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Strategic Scenarios for Enhancing Urban Environmental Resilience in the Cities of Kurdistan Province, Iran

Akbar. Heydari[1*]⊕, Fardin. Shokravi[2]⊕, Esmaeil. Safaralizadeh[3]⊕, Robab. Hoseinzadeh[3]⊕, Mohammad Ali. Gholami Sefidkouhi[4]⊕, Shadieh. Heydari Tashe Kaboud[4]⊕

[1] Department of Geography & Urban Planning, Ferdowsi University of Mashhad, Mashhad, Iran
[2] Department of Environmental Economics, Allameh Tabataba'i University, Tehran, Iran
[3] Department of Urban Geography, Payam-e-Noor University, Tehran, Iran
[4] Department of Water Engineering, Faculty of Agricultural Engineering, Sari Agricultural Sciences and Natural Resources University, Sari, Iran

* Corresponding author email address: Heydariakbar@gmail.com

This study aims to investigate the drivers and scenarios of urban environmental resilience in the cities of Kurdistan Province, Iran, employing the Causal Layered Analysis (CLA) approach in conjunction with Mic Mac and Scenario Wizard software tools. The research utilizes a descriptive-analytical technique, incorporating quantitative methodologies such as the snowball and Delphi approaches. A non-random targeted sampling method was employed to select a statistical sample of 60 experts with executive and academic expertise in urban environmental sustainability, whose opinions were gathered at various stages of the research. To ensure robust findings, the study assessed literacy levels, systemic perspectives, worldviews, and alternative metaphors related to environmental resilience within the study area. A 30x30 matrix was employed to evaluate different scenarios related to the research variables, using elite panels and supplementary questionnaires that included impact rating options (0 to P). The study identified key drivers and 16 influential descriptors, leading to the development of probable scenarios (-3 to +3) across four categories: desirable, acceptable, crisis, and disaster. Based on these findings, recommendations were formulated to enhance the environmental resilience of cities in Kurdistan Province.

Keywords: Scenario Planning, Urban Environment, Environmental Resilience, Sustainability.

1. Introduction

Global communities are frequently impacted by both natural and human-induced catastrophes, which can severely deplete their capacity to respond to emergencies. To facilitate recovery and adaptation in the aftermath of such disasters, policymakers, researchers, and professionals have increasingly adopted the concept of resilience. The development of resilience is particularly critical for communities residing in urban areas due to the escalating frequency and intensity of crises. Effective collaboration among all levels of government, non-profit organizations, corporations, and other stakeholders is essential to building resilient communities (Bruneau et al., 2003; Campanella, 2006). Urbanization, driven by population growth, migration, and the opportunities offered by urban systems in education, culture, and socio-economic advancement, presents a significant global challenge (Janparvar et al., 2022; Rajaee, 2023). Urbanization trends are unequal

across the globe, with developing Asian countries experiencing particularly rapid urban growth. In 1800, only 3% of the world's population resided in urban centers; by 1900, this figure had increased to 14%, and by 2016, approximately 54% (2.5 billion people) lived in urban areas. Currently, around 65% of the world's population resides in urban areas, and according to a United Nations report, this figure is projected to rise to 68% by 2050. However, urban resilience policies, plans, and practices have not kept pace with the growth of urbanization and economic development. Additionally, there is no universally accepted definition of urban resilience (Rezaei, 2023).

The vulnerability of urban areas to crises is evident across various domains, including infrastructure, telecommunications, transportation, and energy grids. Addressing the resultant damages requires substantial investment of time and resources (Mirzaei, 2013). However, the absence of a strategic plan for building resilience and mitigating the adverse impacts of crises has emerged as a critical challenge in urban crisis management, underscoring the urgency of this issue. According to definitions by Lichenko (2011) and Lewand (2013), resilience refers to the ability of urban environments to withstand a wide range of shocks and stresses, thereby enhancing the effectiveness of critical structures and functions during crises for self-preservation (Lewand, 2013; Lichenko, 2011). The ability to withstand pressure and respond positively to change is a fundamental aspect of all these approaches, which gained greater prominence in the field of risk reduction, particularly concerning environmental hazards, around the year 2000. Enhancing resilience to both natural and human-induced disasters can facilitate society's capacity for adaptation and sustainable survival. This approach seeks to reduce communities' vulnerability and enhance individuals' ability to mitigate risks posed by both natural and, occasionally, anthropogenic catastrophes (Majidi, 2023; Taheri et al., 2022).

In this context, the four fundamental components of urban resilience are socioeconomic, institutional, physical, and environmental. The social dimension, which represents the first component, involves the ability of social organizations and societies to withstand and recover from disasters. The financial aspect constitutes the second element. Economic resilience refers to the inherent capacity of individuals and communities to respond to and adapt to hazards in ways that minimize potential losses and damages. The third element of resilience, the institutional dimension, encompasses aspects related to planning, past disaster experience, and communities' ability to mitigate risks. Local engagement in risk reduction efforts strengthens organizational ties and enhances system protection (Kapucu & Hu, 2020; Nasrabadi, 2015). These efforts also have significant implications for social issues within society. The physical-environmental dimension, the fourth element, assesses the community's ability to respond to and recover from disasters, including the availability of shelters, vacant or rented residential units, and related facilities. A sustainable city must balance social, economic, and environmental requirements and respond to pressures from all directions. A successful sustainable city provides efficient and safe infrastructure (such as water, electricity, population management, environmental regulations, etc.) and offers these amenities to investors. The needs of its citizens should be prioritized in all planning efforts. A successful community recognizes and leverages its natural resources, people, and environment to maximize returns. Therefore, sustainable urban development is not optional but essential if cities are to serve their residents' needs. To house humanity's future, urban areas must be socially just, economically prosperous, and ecologically sound (Heydari & Bakhtar, 2018; Heydari et al., 2020).

To develop comprehensive perspectives and identify weaknesses, opportunities, strengths, and threats for future strategic plans, it is essential to examine the various dimensions of resilience and assess the situation of different communities and cities concerning indicators of future scenarios that can enhance the conditions in multiple regions (Heydari & Bakhtar, 2018). Iran faces numerous urban environment-related challenges each year, some of which can lead to severe consequences. This is evident from the urban environmental crises in 2018 and 2019 in Iranian cities, including Khorramabad, Gilan, Sistan and Baluchistan, Ilam, Ahvaz, Golestan, and other northern and western regions. If these challenges are not addressed through the development of strategic plans, they may soon spread to other residential areas of the country, posing a severe threat to the security of both urban and rural areas (Fanni et al., 2014; Heydari et al., 2020).

Therefore, it is crucial to enhance the resilience of urban areas in the Kurdistan provinces against natural and human-made crises. This should be achieved by leveraging appropriate national and international experiences to minimize risks related to urban environmental resilience before, during, and after an emergency. Additionally, considering the sensitive border location of Kurdistan province in Iran and the lack of preparedness to face urban environmental challenges and crises in the near future, it is essential to develop strategic documents and implement wise and intelligent environmental management. Furthermore, measuring the capacity of urban resilience infrastructures is necessary to prevent crises in the survival of urban areas, as demonstrated in the case study region of this paper. Consequently, the primary objectives of this article are to explore and answer the following fundamental research questions:

What is the current status of urban environmental resilience indicators in the cities within Kurdistan province?

What are the key driving factors and uncertainties that influence urban environmental resilience in the cities of Kurdistan province?

What feasible scenarios could be recommended to enhance urban environmental resilience in Kurdistan province?

2. Methods and Materials

The present research is an applied study employing a descriptive-analytical technique, utilizing quantitative methodology in the snowball and Delphi approaches. A statistical sample of 60 individuals with executive and scientific knowledge and experience in urban environmental sustainability was selected based on targeted sampling techniques. Their opinions were gathered at different stages of the research.

The cross-impact matrix analysis method, frequently used for strategic planning and evaluating urban sustainability in terms of environmental resilience, was implemented in this study due to the methodological approach of future studies. After defining the society and statistical sample, the researcher created a list of the most crucial factors influencing the topic, which was discussed with experts during the Delphi sessions. Participants then finalized the list of key influential variables after classifying these variables and the areas

associated with each (e.g., management, policymaking, etc.). The results were quantified by averaging scores to measure the impact of the variables, with scores ranging from 0 to P. Subsequently, by accepting the final opinion of the other research groups, creating impact and uncertainty matrices (30x30) within the Mic Mac software environment, and compiling questionnaires related to each, the results obtained in each category were scored (0: neutral, 1: low, 2: medium, 3: high, and P: potential). After identifying the most critical direct, indirect, and potential impacts, uncertainties, and drivers, the researcher compiled 16 key descriptors related to possible situations in urban environmental resilience in Kurdistan province. Based on these descriptors, four scenarios—desirable, acceptable, disaster, and crisis—were developed. To verify the consistency of the scenarios and finalize the descriptors, the researcher created a balanced cross matrix and a probability questionnaire. A statistical sample completed the questionnaire, with scores ranging from -3 to +3, where -3 represented extreme negative probability, -2 moderate negative, -1 weak negative, 0 neutral, 1 weak positive, 2 average positive, and 3 strong positive.

3. Findings and Results

3.1. The Status of Private and Public Sectors in Urban Environmental Resilience in Kurdistan

A regression analysis was conducted to explore the relationship between urban environmental resilience, the dependent variable, and the performance of the private and public sectors, the independent variable. The findings indicate significant challenges in this area, including inadequate performance in both sectors and strategic deficiencies in urban resilience policies, such as the absence of strategic documents, insufficient infrastructure investment, and lack of inter-organizational coordination. The analysis revealed an adjusted coefficient of determination of 0.485, indicating that the dimensions of the independent variable have a substantial capacity to explain 48.5% of the variance in the dependent variable. The remaining 51.5% of the variance is attributed to other factors outside the model, as reflected in the error term. Furthermore, the Durbin-Watson statistic value of 1.615 suggests that the residuals are independent. These findings enhance the

understanding of factors influencing urban resilience and highlight the need for effective policies and inter-sectoral cooperation to address the challenges in this field.

As indicated in Table 1, the regression statistic for this model is 13.26, and the residual value is 11.05, reflecting the model's high explanatory power in predicting changes in the dependent variable based on the independent variable. The F-statistic is 71.64, with a significance level of 0.000, which is below the 0.05 threshold, indicating that the dimensions of the independent variable significantly influence the dimensions of the dependent variable. Thus, it can be concluded that the performance of the private and public sectors significantly impacts urban environmental resilience in the cities of Kurdistan province, with a 95% confidence level. However, this finding does not imply that the performance of these sectors is necessarily positive; rather, it confirms the accuracy of the methodology and statistical tests used in analyzing the research indicators and their significance.

Table 1

Summary of Regression Model

Model	Sum of Squares	Degrees of Freedom	F	Significance Level
Regression	13.26	3.34		
Residual	11.05	0.021	71.645	0.00
Total	24.26	--		

The regression coefficient (beta) for the independent variable in this model is 0.541, indicating a strong influence of the independent variable on the dependent variable (Table 2).

Table 2

Unstandardized and Standardized Regression Coefficient, t-statistics, and Significance Level

Model	Unstandardized Coefficient	Beta Coefficient	T	Significance Level
Constant	0.495	--	1.18	0.002
Private & public sectors performance	0.523	0.541	11.37	0.000

3.2. Driving Factors at the Litany Level in Urban Environmental Resilience of Kurdistan Cities

In the context of Causal Layered Analysis within the Mic Mac model, various modes of understanding—scientific-experimental, interpretive-hermeneutic, and philosophical-critical—are integrated. The value of this method lies not only in providing more accurate future predictions but also in creating transitional spaces necessary for generating alternative futures. Moreover, the application of this method to public and long-term policymaking results in more comprehensive, profound, and effective insights. At the litany level, the discussion revolves around quantitative trends, problems, and issues often exaggerated for political reasons and frequently reported in the media. These issues are typically associated with a sense of helplessness, passivity, and expectation from others. Deep analysis is not required to comprehend this layer, and the underlying assumptions are rarely questioned. According to surveys and interviews with experts in urban environmental resilience in the Kurdish cities of the Kurdistan region, Table 3 lists the variables at the litany level. The findings indicate that the component "Strategic Documents of Urban Environmental Resilience" received an average score of 4.52 out of 5, representing the highest influence. In contrast, the "Index of Environmental Conflicts with Neighboring Countries" received a score of 4.47, highlighting significant levels of influence at this level.

Table 3

Driving Factors at the Litany Level in Urban Environmental Resilience of the Study Area

Litany Level	Impact Layer (%)		Impact (%)		AVG
	Apparent	Hidden	Short term	Long term	
Strategic Documents of Urban Environmental Resilience	65	35	45	55	4.52
Ineffective and unfamiliar managers with the resilience of the urban environment	40	60	63	37	4.47
Environmental conflicts with neighbouring countries	45	55	74	26	3.36

If current trends continue, future studies may lead to significant negative effects, such as a lack of depth and breadth in the scope of analysis, limited exploration of alternative frameworks, uncritical acceptance of the status quo, and the tendency to oversimplify or exaggerate future predictions. These tendencies may foster a sense of hopelessness, fear, or extreme optimism about the future, apathy toward future events, the perpetuation of existing social structures in future societies, and the consolidation of power by those in authority.

3.3. Driving Factors at the Systematic Level in Urban Environmental Resilience of Kurdistan

At the systematic level, the performance of official institutions and related variables in analyzing environmental resilience in the cities of Kurdistan is examined. This level identifies the most important trends from the past to the present, emphasizing the analysis of drivers affecting the subject through a combination of quantitative and qualitative dimensions. The weight, duration, and intensity of each factor's influence have been determined. According to Table 4, variables such as A5 (Local Government Programs for Urban Environment Resilience), A9 (Rural-Urban Migration & Urban Environment Resilience), A14 (Financial Investment in Urban Environment Resilience Infrastructures), A23 (Non-experts' Mastery of Environmental Resilience Processes), and A29 (Destruction of Ecological Areas in the Kurdistan Cities in Line with the Rent Game of Urban Lands) received the highest scores of 4.84, 4.73, 4.42, 4.33, and 4.10, respectively, indicating their significant impact and intensity as event coefficients.

Table 4

Driving Factors at the Systematic Level in Urban Environmental Resilience of the Study Area

Systematic Level	Impact Layer (%)		Impact (%)		AVG
	Apparent	Hidden	Short term	Long term	
Local Government Programs for Urban Environment Resilience	15	85	60	40	4.84
Rural-Urban Migration & Urban Environment Resilience	55	45	36	64	4.73
Financial Investment in Urban Environment Resilience Infrastructures	74	26	70	30	4.42
Non-experts' Mastery of Environmental Resilience Processes	46	54	62	38	4.33
Destruction of Ecological Areas in the Kurdistan Cities in Line with the Rent Game of Urban Lands	48	52	47	53	4.10

3.4. Driving Factors at the Discourses-Worldviews Level in Urban Environmental Resilience

At this level, analyzing urban environmental resilience in Kurdistan involves futurists entering post-structural thinking and the domain of critical futurism, critiquing existing frameworks and perspectives related to the research topic. Following Michel Foucault's approach, Sohail Enayatullah considers this level crucial for recognizing the deeper environmental assumptions underlying the subject. This understanding is essential for creating a future vision with a more profound comprehension of the topic. At this stage, it is possible to explore how different discourses on the urban environment and its resilience operate within the study area, creating significant effects.

Table 5

Driving Factors at the Discourses-Worldviews Level in Urban Environmental Resilience

Discourses-Worldviews Level	Impact Layer (%)		Impact (%)		AVG
	Apparent	Hidden	Short term	Long term	
Opaque Environmental Policies	63	37	43	57	4.82
Nuclear Waste and Urban Environmental Pollution	41	59	39	61	4.70
Urban and Rural Land Use Changes	26	74	25	75	4.60
Using New Environmental Technologies	64	36	53	47	4.45
Improper Recycling of Municipal and Chemical Waste	52	48	61	49	4.33
Construction of Numerous Dams & Destruction of Biodiversity (Urban Rivers, etc.)	42	58	71	29	4.20
Resilience and Attention to Climatic Conditions in the Area	53	47	82	18	4.10

3.5. Driving Factors at the Myth and Metaphor Level in Urban Environmental Resilience

At this stage, elites and study groups involved in the research were asked to discuss various scenarios related to the future resilience of the urban environment in the cities of Kurdistan province. These discussions involved posing deep questions and developing corresponding scenarios based on final variables. Among these variables, indicators A21, A13, A3, A6, A17, A24, and A30 had the greatest impact on other research variables, with respective effect sizes of 4.93, 4.91, 4.87, 4.85, 4.73, 4.50, and 4.34. The realization of alternative and executable scenarios depends on the presence of these elements in future perspectives.

Table 6

Driving Factors at the Myth and Metaphor Level in Urban Environmental Resilience

Myth and Metaphor Level		Impact Layer (%)		Impact (%)		AVG
		Apparent	Hidden	Short term	Long term	
The Uncontrollable Nature of Some Environmental Crises (Fine Dust)	A21	51	49	62	38	4.93
Resilience and Attention to Climatic Conditions in the Area	A13	25	75	43	57	4.91
Management of Resilience Processes at Local and Regional Levels	A3	27	73	35	65	4.87
Urban Environment Resilience Diplomacy	A6	46	54	52	48	4.85
Human Hazards and Natural Disasters	A17	31	69	60	40	4.73
Neglecting the Protection of Urban Ecological Areas	A24	72	28	39	61	4.50
Inefficient and Unfamiliar Managers with the Resilience of the Urban Environment	A30	60	40	68	32	4.34

3.6. Final Key Drivers of Urban Environmental Resilience in the Cities of Kurdistan Province

Drivers are the most critical elements influencing the process of environmental resilience in the urban area under study. Without considering these drivers, developing any document or program to enhance the future state of the environmental resilience system in the study area will face challenges and potential failure. This section lists the most influential drivers on the subject, as shown in Table 7.

Table 7

*Final Key Drivers of Urban Environmental Resilience in the Cities of Kurdistan Province*

Rank	ABB	Explanation of drivers	Score
1	A1	Strategic Documents of Urban Environment Resilience	4.99
2	A24	Neglecting the Protection of Urban Ecological Areas	4.95
3	A17	Human Hazards and Natural Disasters	4.93
4	A30	Inefficient and Unfamiliar Managers with the Resilience of the Urban Environment	4.81
5	A20	Environmental Conflicts with Neighboring Countries	4.79
6	A5	Local Government Programs for Urban Environment Resilience	4.76
7	A9	Rural-Urban Migration & Urban Environment Resilience	4.75
8	A14	Financial Investment in Urban Environment Resilience Infrastructures	4.73
9	A27	Opaque Environmental Policies	4.71
10	A15	Nuclear Waste and Urban Environmental Pollution	4.68
11	A19	Urban and Rural Land Use Changes	4.53
12	A18	Use of Renewable Energy	4.44
13	A25	Improper Recycling of Municipal and Chemical Waste	4.31
14	A28	Construction of Numerous Dams and Destruction of Biodiversity (Urban Rivers)	4.22
15	A13	Resilience and Attention to Climatic Conditions in the Area	4.11
16	A21	The Uncontrollable Nature of Some Environmental Crises (Fine Dust)	4.05

The unpredictability and uncertainty of each transformation should be examined to develop final scenarios. Figure 1 demonstrates how scenario design and prediction methods can be applied to different time horizons. In the short-term horizon, when predictability is high, prediction is the preferred method. In the very long-term horizon, uncertainty is pervasive, and planning benefits diminish, leaving hopeful expectations as the only knowns about the future. Scenarios are most applicable in the middle region, where significant predictability and uncertainty coexist. The central area in the figure below represents a strategic decision-making horizon due to its sensitive and critical structural uncertainties. This section identifies important uncertainties in various areas of environmental resilience in urban areas in Kurdistan province using the uncertainty and impact matrix, incorporating the previously identified key factors and drivers.

Figure 1

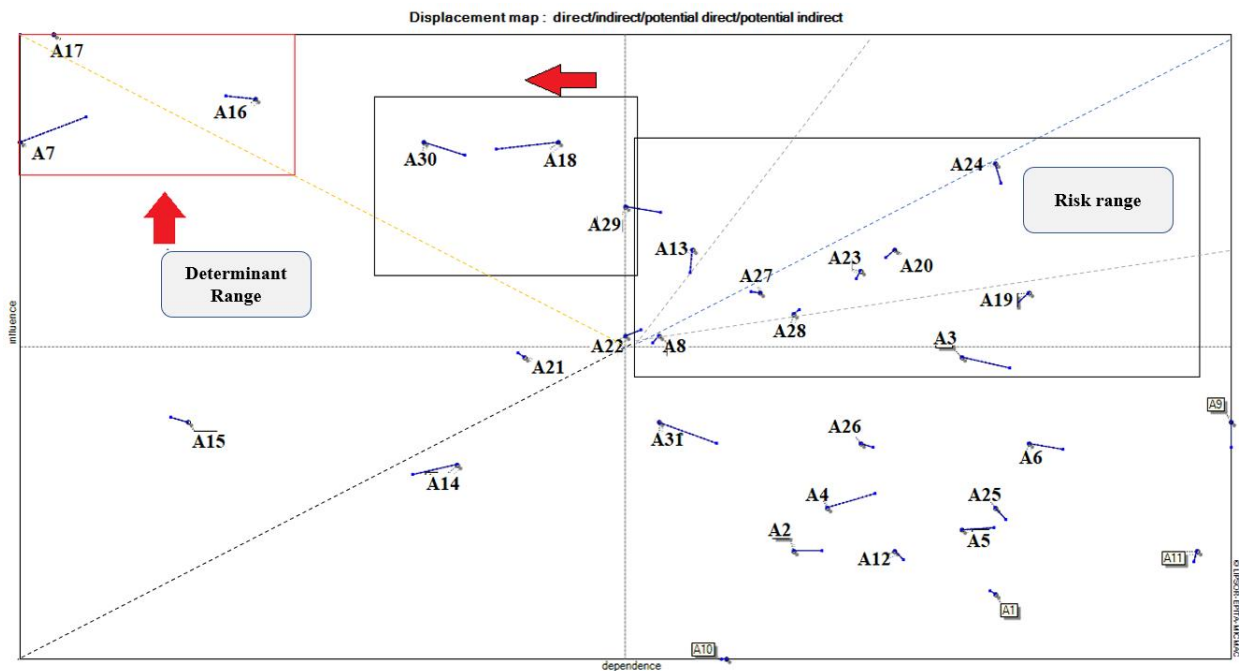*The Uncertainty Matrix and Impact Level of Urban Environmental Resilience in the Study Area*
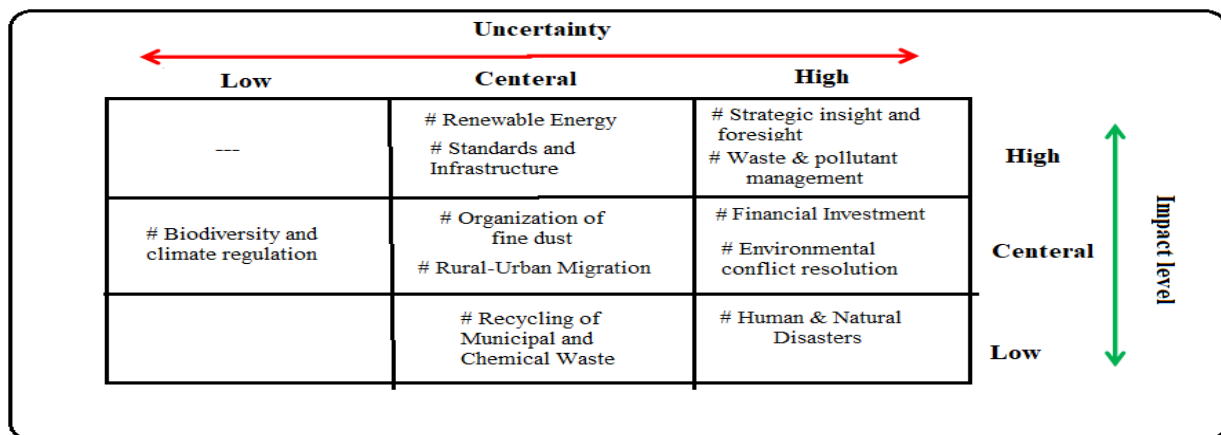
In correspondence with above results, the probability of variable events in the research and their statuses are illustrated in Figure 1 with a probability displacement rate. This diagram indicates a high level of instability in the urban environmental resilience system in the cities of Kurdistan province and shows the uneven distribution of research variables. Additionally, most determining statuses are at risk.

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Figure 2

Probability of Variable Events in Research and Their Statuses

Following the conducted analyses, the most significant research scenarios can be presented as follows:

Scenario One (Optimal Urban Environmental Resilience in the Study Area): In this scenario, the presence of descriptors such as active participation and empowerment, visionary planning, adept event and process intelligence, utilization of clean and low-carbon energy, adherence to high-level environmental standards, well-structured waste management contracts and recycling laws, up-to-date regulations and guidelines, substantial investment and financial provision, effective user integration, and meticulous management of particulate matter and various environmental aspects will contribute to achieving an outstanding and desirable level of urban environmental resilience.

Scenario Two (Satisfactory Urban Environmental Resilience in the Study Area): In this scenario, the inclusion of descriptors such as active participation and empowerment, visionary planning, adept event and process intelligence, utilization of clean and low-carbon energy, adherence to high-level environmental standards, well-structured waste management contracts and recycling laws, up-to-date regulations and guidelines, substantial investment and financial provision, effective user integration, and meticulous

management of particulate matter and various environmental aspects will result in an acceptable level of urban environmental resilience.

Scenario Three (Insufficient Urban Environmental Resilience in the Study Area): In this scenario, the presence of descriptors such as active participation and empowerment, visionary planning, adept event and process intelligence, utilization of clean and low-carbon energy, adherence to high-level environmental standards, well-structured waste management contracts and recycling laws, up-to-date regulations and guidelines, substantial investment and financial provision, effective user integration, and meticulous management of particulate matter and various environmental aspects will lead to an inadequate and unacceptable level of urban environmental resilience.

Scenario Four (Crisis Emergence in Urban Environmental Resilience in the Study Area): In this scenario, the manifestation of descriptors such as active participation and empowerment, visionary planning, adept event and process intelligence, utilization of clean and low-carbon energy, adherence to high-level environmental standards, well-established waste contracts, and recycling infrastructures, up-to-date regulations and guidelines, substantial investment and financial provision, effective user integration, and

meticulous management of particulate matter and all forms of environmental issues will result in a vulnerable and crisis-prone level of urban environmental resilience.

4. Discussion and Conclusion

This research conducted a comprehensive analysis of urban environmental resilience in the study area, utilizing a robust model that underwent two rounds of rotation. The model's goodness of fit coefficient, an impressive 96.96%, attests to its accuracy and effectiveness in analyzing various facets of urban environmental resilience. This coefficient serves as a reliable metric for assessing the sustainability or unsustainability of urban environmental resilience. Among the 903 calculated values, 58 were identified as neutral regarding impact-dependence relationships among variables. Additionally, the ranking values exhibited relative weakness, with 156 cases falling below the average impact of 412 points. The cross-impact matrix analysis method, commonly used in strategic planning and the assessment of urban sustainability, was pivotal in this study, given the future-oriented methodology employed.

After defining the research population and statistical sample, the researcher compiled a list of the most critical factors influencing the topic, which was then refined during Delphi sessions with experts. Participants finalized the list of key variables, which were classified into areas such as management and policymaking. The results were quantified, with impacts scored from 0 to P. By integrating the final opinions from other research groups and creating impact and uncertainty matrices (30x30) within the Mic Mac software environment, the results in each category were scored (0: neutral, 1: low, 2: medium, 3: high, and P: potential). Once the most important direct, indirect, and potential impacts, uncertainties, and drivers were identified, the researcher developed 17 descriptors and four scenarios—desirable, acceptable, disaster, and crisis—based on these descriptors. To ensure consistency, a balanced cross matrix and a probability questionnaire were employed to finalize the descriptors.

The analysis revealed that the adjusted coefficient of determination was 0.485, indicating that the independent variable dimensions could explain 48.5% of the variance in the dependent variable. The remaining 51.5% of the variance is attributed to other factors outside the model, as indicated by the error term. The Durbin-Watson statistic of 1.615 further supports the model's explanatory power. The F-statistic of 71.64, with a significance level of 0.000 (below the 0.05 threshold), indicates that the independent variable dimensions significantly influence the dependent variable. According to surveys and expert interviews on urban environmental resilience in Kurdish cities of the Kurdistan region, the "Strategic Documents of Urban Environmental Resilience" component received the highest average score of 4.52 out of 5. In contrast, "Ineffective and Unfamiliar Managers with the Resilience of the Urban Environment" received a score of 3.36, while the "Index of Environmental Conflicts with Neighboring Countries" scored 4.47. Variables such as A5 (Local Government Programs for Urban Environment Resilience), A9 (Rural-Urban Migration & Urban Environment Resilience), A14 (Financial Investment in Urban Environment Resilience Infrastructures), A23 (Non-experts' Mastery of Environmental Resilience Processes), and A29 (Destruction of Ecological Areas in Kurdistan Cities in Line with Urban Land Rent Games) were identified as having the most significant impact and intensity, with scores of 4.84, 4.73, 4.42, 4.33, and 4.10, respectively.

Following the comprehensive analyses conducted in this research, several strategic recommendations have emerged to strengthen urban environmental resilience in the municipalities of Kurdistan Province. Utilizing the sophisticated Causal Layered Analysis (CLA) methodology to meticulously explore the complex layers affecting environmental resilience, the following suggestions are proposed as strategic imperatives for fostering sustainable urban development and reducing vulnerabilities:

Achievable Visions and Missions: Establish realistic and attainable visions and missions specific to the study area, ensuring alignment with environmental resilience goals.

Conflict Resolution: Engage in active conflict resolution processes with neighboring countries, such as Iraq and Turkey, to address shared environmental challenges and enhance regional resilience.

Investment in Low-Carbon Urbanization: Increase investment in low-carbon urbanization initiatives to minimize the environmental footprint and promote sustainable development.

Employment Improvement in Rural Areas: Implement measures to improve employment rates in rural areas to reduce migration and contribute to balanced regional development.

Climate Change Mitigation: Develop and implement strategies to address climate change, focusing on reducing its harmful effects through sustainable practices and policies.

Waste Reduction and Management: Implement effective waste reduction measures and prevent the accumulation of hazardous chemical and nuclear waste in residential and ecological areas to safeguard the environment and public health.

Multi-Dimensional Vulnerability Assessment: Conduct a comprehensive multi-dimensional vulnerability assessment to identify and prioritize specific vulnerabilities within the urban environmental system.

Dynamic Modeling for Resilience Dynamics: Employ dynamic modeling techniques to simulate urban resilience dynamics in response to various stressors, aiding in scenario forecasting and adaptive capacity assessment.

Cross-Sectoral Collaboration Framework: Develop a cross-sectoral collaboration framework involving governmental, academic, and private sectors to enhance coordination in addressing environmental resilience challenges.

Integrated Risk and Opportunity Assessment: Conduct an integrated risk and opportunity assessment to devise adaptive strategies that capitalize on positive developments while mitigating risks.

Enhanced Community Engagement Strategies: Strengthen community engagement strategies by integrating participatory approaches and citizen science initiatives, fostering a sense of ownership and active contribution to environmental sustainability.

Real-Time Monitoring Systems: Implement advanced real-time monitoring systems for environmental indicators and resilience parameters, utilizing emerging technologies like IoT and remote sensing for adaptive decision-making and early warnings.

Resilience Capacity Building Programs: Establish capacity-building programs to enhance the knowledge and skills of local policymakers, urban planners, and community leaders, ensuring a proactive approach to urban environmental resilience.

Scenario Validation Workshops: Organize scenario validation workshops with stakeholders to refine and validate identified scenarios, ensuring that diverse perspectives are considered for robust and contextually relevant resilience strategies.

Developing Strategic Documents: Formulate comprehensive strategic documents to enhance urban environmental resilience in Kurdistan Province, providing a clear roadmap for sustainable development.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Declaration of Interest

The authors report no conflict of interest.

Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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