}^2\right)^{\lambda} - \left(1-\nu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}}\right\} \quad (4)$$

Spherical weighted arithmetic mean operator (SWAM) of i SFS ($\tilde{s}_i$).

$$\begin{aligned}&SWAM\\ &= \langle \sqrt{\left[\mathbf{1} - \prod_{i=1}^{n}\left(\mathbf{1} - \boldsymbol{\mu}_{\tilde{S}_i}^2\right)^{w_i}\right]}, \prod_{i=1}^{n} \boldsymbol{\nu}_{\tilde{S}_i}^{w_i}, \sqrt{\left[\prod_{i=1}^{n}\left(\mathbf{1} - \boldsymbol{\mu}_{\tilde{S}_i}^2\right)^{w_i} - \prod_{i=1}^{n}\left(\mathbf{1} - \boldsymbol{\mu}_{\tilde{S}_i}^2 - \boldsymbol{\pi}_{\tilde{S}_i}^2\right)^{w_i}\right]} \rangle\end{aligned} \quad (5)$$

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where $i = 1, 2, \ldots, n$; $w_i \in [0,1]$ and $\sum_{i=1}^{n} w_i = 1$.

Spherical weighted geometric mean operator (SWGM) of i SFS ($\tilde{s}_i$).

$$SWGM = \left[\prod_{i=1}^{n} \left(\mu_{\tilde{S}_i}\right)^{w_i}, \sqrt{1 - \prod_{i=1}^{n} \left(1 - \nu_{\tilde{S}_i}^2\right)^{w_i}}, \sqrt{\prod_{i=1}^{n} \left(1 - \nu_{\tilde{S}_i}^2\right)^{w_i} - \prod_{i=1}^{n} \left(1 - \nu_{\tilde{S}_i}^2 - \pi_{\tilde{S}_i}^2\right)^{w_i}}\right] \quad (6)$$

In this article, the SFS version of the AHP (SF-AHP) was used to determine the criteria weights. The fundamental steps of the technique include the following (Kutlu Gündoğdu & Kahraman, 2019):

1. Definition of the hierarchical structure of the problem
2. Construction of pairwise comparison matrices by using spherical fuzzy linguistic evaluation scale
3. Consistency check where consistency ratio ≥ 0.1
4. Calculation of spherical fuzzy local weights of criteria with SWAM operator
5. Aggregation of spherical fuzzy weights
6. Defuzzyfication of final scores

The first step of the AHP methodology involves defining the problem and criteria to establish a scoring index. When the purpose is to select the best alternative based on the defined criteria, at least two alternatives should be identified at this level. In the second step, pairwise comparison matrices are constructed for each expert involved in the decision-making process. Table 1 presents the spherical fuzzy linguistic evaluation scale used by the experts (Kutlu Gündoğdu & Kahraman, 2019). The score indices are calculated using Equations 7 and 8. The SWGM operator (Eq. 6) is employed to aggregate the individual expert matrices.

$$SI = \sqrt{\left|100 \times \left[\left(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2 - \left(\nu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2\right]\right|} \quad (7)$$

$$\frac{1}{SI} = 1 \Big/ \sqrt{\left|100 \times \left[\left(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2 - \left(\nu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2\right]\right|} \quad (8)$$

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Table 1
Linguistic measures with spherical fuzzy numbers and score indices (Kutlu Gündoğdu & Kahraman, 2019).

	(μ, ν, π)	Score Index
Absolutely more important	(0.9, 0.1, 0.0)	9
Very high importance	(0.8, 0.2, 0.1)	7
High importance	(0.7, 0.3, 0.2)	5
Slightly more important	(0.6, 0.4, 0.3)	3
Equally important	(0.5, 0.5, 0.4)	7
Slightly more important	(0.4, 0.6, 0.5)	1/3
Low importance	(0.3, 0.7, 0.6)	1/5
Very low importance	(0.2, 0.8, 0.7)	1/7
Absolutely low importance	(0.1, 0.9, 0.8)	1/9

Before proceeding with the calculations, step 3 of the AHP methodology involves conducting a consistency check using the consistency ratio (CR). Any ratio above 0.10 is considered inconsistent. In the subsequent step, the SWAM operator (Eq. 5) is utilized to calculate the spherical weights of the criteria. Once the spherical fuzzy weights have been aggregated, the following score function (Eq. 9) is employed to defuzzify the criteria weights obtained through the SWAM operator.

It is crucial to ensure consistency in the pairwise comparisons before further analysis. Inconsistent pairwise comparisons may lead to unreliable results. The consistency ratio (CR) is computed to evaluate the consistency of the judgments provided by the experts. If the CR exceeds 0.10, it indicates inconsistency, and further adjustments may be necessary.

The SWAM operator (Spherical Weighted Aggregation Method) is employed to calculate the spherical weights of the criteria. This operator considers the experts' assessments and aggregates them to determine the overall weights assigned to the criteria. To defuzzify the criteria weights obtained from the SWAM operator, a score function is applied. This function transforms the fuzzy weights into crisp values for further analysis and decision-making.

The specific mathematical equations and steps for consistency checking, spherical weighting, and defuzzification depend on the specific methodology and approach used in the study.

$$S(w_j) = \sqrt{\left|100 * \left[\left(3\mu_{\tilde{S}} - {\pi_{\tilde{S}}}/{2}\right)^2 - \left({\nu_{\tilde{S}}}/{2} - \pi_{\tilde{S}}\right)^2\right]\right|} \tag{9}$$

where $j = 1, 2, \ldots, k$

2.2 TOPSIS

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, developed by Hwang and Yoon (1981), is widely used in various fields to address multi-criteria decision-making (MCDM) problems. It is considered a simple and straightforward method that provides easily understandable results with a small number of input parameters. The TOPSIS method aims to identify the alternative that is closest to the ideal solution while being farthest from the non-ideal solution (Yoon & Hwang, 1995).

The traditional TOPSIS method involves several main steps. In the first step, a decision matrix is constructed using the performance scores $(y_{1k}, y_{2k}, \ldots, y_{nk})$ of the alternatives $(a_1, a_2, \ldots, a_n)$ with respect to the criteria $(c_1, c_2, \ldots, c_k)$. In the second step, the performance scores are normalized using Equation 10 to ensure that the scores are on a common scale. Normalization is performed to eliminate the potential bias caused by the differences in measurement scales among the criteria. By normalizing the performance scores, each criterion is given equal importance in the subsequent analysis.

The specific equations and calculation steps for the normalization process can be found in references such as Behzadian et al. (2012) and Papathanasiou & Ploskas (2018).

$$Z_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{n} \left(y_{ij}\right)^2}} \tag{10}$$

where $j = 1, 2, \ldots, k;\ i = 1, 2, \ldots, n$

Then, the normalized matrix is weighted by criteria weights (Eq. 11).

$$X_{ij} = w_j z_{ij} \tag{11}$$

In the fourth step, $m^* = [\, x_1^*, x_2^*, \ldots, x_k^*]$ and $m^- = [\, x_1^-, x_2^-, \ldots, x_n^-]$ ideal points are defined. Here, the maximum and minimum values are determined in each column in the weighted matrix (X) respectively. Then, the distances to the maximum and minimum ideal points are calculated with Equations 12 and 13.

$$S_i^* = \sqrt{\sum_{j=1}^{k} \left(x_{ij} - x_j^*\right)} \tag{12}$$

$$S_i^- = \sqrt{\sum_{j=1}^{k} \left(x_{ij} - x_j^-\right)} \tag{13}$$

Finally, the relative ranking and score of each alternative is calculated according to Equation 14.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{14}$$

where $0 \le \boldsymbol{C_i^*} \le 1$.

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2.3 Study design

This research aims to assist decision-makers in analyzing the most suitable location for PPP installations by utilizing a hybrid approach combining the SF-AHP and TOPSIS methodologies. The SF-AHP is employed to determine the weights of the evaluation criteria, while TOPSIS is used to prioritize candidate locations. Selecting establishment districts or specific locations for PPP installations involves greater complexity and diversity compared to regional selection. Furthermore, the qualitative nature of most of the factors further complicates the selection process. Based on limited literature research and consultation with three industry professionals, the following evaluation criteria were defined:

C1: Population Distribution (Yildiz et al., 2020)
C2: Age Distribution (Percentage of young and middle-aged individuals) (Yalcin Kavus et al., 2023)
C3: University and Above Education Levels (Roig-Tierno et al., 2013)
C4: Socioeconomic Status (Sum of Groups A+, A, and B) (Expert view)
C5: Number of Households (Yildiz et al., 2020)
C6: Average Income Per Capita (Yildiz et al., 2020)
C7: E-Commerce Trends (Percentage of Population Engaged in E-Commerce) (Expert view)
C8: Rental Price of Commercial Property per square meter (Simić et al., 2021)
C9: Number of Cargo Branches (Yalcin Kavus et al., 2023)
C10: Number of Branded Housing Projects (Expert view)
C11: Number of Shopping Centers (Yalcin Kavus et al., 2023)
C12: Number of Parcel Boxes (Yildiz et al., 2020)

To evaluate these criteria, six experts from various logistics and cargo companies, possessing expertise and knowledge in the parcel delivery sector, conducted pairwise comparisons. Linguistic measures using spherical fuzzy numbers were employed, and the scoring index of the evaluation form is presented in Table 1.

To ensure an up-to-date analysis for optimal location selection, actual data regarding the candidate districts in Istanbul, namely Atasehir, Besiktas, Kadikoy, Umraniye, and Sisli, were collected with respect to the evaluation criteria (refer to Table 4). This information was obtained from open-source data provided by the respective District Governor's Offices (Atasehir District Governor's Office, 2022; Besiktas District Governor's Office, 2022; Kadikoy District Governor's Office, 2022; Sisli District Governor's Office, 2022; Umraniye District Governor's Office, 2022), as well as other sources such as Endeksa (2022) and TUIK (Turkish Statistical Institute, 2022). These data formed the initial decision matrix for the TOPSIS analysis.

3. Results

To determine the relative importance of the evaluation criteria, pairwise comparison matrices were constructed based on the SF linguistic evaluation scale provided in Table 1. The evaluation matrices of all experts are presented in Table A1-A7. Score indices were calculated using Equations 7 and 8. A consistency check was performed using the consistency ratio (CR) of the AHP method, where any ratio above 0.10 indicates inconsistency. The CR for all matrices was found to exceed the threshold, indicating inconsistency. The SWGM operator (Eq. 6) was then applied to aggregate the individual expert matrices, as shown in Table A7. This operator combines the assessments of each expert to derive an overall consensus. The SWAM operator (where $w_i = 1/n$ in Eq. 5) was adopted in the calculation of spherical weights of the criteria. Detailed figures of SWAMs of each criterion are provided in Table 2.

Table 2
SWAMs of each criterion

	μ	ν	π
C1	0.325	0.676	0.228
C2	0.327	0.675	0.231
C3	0.446	0.578	0.223
C4	0.569	0.450	0.228
C5	0.400	0.612	0.228
C6	0.593	0.429	0.215
C7	0.591	0.430	0.220
C8	0.460	0.554	0.233
C9	0.525	0.492	0.236
C10	0.534	0.475	0.247
C11	0.562	0.449	0.242
C12	0.569	0.445	0.243

The score function (Eq. 9) was used in the defuzzification of criteria weights obtained by SWAM operator. Crisp criteria weights are scaled to 1 $\left(\sum w_i = 1\right)$ and provided in Table 3 below.

Table 3
Criteria weights (SF-AHP)

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0.053	0.053	0.075	0.098	0.066	0.102	0.102	0.077	0.089	0.091	0.096	0.097

To perform TOPSIS in the selection of the optimal locations for PPPs, the following decision matrix in Table 4 was constituted.

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Table 4
Initial decision matrix

Districts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Atasehir	422,594	88	27	65	3.15	6047	54937	42.57	51	34	7	6
Kadikoy	481,983	75	47	72	2.47	7238	62,652	53.28	50	255	2	17
Umraniye	713,803	90	22	62	3.41	5435	92,794	31.52	53	50	6	8
Besiktas	176,513	78	47	82	2.51	8038	22,946	64.31	36	23	2	4
Sisli	266,793	84	30	69	2.64	6869	34,683	48.74	57	33	8	1

Previously detailed well-known steps of the traditional TOPSIS method were followed in the computation and finally, the relative closeness (the distances; S_i^*, $S_i^-$and C_i^*) to the ideal solution figures are used in the ranking of the alternative locations (see Table 5). Normalized and weighted matrices are provided in Table A8-A9.

Table 5
Final rankings

Districts	S_i^+	S_i^-	C	Rank
Atasehir	0.10	0.06	0.35	3
Kadikoy	0.06	0.12	0.69	1
Umraniye	0.09	0.08	0.46	2
Besiktas	0.13	0.04	0.24	5
Sisli	0.12	0.05	0.30	4

The candidate districts were ranked, and the results indicate that the Kadikoy district achieved the highest score, while Besiktas obtained the lowest score. To compare the results, traditional AHP was also employed to obtain the criteria weights. Although there were slight variations in the importance figures of the most critical criteria, the final rankings remained unchanged (refer to Table 6). This comparison demonstrates the consistency of the findings obtained using the hybrid SF-AHP and TOPSIS approach, as well as the traditional AHP method.

Table 6
Criteria weights (traditional AHP)

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0.025	0.07	0.068	0.098	0.015	0.188	0.205	0.047	0.078	0.037	0.023	0.145

A meticulous sensitivity analysis was conducted to ensure the precision of the obtained results. The essence of the sensitivity analysis lies in the systematic comparison of each criterion's weight with that of another criterion (Önüt et al., 2010:1979), resulting in the generation of 66 distinct calculations. The determination of C* values was pursued for each calculation, each denoted by distinct nomenclature. For example, C12 signifies a scenario where the weights of criterion 1 and criterion 2 have been modified, while C34 indicates an alteration in the weights of criterion 3 and criterion 4. The graphical representation of the updated C* values for the alternatives is encapsulated in Figure 3.

Additionally, Table A10 in the appendix provides a comprehensive overview of the new C* values.

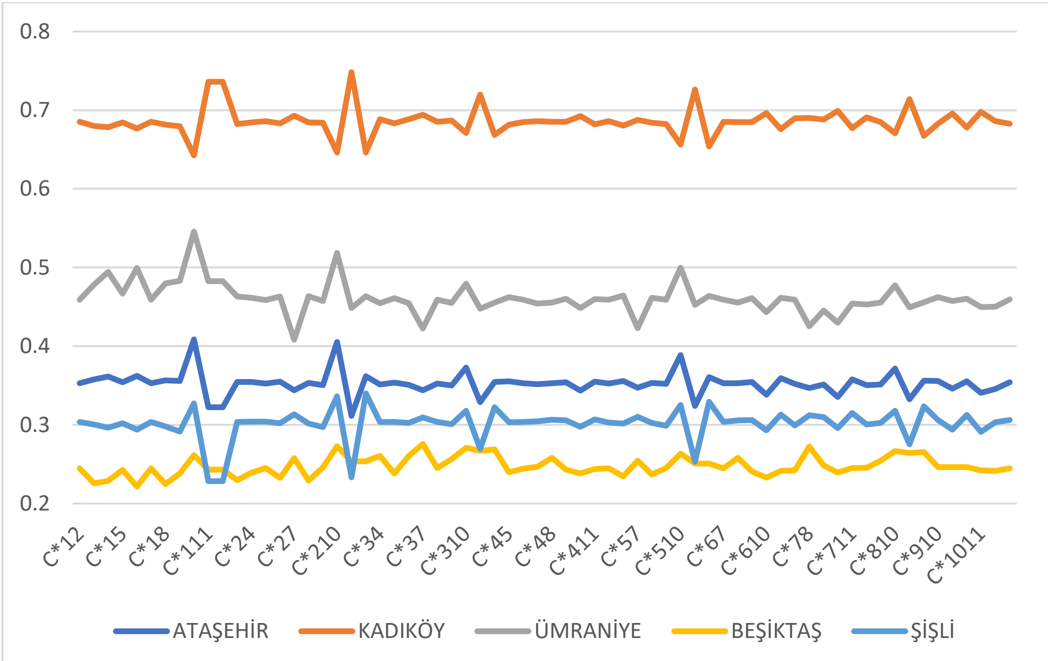

Figure 3 New C* values of the alternative locations

As illustrated in Figure 3 and elaborated upon in Table A10, Kadikoy consistently emerges as the optimal alternative in all calculations. The rankings of the other locations, in subsequent analyses, remain largely consistent with the original TOPSIS results. Notably, in the 10th, 11th, 20th, and 44th calculations, there are variations in the rankings of Beşiktaş and Şişli. Hence, the proposed methodology yields a robust decision for addressing the location selection problem.

4. Discussion and conclusion

This study contributes to addressing the asymmetry in access to information and services, particularly in the context of e-commerce delivery, which has been exacerbated by the Covid-19 pandemic. The unequal distribution of services and information has disproportionately affected individuals residing in crowded cities and metropolitan areas. As a consequence, cargo companies have faced challenges in maintaining quality delivery services in these densely populated regions, leading to increased costs. In light of these issues, this research focuses on the selection of suitable locations for PPPs as an eco-friendly solution to mitigate the existing asymmetry.

The primary objective of this article is to identify the most suitable districts within Istanbul, Turkey's largest city, for PPP installations. To account for the uncertainty inherent in linguistic evaluations of decision criteria, a novel fuzzy approach combining the SF-AHP and TOPSIS methodologies is employed. The SF-AHP method allows for the calculation of criterion weights, considering the ambiguity in the evaluations.

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Subsequently, the TOPSIS method, known for its practicality and robustness, is utilized to assess the performance of candidate districts based on the identified criteria.

The selection of evaluation criteria was informed by an extensive literature review and expert consultations. The SF-based AHP method was employed to derive criterion weights, providing decision makers with an easily understandable framework. Key criteria such as social economic status, average income per capita, e-commerce trends, the number of shopping centers, and the number of existing PPPs were found to be particularly significant. These weights were then integrated into the TOPSIS method, which facilitated the ranking of candidate districts.

By taking into account the prior studies in the field, particularly those related to the specific problem of selecting the optimal location for PPPs, this study bridges gaps in the existing literature. It offers a comprehensive overview tailored for area experts, using the example of Istanbul, Turkey's most populous and promising city in the field of e-commerce. The chosen criteria are specifically pertinent, aligning with both the applied methodologies and literature, as well as expert opinions. The proposed methodology, as evidenced by the comparative and sensitivity analysis results, consistently yields robust outcomes in addressing the specific problem at hand.

Moving forward, future research endeavors should contemplate customizing criteria to suit the distinctive characteristics of various entities, such as PPP producers and adopters, as well as cargo companies, separately. By customizing the criteria selection process, location decisions can be better aligned with individual company requirements. Additionally, it is worth noting that the literature on PPP location selection is currently limited, making this study a pioneering effort in the field. In Istanbul for example, the identification of Kadikoy, Umraniye, and Atasehir as potential preliminary locations for PPP installations contributes to practical decision-making of sector professionals.

This article aims to serve as a guiding framework for future investigations. Researchers can extend this study by applying diverse decision-making methods with distinct sets of criteria to various companies within the sector, addressing a primary limitation of the current study. Furthermore, further exploration and refinement of methods, as well as a deeper examination of the study's implications, are recommended for future research endeavors. By continuing to build upon these findings, researchers can contribute to the development of more comprehensive and effective location selection strategies for PPPs.

APPENDIX A

Table A1
Evaluation matrix of Expert 1 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.7	0.3	0.2	0.6	0.4	0.3	0.4	0.6	0.3	0.7	0.3	0.2	0.2	0.8	0.1
C2	0.3	0.7	0.2	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1
C3	0.4	0.6	0.3	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4	0.7	0.3	0.2	0.2	0.8	0.1
C4	0.6	0.4	0.3	0.8	0.2	0.1	0.5	0.4	0.4	0.5	0.4	0.4	0.7	0.3	0.2	0.5	0.4	0.4
C5	0.3	0.7	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.5	0.4	0.4	0.2	0.8	0.1
C6	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.8	0.2	0.1	0.5	0.4	0.4
C7	0.9	0.1	0	0.9	0.1	0	0.8	0.2	0.1	0.5	0.4	0.4	0.8	0.2	0.1	0.3	0.7	0.2
C8	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.7	0.3	0.2	0.3	0.7	0.2
C9	0.7	0.3	0.2	0.9	0.1	0	0.9	0.1	0	0.8	0.2	0.1	0.9	0.1	0	0.7	0.3	0.2
C10	0.8	0.2	0.1	0.7	0.3	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.7	0.3	0.2	0.4	0.6	0.3
C11	0.8	0.2	0.1	0.8	0.2	0.1	0.9	0.1	0	0.7	0.3	0.2	0.9	0.1	0	0.7	0.3	0.2
C12	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.8	0.2	0.1	0.9	0.1	0	0.8	0.2	0.1

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.1	0.9	0	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1	0.2	0.8	0.1	0.1	0.9	0
C2	0.1	0.9	0	0.3	0.7	0.2	0.1	0.9	0	0.3	0.7	0.2	0.2	0.8	0.1	0.1	0.9	0
C3	0.2	0.8	0.1	0.3	0.7	0.2	0.1	0.9	0	0.3	0.7	0.2	0.1	0.9	0	0.1	0.9	0
C4	0.5	0.4	0.4	0.5	0.4	0.4	0.2	0.8	0.1	0.7	0.3	0.2	0.3	0.7	0.2	0.2	0.8	0.1
C5	0.2	0.8	0.1	0.3	0.7	0.2	0.1	0.9	0	0.3	0.7	0.2	0.1	0.9	0	0.1	0.9	0
C6	0.7	0.3	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.6	0.4	0.3	0.3	0.7	0.2	0.2	0.8	0.1
C7	0.5	0.4	0.4	0.6	0.4	0.3	0.2	0.8	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1
C8	0.4	0.6	0.3	0.5	0.4	0.4	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1	0.1	0.9	0
C9	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4
C10	0.5	0.4	0.4	0.7	0.3	0.2	0.3	0.7	0.2	0.5	0.4	0.4	0.2	0.8	0.1	0.1	0.9	0
C11	0.7	0.3	0.2	0.8	0.2	0.1	0.5	0.4	0.4	0.8	0.2	0.1	0.5	0.4	0.4	0.1	0.9	0
C12	0.8	0.2	0.1	0.9	0.1	0	0.5	0.4	0.4	0.9	0.1	0	0.9	0.1	0	0.5	0.4	0.4

Table A2
Evaluation matrix of Expert 2 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1
C2	0.8	0.2	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2
C3	0.7	0.3	0.2	0.7	0.3	0.2	0.5	0.4	0.4	0.6	0.4	0.3	0.7	0.3	0.2	0.5	0.4	0.4
C4	0.8	0.2	0.1	0.8	0.2	0.1	0.4	0.6	0.3	0.5	0.4	0.4	0.4	0.6	0.3	0.3	0.7	0.2
C5	0.7	0.3	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.6	0.4	0.3	0.5	0.4	0.4	0.2	0.8	0.1
C6	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.7	0.3	0.2	0.8	0.2	0.1	0.5	0.4	0.4
C7	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.9	0.1	0
C8	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.3	0.7	0.2	0.3	0.7	0.2	0.8	0.2	0.1
C9	0.7	0.3	0.2	0.7	0.3	0.2	0.4	0.6	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.8	0.2	0.1
C10	0.6	0.4	0.3	0.6	0.4	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1	0.8	0.2	0.1
C11	0.6	0.4	0.3	0.6	0.4	0.3	0.3	0.7	0.2	0.4	0.6	0.3	0.3	0.7	0.2	0.8	0.2	0.1
C12	0.9	0.1	0	0.6	0.4	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3	0.8	0.2	0.1

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.4	0.6	0.3	0.4	0.6	0.3	0.1	0.9	0
C2	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3	0.4	0.6	0.3	0.4	0.6	0.3
C3	0.5	0.4	0.4	0.5	0.4	0.4	0.6	0.4	0.3	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2
C4	0.3	0.7	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.6	0.4	0.3	0.7	0.3	0.2
C5	0.3	0.7	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.8	0.2	0.1	0.7	0.3	0.2	0.6	0.4	0.3
C6	0.1	0.9	0	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C7	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.4	0.6	0.3	0.4	0.6	0.3
C8	0.8	0.2	0.1	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C9	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C10	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2
C11	0.6	0.4	0.3	0.8	0.2	0.1	0.8	0.2	0.1	0.3	0.7	0.2	0.5	0.4	0.4	0.7	0.3	0.2
C12	0.6	0.4	0.3	0.8	0.2	0.1	0.8	0.2	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.5	0.4	0.4

Table A3
Evaluation matrix of Expert 3 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1
C2	0.8	0.2	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2
C3	0.7	0.3	0.2	0.7	0.3	0.2	0.5	0.4	0.4	0.6	0.4	0.3	0.7	0.3	0.2	0.5	0.4	0.4
C4	0.8	0.2	0.1	0.8	0.2	0.1	0.4	0.6	0.3	0.5	0.4	0.4	0.4	0.6	0.3	0.3	0.7	0.2
C5	0.7	0.3	0.2	0.7	0.3	0.2	0.3	0.7	0.2	0.6	0.4	0.3	0.5	0.4	0.4	0.2	0.8	0.1
C6	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.7	0.3	0.2	0.8	0.2	0.1	0.5	0.4	0.4
C7	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.9	0.1	0
C8	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.3	0.7	0.2	0.3	0.7	0.2	0.8	0.2	0.1
C9	0.7	0.3	0.2	0.7	0.3	0.2	0.4	0.6	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.8	0.2	0.1
C10	0.6	0.4	0.3	0.6	0.4	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1	0.8	0.2	0.1
C11	0.6	0.4	0.3	0.6	0.4	0.3	0.3	0.7	0.2	0.4	0.6	0.3	0.3	0.7	0.2	0.8	0.2	0.1
C12	0.9	0.1	0	0.6	0.4	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3	0.8	0.2	0.1

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.2	0.8	0.1	0.2	0.8	0.1	0.8	0.2	0.1	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1
C2	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C3	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C4	0.2	0.8	0.1	0.8	0.2	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1
C5	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C6	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1
C7	0.5	0.4	0.4	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1
C8	0.2	0.8	0.1	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C9	0.2	0.8	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1
C10	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.8	0.2	0.1	0.8	0.2	0.1
C11	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.2	0.8	0.1	0.5	0.4	0.4	0.8	0.2	0.1
C12	0.2	0.8	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.5	0.4	0.4

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Table A4
Evaluation matrix of Expert 4 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.4	0.6	0.3	0.2	0.8	0.1	0.2	0.8	0.1	0.5	0.4	0.4	0.2	0.8	0.1
C2	0.6	0.4	0.3	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.5	0.4	0.4	0.2	0.8	0.1
C3	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4	0.8	0.2	0.1	0.4	0.6	0.3
C4	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.5	0.4	0.4	0.8	0.2	0.1	0.4	0.6	0.3
C5	0.5	0.4	0.4	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.5	0.4	0.4	0.5	0.4	0.4
C6	0.8	0.2	0.1	0.8	0.2	0.1	0.6	0.4	0.3	0.6	0.4	0.3	0.5	0.4	0.4	0.5	0.4	0.4
C7	0.9	0.1	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.9	0.1	0	0.9	0.1	0
C8	0.5	0.4	0.4	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.5	0.4	0.4	0.5	0.4	0.4
C9	0.5	0.4	0.4	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4
C10	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.6	0.3	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C11	0.5	0.4	0.4	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4
C12	0.5	0.4	0.4	0.5	0.4	0.4	0.7	0.3	0.2	0.8	0.2	0.1	0.5	0.4	0.4	0.5	0.4	0.4

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.1	0.9	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C2	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C3	0.5	0.4	0.4	0.7	0.3	0.2	0.3	0.7	0.2	0.6	0.4	0.3	0.3	0.7	0.2	0.3	0.7	0.2
C4	0.5	0.4	0.4	0.8	0.2	0.1	0.3	0.7	0.2	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1
C5	0.1	0.9	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C6	0.1	0.9	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C7	0.5	0.4	0.4	0.9	0.1	0	0.3	0.7	0.2	0.9	0.1	0	0.3	0.7	0.2	0.3	0.7	0.2
C8	0.1	0.9	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C9	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C10	0.1	0.9	0	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C11	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4
C12	0.7	0.3	0.2	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4

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Table A5
Evaluation matrix of Expert 5 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.5	0.4	0.4	0.4	0.6	0.3
C2	0.8	0.2	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1
C3	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.4	0.6	0.3	0.3	0.7	0.2	0.2	0.8	0.1
C4	0.7	0.3	0.2	0.8	0.2	0.1	0.6	0.4	0.3	0.5	0.4	0.4	0.4	0.6	0.3	0.2	0.8	0.1
C5	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.6	0.4	0.3	0.5	0.4	0.4	0.3	0.7	0.2
C6	0.6	0.4	0.3	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4
C7	0.6	0.4	0.3	0.5	0.4	0.4	0.7	0.3	0.2	0.7	0.3	0.2	0.8	0.2	0.1	0.7	0.3	0.2
C8	0.5	0.4	0.4	0.7	0.3	0.2	0.8	0.2	0.1	0.7	0.3	0.2	0.8	0.2	0.1	0.8	0.2	0.1
C9	0.6	0.4	0.3	0.6	0.4	0.3	0.6	0.4	0.3	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2
C10	0.7	0.3	0.2	0.6	0.4	0.3	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.8	0.2	0.1
C11	0.6	0.4	0.3	0.7	0.3	0.2	0.7	0.3	0.2	0.7	0.3	0.2	0.8	0.2	0.1	0.7	0.3	0.2
C12	0.7	0.3	0.2	0.7	0.3	0.2	0.6	0.4	0.3	0.8	0.2	0.1	0.8	0.2	0.1	0.7	0.3	0.2

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.4	0.6	0.3	0.5	0.4	0.4	0.4	0.6	0.3	0.3	0.7	0.2	0.4	0.6	0.3	0.3	0.7	0.2
C2	0.5	0.4	0.4	0.3	0.7	0.2	0.4	0.6	0.3	0.4	0.6	0.3	0.3	0.7	0.2	0.3	0.7	0.2
C3	0.3	0.7	0.2	0.2	0.8	0.1	0.4	0.6	0.3	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3
C4	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1
C5	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1	0.2	0.8	0.1
C6	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2
C7	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.2	0.8	0.1
C8	0.7	0.3	0.2	0.5	0.4	0.4	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1	0.3	0.7	0.2
C9	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.2	0.8	0.1	0.3	0.7	0.2	0.2	0.8	0.1
C10	0.7	0.3	0.2	0.7	0.3	0.2	0.8	0.2	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.2	0.8	0.1
C11	0.7	0.3	0.2	0.8	0.2	0.1	0.7	0.3	0.2	0.7	0.3	0.2	0.5	0.4	0.4	0.3	0.7	0.2
C12	0.8	0.2	0.1	0.7	0.3	0.2	0.8	0.2	0.1	0.8	0.2	0.1	0.7	0.3	0.2	0.5	0.4	0.4

Table A6
Evaluation matrix of Expert 6 in SF numbers

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.5	0.4	0.4	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.1	0.9	0
C2	0.5	0.4	0.4	0.5	0.4	0.4	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.1	0.9	0
C3	0.8	0.2	0.1	0.8	0.2	0.1	0.5	0.4	0.4	0.1	0.9	0	0.2	0.8	0.1	0.1	0.9	0
C4	0.8	0.2	0.1	0.8	0.2	0.1	0.9	0.1	0	0.5	0.4	0.4	0.9	0.1	0	0.9	0.1	0
C5	0.7	0.3	0.2	0.8	0.2	0.1	0.8	0.2	0.1	0.1	0.9	0	0.5	0.4	0.4	0.1	0.9	0
C6	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.1	0.9	0	0.9	0.1	0	0.5	0.4	0.4
C7	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.1	0.9	0	0.8	0.2	0.1	0.1	0.9	0
C8	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.1	0.9	0	0.8	0.2	0.1	0.1	0.9	0
C9	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.1	0.9	0	0.7	0.3	0.2	0.1	0.9	0
C10	0.8	0.2	0.1	0.7	0.3	0.2	0.7	0.3	0.2	0.1	0.9	0	0.7	0.3	0.2	0.1	0.9	0
C11	0.9	0.1	0	0.7	0.3	0.2	0.7	0.3	0.2	0.1	0.9	0	0.7	0.3	0.2	0.1	0.9	0
C12	0.8	0.2	0.1	0.6	0.4	0.3	0.7	0.3	0.2	0.1	0.9	0	0.7	0.3	0.2	0.1	0.9	0

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.1	0.9	0	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.8	0.1	0.1	0.9	0	0.2	0.8	0.1
C2	0.1	0.9	0	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3
C3	0.1	0.9	0	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2
C4	0.7	0.3	0.2	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0
C5	0.2	0.8	0.1	0.2	0.8	0.1	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2
C6	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0	0.9	0.1	0
C7	0.5	0.4	0.4	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1	0.8	0.2	0.1
C8	0.2	0.8	0.1	0.5	0.4	0.4	0.3	0.7	0.2	0.3	0.7	0.2	0.3	0.7	0.2	0.4	0.6	0.3
C9	0.2	0.8	0.1	0.7	0.3	0.2	0.5	0.4	0.4	0.4	0.6	0.3	0.4	0.6	0.3	0.4	0.6	0.3
C10	0.2	0.8	0.1	0.7	0.3	0.2	0.6	0.4	0.3	0.5	0.4	0.4	0.3	0.7	0.2	0.3	0.7	0.2
C11	0.2	0.8	0.1	0.7	0.3	0.2	0.6	0.4	0.3	0.7	0.3	0.2	0.5	0.4	0.4	0.7	0.3	0.2
C12	0.2	0.8	0.1	0.6	0.4	0.3	0.6	0.4	0.3	0.7	0.3	0.2	0.3	0.7	0.2	0.5	0.4	0.4

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Table A7
SWGMs of each criterion

	C1			C2			C3			C4			C5			C6		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.50	0.40	0.40	0.39	0.62	0.24	0.31	0.70	0.18	0.24	0.76	0.15	0.38	0.61	0.26	0.20	0.80	0.12
C2	0.53	0.48	0.27	0.50	0.40	0.40	0.26	0.74	0.17	0.20	0.80	0.10	0.29	0.71	0.20	0.19	0.81	0.10
C3	0.62	0.41	0.23	0.73	0.27	0.17	0.50	0.40	0.40	0.33	0.68	0.25	0.52	0.53	0.16	0.23	0.77	0.17
C4	0.75	0.26	0.17	0.80	0.20	0.10	0.59	0.40	0.30	0.50	0.40	0.40	0.63	0.41	0.22	0.36	0.65	0.21
C5	0.56	0.43	0.28	0.69	0.29	0.23	0.36	0.67	0.16	0.27	0.74	0.16	0.50	0.40	0.40	0.22	0.78	0.16
C6	0.78	0.24	0.16	0.80	0.21	0.12	0.72	0.28	0.23	0.49	0.55	0.21	0.74	0.25	0.21	0.50	0.40	0.40
C7	0.81	0.22	0.15	0.70	0.28	0.27	0.68	0.29	0.27	0.46	0.56	0.24	0.80	0.21	0.12	0.39	0.66	0.12
C8	0.67	0.30	0.27	0.69	0.29	0.23	0.49	0.54	0.21	0.25	0.76	0.14	0.61	0.40	0.22	0.35	0.67	0.17
C9	0.54	0.48	0.24	0.70	0.29	0.24	0.54	0.51	0.20	0.46	0.59	0.14	0.61	0.41	0.23	0.40	0.63	0.18
C10	0.69	0.30	0.24	0.64	0.34	0.28	0.57	0.46	0.22	0.37	0.65	0.20	0.55	0.47	0.22	0.37	0.66	0.19
C11	0.54	0.48	0.24	0.67	0.31	0.25	0.65	0.39	0.18	0.37	0.66	0.17	0.63	0.40	0.22	0.40	0.63	0.18
C12	0.60	0.45	0.20	0.67	0.32	0.27	0.63	0.41	0.20	0.38	0.66	0.11	0.66	0.35	0.25	0.41	0.63	0.17

	C7			C8			C9			C10			C11			C12		
	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π	μ	ν	π
C1	0.16	0.84	0.10	0.29	0.70	0.22	0.38	0.63	0.23	0.28	0.72	0.20	0.33	0.68	0.22	0.25	0.76	0.15
C2	0.23	0.77	0.19	0.29	0.71	0.20	0.25	0.75	0.19	0.34	0.66	0.25	0.30	0.70	0.22	0.28	0.72	0.22
C3	0.26	0.74	0.20	0.39	0.63	0.20	0.32	0.70	0.18	0.36	0.65	0.20	0.27	0.74	0.15	0.28	0.73	0.17
C4	0.38	0.61	0.26	0.63	0.40	0.22	0.36	0.66	0.16	0.49	0.54	0.22	0.48	0.56	0.20	0.40	0.64	0.12
C5	0.19	0.81	0.10	0.31	0.70	0.19	0.29	0.72	0.19	0.36	0.65	0.21	0.27	0.73	0.17	0.27	0.74	0.18
C6	0.34	0.71	0.11	0.46	0.57	0.19	0.43	0.59	0.21	0.45	0.58	0.21	0.43	0.59	0.21	0.40	0.62	0.19
C7	0.50	0.40	0.40	0.52	0.53	0.17	0.34	0.69	0.13	0.51	0.53	0.20	0.44	0.59	0.21	0.38	0.65	0.17
C8	0.31	0.71	0.14	0.50	0.40	0.40	0.25	0.75	0.17	0.29	0.71	0.20	0.25	0.75	0.17	0.25	0.75	0.19
C9	0.49	0.56	0.12	0.72	0.26	0.21	0.50	0.40	0.40	0.32	0.68	0.20	0.33	0.67	0.25	0.30	0.69	0.23
C10	0.32	0.70	0.16	0.69	0.29	0.23	0.60	0.42	0.24	0.50	0.40	0.40	0.41	0.60	0.22	0.34	0.68	0.18
C11	0.45	0.58	0.18	0.72	0.26	0.21	0.64	0.33	0.29	0.48	0.54	0.22	0.50	0.40	0.40	0.42	0.61	0.20
C12	0.47	0.57	0.16	0.70	0.29	0.24	0.65	0.32	0.28	0.50	0.53	0.21	0.42	0.60	0.22	0.50	0.40	0.40

Table A8
Normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Atasehir	0.418	0.473	0.334	0.413	0.492	0.398	0.418	0.386	0.457	0.128	0.559	0.298
Kadikoy	0.477	0.403	0.582	0.458	0.386	0.477	0.477	0.483	0.448	0.962	0.160	0.844
Umraniye	0.706	0.484	0.272	0.394	0.533	0.358	0.706	0.286	0.475	0.189	0.479	0.397
Besiktas	0.175	0.419	0.582	0.521	0.392	0.530	0.175	0.583	0.323	0.087	0.160	0.199
Sisli	0.264	0.452	0.371	0.439	0.413	0.453	0.264	0.442	0.511	0.124	0.638	0.050

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Table A9
Weighted matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Atasehir	0.0221	0.0251	0.0251	0.0405	0.0325	0.0406	0.0426	0.0297	0.0407	0.0117	0.0536	0.0289
Kadikoy	0.0253	0.0214	0.0436	0.0449	0.0255	0.0487	0.0486	0.0372	0.0399	0.0875	0.0153	0.0818
Umraniye	0.0374	0.0256	0.0204	0.0386	0.0352	0.0365	0.0720	0.0220	0.0423	0.0172	0.0460	0.0385
Besiktas	0.0093	0.0222	0.0436	0.0511	0.0259	0.0540	0.0178	0.0449	0.0287	0.0079	0.0153	0.0193
Sisli	0.0140	0.0239	0.0278	0.0430	0.0272	0.0462	0.0269	0.0340	0.0455	0.0113	0.0613	0.0048

Table A10
New C* values

	Atasehir	Kadikoy	Umraniye	Besiktas	Sisli
C*12	0.352752876	0.685007799	0.458965788	0.244915176	0.303748437
C*13	0.357627828	0.679826893	0.477977862	0.225491315	0.300583508
C*14	0.361343974	0.67830038	0.494237329	0.229045636	0.296572442
C*15	0.354063129	0.684383125	0.466815511	0.242668139	0.3021993
C*16	0.3624007	0.676711118	0.499356613	0.221651043	0.29381036
C*17	0.352751863	0.685014572	0.458963278	0.244915877	0.30374851
C*18	0.356720131	0.681646532	0.479599261	0.22467231	0.298028735
C*19	0.355815779	0.679428917	0.483221869	0.238156452	0.291648755
C*110	0.408594553	0.642460186	0.545543879	0.261452692	0.327314918
C*111	0.322294388	0.736122214	0.482682001	0.243035321	0.228433102
C*112	0.322294388	0.736122214	0.482682001	0.243035321	0.228433102
C*23	0.354730638	0.682346242	0.463289991	0.229612945	0.30382951
C*24	0.354711424	0.684219536	0.461447264	0.238854656	0.304119794
C*25	0.352418333	0.685828576	0.458496388	0.245069249	0.30399079
C*26	0.355054935	0.683221365	0.463225784	0.232326115	0.302130128
C*27	0.343759826	0.692711936	0.408256139	0.257929453	0.313267839
C*28	0.353477275	0.684487338	0.463426375	0.229219067	0.301572023
C*29	0.350441297	0.683950084	0.457335611	0.245888059	0.297243071
C*210	0.405548002	0.645987422	0.518295388	0.272941497	0.33630326
C*211	0.311440648	0.748086523	0.448448454	0.253575393	0.233270359
C*212	0.36177459	0.646027119	0.463482079	0.253644825	0.340045947
C*34	0.351150058	0.688233378	0.454481109	0.26074732	0.303850908
C*35	0.353913465	0.683145008	0.461281779	0.238126748	0.303585464
C*36	0.350893333	0.688316091	0.45447713	0.26076077	0.302611443
C*37	0.343908597	0.694275244	0.422282541	0.275649156	0.309364321
C*38	0.352611256	0.685242203	0.458933972	0.245032634	0.303530199
C*39	0.350134089	0.686674488	0.454802999	0.256587819	0.300818559
C*310	0.372916864	0.670776396	0.479398625	0.270585622	0.31794093

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C*311	0.328797946	0.71994478	0.447827951	0.267006307	0.26935309
C*312	0.354623928	0.668639964	0.455253732	0.268694017	0.322505296
C*45	0.355385716	0.681660289	0.462453038	0.239742504	0.303213493
C*46	0.352763904	0.684912638	0.459119013	0.244348375	0.303535615
C*47	0.351650065	0.685858283	0.454166179	0.246883826	0.304647494
C*48	0.352964042	0.685188664	0.455189901	0.258335707	0.306444797
C*49	0.353987427	0.685159919	0.46010961	0.243122846	0.305914389
C*410	0.343541427	0.692367958	0.448616051	0.238312263	0.297425361
C*411	0.354989933	0.681967867	0.459704773	0.244083004	0.307019994
C*412	0.352585224	0.685936268	0.45892195	0.24452339	0.30287396
C*56	0.35587654	0.680439664	0.464160674	0.23440298	0.301512636
C*57	0.347175798	0.687607809	0.422726174	0.254415624	0.310208317
C*58	0.353456616	0.683914993	0.46167263	0.237094959	0.30241065
C*59	0.351923707	0.682401388	0.458916646	0.245235621	0.298683295
C*510	0.38867691	0.65649148	0.499603503	0.263457497	0.325170053
C*511	0.324016875	0.726229635	0.452681908	0.250871016	0.253338078
C*512	0.360568312	0.653841414	0.463976847	0.250782668	0.329261103
C*67	0.352752876	0.685007799	0.458965788	0.244915176	0.303748437
C*68	0.353071009	0.684700326	0.455210651	0.258264629	0.30586078
C*69	0.354607699	0.68493714	0.461130653	0.240469672	0.306285784
C*610	0.338383641	0.696321	0.443145728	0.233025687	0.293258041
C*611	0.359510012	0.675770466	0.461440809	0.241531628	0.313228761
C*612	0.351926321	0.689539132	0.458932314	0.242243883	0.299109772
C*78	0.346654528	0.690127763	0.425261898	0.272254023	0.312254585
C*79	0.351150257	0.687919916	0.445322091	0.248437393	0.309800251
C*710	0.335265085	0.698939183	0.429881587	0.239372123	0.295920049
C*711	0.357978799	0.67703	0.45415678	0.245269196	0.31491083
C*712	0.350560819	0.690733376	0.452868436	0.245339408	0.300429291
C*89	0.35140488	0.684926726	0.455553926	0.254382042	0.302645313
C*810	0.371615043	0.670540114	0.477154731	0.266708244	0.317971561
C*811	0.332576995	0.713950958	0.449117384	0.264056949	0.275380354
C*812	0.35621362	0.667083026	0.455949548	0.265524035	0.323506538
C*910	0.355683591	0.682935063	0.46220105	0.246405279	0.306017866
C*911	0.346008218	0.695801964	0.457356909	0.246337773	0.294021904
C*912	0.3552132	0.677756692	0.460354893	0.246377789	0.312656086
C*1011	0.340662101	0.697828765	0.449753581	0.242153725	0.291074441
C*1012	0.345597098	0.686130213	0.450131877	0.241403476	0.303244793
C*1112	0.354042118	0.682557071	0.459379101	0.244889396	0.306262167

REFERENCES

Albayrak, E. (2019). *Atm yer seçiminde başlıca veri madenciliği teknikleri ile tahminleme,* MSc Thesis, Maltepe University.

Atasehir District Governor's Office (2022). Retrieved March 27, 2022, from http://www.atasehir.gov.tr/.

Behzadian, M., Otaghsara, S.K., Yazdani, M. & Ignatius, J. (2012). A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*, *39*(17), 13051-13069. Doi: http://dx.doi.org/10.1016/j.eswa.2012.05.056

Besiktas District Governor's Office (2022). Retrieved March 27, 2022, from http://www.besiktas.gov.tr/.

Dogan, O. (2021). Process mining technology selection with spherical fuzzy AHP and sensitivity analysis. *Expert Systems with Applications*, 178, 114999. Doi: http://dx.doi.org/10.1016/j.eswa.2021.114999

Editorial (2022). COVID-19 e-ticareti nasıl etkiledi?, Retrieved June 20, 2022, from https://retailturkiye.com/genel-haberler/covid-19-e-ticareti-nasil-etkiledi/.

Endeksa Homepage (2022). Retrieved March 27, 2022, from https://www.endeksa.com/tr/.

Goli, A., Olfat, L. & Foukordi, R. (2010). Location of banking automatic teller machines (atms) based on analytic hierarchy process method (AHP) (case study: Keshavarzi bank atms in Tehran municipality, district no.10), *Geography and Development*, *8*(18), 93-108.

González-Varona, J. M., Villafáñez, F., Acebes, F., Redondo, A., & Poza, D. (2020). Reusing newspaper kiosks for last-mile delivery in urban areas. *Sustainability*, *12*(22), 9770. Doi: http://dx.doi.org/10.3390/su12229770

Hwang C. L. & Yoon K. (1981). *Multiple attributes decision making methods and applications.* Springer Verlag.

Kadıköy District Governor's Office (2022). Retrieved on March 27, 2022, from http://www.kadikoy.gov.tr/.

Kilibarda, M., Andreji´ c, M., & Popovi´ c, V. (2020). Research in logistics service quality: A systematic literature review. *Transport*, *35*(2), 224–235.

Kutlu Gündoğdu, F. & Kahraman, C. (2019). Spherical fuzzy sets and spherical fuzzy TOPSIS method. *Journal of Intelligent and Fuzzy Systems*, *36*(1), 337–352. Doi: http://dx.doi.org/10.3233/jifs-181401

Kutlu Gündoğdu, F. & Kahraman, C. (2020). A novel spherical fuzzy analytic hierarchy process and its renewable energy application. *Soft Computing, 24*(6), 4607-4621. Doi: http://dx.doi.org/10.1007/s00500-019-04222-w

Lagorio, A., & Pinto, R. (2020, April). The parcel locker location issues: An overview of factors affecting their location. In *Proceedings of the 8th International Conference on Information Systems, Logistics and Supply Chain: Interconnected Supply Chains in an Era of Innovation, ILS* (pp. 414-421).

Liu, S., Liu, Y., Zhang, R., Cao, Y., Li, M., Zikirya, B. & Zhou, C. (2021). Heterogeneity of spatial distribution and factors influencing unattended lockerpoints in Guangzhou, China: The case of hive box. *ISPRS International Journal of Geo-Information, 10*(6), 409. Doi: http://dx.doi.org/10.3390/ijgi10060409

Mangiaracina, R., Perego, A., Seghezzi, A., & Tumino, A. (2019). Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review. *International Journal of Physical Distribution & Logistics Management, 49*(9), 901-920. Doi: http://dx.doi.org/10.1108/ijpdlm-02-2019-0048

Mathew, M., Chakrabortty, R.K. & Ryan, M. J. (2020). A novel approach integrating AHP and TOPSIS under spherical fuzzy sets for advanced manufacturing system selection. *Engineering Applications of Artificial Intelligence*, 96, 103988. Doi: http://dx.doi.org/10.1016/j.engappai.2020.103988

Min, H. & Melachrinoudis. E. (2002). The three-hierarchical location-allocation of banking facilities with risk and uncertainty. *International Transactions in Operational Research, 8*(4), 381-401. Doi: http://dx.doi.org/10.1111/1475-3995.00272

Moslem, S., & Pilla, F. (2023). A hybrid decision making support method for parcel lockers location selection. *Research in Transportation Economics*, 100, 101320. Doi: http://dx.doi.org/10.1016/j.retrec.2023.101320

Önüt, S., Efendigil, T., & Kara, S. S. (2010). A combined fuzzy MCDM approach for selecting shopping center site: An example from Istanbul, Turkey. *Expert Systems with Applications, 37*(3), 1973-1980. Doi: http://dx.doi.org/10.1016/j.eswa.2009.06.080

Papathanasiou, J. & Ploskas, N. (2018). Topsis. In *Multiple criteria decision aid* (pp. 1-30). Springer Cham. Doi: http://dx.doi.org/10.1007/978-3-319-91648-4_1

Parcelbox Homepage (2022). Retrieved on March 27, 2022, from https://www.datasys.cz/en/produkty/parcelboxes.

Parkhan, A., Vatimbing, A.D. & Widodo, I.D. (2018). Integration AHP and TOPSIS in shipyard location selection. In *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)* (pp. 11-16). IEEE. Doi: http://dx.doi.org/10.1109/iea.2018.8387064

Roig-Tierno, N., Baviera-Puig, A., Buitrago-Vera, J., & Mas-Verdu, F. (2013). The retail site location decision process using GIS and the analytical hierarchy process. *Applied Geography*, 40, 191-198. Doi: http://dx.doi.org/10.1016/j.apgeog.2013.03.005

Rovlocker (2022). Retrieved on June 20, 2022, from https://www.rovenma.com/smart-parcel-locker/.

Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology, 15*(3), 234-281. Doi: http://dx.doi.org/10.1016/0022-2496(77)90033-5

Sajid, M.J., Gonzalez, E.D.S., Zhan, J., Song, X., Sun, Y. & Xie, J. (2021). A methodologically sound survey of Chinese consumers' willingness to participate in courier, express, and parcel companies' green logistics. *PloS One*, *16*(7), e0255532. Doi: http://dx.doi.org/10.1371/journal.pone.0255532

Simić, V., Lazarević, D., & Dobrodolac, M. (2021). Picture fuzzy WASPAS method for selecting last-mile delivery mode: a case study of Belgrade. *European Transport Research Review*, 13, 1-22. Doi: http://dx.doi.org/10.1186/s12544-021-00501-6

Sipahi, S., & Timor, M. (2010). The analytic hierarchy process and analytic network process: an overview of applications. *Management Decision*, *48*(5), 775-808. Doi: http://dx.doi.org/10.1108/00251741011043920

Sisli District Governor's Office (2022). Retrieved on March 27, 2022, from http://www.sisli.gov.tr/.

Statista (2022). Retrieved on December 11, 2023, from https://www.statista.com/statistics/986945/percentage-e-commerce-orders-turkey-by-region/.

Syahputra, A., Puspita, K., Maulida, R., Elnovreny, J. & Fahrozi, W. (2020). Analytic Hierarchy Process (AHP) modelling for ATM machine placement. In *2020 8th International Conference on Cyber and IT Service Management (CITSM)* (pp. 1-4). IEEE. Doi: http://dx.doi.org/10.1109/citsm50537.2020.9268873

TUIK (2022). Data Portal for Statistics, Retrieved on March 27, 2022 from https://data.tuik.gov.tr/.

Umraniye District Governor's Office (2022). Retrieved on March 27, 2022 from http://www.umraniye.gov.tr/.

Yalcin Kavus, B., Ayyildiz, E., Gulum Tas, P., & Taskin, A. (2023). A hybrid Bayesian BWM and Pythagorean fuzzy WASPAS-based decision-making framework for parcel locker location selection problem. *Environmental Science and Pollution Research*, *30*(39), 90006-90023. Doi: http://dx.doi.org/10.1007/s11356-022-23965-y

Yildiz, A., Ayyildiz, E., Taskin Gumus, A., & Ozkan, C. (2020). A modified balanced scorecard based hybrid pythagorean fuzzy AHP-topsis methodology for ATM site selection problem. *International Journal of Information Technology & Decision Making, 19*(02), 365-384. Doi: http://dx.doi.org/10.1142/s0219622020500017

Yıldıztekin, A. (December 2021). Covid-19 döneminde lojistik hizmetler ve son teslimatlar, *Loder Bulletin.*

Yoon, K. P. & Hwang, C.L. (1995). *Multiple attribute decision making: an introduction*. Sage Publications.

Zeydan, M. & Kayserili, S. (2019). A rule-based decision support approach for site selection of Automated Teller Machines (ATMs). *Intelligent Decision Technologies, 13*(2), 161-175. Doi: http://dx.doi.org/10.3233/idt-180084

Zheng, Z., Morimoto, T. & Murayama, Y. (2020). Optimal location analysis of delivery parcel-pickup points using AHP and Network Huff Model: A case study of Shiweitang Sub-District in Guangzhou City, China. *ISPRS International Journal of Geo-Information, 9*(4), 193. Doi: http://dx.doi.org/10.3390/ijgi9040193

Zheng, Z., Morimoto, T. & Murayama, Y. (2021). A GIS-based bivariate logistic regression model for the site-suitability analysis of parcel-pickup lockers: A case study of Guangzhou, China. *ISPRS International Journal of Geo-Information, 10*(10), 648. Doi: http://dx.doi.org/10.3390/ijgi10100648