Cities 150 (2024) 105006

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Enhanced planning capacity in urban renewal: Addressing complex challenges using neutrosophic logic and DEMATEL

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ARTICLE INFO

Keywords:
Cognitive mapping
DEcision MAking Trial and Evaluation Laboratory (DEMATEL)
Neutrosophic logic
Urban renewal

ABSTRACT

Urban renewal is imperative due to growing urbanization (*i.e.*, population migration into cities), requiring acceptable planning to meet peoples' housing needs and playing a key role in highlighting and satisfying societies' needs. Complex urban renewal decisions encompass environmental degradation, poverty, inequality, and inaccessibility to services. Decision makers must meet on-going challenges by transforming urban spaces so that they satisfy all constraints while satisfying residents' needs. A holistic view of urban renewal facilitates efficient strategies for meeting economic, social, and environmental obligations. Multicriteria methodology may ideally be used to develop a complete, transparent, and realistic model that identifies planning factors best resolving urban renewal efforts. Therefore, we rely on cognitive mapping, the decision-making trial and evaluation laboratory technique, and neutrosophic logic, applied by a panel of experts with experience in urban renewal planning in two group work meetings. The results were analyzed and validated by an independent specialist in this field. The contributions and limitations of this methodological framework were also examined.

1. Introduction

The world's growing population has combined with a process of urbanization that has created new needs in most societies (Wang, Esther, et al., 2022). Urban renewal has helped mitigate these problems by improving city residents' quality of life. Yıldız et al. (2020) explore the issues that urban planners should deal with, including environmental degradation, inequality, and poverty, as inherent features of urbanization. The problems arising from the migration of rural populations to cities are becoming larger and more numerous, and city planners have to take into consideration the needs of the multiple stakeholders living in urban zones (Lousada et al., 2021; Pérez et al., 2018), such as the elderly, ethnic minorities, and vulnerable groups (Wang et al., 2014; Yıldız et al., 2020).

According to Wang, Jie, et al. (2022), effective urban renewal processes should analyze the relationships between different interested parties at a government, community, and business level. These groups may get to express their views but fail to generate a consensus, thereby complicating efforts to define which areas of action are the most important. In addition, implemented projects have had a high failure rate. Urban renewal challenges are thus currently being studied by academics and stakeholders in varied fields (Ferreira et al., 2022; Jung et al., 2015), who have found that poorly implemented plans can contribute to issues such as social exclusion and loss of place identity. Thus, making better decisions is crucial to the success of urban renewals (Lousada et al., 2021; Zheng et al., 2017).

The present research seeks to create a multicriteria analytic system/model that may assist city planners in reaching more informed decisions in urban renewal projects. Using a methodology that identifies the most important factors, we adopt a transparent, holistic, and empirically rigorous process that helps reduce existing gaps in the literature by addressing the following questions:

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https://doi.org/10.1016/j.cities.2024.105006
Received 31 October 2023; Received in revised form 4 March 2024; Accepted 29 March 2024
Available online 16 April 2024

- How can urban renewal's main determinants and corresponding key factors be identified?
- What are the most influential relationships among these variables?
- How should decision makers prioritize complex challenges to facilitate urban renewal?

Cognitive mapping was combined with neutrosophic logic and the decision making trial and evaluation laboratory (DEMATEL) technique to produce graphic visualizations of an expert panel's ideas about clusters of determining factors. These clusters were defined based on the specialists' experience, values, and opinions, after which the panel analyzed the cause-and-effect relationships between the criteria. The techniques applied also facilitated a combination of qualitative and quantitative analyses based on objective and subjective variables. This study is thus the first to use cognitive mapping, neutrosophic logic, and DEMATEL together to help urban planners leverage their city's urban renewal capacity.

This study consists of five sections. The following section contains a review of the urban renewal literature and the contributions and limitations of previous studies. Section three outlines the applied methodologies, section four covers the methodological application and results, and the final section presents major conclusions and limitations, as well as suggesting lines of future research.

2. Literature review and research gaps

The real estate sector often acts as a catalyst for urban development by driving investment, shaping the built environment, and revitalizing neighborhoods (Huang et al., 2023). Through strategic planning and development initiatives, real estate developers contribute to the transformation of urban spaces, creating vibrant mixed-use developments, affordable housing options, and modern infrastructure (Lousada et al., 2021; Rodrigues et al., 2023). These developments can stimulate economic growth, attract businesses, and enhance the overall quality of life for residents.

While real estate development responds to urban growth trends, it also influences the direction and pace of urban renewal (Pinto et al., 2023). Different definitions of urban renewal have been developed over time by various authors. For example, Cui et al. (2021, p. 1) state that urban renewal is *"a set of plans and activities to upgrade neighborhoods and suburbs that are in a state of distress or decay"*. The authors also mention related concepts such as "urban regeneration", "urban revitalization", "urban redevelopment", and "urban rehabilitation". Lin et al. (2021) define urban renewal as a process that improves infrastructure through the restoration of buildings and preserves the existing categories. In addition, urban renewal comprises not only reusing resources but also reconstructing city environments (Huang et al., 2020). Zheng et al. (2014) further emphasize that urban renewal is concerned with enhancing land value and improving residents' quality of life by removing run-down neighborhoods and preserving heritage.

Wang, Esther, et al. (2022) connect urban renewal with urban history. Subsequent to urbanization, residents' need to adjust to changes and facilitate urban renewal offering an important strategic planning role to improve urban lifestyles. Also, Shamai and Hananel (2021) examine urban renewal projects in the previous century, where urban slums were raised and residents were required to abandon their homes and find residences in other areas. This history of urban renewal proved controversial due to the insecurity generated by requiring residents to move. Authors also confirm that urban renewal has resulted from the result of rapid urbanization and its consequences (*e.g.*, poverty, disease, and social inequality). Thus, mistakes of previous urban renewal attempts focused primarily on supporting the most disadvantaged local residents. However, gentrification in the 1980s displaced long-term locals—depending on their social class—and required them to move to new neighborhoods which was thought to offer better conditions at lower rents. This process generated justified criticism due to social class issues involved, although gentrification may provide advantages of economic growth and investment (Lin et al., 2021; Wang et al., 2016; Wang, Jie, et al., 2022).

According to Wang et al. (2016), an alternative approach to urban renewal is to divide areas in which the poor and rich live together, thereby emphasizing social and monetary equalities. Traditional urban development has slowed down, reflecting tension in how government agencies and other organizations have implement urban renewal projects. Yıldız et al. (2020) report that, due to rapid population growth, urban planning and management are inadequate, with consequences such as environmental degradation, inaccessible urban services, inequality, and poverty. Thus, decision makers and researchers are becoming more aware of this predicament due to increases in pollution, social fragmentation, and economic recessions. Therefore, current efforts address inequalities, improving residents' well-being and sustainable business development (Ferreira et al., 2022; Huang et al., 2020).

In another argument, Shamai and Hananel (2021) observe that urban renewal projects are criticized for emphasizing growth and competitiveness, which favors both governments and the private sector, instead of focusing on residents' social and technological needs. These questionable practices result in residents finding themselves living in urban areas that are unable to accommodate peoples' changing needs, which will eventually generate additional urban-specific problems. Zhang et al. (2021) reiterate this concern, pointing out that urban renewal is a tool that must address social, economic, and environmental sustainability. When competitiveness and economic development are given the highest priority, disadvantaged groups often experience greater social inequality. In response to possible growing social inequality, urban renewal projects have begun to cover social, environmental, and cultural issues in their action plans.

Wang et al. (2017, p. 164) conclude that urban renewal determinants applied by stakeholders should be defined *"as a group or individual who can affect the achievement of project objectives throughout the life cycle of the construction and operation of* […] *urban rehabilitation project*[s]*"*. These stakeholders, among others, are residents, government agencies, research institutions, entrepreneurs, and financial institutions. Further, Jung et al. (2015) assert that stakeholders' participation is important for ensuring successful implementations of urban renewal projects given their high complexity and high risk of failure. This helps explain why urban renewal continues to be discussed and studied by academics and other experts in the environmental, social, economic, and political fields. Zhou et al. (2021) argue that considering these factors in decision making comprise the first phase of urban renewal and that the choices made affect the implementation and quality of these projects over time. Therefore, decision makers must identify the correct approach that match the socioeconomic context in question. Further, Wang, Jie, et al. (2022) suggest that urban renewal is best achieved *via* the influential relationships among stakeholders such as government agencies, communities, and businesspeople. Each of these actors should express their opinions regarding evaluation indicators used to measure the success of urban renewal projects.

Numerous urban renewal assessment criteria exist. Therefore, deciding which criteria should be given priority is problematic. However, Wang et al. (2014) argue that decision makers must decide on specifics of each project such as where and when projects should be implemented and the proper stakeholders to be included regarding specific decisions. New decision making approaches may be needed to ensure urban renewal projects have positive outcomes.

A number of studies concentrate on important determinants of successful urban renewal projects (*cf.* Mehdipanah et al., 2013; Wang et al., 2016; Yıldız et al., 2020; Zhang et al., 2021). However, prior research displays significant limitations. For example, earlier studies (*e.g.*, Andrade et al., 2022; Rodrigues et al., 2023) suggest that there is a lack of clarity and consensus in identifying the pivotal determinants crucial for successful urban renewal endeavors, leading to a dearth of transparency regarding the cause-and-effect relationships among these factors. Moreover, the existing literature (*e.g.*, Costa et al., 2021; Pinto et al., 2021; Vaz-Patto et al., 2023) additionally notes a lack of in-depth examination of the dynamic interplay between these determinants and their interconnectedness.

To address these gaps and limitations, the present study applies a promising methodology that integrates cognitive mapping, neutrosophic logic, and the DEMATEL technique. These complementary constructivist and process-oriented approaches offer a comprehensive framework for scrutinizing urban renewal complexities. By leveraging such methodologies, researchers can potentially unearth unique insights and valuable findings that contribute to advancing the understanding and efficacy of urban renewal planning and decision-making processes.

3. Methodological background

We apply methodologies based on constructivist principles that integrate objective and subjective elements into decision-making processes. Thus, we include more conscious, human-grounded evaluations and ensure the identification of the measures that best support urban renewal. The decision-support procedures were divided into three major phases: (1) problem structuring; (2) relationship evaluation; and (3) recommendation formulation. The first phase was based on cognitive mapping techniques. The second phase uses neutrosophic logic and DEMATEL to facilitate quantitative evaluations of causal links. The last phase allows for the formulation of recommendations based on the outcomes obtained in the previous two phases. This combination of techniques isolates a greater number of criteria and reveals the decision makers' perceptions regarding which urban renewal determinants are crucial to project success. All three phases are completed in sessions containing decision makers specializing in urban planning.

3.1. Cognitive mapping

Following Eden (2004), Lousada et al. (2021, p. 4) describe cognitive maps as *"the representation of thinking about* [… a] *problem that arises from* [… a] *mapping process"*. These maps are a useful tool for decision makers dealing with issues involving complex contexts. Cognitive mapping facilitates a clearer understanding of problems and potential solutions, as well as encouraging reflection and the creation of new ideas. Carayannis et al. (2018) report that this structuring technique allows decision makers to understand and evaluate problems more fully, learn about criteria, and reduce the number of missing variables, as well as providing a graphic representation of each person or group's ideas.

Notably, cognitive maps depend on individual perspectives, but the mapping process guarantees sufficient data are collected and organized, including cause-and-effect relationships indicated by arrows with plus (+) or minus (−) signs. Cognitive mapping thus allows decision makers to consider many variables, which contributes to a more comprehensive view of the decision problem. To create a cognitive map, interviews must be conducted with specialists whose feedback ensures the results can help decision makers more easily solve the relevant problem. The arrows show connections to the decision problem with a + or − sign, in which the concept at the arrow's head is influenced by the concept at the tail, with the head being the goal and the tail the option (Eden, 2004). According to Village et al. (2013), cognitive maps clarify how the real world works as the system constructed allows decision makers to compare both important concepts and the relationships that arise between them over time based on the maps' nodes and links. The maps' contents reflect the relevant experts' thinking and thus improve their decision-making process, especially when combined with neutrosophic logic and DEMATEL.

3.2. Neutrosophic logic

Pramanik et al. (2016) report that neutrosophic logic was first introduced by Florentin Smarandache, who saw the uncertainty component of data as important and created a concept that addresses not only veracity and falsity but also indeterminacy. The term "neutrosophic" comes from neutrosophy, which is a branch of philosophy that, according to Rivieccio (2008, p. 1860), deals with *"the origin, nature and scope of neutralities, as well as their interactions with different ideational spectra"*. From a neutrosophic perspective, ideas can be said to have trueness or falseness, as well as uncertainty.

Karaaslan (2017) notes that neutrosophic logic is a mathematical tool that seeks to solve incomplete or indeterminate problems and incorporate inconsistent knowledge. Al-Subhi et al. (2018, p. 65), in turn, observe that including indeterminacy can provide a more comprehensive understanding of decision problems and that this concept *"has been widely used in decision-making environments"*. Broumi et al. (2018) also argue in favor of considering uncertainty because issues in real life contain a degree of indeterminacy.

Abdel-Basset et al. (2019) assert that neutrosophic logic is a highly efficient and effective way to aggregate veracity, falsity, and indeterminacy, noting also that this approach seeks to maximize the degree of veracity and minimize the other two qualities. For example, let us say we are evaluating the success of an urban renewal project. Traditional logic might only allow us to categorize the project as either successful or unsuccessful. However, using neutrosophic logic, we can also consider the possibility that the project's success is uncertain or partially successful. This additional flexibility enables us to make more nuanced and realistic assessments, especially when dealing with complex and ambiguous situations. By incorporating neutrosophic logic into our decision-making process, we can better navigate uncertainties and make more informed choices in urban renewal planning. Dhar and Kundu (2017) explain that the existing degrees comprise the interval between $0 \leq T + I + F \leq 3$, in which T = trueness; I = indeterminacy; and F = falseness. In practice, $T, I, F \subset [0,1]$; $t + f = 1$; and $i \in [0,1]$. A simplified neutrosophic matrix can be constructed using Eq. (1):

$$R_A = (a_{ij})_{m \times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix} \tag{1}$$

in which the values a_{ij} are determined collectively by a group of specialists. R_A is the result of a universe $U = \{x_1, x_2, \ldots, x_m\}$ with a set of parameters $E = \{e_1, e_2, \ldots, e_n\}$, while (a_{ij}) is equal to $(T_A(x_i, e_j), I_A(x_i, e_j), F_A(x_i, e_j))$. Both R_A and (a_{ij}) are represented by the ensuing matrix $n \times m$, in which the degree of intensity between the parameters is verified (*cf.* Das et al., 2019).

The current study combined neutrosophic logic with the DEMATEL technique. Due to the characteristics of both methods, the assigned values had to be encompassed in one value through crispification based on Eq. (2):

$$w_k = \frac{1 - \sqrt{\left((1 - T_k)^2 + (I_k)^2 + (F_k)^2\right)/3}}{\sum_{k=1}^{r}\left\{1 - \sqrt{\left((1 - T_k)^2 + (I_k)^2 + (F_k)^2\right)/3}\right\}} \tag{2}$$

According to Pramanik et al. (2016, p. 85), this step is useful because *"decision makers have their own neutrosophic decision weights"*. In this case, weights $w_k = (T_k, I_k, F_k)$ must respect specific conditions including being greater or equal to 0 (*i.e.*, $\varpi_k \geq 0$) and a total crisp weight equal to 1 (*i.e.*, $\sum_{k=1}^{r} \varpi_k = 1$).

3.3. DEMATEL

DEMATEL was created in 1972 by Gabus and Fontela (1972) to solve complex problems in the real world. Quader et al. (2016) and Yazdi et al. (2020) state that this technique constructs and analyzes structural models and identifies cause-and-effect relationships between criteria using rankings to define the importance of each factor within a model. The result of the entire process is based on the decision makers' reasoned opinion, so the outcomes help these experts solve the relevant decision problem with reference to the most significant factors (Horng et al., 2013; Lo et al., 2020; Trivedi, 2018). One of the greatest advantages of this technique—compared to other decision-making methods—is how it facilities useful feedback (Falatoonitoosi et al., 2013; Shafiee et al., 2022). In practice, DEMATEL can be performed through the six steps described below (Pinto et al., 2023; Si et al., 2018; Sumrit & Anuntavoranich, 2013; Vishwakarma et al., 2022).

3.3.1. Step one: Calculation of initial direct influence Matrix A

After identifying the factors to be evaluated, the decision makers need to create a direct influence matrix, in which the group of specialists determines the influence that factor i has on factor j. x_{ij}^{k} represents the score given by each panel member, in which K is the number of decision makers in the group. For the pairwise comparison, DEMATEL uses a 5-point scale: 0 = no influence; 1 = weak influence; 2 = medium influence; 3 = strong influence; 4 = very strong influence (Uygun et al., 2015). The average matrix is created using Eq. (3):

$$a_{ij} = \frac{1}{K}\sum_{k=1}^{k} x_{ij}^{k} \tag{3}$$

3.3.2. Step two: Determination of normalized direct influence Matrix X

This step produces a normalized direct influence matrix. Matrix X is constructed *via* Eq. (4) (Quezada et al., 2022):

$$X = s^{*}A \tag{4}$$

in which s is calculated using Eq. (5):

$$s = Min\left[\frac{1}{Max_{1\leq i\leq n}\sum_{j=1}^{n} a_{ij}}, \frac{1}{Max_{1\leq j\leq n}\sum_{i=1}^{n} a_{ij}}\right] \tag{5}$$

3.3.3. Step three: Calculation of total relation Matrix T

In this step, matrix T is characterized by the total influence of the factors' relationships. This value is calculated with Eq. (6) (Chen et al., 2011):

$$\mathrm{T} = \lim_{h\to\infty}\left(X^{1} + X^{2} + \ldots + X^{h}\right) = X(\mathrm{I} - X)^{-1} \tag{6}$$

3.3.4. Step four: Evaluation of Matrix T rows and columns

In this step, the totals of matrix rows and columns are calculated to determine the R and C vectors, respectively. The totals are estimated using Eqs. (7) and (8) (Braga et al., 2021):

$$R = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{7}$$

$$C = [c_j]_{1\times n} = \left[\sum_{j=1}^{n} t_{ij}\right]_{1\times n}^{T} \tag{8}$$

3.3.5. Step five: Determination of threshold (α) value

This step comprises using matrix T to determine the α value. The calculation is done according to Eq. (9) (Braga et al., 2021):

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \tag{9}$$

in which N is the number of factors in the matrix.

3.3.6. Step six: Creation of cause-and-effect influence relation map (IRM)

In this last step, the $R + C$ values represent the criteria's prominence in the analysis model, so these values help decision makers understand the relative importance of each factor. The $R – C$ values stand for the criteria's relationship within the decision-support system and thus reveals the contribution of each factor to the analysis model. These values provide better information to decision makers, including dividing the criteria into four quadrants by type of factor (Yazdi et al., 2020) (see Fig. 1).

As Fig. 1 shows, the determinants can be divided into four quadrants. The first quadrant (QI) contains the essential factors, which are characterized by strong relationships and greater prominence. The second quadrant (QII) is the determining factors, which have strong relationships but less prominence. The third quadrant (QIII) encompasses the independent factors, which have weak relationships and less prominence. Finally, the fourth quadrant (QIV) encloses impact factors with weak relationships but greater prominence (Yazdi et al., 2020).

In addition, when $R – C > 0$, the factor in question falls into the causes group. When $R – C < 0$, the factor belongs to the effects group. Yazdi et al. (2020, p. 5) note that these results help decision makers more *"objectively distinguish the intricate causal relations between the identified factors and identify* [which merit] *further attention for various decision-making purposes"*.

DEMATEL's compatibility with cognitive mapping and neutrosophic logic along with its suitability for addressing the complexities of urban renewal planning are its main benefits. By integrating DEMATEL with cognitive mapping and neutrosophic logic, our approach can provide a multi-faceted methodology combining qualitative and quantitative analyses, enhancing the robustness and versatility of our approach. This facilitates a more holistic examination of urban renewal planning factors and their interactions, ultimately leading to the generation of unique insights and valuable findings compared to existing methods.

4. Application and results

The structuring phase is essential to ensure the entire decision-making process develops smoothly because, according to Bana e Costa et al. (1997, p. 34), this phase *"provides the actors involved in a problematic situation with a common language for debate and learning and with clear information about the plausible impacts of potential actions on the different options available"*.

In the present study, the decision makers structured the problem based on their professional experience in urban renewal projects (Abdel-Basset et al., 2018). These experts were chosen for their extensive

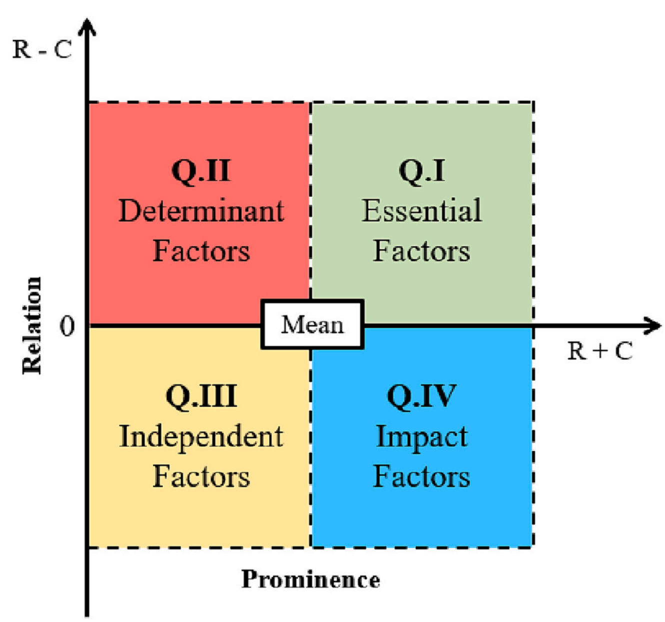

Fig. 1. Influence relation map
Source: Adapted from Yazdi et al. (2020).

experience of more than a decade in urban renewal projects, their diverse backgrounds spanning various institutions and sectors of activity, and their heterogeneity in terms of age and gender. This selection ensured a blend of different perspectives. Bana e Costa et al. (2002, p. 227) suggest that panels should *"typically* […be] *a decision-making group of 5–7 experts and other key players"*. To comply with this guideline, six specialists participated in the first group session.

The next challenge after selecting the panel was to find a date when everyone was available to meet. The first session was held online with the following participants. One expert was a commercial architect who specializes in planning, urbanism, and environmental law, while the second worked as a landscape architect at the Municipality of Vale de Cambra, Portugal. The third panel member was also a commercial architect, the fourth was an environmental engineer from Ourém, and the fifth was a senior technician at the North Portugal Region Coordination and Development Commission in charge of land-use planning services. The last participant was a vice-president of the Alentejo Region Coordination and Development Commission. Two technical assistants helped the facilitator (*i.e.*, one of the authors of this study) during the session. The methodological procedures followed in the current study are presented in Fig. 2.

4.1. Structuring phase: Collective cognitive map

The first meeting with the expert panel lasted around three and a half hours. The session took place online in the Zoom platform. After a brief introduction, each participant was directed to the Miro platform (see https://miro.com/), whose tools were explained.

The facilitator next asked the panel the following trigger question: *"Based on your professional experience, what are the challenges posed by urban renewal and what measures and/or actions can be taken to leverage planning capacity in this context?"*. Each specialist then wrote his or her answers in the space provided, adding a + or – sign depending on the impact of each criterion on urban renewal projects. This part of the process was supported by the "post-its technique" (Ackermann & Eden, 2001). By the end of the first procedure, the panel had identified more than the required minimum of 90–120 criteria (Eden & Ackermann, 2004), reaching a total of 156 urban renewal determinants.

In the second procedure of the first session, the specialists were asked to work together to create clusters of criteria. The panel agreed on six groups after allocating the previously identified factors to the most appropriate cluster. The six clusters were labeled as follows: Legal (C1); Economic (C2); Environmental (C3); Heritage (C4); Social (C5); and Political (C6). At this point, any repeated criteria were eliminated or reformulated.

After the criteria were placed in the most appropriate clusters, the last procedure of the first session was begun (*i.e.*, determining the degree of importance of each criterion within its respective group). Specifically, the decision makers placed the most significant factors at the top of their cluster, under which came any criteria considered to be of intermediate importance followed by the least significant determinants at the bottom. The facilitator and assistants gathered all the information provided by the expert panel in this first session and, using the *Decision Explorer* software (see http://www.banxia.com), constructed a group cognitive map with the 156 criteria (see Fig. 3) (size restrictions prevent a better visualization, but an editable version of the entire group cognitive map can be obtained from the corresponding author upon request).

Fig. 3 was collectively validated by the panel members after intense discussion and negotiation, serving as an aggregated representation of the perspectives of the six decision makers who participated in the group meetings. According to Ferreira et al. (2022, p. 282), this procedure allows *"different expert*[s'] *opinions to be formally projected* [as a map], *creating a holistic framework within which decision criteria and their cause-and-effect relationships* [… can] *be detected and understood"*. The next phase comprised the evaluation of the identified urban renewal factors.

4.2. Evaluation phase: Neutrosophic logic and DEMATEL

The second online meeting was attended by 5 of the initial 6 panel members, which allowed the study to continue because the minimum number of decision makers were present (*cf.* Salmeron, 2009). This session lasted approximately as long as the previous one had (*i.e.*, about three and a half hours) and began with the presentation of the cognitive map created to the expert panel. The participants were then introduced to the nominal group technique (NGT) and multi-voting, with which they could identify the most important criteria in each cluster. Finally, the facilitator explained how neutrosophic logic and the DEMATEL technique would be used.

The decision makers were next asked to identify the cause-and-effect relationships first between clusters (*i.e.*, inter-cluster analysis) and then between the criteria of each cluster (*i.e.*, (six) intra-cluster analyses). The strength of the links was quantified using the previously mentioned DEMATEL scale, in which 0 means no influence, 1 weak influence, 2 medium influence, 3 strong influence, and 4 very strong influence. For each value assigned, the specialists were also asked to assign percentages to their choices according to the level of *T*, *I*, and *F*. The facilitator further explained to the panel that the percentages attributed to each value could add up to more or less than 100% (*cf.* Pramanik et al., 2016). This quantification procedure provided more comprehensive information about the decision problem.

Notably, all the data used in our study were directly provided and approved by the panel members after intense collective discussion and negotiation. The initial results of the second session facilitated analyses of the clusters defined (see Table 1) and their respective cause-and-effect

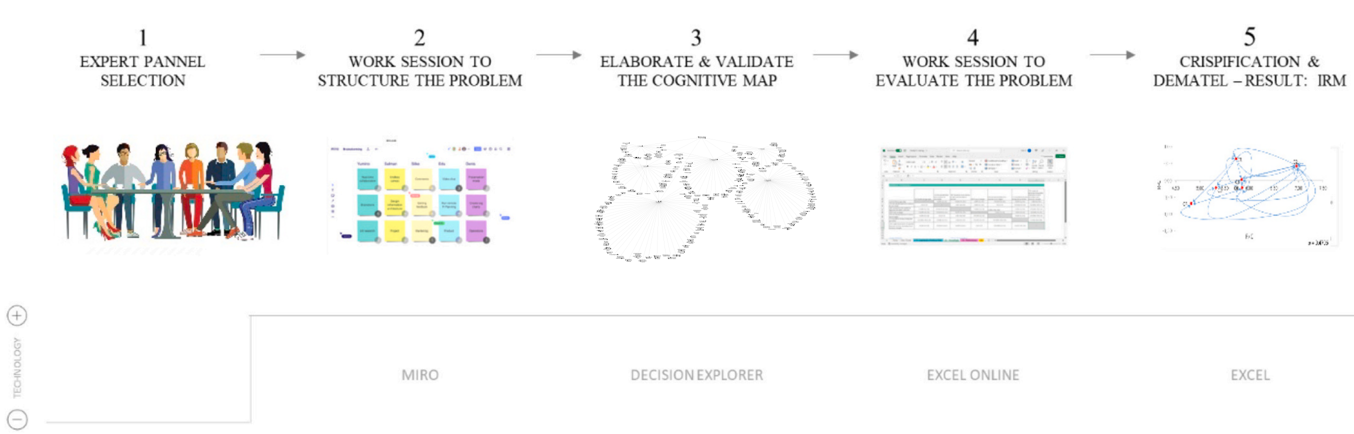

Fig. 2. Procedures followed in the empirical research.

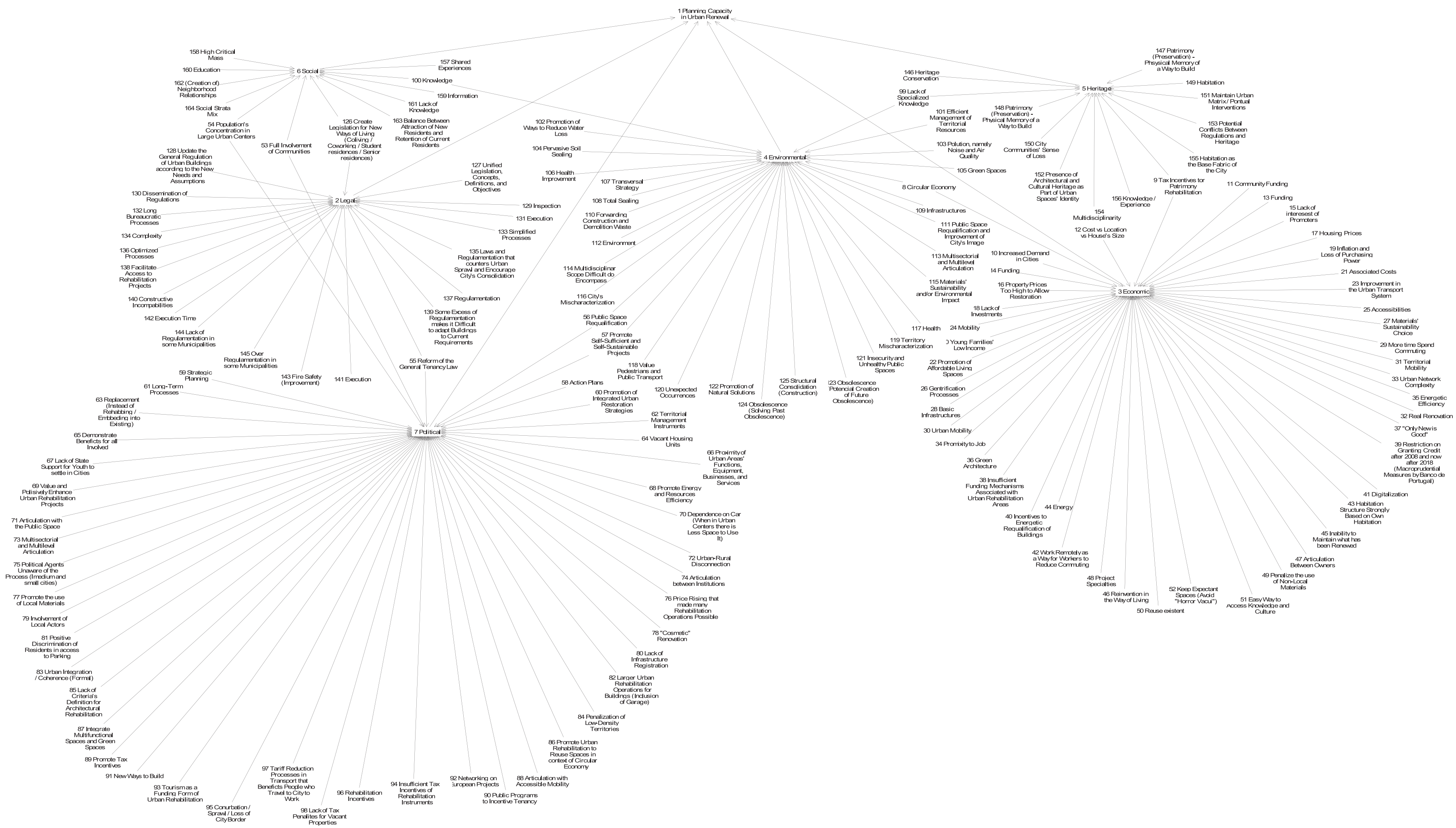

Fig. 3. Group cognitive map.

Table 1
Clusters (Cs) identified by experts.

Clusters	
C1	Legal
C2	Economic
C3	Environmental
C4	Heritage
C5	Social
C6	Political

interrelationships and neutrosophic values (see Table 2). Table 3 shows the calculations performed to achieve neutrosophic crispification.

The values obtained with neutrosophic crispification were input into the direct influence matrix shown in Table 4. The final DEMATEL values could then be calculated, and the remaining steps were completed using the equations given in *subsection 3.3*.

The totals of rows and columns (see Table 5) were used in the intermediate calculations based on the equations listed in *subsection 3.3.2*. The values were processed to produce normalized direct influence matrix (see Table 6). Next, total relation matrix T was constructed *via* the calculations shown in Table 7 (*i.e.*, identity matrix I, matrix $I - X$, and matrix $(I - X)^{-1}$ (see *subsection 3.3.3*)).

Once matrix T had been calculated (see *subsection 3.3.4*), column R revealed the influence that each cluster exerts on the others, while row C reflected the extent to which each cluster is influenced by the others. The results show that C2 has the greatest impact on all the other clusters, with a total R value of 3.6942. C4 has the least influence with 2.0683. Conversely, C2 is also the most affected by the others, with a C value of 3.2652, and the least influenced is C1 with 2.5374.

The α value is 0.4796 (see *subsection 3.3.5*), which highlights the most or least important factors, in green or red respectively, in the decision-support system. C4 is the only cluster with no significant impact on any other cluster. Fig. 4 contains the DEMATEL diagram for the inter-cluster analysis.

The map presented in Fig. 4 shows that C2 is the most important cluster as it is the furthest to the right compared to the rest. Based on the $R + C$ value, C2 is a cluster of essential factors because it appears in QI. C3 also appears in QI, which indicates that this group of criteria has strong relationships and greater prominence. C1 is the only cluster belonging to QII due to its strong relationships and less prominence, making C1 a cluster of determining factors. C4 and C5 are located in QIII, reflecting their weak relationships and less prominence as groups of independent factors. Finally, C6 appears in QIV as this cluster has weak relationships and greater prominence, which shows that C6 contains impact factors.

Table 2
DEMATEL neutrosophic matrix.

	C1	C2	C3	C4	C5	C6
C1	–	4 (0.95, 0.05, 0.00)	3 (0.60, 0.40, 0.00)	2 (0.80, 0.20, 0.05)	4 (0.70, 0.40, 0.10)	4 (33.3, 33.3, 33.3)
C2	3 (0.70, 0.10, 0.20)	–	4 (0.95, 0.05, 0.05)	4 (0.90, 0.30, 0.05)	4 (0.99, 0.40, 0.05)	4 (0.90, 0.40, 0.20)
C3	4 (0.80, 0.20, 0.20)	3 (0.80, 0.40, 0.10)	–	2 (0.60, 0.40, 0.10)	3 (0.80,0.30, 0.08)	4 (0.70, 0.40, 0.50)
C4	2 (0.50, 0.60, 0.60)	3 (0.70, 0.40, 0.30)	2 (0.60, 0.40, 0.30)	–	2 (0.60, 0.40, 0.30)	3 (0.80, 0.20, 0.10)
C5	2 (0.50, 0.60, 0.50)	4 (0.80, 0.40, 0.20)	3 (0.80, 0.60, 0.20)	3 (0.70, 0.40, 0.15)	–	4 (0.95, 0.7, 0.35)
C6	4 (0.91, 0.60, 0.03)	4 (0.80, 0.50, 0.40)	4 (0.90, 0.60, 0.30)	4 (0.70, 0.40, 0.50)	4 (0.98, 0.80, 0.80)	–

Note: C = cluster.

After the inter-cluster analysis was completed, the intra-cluster analyses started with C1. The expert panel selected the most important specific criteria (SC) presented in Table 8. The neutrosophic direct influence matrix for this cluster is presented in Table 9, which resulted in Table 10 after the crispification of the values.

An analysis of Table 11 shows that SC133 exerts the greatest influence on the other factors, with an R value of 6.2584. SC133 is also the most influenced by the other SCs as shown by its C value of 6.1339. In contrast, SC136 has the least influence on the other determinants, with an R value of 3.1897. Fig. 5 contains the IRM for C1.

According to Fig. 5, the most significant factor is SC133, with a total $R + C$ value of 12.3923. The least important is SC136, with a total of 9.3141. The causes group contains SC127, SC130, SC132, and SC133, while SC136 is the only effect. In addition, SC132 and SC133 belong to QI, so they are essential factors. SC127 and SC130 appear in QII as determining factors because they have strong relationships but less prominence. Finally, SC136 has weak relationships and less prominence, placing it in QIII as an independent factor.

The next step was to analyze C2. The SCs selected by the panel members are listed in Table 12. The associated neutrosophic matrix is presented in Table 13 and the values obtained by crispification appear in Table 14.

Based on matrix T, the α value of 1.8916 was used to identify the most and least important SCs. According to Table 15, SC13 exerts the greatest influence on the other factors, with an R value of 14.0983. SC16, SC19, and SC17 are the most affected by the others, with a C value of 13.9485.

According to the IRM in Fig. 6, SC19 is the most important C2 factor due to its $R + C$ value of 27.9411. The least significant determinant is SC31, with an $R + C$ value of 22.6965. The causes group comprises SC13, SC17, SC19, SC20, and SC22, while SC16 and SC31 are effects. The diagram reveals that QI contains the essential factors of SC19, SC17, and SC22, which have strong relationships and greater prominence. In QII, the determining factors are SC20 and SC13 with strong relationships and less prominence. SC31 belongs to QIII as its relationships and prominence are weaker, making this an independent factor. Finally, SC16 appears in QIV because this SC is an impact factor with weak relationships but greater prominence.

The most important SCs in C3 are listed in Table 16. The DEMATEL neutrosophic matrix in Table 17 facilitated the calculation of the values shown in the direct influence matrix (see Table 18), which were then translated into matrix T in Table 19.

Table 19 reveals that SC104 has more influence over the other factors, with an R value of 5.7369. SC122, in turn, is the most affected by the other determinants, with a C value of 5.6925. Fig. 7 contains the IRM diagram for C3. SC104, SC115, and SC122 belong to the causes group (*i.e.*, $R + C > 0$), while SC102 and SC105 are the effects group (*i.e.*, $R + C < 0$). In addition, SC104 and SC122 are essential factors because they fall within QI, given their strong relationships and greater prominence. SC115 is in QII, so it is a determining factor with strong relationships and less prominence. SC102 appears in QIII because it has weak relationships and less prominence (*i.e.*, an independent factor). Finally, SC105 in QIV has weak relationships and greater prominence as an impact factor.

The next cluster to be analyzed was C4, whose most important SCs are listed in Table 20. The DEMATEL neutrosophic matrix for this cluster is presented in Table 21. The calculations then produced the direct influence matrix in Table 22.

According to Table 23, the determinants that have the greatest influence within the cluster are SC152, SC153, SC156, and SC150, all with an R value of 146.3730. SC153 is the most affected by the other factors as it presents a C value of 142.3730.

The $R + C$ values produced the IRM shown in Fig. 8, based on an α value of 29.1146. In this cluster, the most important factors are SC152, SC156, and SC150, with a total of 292.7460. In contrast, SC153 and SC156 have an $R + C$ value of 288.7460, so they appear on the far left

Table 3
Neutrosophic crispification.

	Relationship analyzed	DEMATEL Scale (x)	Neutrosophic values			Neutrosophic Crispification		
			T	I	F	Crispification equation numerator	Crispification weight W	Final value in Matrix X
General matrix	C1-C2	4.0	0.95	0.05	0.00	0.9591751710	0.0471790100	3.83670068
	C1-C3	3.0	0.60	0.40	0.00	0.6734013676	0.0331226358	2.02020410
	C1-C4	2.0	0.80	0.20	0.05	0.8341687605	0.0410303117	1.66833752
	C1-C5	4.0	0.70	0.40	0.10	0.7056079711	0.0347067840	2.82243188
	C1-C6	4.0	0.33	0.33	0.33	0.5285836942	0.0259994797	2.11433478
	C2-C1	3.0	0.70	0.10	0.20	0.7839753101	0.0385614433	2.35192593
	C2-C3	4.0	0.95	0.05	0.05	0.9500000000	0.0467277102	3.80000000
	C2-C4	4.0	0.90	0.30	0.05	0.8151577249	0.0400952147	3.26063090
	C2-C5	4.0	0.99	0.40	0.05	0.7671910655	0.0377358756	3.06876426
	C2-C6	4.0	0.90	0.40	0.20	0.7354248689	0.0361733897	2.94169948
	C3-C1	4.0	0.80	0.20	0.20	0.8000000000	0.0393496507	3.20000000
	C3-C2	3.0	0.80	0.40	0.10	0.7354248689	0.0361733897	2.20627461
	C3-C4	2.0	0.60	0.40	0.10	0.6683375210	0.0328735600	1.33667504
	C3-C5	3.0	0.80	0.30	0.08	0.7867708588	0.0386989481	2.36031258
	C3-C6	4.0	0.70	0.40	0.50	0.5917517095	0.0291065289	2.36700684
	C4-C1	2.0	0.50	0.60	0.60	0.4313759297	0.0212181152	0.86275186
	C4-C2	3.0	0.70	0.40	0.30	0.6633498354	0.0326282304	1.99004951
	C4-C3	2.0	0.60	0.40	0.30	0.6303154498	0.0310033660	1.26063090
	C4-C5	2.0	0.60	0.40	0.30	0.6303154498	0.0310033660	1.26063090
	C4-C6	3.0	0.80	0.20	0.10	0.8267949192	0.0406676141	2.48038476
	C5-C1	2.0	0.50	0.60	0.50	0.4645873865	0.0228516892	0.92917477
	C5-C2	4.0	0.80	0.40	0.20	0.7171572875	0.0352748610	2.86862915
	C5-C3	3.0	0.80	0.60	0.20	0.6170291569	0.0303498523	1.85108747
	C5-C4	3.0	0.70	0.40	0.15	0.6986143113	0.0343627864	2.09584293
	C5-C6	4.0	0.95	0.70	0.35	0.5472307431	0.0269166733	2.18892297
	C6-C1	4.0	0.91	0.60	0.30	0.6092315263	0.0299663097	2.43692611
	C6-C2	4.0	0.80	0.50	0.40	0.6127016654	0.0301369957	2.45080666
	C6-C3	4.0	0.90	0.60	0.30	0.6084219959	0.0299264913	2.43368798
	C6-C4	4.0	0.70	0.40	0.50	0.5917517095	0.0291065289	2.36700684
	C6-C5	4.0	0.98	0.80	0.80	0.3467006812	0.0170531884	1.38680272
If S = -1, the relevant conditions are respected.					Crispification equation denominator	**20.3305489394**	1	

Note: DEMATEL = decision making trial and evaluation laboratory; T = trueness; I = indeterminacy; F = falseness; C = cluster.

Table 4
Direct influence matrix for clusters (Cs).

	C1	C2	C3	C4	C5	C6	Total
C1	0.00	3.84	2.02	1.67	2.82	2.11	12.46
C2	2.35	0.00	3.80	3.26	3.07	2.94	15.42
C3	3.20	2.21	0.00	1.34	2.36	2.37	11.47
C4	0.87	1.99	1.26	0.00	1.26	2.48	7.86
C5	0.93	2.87	1.85	2.10	0.00	2.19	9.93
C6	2.44	2.45	2.43	2.37	1.39	0.00	11.08
Total	9.79	13.35	11.37	10.73	10.90	12.09	

and have less significance within the decision-support system.

The IRM in Fig. 8 reveals that SC150, SC152, SC153, and SC156 are causes, while SC146 is the only effect because it has an $R - C$ value of less than 0. Concurrently, SC152, SC156, and SC150 are positioned in QI as essential factors since they have strong relationships and greater prominence. SC153 is the sole determining factor in QII due to its strong relationships and less prominence. Finally, QIII contains SC146, which makes this an independent factor because it not only has weak relationships but also less prominence.

The most important criteria in C5 are presented in Table 24. The resulting DEMATEL neutrosophic matrix is presented in Table 25. This matrix was then used to generate the direct influence matrix (see

Table 5
Row and column totals.

Max	13.35	15.42
1/max	0.074893	0.064839
1/s	**0.064839**	

Table 6
Normalized direct influence matrix.

	C1	C2	C3	C4	C5	C6
C1	0.0000	0.2488	0.1310	0.1082	0.1830	0.1371
C2	0.1525	0.0000	0.2464	0.2114	0.1990	0.1907
C3	0.2075	0.1430	0.0000	0.0867	0.1530	0.1535
C4	0.0562	0.1290	0.0817	0.0000	0.0817	0.1608
C5	0.0602	0.1860	0.1200	0.1359	0.0000	0.1419
C6	0.1580	0.1589	0.1578	0.1535	0.0899	0.0000

Note: C = cluster.

Table 7
Intermediate calculation and Matrix *T*.

I

	C1	C2	C3	C4	C5	C6
C1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C2	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
C3	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
C4	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
C5	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
C6	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Note: C = cluster.

$I - X$

	C1	C2	C3	C4	C5	C6
C1	1.0000	−0.2488	−0.1310	−0.1082	−0.1830	−0.1371
C2	−0.1525	1.0000	−0.2464	−0.2114	−0.1990	−0.1907
C3	−0.2075	−0.1430	1.0000	−0.0867	−0.1530	−0.1535
C4	−0.0562	−0.1290	−0.0817	1.0000	−0.0817	−0.1608
C5	−0.0602	−0.1860	−0.1200	−0.1359	1.0000	−0.1419
C6	−0.1580	−0.1589	−0.1578	−0.1535	−0.0899	1.0000

Note: C = cluster.

$(I - X)^{-1}$

	C1	C2	C3	C4	C5	C6
C1	1.3644	0.6731	0.5401	0.4980	0.5571	0.5575
C2	0.5543	1.5385	0.6829	0.6310	0.6234	0.6642
C3	0.5124	0.5609	1.3859	0.4440	0.5017	0.5325
C4	0.2931	0.4139	0.3496	1.2592	0.3304	0.4222
C5	0.3521	0.5284	0.4452	0.4402	1.3164	0.4750
C6	0.4612	0.5504	0.5062	0.4819	0.4353	1.3852

Note: C = cluster.

Matrix *T*

	C1	C2	C3	C4	C5	C6	*R*
C1	0.3644	0.6731	0.5401	0.4980	0.5571	0.5575	3.1901
C2	0.5543	0.5385	0.6829	0.6310	0.6234	0.6642	3.6942
C3	0.5124	0.5609	0.3859	0.4440	0.5017	0.5325	2.9375
C4	0.2931	0.4139	0.3496	0.2592	0.3304	0.4222	2.0683
C5	0.3521	0.5284	0.4452	0.4402	0.3164	0.4750	2.5572
C6	0.4612	0.5504	0.5062	0.4819	0.4353	0.3852	2.8201
C	2.5374	3.2652	2.9098	2.7542	2.7642	3.0365	

Note: C = cluster; R = rows vector; C = columns vector.

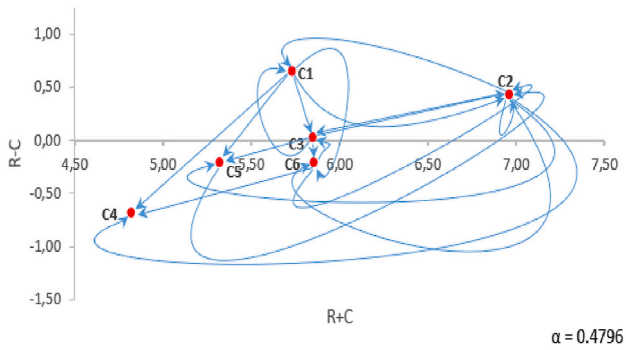

Fig. 4. Influence relation map for clusters (Cs).
Note. C = cluster; R = rows vector; C = columns vector; α = threshold value.

Table 8
Specific criteria (SC) selected by experts for C1.

Selected criteria	
SC127	Unified legislation, concepts, definitions, and objectives
SC130	Dissemination of regulations
SC132	Long bureaucratic processes
SC133	Simplified processes
SC136	Optimized processes

Table 9
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC127	SC130	SC132	SC133	SC136
SC127	–	4 (0.90, 0.60, 0.20)	4 (0.80, 0.05, 0.05)	4 (0.80, 0.05, 0.05)	4 (0.80, 0.05, 0.05)
SC130	4 (0.90, 0.10, 0.10)	–	4 (0.80, 0.05, 0.05)	4 (0.80, 0.05, 0.05)	4 (0.80, 0.05, 0.05)
SC132	4 (0.90, 0.05, 0.05)	4 (0.90, 0.05, 0.05)	–	4 (0.90, 0.05, 0.05)	4 (0.90, 0.05, 0.05)
SC133	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)
SC136	0 (0.90, 0.05, 0.00)	0 (0.90, 0.05, 0.00)	3 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–

Note. SC = specific criteria.

Table 26).

The calculations completed produced Table 27, which reveals that SC157 has the greatest impact on the other factors as it has an R value of 9.3592. SC157 is also the most influenced by the other determinants, with a C value of 7.5395.

Based on an α value of 1.7118, Fig. 9 shows that the most important factor in this cluster is SC162, with an $R + C$ value of 17.9978. SC163 is the least significant because it appears the furthest to the left, given its $R + C$ value of 16.1946. The analysis also defined the cause and effect groups, with SC157, SC160, and SC162 as causes and thus the most influential determinants and SC163 and SC164 as the effects.

In addition, QI includes both SC162 and SC160, making these essential factors with strong relationships and greater prominence. SC157 fits into QII as a determining factor, with strong relationships but less prominence. As SC163 appears in QIII, this SC can be considered an independent factor with weak relationships and less prominence. Finally, SC164 falls into QIV as an impact factor with weak relationships but greater prominence.

The same steps were again followed to analyze C6. The seven criteria chosen by the decision makers are listed in Table 28. The DEMATEL neutrosophic matrix is presented in Table 29 and the direct influence matrix in Table 30.

Table 31 reveals that SC59 most strongly influences the other factors, with an R value of 8.3289. SC59 is also the most affected by others in this cluster, with a C value of 8.5525.

Fig. 10 reflects an α value of 1.0801, revealing that SC59 is again the most important determinant as it appears on the far right with an $R + C$ value of 16.8814. In turn, SC64 is the least significant with an $R + C$ value of 9.3220. The SCs allocated to the causes group are SC62, SC66, and SC72 as their $R – C$ value is less than 0, while SC58, SC59, SC60, and SC64 belong to the effects group.

SC62, SC66, and SC72 appear in QI as essential factors. QIII contains only S64, which is an independent factor with weak relationships and less prominence. Finally, SC59, SC58, and SC60 all fall into QIV, so they are impact factors (*i.e.*, weak relationships and greater prominence).

4.3. Consolidation, discussion, and recommendations

To obtain feedback on the analysis model and its practical application, a consolidation session was held with an additional specialist in urban renewal. At the time of this study, she was urban planner and spatial engineer at the Lisbon City Council Department of Urban Planning, and vice-president of the Portuguese Association of Urban Planners. She was also the Portuguese delegate to the European Council of Spatial Planners-Conseil Européen des Urbanistes (ECSP-CEU). This expert was chosen because she could be impartial about the results of the panel's decision-making process as she did not participate in the two previous group work sessions.

The final session was held online *via* the Teams platform. The meeting lasted about one hour and had the following agenda: a brief contextualization of the study and applied methodologies followed by a presentation of the cognitive map and the results achieved with the neutrosophic logic and DEMATEL techniques.

Regarding the cognitive map, the interviewee commented that the large number of criteria *"makes reaching a decision afterwards very complex"* (in her words). She further observed that the social cluster *"is also very important in urban renewal because, if we do not consider it* [the social dimension] *in conjunction with the buildings, the whole thing doesn't work"* (also in her words). After examining the inter- and intra-cluster analysis results, the specialist considered strategic planning (SC59) in the political cluster (C6) to be the most important, especially given that *"it is the one that is* [...] *most despised. When it is said that it is necessary to plan and then intervene, everyone wants to skip that part and go straight to the intervention"*. She added that *"everyone changes this SC to reflect what they want"* because strategic planning is the most strongly influenced by

Table 10
Direct influence matrix.

	SC127	SC130	SC132	SC133	SC136	Total
SC127	0.00	2.52	3.51	3.51	3.51	13.05
SC130	3.60	0.00	3.51	3.51	3.51	14.13
SC132	3.72	3.72	0.00	3.72	3.72	14.87
SC133	3.74	3.72	3.72	0.00	3.72	14.89
SC136	0.00	0.00	2.81	3.74	0.00	6.55
Total	11.06	9.96	13.54	14.48	14.45	

Note. SC = specific criteria.

Table 11
Matrix *T*.

	SC127	SC130	SC132	SC133	SC136	*R*
SC127	0.8559	0.9406	1.2226	1.2872	1.2855	5.5918
SC130	1.1157	0.8541	1.2983	1.3670	1.3651	6.0002
SC132	1.1588	1.0893	1.1536	1.4249	1.4230	6.2496
SC133	1.1613	1.0906	1.3550	1.2269	1.4247	6.2584
SC136	0.5101	0.4793	0.7462	0.8280	0.6261	3.1897
C	4.8018	4.4538	5.7758	6.1339	6.1244	

Note. SC = specific criteria; R = rows vector; C = columns vector.

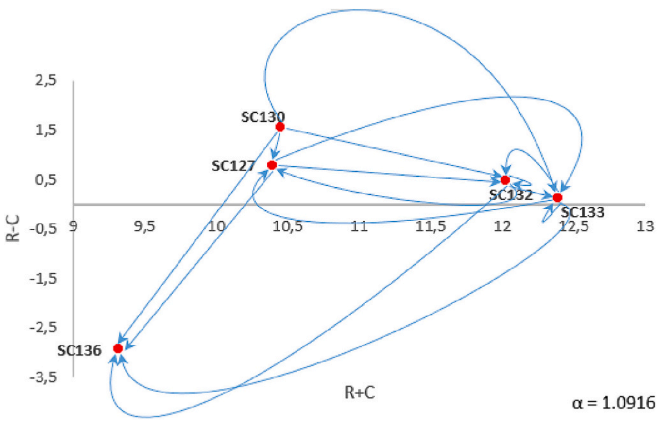

Fig. 5. Influence relation map for C1.
Note. SC = specific criteria; R = rows vector; C = columns vector; *α* = threshold value.

Table 12
Criteria (SC) selected by experts for C2.

Selected criteria	
SC20	Young families' low income
SC16	Property prices too high to allow restoration
SC19	Inflation and loss of purchasing power
SC17	Housing prices
SC22	Promotion of affordable living spaces
SC13	Funding
SC31	Territorial mobility

decision makers (in the interviewee's words).

The interviewee also noted that the applied methodologies were unfamiliar but that they appeared to be interesting in that *"they consider many points. That is, the methodologies can include many factors"*. In general, she found the techniques to be *"a very powerful methodology for this type of assessment and decision support"* (in her words).

When this expert was asked to point out possible advantages and disadvantages, she remarked that something can always be said about these kinds of results as *"they depend on the participants' points of view and background"*. She specifically found the political cluster's weight *"very large"*. In her opinion, *"the social element was a little too small because, in urban renewal,* […] *if we do not carry out a complete urban renewal project* […] *with both social and physical dimensions, it does not work"* (in her words).

The interviewee suggested the findings could be improved by *"testing some of the parameters by applying the measuring attractiveness by a categorical-based evaluation technique* [MACBETH] *to calibrate the model"* (again in her words). In addition, she pointed out that the model created is *"quite interesting but that it should be tested to see if it is valid beyond the scope of urban renewal"*. She concluded that *"it is a very interesting way not to reach decisions but to provide several options for what to do. It might be more interesting as a tool to intervene in or prioritize decisions"* (in her words).

Table 13
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC20	SC16	SC19	SC17	SC22	SC13	SC31
SC20	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.80, 0.10, 0.05)
SC16	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.50)	4 (0.80, 0.10, 0.05)
SC19	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.80, 0.10, 0.05)
SC17	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.80, 0.10, 0.05)
SC22	4 (0.90, 0.20, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC13	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)
SC31	0 (0.80, 0.10, 0.00)	4 (0.90, 0.20, 0.05)	4 (0.90, 0.20, 0.05)	4 (0.90, 0.20, 0.05)	3 (0.90, 0.20, 0.05)	1 (0.90, 0.10, 0.05)	–

Note. SC = specific criteria.

Overall, the consolidation session confirmed that this study provides a methodological framework whose application can result in different findings when the techniques are applied in diverse contexts. Since the methodologies are process-oriented, results for one urban zone should not be generalized to other areas. In some respects, the actual outcomes may not be as critical as the process itself. Bell and Morse (2013, p. 962) note that this approach puts *"less emphasis on outputs per se and more focus on process"*. Although focused primarily on methodological issues, this study is realistic as each geographical area has specific unique characteristics that require different solutions to address urban renewal issues.

5. Conclusion

Urban renewal planning is crucial for addressing multiple problems and challenges when addressing specific and unique urban neighborhood characteristics, especially in diverse domains. Even though each urban renewal project is unique and complicated, experts generally agree that they share a similar purpose: to provide residents with better living conditions and better living standards. By necessity, urban renewal projects involve many entities, including governments and

Table 14
Direct influence matrix.

	SC20	SC16	SC19	SC17	SC22	SC13	SC31	Total
SC20	0.00	3.74	3.74	3.74	3.74	3.74	3.47	22.18
SC16	3.74	0.00	3.74	3.74	3.74	2.82	3.47	21.25
SC19	3.74	3.74	0.00	3.74	3.74	3.74	3.47	22.18
SC17	3.74	3.74	3.74	0.00	3.74	3.74	3.43	22.14
SC22	3.48	3.74	3.74	3.74	0.00	3.74	3.74	22.19
SC13	3.74	3.74	3.74	3.74	3.74	0.00	3.74	22.45
SC31	0.00	3.47	3.47	3.47	2.60	0.91	0.00	13.93
Total	18.45	22.18	2.35	22.18	21.31	18.70	21.33	

Note. SC = specific criteria.

Table 15
Matrix *T*.

	SC20	SC16	SC19	SC17	SC22	SC13	SC31	*R*
SC20	1.6865	2.1206	2.1206	2.1206	2.0529	1.8460	2.0452	13.9926
SC16	1.7644	1.9024	2.0452	2.0452	1.9799	1.7501	1.9722	13.4593
SC19	1.8294	2.1206	1.9778	2.1206	2.0529	1.8460	2.0452	13.9926
SC17	1.8278	2.1186	2.1186	1.9758	2.0510	1.8444	2.0421	13.9784
SC22	1.8145	2.1146	2.1146	2.1146	1.9039	1.8399	2.0484	13.9505
SC13	1.8410	2.1355	2.1355	2.1355	2.0670	1.7152	2.0686	14.0983
SC31	1.1234	1.4361	1.4361	1.4361	1.3613	1.1649	1.2584	9.2164
C	11.8871	13.9485	13.9485	13.9485	13.4688	12.0066	13.4801	

Note. SC = specific criteria; R = rows vector; C = columns vector.

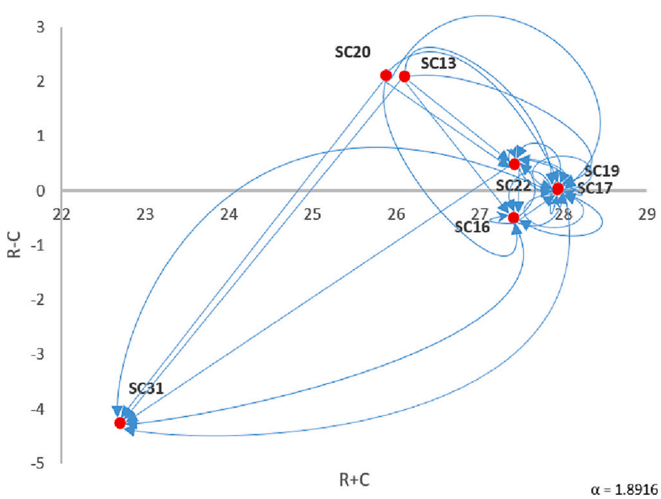

Fig. 6. Influence relation map for C2. Note. SC = specific criteria; R = rows vector; C = columns vector; α = threshold value.

Table 16
Criteria (SC) selected by experts for C3.

Selected criteria	
SC105	Green spaces
SC102	Promotion of ways to reduce water loss
SC104	Pervasive soil sealing
SC115	Materials' sustainability and/or environmental impact
SC122	Promotion of natural solutions

varied public and private organizations. Our literature review confirms that these actors are all seeking to reduce social, economic, and environmental inequalities.

Table 17
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC105	SC102	SC104	SC115	SC122
SC105	–	4 (0.90, 0.05, 0.05)	4 (0.95, 0.05, 0.00)	1 (0.80, 0.20, 0.10)	4 (0.98, 0.05, 0.00)
SC102	3 (0.80, 0.10, 0.10)	–	0 (0.90, 0.05, 0.05)	3 (0.50, 0.20, 0.10)	4 (0.80, 0.10, 0.05)
SC104	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC115	4 (0.98, 0.05, 0.00)	2 (0.90, 0.00, 0.00)	4 (0.90, 0.50, 0.30)	–	4 (0.90, 0.05, 0.00)
SC122	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–

Note. SC = specific criteria.

City planners are often unable to achieve desired attributes in urban areas, including local communities' maintaining unique, desired identities and social inclusion.

Studies document high failure rates in the planning and implementation of urban renewal project plans often due to a lack of consensus among project stakeholders. Thus, stakeholders and further studies needed to facilitate cooperation among relevant entities and clarify participating decision makers' opinions. In addition, urban renewal determinants must be transparently identified and defined, concentrating on cause-and-effect relationships among identified factors. In addressing the scarcity of dynamic analyses, we adopt a new decision-making approach that provides a solution to these problems, including a combination of cognitive mapping, neutrosophic logic and the DEMATEL technique.

Our main contribution is the methodology applied that represents experts' ideas giving them sufficient autonomy to express their opinions and values. Two group work sessions facilitated the participants' constant learning process due to the constructivist stance of the selected techniques. The results confirm that the applied multicriteria methodologies (*i.e.*, cognitive mapping, neutrosophic logic, and DEMATEL)

Table 18
Direct influence matrix.

	SC105	SC102	SC104	SC115	SC122	Total
SC105	0.00	3.72	3.84	0.83	3.88	12.26
SC102	2.58	0.00	0.00	2.05	3.47	8.10
SC104	3.74	3.74	0.00	3.74	3.74	14.97
SC115	3.88	1.88	2.63	0.00	3.74	12.14
SC122	3.74	3.74	3.72	3.74	0.00	14.94
Total	13.93	13.09	10.19	10.36	14.83	

Note. SC = specific criteria.

Table 19
Matrix *T*.

	SC105	SC102	SC104	SC115	SC122	*R*
SC105	0.9146	1.0975	0.9199	0.7799	1.1752	4.8872
SC102	0.7812	0.6160	0.5211	0.6099	0.8598	3.3880
SC104	1.2773	1.2428	0.8422	1.0361	1.3385	5.7369
SC115	1.1378	1.0166	0.8879	0.7197	1.1823	4.9443
SC122	1.2756	1.2412	1.0397	1.0347	1.1367	5.7280
C	5.3866	5.2142	4.2108	4.1803	5.6925	

Note. SC = specific criteria; R = row vector; C = column vector.

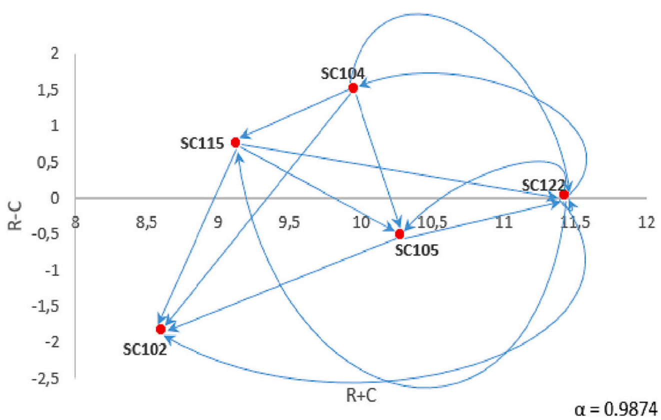

Fig. 7. Influence relation map for C3. Note. SC = specific criteria; R = rows vector; C = columns vector; α = threshold value.

Table 20
Criteria (SC) selected by experts for C4.

Selected criteria	
SC152	Presence of architectural and cultural heritage as part of urban spaces' identity
SC153	Potential conflicts between regulations and heritage
SC156	Knowledge and/or experience
SC146	Heritage conservation
SC150	City communities' sense of loss

allow decision makers to deal with the complex environments that require urban renewal.

Cognitive mapping produces a visual representation of the expert panel's thinking about the clusters of factors affecting urban renewal, while neutrosophic logic incorporates a realistic degree of uncertainty into the findings of the DEMATEL technique. The analyses clarify cause-and-effect relationships among the defined clusters, thereby creating a holistic, transparent model that can be applied by practitioners in real urban settings. This allows the three research questions initially presented to be addressed (*i.e.*, How can urban renewal's main

Table 21
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC152	SC153	SC156	SC146	SC150
SC152	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC153	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC156	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC146	4 (0.90, 0.05, 0.00)	4 (0.90, 0.30, 0.10)	4 (0.90, 0.05, 0.00)	–	4 (0.9, 0.05, 0.00)
SC150	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–

Note. SC = specific criteria.

determinants and corresponding key factors be identified? What are the most influential relationships between these variables? and Which complex challenges should decision makers prioritize to facilitate urban renewal?).

Our findings have significant implications for urban socio-planning and renewal practices, as well as theoretical and practical contributions to management research and the business world. By identifying key factors and relationships through a constructivist methodology, we provide valuable insights for decision-makers to navigate urban development complexities effectively. Specifically, our study highlights the importance of a holistic and process-oriented approach to urban renewal planning, involving experts from diverse fields to ensure inclusivity, transparency, and reflection of the multifaceted nature of urban challenges. Moreover, our approach adds value to the field by offering a practical and innovative method for addressing complex decision problems in urban renewal. The combination of cognitive mapping, neutrosophic logic, and DEMATEL provides a comprehensive framework for analyzing and prioritizing factors, enabling more informed and evidence-based decision-making.

On a theoretical level, the findings contribute to existing knowledge by incorporating valuable know-how from urban renewal experts, and the proposed model complements previous contributions in related fields. From a methodological perspective, this study provides two significant contributions. First, the combination of methods used, confirmed as a novel approach in urban renewal contexts by the

Table 22
Direct influence matrix.

	SC152	SC153	SC156	SC146	SC150	Total
SC152	0.00	3.74	3.74	3.74	3.74	14.97
SC153	3.74	0.00	3.74	3.74	3.74	14.97
SC156	3.74	3.74	0.00	3.74	3.74	14.97
SC146	3.74	3.23	3.74	0.00	3.74	14.46
SC150	3.74	3.74	3.74	3.74	0.00	14.97
Total	14.97	14.46	14.97	14.97	14.97	

Note. SC = specific criteria.

Table 23
Matrix *T*.

	SC152	SC153	SC156	SC146	SC150	*R*
SC152	29.2746	28.6746	29.4746	29.4746	29.4746	146.3730
SC153	29.4746	28.4746	29.4746	29.4746	29.4746	146.3730
SC156	29.4746	28.6746	29.2746	29.4746	29.4746	146.3730
SC146	28.6746	27.8746	28.6746	28.4746	28.6746	142.3730
SC150	29.4746	28.6746	29.4746	29.4746	29.2746	146.3730
C	146.3730	142.3730	146.3730	146.3730	146.3730	

Note. SC = specific criteria; R = row vector; C = column vector.

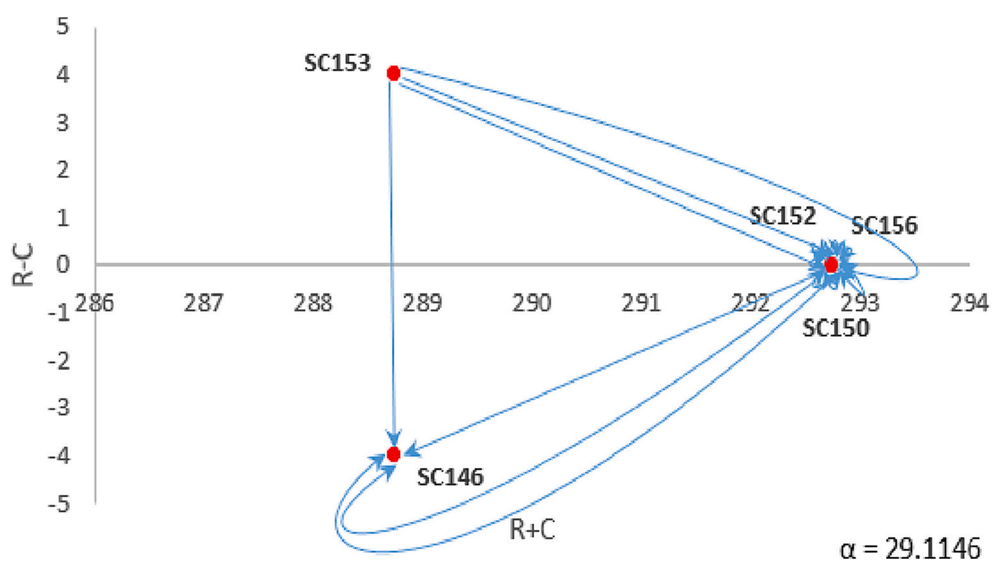

Fig. 8. Influence relation map for C4. Note. SC = specific criteria; R = rows vector; C = columns vector; α = threshold value.

Table 24
Criteria (SC) selected by experts for C5.

Selected criteria	
SC160	Education
SC162	(Creation of) neighborhood relationships
SC163	Balance between attraction of new residents and retention of current residents
SC164	Social strata mix
SC157	Shared experiences

literature review. Second, the detailed description of the procedures followed enables the replication of techniques in other environments. The selected methodology facilitated the creation of a group cognitive map with 156 criteria addressing or affecting the challenges under study. These findings ultimately contribute to mitigating real problems by providing an intuitive decision-support tool for any urban planner.

Table 25
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC160	SC162	SC163	SC164	SC157
SC160	–	4 (0.90, 0.10, 0.10)	4 (0.80, 0.20, 0.10)	4 (0.95, 0.05, 0.05)	4 (0.90, 0.05, 0.00)
SC162	4 (0.90, 0.10, 0.10)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.80, 0.20, 0.10)
SC163	2 (0.70, 0.20, 0.10)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.10, 0.10)	3 (0.70, 0.20, 0.10)
SC164	4 (0.90, 0.05, 0.00)	4 (0.80, 0.10, 0.30)	4 (0.80, 0.20, 0.20)	–	3 (0.70, 0.20, 0.30)
SC157	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–

Note. SC = specific criteria.

Table 26
Direct influence matrix.

	SC160	SC162	SC163	SC164	SC157	Total
SC160	0.00	3.60	3.31	3.80	3.74	14.45
SC162	3.60	0.00	3.74	3.74	3.31	14.39
SC163	1.57	3.74	0.00	3.60	2.35	11.26
SC164	3.74	3.14	3.20	0.00	2.19	12.27
SC157	3.74	3.74	3.74	3.74	0.00	14.97
Total	12.65	14.22	13.99	14.88	11.59	

Note. SC = specific criteria.

Table 27
Matrix *T*.

	SC160	SC162	SC163	SC164	SC157	*R*
SC160	1.5874	1.9385	1.9049	2.0170	1.6693	9.1170
SC162	1.7658	1.7302	1.9094	1.9994	1.6370	9.0419
SC163	1.3795	1.6052	1.3893	1.6555	1.3170	7.3464
SC164	1.5789	1.6909	1.6750	1.5786	1.4084	7.9317
SC157	1.8279	1.9912	1.9696	2.0626	1.5079	9.3592
C	8.1395	8.9560	8.8482	9.3130	7.5395	

Note. SC = specific criteria; R = row vector; C = column vector.

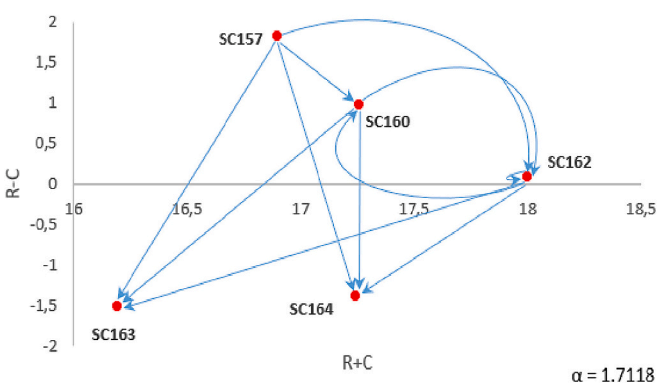

Fig. 9. Influence relation map for C5. Note. SC = specific criteria; R = rows vector; C = columns vector; α = threshold value.

Table 28
Criteria (SC) selected by experts for C6.

Selected criteria	
SC64	Vacant housing units
SC60	Promotion of integrated urban restoration strategies
SC62	Territorial management instruments
SC66	Proximity of urban areas' functions, equipment, businesses, and services
SC72	Urban-rural disconnection
SC58	Action plans
SC59	Strategic planning

Table 29
Decision making trial and evaluation laboratory neutrosophic matrix.

	SC64	SC60	SC62	SC66	SC72	SC58	SC59
SC64	–	4 (0.90, 0.05, 0.00)	1 (0.80, 0.30, 0.40)	2 (0.80, 0.20, 0.20)	2 (0.80, 0.20, 0.20)	1 (0.80, 0.20, 0.20)	3 (0.80, 0.10, 0.10)
SC60	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	2 (0.80, 0.20, 0.20)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC62	0 (0.90, 0.05, 0.05)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (1.00, 0.00, 0.00)	4 (1.00, 0.00, 0.00)
SC66	1 (0.80, 0.05, 0.05)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (1.00, 0.00, 0.00)	4 (1.00, 0.00, 0.00)
SC72	4 (0.90, 0.05, 0.00)	2 (0.80, 0.05, 0.05)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)
SC58	1 (0.80, 0.05, 0.05)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–	4 (0.90, 0.05, 0.00)
SC59	3 (0.80, 0.30, 0.10)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	4 (0.90, 0.05, 0.00)	–

Note. SC = specific criteria.

This tool can facilitate and guide decision-makers' strategic planning, ensuring appropriate decisions and stimulating further discussions on the benefits of urban renewal.

No methodological approach is free of limitations. To strengthen the proposed model, future investigations can include selecting other panels of experts from different regions and other backgrounds to verify whether the above findings are still valid. Researchers may also want to take into consideration that each urban area has specific characteristics that, as mentioned in the consolidation session, may make the proposed model appropriate for one region but less relevant in another. Additional studies could compare the model with new results produced by applying, for example, MACBETH to determine if the findings are different and the calibrations more precise, as suggested in the consolidation session. Finally, the same specialist indicated that the techniques could be used to address decision problems in other areas besides urban renewal as she considered the methodologies to be quite interesting. Overall, this research comprises a significant contribution to the existing literature on this topic and offers improved methodologies that enhance planning capacity in urban renewal.

Table 30
Direct influence matrix.

	SC64	SC60	SC62	SC66	SC72	SC58	SC59	Total
SC64	0.00	3.74	0.69	1.60	1.60	0.80	2.58	11.01
SC60	3.74	0.00	3.74	3.74	1.60	3.74	3.74	20.31
SC62	0.00	3.74	0.00	3.74	3.74	4.00	4.00	19.23
SC66	0.88	3.74	3.74	0.00	3.74	4.00	4.00	20.10
SC72	3.74	1.76	3.74	3.74	0.00	3.74	3.74	20.46
SC58	0.88	3.74	3.74	3.74	3.74	0.00	3.74	19.59
SC59	2.35	3.74	3.74	3.74	3.74	3.74	0.00	21.06
Total	11.59	20.46	19.40	20.31	18.17	20.03	21.80	

Note. SC = specific criteria.

Table 31
Matrix *T*.

	SC64	SC60	SC62	SC66	SC72	SC58	SC59	R
SC64	0.3788	0.7668	0.6515	0.7007	0.6364	0.6712	0.7670	4.5725
SC60	0.7767	1.0721	1.2084	1.2361	1.0623	1.2364	1.2904	7.8824
SC62	0.6550	1.2283	1.0938	1.2637	1.1607	1.2771	1.3226	8.0011
SC66	0.7023	1.2546	1.2627	1.1412	1.1825	1.3001	1.3490	8.1926
SC72	0.7818	1.1542	1.2164	1.2442	1.0010	1.2446	1.2990	7.9412
SC58	0.6876	1.2293	1.2373	1.2618	1.1587	1.1190	1.3133	8.0072
SC59	0.7672	1.2736	1.2749	1.3023	1.1955	1.3043	1.2111	8.3289
C	4.7495	7.9789	7.9449	8.1500	7.3971	8.1528	8.5525	

Note. SC = specific criteria; R = row vector; C = column vector.

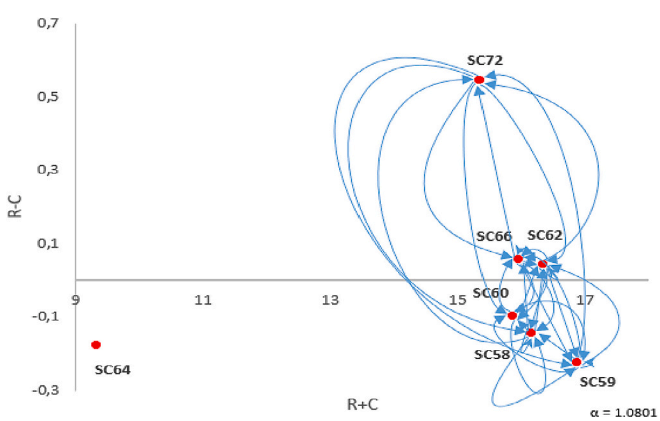

Fig. 10. Influence relation map for C6. Note. SC = specific criteria; R = row vector; C = column vector; α = threshold value.

CRediT authorship contribution statement

Tiago A.A. Cordeiro: Investigation, Writing – original draft. **Fernando A.F. Ferreira:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ronald W. Spahr:** Formal analysis, Writing – original draft, Writing – review & editing, Data curation. **Mark A. Sunderman:** Writing – original draft, Writing – review & editing, Data curation, Formal analysis. **Neuza C.M.Q.F. Ferreira:** Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Funding acquisition, Resources, Software.

Data availability

Data will be made available on request.

Acknowledgments

This research was partially funded by the Portuguese Foundation for Science and Technology (Grants UIDB/00315/2020 and UIDB/04630/2020). Records of the expert panel meetings, including photographs, software output, and non-confidential information, can be obtained from the corresponding author upon request. The authors gratefully acknowledge the contribution of the panel members: Carmen Carvalheira, Iara Ferreira, João Valério, José Lopes, Maria João Pessoa, and Sónia Marques. The authors are also grateful to Paula Pacheco, vice-president of the Portuguese Association of Urban Planners and Portuguese delegate to the European Council of Spatial Planners – Conseil Européen des Urbanistes (ECSP-CEU), for the insights she provided during this study's consolidation phase.

References

Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Smarandache, F. (2019). A novel method for solving the fully neutrosophic linear programming problems. *Neural Computing and Applications, 31*, 1595–1605.

Abdel-Basset, M., Manogaran, G., Gamal, A., & Smarandache, F. (2018). A hybrid approach of neutrosophic sets and DEMATEL method for developing supplier selection criteria. *Design Automation for Embedded Systems, 22*(4), 257–278.

Ackermann, F., & Eden, C. (2001). SODA–journey making and mapping in practice. In J. Rosenhead, & J. Mingers (Eds.), *Rational analysis for a problematic world revisited: Problem structuring methods for complexity, uncertainty and conflict* (pp. 43–60). Chichester: John Wiley & Sons.

Al-Subhi, S., Pupo, I., Vacacela, R., Pérez, P., & Vásquez, M. (2018). A new neutro- sophic cognitive map with neutrosophic sets on connections, application in project management. *Neutrosophic Sets and Systems, 22*, 63–75.

Andrade, F., Ferreira, F., & Correia, R. (2022). Ranking residential neighborhoods based on their sustainability: A CM-BWM approach. *International Journal of Strategic Property Management, 26*(6), 410–423.

Bana e Costa, C., Corrêa, É., Corte, J., & Vansnick, J. (2002). Facilitating bid evaluation in public call for tenders: A socio-technical approach. *Omega–The International Journal of Management Science, 30*(3), 227–242.

Bana e Costa, C., Stewart, T., & Vansnick, J. (1997). Multicriteria decision analysis: Some thoughts based on the tutorial and discussion sessions of the ESIGMA meetings. *European Journal of Operational Research, 99*(1), 28–37.

Bell, S., & Morse, S. (2013). Groups and facilitators within problem structuring processes. *Journal of the Operational Research Society, 64*(7), 959–972.

Braga, I., Ferreira, F., Ferreira, J., Correia, R., Pereira, L., & Falcão, P. (2021). A DEMATEL analysis of smart city determinants. *Technology in Society, 66*, 1–13.
Broumi, S., Bakali, A., Talea, M., Smarandache, F., Dey, A., & Son, L. (2018). Spanning tree problem with neutrosophic edge weights. *Procedia Computer Science, 127*, 190–199.
Carayannis, E., Ferreira, F., Bento, P., Ferreira, J., Jalali, M., & Fernandes, B. (2018). Developing a socio-technical evaluation index for tourist destination competitiveness using cognitive mapping and MCDA. *Technological Forecasting and Social Change, 131*, 147–158.
Chen, F., Hsu, T., & Tzeng, G. (2011). A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. *International Journal of Hospitality Management, 30*(4), 908–932.
Costa, J., Ferreira, F., Spahr, R., Sunderman, M., & Pereira, L. (2021). Intervention strategies for urban blight: A participatory approach. *Sustainable Cities and Society, 70*, 1–14.
Cui, J., Broere, W., & Lin, D. (2021). Underground space utilisation for urban renewal. *Tunnelling and Underground Space Technology, 108*, 1–10.
Das, S., Kumar, S., Kar, S., & Pal, T. (2019). Group decision making using neutrosophic soft matrix: An algorithmic approach. *Journal of King Saud University, Computer and Information Sciences, 31*(4), 459–468.
Dhar, S., & Kundu, M. (2017). Accurate segmentation of complex document image using digital shearlet transform with neutrosophic set as uncertainty handling tool. *Applied Soft Computing, 61*, 412–426.
Eden, C. (2004). Analyzing cognitive maps to help structure issues or problems. *European Journal of Operational Research, 159*(3), 673–686.
Eden, C., & Ackermann, F. (2004). Cognitive mapping expert views for policy analysis in the public sector. *European Journal of Operational Research, 152*(3), 615–630.
Falatoonitoosi, E., Leman, Z., Sorooshian, S., & Salimi, M. (2013). Decision-making trial and evaluation laboratory. *Research Journal of Applied Sciences, Engineering and Technology, 5*(13), 3476–3480.
Ferreira, F., Spahr, R., Sunderman, M., Govindan, K., & Meidutė-Kavaliauskienė, I. (2022). Urban blight remediation strategies subject to seasonal constraints. *European Journal of Operational Research, 296*(1), 277–288.
Gabus, A., & Fontela, E. (1972). *World problems: An invitation to further thought within the framework of DEMATEL*. Geneva: Battelle Geneva Research Centre.
Horng, J., Liu, C., Chou, S., & Tsai, C. (2013). Creativity as a critical criterion for future restaurant space design: Developing a novel model with DEMATEL application. *International Journal of Hospitality Management, 33*, 96–105.
Huang, L., Zheng, W., Hong, J., Liu, Y., & Liu, G. (2020). Paths and strategies for sustainable urban renewal at the neighbourhood level: A framework for decision-making. *Sustainable Cities and Society, 55*, 1–14.
Huang, Y., Wei, W., & Ferreira, F. (2023). How to make urban renewal sustainable? Pathway analysis based on fuzzy-set qualitative comparative analysis (fsQCA). *International Journal of Strategic Property Management, 27*(3), 146–158.
Jung, T., Lee, J., Yap, M., & Ineson, E. (2015). The role of stakeholder collaboration in culture-led urban regeneration: A case study of the Gwangju project, Korea. *Cities–The International Journal of Urban Policy and Planning, 44*, 29–39.
Karaaslan, F. (2017). Possibility neutrosophic soft sets and PNS-decision making method. *Applied Soft Computing, 54*, 403–414.
Lin, S., Huang, X., Fu, G., Chen, J., Zhao, X., Li, J., & Tzeng, G. (2021). Evaluating the sustainability of urban renewal projects based on a model of hybrid multiple-attribute decision-making. *Land Use Policy, 108*, 1–21.
Lo, H., Liou, J., Huang, C., Chuang, Y., & Tzeng, G. (2020). A new soft computing approach for analyzing the influential relationships of critical infrastructures. *International Journal of Critical Infrastructure Protection, 28*, 1–16.
Lousada, A., Ferreira, F., Meidutė-Kavaliauskienė, I., Spahr, R., Sunderman, M., & Pereira, L. (2021). A sociotechnical approach to causes of urban blight using fuzzy cognitive mapping and system dynamics. *Cities–The International Journal of Urban Policy and Planning, 108*, 1–13.
Mehdipanah, R., Malmusi, D., Muntaner, C., & Borrell, C. (2013). An evaluation of an urban renewal program and its effects on neighborhood resident's overall wellbeing using concept mapping. *Health & Place, 23*, 9–17.
Pérez, M., Laprise, M., & Rey, E. (2018). Fostering sustainable urban renewal at the neighborhood scale with a spatial decision support system. *Sustainable Cities and Society, 38*, 440–451.
Pinto, A., Ferreira, F., Spahr, R., Sunderman, M., Govindan, K., & Meidutė-Kavaliauskienė, I. (2021). Analyzing blight impacts on urban areas: A multi-criteria approach. *Land Use Policy, 108*, 1–14.
Pinto, B., Ferreira, F., Spahr, R., Sunderman, M., & Pereira, L. (2023). Analyzing causes of urban blight using cognitive mapping and DEMATEL. *Annals of Operations Research, 325*(2), 1083–1110.
Pramanik, S., Banerjee, D., & Giri, B. (2016). TOPSIS approach for multi attribute group decision making in refined neutrosophic environment. In F. Smarandache, & S. Pramanik (Eds.), *New trends in Neutrosophic theory and applications* (pp. 79–91). Brussels, Belgium, EU: Pons Editions.
Quader, M., Ahmed, S., Ghazilla, R., Ahmed, S., & Dahari, M. (2016). Evaluation of criteria for CO2 capture and storage in the iron and steel industry using the 2-tuple DEMATEL technique. *Journal of Cleaner Production, 120*, 207–220.
Quezada, L., López-Ospina, H., Ortiz, C., Oddershede, A., Palominos, P., & Jofré, P. (2022). A DEMATEL-based method for prioritizing strategic projects using the perspectives of the balanced scorecard. *International Journal of Production Economics, 249*, 1–11.
Rivieccio, U. (2008). Neutrosophic logics: Prospects and problems. *Fuzzy Sets and Systems, 159*(14), 1860–1868.
Rodrigues, M., Ferreira, F., & Ferreira, N. (2023). Constructing smarter and more sustainable urban ecosystems: A dynamic analysis of challenges and initiatives. *Annals of Operations Research*. https://doi.org/10.1007/s10479-023-05406-2
Salmeron, J. (2009). Augmented fuzzy cognitive maps for modelling LMS critical success factors. *Knowledge-Based Systems, 22*(4), 275–278.
Shafiee, M., Zare-Mehrjerdi, Y., Govindan, K., & Dastgoshade, S. (2022). A causality analysis of risks to perishable product supply chain networks during the COVID-19 outbreak era: An extended DEMATEL method under Pythagorean fuzzy environment. *Transportation Research Part E: Logistics and Transportation Review, 163*, 1–17.
Shamai, M., & Hananel, R. (2021). One+one+one=a lot: The cumulative effect of Israel's flagship urban renewal policy on neighborhood diversity. *Land Use Policy, 100*, 1–12.
Si, S., You, X., Liu, H., & Zhang, P. (2018). DEMATEL technique: A systematic review of the state-of-the-art literature on methodologies and applications. *Mathematical Problems in Engineering*. https://doi.org/10.1155/2018/3696457
Sumrit, D., & Anuntavoranich, P. (2013). Using DEMATEL method to analyze the causal relations on technological innovation capability evaluation factors in thai technology-based firms. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 4*(2), 81–103.
Trivedi, A. (2018). A multi-criteria decision approach based on DEMATEL to assess determinants of shelter site selection in disaster response. *International Journal of Disaster Risk Reduction, 31*, 722–728.
Uygun, Ö., Kaçamak, H., & Kahraman, Ü. (2015). An integrated DEMATEL and fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company. *Computers & Industrial Engineering, 86*, 137–146.
Vaz-Patto, C., Ferreira, F., Govindan, K., & Ferreira, N. (2023). Rethinking urban quality of life: Unveiling causality links using cognitive mapping, neutrosophic logic and DEMATEL. *European Journal of Operational Research*. https://doi.org/10.1016/j.ejor.2023.12.034
Village, J., Salustri, F., & Neumann, W. (2013). Cognitive mapping: Revealing the links between human factors and strategic goals in organizations. *International Journal of Industrial Ergonomics, 43*(4), 304–313.
Vishwakarma, A., Dangayach, G., Meena, M., & Gupta, S. (2022). Analysing barriers of sustainable supply chain in apparel & textile sector: A hybrid ISM-MICMAC and DEMATEL approach. *Cleaner Logistics and Supply Chain, 5*, 1–10.
Wang, A., Hu, Y., Li, L., & Liu, B. (2016). Group decision making model of urban renewal based on sustainable development: Public participation perspective. *Procedia Engineering, 145*, 1509–1517.
Wang, H., Shen, Q., Tang, B., Lu, C., Peng, Y., & Tang, L. (2014). A framework of decision-making factors and supporting information for facilitating sustainable site planning in urban renewal projects. *Cities–The International Journal of Urban Policy and Planning, 40*(A), 44–55.
Wang, S., Esther, H., Yu, Y., & Tsou, J. (2022). Right to the city and community facility planning for elderly: The case of urban renewal district in Hong Kong. *Land Use Policy, 114*, 1–16.
Wang, Y., Li, J., Zhang, G., Li, Y., & Asare, M. (2017). Fuzzy evaluation of comprehensive benefit in urban renewal based on the perspective of core stakeholders. *Habitat International, 66*, 163–170.
Wang, Z., Jie, H., Fu, H., Wang, L., Jiang, H., Ding, L., & Chen, Y. (2022). A social-media-based improvement index for urban renewal. *Ecological Indicators, 137*, 1–14.
Yazdi, M., Khan, F., Abbassi, R., & Rusli, R. (2020). Improved DEMATEL methodo- logy for effective safety management decision-making. *Safety Science, 127*, 1–17.
Yıldız, S., Kıvrak, S., Gültekin, A., & Arslan, G. (2020). Built environment design: Social sustainability relation in urban renewal. *Sustainable Cities and Society, 60*, 1–8.
Zhang, W., Zhang, X., & Wu, G. (2021). The network governance of urban renewal: A comparative analysis of two cities in China. *Land Use Policy, 106*, 1–13.
Zheng, H., Shen, G., & Wang, H. (2014). A review of recent studies on sustainable urban renewal. *Habitat International, 41*, 272–279.
Zheng, W., Shen, G., Wang, H., Hong, J., & Li, Z. (2017). Decision support for sustainable urban renewal: A multi-scale model. *Land Use Policy, 69*, 361–371.
Zhou, Y., Lan, F., & Zhou, T. (2021). An experience-based mining approach to supporting urban renewal mode decisions under a multi-stakeholder environment in China. *Land Use Policy, 106*, 1–13.