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Evaluating urban square management success: A model for urban public spaces in Istanbul

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ABSTRACT

Urban public spaces, particularly city squares, play a critical role in fostering community interaction, enhancing socio-cultural well-being, and contributing to the overall cultural value of a city. Effective planning and management of these squares are essential to ensure accessibility, functionality, and inclusivity, thereby enabling them to serve as dynamic centers for social engagement and urban life. Prior research has often neglected the public's perspective in square planning and management. Thus, this study aims to develop an Urban Square Management (USM) success score model to assess the effectiveness of urban squares planning from the public's perspective. Initially, expert evaluations of relevant criteria were conducted using the Interval Type-2 Fuzzy Analytical Hierarchy Process (IT2F-AHP), chosen to address the uncertainties and subjective judgments inherent in expert assessments. The resulting weighted criteria formed the basis for a user questionnaire. A total of 157 questionnaires were collected from visitors at Uskudar Square in Istanbul, a recently redesigned public space. The data underwent Exploratory Factor Analysis to identify key factors and refine the model's structure. Applying the developed USM model to Uskudar Square resulted in a success score of 70.2, providing an overall evaluation of the square's management performance. Crucially, the model allows for a detailed analysis of the constituent subdimensions contributing to the total score, such as accessibility, safety, maintenance, amenities, social activity, and environmental quality. This granular perspective enables urban planners and managers to identify specific areas requiring improvement and implement targeted interventions to enhance the overall quality, usability, and public satisfaction with urban squares.

1. Introduction

Public spaces are communal areas accessible to individuals and various social groups. These spaces serve as venues for the exchange of ideas and information, playing a crucial role in the formation and strengthening of social networks. Urban squares, as a specific type of public space, have long played a central role in facilitating social interactions and shaping urban identity (Heng and Chan, 2000). Throughout urban history, squares have evolved as integral components of city development, serving as vital hubs for social, economic, and political life. A brief examination of urban squares across different historical periods reveals that these spaces have played a significant role in shaping the identity of their inhabitants (Çengel and Singery, 2024). Urban squares contribute to this identity by fostering values and qualities such as a sense of security, comfort, balance, order, enclosure, and remembrance, among various other factors (Mele et al., 2025).

Local governments are responsible for providing essential services to their citizens based on their needs and expectations. City squares serve as critical interfaces for citizen-local government interaction. As such, the management of urban squares requires careful planning, adopting a straightforward and practical approach. Municipalities, therefore, must develop comprehensive Urban Square Management (USM) strategies, delineating the key dimensions that contribute to their efficacy (Montgomery, 1998).

In Turkiye, the authority for protecting the historical texture and artifacts of the cities rests with the municipalities and provincial administrations (Özeren, Qurraie, & Eraslan, 2024). These administrations have responsibilities to work on tourism, culture, art, and natural assets, especially meeting the everyday needs of citizens living within their jurisdiction (Sezik, 2016). In this respect, the Istanbul Metropolitan Municipality (IMM) Urban Design Directorate planned to establish a management system for the squares in Istanbul. This proposed system aims to enhance the efficiency of square utilization, enrich the quality of social

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interaction within these spaces, and promote the implementation of sustainable design principles. From a managerial perspective, the success of a square is contingent upon its ability to fulfill pre-defined objectives, as evaluated against specific performance criteria (Istanbul Metropolitan Municipality, 2016).

Uskudar Square, a prominent urban space in Istanbul, holds significant historical and contemporary importance. Dating back to the 5th century BC, Uskudar is recognized as a key tourist destination, celebrated for its historical landmarks and natural attractions. Its central location within Istanbul's transportation network, served by various modes, including ferries, the Marmaray commuter rail line, metro lines, and public buses, further underscores its significance. In response to the district's growing importance, a major expansion project for Uskudar Square commenced in 2014.

This study proposes a USM success score model to evaluate the new Uskudar Square, completed in 2018, considering the need mentioned earlier. In the first stage of the study, USM success criteria were obtained after a comprehensive literature review and face-to-face interviews with experts. In the second stage, expert opinions about the relevance of each criterion were taken. Undoubtedly, this process requires subjective evaluation of the data collected under various uncertainties by the experts (Kuşakcı, Ayvaz, Öztürk & Sofu, 2019; Temur, Kaya & Kahraman, 2014; Zadeh, 1965). Fuzzy logic provides a suitable framework when uncertainties exist or subjective decisions must be made with imprecise information. Therefore, the evaluation of expert opinions was carried out with the Interval Type-2 Fuzzy AHP (IT2F-AHP) method in this study (Yilmaz, Kusakci, Tatoglu, Icten & Yetgin, 2019). In the third stage of the study, a survey was conducted with the citizens using the square to evaluate the management of Uskudar Square according to the proposed evaluation model. Then, the obtained data were analyzed. Finally, the USM Success Score for Uskudar Square was calculated according to the revised evaluation criteria. In addition, the study provides suggestions for improvement regarding the management of urban squares.

The current body of research on urban square management presents certain limitations. First, existing studies often focus on individual criteria, such as accessibility or aesthetic appeal, without providing a holistic framework (Zawidzki, 2016; Zamri & Abdullah, 2015). This weakens an understanding of what truly should be an effective urban square management (Melone et al., 2024). Second, the emphasis on expert evaluations in previous studies has often overlook the critical role of public perception (Erdoğan & Kaya, 2016a). In addition, subjective biases within expert assessments and the resulting uncertainties in criteria weighting consistently undermine the reliability of evaluations (Dorfeshan et al., 2018). To address these issues, this research employs the IT2F-AHP. This methodological choice allows a more robust and reliable weighting of success criteria.

The structure of this study proceeds as follows. The next section establish the theoretical foundation of the study through a review of the relevant literature. Section 3 describes the methodological framework of the study and sources of the dataset employed in the analysis. Next, Section 4 presents the obtained result for this study. Finally, Section 5 opens a discussion by concluding the study key findings and outlining implications for future research.

2. Literature review

Urban public spaces play a vital role in shaping urban environments, serving as crucial venues for social interaction, cultural expression, economic activity, and recreation. These spaces, including parks, plazas, squares, and streets, contribute to the character and identity of a city (Ali and Qurraie, 2023). Effective management of these spaces directly influences quality of life by fostering community cohesion, promoting physical and mental well-being, and providing access to essential amenities (Amiraslani, 2021). When implemented successfully, such management yields both direct benefits, such as improved infrastructure and enhanced safety, and indirect benefits, such as increased property values and a stronger sense of place (Abou El Ezz, Eid, Khalifa & Hamhaber, 2017). The most important functions of modern squares are to provide citizens with the opportunity to spend time together, meet their needs, and reflect the culture of that region (Önder, 2002).

Primarily, squares host recreational activities and provide opportunities for these activities. However, the traditional concept of a square has evolved to encompass a broader range of functions. Contemporary squares often function as multifunctional spaces, accommodating shopping, entertainment, social interaction, rest, and transportation (Gezer and Qurraie, 2021). Consequently, these spaces are designed as open, communal areas that facilitate a diverse array of activities (Özalp, 2008). Different researchers have determined different criteria to evaluate urban spaces. One of the first studies in this field was conducted by Montgomery (1998). The study proposed the following success criteria for urban spaces: complexity, diverse movement patterns, a mix of primary uses, a robust economy, vibrant street life, varied operating hours, accessible transportation options, legibility, imageability, and cognitive mapping (Montgomery, 1998).

Carmona, De Magalhães & Hammond (2008) discussed the square management models with three basic approaches: the state-oriented model, the market-oriented model (market-centered), and the community-centered model. In addition, the authors handled the level of coordination, regulation, maintenance, and investment (Istanbul Metropolitan Municipality, 2016).

Eruran (2011) defined squares as the lifeblood of cities and described them as the center of social and cultural life. The fact that the square is an area where the needs of the citizens are met in a short time has been stated as a prominent functional feature (Eruran, 2011).

In another study, squares and their surroundings were examined in terms of spatial quality parameters, starting from the historical change process. These quality parameters are attainability, accessibility, variation, flexibility, security, spatial integrity, comfort, and sustainability (Çınar Altınçekiç, Ergin & Tanfer, 2015). Likewise, some of the elements that successful urban spaces should have are given as: image and identity, attractions and destinations, amenities, flexible design, seasonal strategy, access, the inner square and the outer square, reaching out like an octopus, the central role of management, diverse funding sources (PPS, 2015).

While existing literature addresses the functions of public squares within social and economic life, comprehensive research on square management based on these functional determinations remains limited. The Istanbul Metropolitan Municipality's (IMM) Square Management System (SMS) project represents a notable exception. This project analyzed twelve squares, considering the following dimensions: Transportation, Safety, Conformity, Maintenance, Environment, Functionality, Socialization, and Aesthetics (Istanbul Metropolitan Municipality, 2016).

In general, the inferences about the functions of the squares from the literature review and the project carried out by IMM formed the basis of our work. Accordingly, the proposed USM Success Score model was designed to cover the expectations of all stakeholders in eight subdimensions: Transportation, Safety, Conformity, Maintenance, Environment, Functionality, Socialization, and Aesthetics, for which the views of the end-users are collected, and improvement suggestions are given

3. Methodology

The research adopts a mixed-method approach, combining qualitative and quantitative methodologies to develop and validate the Urban Square Management (USM) success score model from the public's perspective. The qualitative phase begins with expert input to identify and prioritize the criteria essential for effective urban square management. In the quantitative phase, these expert-defined criteria are translated into a structured questionnaire administered to 157 visitors of Üsküdar Square, a recently redesigned urban space in Istanbul. This phase captures the citizens' perspectives and experiences, providing empirical data on the performance of the square across the predefined dimensions. The model is grounded in the Resource-Based View (RBV) theory (Barney, 1991). RBV, a strategic management theory, posits that sustainable success is achieved when organizations effectively utilize valuable, rare, inimitable, and non-substitutable resources. In the context of USM, the study conceptualizes public space attributes—such as accessibility, safety, amenities, and environmental quality—as strategic urban resources that contribute to the socio-cultural value and performance of a city.

In this study, a two-stage methodology is proposed. The criteria to be evaluated for the USM success score were determined in the first stage. In this context, a literature review was conducted to determine what squares mean for local governments. Next, eight managers from the Istanbul Metropolitan Municipality were interviewed, comprising both mid-level and upper-level personnel. These individuals were selected based on their significant expertise and direct involvement in transportation and urban space management in the local government. Experts evaluated the criteria extracted from the literature for ideal urban square management. The IT2FAHP method was used to determine which criteria were more important and prioritized, and criteria weights were determined. The motivation behind using IT2FAHP method is that the decision-makers can include both objective and subjective views in the decision process while evaluating the model criteria (Kuruüzüm, 2001). The final outcome of the first stage is importance scores of the selected criteria for urban square management.

In the IT2F-AHP approach, where the same steps are followed as the deterministic AHP, the computing stages are defined under the Type-2 Fuzzy environment. The details of the calculations will not be given here in order not to expand this study. For the interested readers, two studies by Görener et al. (2017) and Yilmaz et al. (2019) can be referred to..

The second stage of the proposed methodology consists of a survey . To this end, a field study was conducted to evaluate by the citizens who benefit from the square and related facilities. A face-to-face survey method was preferred, and the data obtained from the survey was analyzed using the SPSS program. The data obtained were evaluated with exploratory factor analysis to justify the survey items and underlying constructs. In light of the analysis, the USM Success Score has been revealed. The proposed methodology is an original model because it allows for subjective evaluation of the criteria and focuses on public's opinion who uses the city square. The most important output of the model, USM Success Score, reveals the good and open-to-development aspects of the city square. In this respect, it will guide administrative bodies on urban management processes. The general steps of the methodology followed in the study are given in Fig. 1.

3.1. Interval type-2 fuzzy sets

IT2F sets are presented as an extension of type-1 fuzzy sets to cope with the high degree of uncertainty associated with vague verbal expressions of subjective judgments (Saima et al., 2011). The concept has been employed in various fields comprising a considerably high degree of subjectivity (Erdoğan and Kaya, 2016b; Görener, Ayvaz, Kuşakcı, and Altınok, 2017; Mohagheghi, Mousavi, Vahdani, and Shahriari, 2017; Dorfeshan, Mousavi, Mohagheghi, and Vahdani, 2018; Dorfeshan and Mousavi, 2019). In this section, some basic definitions of IT2F sets are presented (Chen and Lee, 2010) as follows:

Definition 1. A type 2 fuzzy set, $\tilde{\tilde{A}}$, is given by a type-2 membership function, $\mu_{\tilde{\tilde{A}}}$, and defined in the universe of discourse X as:

$$\tilde{\tilde{A}} = \left\{ \left((x,u), \mu_{\tilde{\tilde{A}}}(x,u)\right) | \forall x \in X, \forall u \in J_x \subseteq [0,1], 0 \le \mu_{\tilde{\tilde{A}}}(x,u) \le 1 \right\}$$

Alternatively, $\tilde{\tilde{A}}$ can be denoted as:

$$\tilde{\tilde{A}} = \int_{x\in X} \int_{u\in J_x} \mu_{\tilde{\tilde{A}}}(x,u)/(x,u)$$

$J_x \subseteq [0,1]$ and $\iint$ is union over all admissible x and u.

Definition 2. For any $\tilde{\tilde{A}}$, if all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$, then $\tilde{\tilde{A}}$ is called an IT2F set. An IT2F set can be regarded as a special type-2-fuzzy set, where

$$\tilde{\tilde{A}} = \int_{x\in X} \int_{u\in J_x} 1/(x,u), J_x \subseteq [0,1]$$

Definition 3. The upper and lower membership functions of an IT2F set are type-1 membership functions. As seen in Fig. 2, a trapezoidal IT2F set, $\tilde{\tilde{A}}_i$, is denoted as;

$$\tilde{\tilde{A}}_i = \left(\tilde{A}_i^U, \tilde{A}_i^L\right) = \left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(\tilde{A}_i^U\right), H_2\left(\tilde{A}_i^U\right)\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(\tilde{A}_i^L\right), H_2\left(\tilde{A}_i^L\right)\right),$$

where $H_j(\tilde{A}_i^U)$ denotes the membership value of the element $a_{i(j+1)}^U$ in the upper trapezoidal membership function, $\tilde{A}_i^U, 1 \le j \le 2$, whereas $H_j(\tilde{A}_i^L)$ denotes the membership value of the element $a_{i(j+1)}^L$ in the lower trapezoidal membership function $\tilde{A}_i^L, 1 \le j \le 2$, $H_1(\tilde{A}_i^U) \in [0,1]$, $H_2(\tilde{A}_i^U) \in [0,1]$, $H_1(\tilde{A}_i^L) \in [0,1]$, $H_2(\tilde{A}_i^L) \in [0,1]$ and $1 \le i \le n$.

Definition 4. Given $\tilde{\tilde{A}}_1$ and $\tilde{\tilde{A}}_2$ as $\tilde{\tilde{A}}_1 = (\tilde{A}_1^U, \tilde{A}_1^L) = (a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U))$, $(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L))$, and $\tilde{\tilde{A}}_2 = (\tilde{A}_2^U, \tilde{A}_2^L) = (a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U))$, $(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L))$:

The addition operation between two trapezoidal IT2F sets is defined as follows:

$$\tilde{\tilde{A}}_1 \oplus \tilde{\tilde{A}}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \oplus \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = [a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)], [a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)] \tag{1}$$

Definition 5. Similarly, the subtraction operation with IT2F sets is defined as follows:

$$\tilde{\tilde{A}}_1 \ominus \tilde{\tilde{A}}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \ominus \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = [a_{11}^U - a_{21}^U, a_{12}^U - a_{22}^U, a_{13}^U - a_{23}^U, a_{14}^U - a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)], [a_{11}^L - a_{21}^L, a_{12}^L - a_{22}^L, a_{13}^L - a_{23}^L, a_{14}^L - a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)] \tag{2}$$

Definition 6. The multiplication operation can be formulated as follows:

$$\tilde{\tilde{A}}_1 \otimes \tilde{\tilde{A}}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \otimes \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = [a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U \times a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)], [a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)] \tag{3}$$

Definition 7. Similarly, the division operation with two trapezoidal IT2F sets is defined as follows:

$$\frac{\tilde{\tilde{A}}_1}{\tilde{\tilde{A}}_2} =! \left[\frac{a_{11}^U}{a_{24}^U}, \frac{a_{12}^U}{a_{23}^U}, \frac{a_{13}^U}{a_{22}^U}, \frac{a_{14}^U}{a_{21}^U}; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)\right], \left[\frac{a_{11}^L}{a_{24}^L}, \frac{a_{12}^L}{a_{23}^L}, \frac{a_{13}^L}{a_{22}^L}, \frac{a_{14}^L}{a_{21}^L}; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right] \tag{4}$$

Definition 8. The arithmetic operations between a scalar, k, and a trapezoidal IT2F set, $\tilde{\tilde{A}}_1$, is given as:

$$k\tilde{\tilde{A}}_1 = \left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left[k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right]$$
$$\frac{\tilde{\tilde{A}}_1}{k} = \left(a_{11}^U/k, a_{12}^U/k, a_{13}^U/k, a_{14}^U/k; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L/k, a_{12}^L/k, a_{13}^L/k, a_{14}^L/k; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right) \tag{5}$$

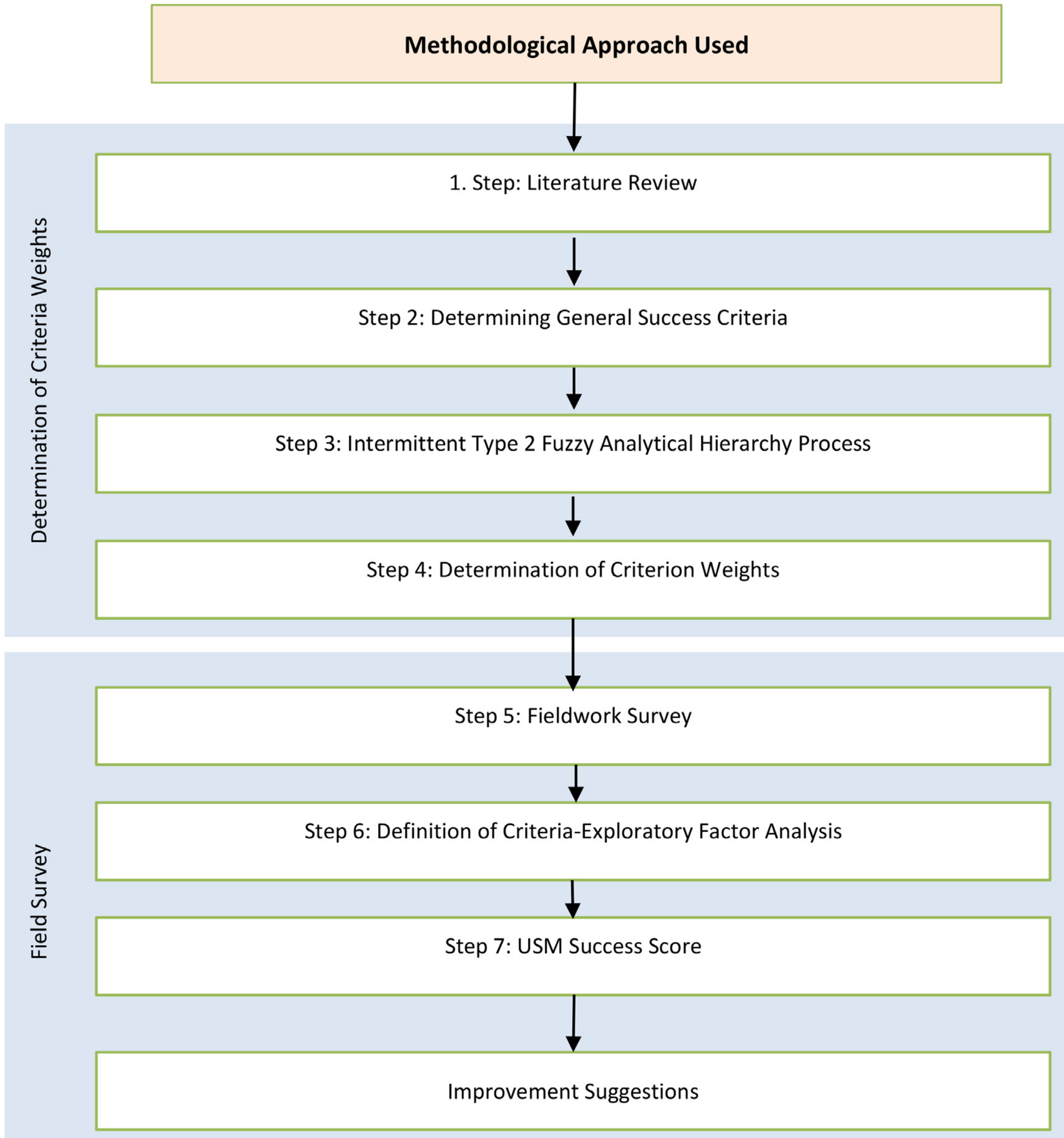

Fig. 1. Research framework.

Definition 9. The ranking value, Rank $(\tilde{\tilde{A}}_i)$, of $\tilde{\tilde{A}}_i$ is given as follows (Celik et al., 2013):

$$Rank\left(\tilde{\tilde{A}}_i\right) = M_1\left(\tilde{A}_i^U\right) + M_1\left(\tilde{A}_i^L\right) + M_2\left(\tilde{A}_i^U\right) + M_2\left(\tilde{A}_i^L\right) + M_3\left(\tilde{A}_i^U\right) + M_3\left(\tilde{A}_i^L\right) - \frac{1}{4}\left(S_1\left(\tilde{A}_i^U\right) + S_1\left(\tilde{A}_i^L\right) + S_2\left(\tilde{A}_i^U\right) + S_2\left(\tilde{A}_i^L\right) + S_3\left(\tilde{A}_i^U\right) + S_3\left(\tilde{A}_i^L\right) + S_4\left(\tilde{A}_i^U\right) + S_4\left(\tilde{A}_i^L\right)\right) + H_1\left(\tilde{A}_i^U\right) + H_1\left(\tilde{A}_i^L\right) + H_2\left(\tilde{A}_i^U\right) + H_2\left(\tilde{A}_i^L\right), \tag{6}$$

where $M_p(\tilde{A}_i^j)$ is the average and is defined as $M_p(\tilde{A}_i^j) = \frac{(a_{ip}^j + a_{i(p+1)}^j)}{2}$, $1 \le p \le 3$, whereas the standard deviation of the elements a_{ip}^j and $a_{i(p+1)}^j$, $S_p(\tilde{A}_i^j) = \sqrt{\frac{1}{2}\sum_{k=q}^{q+1}(a_{ik}^j - \frac{1}{2}\sum_{k=q}^{q+1} a_{ik}^j)^2}$, $1 \le q \le 3$, denotes the standard deviation of the elements $a_{i1}^j, a_{i2}^j, a_{i3}^j, a_{i4}^j$, $S_4(\tilde{A}_i^j) = \sqrt{\frac{1}{4}\sum_{k=1}^{4}(a_{ik}^j - \frac{1}{4}\sum_{k=1}^{4} a_{ik}^j)^2}$ $H_p(\tilde{A}_i^j)$, which signifies the membership value of the element $a_{i(p+1)}^j$ in the trapezoidal membership function $\tilde{A}_i^j$, $1 \le p \le 3$, $j \in \{U, L\}$, and $1 \le i \le n$.

Definition 10. The reciprocal of $\tilde{\tilde{A}}$ is calculated as:

$$1/\tilde{\tilde{A}} = \begin{bmatrix} \left(\frac{1}{a_4^U}, \frac{1}{a_3^U}, \frac{1}{a_2^U}, \frac{1}{a_1^U}; \quad H_1^U(\mathrm{A}), H_2^U(\mathrm{A}) \right) \\ \left(\frac{1}{a_4^L}, \frac{1}{a_3^L}, \frac{1}{a_2^L}, \frac{1}{a_1^L}; \quad H_1^L(\mathrm{A}), H_2^L(\mathrm{A}) \right) \end{bmatrix} \tag{7}$$

Definition 11. For any $\tilde{\tilde{A}}$, $\sqrt[m]{\tilde{\tilde{A}}}$ is defined as:

$$\sqrt[m]{\tilde{\tilde{A}}} = \begin{pmatrix} \left(\sqrt[m]{a_1^U}, \sqrt[m]{a_2^U}, \sqrt[m]{a_3^U}, \sqrt[m]{a_4^U}; H_1^U(\mathrm{A}), H_2^U(\mathrm{A}) \right), \\ \left(\sqrt[m]{a_1^L}, \sqrt[m]{a_2^L}, \sqrt[m]{a_3^L}, \sqrt[m]{a_4^L}; H_1^L(\mathrm{A}), H_2^L(\mathrm{A}) \right) \end{pmatrix}. \tag{8}$$

3.2. Interval type-2 fuzzy AHP

AHP has been a standard tool for multi-criteria decision-making (MCDM). Deterministic forms of AHP are criticized due to their inability to deal with the inherent subjectivity that MCDM problems involve (Kilic and Kaya, 2015). IT2F-AHP is a novel systematical MCDM method applied in various decision-making cases requiring intensive personal

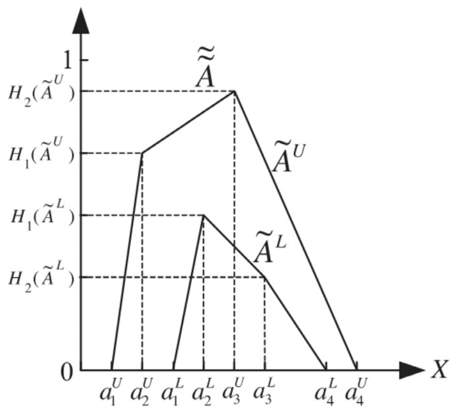

Fig. 2. The upper and lower trapezoidal membership functions, $\tilde{A}_i^U$ and $\tilde{A}_i^L$, of the interval type-2 fuzzy set $\tilde{\tilde{A}}_i$.

judgments under fuzziness. A recent IT2F-AHP model was presented by Kahraman et al. (2012, 2014), which provides a basis for our study as well.

Given n criteria subjectively evaluated by m decision makers, the main steps of IT2F-AHP are described below:

Step 1. Define the problem and construct a problem hierarchy.

Step 2. Construct m fuzzy pairwise comparison matrices, $\tilde{\tilde{A}}^k$, where $k = 1, \ldots, m$. $\tilde{\tilde{A}}^k$ is constructed by one decision maker as a matrix of nxn trapezoidal IT2F sets.

$$\tilde{\tilde{A}}^k = \begin{bmatrix} 1 & \tilde{\tilde{a}}_{12}^k & \ldots & \tilde{\tilde{a}}_{1n}^k \\ \tilde{\tilde{a}}_{21}^k & 1 & \ldots & \tilde{\tilde{a}}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{a}}_{n1}^k & \tilde{\tilde{a}}_{n2}^k & \ldots & 1 \end{bmatrix} \tag{9}$$

where $\tilde{\tilde{a}}_{ji}$ is reciprocal of $\tilde{\tilde{a}}_{ij}$. Namely, $\tilde{\tilde{a}}_{ji} = 1/\tilde{\tilde{a}}_{ij}$ which is calculated with Eq. (7). Additionally, $i = 1, \ldots, n$ and $j = 1, \ldots, n$. Here, $\tilde{\tilde{a}}_{ij}^k$ represents the IT2F pairwise comparison between criteria i and j made by k^{th} decision maker.

Step 3. Examine the consistency of the fuzzy pairwise comparison matrices. In this step, the fuzzy reciprocal matrices are defuzzified and checked for consistency by Kahraman et al. (2014). Given an IT2F set with the following notation as before:

$$\tilde{\tilde{A}} = \left(\tilde{A}^U, \tilde{A}^L\right) = \left(a_1^U, a_2^U, a_3^U, a_4^U; H_1\left(\tilde{A}^U\right),\ H_2\left(\tilde{A}^U\right)\right),$$
$$\left(a_1^L, a_2^L, a_3^L, a_4^L; H_1\left(\tilde{A}^L\right),\ H_2\left(\tilde{A}^L\right)\right).$$

Defuzzification with Trapezoidal Type-2-Fuzzy Set (DTraT) approach is performed using Eq. (10) (Kahraman et al., 2014);

$$DTraT_{\tilde{\tilde{A}}} = \tfrac{1}{2}\left\{ \left[\left(a_4^U - a_1^U\right) + \left(H_1\left(\tilde{A}^U\right)a_2^U - a_1^U\right) + \left(H_2\left(\tilde{A}^U\right)a_3^U - a_1^U\right)\right]/4 + a_1^U + \left[\left(a_4^L - a_1^L\right) + \left(H_1\left(\tilde{A}^L\right)a_2^L - a_1^L\right) + \left(H_2\left(\tilde{A}^L\right)a_3^L - a_1^L\right)\right]/4 + a_1^L \right\} \tag{10}$$

After obtaining the crisp reciprocal matrix, A^k, the consistency index, CI^k, for k^{th} decision maker is calculated and compared with the random consistency index, RI Saaty (1987).

Step 4. Aggregate the pairwise comparisons of m decision makers, $\tilde{\tilde{r}}_{ij}$, by using the geometric mean approach.

$$\tilde{\tilde{r}}_{ij} = \left[\tilde{\tilde{a}}_{ij}^1 \ldots \otimes \tilde{\tilde{a}}_{ij}^k \otimes \ \ldots\ \otimes \tilde{\tilde{a}}_{ij}^m\right]^{1/m} \tag{11}$$

Where Eq. (3) and Eq. (8) are employed. Here, $\tilde{\tilde{r}}_{ij}$ is a matrix composed of nxn IT2F sets.

Step 5. Estimate the fuzzy weights for each criterion. To do this, the geometric mean of each row, $\tilde{\tilde{r}}_i$, is calculated using Eq. (11). Subsequently, the fuzzy priorities are computed by normalization of each row. Accordingly, the fuzzy weight of the i^{th} criterion, $\tilde{\tilde{w}}_i$, is calculated as follows:

$$\tilde{\tilde{w}}_i = \tilde{\tilde{r}}_i \otimes \left[\tilde{\tilde{r}}_1 \oplus \ldots \oplus \tilde{\tilde{r}}_i \oplus \ldots \oplus \tilde{\tilde{r}}_n\right]^{-1} \tag{12}$$

where Eq. (1) and Eq. (4) are used for summation and division operations, respectively.

Step 6. Calculate the ranking value, $Rank(\tilde{\tilde{w}}_i)$, of the T2F weights using Eq. (6). Thereafter, obtain ranking scores, R_i, of the alternatives:

$$R_i = \text{Rank}\left(\tilde{\tilde{w}}_i\right) \tag{13}$$

Verbal expressions and Trapezoidal IT2F numbers used in pairwise evaluations within the scope of the study are presented in Table 1.

3.3. Uskudar urban square

Uskudar, with its roots tracing back to the 5th century BC, stands as a prominent tourist destination in Istanbul, renowned for its historical artifacts and natural beauty. Strategically positioned within a bustling transportation hub, Uskudar offers convenient access via various modes of transport, including ferries, railroads, and metro. Fig. 3 shows the historical and cultural places in Uskudar Square and its surroundings, which confirms Square's significance. Fig. 4 also shows the state of Uskudar Square before the project.

In recent years, the significance of public squares has grown, leading to various development projects for Uskudar Square. Among these initiatives, the most prominent is the project aimed at expanding the square through the addition of a new land reclamation area into the sea of Marmara, which commenced in 2014. Figs. 5 and 6 illustrate the state of Uskudar Square after the land reclamation area was built.

The square area created in the project extends from the Yeni Valide Sultan Mosque to the existing coastline, covering approximately 15,000 square meters. However, due to the inclusion of Marmaray Station structures and roadways, the use of simple open space is fragmented into 1,000–2,000 m² sections. With the addition of a new area to be reclaimed from the sea, the square area between the sea and the roadway measures 10,000 square meters (Üsküdar Square Urban Design, 2015). The project was completed in 2018, and since then, it has contributed significantly to Istanbul's urban fabric, increasing the number of public service areas in the heart of the city.

According to the information obtained from the project bulletin, the benefits of the new square project are listed as follows:

- Pedestrian access will be provided continuously in all directions.
- Various outdoor events and activities can be organized in the new area.
- The added area can be used as a gathering area in the event of natural disasters such as earthquakes.
- A significant square space can be created within the existing urban fabric of Istanbul.

3.4. Data set

The importance of the eight dimensions, Transport (C_1), Security/Safety (C_2), Comfort (C_3), Maintenance (C_4), Environment (C_5), Functionality (C_6), Social (C_7), Aesthetic (C_8), evaluated for the USM

Table 1
Verbal expressions used and equivalents for IT2F numbers.

Verbal expressions		Trapezoidal interval type 2 fuzzy sets
Much more important	AS	$\tilde{\tilde{AS}} = ((7,8,9,9;1,1),(7.2,8.2,8.8,9;0.8,0.8))$
Too much important	VS	$\tilde{\tilde{VS}} = ((5,6,8,9;1,1),(5.2,6.2,7.8,8.8;0.8,0.8))$
Pretty much important	FS	$\tilde{\tilde{FS}} = ((3,4,6,7;1,1),(3.2,4.2,5.8,6.8;0.8,0.8))$
A little too important	SS	$\tilde{\tilde{SS}} = ((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))$
Of equal importance	E	$\tilde{\tilde{E}} = ((1,1,1,1;1,1), (1,1,1,1;1,1))$
Little bit important	1/SS	$\tilde{\tilde{SW}} = 1/\tilde{\tilde{SS}} = ((0.200,0.250,0.500,1; 1,1),(0.208,0.263,0.454,0.833; 0.8,0.8))$
Considerably less important	1/FS	$\tilde{\tilde{FW}} = 1/\tilde{\tilde{FS}} = ((0.143,0.167,0.250,0.333; 1,1), (0.147,0.172,0.238,0.312; 0.8,0.8))$
Very little important	1/VS	$\tilde{\tilde{VW}} = 1/\tilde{\tilde{VS}} = ((0.111,0.125,0.167,0.200; 1,1), (0.114,0.128,0.161,0.192; 0.8,0.8))$
Much less important	1/AS	$\tilde{\tilde{AW}} = 1/\tilde{\tilde{AS}} = ((0.111,0.111,0.125,0.143; 1,1), (0.111,0.114,0.122,0.139; 0.8,0.8))$

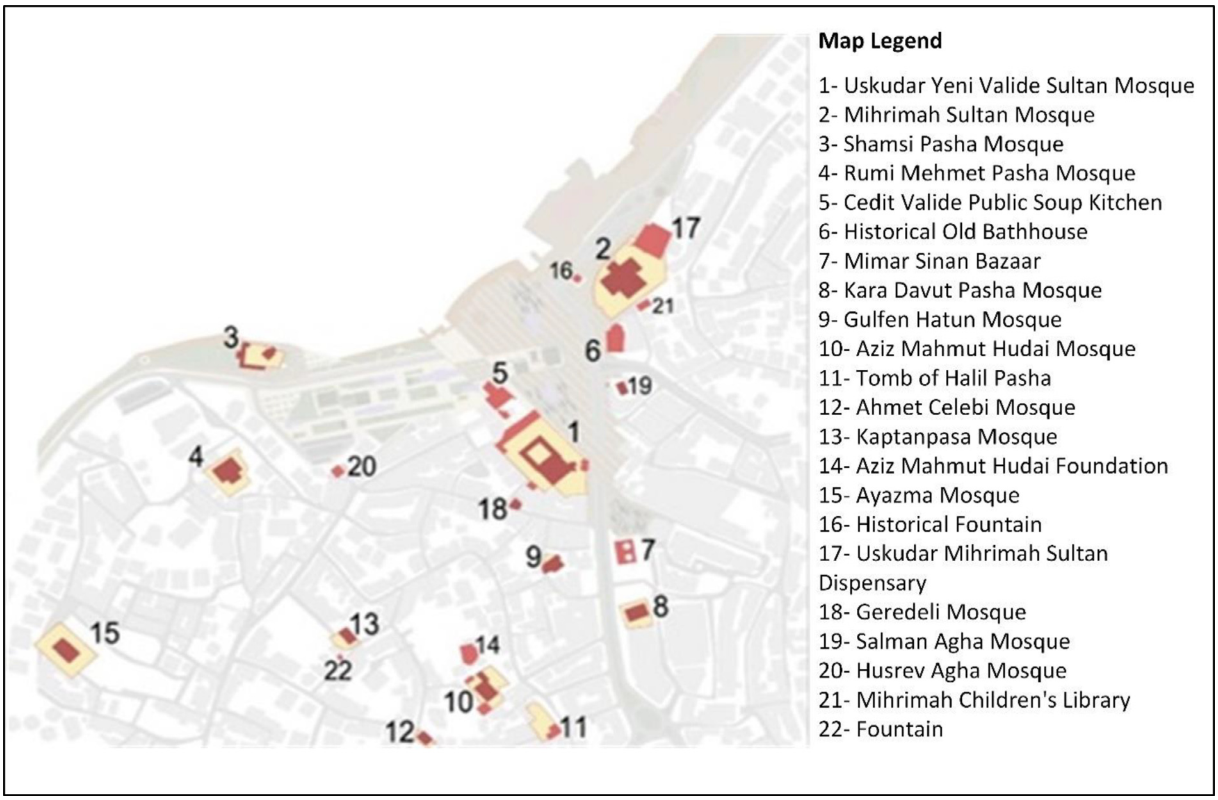

Fig. 3. Historical and cultural heritage in Uskudar square and its surroundings.

success score was evaluated by the experts working in IMM with Interval Type 2 Fuzzy (AHP). Eight experts at the executive level participated in this evaluation process. According to the main criteria obtained, a scale was created to model the success score of the new Uskudar Square, and the scale was applied to Uskudar Square using a face-to-face interview method.

The survey was conducted with 165 citizens residing near Uskudar Square or using the square by bus, minibus, Marmaray, or ferry. By examining the data obtained, incompletely filled questionnaires were eliminated, and as a result, 157 filled questionnaires were considered in the analysis. For the survey, the square was visited at randomly determined times during the day. All citizens using the square for participation were evaluated within the sample space, and a special user group was not targeted. However, among the citizens who were asked to participate in the survey, those who had time and volunteers participated. For this reason, the convenience sampling method was adopted. It aims to get the participants' opinions about the newly designed square and their expectations about the square in the future. The demographic information of the respondents is shown in Table 2.

Table 2
Demographic information of participants.

Age	Educational status	Gender		Total
		Female	Male	
18–30	High school and below	9	20	29
	Undergraduate	35	39	74
	Master's and above	1	3	4
	Total	**45**	**62**	**107**
31–40	High school and below	7	5	1
	Associate-bachelor's	2	4	1
	Graduate	0	2	1
	Total	**9**	**11**	**20**
41 and above	High school and below	10	4	14
	Undergraduate	4	8	12
	Master's and above	2	2	4
	Total	**16**	**14**	**30**
Total	High school and below	26	29	55
	Undergraduate	41	51	92
	Master's and above	3	7	10
	Total	**70**	**87**	**157**

Fig. 4. Uskudar square before the land reclamation project.

Fig. 5. New Uskudar square after the land reclamation project.

4. Results

4.1. IT2F AHP application

In the pairwise comparison matrices obtained in the first step of the IT2F-AHP method, the importance of each pair of binary criteria relative to each other was evaluated by eight experts with IT2F verbal expressions. A sample evaluation is given in Table 3.

The weights of the eight criteria were determined as given in Eqs. (9)–13. The resulting fuzzy weights were normalized after clarification. The deterministic equivalents of normalized weights are shown in Fig. 7.

Upon evaluating the weights of the aforementioned criteria, it is evident that "Transportation" is the paramount factor for decision-makers, followed by "Maintenance" as the secondary criterion. The criterion with the lowest weight is "Aesthetics." Moreover, we determined that the weights are closely aligned, and that no criterion is assigned a significantly low weight by the experts, thus not deemed irrelevant. Consequently, these eight dimensions will be evaluated and will contribute to the USM Success Score.

Fig. 6. The new urban square area in Uskudar (drone footage).

Table 3
Pairwise comparison form filled by the experts.

USM success score		1 C_1	2 C_2	3 C_3	4 C_4	5 C_5	6 C_6	7 C_7	8 C_8
1	C_1	E	E	SS	1/SS	SS	1/SS	1/SS	SS
2	C_2		E	1/SS	1/SS	E	E	E	SS
3	C_3			E	1/SS	E	1/SS	1/SS	SS
4	C_4				E	SS	SS	1/SS	SS
5	C_5					E	E	E	SS
6	C_6						E	1/SS	E
7	C_7							E	SS
8	C_8								E

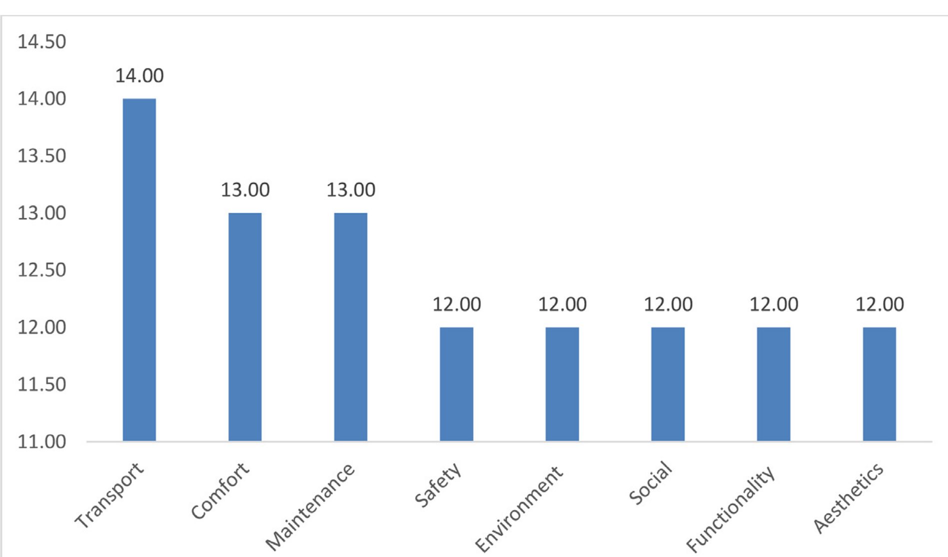

Fig. 7. Normalized weights for eight dimensions.

Table 4
Results of KMO and Bartlett's test.

Kaiser-Meyer-Olkin sample fit test		0.869
Bartlett's sphericity test	Approximate chi-square	3807.768
	Degrees of freedom	703
	Significance value	0.000

4.2. Exploratory factor analysis

There are two main considerations when determining whether a particular data set is suitable for factor analysis: sample size and the strength of the relationships between variables as well as the intercorrelations that exist among the items. According to Tabachnick and Fidell (2013), a sample size of 150 is generally considered the minimum for conducting factor analysis, provided that the data meets other assumptions such as sufficient correlations among variables. For relationship between variables, it is generally recommended to examine the correlation matrix for evidence of correlation coefficients greater than 0.3. If there are few correlations above this threshold, factor analysis may not be appropriate. Additionally, there are two statistical measures that can help assess the suitability of data for factor analysis: Bartlett's test of sphericity (Bartlett, 1950) and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (Kaiser, 1970). KMO takes a value between 0 and 1. The closer it is to 1, the more suitable the sample is for factor analysis. If the KMO test result is less than 0.50, it is interpreted that factor analysis cannot proceed (Kaya & Kaya, 2013). Similarly, for factor analysis to be deemed appropriate, Bartlett's test must yield a significant result of $p < 0.05$.

A 40-question questionnaire was designed to measure the 8 identified basic dimensions (latent variables), and data were collected in Uskudar Square by convenient sampling method. The data for factor analysis was tested using KMO and Bartlett's test. According to the results presented in Table 4, the data were found to be suitable for analysis (KMO>0.8 and significance value <0.05).

Varimax rotation was applied to facilitate the interpretation of the factors by maximizing the variance of squared factor loadings. This orthogonal rotation method ensures that the factors are uncorrelated and helps achieve a clearer, more interpretable factor structure. For factor extraction, factors were retained based on the eigenvalue greater than 1 criterion, which is a commonly used threshold for determining the number of factors to retain (Kaiser, 1970). During the EFA, two variables were removed due to low factor loadings, as they did not contribute meaningfully to the factors. These variables were excluded to ensure the robustness of the factor structure and to retain only those items that demonstrated strong relationships with the factors. Consequently, the number of variables, which was 40 with the revision of the analysis, decreased to 38 with the removal of 2 variables.

Accordingly, the factors, on which the survey questions were loaded, were reviewed, and it was concluded that eight factors were named correctly. Thirty-eight questions were determined to measure these eight hidden variables. According to the exploratory factor analysis, eight main criteria predicted for the USM Success Score were also supported by the collected survey data (Table 5). The final version of the distribution of the variables and their corresponding Cronbach alpha values are given in Table 6.

5.3. Findings

In this section, the average scores of the eight factors, evaluated specifically for the new Uskudar Square, on a 5-point Likert scale will be presented. The Transport dimension received the highest score, with an overall average of 4.08 out of 5, indicating that 81.61 % of participants were satisfied with the transportation aspects of Uskudar Square. This result is not surprising, as the square serves as the main intersection for various modes of transport, such as ferries, subways, trains, and buses.

The average score for the Safety criterion was 3.74 out of 5, reflecting that 74.96 % of participants were satisfied with safety features in Uskudar Square. The average score for Comfort was 3.39 out of 5, with 67.89 % of participants agreeing that the square is suitable for public gatherings. The Maintenance criterion received an average score of 3.85 out of 5. This indicate that 77.07 % of participants evaluated Uskudar Square positively in terms of maintenance. The average score for the Environment was 3.02 out of 5, with 60.31 % of participants expressing satisfaction with the environmental regulations in the square.

The overall average score of the Functionality criterion was calculated as 3.64 out of 5. In the percentile, 72.89 % of the participants find Uskudar Square functional. The general average score of the social top criterion was calculated as 3.31 out of 5. In the percentile, 66.15 % of the participants find Uskudar Square to be pleasing in terms of socializing. The general average score of the Aesthetic criterion was calculated as 2.94 out of 5. In the percentile, it was calculated that 58.82 % of the participants find Uskudar Square to be aesthetically appealing. Based on this, it is recommended that further studies and efforts be directed towards enhancing the aesthetic and visual aspects of the square.

The averages scores obtained for the main dimensions of the USM Success Score after the analysis of the survey data are shown in Fig. 8.

In the last stage of the USM Score, the average score of each criterion and the criterion weights were multiplied to form the total weighted score. Accordingly, the USM Score for Uskudar Square was found to be 70.2 (Fig. 9).

When this average score is evaluated according to the USM Success Score model presented in this study, it is concluded that those who use the square are relatively satisfied with Uskudar Square while expect some potential improvements in some areas such as aesthetic and functionality.

6. Discussion and conclusion

Urban squares are important in terms of people's presence and social participation; however, what makes these spaces socially active is primarily the physical factors that can facilitate people's involvement; including access, visual attractions, natural factors, and many other factors. Today, squares constitute the focal point of access to public services as well as the socializing area for the public. Along with all these, it is observed that today's squares are unable to meet the needs of citizens due to immigration from cities. Many squares in the world are being renovated and made compatible with the increasing population and changing conditions.

The central role of urban squares in contemporary city life, as highlighted in this study, underscores their significance as not only focal points for public service access and social interaction but also as crucial elements of a city's identity and image. As cities face the challenges of increasing populations and evolving urban needs, the effective management of these public spaces becomes paramount. This research contributes to the field urban planning and management by developing and validating an Urban Square Management (USM) success score model. The model directly addresses the gap in understanding and measuring management effectiveness from the public's viewpoint.

The case of Uskudar Square in Istanbul illustrates the need for a systematic approach to public space management. As observed, squares are multifunctional spaces used for transportation, trade, social gatherings, and recreation. The USM model involve eight key dimensions Transportation, Safety, Comfort, Functionality, Aesthetics, Social, Environment, and Maintenance. The model represents a holistic framework for evaluating urban square management while each dimension plays a crucial role in shaping public perception and satisfaction.

The dimension Transportation addresses the accessibility and connectivity of the square. It includes factors such as pedestrian flow, public transportation integration, and ease of access for all groups. Effec-

Table 5
Distribution of pattern matrix and questions by factors.

	Component							
	1	2	3	4	5	6	7	8
Transport 1	.768							
Transport4	.753							
Transport 2	.716							
Transport 5	.673							
Transport 3	.634							
Transport 6	.606							
Transport 7	.593							
Transport 4		.746						
Aesthetic 2		.733						
Aesthetic 3		.721						
Aesthetic 1		.691						
Aesthetic 5		.592						
Environment 1			.917					
Environment 2			.909					
Functionality 3				.744				
Functionality 2				.607				
Functionality 6				.562				
Functionality 1				.547				
Functionality 4				.523				
Functionality 7	.354			.523				
Functionality 5				.502				
Functionality 8				.400				
Maintenance 3					−0.874			
Maintenance 5					−0.806			
Maintenance 4					−0.794			
Maintenance 1					−0.768			
Maintenance 2					−0.759			
Comfort 1						−0.738		
Comfort 2						−0.716		
Comfort 3						−0.700		
Comfort 4						−0.466		
Safety 2							.657	
Safety 3							.619	
Safety 4							.616	
Safety 1							.565	
Social 2								.805
Social 1								.795
Social 3								.570

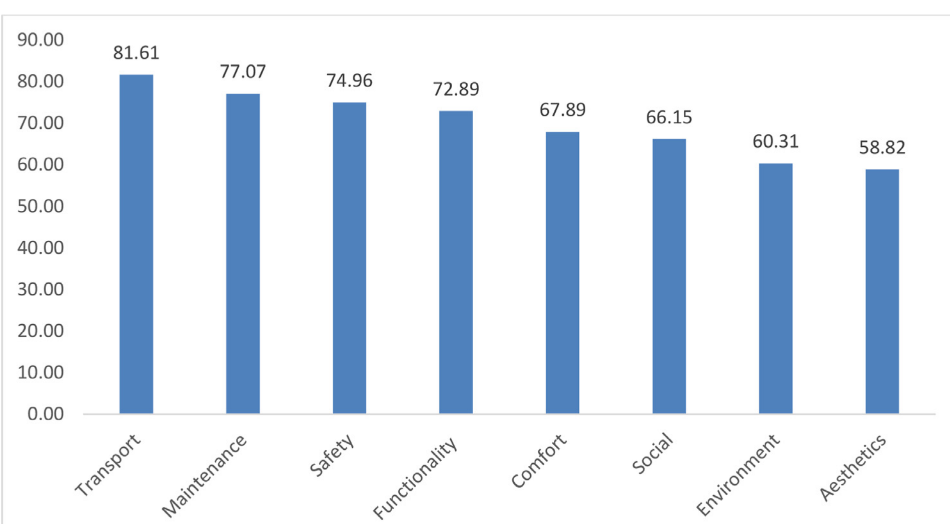

Fig. 8. Average scores of eight dimensions.

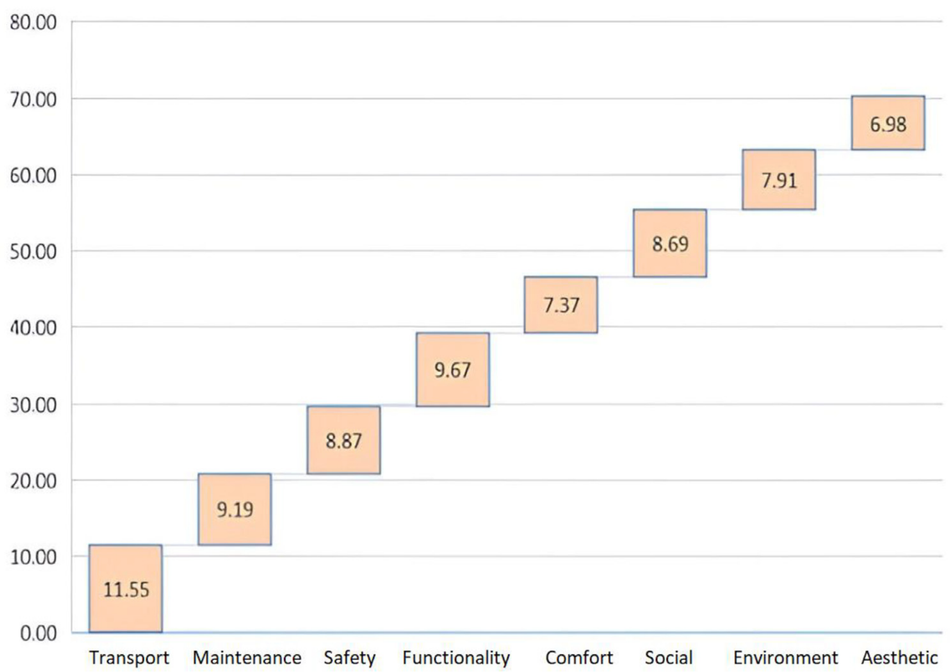

Fig. 9. Contribution of criteria to weighted score.

Table 6
Distribution of variables after exploratory factor analysis.

main criterion	Number of items	Cronbach alpha
Transport	7	0.77
Safety	4	0.87
Comfort	4	0.82
Maintenance	5	0.91
Environment	2	0.77
Functionality	8	0.87
Social	3	0.75
Aesthetic	5	0.84

tive transportation management ensures that the square is seamlessly integrated into the city's mobility network. Safety dimension encompasses both physical and perceived sense of security by people. Increasing the sense of security can encourage public use and social interaction in the public spaces. Comfort focuses on the availability of essential services, such as restrooms, seating, and information kiosks. Comfort squares cater to the diverse needs of users, enhancing their overall experience and encouraging people to stay and spend more times in the public space. Functionality relates to the square's ability to serve its intended purposes, whether as a space for public gatherings, events, shopping or everyday activities. Functional squares should be adaptable and responsive to the needs of the community for wide range of activities. Aesthetics reflect the visual appeal and design quality of the square (landscaping, architectural features, public art, etc.). Aesthetically pleasing squares contribute to a positive urban experience and enhance the city's visual identity. Social dimension addresses the square's role in fostering social interaction and community engagement. This includes the presence of spaces for social gatherings, events, and cultural activities. Socially active squares strengthen community bonds and promote inclusivity. Environment focuses on the square's environmental sustainability and ecological impact. This includes factors such as green spaces, water management, and waste disposal, which all contribute to more sustainable urban environment. Care encompasses the maintenance of the square, including cleanliness, infrastructure maintenance. Well-maintained public spaces demonstrate a commitment to public service and enhance the overall user experience.

The application of the Interval Type-2 Fuzzy Analytical Hierarchy Process (IT2F-AHP) for expert evaluations allowed for the incorporation of inherent uncertainties and subjective judgments. Based on that, a questionnaire was developed. The Exploratory Factor Analysis validated the model's structure and ensured its relevance to public perceptions. The resulting success score of 70.2 for Uskudar Square provides a quantitative measure of its management performance. It offers a valuable tool for urban planners and policymakers. This score, however, is not only a number; it represents a comprehensive evaluation derived from public feedback which emphasizes on the importance of citizen-centric approaches in urban planning.

The analysis of sub-dimensions provides actionable insights. For instance, if the safety dimension scores lower, targeted interventions such as increased lighting or security patrols can be implemented. Similarly, improvements in environmental quality can be prioritized based on the model's detailed feedback. This approach aligns with the understanding that public satisfaction with urban spaces is directly linked to the decisions and actions of city administrations (Suhardono, Lee, & Suryawan, 2024).

The generalizability of the USM model to other squares in Istanbul and beyond is a significant contribution of this study. By standardizing the success criteria and providing a measurable and controllable framework, cities can systematically assess and improve the quality of their public spaces. Future research could explore the application of the USM model in diverse urban contexts and explore its variations in cultural, economic, and social factors. Additionally, longitudinal studies could assess the impact of implemented interventions on public satisfaction and the long-term sustainability of urban squares.

The integration of public perspectives in urban square management, as demonstrated in this study, is crucial for creating inclusive and functional public spaces that enhance the overall quality of urban life (Chen and Lee, 2010). By prioritizing citizen-centric approaches and utilizing robust evaluation models, cities can ensure that their squares remain vibrant, accessible, and responsive to the needs of their communities.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Vural Erce: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Ali Osman Kusakci:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Misagh Haji Amiri:** Writing – review & editing, Visualization, Validation, Conceptualization.

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