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Spatial analysis of unsafe areas in molavi neighborhood of qazvin city based on the analytic network process (ANP) and geographic information system (GIS)

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158

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Abstract

Ensuring environmental security in urban contexts, particularly in neighborhoods with deteriorated fabric, is a fundamental component for improving urban quality of life and preventing spaces from becoming crime hotspots. This is a fundamental necessity in the urban planning and management process and plays an important role in creating a sense of security, social sustainability, and increasing the desirability of public spaces. This research, using a quantitative method and focusing on practical results, aims to provide a precise and operational analytical framework. The main goal of this research is a comprehensive spatial analysis and prioritization of unsafe urban spaces. The study area of this research is the Molavi neighborhood of Qazvin, which is one of the sensitive urban contexts that requires targeted intervention in environmental security. To achieve this goal, researchers developed an advanced analytical framework that integrated analytic network process (ANP) and spatial analysis of the Geographic Information System (GIS), with the Fuzzy ANP method. The results of the ANP analysis showed that, among the three main criteria for determining unsafe spaces in the neighborhood, “function” had the highest priority (0.488), followed by “physical form” (0.308) and “environmental quality” (0.204). Among the sub-criteria, “neighborhood blind spots” (0.223) and “insufficient lighting” (0.213) had the highest weights, while “inconsistent walls” (0.001) had the least importance in intensifying the feeling of insecurity. The Fuzzy ANP spatial analysis showed that most unsafe spaces were concentrated in the central, western, and southwestern parts of the Molavi neighborhood. This analysis clearly revealed the spatial heterogeneity in the distribution of security in the Molavi neighborhood. Insecurity hotspots were systematically associated with structural weaknesses in the physical form of the neighborhood (passages with inappropriate geometry and blind spots), lack of social supervision by residents, lack of lighting, the presence of abandoned buildings, and the management-development gap of the neighborhood, which practically removed these areas from the circle of attention and effective urban planning interventions. Finally, according to the map of unsafe spaces, the neighborhood was zoned into three security levels: ‘weak’, ‘medium’, and ‘high’ to formulate targeted intervention strategies. Key suggested solutions include: increasing social surveillance in the neighborhood (through mixing local uses and designing pause spaces in the neighborhood), emphasizing active and adaptive lighting, using high-resolution cameras and night vision, and employing modern security technology such as a WebGIS-based continuous monitoring system and smart cameras (equipped with analytical capabilities). These solutions offer a practical tool for urban designers and planners to take an effective step towards enhancing neighborhood security by targeting areas prone to crime.

Keywords

ANP network analysis
Environmental security
Fuzzy ANP spatial analysis
Molavi Neighborhood
Qazvin city

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1. Introduction

Given the rapid urbanization process and increasing population concentration, cities act as complex socio-technical systems whose inherent characteristics significantly increase the level of risk and add to the complexity of security challenges.

Security in the city goes beyond the mere control of physical crime; it is a multidimensional and dynamic construct that encompasses physical, social, perceptual, and technological dimensions (Nicolini, 2024). The issue of a city's security includes the interests of all residents. Security is a common good and a resource to which residents have equal or universal access. Protecting the lives and property of residents is the fundamental goal of urban security because effective urban security measures can not only reduce the level of crime, traffic accidents, and injuries from other incidents, but more importantly, can ensure the safety and well-being of residents.

Therefore, a suitable urban space should be able to provide security to various user groups to a large extent. Today, the success of an urban space can be evaluated and examined according to the number of women and men using it, as well asthe variety of characteristics of people who work in these spaces with a sense of security and comfort (Haji Ahmadi Hamedani et al., 2015).

On the contrary, unsafe neighborhoods are the site of major social anomalies that, in addition to financial and personal losses to residents, cause irreparable mental and psychological harm to families and severely affect the upbringing of future generations (Sakip and Abdullah, 2012). People in these neighborhoods feel insecure, which is an emotional and perceptual phenomenon more related to the psychological feeling of citizens about threatening factors, such as crime. The level of an individual's sense of insecurity may not correspond to the external reality of the level of threatening factors, or vice versa; it may be consistent with it. Therefore, the feeling of insecurity is an attitude of the individual towards the external environment and a threatening factor (Gholam-Hosseini 2012). Fear of crime and lack of security prevent citizens from being present in urban spaces. It can be said that the presence of individuals in society is directly related to their sense of security (Mostofi al-Mamalaki and Bahrami, 2014: 94-95). The lack of security not only disrupts cultural growth and public participation but also imposes great costs on society. It leads to a behavioral gap in society and the emergence of abnormal urban behaviors (Afsari et al, 2014).

The innovation and importance of this research lie in providing a systematic and practical approach to identifying and evaluating unsafe spaces in old and deteriorated urban neighborhoods. This research, beyond describing the current situation, focuses on ranking environmental factors and insecure spaces so that limited resources are allocated in a targeted manner for the intervention of municipalities and security institutions. This will be an effective step in improving the security situation and enhancing the citizens' quality of life, because it not only reveals the main environmental problems of the neighborhood, but also allows for detailed planning to improve spaces, develop appropriate infrastructure, and promote a security-oriented culture in society.

The context of this research, at a neighborhood scale, is specifically focused on the Molavi neighborhood of Qazvin. The Molavi neighborhood, as one of the oldest neighborhoods in the city, is a prominent example of an urban area that simultaneously struggles with physical, functional, and security challenges due to its location in the historical, traditional, and deteriorated area of Qazvin. In such neighborhoods, environmental factors have a double impact on the perception and experience of insecurity.

In this regard, this study seeks to answer the following main questions:

- What environmental factors affect the determination of insecure spaces in the Molavi neighborhood, and how are they prioritized?
- What are the insecure spaces and points in the Molavi neighborhood of Qazvin city based on the identified environmental criteria?

The answer to these questions can provide the necessary scientific basis for intervention policies to promote the resilience and security of the Molavi neighborhood.

2. Theoretical foundations of the research

2.1. Security

Although the Oxford Dictionary defines it as a state of being free from danger or threat, the word 'security' originates from the Old French word 'securite' or the Latin word 'securitas' from 'securus', meaning freedom from fear. Webster's dictionary also defines security as the quality or condition of being free from danger, injury, or harm. In fact, security refers to a state of protection against life-threatening and disabling events (Brown, Dike, and Chikagbum, 2015). Security has two basic elements: threat and opportunity, and its establishment depends on relative freedom from threat and optimal use of opportunities. In this way, the realization of security depends on confronting dangers on the one hand. On the other hand, it is a result of having facilities and improving living conditions and systems (Mohseni, 2009).

Table1. Security and its conceptual dimensions, Source: (Mohseni, 2009)

Security	Dimensions
Preserving life	Coping with risks
Improving living standards	Seizing opportunities

In the life of any society at any time, security and its sense are considered important factors for its existence and maintenance. Historical evidence also shows that whenever a society enjoys security and the peace that comes from it, it grows and achieves its highest aspirations. On the other hand, when the security of a society changes, the sense of security decreases, and even its basic affairs will not progress (Motamedi, 2014). It is stated in the Universal Declaration of Human Rights as one of the social rights of man and is placed on the same level as freedom. The need for security has always been considered one of the most fundamental human needs. With the increase and complexity of societies, the conditions for meeting this need and resolving this issue have also become more complex (Heshmati, 2003).

2.2. Security in urban spaces / environmental security

Security is the foundation of a healthy society, and a sense of security is the foundation for the development of human societies. The prosperity of a society depends on the preservation and survival of security and the feeling of security that comes from it (Kamran and Shoa Barabadi, 2009: 25). In this context, environmental security is defined as the peace, security, and lack of fear of citizens from any environmental danger and threat (natural and man-made) that affects the vitality, health, presence, and public participation of citizens (Kiani et al., 2013: 110). Environmental security emphasizes the security of citizens and their sense of safety from natural and man-made disasters. The urban structure and construction standards, as well as compliance with the city's physical security criteria, play a prominent role in creating a sense of environmental security. In a safe city, safety is ensured in urban spaces, and individuals feel safe and free from danger in the city. In a safe city, efforts are made to minimize the risk level for citizens (Pourjafar et al, 2008).

The sense of insecurity is among the primary issues in urban spaces, creating conditions more susceptible to crime occurrence. The feeling of security in urban spaces is one of the indicators of the quality of space, and even though the issue of safe urban space in every society is a complex issue with diverse and numerous social, economic, and cultural dimensions. However, meeting this need should not ignore the role and impact of environmental and physical factors. Urban spaces, as an environment in which public human behavior takes place, are always in a two-way interaction with humans. Therefore, urban spaces as a platform for public human activities must be both easily understandable and safe (Kiani et al., 2013: 110). Thus, the presence of security in urban environments can be considered one of the basic requirements of the quality of life.

2.3. Main theories related to the issue of urban security

Jane Jacobs' theory

Jane Jacobs, in her book "The Death and Life of Great American Cities" (1961), proposes a new perspective on the role of urban designers, planners, and architects in influencing crime levels. Early in his book (1961: 30), Jacobs identifies safety and security as key elements of a well-functioning city: "The bedrock of a successful urban neighborhood is that one feels safe and secure on the street." He also observes that a few incidents of violence can create fear among residents, which can reduce street use and make it more unsafe. He argues that crime is not a problem in slums, but "in fact, the problem is more serious in quiet, seemingly aristocratic residential areas."

As successful neighborhood streets are, city streets must have three main qualities to deal with outsiders and to protect their assets (Jacobs, 2007: 31):

- There should be a clear demarcation between public and private space, and private and public spaces should not interfere with each other.
- Eyes must be open to the streets, eyes that belong to

the street's legitimate owners. Street buildings, equipped to face strangers and also to ensure their safety and that of their residents, must face the street.

- Sidewalks should be used continuously, both to increase the number of eyes on the street and to encourage a sufficient number of people living in buildings along the street to look at the sidewalks. A basic prerequisite for such care is a significant number of shops and other public spaces scattered along the sidewalks of an area. The presence of public spaces and businesses that are used in the evening and at night is essential. For example, shops, bars, and restaurants act in different and complex ways to enhance the sidewalks.

The theory of defensible space

In the late 1960s and early 1970s, an American architect and urban planner, Oscar Newman, studied crime rates and the design of public housing. He published his findings in "Defensible Space: Crime Prevention through Urban Design in 1972." In many ways, this work is considered a scientificization of Jacobs' theories. In both the United States and Britain, Newman's work quickly gained widespread attention. This occurred during a period of increasing crime rates and widespread dissatisfaction with current methods for addressing crime.

Newman (1973) developed his hierarchy of defensible space, influenced by Jacobs' (1961) concept of the distinction between private and public space.

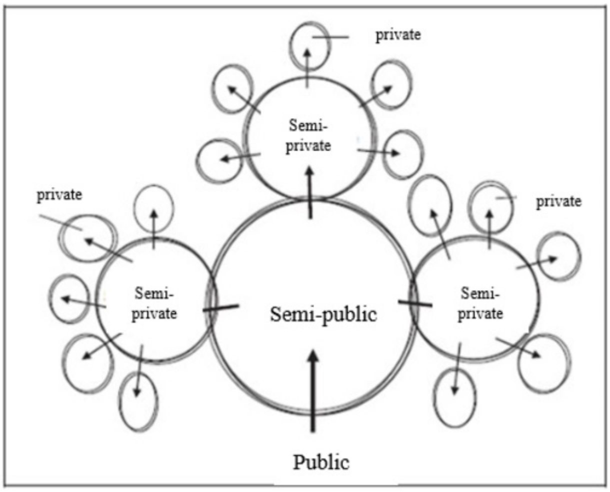


Figure 1. Hierarchy of defensible space Source: Newman (1973)

Five factors make a space defensible (Newman, 1973):

- Territorialization: The idea that one's home is sacred. In Newman's view, people need to define and defend their territory. In his opinion, good design encourages people to define their territory and makes them defend the boundaries of their territory against strangers.
- Natural surveillance: In this type of surveillance, residents routinely and casually monitor the public and semi-public spaces of their living area and identify strangers in the area.
- Mental image: Newman believes that by designing a crime-resistant space, all the negative and incorrect influences that create a bad mental image in the community are neutralized and ineffective.
- Social environment and conditions: Other features that may affect security, such as proximity to a police station or busy commercial areas.
- Safe neighborhoods: For better security, residents gain more ability to monitor the surrounding area through the design of the surrounding area.

Broken Windows Theory

The "Broken Windows Theory" is one of the most famous theories regarding the importance of crime attitudes. This theory, proposed by Kling and Wilson in 1982, suggests that the physical environment plays a significant role in the level of criminal activity and fear of crime. Kling and Wilson, by suggesting that law enforcement only focuses on serious crimes, believe that serious crimes occur as a result of a series of minor crimes that lead to the final serious crime (Cozens, 2008). The Broken Windows Theory addresses the issue of crime prevention by focusing on residents' awareness of suspicious behavior, environmental protection, and its consequences. It emphasizes the critical importance of environmental protection as a physical indicator of social solidarity and cohesion, as well as informal social control (Nazarian et al., 2013: 61).

This theory is often equated with crime reduction. From this theory's perspective, social disorganization is transformed into serious crimes through intermediaries. The theory essentially states that crime is no different from social disorder. If society is indifferent to social disorder, these social disorders will gradually become more severe and will turn into crime (Gau et al., 2014).

The main premise of this theory is that visual cues in public places, such as the neighborhood's dirtiness and abandoned cars, attract criminals and make them think that residents are indifferent to what is happening in their neighborhood. In other words, the broken windows theory shows that the image of neighborhoods with proper lighting, care, and maintenance has a great impact on reducing the fear of crime. According to this theory, three hypotheses have been proposed about the motivation of public fear. Public fear is caused by the fear of becoming a victim of crime, fear of disturbing people, and fear that arises from the disorder and neglect of a physical environment. This theory is based on environmental neglect and forgetfulness, suggesting that an unrepaired broken window indicates a lack of care, making it seem acceptable to break more windows. The broken windows theory is consistent with the defensible space and CPTED theories because, like them, it believes that the poor quality of the environment in which people live can hurt residents' sense of pride in their surroundings, so they are less reactive to environmental problems and crime in their neighborhoods (Farid Tehrani, 2011: 33-34). According to the broken windows theory, crime imitates disorder; if disorder is eliminated, serious crime does not occur. A particular criticism of this theory is the link between undesirable phenomena such as homelessness and crime. However, other researchers have shown that such a link often does not exist. The theory has also been criticized for offering a short-term partial solution, criminalizing communities of color, implicitly biasing against racial or cultural minorities, assuming a causal relationship between social disorder and crime, ignoring a third factor, namely collective effectiveness, and generally for not being theoretically strong enough (Piroozfara et al, 2019).

3. Research background (research background in time and space)

Sou et al. (2023) measured the relationship between urban design quality at a human scale and crime density on streets around the entrance to the New York subway. The results showed a significant relationship between urban design quality and crime density. "Person", "safety", and "complexity" are associated with higher crime density, while "bench", "streetlight", "skyscrapers", "human scale", and "Imageability" are associated with lower crime risk. The results of Rafifa and Tarigan's (2023) study on vertical housing in Greater Jakarta demonstrated that all aspects of CPTED, including accessibility, territory, and community, should be considered in designing a safe and comfortable vertical housing environment. The scale of the building is also a key factor in the occurrence of crime. When the scale is too large, surveillance and bonding between residents are not strong. However, it is important to emphasize that CPTED was created to reduce crime, not eliminate it. Karimi et al. (2024) stated in an article titled "Identifying and prioritizing spatial-physical indicators affecting security in urban spaces (Case study: Golestan Alley, Sabzevar)" that the spatial-physical characteristics of Golestan Alley affecting the feeling of security can be identified in the form of 19 indicators and 6 main criteria. The geometry of passages, grade (width of the passages), and block system are the first three important indicators. The physical permeability, presence, and visual permeability are the three key spatial-physical criteria that impact the sense of security among citizens in the Golestan Alley neighborhood of Sabzevar. Also, Zahra Hamafar et al. (2023) in their study titled "Identifying unsafe public spaces in urban neighborhoods and redesigning them with an approach to improving environmental security (case study: Narmak, Sanglaj, Kargar Shomali, and Bagh Shater neighborhoods in Tehran)" concluded that there are about 20 unsafe locations or spaces in the Sanglaj neighborhood, the most important features of which are the open-ended alleys and easy escape possibilities for criminals, the unsafe corners created by setback of buildings, lack of light and lamps, lack of retail or related services that have a greater presence and security, and the presence of homeless people and groups of criminals and addicts on some routes. However, making urban neighborhoods safe, especially in the central part of cities, is not realized only through physical measures and design; it also requires social, policy, and management measures. In another study, Mohammadi et al. (2019) addressed the zoning of defenseless and crime-prone spaces in the city of Ardabil. The results showed that most marginal neighborhoods and villages integrated into the organic fabric of the northern, northwestern, and western regions of Ardabil have unfavorable conditions in terms of their ability to defend themselves against criminal behavior and are largely vulnerable to the emergence of criminal behavior. They offered suggestions to improve the conditions through employing appropriate security equipment, making spaces desirable by using appropriate lighting systems, eliminating dead and abandoned spaces and obstacles to observer vision, and educating citizens. Considering the necessity and importance of women's feelings of safety in urban spaces, Sarah Schuberleitner (2022) stated in "Examining gender-related planning opportunities to encourage urban safety" that safety should be considered in a broader context with related factors, such as access to services and meeting basic human needs. For urban planners, this means engaging at the local level and treating residents as experts to develop effective strategies that do not exacerbate their feelings of insecurity. This, in combination with aspects of existing planning approaches, can lead to safer and more inclusive cities. Also, Babaei Mohammadi et al. (2023) identified the factors that make women in Tehran's 19th district feel insecure and strategies to improve safety. The findings showed that the main causes of insecurity among women are the lack of visibility of the place, light and illumination, and visual pollution, with an emphasis on the presence of homeless people and addicts in public spaces. The next case is completely male activities and brick kilns, which play an important role in creating a sense of insecurity among women in the region due to attracting deviant activities and factors. To minimize the feeling of insecurity in the region and its negative consequences, there is a need to consider plans for "creating and strengthening local social oversight" with a community-based approach.

As one of the first scientific efforts to identify unsafe neighborhood spaces, this study presents the Fuzzy ANP method, combining complex priority structuring with ANP and spatial capabilities (ArcGIS). This methodological combination provides a solid basis for a deep understanding of the spatial distribution and factors affecting the sense of insecurity in the deteriorated and old urban neighborhoods.

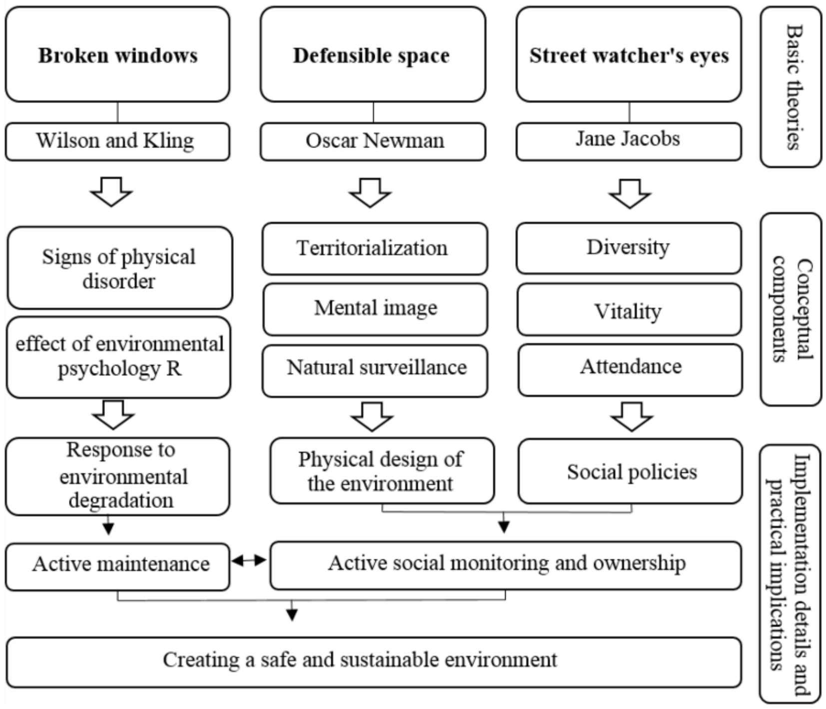
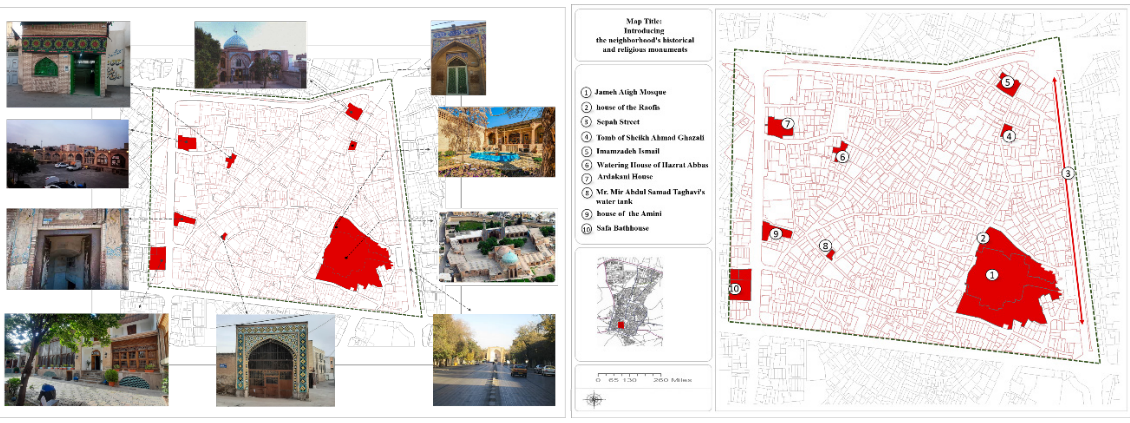


Figure 2. Conceptual research model

3.1. The neighborhood under study

According to the regional division and neighborhood map of Qazvin city, Molavi neighborhood is in District 1 of Qazvin; it is adjacent to Shahid Ansari Street from the north, Shohada Street (the first pre-designed street in Iran) from the east, Molavi Street from the west, and Montazeri Street from the south. This neighborhood is located in the center of Qazvin. Many historical and religious monuments and buildings, such as the Atiq Jameh Mosque or the Great Jameh Mosque, the Raofi House, the Imamzadeh of Ismail (AS), the tomb of Sheikh Ahmad Ghazali, the Saqakhaneh of Hazrat Abbas (AS), the Ardakani Palace, and the like, are located in the neighborhood. Map 1 shows the location of the Molavi neighborhood in Qazvin, and Map 2 shows the status of historical, religious, and old monuments in the Molavi neighborhood.

Map 1. Location of the Molavi neighborhood



Map 2. Status of historical, religious, and old monuments in the neighborhood

4. Materials and methods

This research is classified within the framework of quantitative research. It is an applied research in terms of purpose, and an analytical-spatial research in terms of methodology. The process of locating unsafe spaces, due to its multifactorial nature, requires accurate modeling based on raster layers and the use of specialized GIS software that supports multi-criteria spatial decision-making (MCDM) processes. The detailed stages of conducting the research are described step by step (Figure 3).

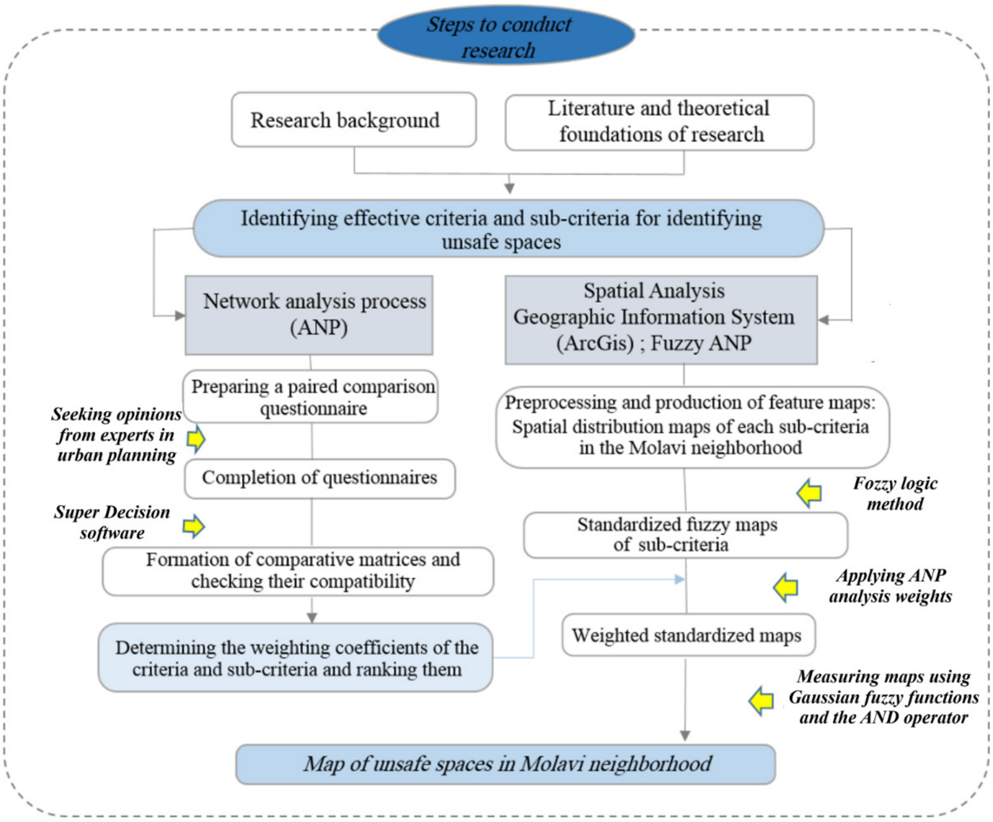


Figure 3. Research steps

4.1. Identification of criteria and sub-criteria

Based on the theoretical foundations and background of existing research, physical, functional, and environmental quality criteria of urban space that exert their direct and indirect effects on environmental security patterns and have accessible statistics were extracted. For this purpose, twelve sub-criteria were considered and prepared for standardization, ANP network analysis process, and final processing in ArcGIS (Table2). They include low-width passages, blind and indefensible spots, walls inconsistent with the environment, dead-end passages, gathering place for criminals, abandoned buildings and wasteland and inactive areas, lack of night activities, lack of a proper mix of uses and diversity of activities, lack of separation of motorists from pedestrians, lack of security cameras, lack of lighting (dark pavement), and lack of urban furniture. Importantly, all of the mentioned sub-criteria have an inverse relationship with the issue of environmental security sensitivity; that is, increasing these sub-criteria will lead to a decrease in the degree of environmental security sensitivity.

Table 2. Effective criteria and sub-criteria for identifying unsafe spaces in the Molavi neighborhood

Code	Criteria	Subcriterion	Source
PF	Physical form	Low-width passages	(Meysam Karimi et al., 2024; Carmona, 2003; Asarian, 2007)
		Dead-ends	(Salehi, 2008)
		Blind and indefensible spots	(Zahra Hamafar et al., 2023; Mahboobeh Babaei Mohammadi et al., 2023; Assarian, 2007)
		Inconsistent wall with the environment	(Su et al., 2023) (Kling and Wilson, 1982)

Code	Criteria	Subcriterion	Source
P	Functional	Gathering place for criminals	(Alikhah and Najibi, 2006; Zahra Hamafar et al., 2023; Mahboobeh Babaei Mohammadi et al., 2023; Kling and Wilson, 1982; Carmona, 2003)
		Abandoned buildings, wasteland, and inactive areas	(Su et al., 2023; Kling and Wilson,1982; Alikhah and Najibi, 2006; Assarian, 2007)
		Lack of night activities	(Meysam Karimi et al., 2024; Jane Jacobs, 2007; Newman, 1973)
		Lack of a proper mix of uses and diversity of activities	(Sarah Schuberleitner, 2022; Mahboobeh Babaei Mohammadi et al., 2023; Zahra Hamafar et al., 2023; Jane Jacobs, 2007; Newman, 1973; Salehi, 2008)
		Lack of separation of motorists from pedestrians	(Salehi, 2008)
EQ	Environmental quality	Lack of security cameras	(Mahboobeh Babaei Mohammadi et al., 2023; Kling and Wilson, 1982)
		Lack of lighting (dark pavement)	(Mahboobeh Babaei Mohammadi et al., 2023; Zahra Hamafar et al., 2023; Su et al., 2023; Kling and Wilson, 1982; Carmona, 2003)
		Lack of urban furniture	(Kling and Wilson, 1982; Su et al., 2023)

4.2. Analytical network process (ANP)

The analytical network process is an advanced multi-criteria decision-making method designed to solve complex problems and consider dependencies and interactions between criteria and options. This method, an extension of the AHP (analytical hierarchy process) model, enables the examination of indirect relationships and cross-correlations. In ANP, unlike AHP, which assumes the criteria and options as independent, dependencies and recursive relationships are considered, adding to the accuracy and flexibility of the method.

The applications of ANP are very broad and include areas such as project management, strategic planning, risk assessment, and decision-making in complex situations. This method not only helps decision-makers better understand the impact of complex relationships but also enables more comprehensive analysis and more informed choices.

First, the subject, goal, criteria, and sub-criteria must be formed as a network of factors. Figure 4 shows the network diagram of this research. As the figure shows, this model includes one goal, three main criteria, and 12 sub-criteria.

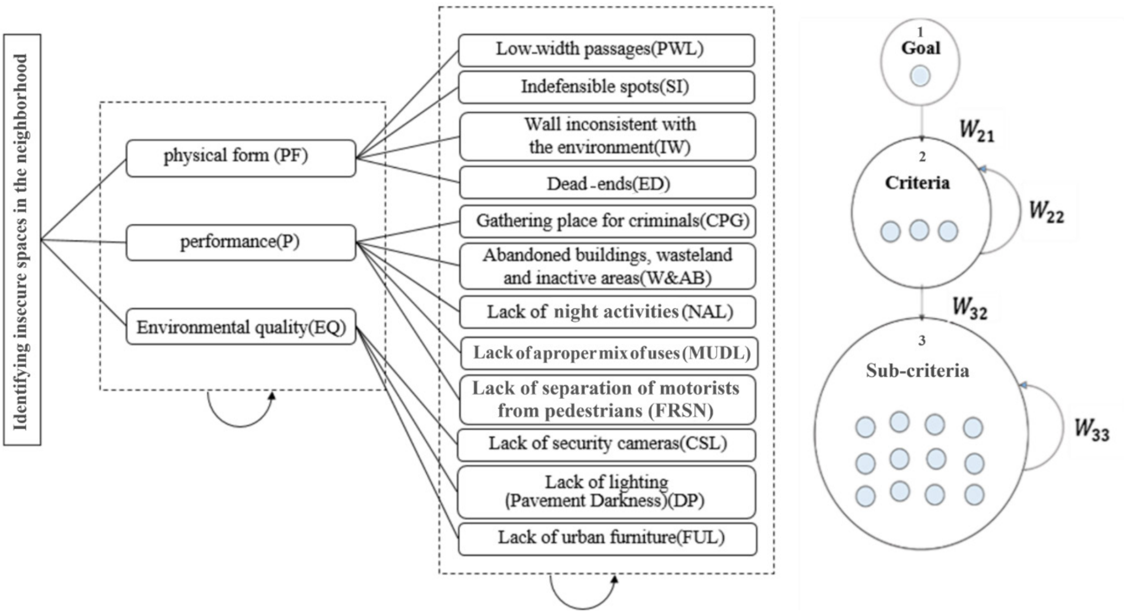


Figure 4. Network model for selecting unsafe spaces in the Molavi neighborhood

The scores and relationships between the factors studied are based on the collection of specialized data. The necessary data were provided to twenty prominent experts and professors in urban planning and urban design through a targeted and specialized questionnaire. This data collection process ensured the inclusion of expert views in the analysis. The main basis for scoring and determining the weight of factors in this section was the results extracted from the nine-quantity hourly table (Table 3). This analysis provided a comprehensive and accurate review of the opinions and views of experts, which were collected in the form of quantitative data from questionnaires. Super Decision software was used to conduct this analysis, and three clusters of objectives, criteria, and sub-criteria were created.

Table3. Nine-quantity hourly table for scoring in pairwise comparisons (Saati, 1999 cited in Zabardast, 2002:15)

Score	Definition	Explanation
1	Equal importance	In achieving the goal, the two criteria are of equal importance.
3	Slightly more important	Experience shows that for achieving the goal, the importance of i is slightly greater than that of j.
5	More important	Experience shows that the importance of i is greater than that of j.
7	Much more important	Experience shows that the importance of i is much greater than that of j.
9	Absolute importance	The much greater importance of i than j has been definitively proven.
2,4,6,8	Intermediate values	When there are intermediate states.

To construct the initial supermatrix, it is necessary first to obtain the vectors W22, W21, W32, and W33. All the quantitative values of these vectors, which indicate the intensity and direction of influence between the components, are presented comprehensively and documented in the research findings section.

To determine the consistency of the comparisons, the criteria weight consistency index was used, which is calculated using equation 1:

$$CI = \frac{\lambda - n}{n - 1}$$

Equation 1. Equation for calculating the consistency of comparisons

Generally, if the CI is less than 0.1, the comparison is considered confirmed.

Geographic information system (GIS) spatial analysis; Fuzzy ANP analysis

Preprocessing and production of feature maps

Spatial analyses based on geographic information systems (GIS) constitute the core of this research. In this stage, all defined sub-criteria were processed and spatially analyzed using ArcGIS software. The output was a set of feature maps, each indicating the spatial distribution of a specific sub-criterion in the study area.

Standardization of criteria

Since the sub-criteria under study had heterogeneous scales and measurement units, it was necessary to harmonize their scales before entering the multi-criteria evaluation process. To create spatial comparability, three main approaches (definite, probabilistic, and fuzzy) can be applied in the GIS environment. Given the nature of urban phenomena and the inherent uncertainty in some of the sub-criteria characteristics, as well as the use of linguistic variables in expert evaluation, the fuzzy method was used to standardize the data quantitatively.

Fuzzy logic

Lotfizadeh presented Fuzzy theory in 1965 to consider the uncertainty and ambiguity in solving various problems. Fuzzy logic provides a natural technical tool for evaluating phenomena and matters in examining ambiguous conditions and situations where conventional mathematics is not very effective. This method reflects human thinking in using approximate and uncertain information for decision-making. It provides tools to give mathematical form to human reasoning and decision-making, become closer to human actions and mindsets, and transfer human thinking to technology. In the fuzzy method, the certainty of Boolean logic does not exist, and the criteria are graded in a range between zero and one. The parts with high desirability are assigned a value of one, and the value of zero is assigned to the lowest desirability.

Weighted standardized maps

After determining the specialized weights of each criterion (obtained through the ANP analysis method), the final weight of each feature map was calculated.

This weighting was applied in the range of zero to the final weight of the criterion. Spatial integration of these weighted maps was carried out using fuzzy membership functions (Table 4) and using spatial aggregation operators in the ArcGIS environment. In this study, the logical AND operator was used to combine information layers based on fuzzy logic principles to show the areas that simultaneously have the highest degree of membership in all criteria.

Table 4. GIS fuzzy functions

Fuzzy functions	Description
Gaussian	In this method, an attempt is made to distribute the original values of the cells normally. The best value for a normal distribution is considered to be 1. This value is located in the center of the graph and decreases towards positive and negative values.

The Gaussian membership function is generally as follows:

$$\mu(x) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$$

Equation 2. Equation for calculating the Gaussian membership function

In this formula:

(x) μ: Membership degree (between 0 and 1) for distance x.

c: Same as MidPoint (center)

σ: Same as Spread (spread or standard deviation).

Choosing the optimal value for Spread is a crucial step in the sensitivity analysis of this function. This parameter directly manages the trade-off between accuracy and coverage in urban planning scenarios.

5. Research findings

Initially, the relationship between the goal and the main criteria was established through a pairwise comparison of the main criteria, as outlined in Table 5, to calculate the W21 vector. In each of the matrices, the compatibility coefficient must be checked. As long as its value was less than 0.1, the matrix values had acceptable compatibility. In all matrices of this study, the compatibility coefficient value was checked, which was always less than 0.1

Table 5. Pairwise comparison matrix of the main criteria for calculating the W21 vector

ROW	Criteria	(PF)	(P)	(EQ)	W21	CI
1	physical form (PF)	1	1.2	1.9	0.308	
2	Performance (P)	2	1	1.9	0.488	0.05
3	Environmental quality (EQ)	1/1.9	1/1.9	1	0.204	

Then, to calculate the W22 vector, the relationships between the main criteria were examined. According to experts, all three criteria were interrelated, so it was necessary to measure the relationship between the other criteria each time by controlling one of them. As a result of this step, the W22 vector was a 3× 3 vector. The result of this vector is shown in Table 6.

Table 6. Results of pairwise comparison of criteria, each time controlling one of the criteria

$$W22 = \begin{matrix} PF \\ P \\ EQ \end{matrix}\begin{bmatrix} 0.565 & 0 & 0.401 \\ 0 & 0.642 & 0.598 \\ 0.434 & 0.357 & 0 \end{bmatrix}$$

Next, to calculate the vector, W32, the relationship between the main criteria and their sub-criteria was examined. On this basis, a 4×4 matrix was prepared for the physical form criterion with 4 sub-criteria, a 5×5 matrix for the performance criterion with 5 sub-criteria, and a 3×3 matrix for the environmental quality criterion with 3 sub-criteria. The results of all these matrices are shown in Table7.

Table 7. Results of pairwise comparison of sub-criteria of each criterion

W32 =

PWL	0.239	0	0
SI	0.433	0	0
IW	0.122	0	0
ED	0.206	0	0
CPG	0	0.366	0
W&AB	0	0.249	0
NAL	0	0.087	0
MUDL	0	0.205	0
FRSN	0	0.091	0
CSL	0	0	0.345
DP	0	0	0.545
FUL	0	0	0.107

To find the vector W33, the relationship between the sub-criteria must be examined. For this purpose, in Table 8, the experts considered the relationship between the sub-criteria of all three main criteria:

Table 8. Relationship between the sub-criteria of all three main criteria

	Substandard	FUL	DP	CSL	FRSN	MUDL	NAL	W&AB	CPG	ED	IW	SI	PWL
1	Low-width passages (PWL)		*	*					*			*	
2	Indefensible spots (SI)		*	*					*				*
3	Wall inconsistent with the environment (IW)			*				*	*			*	
4	Dead-ends (ED)		*	*				*				*	
5	Gathering place for criminals (CPG)		*	*				*		*		*	
6	Abandoned buildings, wasteland, and inactive areas (W&AB)			*					*				
7	Lack of night activities (NAL)	*	*			*			*				
8	Lack of a proper mix of uses and diversity of activities (MUDL)	*	*				*		*				*
9	Lack of separation of motorists from pedestrians (FRSN)	*											*
10	Lack of security cameras (CSL)							*	*	*		*	*
11	Lack of lighting Pavement darkness (DP)					*	*		*	*		*	
12	Lack of urban furniture (FUL)				*	*	*						*

Table guide: (*) in the table indicates the relationship of each sub-criterion to several other sub-criteria.

Based on the fact that each sub-criterion was related to several other sub-criteria, matrices were formed, and binary comparisons of interdependent sub-criteria were made with each sub-criterion. The W33 vector can be seen in Table 9.

Table 9. Results of pairwise comparison of sub-criteria with respect to each other

W_{33} =

PWL	0	0.254	0	0	0	0	0	0.185	0.833	0.245	0	0.297
SI	0.242	0	0.357	0.337	0.270	0	0	0	0	0.393	0.393	0
IW	0	0	0	0	0	0	0	0	0	0	0	0
ED	0	0	0	0	0.116	0	0	0	0	0.069	0.107	0
CPG	0.240	0.182	0.312	0	0	0.607	0.212	0.253	0	0.193	0.191	0
W&AB	0	0	0.171	0.165	0.170	0	0	0	0	0.098	0	0
NAL	0	0	0	0	0	0	0	0.148	0	0	0.060	0.178
MUDL	0	0	0	0	0	0	0.316	0	0	0	0.246	0.419
FRSN	0	0	0	0	0	0	0	0	0	0	0	0.104
CSL	0.126	0.152	0.157	0.115	0.066	0.392	0	0	0	0	0	0
DP	0.389	0.329	0	0.382	0.376	0	0.383	0.350	0	0	0	0
FUL	0	0	0	0	0	0	0.087	0.062	0.666	0	0	0

By placing these vectors in a matrix as follows, the initial unweighted supermatrix was formed. Then, due to the imbalance of this initial supermatrix, column balancing steps were performed, and a weighted supermatrix was created. Finally, by taking this supermatrix to the limit, the limit matrix was formed. When the matrix reached the limit, and all the rows opposite the sub-criteria converged, $WANP$ was formed as follows, which is equivalent to one of the columns of the limit matrix and is shown in Table10.

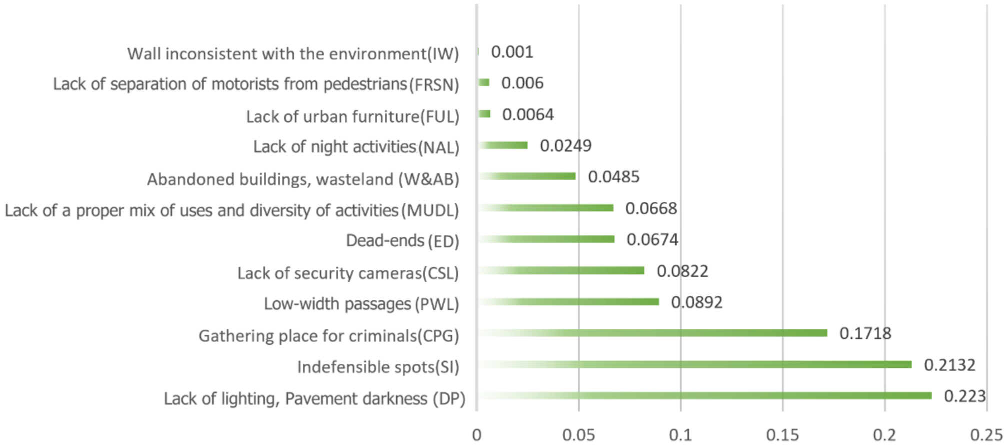


Figure 5. Ranking of indicators based on ANP analysis

Table 11. Final matrix $WANP$

$$W_{ANP} = \begin{array}{r} PWL \\ SI \\ IW \\ ED \\ CPG \\ NAL \\ W\&AB \\ MUDL \\ FRSN \\ CSL \\ DP \\ FUL \end{array} \begin{bmatrix} 0.0892 \\ 0.2132 \\ 0.0010 \\ 0.0674 \\ 0.1718 \\ 0.0485 \\ 0.0249 \\ 0.0668 \\ 0.0060 \\ 0.0822 \\ 0.2230 \\ 0.0064 \end{bmatrix}$$

After extracting the final weights in the ANP analysis hierarchy process (according to the previous sections), a separate thematic map was prepared in ArcGIS for each of the identified sub-criteria. These maps display the spatial distribution of each sub-criterion at the level of the Molavi neighborhood (Figure 6-11).

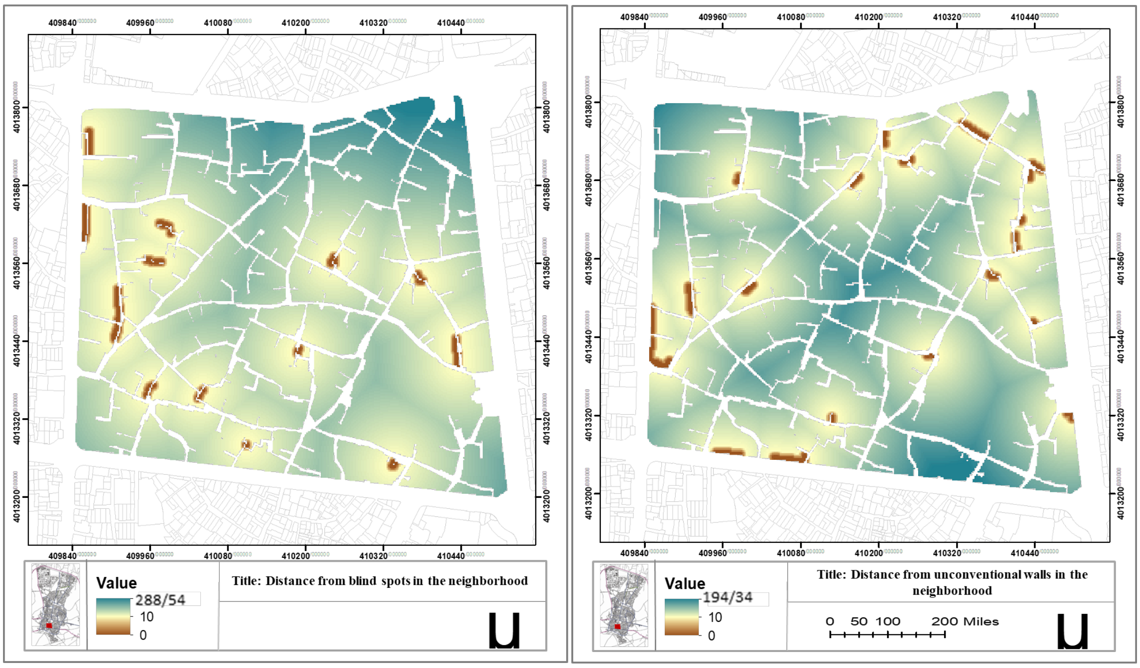


Figure 6. Map of criteria 1 and 2, in GIS format

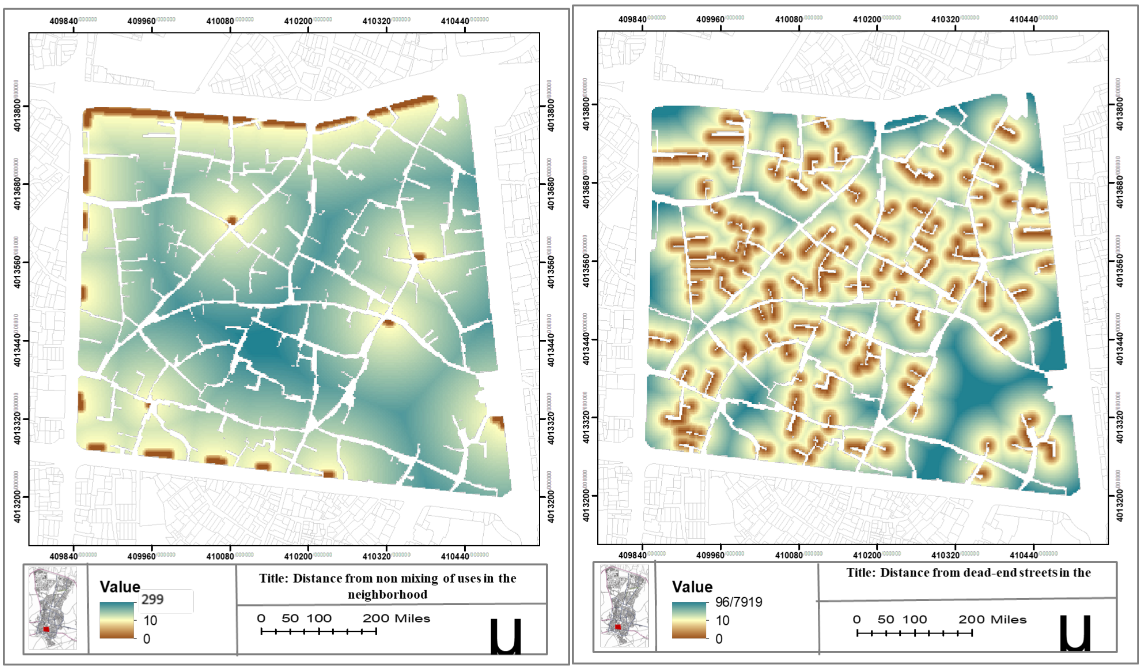


Figure 7. Map of criteria 3 and 4, in GIS format

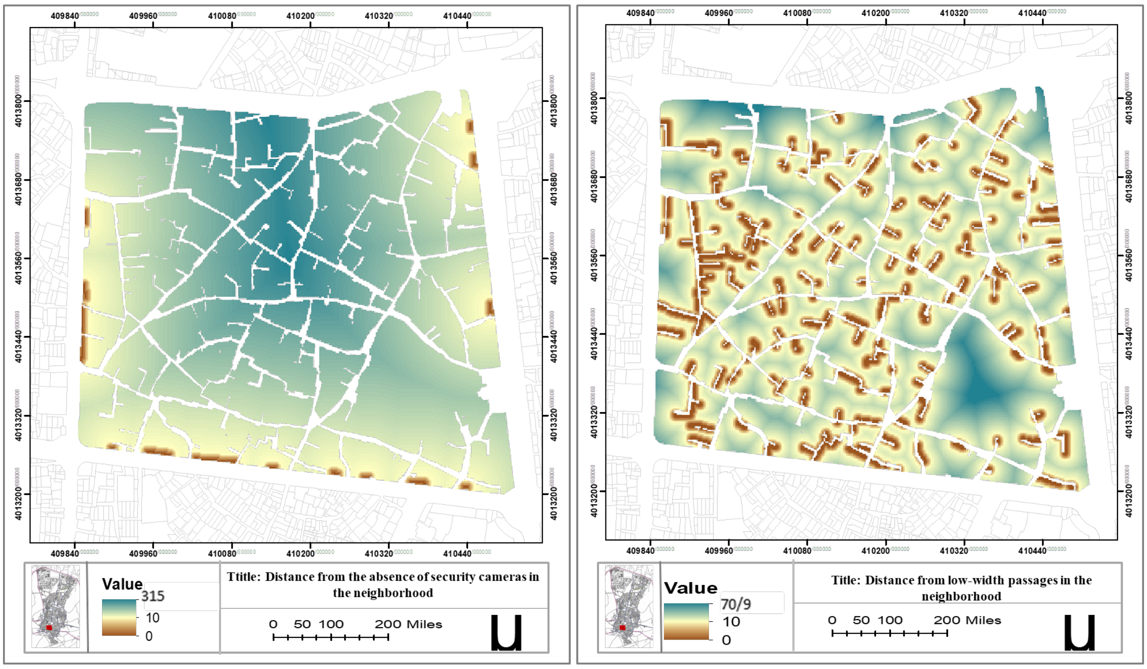


Figure 8. Map of criteria 5 and 6, in GIS format

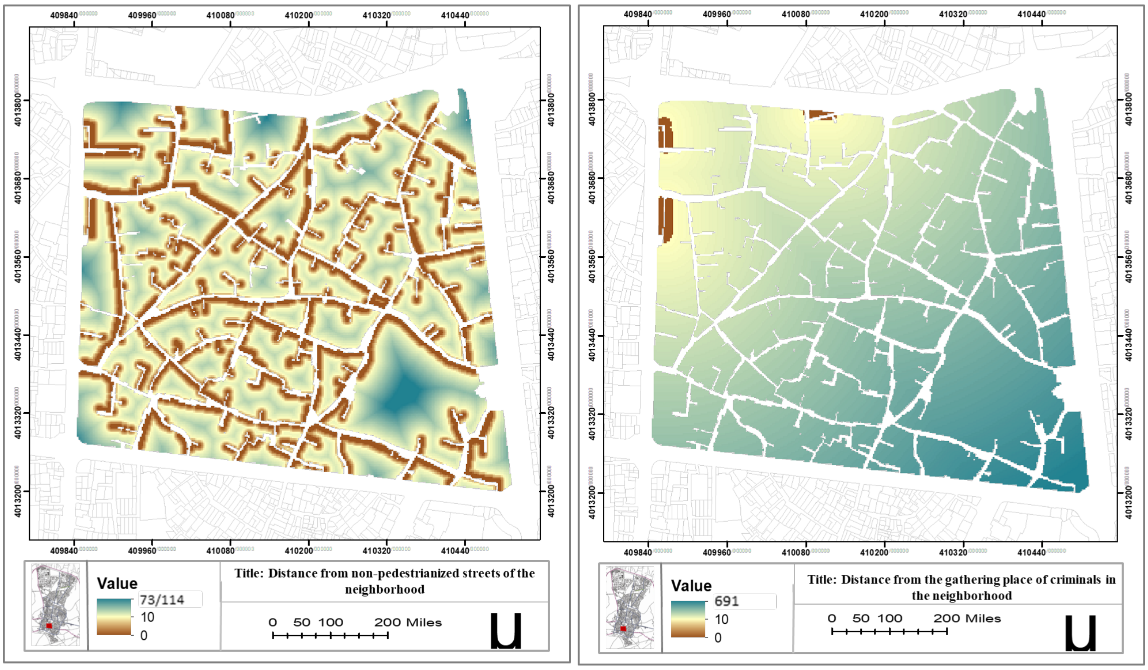


Figure 9. Map of criteria 7 and 8, in GIS format

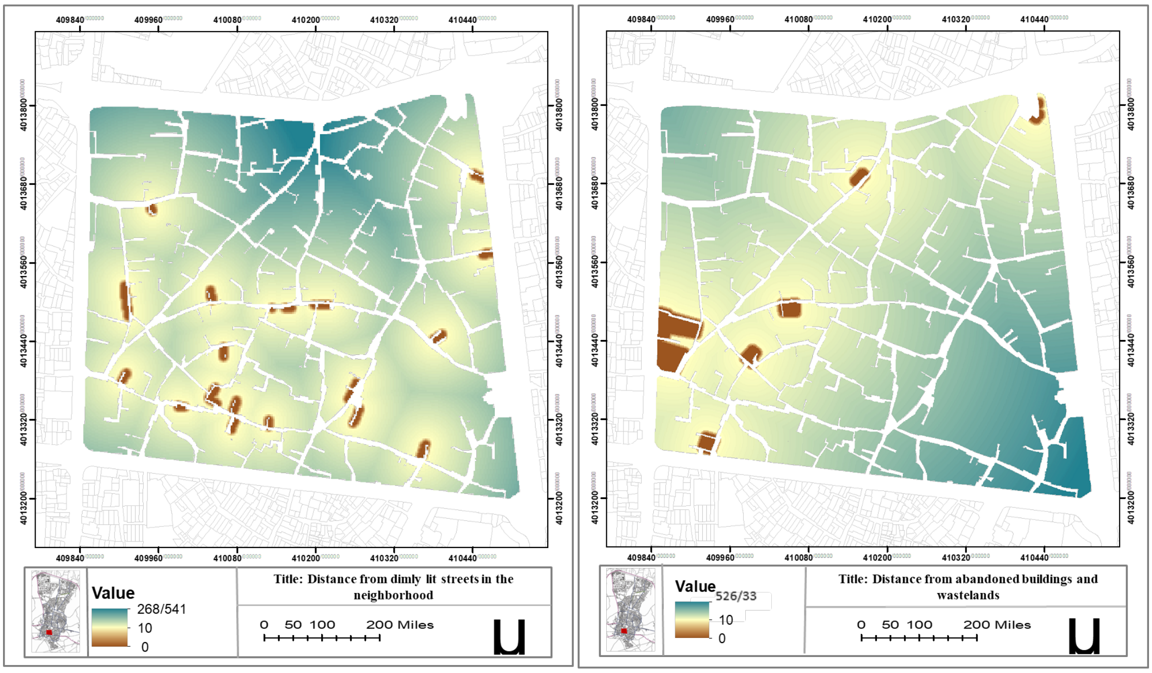


Figure 10. Map of criteria 9 and 10, in GIS format

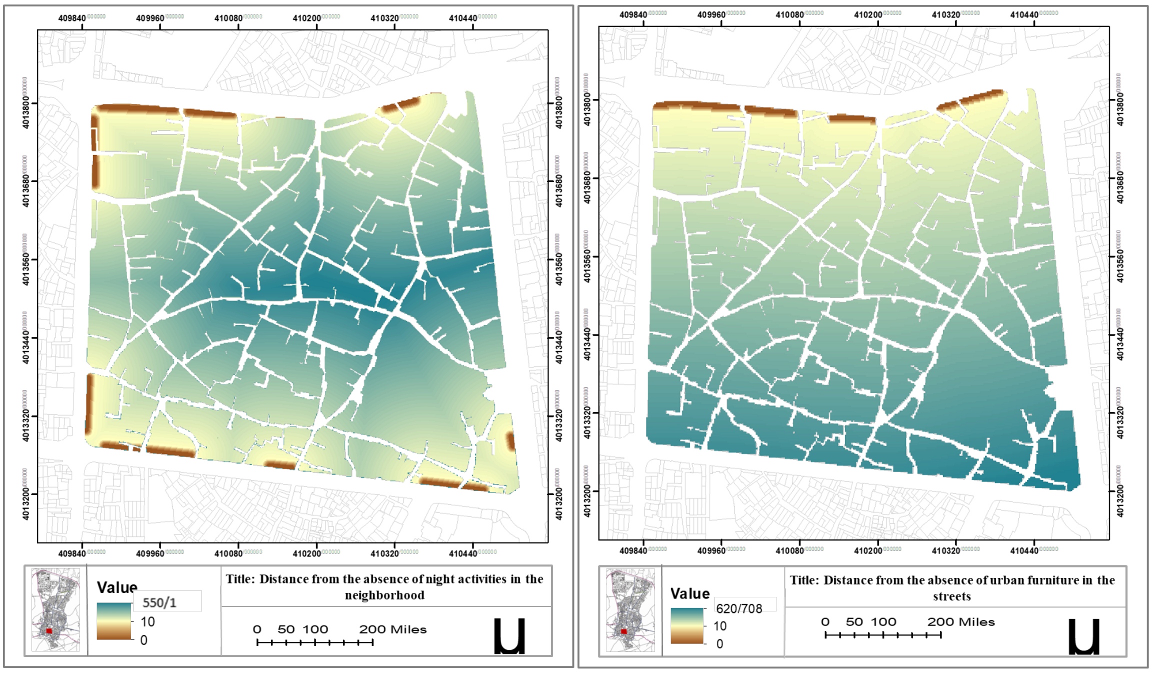


Figure 11. Map of criteria 11 and 12, in GIS format

At this stage, for each sub-criterion, the relevant spatial data (distance from blind spots, distance from dead-end streets, etc.) were subjected to a fuzzy standardization process so that all values were converted to a fuzzy membership degree in the range [0.1]. This normalization allows for a fair integration of sub-criterions with different scales (Figures 12-17).

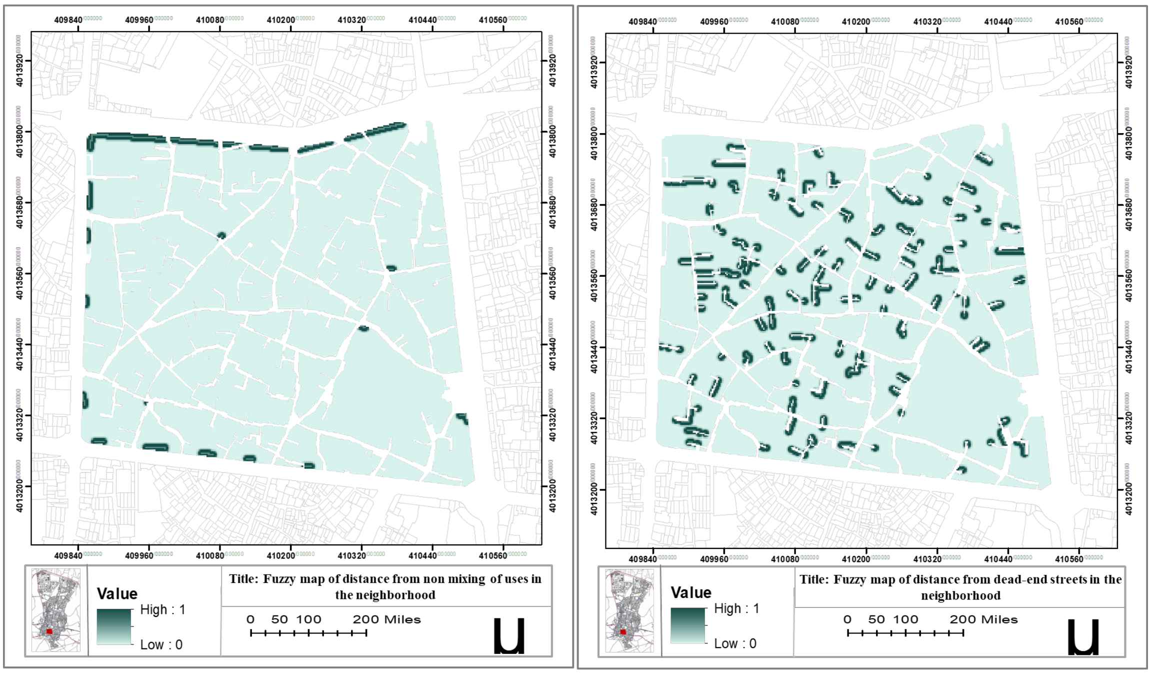


Figure 12. Standardized map of criteria 1 and 2

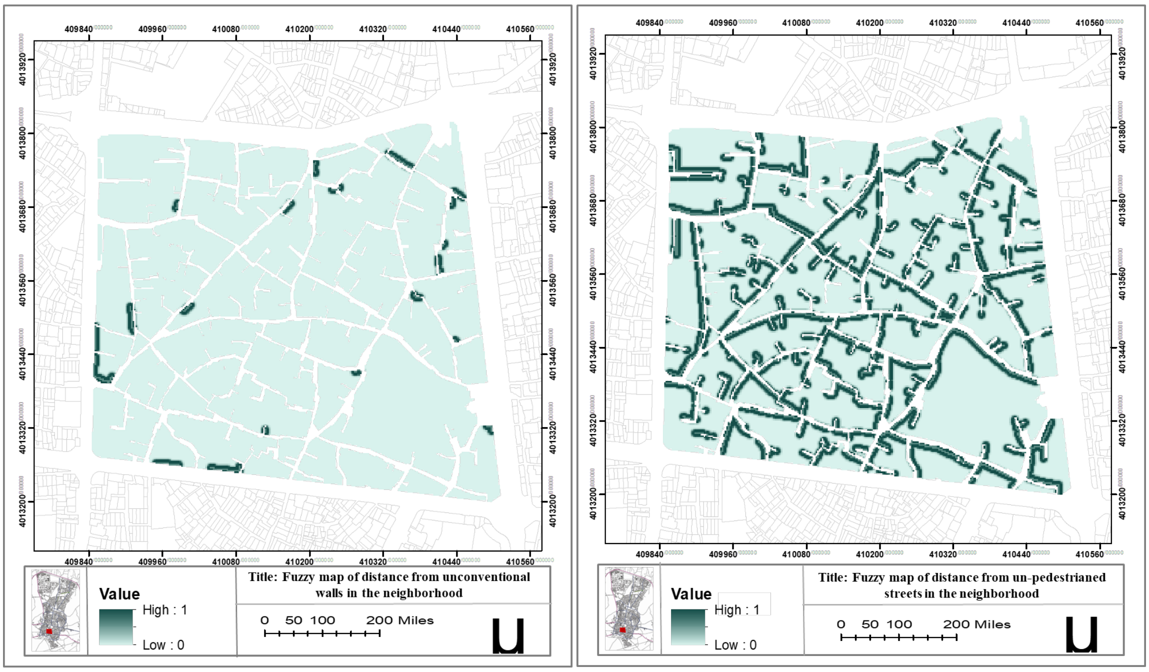


Figure 13. Standardized map of criteria 3 and 4

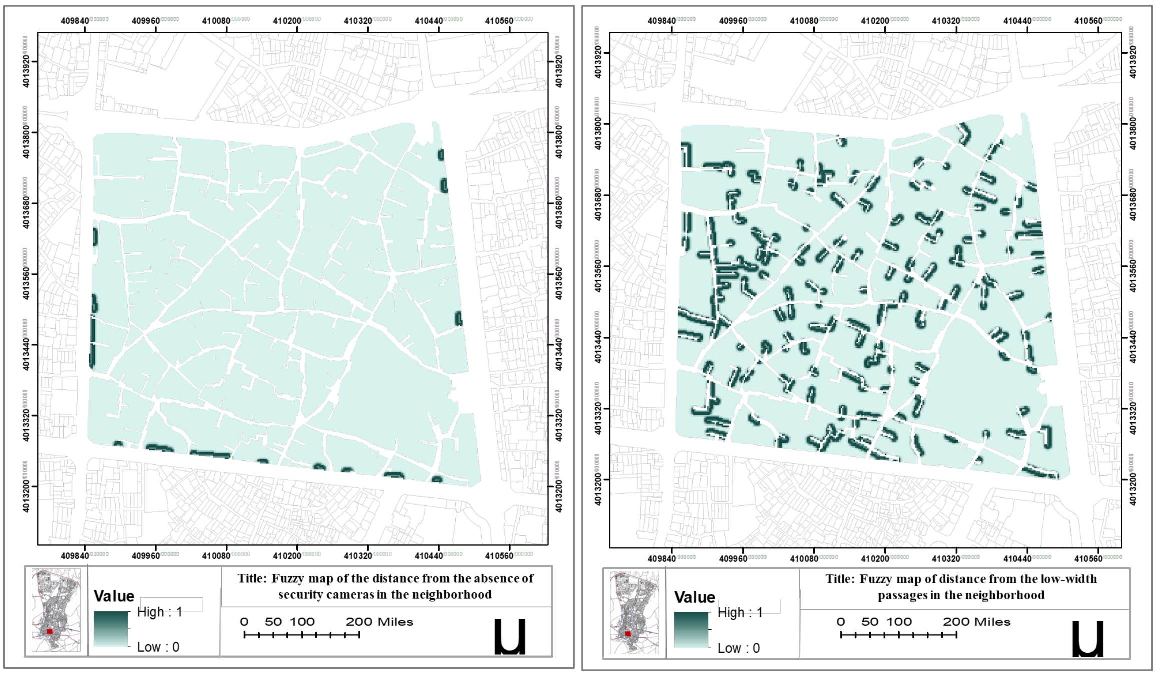


Figure 14. Standardized map of criteria 5 and 6

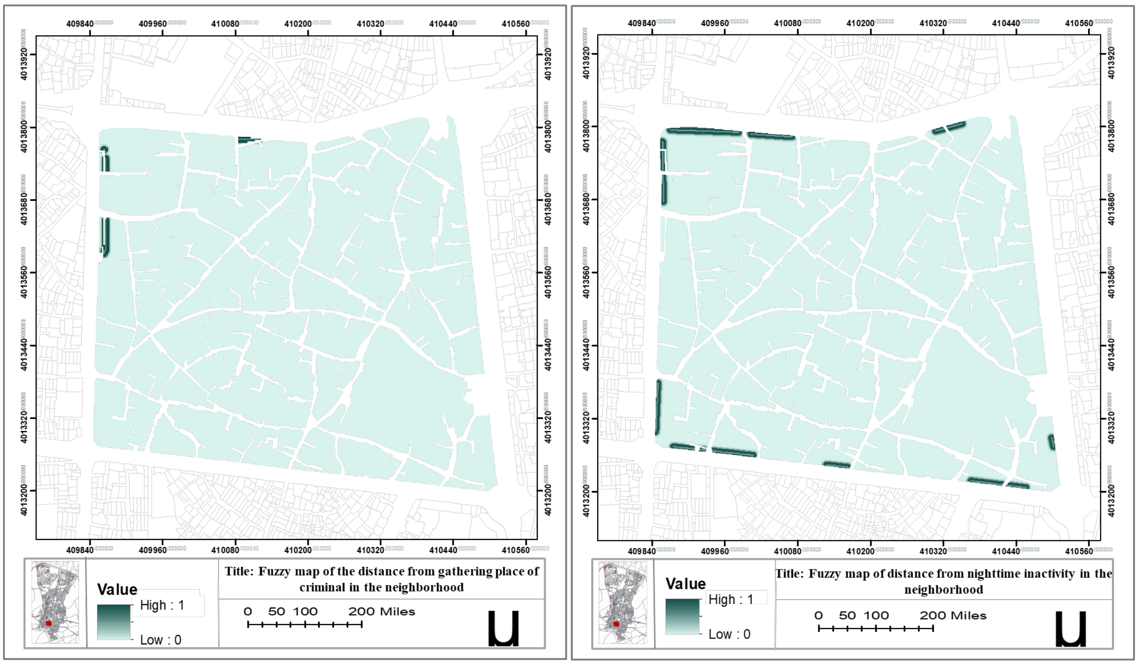


Figure 15. Standardized map of criteria 7 and 8

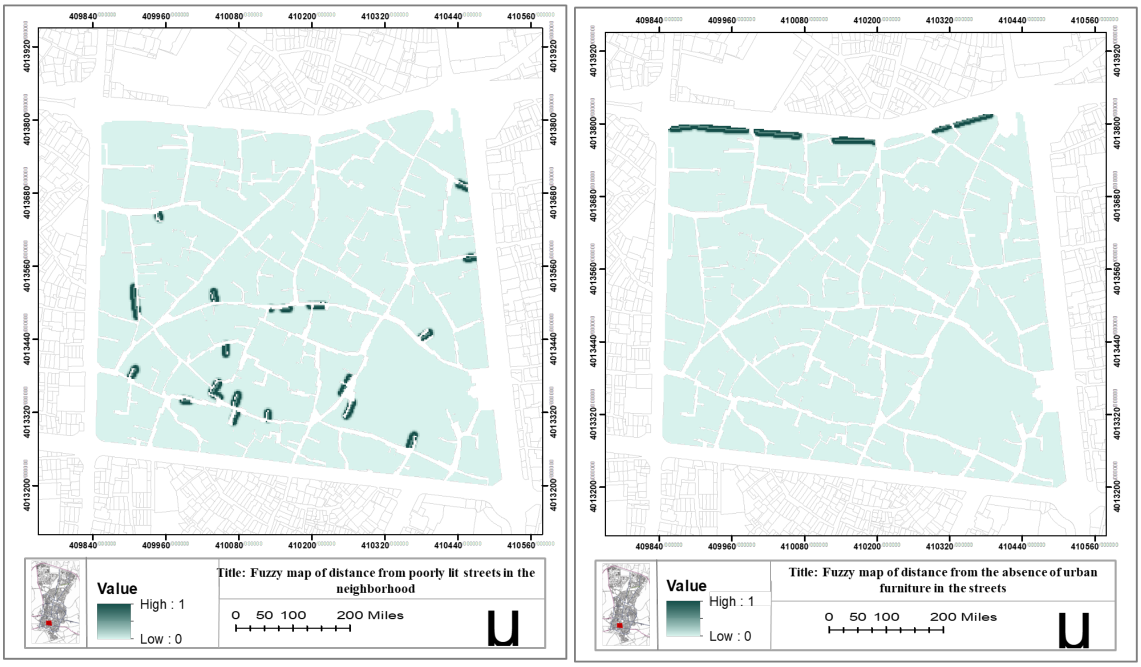


Figure 16. Standardized map of criteria 9 and 10

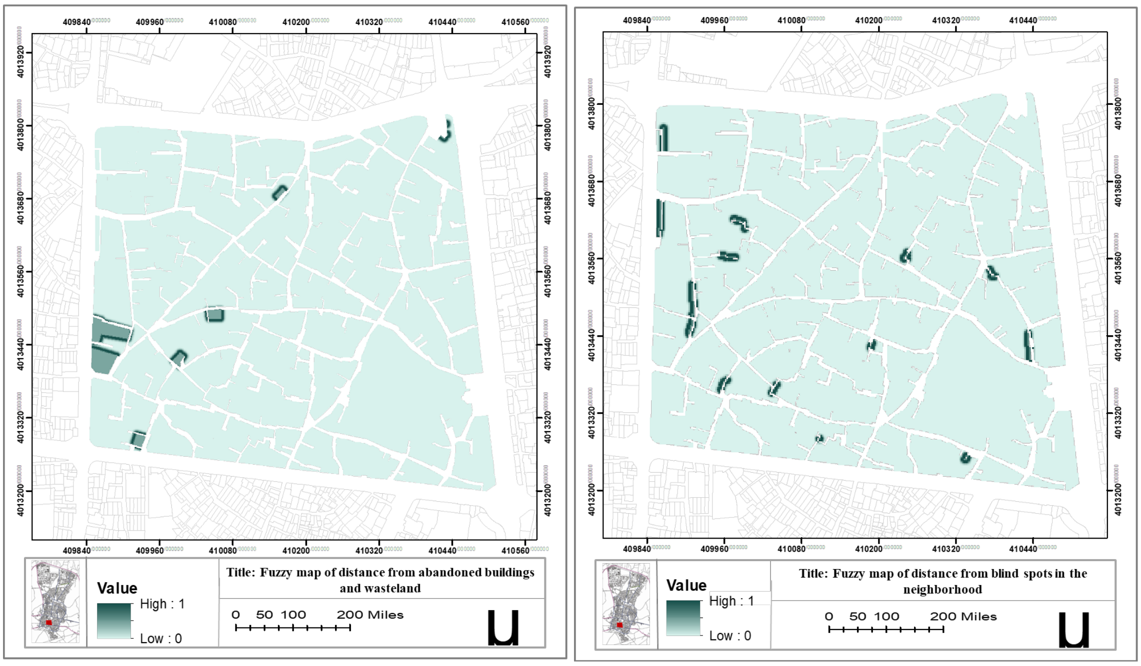


Figure 17. Standardized map of criteria 11 and 12

In the final step, the normalized fuzzy maps (Figures 12-17) were applied as input data to the GIS environment. This process was carried out by applying weighting coefficients extracted from the analytic network process (ANP). This step ensures that the input maps are not simple averages, but rather reflect the relative influence of each factor on the final result. In this environment, a fuzzy membership degree is determined for each unit cell (pixel) of the map. This value indicates the degree to which that location conforms to the desired definition for each sub-criterion; Gaussian membership functions was used for determining the membership degree.

Finally, these maps were merged through the AND operator in the ARCGIS, and the map of insecure spaces in the Molavi neighborhood was formed (Figure 18). The AND operator ensures that a pixel is recorded in the final map only if it simultaneously achieves high membership degrees in all input subcriteria.

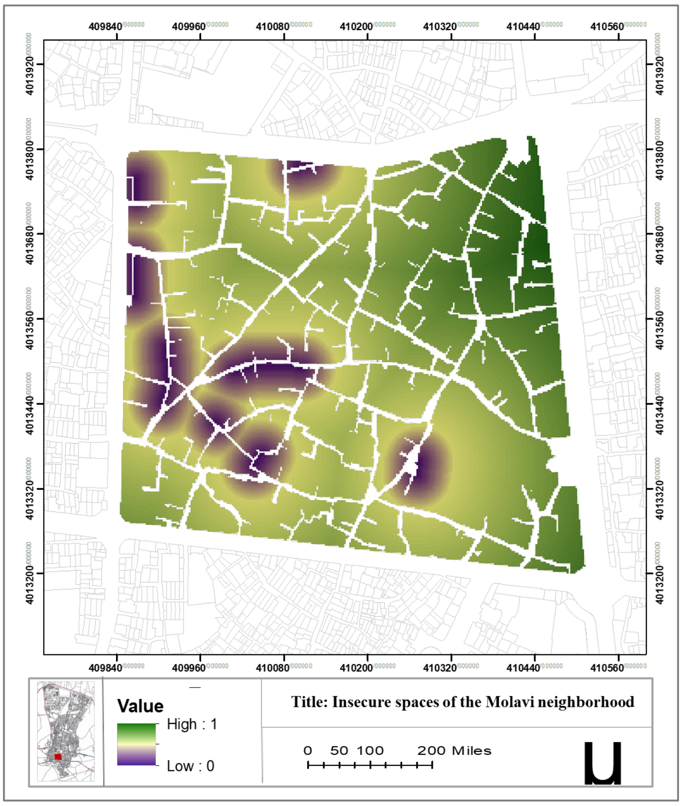


Figure 18. Map of insecure spaces in the Molavi neighborhood

The analysis of insecurity hotspots (dark purple dots) in this neighborhood is not uniformly distributed. The most intense concentration points and the greatest overlap of sub-criteria are observed in three main areas: the center of the neighborhood, as well as parts of the west and southwest. From the perspective of urban policy analysis, these points are identified as critical intervention areas.

The identification and characteristics of insecurity hotspots in physical surveys, as well as the overlap of sub-criteria maps, indicate that these insecurity hotspots are systematically related to structural weaknesses in the physical form of the neighborhood. As can be seen in the map, insecurity hotspots are primarily due to the presence of low-width and elongated passages with severe restrictions on adequate sight lines, accompanied by a lack of environmental lighting and the absence of social supervision by residents, which directly deprives residents of the possibility of active visibility and supervision. Additionally, spaces with signs of disorder and wear and tear, proximity to abandoned or deteriorated buildings, are prone to concealment. According to the broken windows theory, they send a message to society that the neighborhood lacks social control, which exacerbates the incidence of petty crime. Molavi neighborhood is vulnerable in this regard due to the significant number of old and deteriorated historical buildings.

In contrast, according to the findings, the eastern and northeastern fringe areas of the neighborhood, especially those adjacent to major streets such as Sepah Street, enjoy a higher level of environmental security. This advantage is due to a combination of factors. First, the appropriate mix of residential, commercial, and service uses ensures the constant presence of citizens and continuous informal surveillance throughout the day. Second, improving the physical quality and infrastructure, which includes standard and optimal lighting, official surveillance systems (such as municipal and private CCTV cameras), and the removal of abandoned buildings, which itself is a testament to the effectiveness of the regeneration and renovation processes in this deteriorated and old area.

Based on the integration of data and analysis of Figure 18, the Molavi neighborhood has been divided into three main zones, and an intervention strategy tailored to each is defined (Figure19) :

1. Zone with weak environmental security: includes the main centers of insecurity (mainly the central, western, and southwestern areas).

2. Zone with medium environmental security: the southern and southwestern parts (which require intervention to prevent falling into a weaker zone).

3. Zone with high environmental security: the eastern and northeastern peripheral areas.

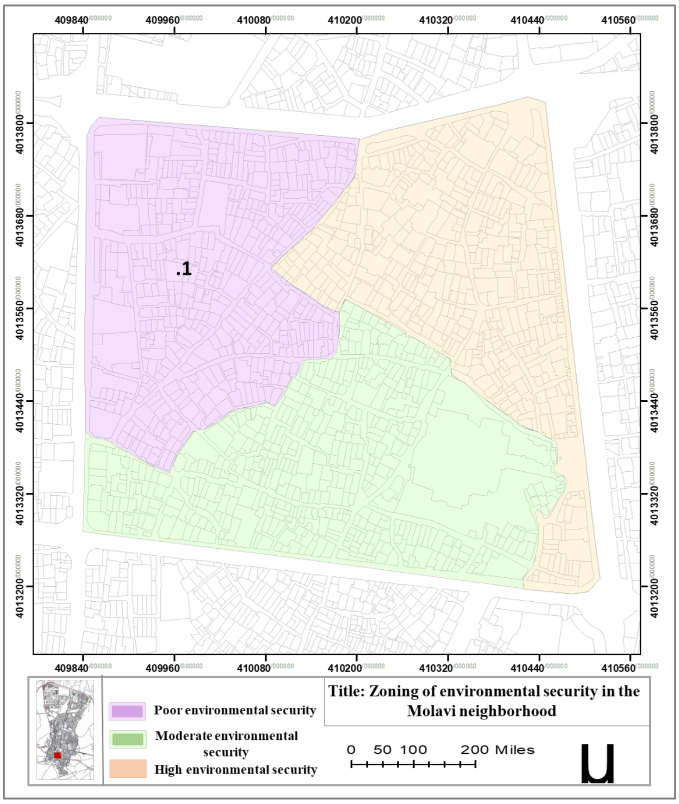


Figure 19. Zoning of environmental security in the Molavi neighborhood

The findings support the fundamental point that for effective urban policymaking, the focus should be on identifying and addressing underlying causes and environmental deficiencies (such as lighting, passageways, and deteriorated land uses) at precise points of insecurity hotspots. This targeted intervention approach will maximize the allocation of limited public resources and prevent budget waste in implementing extensive and unnecessary measures throughout the neighborhood (especially in secure areas).

5. Discussion

This section provides an in-depth interpretation and analysis of the findings from the Analytical Network Process (ANP) and Geographic Information System (GIS) in the Molavi neighborhood of Qazvin. The results of the network analysis clearly show that, in the Molavi neighborhood of Qazvin, the criterion of "performance", with a relative weight of 0.488, has gained more importance than "physical form", with a weight of 0.308. It indicates that although the existing physical structure (such as low-width passages, the presence of blind spots, and a lack of visibility) is the basis for the formation and potential of crime, the mix of uses and nighttime activities in space has a more immediate, tangible, and decisive impact on citizens' daily perception of insecurity. According to Jacobs' theory, "eyes watching the street" does not simply mean the physical presence of healthy buildings, but also the active and purposeful human presence.

The sub-criterion "lack of appropriate urban furniture," with a relatively low but vital weight of 0.0064, was identified as a contributing factor in exacerbating feelings of insecurity. This factor, although not ranked among the top priorities in terms of weight, plays an important role in weakening natural surveillance. Standard urban furniture (such as appropriate benches in the active design of sidewalks and neighborhood centers) directly impacts the encouragement of citizens to attend and use the spaces. In the Molavi neighborhood, the lack of this element on Shahid Ansari and Molavi streets, as well as the neighborhood center, has decreased the presence of people, weakening the street's eyes. This reduced presence, in turn, lowers the quality of social interactions and exacerbates the feeling of vulnerability and insecurity in public spaces. This finding shows that even minor physical elements can act as a catalyst for perceived insecurities.

To ensure the validity of the results obtained for the Molavi neighborhood, a comparative study with previous research on similar historical and deteriorated contexts is necessary. For instance, Hamafar et al. (2023) focused on identifying and redesigning insecure public spaces in some urban neighborhoods of Tehran, with the approach of improving environmental security. The studied neighborhoods, such as the Molavi neighborhood, share common characteristics of deteriorated and historical contexts, including physical factors: the lack of light and illumination, as well as insecure corners and recesses due to the setback of buildings in alleys. Despite the alignment in the ultimate goal (identifying insecure spaces), key differences exist in methodology: The aforementioned article used hierarchical analysis (AHP), the present study has used the more comprehensive model of the analytical network process (ANP) due to the nature of dependencies and the network nature of the factors affecting insecurity. Hamafar et al. (2023) emphasized qualitative methods, including in-depth field observations and residents' opinions, to identify factors, and covered social factors well. It prioritized the factor "supporting activities," while this research categorizes the criterion "functionality" as high priority. This comparison highlights that providing security in deteriorated and old neighborhoods requires a multifaceted approach that, beyond purely physical and design measures, focuses on the human and social activities of the space.

Every scientific research faces limitations, understanding of which is crucial for generalizing the results and planning further research. The dominant approach of this study, which was based on spatial data (GIS), led to the ignorance of the impact of social factors. Indicators such as social participation, neighborhood cohesion, social capital, and public trust were overlooked. Future research can also focus on the use of new technologies (ICT) to achieve environmental security through environmental monitoring systems in deteriorated structures.

6. Conclusion

This research was conducted to identify insecure spaces in the Molavi neighborhood of Qazvin city. The research methodology focused on spatial analysis and used a simultaneous combination of two powerful approaches: the analytical network process (ANP) for weighting and prioritizing criteria and sub-criteria, and the capabilities of the geographic information system (GIS) for analyzing the location of data references. To integrate the uncertainty resulting from qualitative judgments, the Fuzzy ANP method was used to obtain a comprehensive and valid analysis of the distribution of insecurity at the neighborhood level.

Using the Analytical Network Process (ANP), the importance of each criterion and sub-criterion mentioned earlier was assessed. The criteria identified as most significant by experts for determining insecure spaces were "performance" (weight of 0.488), "physical form" (weight of 0.308), and "environmental quality" (weight of 0.204). Among the sub-criteria, two were highlighted as the most impactful factors contributing to insecurity: "neighborhood blind spots" (weight of 0.223) and "lack of lighting" (weight of 0.213). Conversely, the sub-criteria identified as the least important factors were "inconsistent walls" (weight of 0.001) and "lack of separation between motorists and pedestrians" (weight of 0.006).

In the next stage of spatial analysis, the most important insecure spatial hotspots were identified using ArcGIS software and the Fuzzy ANP method. The results showed that most of these spaces are located in the central, western, and southwestern parts of the Molavi neighborhood. This clearly revealed the spatial heterogeneity in the distribution of Molavi neighborhood security.

The insecurity hotspots were systematically related to the structural weakness in the physical form of the neighborhood (passages with inappropriate geometry and blind spots), lack of social supervision by residents, lack of lighting, presence of abandoned buildings, and also a management-development gap in the neighborhood, which practically exclude these areas from the circle of attention and effective urban planning interventions. In contrast, the areas covered in urban regeneration programs (especially the Sepah

Street axis in the eastern part) were free of insecure spaces due to the successful integration of elements providing environmental security. Therefore, to gain a deeper understanding and facilitate the development of improvement strategies, the level of environmental security in the neighborhood was categorized into "weak", "medium", and "high", based on the findings of the analysis. This spatial division provided the necessary basis for developing effective and targeted policy recommendations to enhance the environmental security approach of the Molavi neighborhood, particularly in the identified insecure spaces.

A subset of proposed strategies and policies is presented at three physical, environmental quality, and functional levels. These recommendations focus on improving the points identified in the GIS maps, particularly on improvements that are feasible in situations where physical interventions require more time.

- Consolidation and coordination of parts in the area identified as insecure points, a targeted measure to eliminate existing blind spots and improve visibility and surveillance levels.
- Emphasis on active and adaptive lighting in identified secondary streets: Replace old lights with smart LED lighting systems in high-risk areas. These systems should be able to adjust the intensity of the light; the light should be maximized during low-traffic hours and at midnight (when the natural surveillance is reduced).
- Use high-resolution cameras equipped with night vision in blind spots in the neighborhood
- Design pause spaces in the neighborhood: Place benches and small seating areas near the entrances of buildings or in corners with sufficient visibility. These spaces should provide physical comfort and sensory stimulation, catering to different age groups.
- Create small-scale and multi-purpose uses at the neighborhood level, prioritizing identified insecure spaces to increase dynamism and natural surveillance at different times of the day by creating social demand for presence in the space.
- Carefully identify and map abandoned spaces, transforming them into temporary focal points through creative interventions and flexible uses. This process will directly lead to improving the neighborhood's dynamism.
- Strengthen environmental security with technology: deploying and integrating communication infrastructures for smart, continuous environmental monitoring (instead of traditional patrolling), with the central role of information and communication technology (ICT) to increase neighborhood resilience and environmental security. This includes the following infrastructures and measures:

1) Pivotal technologies: advanced surveillance equipment, including smart cameras (equipped with analytics), a variety of environmental sensors, and advanced real-time data analysis software; and

2) Spatial database (WebGIS): creating and operating a continuous monitoring system based on WebGIS as the central core of geographic information for aggregating, displaying, and periodically updating insecurity maps. This platform is also crucial for assessing the impact of implemented policies and conducting future interventions.

- Establishing night-time uses, such as cafes, restaurants, and fast food, with longer opening hours on Ansari Street, to create continuous and legal activity that helps strengthen the sense of security on this passageway.

Environmental security is a fundamental component of the quality of citizens' social life. The analytical model used in this research has high potential for practical application by urban designers and planners. The strategic goal of this model is to reduce crime-prone areas, prevent the spread of crime in the neighborhood, and ultimately improve neighborhood spaces to the highest level of environmental security. Therefore, integrating the results of this model into decision-making processes will be an effective step towards achieving a safer neighborhood and sustainably improving the quality of life of residents.

Authors' Contributions

The authors contributed equally to this research.

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Conflict of Interest

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