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Evaluation of the Effective Consequences on Urban Water and Wastewater Assets in the Face of Environmental Pollution: A Case Study of Hamedan City, Iran

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ABSTRACT

In this study, with the aim of presenting an optimal pattern, the consequences affecting the water and wastewater assets of Hamedan City, Iran, in the face of environmental pollution were preliminarily evaluated using the SECA (Simultaneous Evaluation of Criteria and Alternatives) technique. This was done by preparing, distributing, and analyzing expert questionnaires, considering criteria such as "human consequence, physical and structural consequence, security consequence, economic consequence, environmental consequence, socio-political consequence, and functional-reputational consequence." The evaluation utilized software tools such as Google Earth Pro, LINGO 18.0, and ArcGIS. The initial results indicate that among the criteria for evaluating consequences, the environmental consequence with a weight of 0.2286, the human consequence with a weight of 0.1467, and the socio-political consequence with a weight of 0.1425 have taken the first to third priorities, respectively. Among the water and wastewater assets of the studied city, based on sensitivity, water treatment plants, surface water resources, and water pumping stations ranked first to third, respectively. Finally, to validate the applied pattern, the consequences affecting the assets in the face of environmental pollution were re-evaluated based on the weights of the obtained criteria and expert feedback. The results indicated that the city's water treatment plants, with a score of 3.6255, were identified as the priority asset. The alignment of these results with the initial evaluation confirms the accuracy and validity of the applied pattern. According to the definition of consequence levels, the priority asset falls into the "high" category, necessitating the implementation of control measures.

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INTRODUCTION

Today, cities are typically constructed and expanded in areas that are constantly threatened by various natural and human-made hazards due to technological advancements. The vulnerability of important, sensitive, and vital assets in a city to various hazards can lead to their inefficiency and, consequently, an increase in public dissatisfaction (social crisis) and a lack of service provision in emergency situations. From this perspective, while hazards and their potential impacts on a city's physical assets may initially appear as serious obstacles to development, it can be argued that if, prior to disasters, comprehensive crisis management and foresight approaches are considered, potential disasters in a city can be identified, and the impacts on its physical assets can be evaluated and prioritized in facing those disasters, especially human-

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made ones. By understanding the consequences and their negative impacts as obstacles, the potential and capacities arising from disasters can also be identified as opportunities for achieving development. Subsequently, strategies can be proposed to mitigate impacts and leverage existing opportunities to achieve regional sustainable development goals. In this context, consequences are among the defining factors of a threat or disaster, representing the outcomes of a threat or disaster that affect objectives. Any disaster can lead to a wide range of impacts; therefore, when examining the impacts on urban assets, the worst-case scenario resulting from the threat should be considered. Analyzing the impacts resulting from targeting urban assets is a crucial part of determining the risk scope of those assets. Therefore, the consequences of targeting infrastructure and assets by hypothetical threats are analyzed based on the vulnerability of the infrastructure (Vejdani Nozar et al, 2025).

Although, by examining and searching different databases, it was determined that there is extensive research in the field of assessing urban risk and vulnerability in the face of a specific hazard; however, the lack of studies in the field of accidents and crisis management that evaluate the consequences of hazards on urban assets in the face of disasters is obvious. Therefore, new patterns and scientific methods are needed to evaluate the impacts on urban assets in the face of various disasters (both natural and man-made). In this regard, by reviewing the history of studies related to the performance assessment of urban assets, such as water and wastewater infrastructure, in the face of various disasters, it can be said that the studies are generally categorized into several groups:

1. Studies Focused on Asset Risk Assessment: In this category of studies, although models and frameworks have been presented for assessing asset risks in the face of various disasters, their approach does not introduce a model for accurately evaluating the consequences affecting assets. Even if consequences are considered, it is solely for the purpose of understanding and defining control measures in line with risk management. In this regard, Lewis (2020), in the third edition of his book titled “The Role of Critical Infrastructure Protection in National Security,” introduced a combined approach that includes a simple ranking method called RAMCAP (Risk Analysis and Management for Critical Asset Protection) and a model known as MBRA(Model-Based Risk Assessment) (Lewis, 2020). Although this model estimates and evaluates risk using the equation “Risk = Threat × Vulnerability × Consequence” it does not provide a framework for comprehensively assessing consequences. Sheykhali et al. (2020) conducted a study aimed at identifying and assessing the risk of Tehran’s water and wastewater network assets against threats using a combined AHP (Analytic Hierarchy Process) and RAMCAP method. They examined the entire water and wastewater network of the Tehran metropolis in terms of asset value and risk (Sheykhali et al., 2020). However, the presented model does not have the ability to directly evaluate the consequences. Omidvar and Vejdani Nozar (2021), in their research, conducted a qualitative risk assessment of urban water supply critical infrastructure in the face of environmental hazards using a combined method of CARVER (Criticality-Accessibility-Recuperability-Vulnerability-Effect-Recognizability) - Risk Matrix (Omidvar & Vejdani Nozar, 2021). However, the introduced method lacks the capability to accurately evaluate consequences. Reuben (2021), in a study titled “Multi-Hazard and Risk Assessment Report for the Mataniko River Watershed in Guadalcanal, Solomon Islands”, identified potential hazards in the Mataniko River Basin and assessed their risk (Reuben, 2021). The study did not address the issue of consequences and their assessment.Wenling Guan et al. (2022), in their article “ Risk assessment method for industrial accident consequences and human vulnerability in urban areas”, propose a comprehensive risk assessment framework. Although this framework integrates the consequences of industrial accidents with the vulnerability of the local population,

it does not provide a comprehensive model for evaluating asset consequences (Guan et al., 2022). Additionally, it is not generalizable to various types of disasters and different regions. Abdel-Basset et al. (2022), in their article titled " A Risk Assessment Model for Cyber-Physical Water and Wastewater Systems: Towards Sustainable Development," propose a novel risk assessment framework termed RAF-CPWS (Risk Assessment Framework - Cyber-Physical Water Systems). This framework aims to comprehensively evaluate risks associated with water and wastewater technologies. It incorporates a multi-criteria group decision-making (MCGDM) approach, grounded in neutrosophic theory, to assess risks by considering a range of factors, including economic, environmental, technological, cybersecurity, and social dimensions (Abdel-Basset et al., 2022). However, despite its comprehensive design, the model has limitations. Specifically, it lacks the capability to assess consequences in detail and cannot be generalized to evaluate risks arising from various types of disasters.

2. Studies Focused on Assessing Asset Vulnerability: In this category of studies, the approach of the models and patterns presented is for assessing the vulnerability of assets in the face of various disasters and is not applicable for assessing the consequences affecting assets. Taghinezhad and Zonemat Kermani (2016) conducted a study titled "Using the RAMCAP Approach to Assess the Vulnerability of Dams and Water Transmission Lines Against Natural Threats and Threats from Weapons." They employed the combined RAMCAP-CARVER method alongside SPSS (Statistical Package for the Social Sciences) software to qualitatively analyze assets, threats, and vulnerability indicators related to dams and water transmission lines (Taghinezhad & Zonemat Kermani, 2016). However, their study focused solely on vulnerability assessment and did not incorporate outcome assessment into their model. Roudbari et al. (2017), in their article titled " Assessing the Vulnerability of Water Supply System Components," utilized a Likert scale to assess the sensitivity and value of assets while selecting assets and potential threats. Based on predefined criteria, they evaluated these factors and ultimately identified and analyzed the most vulnerable components of the water supply system using SPSS software (Roudbari et al., 2017). However, their study is specifically tailored for vulnerability assessment and lacks the capability to evaluate consequences. Similarly, Rostam Asl et al. (2020) in a study assessed human and environmental vulnerabilities of a river basin in southwestern Iran simultaneously using a combined RBV (Risk-Based Vulnerability) - GIS (Geographic Information System) method. And Chapajin et al. (2021) in the Biratnagar metropolis, Nepal conducted an assessment of the vulnerability of urban assets to multiple hazards using an analytical method and a geographic information system (Rosatm Asl et al, 2020 & Chapagain et al, 2021). In these studies, the methods used are also not able to accurately assess the consequences in full.

3- Studies that examine the consequences but do not precisely evaluate them in the context of various disasters: Kolba et al. (2017), in their study titled "Scenario analysis of management processes in the prevention and the elimination of consequences of man-made disasters," proposed a model for analyzing anthropogenic hazards, identifying critical assets at risk, detecting emergency situations, and evaluating processes related to scenario planning and safety management (Kulba et al., 2017). However, in this model, with the aim of eliminating effective consequences; the risk of selected assets against man-made disasters is assessed in a scenario-based manner, which results in the definition of safety principles, in fact, the model does not have the ability to accurately assess the consequences. Fabbri and Heraty-Wood (2019) introduced a damage analysis module as a novel tool for consequence assessment. While they compared the model, developed by the European Commission's Joint Research Centre for evaluating the consequence of industrial accidents, across various scenarios and scientifically assessed its performance (Fabbri & Wood, 2019). the model lacks flexibility and is unsuitable for large-scale hazard analysis. Boakye et al. (2022), in their article titled "Which Consequences

Matter in Risk Analysis and Disaster Assessment?", explore the nature of diverse environmental hazards, both natural and anthropogenic, and underscore their significant impacts on assets, economic stability, and human lives. While the study investigates the consequences of past disasters, forecasts potential outcomes of future natural hazards, and stresses the importance of understanding and categorizing consequences to enhance risk analysis and disaster assessment frameworks (Boakye et al., 2022). it approaches consequence assessment in a broad context and does not propose a generalizable model. Fadaei (2023), in a review article examining and studying 86 related research and articles between 2014 and 2023, shows that although various groups of emerging and destructive threats have been found in Iran's drinking water supply system and have sometimes been evaluated using certain methods, these studies are still not sufficient to assess the feasibility of the threats, their vulnerability, and their consequences (Fadaei, 2023). Ferdowsi et al. (2024), in their article titled "Urban Water Infrastructure: A Critical Review on Climate Change Impacts and Adaptation Strategies, " examine the challenges facing urban water infrastructure in ensuring access to safe drinking water while advancing sustainable development goals (Ferdowsi et al., 2024). However, the study has yet to propose a comprehensive model for accurately assessing the impacts on urban water and wastewater systems in the face of various disasters. Such a model would require a precise approach to identify the consequences affecting the performance of this critical infrastructure. Schillinger and Ozerol (2024), in their article titled " For Better or Worse: The Influence of Conflict-Driven Decentralization on the Resilience of Urban Water Supply Infrastructure in the Middle East ", examined the development of decentralized water infrastructure as a strategy to address human-made disasters in five cities across Iraq, Syria, and Yemen. They explored the consequences of decentralization on the resilience of urban water supply systems (Schillinger & Ozerol, 2025). However, they did not provide a comprehensive model for identifying and assessing these consequences, leaving room for further research.

A review of the literature reveals that the occurrence of any threat to a city's assets encompasses two categories of primary and secondary consequences. Generally, the consequences and effects resulting from the occurrence of threats on urban assets can be summarized as follows:

- Disruption and cessation of ongoing activities and functions, leading to social, economic, political, security, etc., damages.
- Destruction of the existing spatial structure, resulting in severe or scattered devastation in the city.
- Casualties and injuries leading to human and managerial damages in the city.
- Economic disruptions and high financial costs.
- Significant environmental damages.
- Loss of critical and valuable information (Amini Varaki et al., 2014; UNESCO, 2021).

Although the consequences of an incident may vary depending on its nature, the most significant general consequences are as follows:

- Fatalities, poisonings, and irreparable injuries
- Release of pollutants into air, soil, and water
- Financial and human losses, as well as the destruction of assets
- Injury or long-term effects on the population
- Impact on the health of plants and animals
- Disruption and interruption of operations
- Other health and environmental effects (Vejdani Nozar et al, 2025; Tavakoli Moghadam et al., 2013).

However, the consequences of various disasters, especially environmental pollution, compel decision-makers to consistently consider consequence reduction as an important criterion in their calculations.

It is important to note that when discussing environmental pollution, these threats manifest in the following ways:

- Environmental pollution resulting from various natural hazards, such as earthquakes, floods, and wildfires.
- Environmental pollution arising from human errors and the occurrence of unintentional human-made and technological hazards.
- Environmental pollution due to intentional human-made threats aimed at causing harm.
- Pollution resulting from unconventional human activities.

Moreover, it should be noted that environmental pollution spreads in air, water, and soil, leading to impacts on related infrastructures and assets, ultimately resulting in crises in human communities such as cities.

A review of drinking water contaminants and their health consequences in Iran reveals the presence of various emerging pollutants, including THMs, nitrate (NO_3), fluoride (F), radon, and heavy metals such as arsenic (As), lead (Pb), nickel (Ni), cadmium (Cd), zinc (Zn), copper (Cu), and chromium (Cr). However, epidemiological studies on the health consequences of these contaminants remain limited (Fadaei, 2023). In this context, mining, considered one of the most destructive human activities for the environment, consistently leads to pollution such as the release of heavy metals and oil contamination in drinking water resources, especially for residents near mining sites (Badamasi et al., 2023). Additionally, the impact of leachate from landfills on the quality of water resources, particularly groundwater, should be recognized as one of the most significant water pollutants, leading to increased organic matter, nutrients, salts, and heavy metals in water sources (De et al., 2017). Currently, developing countries face significant challenges in maintaining natural sustainability due to the pollution of water resources with heavy metals, human wastewater discharge, and agricultural and industrial runoff into surrounding rivers (Al Sadikul Islam et al., 2023).

In this study, the primary objective was to propose an optimal pattern for evaluating the consequences affecting the water and wastewater assets of Hamedan City, one of the most prominent cities in western Iran. To achieve this goal, the following steps were undertaken. First, various disaster-induced consequences were identified and defined as evaluation criteria. Data were collected through both library research and field studies. A location map of the studied assets was developed using Google Earth Pro software. Subsequently, a structured questionnaire was designed, and insights were gathered from 20 relevant experts in the field.

Using the SECA (Simultaneous Evaluation of Criteria and Alternatives) multi-criteria decision-making technique within the LINGO 18.0 software environment, the criteria were weighted, the assets were classified, and an initial assessment of the consequences was conducted. Following this, the topic was thoroughly analyzed, and a final evaluation of the consequences affecting the priority assets in the study area was carried out. This final evaluation was based on the derived criteria weights and additional expert feedback.

In this study, although the consequences of a disaster may vary depending on its nature, they were ultimately defined as follows and selected as evaluation criteria based on the opinions of experts and scientific consultation with them:

- Human Consequence (P1)

Human consequence pertains to the direct and indirect outcomes of an event or decision on individuals' lives, health, well-being, and rights. These consequences may encompass loss of life, physical and psychological harm, population displacement, or shifts in quality of life.

- Physical and structural Consequence (P2)

These consequences involve changes to the physical environment and human-made structures. This includes the destruction of buildings, infrastructure (such as roads, bridges, power grids, and water systems), and alterations to the geology or geography of a region.

- Security Consequence (P3)

Security consequence relates to the effects of an event or decision on individual, societal, national, or international security. This may involve heightened terrorist threats, public unrest, military conflicts, or a decline in the rule of law.

- Economic Consequence (P4)

Economic consequence refers to the effects of an event or policy on the economy at both micro (individuals and businesses) and macro (national or regional) levels. This includes fluctuations in GDP, unemployment rates, inflation, poverty levels, and income distribution.

- Environmental Consequence (P5)

Environmental consequence refers to the effects of an event or decision on ecosystems, natural resources, and the environment. This includes water, air, and soil pollution, deforestation, species extinction, and climate change.

- Social and Political Consequence (P6)

Social consequence involves changes in social structures, relationships, and norms, while political consequence pertains to effects on power dynamics, governance, and public policies. This may include changes in political engagement, social unrest, or legislative reforms.

- Functional and Reputational Consequence (P7)

Functional consequence refers to the effects of an event or decision on the performance of an organization, system, or institution, while reputational consequence involves impacts on public trust, reputation, and social standing.

MATERIALS AND METHODS

Hamedan, a cold mountainous city with an area of approximately 72 square kilometers and a population of over 554,406, is located in the west of Iran. The center of this city is situated at a longitude of 48 degrees 51 minutes and a latitude of 34 degrees 79 minutes at the foot of Mount Alvand. The city's elevation ranges from 1,750 to 2,100 meters above sea level, making it one of the highest areas in the country (Figure 1). In this city, the critical assets under study include water and wastewater infrastructure for supplying drinking water and collecting sewage. The water supply is sourced from surface water (approximately 72.5% from two reservoirs) and groundwater (less than 27.5% from 61 wells), with a total consumption of about 1,800 liters per second. The infrastructure includes four water treatment plants, 18 main reservoirs (both ground and elevated), 12 water pumping stations, about 200 kilometers of main water transmission lines, 93 kilometers of secondary water transmission lines, over 1,000 kilometers of water distribution network, 260 kilometers of sewage collection network, 37 kilometers of sewage transmission lines, and one wastewater treatment plant (Figure 2).

In this study, the impacts of environmental pollution on the water and wastewater infrastructure of Hamedan city were evaluated. Data was gathered through a combination of library research and interviews with experts. To begin, a map of the studied assets was created using Google Earth Pro, as illustrated in Figure 2. Following the definition of evaluation criteria and the preparation of a questionnaire, expert opinions were summarized, criteria were weighted, assets were ranked, and impacts were evaluated using the SECA (Simultaneous Evaluation of Criteria and Alternatives) multi-criteria decision-making technique in the LINGO 18.0 software environment. Finally, to create a mapping of the impacts on the assets, ArcGIS software was utilized.

In this context, the difference between the SECA technique and other methods is that in

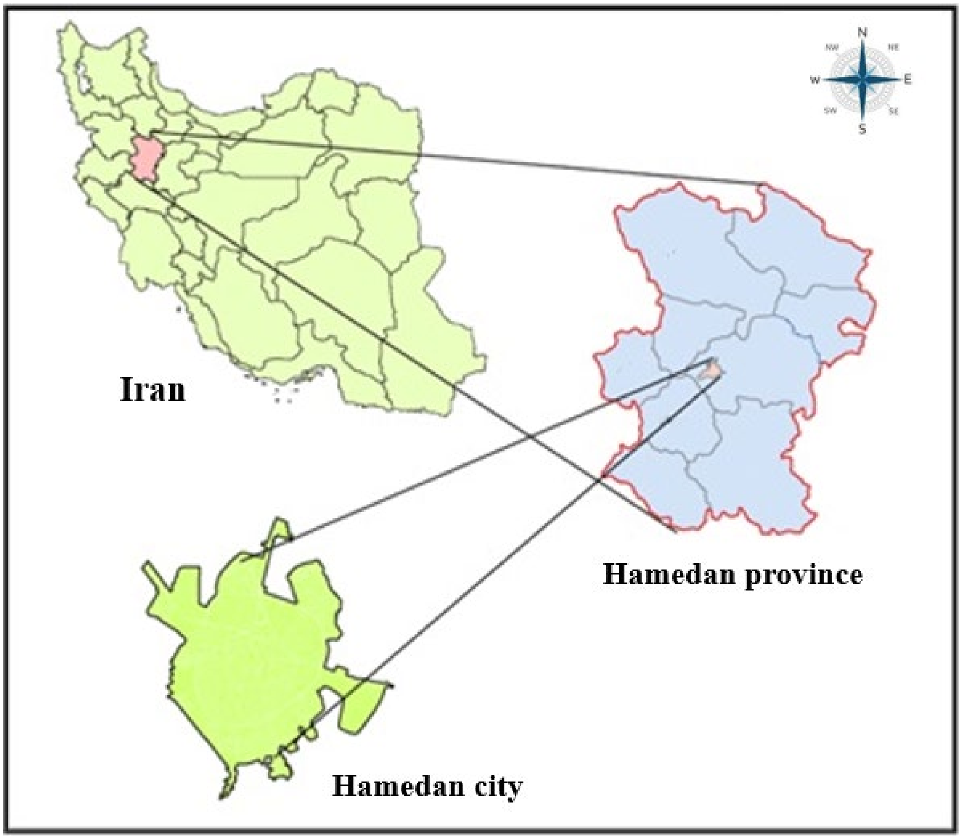

Fig. 1. Geographic location of Hamedan city (NCC, 2021)

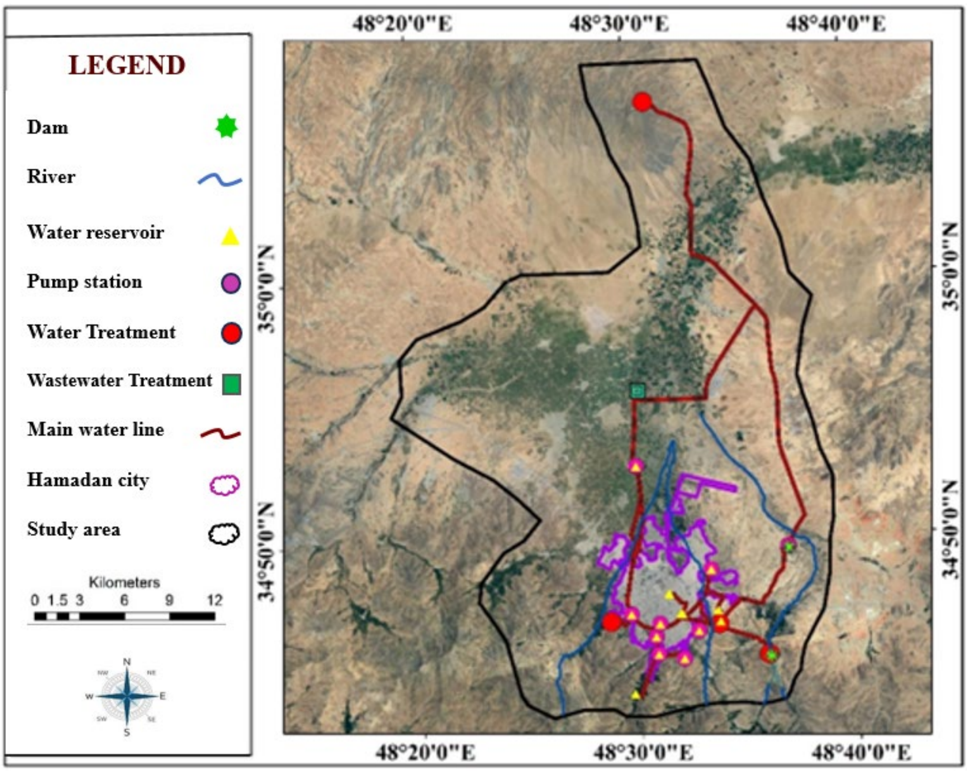

Fig. 2. Location of the study area and vital water and wastewater assets of Hamedan city

similar methods, the weights of the criteria are initially calculated using another secondary method and then provided as input to these methods. However, in the SECA method, both the weight of the criteria and the ranking of the options are performed simultaneously. This advantage leads to greater accuracy and better results in calculations. Additionally, the inputs of this method include both qualitative and quantitative criteria, which further enhances its flexibility (Keshavarz Ghorabaee et al., 2018). The steps of the SECA method are as follows:

- Formation of the Decision Matrix:

The first step in multi-criteria decision-making methods is to form the decision matrix. The decision matrix is a row-column matrix where the columns represent the decision-making criteria and the rows represent the options we intend to rank. Each cell in this decision matrix evaluates each option against each criterion.

- Normalization of the Decision Matrix:

In this section, the normalization for positive criteria uses Equation 1, and for negative criteria, it uses Equation 2. In these equations, i represents the row and j represents the column in the decision matrix. Also, BC includes criteria with a benefit aspect (or positive criteria), while NC includes criteria with a cost aspect (or negative criteria).

$$X_{ij}^{N} = \begin{cases} \dfrac{X_{ij}}{max_k X_{kj}} & \text{if} \quad j \in BC, \quad (1) \\ \dfrac{min_k X_{kj}}{X_{ij}} & \text{if} \quad j \in NC, \quad (2) \end{cases}$$

- Formation of the Optimization Model

Assuming $V_j = \left[X_{ij}^{N}\right]_{n\times1}$ represents the jth criterion vector. The standard deviation of each vector (σ_j) indicates the internal changes in the vector's information. To obtain inter-criteria information in the decision matrix, the correlation between each pair of vectors must be calculated, where r_{jl} represents the correlation between the jth and lth vectors. In total, the value (π_j) indicates the degree of conflict between the jth criterion and other criteria, which is obtained from Equation 3.

$$\pi_j = \sum_{l=1}^{m}(1 - r_{jl}) \quad (3)$$

Increasing variability in a criterion vector (σ_j), as well as increasing the degree of difference between criterion j and other criteria (π_j) enhances the importance (weight) of the criterion. Accordingly, the normalized values (σ_j) and (π_j) are defined as reference points for the weights of the criteria. These values can be calculated using Equations 4 and 5:

$$\sigma_j^N = \frac{\sigma_j}{\sum_{l=1}^{m}\sigma_l} \quad (4)$$

$$\pi_j^N = \frac{\pi_j}{\sum_{l=1}^{m}\pi_l} \quad (5)$$

Based on the above explanations and using the weighted Sum methods, the following multi-objective optimization model has been presented.

$$\text{Max } S_i = \sum_{j=1}^{m} W_j X_{ij}^N, \qquad \forall_i \in \{1,2,\ldots n\} \qquad 6$$

$$\text{Min } \lambda_b = \sum_{j=1}^{m} (W_j - \sigma_j^N)^2 \qquad 7$$

$$\text{Min } \lambda_c = \sum_{j=1}^{m} (W_j - \pi_j^N)^2 \qquad 8$$

$$\text{s.t. } \sum_{j=1}^{m} W_j = 1 \qquad 9$$

$$W_j \leq 1, \forall_j \in \{1,2,\ldots,m\} \qquad 10$$

$$W_j \geq, \forall_j \in \{1,2,\ldots,m\} \qquad 11$$

Equation 6 enhances the overall performance of each option, while Equations 7 and 8 minimize the standard deviations and correlations of weights from the reference points for each criterion. Equation 9 ensures that the sum of the weights equals 1. Equations 10 and 11 determine the weights of the criteria for some values in the range of 1 to ε. It is worth noting that ε is considered a small positive parameter as a lower bound for the weight of the criteria. The above multi-objective model can be converted into a single-objective model, according to the objective performance of the model based on the 12 equation, the minimum overall score of the options is maximized. Since the deviation from the reference points must be minimized, they are subtracted from the target performance with a coefficient B. This coefficient affects the importance of achieving the reference points of the weight criteria. Equation 13 specifies a minimum value for the overall performance score of each option (Si). Equation 14 calculates the sum of the product of the weight of each criterion with the elements of the normalized matrix. Equations 15 and 16 derive the total standard deviations of the weights from the reference points (standard deviation and correlation) for each criterion. Equation 17 specifies that the sum of the weights must equal 1. Equations 18 and 19 indicate that the obtained weight must be between zero and one, meaning it must be greater than zero.

$$\text{Max Z} = \lambda_a - \beta(\lambda_b + \lambda_c), \qquad 12$$

$$\text{s.t. } \lambda_a \leq S_i, \qquad \forall_i \in \{1,2,\ldots n\} \qquad 13$$

$$S_i = \sum_{j=1}^{m} W_j X_{ij}^N . \qquad \forall_i \in \{1,2,\ldots n\} \qquad 14$$

$$\lambda_b = \sum_{j=1}^{m} (W_j - \sigma_j^N)^2, \qquad 15$$

$$\lambda_c = \sum_{j=1}^{m} (W_j - \pi_j^N)^2 \qquad 16$$

$$\sum_{j=1}^{m} W_j = 1 \qquad 17$$

$$W_j \leq 1, \forall_j \in \{1,2,\ldots,m\} \qquad 18$$

$$W_j \geq \; , \; \forall_j \; \epsilon \; \{1,2,\ldots,m\} \qquad 19$$

The definitions of the variables in Equations 12 to 19 are provided below:

λ_a = Minimum score of each option

λ_b = Total distance of the weight of each criterion from the normalized standard deviation

λ_c = Total distance of the weight of each criterion from the normalized correlation

β = Coefficient for subtracting from the overall target

W_j = Weight of each criterion

X_{ij}^N = Element in row i and column j of the initial matrix

S_i = Score of each option

m = Number of criteria

ε = Small positive parameter

r_{jl} = Correlation between the jth and lth vectors

It is noteworthy that in this study, for analyzing the criteria related to assessing the impacts on urban water and wastewater assets in the face of environmental pollution and data preparation, a scoring range from 1 to 5 was used based on expert opinions regarding the qualitative description of the criteria, as shown in Table 1 (a,b,c,d,e). After preparing and distributing the questionnaire among 20 relevant experts, information was gathered based on this scoring, and the results were estimated as an arithmetic mean for use in the SECA analysis. Additionally, the levels of assessing the effective consequences on assets (C) in the face of environmental pollution were defined according to expert opinions as follows:

- Lower level ($1 \leq C \leq 2$) – Blue color spectrum
- Medium level ($2 < C \leq 3$) – Yellow color spectrum
- Higher level ($3 < C \leq 4$) – Orange color spectrum
- Highest level (Critical) ($4 < C \leq 5$) – Red color spectrum

RESULTS AND DISCUSSION

By examining the overall list of urban water and wastewater assets (Table 2) and identifying these assets in the study area (Figure 2), the weighting of relevant criteria in this research (human impact, physical and structural impact, security impact, economic impact, environmental impact, social and political impact, and functional and reputational impact) is carried out. The ranking of impacts on assets in the face of environmental pollution is performed through the SECA method and the application of Lingo software. To this end, a 7×10 decision matrix (with rows representing 10 assets and columns representing 7 criteria) is formed based on the opinions and summarized information from experts. Subsequently, using specified relationships, the normalization of the matrix, determination of σ_j and calculation of normalized values σ_j and σj are estimated in Tables 3 to 6. It should be noted that in the SECA technique, multiple objective functions are transformed into a single objective function using an equivalence method (such as weighting or normalization).

Next, using the SECA technique, the nonlinear optimization equations (Eqs. 12–19) are

Table 1(a). Criteria for assessing effective consequences on urban water and wastewater assets in the face of environmental pollution.

Criteria impact	Criteria	Qualitative description of the criterion	Score
Very low (lowest)	Human consequence	There were very few injuries on site, no casualties or injuries outside.	1
	Physical consequence	Limited and very little physical damage has been done to a part of the property.	
	Security consequence	There are no security effects and consequence.	
	Economic consequence	There is very little financial loss and no economic consequences.	
	Environmental consequences	There is no environmental damage.	
	Social and political consequences	There are no injuries and social and political consequences.	
	Functional and credit consequence	Functional impairment is limited and less than one week and does not lead to credit impairment of the collection.	

Table 1(b). Criteria for assessing effective consequences on urban water and wastewater assets in the face of environmental pollution.

Criteria impact	Criteria	Qualitative description of the criterion	Score
Low (less)	Human consequence	Injuries in the place and with a small extent in its vicinity, there are no casualties and injuries outside the place.	2
	Physical consequence	The physical and bodily damages are small and if no action is taken in time, there is a possibility of spreading.	
	Security consequence	The effects and consequences of security are not evident.	
	Economic consequence	The financial loss is small and the economic consequences are not evident.	
	Environmental consequences	There is little environmental damage in the place and if timely action is not taken, there is a possibility of spreading.	
	Social and political consequences	The damage and social and political consequences are not evident.	
	Functional and credit consequence	Functional impairment less than one month and if necessary, action can lead to credit impairment of the collection.	

Table 1(c). Criteria for assessing effective consequences on urban water and wastewater assets in the face of environmental pollution.

Criteria impact	Criteria	Qualitative description of the criterion	Score
Average	Human consequence	There is a possibility of serious injuries on site, no casualties or injuries outside the site.	3
	Physical consequence	The physical and bodily damages are tangible in the place, and if timely action is not taken, there is a possibility of spreading abroad.	
	Security consequence	In case of failure to act on time, the effects and consequences of security will appear.	
	Economic consequence	There is a moderate and tangible financial loss and the possibility of economic consequences.	
	Environmental consequences	There is environmental damage on site and very little off site.	
	Social and political consequences	There is a possibility of injuries and social and political consequences if timely action is not taken.	
	Functional and credit consequence	Moderate functional impairment is evident for a few months and credit impairment.	

solved employing Lingo software. In this model, for values of β ranging from 0.1 to 7, the model is executed, and each time the weights of the criteria and scores for each urban water and wastewater asset are estimated. The estimates for different values of β are displayed in Tables 7 and 8, and also represented graphically in Figures 3 and 4.

Table 1(d). Criteria for assessing effective consequences on urban water and wastewater assets in the face of environmental pollution.

Criteria impact	Criteria	Qualitative description of the criterion	Score
High (more)	Human consequence	There is a possibility of serious on-site casualties and off-site injuries.	4
	Physical consequence	The physical and bodily damages are serious in the place and its effects and secondary consequences are evident outside.	
	Security consequence	The security implications are obvious and high.	
	Economic consequence	The financial loss is high and the economic consequences are significant.	
	Environmental consequences	There are many environmental consequences on site and off site.	
	Social and political consequences	The damage and social and political consequences are significant.	
	Functional and credit consequence	There is a lot of dysfunction in the range of a few months to a few years and a lot of credit consequences.	

Table 1(e). Criteria for assessing effective consequences on urban water and wastewater assets in the face of environmental pollution.

Criteria impact	Criteria	Qualitative description of the criterion	Score
Very high (most)	Human consequence	There are too many casualties and injuries on site and off site.	5
	Physical consequence	There is a lot of physical and bodily damage in the place and a lot outside the place.	
	Security consequence	The security implications are significant and huge.	
	Economic consequence	A huge financial loss and a significant economic consequence that there is a possibility of a wide disruption in the national economy.	
	Environmental consequences	There is a lot of environmental impact on site and off site.	
	Social and political consequences	The damage and social and political consequences are obvious and very large.	
	Functional and credit consequence	Too much functional disruption, long periods of interruption of production and service provision and loss of asset credit	

Table 2. Overall list of urban water and wastewater assets

Water and sewage assets	Representative
Surface water sources	D1
Groundwater sources	D2
Water treatment plants	D3
Water storage tanks	D4
Water pumping stations	D5
Water transmission lines	D6
Water distribution network	D7
Sewage collection network	D8
Sewage transmission lines	D9
Sewage treatment plant	D10

As shown in both the tables and the graphs, for values of $\beta > 5$, the graphs converge and do not show significant changes. Therefore, $\beta = 5$ can be considered the converged value, where the weights of the criteria and asset scores remain constant for the problem.

Thus, for $\beta = 5$, the final weights of the criteria and the final scores of the assets are estimated, with results shown in Tables 9 and 10 and graphically in Figures 5 and 6. Accordingly, among the criteria, the environmental impact with a weight of 0.2286, the human impact with a weight of 0.1467, and the social and political impact with a weight of 0.1425 rank first to third,

Table 3. Decision matrix

	P1	P2	P3	P4	P5	P6	P7
D1	3.2	4.3	3.9	4.1	3.6	4.6	4.0
D2	1.3	2.2	2.8	2.0	3.1	3.2	2.4
D3	4.1	4.7	4.5	4.8	4.7	4.6	4.9
D4	2.7	3.7	3.7	3.6	2.5	3.7	3.8
D5	2.6	3.7	3.7	3.8	3.1	3.1	4.0
D6	1.6	3.0	3.7	3.4	2.6	4.1	4.2
D7	2.2	2.3	2.1	2.2	1.9	2.8	2.5
D8	1.5	2.2	1.7	2.2	3.7	2.8	2.3
D9	1.0	2.3	1.8	2.3	3.6	2.4	2.2
D10	2.4	3.2	2.6	3.2	4.4	2.5	2.8

Table 4. Normalized matrix

	P1	P2	P3	P4	P5	P6	P7
D1	0.780	0.915	0.867	0.854	0.766	1.000	0.816
D2	0.317	0.468	0.622	0.417	0.660	0.696	0.490
D3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
D4	0.659	0.787	0.822	0.750	0.532	0.804	0.776
D5	0.634	0.787	0.822	0.792	0.660	0.674	0.816
D6	0.390	0.638	0.822	0.708	0.553	0.870	0.857
D7	0.537	0.489	0.467	0.458	0.404	0.609	0.510
D8	0.366	0.489	0.378	0.458	0.787	0.609	0.469
D9	0.244	0.489	0.400	0.479	0.766	0.522	0.449
D10	0.585	0.681	0.578	0.667	0.936	0.543	0.571

Table 5. Values of π_j

	P1	P2	P3	P4	P5	P6	P7	π_j
P1	0.000	0.079	0.239	0.123	0.640	0.313	0.224	1.618
P2	0.079	0.000	0.117	0.017	0.587	0.224	0.107	1.131
P3	0.239	0.117	0.000	0.097	0.849	0.133	0.041	1.476
P4	0.123	0.017	0.097	0.000	0.606	0.229	0.056	1.128
P5	0.640	0.587	0.849	0.606	0.000	0.874	0.828	4.384
P6	0.313	0.224	0.133	0.229	0.874	0.000	0.151	1.924
P7	0.224	0.106	0.042	0.056	0.828	0.152	0.000	1.408

Table 6: Normalized values of π_j and σj

	σj normal	π_j normal
P1	0.1655	0.1238
P2	0.1380	0.0865
P3	0.1556	0.1129
P4	0.1417	0.0863
P5	0.1309	0.3355
P6	0.1266	0.1472
P7	0.1417	0.1077

Table 7. Weights of criteria for different values of β

	β											
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
P1	0.1021	0.1329	0.1431	0.1482	0.1513	0.1548	0.1497	0.1481	0.1472	0.1467	0.1464	0.1461
P2	0.1034	0.1072	0.1085	0.1091	0.1095	0.1104	0.1113	0.1116	0.1118	0.1119	0.1120	0.1113
P3	0.0353	0.0865	0.1035	0.1121	0.1172	0.1269	0.1306	0.1318	0.1324	0.1328	0.1330	0.1330
P4	0.0387	0.0750	0.0871	0.0932	0.0968	0.1044	0.1092	0.1108	0.1116	0.1121	0.1124	0.1120
P5	0.2018	0.2044	0.2053	0.2057	0.2060	0.2102	0.2217	0.2255	0.2274	0.2286	0.2294	0.2320
P6	0.3824	0.2620	0.2219	0.2019	0.1898	0.1651	0.1510	0.1463	0.1440	0.1425	0.1416	0.1408
P7	0.1364	0.1320	0.1306	0.1298	0.1294	0.1281	0.1264	0.1259	0.1256	0.1254	0.1253	0.1248

Table 8. Scores of urban water and wastewater assets for different values β

	β											
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
D1	0.8861	0.8671	0.8607	0.8576	0.8557	0.8517	0.8491	0.8483	0.8479	0.8476	0.8475	0.8471
D2	0.5850	0.5593	0.5508	0.5465	0.5439	0.5397	0.5397	0.5397	0.5397	0.5397	0.5397	0.5401
D3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
D4	0.7273	0.7211	0.7191	0.7180	0.7174	0.7156	0.7130	0.7122	0.7117	0.7115	0.7113	0.7107
D5	0.7079	0.7183	0.7218	0.7235	0.7246	0.7266	0.7277	0.7280	0.7282	0.7283	0.7283	0.7281
D6	0.7233	0.6985	0.6903	0.6862	0.6837	0.6788	0.6764	0.6756	0.6752	0.6750	0.6748	0.6743
D7	0.5235	0.5080	0.5028	0.5002	0.4987	0.4950	0.4919	0.4908	0.4903	0.4900	0.4897	0.4894
D8	0.5746	0.5505	0.5424	0.5384	0.5360	0.5325	0.5343	0.5350	0.5353	0.5355	0.5356	0.5363
D9	0.5235	0.5080	0.5028	0.5002	0.4987	0.4973	0.5009	0.5021	0,5028	0.5031	0.5034	0.5042
D10	0.6507	0.6597	0.6627	0.6642	0.6651	0.6683	0.6734	0.6751	0.6760	0.6765	0.6768	0.6777

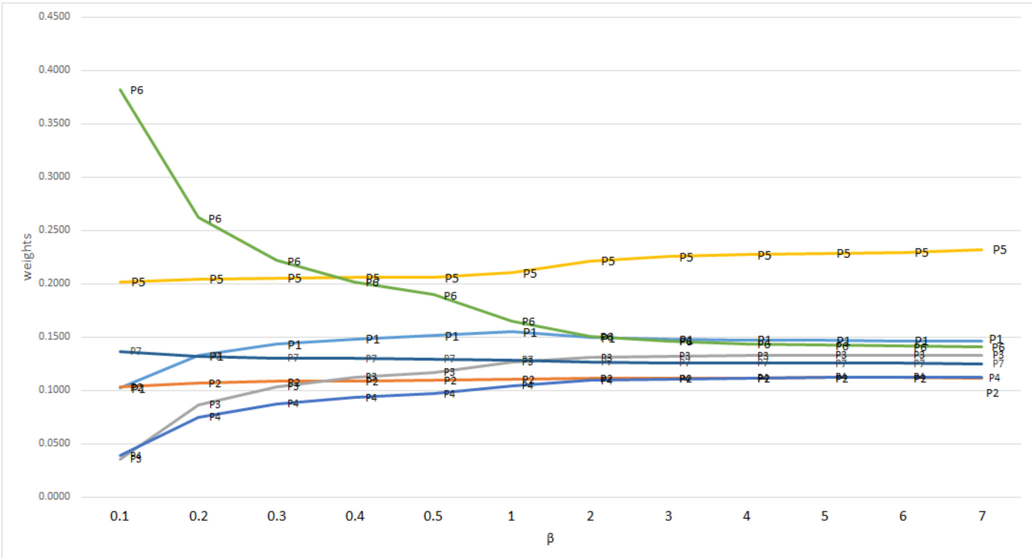

Fig. 3. Changes in weights of criteria for different values β

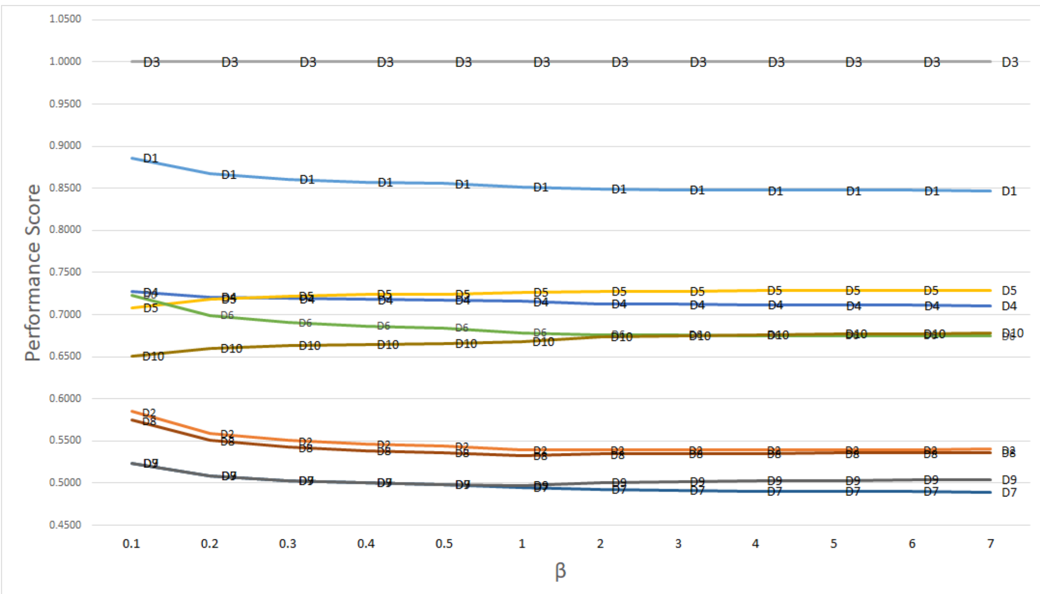

Fig. 4. Changes in scores of urban water and wastewater assets for different values β

Table 9. Ranking of evaluation criteria based on acquired weight

Criterion name	Criterion code	Final weight	Rank
Human consequences	P1	0.1467	2
Physical and structural consequences	P2	0.1119	7
Security consequences	P3	0.1328	4
Economic consequences	P4	0.1121	6
Environmental consequences	P5	0.2286	1
Social and political consequences	P6	0.1425	3
Functional and reputational consequences	P7	0.1254	5

Table 10. Ranking of urban water and wastewater assets based on acquired score

Asset	Code	Final score	Rank
Surface water sources	D1	0.8476	2
Groundwater sources	D2	0.5397	7
Water treatment plants	D3	1.0000	1
Water storage tanks	D4	0.7115	4
Water pumping stations	D5	0.7283	3
Water transmission lines	D6	0.6750	6
Water distribution network	D7	0.4900	10
Sewage collection network	D8	0.5355	8
Sewage transmission lines	D9	0.5031	9
Sewage treatment plant	D10	0.6765	5

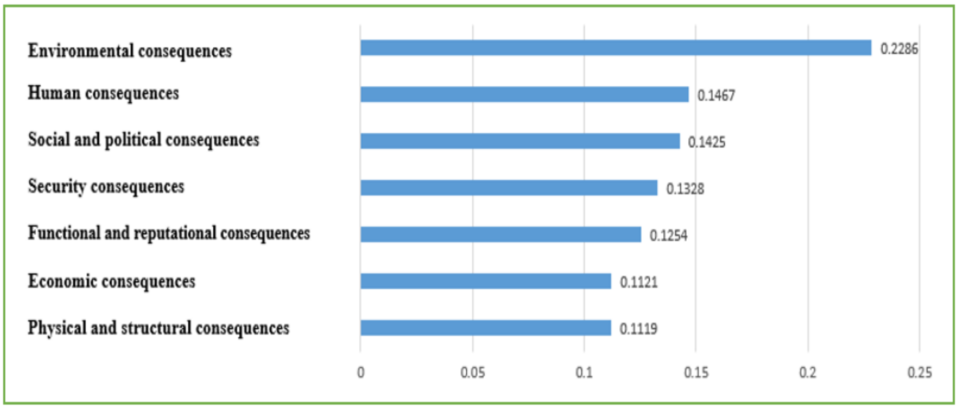

Fig. 5. Ranking of evaluation criteria based on acquired weight

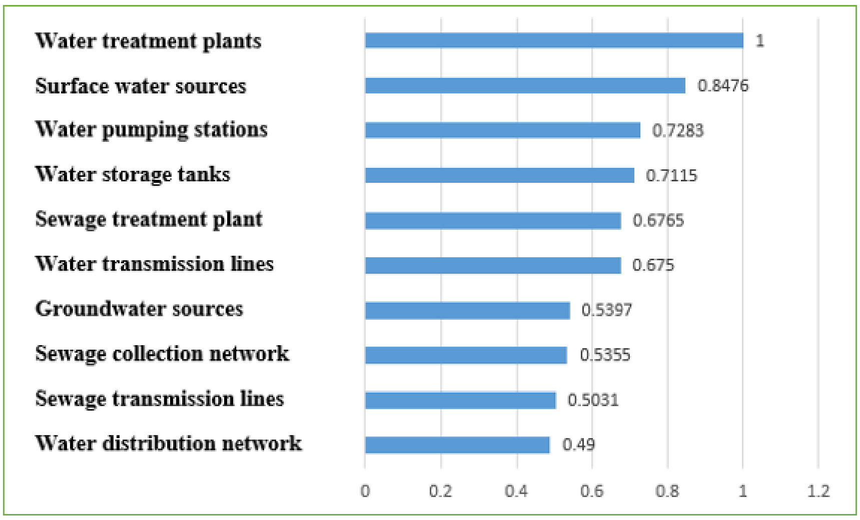

Fig. 6. Ranking of urban water and wastewater assets based on acquired score

Table 11. Consequences assessment on the water and wastewater assets of Hamedan city in the face of environmental pollution

Hazard - Threat	**Priority assets**	**Evaluation criteria for the effective consequences on assets**							**Level of consequence**
		Human consequences	**Physical and structural consequences**	**Security consequences**	**Economic consequences**	**Environmental consequences**	**Social and political consequences**	**Functional and reputational consequences**	-Lower level ($1 \leq C \leq 2$) -Medium level ($2 < C \leq 3$) -Higher level ($3 < C \leq 4$) -Highest level (Critical) ($4 < C \leq 5$)
		0.1467	**0.1119**	**0.1328**	**0.1121**	**0.2286**	**0.1425**	**0.1254**	**Final score**
Man-made - Environmental pollution	Surface water sources	3	2	3	3	5	4	3	3.4878
	Groundwater sources	2	2	2	3	4	3	3	2.8372
	Water treatment plants	3	4	3	3	4	5	3	3.6255
	Water storage tanks	3	2	4	3	3	5	4	3.4313
	Water pumping stations	3	2	3	2	2	2	2	2.2795
	Water transmission lines	2	2	3	2	2	4	2	2.4178
	Water distribution network	4	2	4	2	2	4	2	2.8440
	Sewage collection network	1	1	1	1	1	1	1	1.0000
	Sewage transmission lines	1	1	1	1	1	1	1	1.0000
	Sewage treatment plant	1	1	1	1	1	1	1	1.0000

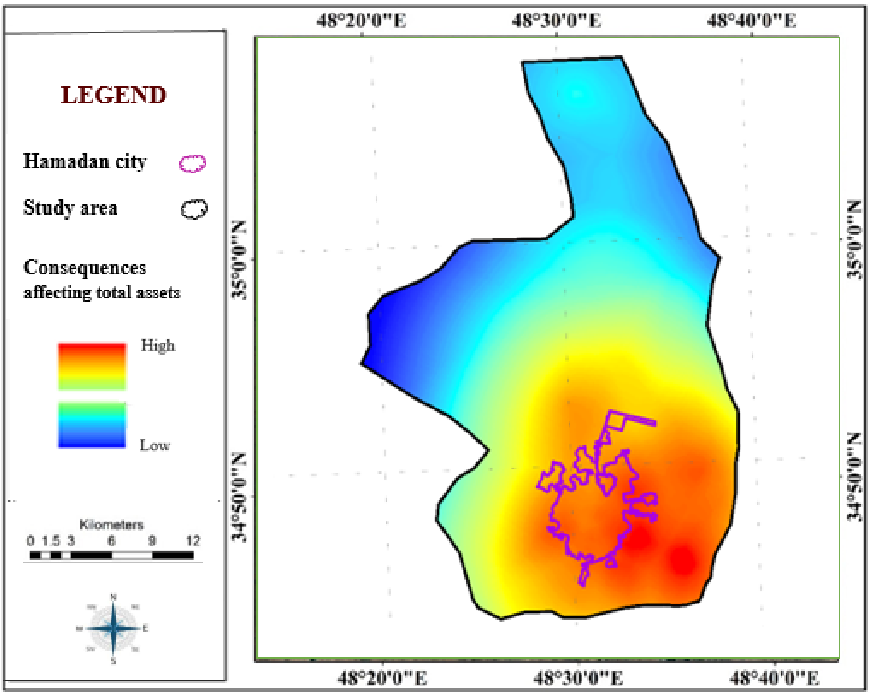

Fig. 7. Zoning of the consequences affecting water and wastewater assets in Hamedan city in the face of environmental pollution

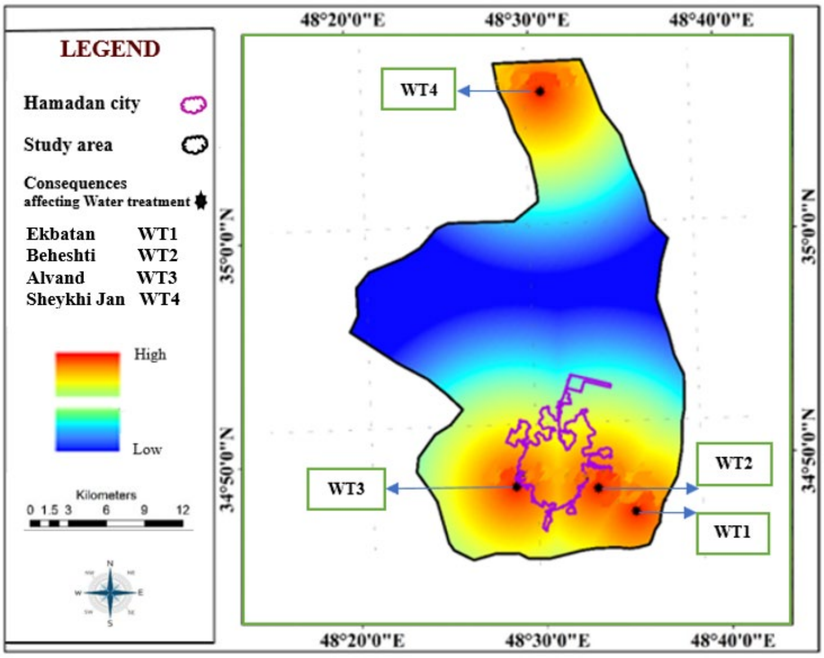

Fig. 8. Zoning of the consequences affecting water treatment plants in Hamedan city in the face of environmental pollution

respectively. Among the urban water and wastewater assets in the study area, water treatment plants ranked first, surface water resources second, and water pumping stations third.

Ultimately, in line with the main objective of the research, the final consequences assessment on the water and wastewater assets of Hamedan city in the face of environmental pollution was conducted, considering the weighted coefficients of the evaluation criteria and obtaining further opinions from experts, as detailed in Table 11. This was implemented in a GIS environment, resulting in the mapping of the impacts on the urban water and wastewater assets of Hamedan, as shown in Figure 7. The results indicate that the city's water treatment plants, with a score of 3.6255, ranked first and are classified at a higher impact level, necessitating control measures and impact reduction. Hamedan has four water treatment plants: Ekbatana Treatment Plant (WT1) with a capacity of 400 liters per second, Shahid Beheshti Treatment Plant (WT2) with a capacity of 1000 liters per second, Alvand Treatment Plant (WT3) with a capacity of 300 liters per second, and Sheikhi Jan Treatment Plant (WT4) with a capacity of 1800 liters per second, totaling a capacity of 3500 liters per second. The impact mapping for the water and wastewater treatment plants of Hamedan is illustrated in Figure 8.

CONCLUSION

In this study, the consequences affecting the water and wastewater assets of Hamedan city, as one of the most important cities in the western region of Iran, were evaluated in the face of environmental pollution. The results indicate that among the assessed criteria in this city, the environmental consequence with a weight of 0.2286, the human consequence with a weight of 0.1467, the social and political consequence with a weight of 0.1425, the security consequence with a weight of 0.1328, the functional and credibility consequence with a weight of 0.1254, the economic consequence with a weight of 0.1121, and the physical and structural consequence with a weight of 0.1119 are ranked first to sixth in priority, respectively. In this context, since the weight difference between some criteria, such as human consequence and social and political consequence, as well as economic consequence and physical and structural consequence, is very minimal, the reason can be attributed to the close interconnection of these criteria in reality. Therefore, by grouping them into a single priority category, the revised prioritization of the criteria will be as follows: "Environmental consequence as the first priority, human, social, and political consequences as the second priority, security consequence as the third priority, functional and economic consequences as the fourth priority, and economic, physical, and structural consequences as the fifth priority." Among water and wastewater assets, based on their susceptibility and following an initial assessment, water treatment plants are prioritized first, surface water resources are second, pumping stations along with water storage reservoirs are third, wastewater treatment plants along with water transmission lines are fourth, groundwater resources along with wastewater collection networks are fifth, and finally, wastewater transmission lines along with water distribution networks are sixth in priority. Additionally, in the final assessment of the consequences affecting assets, the city's water treatment plants, with a score of 3.6255, ranked first. According to the definition of consequence levels, this falls into the Higher category, necessitating the implementation of control measures and consequence mitigation. Given that one of the objectives of this research is to propose a Pattern that can achieve practical goals while being generalizable to similar studies across various regions and scenarios, by examining the evaluation Pattern used in this study and comparing it with established evaluation Patterns in prior research, the optimal Pattern derived from this study is presented as shown in Figure 9.

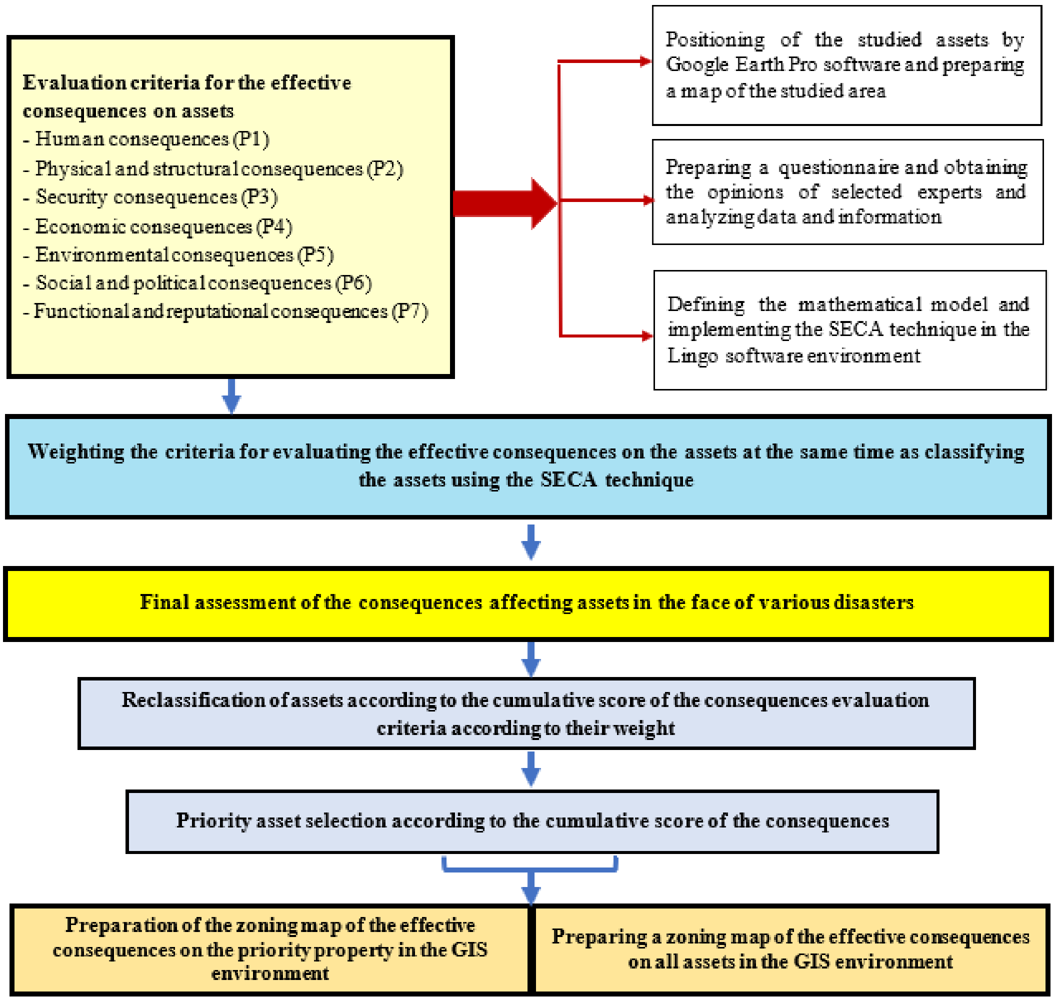

Fig. 9. The pattern for assessing effective consequences urban assets in the face of various types of disasters

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Furthermore, ethical issues related to plagiarism, informed consent, misconduct, data fabrication, duplicate publication, and redundancy have been respected, and the manuscript has been thoroughly reviewed by the authors.

LIFE SCIENCE REPORTING

No scientific threats were utilized in this research.

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