Journal of Studies in Science and Engineering

EngiScience Publisher

Research Article

Integrated Methodology for Construction Site Selection: A Case Study of the Tazeh Abad Neighborhood, Sanandaj City

Salah Vaisi [1,*], Elham Shariati [1], Nina Ghaslani [2]

[1] Department of Architecture, Faculty of Art and Architecture, University of Kurdistan, Sanandaj, 66177-15175, Iran

[2] Department of Architecture, Faculty of Architecture and Urbanism, Shahid Beheshti University, Tehran, 1983963113, Iran

*Corresponding Author: Salah Vaisi, E-mail: svaisi@uok.ac.ir

Article Info

Article History

Received Feb 10, 2024

Revised Jun 17, 2024

Accepted Jun 26, 2024

Keywords

Site plan analysis

Multi-Dimensional Matrix

Urban regeneration

Sustainable development

Site selection criteria

Abstract

The best site selection for building construction projects is a substantial challenge in urban and architectural engineering because, in most cases, selecting a project's location is influenced by the intentions of politicians and the commands of governments rather than logical decisions. This gap has resulted in catastrophic mistakes in some cases. This research presents an expanded authentic method to address the gaps and aims to develop a technical approach for site selection by integrating qualitative parameters with quantitative factors using a Multi-Dimensional Matrix (MDM). About 70 qualitative and quantitative indicators, such as physical attributes, infrastructures, land features, access to services, brownfields, population density, landscape, environmental characters, and other effective parameters, based on the analysis of the research background as well as the opinions of 10 experts, were identified and classified. The method was implemented using a case study in which effective factors were analyzed in detail. In addition, the questionnaire method was also applied to discover the deficiencies of the case study site and its potential and to consider the residents' demands as the real participants of the project. The suggested method is a proper alternative to current arbitrary methods and minimizes mistakes.

1. Introduction

In 2008, for the first time in history, the urban population constituted more than half of the world's population, about 6.8 billion [1], so the urban population became more than 3.44 billion people. In addition, the world population was around 8 billion in 2022, whereas the world's urban population will reach approximately 5 billion by 2030 [2, 3]. In the 20th century, the world population exploded from 220 million people to 2.8 billion people, while the United Nations suggested that the size of the global population will grow to approximately 11 billion by around 2100. Thus, planning for sustainable and resilient cities that host this vast population and other creatures' habitats is crucial. Particularly in Asia and Africa, in 2030, the urban population will be two times higher than in 2000. Therefore, site planning and development for new construction projects are crucial. Moreover, cities are the primary source of environmental detriments due to the production of CO_2 caused by transportation (23%), industry (32%), building construction (40%), and others (6%) [4, 5].

Sustainable urban planning without considering the environmental conditions of land development is meaningless because land is a place for project construction, and at the same time, it is a resource for food production and waste disposal [6-8]. New approaches for evaluating the site (project's land) selection based on various indicators have been examined over the last two decades [8-10]. In Iran, however, scientific methods of site selection for construction developments are hardly taken into account, while in most cases, politics and personal manners play a fundamental role in site selection [11-13].

An essential phase in the development process of a construction project is selecting the most appropriate site. This paper has reviewed the state-of-the-art theories for site selection, determining the weight of indicators, evaluating the methods, and ranking the criteria based on a scientific analysis. It developed a novel method and explains how to convert qualitative factors into quantitative ones and evaluate them using a Multi-Dimensional Matrix (MDM).

The current research aims to provide a scientific construction sustainable site selection method to avoid arbitrary and harmful approaches. It has three aims; the first is to provide the most important parameters for the scientific site selection, including various qualitative and quantitative indicators. The reviewed indicators were developed in the current research, and the gaps in previous research were addressed. The second aim is to limit personal or political opinions and the related negative impacts on the project's location and construction. The last aim is sustainable site selection and analysis, achieving life cycle sustainability.

This research presents a comprehensive method based on mathematical approaches and provides a complete list of indicators for site selection analysis. The uncertain characters that may negatively affect decision-making were eliminated. Regarding the presented method to properly fit with site analysis for sustainable development, valuable practical recommendations for engineers in the construction sector, such as architects and civil engineers, were provided. Since the literature in the area was extensively reviewed, state-of-the-art knowledge was presented that could increase the reliability of indicators.

2. Literature Review

Appropriate site selection is one of the essential aspects of environmental sustainability [14]. This is why the issue of site selection criteria and evaluation for a project has become essential since 2000. The idea of sustainable development at the Earth Summit in Rio de Janeiro in 1992 was recognized as a fundamental action. At the summit, 172 countries and 2400 non-governmental organizations (NGOs) suggested various sustainable architectural and urban design approaches.

In 2011, the Department of Education of the State of Alaska in Canada investigated the methods of scientific site analysis and published a handbook [9] that presents three essential factors for evaluating a construction site for future projects. They include (1) social and land use factors, (2) the total price of building construction, and (3) the cost of the building operation and maintenance. These minimum general factors were divided into sub-sections and details. Table 1 shows the details of these three factors. The handbook also explains how to weigh the indicators as well. The method is practical; however, the proposed criteria for measuring a site for future development are limited, and many basic parameters were not included.

Table 1. A set of influential post-construction criteria affecting site selection [9]

Criteria	WF*	Site 1		Site 2		Site 3		Site 4	
		Scores	Scores ×WF	Scores	Scores ×WF	Scores	Scores ×WF	Scores	Scores ×WF
Site Drainage	3	4	12	3	9	3	9	n/a	n/a
Flooding	4	4	16	4	16	2	8	n/a	n/a
Site Erosion	4	3	12	3	12	3	12	n/a	n/a
Sun Orientation	2	2	4	1	2	1	2	n/a	n/a
Protection from Elements	2	3	6	3	6	2	4	n/a	n/a
Proximity to Natural Hazards	4	0	0	3	12	4	16	n/a	n/a
Alternative Energy Sources	3	1	3	1	3	2	6	n/a	n/a
Air Invention/Katabatic winds	2	4	8	4	8	4	8	n/a	n/a
TOTAL			61		68		65		n/a

* Weighting Factors (WF), 1=not very important, 2=somewhat important, 3=important, 4=very important, 5=essential, Criteria Ranking Scores 0=unacceptable (least desirable least cost effective), 1=poor, 2=fair, 3=good, 4=excellent (most desirable/ most cost effective)

In 2008, the Department of Design and Construction, New York City Municipal, published the "Sustainable Urban Site Design Manual" [15], which presented suggestions for sustainable and responsible urban site design. The manual emphasized the site design using a sustainable approach but did not propose a proper and optimal site selection method.

The authors of "Sustainable Site Design: Criteria, Process, and Case Studies for Integrating Site and Region in Landscape Design" [16] have presented several factors, such as sewage, water pollution, particularly surface and underground water, and biodiversity for site sustainability in landscape engineering. The research emphasizes endangered animal species, waste of resources, energy, soil, and air. The Handbook of Green Building Design and Construction [17] highlights the fundamental sustainability standards and assessment methods such as LEED, BREEAM, CIBSE, and Green Globes [18]. Several indicators for sustainable site assessment were presented for these standards.

One of the crucial sources for site selection is "Site Analysis: A Contextual Approach to Sustainable Land Planning and Site Design" [19], in which the author has divided the site selection into four general categories. The first category is devoted to topography, soil science, and geology. The second category includes the capacity of the market, services (transportation, school, police, and fire stations, etc.), and climate. The third is the compatibility category, which covers costs, profits, and the benefits of projects.

The fourth is the affordability category, which examines whether site development allocated to a desired project is cost-effective. In this category, the calculations of the investment return period and the profit and loss of the project are analyzed. Another source is "Environmental Planning for Site Development" [20], which contains overviews and macro views of the site characteristics assessment.

Thomas H. Russ published a book [21] and presented a sustainable perspective on the project's site plan. Russ investigated the basic rules of sustainable site design. He divided them into ten categories, including (1) not to harm the site and its surroundings through inappropriate and unnecessary interference, (2) precautionary principles to reduce risk and damaging humans and the environment, (3) design with nature and culture, (4) using the decision-making hierarchy method to protect, preserve, and regenerate the site's resources and potentials, (5) providing renewable reproductive systems to achieve intergenerational equity, (6) supporting the balanced life process, (7) the use of systematic thinking against arbitrary and forced thinking, (8) using a team approach based on ethics, (9) maintaining integrity in leadership and research, and (10) improving environmental monitoring.

2.1. The Method of Dealing with the Old Part of the Urban Fabric

Urban development in suburb areas needs high financial costs to provide the infrastructure and, on the other hand, increases the environmental impact because of urban sprawl, which is a key driver of unsustainability, resulting in further travel, use of productive land, and social inequality [22, 23]. Therefore, in recent years, the development of existing old-traditional neighbourhoods and brownfields has attracted the attention of urban designers and architects due to its sustainability characteristics. The regeneration of old buildings and the revival and repairing existing urban contexts contribute to sustainable development [24]. Deprived and worn-out urban neighbourhoods have problems such as lower urban services, lower quality of life standards, weak access to transportation networks, old infrastructure, lower security, and aged buildings [25, 26]. In the case of rehabilitation and redevelopment, they have great potential to achieve high-quality, healthy, and sustainable cities [27] because local resources and urban infrastructure are retained and reused. At the same time, old buildings are rebuilt to provide new opportunities for the optimum use of spaces [28]. Fertile lands are a crucial food and economic resource in the current decade; therefore, reasonable land management has become a hot urban planning topic. Optimum use of brownfields and worn-out urban textures through regeneration plans is one of the sustainable approaches for land supply [8, 29, 30].

Although urban renewal approaches usually focus on sustainable development, demolishing existing buildings to accelerate the process of urban renovation has become a controversial topic worldwide [31]. It is strongly recommended that any urban revitalization model should be consistent with overall contextual and spatial conditions [32]. Similarly, the potential of previously used sites should be evaluated according to site-based factors and adapted for different urban contexts [24, 25]. Urban worn-out refers to an area or part of a city where more than 50% of the structures—including buildings, streets, and other property-grained elements—are prone to instability, according to standards authorized by Iran's Supreme Council for Planning and Architecture [33]. Previous studies about worn-out urban textures emphasize the address of residents' needs and participation in urban regeneration planning [34, 35]; however, proper site selection methodology was neglected as a base for sustainable urban revitalization. In addition, the integrated analysis results indicate that the quantitative sustainability indicators considerably improve the optimum land use patterns [36].

2.2. Sustainability Assessment Tools

Analysis of sustainable urban development, which responds to the adverse effects of rapid urbanization, climate change, and excessive use of natural resources, needs sustainable assessment tools [37, 38]. Sustainable assessment tools support decision-making and guidelines for urban development projects and evaluate the sustainability level of cities [37-39]. Several indicator-based tools are applied at the urban or single-building scale [14]. A few studies highlighted the importance of urban sustainability assessment at the neighbourhood scale [40, 41]. Zarghami et al. [42] have developed a sustainability assessment tool for individual residential buildings but did not consider urban neighbourhood characteristics, which are more significant for a successful large-scale development. Tam et al. reviewed 20 international neighbourhood assessment systems [43], among which "BREEAM", "CASBEE-UD", and "LEED-ND" are more prominent [44, 45]. Table 2 represents the features and details of these tools and the approach that they considered land use and site selection indicators[46-48].

Some studies identified and addressed the weaknesses of Neighborhood Sustainability Assessment (NSA) standards, approaches, or tools. The main limitation of using NSA tools is that they apply only for the certification of the existing buildings and neighbourhoods, not for developing or future development plans. In addition, the NSA tools did not support other spatial analysis tools, e.g., GIS. The other weaknesses include the static nature of NSA, environmental bias, lack of appropriate socio-economic assessment approaches, data imperfections and reliability, market-driven failure to address context-sensitive concerns, and expert-dependent non-inclusive approach [49-52]. Furthermore, the complete list of fundamental sustainability indicators was not provided, nor was it completely analyzed. The overwhelming number of indicators is insufficient to assess manually [53]. In addition, the impact of the NSA tools on environmental justice needs to be taken into account further [54].

2.3. Negative Impacts of Erroneous Site Selection

In developing countries such as Iran, which is faced with rapid population growth, intensive rural immigration [55], and on the other hand, depletes a lot of national resources such as productive lands (usable for agriculture and food) [11], water bodies, fossil energy [56], water crisis, depletion of underground resources [57], inefficient, traditional transportation systems [58], unsustainable development, and an unstable economy [59, 60], the sustainable land and urban development method for construction projects is a fundamental approach [58]. Large-scale land development, such as urban development; medium-scale, such as residential building complexes; and small-scale, such as hotel or residential apartment construction, all need a sustainable development methodology.

Table 2. Urban sustainability assessment tools [37, 45, 47]

Standard/approaches	launched by	Indicators	Site sub-criteria	Location		
				Issues covered	**Sub-criteria**	**%**
BREEAM community (2012)	BRE/UK	Governance Social and economic well-being Resources and Energy Land use and ecology Transport and movement	Accessibility Hazards Site selection Ecological value of site and protection of ecological features Enhancing site ecology Long-term impact on biodiversity Surface water run-off Public transport accessibility Proximity to amenities	Land use Place-shaping Policy and governance Affordable housing	7	14%
CASBEE-UD (2007)	Japan GreenBuild Council and the Japan Sustainable Building Consortium	Natural environment (microclimates and ecosystems). Service functions for the designated area Contribution to the local community (history, culture, scenery and revitalization) Environmental impact on microclimates, façade and landscape Social infrastructure Management of the local environment	Preservation and conservation of biotope Townscape and Landscape	Land use Place-shaping Policy and governance Affordable housing	3	4%
LEED-ND (2009)	US Green Building Council	Smart Location and Linkage Neighborhood pattern and design Green Infrastructure and Buildings Innovation & Design Process Regional Priority credit	Site selection Compact development Rainwater Management	Land use Place-shaping Policy and governance Affordable housing	5	9%

Some examples of improper site selection that led to environmental drawbacks are as follows: Gotvand Dam, located on the Karun River in the southwest of Iran, is mistakenly located next to a large salt mine. When the dam completely went underwater, it penetrated the mine and dissolved large amounts of salt. The salt accumulation in the dam has been estimated at around 66.5 million metric tons, leading to a dramatic increase in the water salinity [61-63]. This problem is a serious hazard to downstream agricultural lands and has dried up many trees. The dam is located in a high seismicity zone and is susceptible to instability and potential seepage [64].

Originating from a political and non-participatory top-down policy, Mehr Housing, the Iranian national social housing project supported by the national government, was started in 2009 as a solution for affordable housing. The projects were primarily constructed in suburbs to reduce the cost of land, but they ultimately caused many negative environmental and social effects and the extra costs for providing the urban infrastructures. Rather than regenerating worn-out urban areas and empowering their infrastructures, the politicians of Meher Housing converted the productive lands into buildings and destroyed many agricultural resources. The Iranian government has increased the risk of destroying both biological and food supply resources. They dug the natural shape of the earth and destroyed the beautiful natural landscape, which is a desirable place for citizens to spend their free time, fleeing from the noise and pollution of a city [13, 65]. From a social perspective, the project did not meet people's satisfaction. Residents of the Mehr Housing project suffer from a lack of transportation facilities, security, education, healthcare, parks, and entertainment services [66, 67].

Another example of the project's misleading site is improper actions on Urmia Lake, which resulted in a significant decrease in water level and catastrophic environmental impacts. The construction of various unnecessary dams from the 1970s around the lake basin shows the lack of comprehensive spatial planning to manage water resources. The number of dams (existing, under construction, and understudy) in the lake basin indicates an increase in the diversion of surface water beyond the current level, which currently appears unsustainable [68-72].

3. Materials and Methods

Selecting comprehensive and relevant indicators to analyze and recommend the best site location for developing a construction project is substantial. Research on indicator-based approaches for site selection is relatively rare. In this study, a mixed method for decision-making was applied and presented in Figure1.

The Multi-Dimensional Matrix (MDM) method typically involves evaluating alternatives based on various indicators and evaluation systems (Figure 2). The developed method facilitates decision-making processes, whether for selecting a new site or choosing the best project for renewal at a neighbourhood scale in a city context [73-76]. The technique considers a system of interacting criteria executed to assess the potential of a construction site or a developing function. The MDM can be used in the primary architectural or urban planning design processes to identify interactions affecting site location. The method can also be used as a guideline and evaluation system during decision-making for developing a construction site.

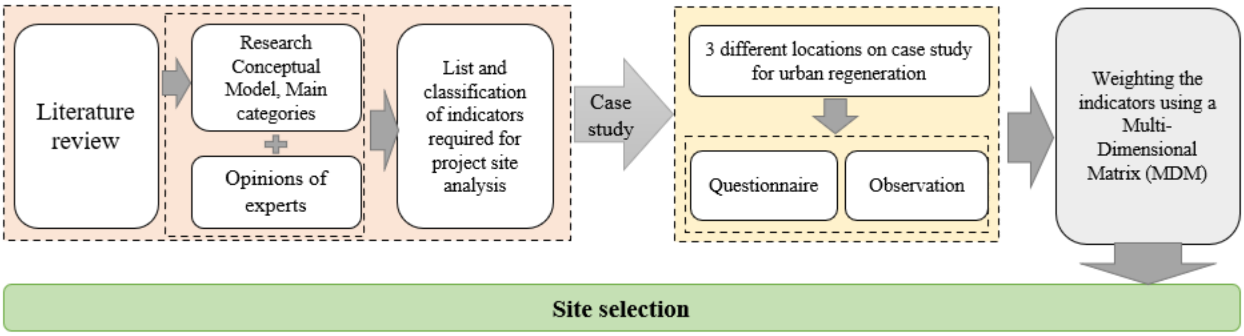

Figure 1. Research methodology flowchart

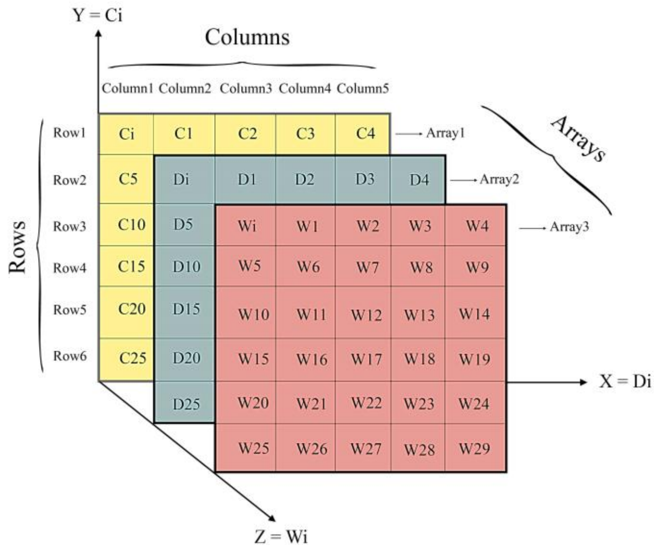

Figure 2. The concept of MDM

Furthermore, MDM supports analysis of a system's structure across multiple domains and simplifies different levels of analysis into one Design Structure Matrix (DSM) at one time. The developed system considers the effect of multi-criteria on each other and their interactions. Accordingly, some criteria may nullify or reinforce the others.

The selection of effective indicators for analysis and a deep understanding of the site elements have been conducted through a critical literature review and experts' opinions in the subject area. At this stage, the opinions of 10 experts were obtained. In the developed method, 71 indicators have been classified into 11 categories, which is a great upgrade compared with the six simple indicators reviewed in the literature. Each defined category has unique indicators, but the number of indicators in the categories is not necessarily equal. For example, the landscape category has six indicators, while the urban context and existing buildings category (applicable in urban regeneration projects) has 11 indicators. Table 3 presents the categories and their sub-sections.

Table 3. List and classification of indicators required for project site analysis

1. Vegetation and wildlife	1-1	Diversity of wildlife
	1-2	Existing vegetation
	1-3	The relationship between vegetation and climate characters
	1-4	Evergreen trees (mostly coniferous)
	1-5	Seasonal trees (mostly broadleaf)
	1-6	Endangered plant and animal species (recognition, number, status, threats)
	1-7	Size, area, and amount of green space
	1-8	Soil condition, soil type, and agricultural capability
	1-9	Cultivable land, pasture, and barren land
2. Natural Resources (Ground or underground)	2-1	Mines and other underground reserves
	2-2	Underground water, plant, animal ecosystem; water ecosystem, wetlands, etc.
	2-3	Surface water (river, lake, domes, spring, aqueduct), area and their volume and depth,
	2-4	Groundwater (aquifers, groundwater levels, hot springs, and mineral waters)
	2-5	Hydrometry, physical and chemical condition of water, water pollution, acid-alkaline condition of water (PH)
	2-6	Water flow
	2-7	Watershed for river, lagoon, marsh
3. Site potentials and limitations	3-1	Scope and geometry of the site
	3-2	Dimensions and size of the site (area and perimeter)
	3-3	Topography (positive and negative slopes, channels, valleys, depressions and ridges, ravines, drainage, etc.), slope percentage
	3-4	Soil Physics (soil type, density, permeability, PH, structural resistance, ...)
	3-5	Site obstacles (noise pollution, air pollution, chemical pollution, site expansion restrictions, unpleasant smell, proximity to dangerous and polluting sites, landscape)
	3-6	The capacities and potentials of the site (natural resources, proper access, scenery, vicinity of the site (close to shopping, educational, medical centers, etc.)
	3-7	Ability to expand and develop the site in the future
4. Urban context and existing buildings	4-1	Buildings quality
	4-2	Buildings age
	4-3	Number of floors
	4-4	Pure and impure (gross/net) density (occupancy level and density)
	4-5	Usage of buildings
	4-6	Building heights, sky view
	4-7	Full and empty parts of the site (free lands), brownfields
	4-8	Valuable and heritage buildings, cultural heritage
	4-9	Building Materials
	4-10	Architectural pattern, valuable and historical urban context
	4-11	The degree of permeability of the site
	5-1	Type of access (vehicle accessibility, transportation systems, pedestrians, bicycle and stroller, wheelchair, ...)

5. Circulation and access to the site	5-2	Material of road surface (asphalt, concrete, soil, sand, etc.), paving
	5-3	Hierarchy of access (freeway, highway, 1st, 2nd, and 3rd degree arterial, secondary, main, etc.), average highway speed, approach speed, road capacity
	5-4	Traffic type (traffic node, traffic load, speed limitation, traffic zones)
	5-5	Public transportation (access to railway, airport, bus, taxi station, metro)
	5-6	Parking availability- type of parking (indoor, outdoor, story parking)
	5-7	Run-off water collection and management system
6. Landscape	6-1	Favorable and unfavourable view
	6-2	Favorable view of a park, green space, and urban skyline
	6-3	Unfavourable view to visual pollution, view to the cemetery, abandoned area
	6-4	Overlooking
	6-5	Skyline
	6-6	Night view (landscape)
7. Infrastructures	7-1	Transportation
	7-2	Municipal services (Piped water network, on-grid electricity, gas, internet, telephone, sewage, garbage collection service)
8. Social, cultural, economic potentials and structure	8-1	Social parameters, diversity, justice, education level
	8-2	Population: population size, growth rate, population pyramid, gender ratio, active population, literacy rate, employed population and unemployment rate, population forecast, household size, etc.
	8-3	Immigration and the related details
	8-4	Social beliefs, social capital, social networks, active communities in the region, NGOs, ethnic, racial, religious diversity, convergences or divergences
	8-5	Cultural diversity, languages, historical background, local/national customs, local clothing patterns, rituals, identity
	8-6	Economic, the price of land, the cost of obtaining the necessary permits such as the municipal permit, tax, the cost of engineering maps, the cost of building construction, added value, regional price, investment return period,
	8-7	Livelihood, the income rate in the area, welfare level, poverty level, GNP (gross national product), GDP (gross domestic product), export and import, production rate
9. Climatic characteristics	9-1	Weather
	9-2	Longitude and latitude
	9-3	Height above mean sea level (altitude)
	9-4	Humidity (absolute, relative)
	9-5	Temperature, average annual, monthly average, minimum average, maximum average, minimum and maximum, etc.
	9-6	Wind (prevailing wind, wind direction, wind speed, seasonal winds, polar wind)
	9-7	Precipitation (rain, snow, hail, heavy rain, amount of precipitation, rain load), annual, monthly daily precipitation
	9-8	Number of frosty days, number of cloudy days
	9-9	Proper orientation of the building (south-facing for the northern hemisphere)
	9-10	Sun path, daylighting, and shadow

	9-11	The amount of radiation
10. Upstream rules, local policies, laws, local regulatory frameworks and regulations	10-1	Municipal regulations, constitution laws/standards, bylaws, national and regional regulations; upstream rules, military and police restrictions; cultural heritage restrictions, allocating functions to the urban pieces
11. Risks and hazards	11-1	Natural disasters such as faults, floods, earthquakes, fires, landslides
	11-2	Proximity to the nuclear power plant and military and areas restricted by law
	11-3	Passive defense limitations

The complete checklist (Table 3) has not been comprehensively presented in any reviewed studies. The purpose of the developed checklist is to consider all the necessary indicators required to evaluate a site. In addition, the indicators that show the sustainability impacts after the construction process, such as roads, bicycle parking, rainwater management, access to public transportation, etc., have been considered. Regarding surface water management, indicators such as water run-off, surface water, land depression, and ridge, as well as the design and size of channels, are fundamental. Relying on only qualitative or minimal quantitative factors will likely make the analysis erroneous. Therefore, a comprehensive list of qualitative factors was converted into quantitative parameters to be interpreted in descriptive statistics. Both factors are measured based on a single scientific system, and personal beliefs will not be included in the selections.

After providing the indicators needed to evaluate a site plan according to the usage and purposes of the project, the required indicators could be selected from the main list (Table 3). Then, the appropriate weight is allocated to each indicator. For example, for an airport project, the number of trees on the site is a negative factor, but for a college project, trees can create a beautiful landscape, which will be a positive factor. According to the developed Multi-Dimensional Matrix (MDM), the first layer of the system is indicators, and the second layer is weights of various coefficients such as quality, quantity, importance ratio, frequency, and priority. The weight for each row of indicators is calculated, and finally, the total obtained points are determined by mathematical calculations based on Eq. (1).

$$f(x) = a_0 + \sum_{i=1}^{n}(fi \times wi \times mi) \tag{1}$$

where a_0: is the primary constant value that the assessor may consider regarding the importance of the indicators. For example, the landscape quality in the north or south direction should be considered a fixed value in restaurant projects. *fi:* is the frequency of the indicators, while wi is the initial weight of an indicator. *mi:* is the magnitude of the factor, such as the area.

The MDM provides the possibility of comparison of different options more accurately. The final weight of each site plan is obtained from the sum of the weights of single indicators. This mathematical method can more accurately evaluate the project sites and determine the most suitable one for developing a project. The selection of important and required indicators for site analysis depends on the land use and future development plans. If a project has future development phases, such as a need for land use, this should be included in the site analysis.

In the next step, the shortlist of indicators influencing a specific site selection is prepared. Furthermore, weighting the indicators is the most essential task. For the weighting of factors, the goals and function of the project play the most critical roles. Finally, the final variables were ranked by calculating the values (weights assigned to different parameters) and the comparative comparison method. An alternative that has attained the most points (first rank) is a winner.

Presenting a practical example in the following sections, the weighting of the indicators in a sample site plan will be explained in detail. A questionnaire, including a combination of open and closed questions, was conducted to discover the interests, needs, and views of the residents of the Tazeh Abad neighbourhood. The questionnaire contained 12 questions designed to improve the designer's understanding of the site, the needs of the residents, and their loyalty to the neighbourhood.

Since this research's methodology is fundamental, it tried to clarify how calculations are made by presenting several examples. The method can be implemented, imitated, and repeated for different types of sites worldwide.

4. Site Analysis Using the Multi-Dimensional Matrix Method, Based on a Case Study

4.1. Physical Characteristics of the Case Study

There are two groups of urban textures: historical and deprived areas, including (a) the annexation of separate urban areas due to the development of cities and (b) the worn-out texture formed with city development during the past centuries. Based on this classification, the Tazeh Abad neighbourhood in Sanandaj City, the centre of Kurdistan province, is considered group (b) [77]. This case study is presented in detail from a site selection point of view.

In the Tazeh Abad neighbourhood, three different sites for urban regeneration to build a new residential complex and empower the traditional texture in the historical part of Sanandaj City were evaluated as an example. The goal is to select the best site for the new construction developments. In the analysis of these sites, in addition to the physical parameters, the questionnaire method was also applied to discover the project participants' deficiencies, potential, and queries. Figure 3 shows the Tazeh Abad neighbourhood in Sanandaj City and the three sites identified for future developments. The MDM method was conducted to select the best location based on the data presented in Table 3 and the quantitative and qualitative evaluation using the resident's beliefs.

The reasons for choosing sites 1, 2, and 3 are as follows: There are two mosques and a building with historical and heritage value in the Tazeh Abad neighbourhood. These units enhance the social sustainability of the neighbourhood and preserve its identity. Therefore, areas including such strong social characters were excluded from the authors' selection. The reason is that these places are alive and desirable and have no regeneration needs. On the other hand, some residential units on the ground floor had commercial uses such as tailoring, grocery stores, upholstery workshops, and restaurants. Since this contributes to the neighbourhood's economic sustainability and diversifies the functions, these spots were also excluded from the regeneration boundary. Among the areas with potential for redevelopment, sites 1 and 3 were chosen due to the maximum number of demolished units (vacant land), which decreases neighbourhood vitality, reduces safety, and diminishes the environmental aesthetic [29]. Site 2 was selected due to its central location in the neighbourhood, which can provide floors with public services such as a library, sports centre, or café in the design of a new residential complex. For example, utilizing green spaces in the design could create better views and landscapes for other locations in the neighbourhood. In addition, sites 1, 2, and 3 in the master plan of Sanandaj City, the main superior local regulatory framework, have residential functions.

Figure 3. Tazeh Abad neighbourhood in Sanandaj City and its three sites

The critical physical characteristics of sites 1, 2, and 3 are listed in Table 4. According to the analysis of physical attributes, the areas of sites 1, 2, and 3 are 1718 m^2, 1951 m^2, and 1968 m^2, respectively. Accordingly, the number of existing buildings in the analyzed sites is 13, 18, and 8, respectively. The total footprint of the buildings of all three sites is 3389 m^2.

Table 4. Physical features of sites

Sites	Gross area (m^2)	Number of buildings	Perimeter (m)	The total footprints of the buildings
1	1718	13	190	1114
2	1951	18	199	1390
3	1968	8	195	885
Total	5637	39	584	3389

4.1.1. Number of Floors

All three sites in the urban neighbourhood of Tazeh Abad were compared in terms of the number of building floors. According to the purpose of the project, i.e., urban regeneration, the lower number of floors belonging to worn-out buildings is better because, in case of the need for demolition to increase the width of the passages (providing access for cars in emergency conditions such as fire extinguishing truck access) or renovating the buildings, fewer relocations of residents are required. In other words, fewer residential units are destroyed, and fewer households are forced to move out and resettle in other places temporarily. In Figure 4, the studied sites are compared based on the number of floors, quality, and age of the existing residential buildings.

4.1.2. Building Quality

In the regeneration project of the Tazeh Abad neighbourhood, the building quality (Figure 4) indicator provides four important parameters for urban designers and architects. First, which part of the site should be prioritized for revitalization and restoration? Second, which buildings may have the value of cultural heritage? So, this building type should not be manipulated. Third, which building blocks have suitable quality and can be maintained or restored? Fourth, which building blocks are worn- out and should be destroyed? The greater the number of worn-out blocks on a site, the higher the score because architects and urban designers will have more freedom to act on their plans.

4.2. Cultural Heritage Values of the Buildings

Another important indicator of the Tazeh Abad development site is the antiquity of the building. The antiquity of a building indicates the cultural heritage, construction technology, age, materials, historical values, identity, and style. The antiquity of a building determines its architectural value. This type of audit is significant, particularly in old urban textures and city centres, because it shows cultural heritage value. From the point of view of this research, the greater the number of long-lived (valuable) buildings, the higher the project limitations, and as a result, this indicator can be considered the weak point for a site in terms of new building establishment.

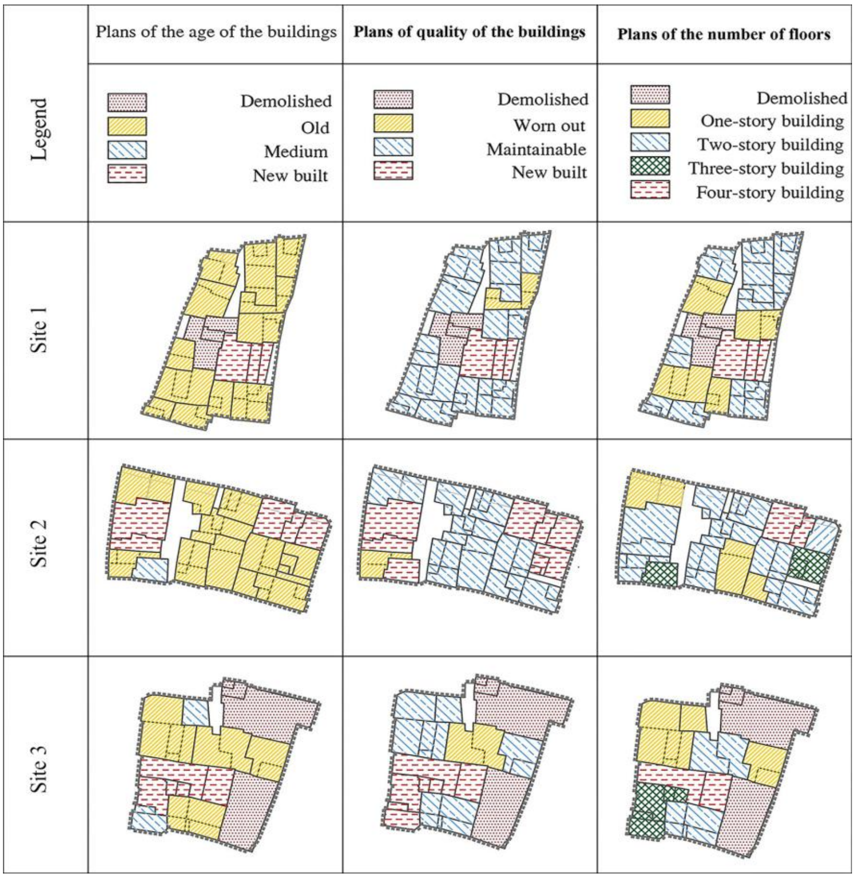

Figure 4. Number of floors, age, and quality of buildings

4.3. Questionnaire Results and Analysis

The preliminary questions aim to discover the resident's view, while the other questions were designed to understand the site physically. Out of 180 distributed questionnaires, 169 filled them out completely without defects. About 11% of the participants were between 14 and 20 years old, 47% were between 20 and 35, 23% were between 35 and 50, and 19% were over 50 (Table 5). Regarding literacy, 41% of the respondents had a diploma or an associate degree, 31% had a bachelor's degree or higher, and 28% had less than a diploma. Almost 60% of the respondents were male, and the rest were female. In terms of employment status, 38% of the respondents were employed, 24% were unemployed, 20% were housekeepers, and about 18% did not answer. 76% of the participants have lived in the neighbourhood for 5-15 years, while 24% have lived there for less than five years.

As shown in Figure 5, only 17% of the respondents stated that they are indifferent to the neighbourhood and do not have a special feeling about it. The right graph measures their desire to participate in the neighbourhood reconstruction. 31% of the respondents only want to participate intellectually, which refers to the low financial ability of the residents. Nevertheless, 27% are willing to cooperate both in the form of providing human resources (the labour force) and in the form of financial participation under the condition of government support such as long-term loans, and 25% have not set any conditions for human and economic involvement. These results are consistent with the results of the left graph.

Table 5. Demographic Information

	Scale/ Category	N	%
Age group (yrs.)	<20	19	11.24
	20-35	79	46.74
	35-50	39	23.07
	>50	32	18.93
Gender	Female	68	40.23
	Male	101	59.76
Work status	Employed	64	37.86
	Unemployed	41	24.26
	Housekeeper	34	20.11
	Not answered	30	17.75
Literacy	Less than diploma	47	27.81
	Diploma and associate degree	69	40.82
	Bachelor and higher	53	31.36
Occupation duration in Tazeh Abad	<5	41	24.26
	5-10	46	27.21
	10-15	20	11.83
	>15	62	36.68

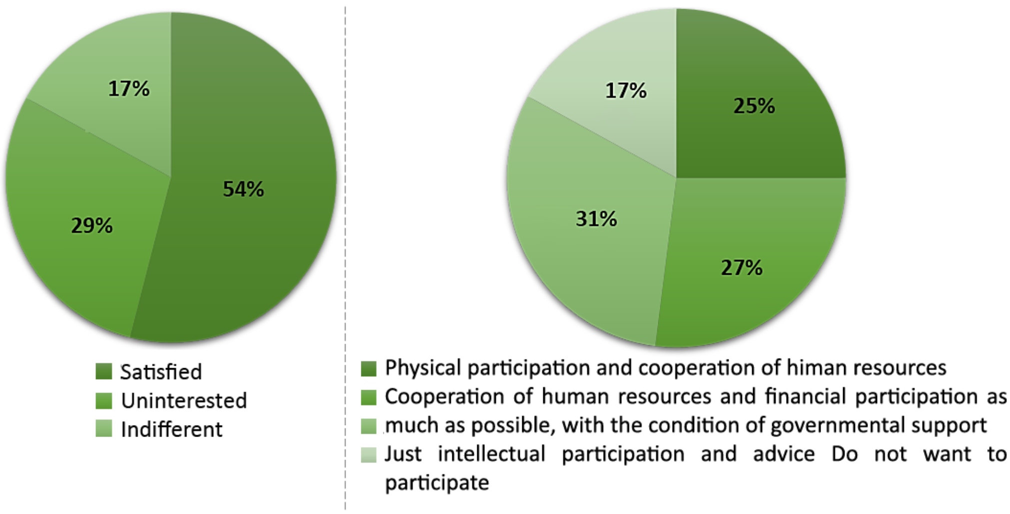

Figure 5. Residents' viewpoints about their neighbourhood

In Figure 6, the residents' opinions are analyzed regarding the quality, quantity, facilities, equipment, and problems related to the parks and green spaces in or near the neighbourhood. According to the results, approximately 40% of the residents mentioned the lack of proper facilities in the parks as the most critical problem. About 29% believed that the small area of parks and green spaces was their most important problem. Only 4% of the residents thought the existing park and green spaces were suitable for area and quality.

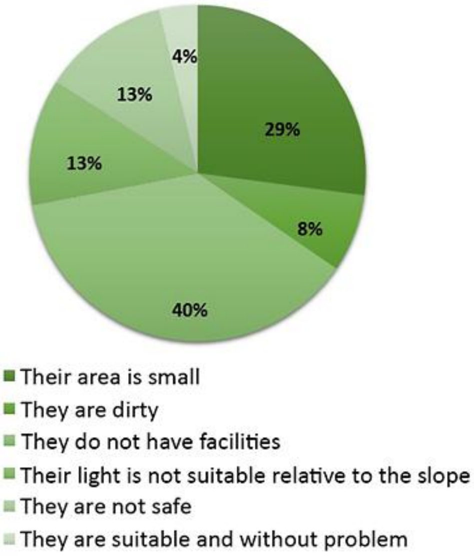

Figure 6. Residents' opinion about the park and green space in the neighbourhood

The deficiencies and the most critical problems from the residents of the Tazeh Abad neighbourhood perspective were ranked and shown in Figure 7. The deficiency of green spaces and their equipment, as well as the low quality and quantity of recreational facilities, are the most important problems. Providing green spaces for redeveloped sites is a solution for increasing green spaces. Other problems, due to their priority, are the narrow width of the alley's hard accessibility, inappropriate paving of the alleys, lack of educational/sports/commercial services, poor garbage collection services, and poor health and safety in the neighbourhood. It should be tried to select the best site in the neighbourhood to address most of these problems.

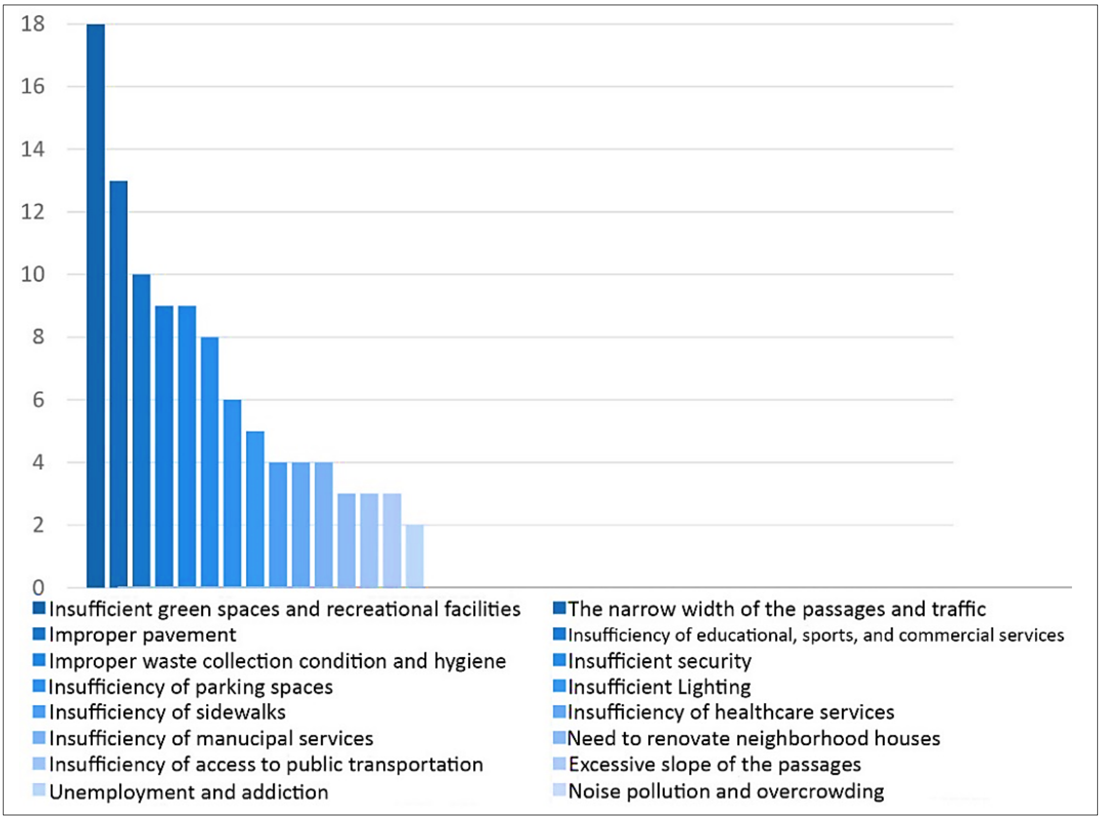

Figure 7. Rating of deficiencies and problems of the neighbourhood

5. Selecting the Most Suitable Site Using the Multi-Dimensional Matrix Method

The MDM can be created and applied for programming on platforms such as MATLAB and Simulink. The number of rows and columns and the parameters' weight should be mentioned to form an MDM in MATLAB. MATLAB offers several ways to create MDMs. The first way is to ask MATLAB to create a 3-dimensional matrix and fill it with zeros. The Zeros () function helps to do the site analysis model. For example, to create a 2x3x3 matrix, type aj=zeros (2, 3, 3) and press the Enter key. The following output, Eq. (2), is an example of a simple polynomial matrix.

$$a_j(:,:,1) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad a_j(:,:,2) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \qquad a_j(:,:,3) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{2}$$

Table 6 includes the indicators selected for site analysis in the Tazeh Abad neighbourhood. Based on the survey, the information from the questionnaires, the potential of each site, and the desires of the residents, the most proper indicators were selected and applied in the analysis. A relevant score for each category was defined and used in the assessments.

Table 6. Important indicators applied for the Tazeh Abad neighbourhood site analysis

Indicator	**Scoring method**		**Site 1**	**Site 2**	**Site 3**
	Range	**Value**			
Effect of occupied units on the site	n: The number of units with considered floors		28	38	15
	Four floors above	0			
	3	1 if(n): (n)×1			
	2	2 if(n): (n)×2			
	1	3 if(n): (n)×3			
Density of coverage	A/B A: lot coverage × number of stories B: area		800	800	1000
	A/B<1	1000			
	1<A/B<2	500			
	2<A/B<3	500			
	3<A/B<4	200			
	4<A/B<5	100			
	5<A/B<6	0			
Demolished units (Gray and brownfields)	< $200m^2$	0	0	0	400
	201-400	100			
	401-600	250			
	601-800	400			
	801-1000	800			
	1001-1200	1000			
	>1200	2000			

Worn-out units		Ratio >50	1000	100	100	200
		40-50%	800			
		30-39%	600			
		20-29%	400			
		10-19%	200			
		5-9%	100			
		<5%	20			
Number of units that should be destructed		Number >25	0	400	200	500
		20-25	100			
		15-19	200			
		10-14	400			
		5-9	500			
		<5	800			
Access to services		Service access radius: (Max+Min)/2		500	300	500
		<200m	500			
		200-399m	300			
		400-599m	200			
		600-799m	100			
		>800	10			
Population		Number of occupied units×Family size (Family size= 3.3)		50	50	50
		>2000	1000			
		1500-2000	80			
		1499-1000	600			
		999-800	500			
		799-500	300			
		499-200	150			
		<200	50			
Ratios	Lot coverage area / the whole site	<80%	200	200	200	300
		<50%	300			
		<40%	400			
		<30%	500			
		<20%	600			
		<10%	800			
	Worn-out units' area/ the whole site	<80%	800	200	200	200
		<50%	600			
		<40%	500			
		<30%	400			
		<20%	300			
		<10%	200			
		<80%	200	600	600	300

	Circulation area/ the whole site	<50%	200			
		<40%	400			
		<30%	500			
		<20%	600			
		<10%	800			
Natural features of the site	Dimensions and size of the site	Excellent	100	50	50	100
		Good	50			
		Ordinary	25			
		Poor	0			
	Sun orientation (south facing orientation)	Excellent	100	25	25	50
		Good	50			
		Ordinary	25			
		Poor	0			
	topography	Excellent	100	50	50	50
		Good	50			
		Ordinary	25			
		Poor	0			
	View/ landscape	Excellent	100	25	0	0
		Good	50			
		Ordinary	25			
		Poor	0			
Total				3028	2613	3665

The indicators were used, including (1) Effect of occupied units, (2) Density, (3) Demolished units, (4) Worn-out units, (5) Number of units that should be destructed, (6) Access to services, (7) Population, (8) Ratios, and (9) Natural features of the site. Table 7 shows the detailed calculation of scores for site 1 for one of the indicators. It is not possible to provide the calculation details for all rows. The values are defined based on the project's aims, usage of the project, experience, and characters of the project.

Table 7. Calculate the scores obtained from the indicator of occupied units in site 1

Indicator	Number of buildings story	Value	Number of buildings on the site 1	Score
Effect of occupied units in the site	Four and above	0	1	4×0×1=0
	3	1	0	3×1×0=0
	2	2	8	2×2×8=16
	1	3	4	1×3×4=12
Total score				28

Figure 8 shows the final results that were extracted from the Expert Choice software based on the weights of the indicators. It indicates the ranking of three sites in the neighbourhood. This graph shows that the highest final score belonged to site 3. As illustrated, the demolished units that made vacant lands had the greatest impact on choosing the best site for the Tazeh Abad neighbourhood regeneration, followed by the density of coverage, the number of worn-out units, and the number of units that should be destructed. On the other hand, the effect of occupied units on the site, ratios, and population have the lowest influence on site selection.

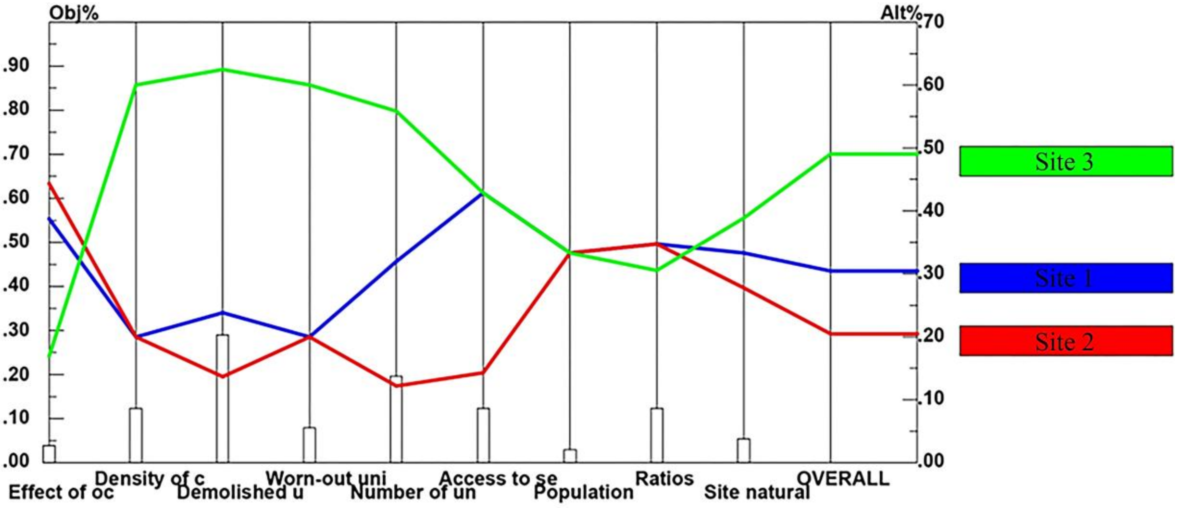

Figure 8. Performance sensitivity graph for factors affecting the ranking of sites

6. Conclusion

In developing countries such as Iran, primarily arbitrary, personal beliefs, peremptory, or political manners of a single person affect the selection of a project's site; however, an authentic methodology based on a Multi-Dimensional Matrix (MDM) for analyzing site plans (project land) was developed. A comprehensive method consisting of various data was presented using MATLAB and statistical analysis techniques. About 70 indicators, including qualitative and quantitative parameters, were classified into 11 categories. All the characteristics of qualitative results, such as the quality of the landscape, were converted into quantitative factors that are scientifically interpretable. It is possible to ensure that the selected site for a construction project is more reliable. The methodology was explained in further detail based on a sample project for the Tazed Abad neighbourhood in Sanandaj City. According to the analysis based on MDM for the Tazeh Abad neighbourhood, the total scores for sites 1, 2, and 3 are 3028, 2613, and 3665, respectively. Among the analyzed indicators for the neighbourhood, the demolished units, the density of coverage, the number of worn-out units, and the number of units that should be destructed had the greatest impact on site selection.

On the other hand, the effect of occupied units on the site, ratios, and population have the lowest influence. Therefore, site 3 is the best option for residential development in the urban context of Tazeh Abad. By applying the methodology, engineers can accurately select the best location for developing or future construction projects. This methodology limits and eliminates unscientific, illogical, arbitrary, irrational, and personal judgments about a construction site, which is a fundamental decision-making in the engineering. The developed methodology minimizes the failure of site selection and reduces the sustainability risks.

This research has several limitations. The assessment site analysis was based solely on external appearance, whereas a comprehensive evaluation should include subcriteria such as local structural condition and energy efficiency. The primary reason for omitting these details is the absence of reliable data for the analyzed sample site, as many buildings were constructed informally in the past. Some GIS data fields for the Tazeh Abad are incomplete, making it challenging to obtain the related information. Future research could benefit from the methodology and the comprehensive list of indicators, paving the way for machine learning approaches in site selection analysis. It could focus on further exploration of appropriate multi-criteria decision methods considering more local criteria. According to the developed model, a web-based decision support system and perhaps more modern facilities such as artificial intelligence that would allow decision makers to make such vital decisions better and more efficiently are highly recommended.

Acknowledgements: We are grateful to all the Master's students in Architecture at the University of Kurdistan who had Architectural Studio 2 between 2015 and 2016. All people have completed the site indicators and the questionnaires during the research.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest: The authors declare they have no known competing interests.

References

[1] Worldometers.info. "world population." https://www.worldometers.info/world-population/ (accessed 2023).

[2] U. UNFPA, "State of world population 2007: Unleashing the potential of urban growth," *United Nations Population Fund*, 2007.

[3] U. N. P. Fund, "Reaching Common Ground: Culture, Gender and Human Rights," ed: UNFPA New York, 2008.

[4] K. Ahmed Ali, M. I. Ahmad, and Y. Yusup, "Issues, impacts, and mitigations of carbon dioxide emissions in the building sector," *Sustainability,* vol. 12, no. 18, p. 7427, 2020, doi: 10.3390/su12187427.

[5] F. Chen and D. Zhu, "Research on the content, models and strategies of low carbon cities," in *Urban Planning Forum*, 2009, vol. 4, pp. 7-13.

[6] C. M. Souza Jr, J. Z. Shimbo, M. R. Rosa, L. L. Parente, A. A. Alencar, B. F. Rudorff, H. Hasenack, M. Matsumoto, L. G. Ferreira, and P. W. Souza-Filho, "Reconstructing three decades of land use and land cover changes in brazilian biomes with landsat archive and earth engine," *Remote Sensing,* vol. 12, no. 17, p. 2735, 2020.

[7] Y. Rezaeisabzevar, A. Bazargan, and B. Zohourian, "Landfill site selection using multi criteria decision making: Influential factors for comparing locations," *Journal of Environmental Sciences,* vol. 93, pp. 170-184, 2020.

[8] Q. Shen, H. Wang, and B.-s. Tang, "A decision-making framework for sustainable land use in Hong Kong's urban renewal projects," *Smart and Sustainable Built Environment,* vol. 3, no. 1, pp. 35-53, 2014.

[9] S. Kito and S. Thomas, "Site selection criteria and Evaluation Handbook," *State of Alaska Department of Education Juneau, Alaska–USA*, 2011.

[10] S. K. Mallick, S. Rudra, and B. Maity, "Land suitability assessment for urban built-up development of a city in the Eastern Himalayan foothills: A study towards urban sustainability," *Environment, Development and Sustainability,* vol. 26, no. 2, pp. 3767-3792, 2024.

[11] F. Golmohammadi, "Land use changes in natural resources and rural areas: Great threats for sustainable development in Iran," *Black Sea Journal of Public and Social Science,* vol. 3, no. 2, pp. 59-67, 2020.

[12] S. Ramezani, M. Nastaran, H. Nooraie, and K. Otsuki, "The role of the institutional environment in land use planning in Iran: A conceptual framework," *Land Use Policy,* vol. 135, p. 106942, 2023.

[13] S. Zanganeh Shahraki, N. Ahmadifard, H. Farhadikhah, B. Fotouhi Mehrabani, A. Haydari, Y. Abdali, V. Abbasi Fallah, E. Farhadi, S. Cividino, and S. Vinci, "Spatial planning, urban governance and the economic context: The case of 'mehr'housing plan, Iran," *Land,* vol. 9, no. 5, p. 169, 2020.

[14] U. Berardi, "Sustainability assessments of buildings, communities, and cities," in *Assessing and measuring environmental impact and sustainability*: Elsevier, 2015, pp. 497-545.

[15] G. Samton and M. Neilsen, "Sustainable Urban Site Design Manual," *DDC, New York,* 2008.

[16] C. Dinep and K. Schwab, *Sustainable site design: criteria, process, and case studies for integrating site and region in landscape design*. John Wiley & Sons, 2010.

[17] S. Kubba, *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*. Butterworth-Heinemann, 2012.

[18] S. Vaisi, D. Dyer, and F. Pilla, "Energy requirement mapping for university campus using CIBSE benchmarks and comparing CIBSE to display energy certificate (DEC) to extract a new criterion," in *Proceedings of the Energy Systems Conference, London, UK*, 2014, pp. 24-25.

[19] J. A. LaGro Jr, *Site analysis: A contextual approach to sustainable land planning and site design*. John Wiley & Sons, 2011.

[20] A. Beer and C. Higgins, *Environmental planning for site development: A manual for sustainable local planning and design*. Routledge, 2004.

[21] T. H. Russ, *Site planning and design handbook*. McGraw-Hill Education, 2002.

[22] M. G. R. Pérez and E. Rey, "A multi-criteria approach to compare urban renewal scenarios for an existing neighborhood. Case study in Lausanne (Switzerland)," *Building and Environment,* vol. 65, pp. 58-70, 2013, doi: 10.1016/j.buildenv.2013.03.017.

[23] J. Kleemann, J. N. Inkoom, M. Thiel, S. Shankar, S. Lautenbach, and C. Fürst, "Peri-urban land use pattern and its relation to land use planning in Ghana, West Africa," *Landscape and Urban Planning,* vol. 165, pp. 280-294, 2017, doi: 10.1016/j.landurbplan.2017.02.004.

[24] H. W. Zheng, G. Q. Shen, Y. Song, B. Sun, and J. Hong, "Neighborhood sustainability in urban renewal: An assessment framework," *Environment and Planning B: Urban Analytics and City Science,* vol. 44, no. 5, pp. 903-924, 2017, doi: 10.1177/0265813516655547.

[25] F. Monjezi and H. Beik Mohammadi, "Reconstruction of urban worn-out textures and reduction in risk taking (case study: Shushtar City)," *American Journal of Civil Engineering,* vol. 3, no. 2-1, pp. 24-29, 2015, doi: 10.11648/j.ajce.s.2015030202.15.

[26] A. Ragheb and R. El-Ashmawy, "Strategic actions of urban development to define the intervention policies of slums," *City, Territory and Architecture,* vol. 8, no. 1, p. 10, 2021.

[27] J. Fang, "Chinese urban redevelopment policies analysis: the innovation of new era urban redevelopment in the Guangdong-Hong Kong-Macau greater bay area," 2023.

[28] Y. Liu, L. Shen, Y. Ren, and T. Zhou, "Regeneration towards suitability: A decision-making framework for determining urban regeneration mode and strategies," *Habitat International*, vol. 138, p. 102870, 2023.

[29] P. Zhang and S. Park, "VLAS: Vacant Land Assessment System for Urban Renewal and Greenspace Planning in Legacy Cities," *Sustainability*, vol. 15, no. 12, p. 9525, 2023.

[30] L. Huang, W. Zheng, J. Hong, Y. Liu, and G. Liu, "Paths and strategies for sustainable urban renewal at the neighbourhood level: A framework for decision-making," *Sustainable Cities and Society*, vol. 55, p. 102074, 2020.

[31] K. Xu, G. Q. Shen, G. Liu, and I. Martek, "Demolition of existing buildings in urban renewal projects: A decision support system in the China context," *Sustainability*, vol. 11, no. 2, p. 491, 2019, doi: 10.3390/su11020491.

[32] M. Chahardowli, H. Sajadzadeh, F. Aram, and A. Mosavi, "Survey of sustainable regeneration of historic and cultural cores of cities," *Energies*, vol. 13, no. 11, p. 2708, 2020, doi: 10.3390/en13112708.

[33] A. Gorjinia and E. Amini, "Strategies for Rehabilitation and Renovation of Old Urban, with a Sustainable Development Approach Case Study: Nineteen Region of Tehran," *Bulletin De La Société Royale Des Sciences De Liège*, vol. 85, pp. 1717-1729, 2016, doi: 10.25518/0037-9565.6425.

[34] F. B. N. Beiglu, S. M. H. Ghafari, and A. Taheri, "Infill Architecture as a Solution for Livability and Historical Texture Quality Promotion," *Civil Engineering Journal*, vol. 5, no. 1, pp. 165-171, 2019, doi: 10.28991/cej-2019-03091234

[35] W. Yan, L. Zhang, X. Duan, and F. Wu, "Strategic approaches to realize sustainable neighborhoods in urban renewal: A case study of Banan, Chongqing, China," *Sustainability*, vol. 15, no. 4, p. 3515, 2023.

[36] M. Morio, S. Schädler, and M. Finkel, "Applying a multi-criteria genetic algorithm framework for brownfield reuse optimization: Improving redevelopment options based on stakeholder preferences," *Journal of environmental management*, vol. 130, pp. 331-346, 2013, doi: 10.1016/j.jenvman.2013.09.002.

[37] R. F. M. Ameen, M. Mourshed, and H. Li, "A critical review of environmental assessment tools for sustainable urban design," *Environmental Impact Assessment Review*, vol. 55, pp. 110-125, 2015, doi: 10.1016/j.eiar.2015.07.006.

[38] H. Kaur and P. Garg, "Urban sustainability assessment tools: A review," *Journal of cleaner production*, vol. 210, pp. 146-158, 2019, doi: 10.1016/j.jclepro.2018.11.009.

[39] S. Charoenkit and S. Kumar, "Environmental sustainability assessment tools for low carbon and climate resilient low income housing settlements," *Renewable and sustainable energy reviews*, vol. 38, pp. 509-525, 2014, doi: 10.1016/j.rser.2014.06.012.

[40] A. Sharifi and A. Murayama, "A critical review of seven selected neighborhood sustainability assessment tools," *Environmental impact assessment review*, vol. 38, pp. 73-87, 2013, doi: 10.1016/j.eiar.2012.06.006.

[41] T. Yigitcanlar, M. Kamruzzaman, and S. Teriman, "Neighborhood sustainability assessment: Evaluating residential development sustainability in a developing country context," *Sustainability*, vol. 7, no. 3, pp. 2570-2602, 2015, doi: 10.3390/su7032570.

[42] E. Zarghami, H. Azemati, D. Fatourehchi, and M. Karamloo, "Customizing well-known sustainability assessment tools for Iranian residential buildings using Fuzzy Analytic Hierarchy Process," *Building and Environment*, vol. 128, pp. 107-128, 2018, doi: 10.1016/j.buildenv.2017.11.032.

[43] V. W. Tam, H. Karimipour, K. N. Le, and J. Wang, "Green neighbourhood: Review on the international assessment systems," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 689-699, 2018, doi: 10.1016/j.rser.2017.09.083.

[44] D. Dizdaroglu, "The role of indicator-based sustainability assessment in policy and the decision-making process: A review and outlook," *Sustainability*, vol. 9, no. 6, p. 1018, 2017, doi: 10.3390/su9061018.

[45] A. Haapio, "Towards sustainable urban communities," *Environmental Impact Assessment Review*, vol. 32, no. 1, pp. 165-169, 2012, doi: 10.1016/j.eiar.2011.08.002.

[46] A. Komeily and R. S. Srinivasan, "A need for balanced approach to neighborhood sustainability assessments: A critical review and analysis," *Sustainable Cities and Society*, vol. 18, pp. 32-43, 2015, doi: 10.1016/j.scs.2015.05.004.

[47] E. Talen, E. Allen, A. Bosse, J. Ahmann, J. Koschinsky, E. Wentz, and L. Anselin, "LEED-ND as an urban metric," *Landscape and Urban Planning,* vol. 119, pp. 20-34, 2013, doi: 10.1016/j.landurbplan.2013.06.008.

[48] B. Mattoni, C. Guattari, L. Evangelisti, F. Bisegna, P. Gori, and F. Asdrubali, "Critical review and methodological approach to evaluate the differences among international green building rating tools," *Renewable and Sustainable Energy Reviews,* vol. 82, pp. 950-960, 2018.

[49] L. Boyle, K. Michell, and F. Viruly, "A critique of the application of neighborhood sustainability assessment tools in urban regeneration," *Sustainability,* vol. 10, no. 4, p. 1005, 2018, doi: 10.3390/su10041005.

[50] J. Pedro, C. Silva, and M. D. Pinheiro, "Integrating GIS spatial dimension into BREEAM communities sustainability assessment to support urban planning policies, Lisbon case study," *Land Use Policy,* vol. 83, pp. 424-434, 2019, doi: 10.1016/j.landusepol.2019.02.003.

[51] S. Ferrari, M. Zoghi, T. Blazquez, and G. Dall'O, "Towards worldwide application of neighborhood sustainability assessments: A systematic review on realized case studies," *Renewable and Sustainable Energy Reviews,* vol. 158, p. 112171, 2022, doi: 10.1016/j.rser.2022.112171.

[52] A. Sharifi, A. Dawodu, and A. Cheshmehzangi, "Limitations in assessment methodologies of neighborhood sustainability assessment tools: A literature review," *Sustainable Cities and Society,* vol. 67, p. 102739, 2021, doi: 10.1016/j.scs.2021.102739.

[53] A. López Chao, A. Casares Gallego, V. Lopez-Chao, and A. Alvarellos, "Indicators framework for sustainable urban design," *Atmosphere,* vol. 11, no. 11, p. 1143, 2020, doi: 10.3390/atmos11111143.

[54] A. Dawodu, A. Cheshmehzangi, A. Sharifi, and J. Oladejo, "Neighborhood sustainability assessment tools: Research trends and forecast for the built environment," *Sustainable Futures,* vol. 4, p. 100064, 2022, doi: 10.1016/j.sftr.2022.100064.

[55] S. Esfandeh, A. Danehkar, A. Salmanmahiny, S. M. M. Sadeghi, and M. V. Marcu, "Climate change risk of urban growth and land use/land cover conversion: An in-depth review of the recent research in Iran," *Sustainability,* vol. 14, no. 1, p. 338, 2021.

[56] S. Solaymani, "A review on energy and renewable energy policies in Iran," *Sustainability,* vol. 13, no. 13, p. 7328, 2021.

[57] E. Rafiei-Sardooi, A. Azareh, S. J. Shooshtari, and E. J. Parteli, "Long-term assessment of land-use and climate change on water scarcity in an arid basin in Iran," *Ecological Modelling,* vol. 467, p. 109934, 2022.

[58] V. Moshfeghi, G. Haghighat Naeini, and M. Habibi, "Land Use and the Efficiency of Transportation Laws with Regard to Air Pollution in Tehran Metropolitan Area," *Space Ontology International Journal,* vol. 9, no. 1, pp. 65-75, 2020.

[59] M. Azami, E. Mirzaee, and A. Mohammadi, "Recognition of urban unsustainability in Iran (case study: Sanandaj City)," *Cities,* vol. 49, pp. 159-168, 2015.

[60] K. Hassanzadehkermanshahi and S. Shirowzhan, "Measuring urban sustainability over time at national and regional scale for addressing united nations sustainable development goal (SDG) 11: Iran and Tehran as case studies," *Sustainability,* vol. 14, no. 12, p. 7402, 2022.

[61] M. Heydari, F. Othman, and M. Noori, "A review of the Environmental Impact of Large Dams in Iran," *International Journal of Advancements Civil Structural and Environmental Engineering, IJACSE,* vol. 1, no. 1, p. 4, 2013.

[62] M. Mansournejad, B. Kalantari, and M. M. Adeli, "The investigation of negative effects of salt dome on the quality of water in Gotvand Olya dam and the use of cut-off wall as treatment," *American Journal of Civil Engineering,* vol. 3, no. 2-2, pp. 53-56, 2015.

[63] L. Jalali, M. Zarei, and F. Gutiérrez, "Salinization of reservoirs in regions with exposed evaporites. The unique case of Upper Gotvand Dam, Iran," *Water research,* vol. 157, pp. 587-599, 2019.

[64] A. Barjasteh, "The impact of active faulting on the geotechnical properties of the Upper Gotvand Dam, southwest Iran," *Bulletin of Engineering Geology and the Environment,* vol. 78, no. 2, pp. 709-722, 2019.

[65] M. Ghasemi and N. Ozay, "A discussion on affordable housing projects; case study Mehr Housing, Iran," *Journal of Contemporary Urban Affairs,* vol. 2, no. 3, pp. 137-145, 2018.

[66] R. Etminani-Ghasrodashti, H. Majedi, and M. Paydar, "Assessment of residential satisfaction in Mehr housing scheme: A case study of Sadra New Town, Iran," *Housing, Theory and Society,* vol. 34, no. 3, pp. 323-342, 2017.

[67] A. Karji, A. Woldesenbet, M. Khanzadi, and M. Tafazzoli, "Assessment of social sustainability indicators in mass housing construction: a case study of Mehr housing project," *Sustainable Cities and Society,* vol. 50, p. 101697, 2019.

[68] M. Ouria and H. Sevinc, "The role of dams in drying up lake Urmia and its environmental impacts on Azerbaijani districts of Iran," *Saussurea,* vol. 6, no. 1, pp. 54-65, 2016.

[69] S. Okhravi, S. Eslamian, and S. T. Esfahany, "Drought in lake urmia," in *Handbook of Drought and Water Scarcity*: CRC Press, 2017, pp. 605-618.

[70] O. Alizadeh-Choobari, F. Ahmadi-Givi, N. Mirzaei, and E. Owlad, "Climate change and anthropogenic impacts on the rapid shrinkage of Lake Urmia," *International Journal of Climatology,* vol. 36, no. 13, pp. 4276-4286, 2016.

[71] A. Rahimi and J. Breuste, "Why is Lake Urmia drying up? Prognostic modeling with land-use data and artificial neural network," *Frontiers in Environmental Science,* vol. 9, p. 603916, 2021.

[72] M. Shams Ghahfarokhi and S. Moradian, "Investigating the causes of Lake Urmia shrinkage: climate change or anthropogenic factors?," *Journal of Arid Land,* vol. 15, no. 4, pp. 424-438, 2023.

[73] D. Shach-Pinsly, S. Bindreiter, I. Porat, S. Sussman, J. Forster, and M. Rinnerthaler, "Multiparametric analysis of urban environmental quality for estimating neighborhood renewal alternatives," *Urban Planning,* vol. 6, no. 4, pp. 172-188, 2021.

[74] M. Pazzini, R. Corticelli, C. Lantieri, and C. Mazzoli, "Multi-Criteria Analysis and Decision-Making Approach for the Urban Regeneration: The Application to the Rimini Canal Port (Italy)," *Sustainability,* vol. 15, no. 1, p. 772, 2022.

[75] J. Chen, Y. Chen, Y. Zhu, M. Xiao, H. Yang, H. Huang, and L. Li, "Assessing the Sustainability of Urban Community Renewal Projects in Southern China Based on a Hybrid MADM Approach," *Sustainability*, vol. 15, no. 4, p. 3023, 2023.

[76] S.-H. Lin, X. Huang, G. Fu, J.-T. Chen, X. Zhao, J.-H. Li, and G.-H. Tzeng, "Evaluating the sustainability of urban renewal projects based on a model of hybrid multiple-attribute decision-making," *Land Use Policy,* vol. 108, p. 105570, 2021.

[77] A. A. Shahraki, "Renovation programs in old and inefficient neighborhoods of cities with case studies," *City, Territory and Architecture,* vol. 9, no. 1, p. 28, 2022, doi: 10.1186/s40410-022-00174-1.