International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 12 No. 1, 2026
https://theaspd.com/index.php

GIS-MCDA for Outdoor Recreation Site Suitability and Urban Well-Being: Evidence From Riyadh

Abdulkader Murad[1], Abdullah Mahboob[2], Ali Alhumaidi[3]
Department of Urban and Regional Planning, Faculty of Architecture and Planning, King Abdulaziz University, Jeddah, Saudi Arabia,amurad@kau.edu.sa
Department of Urban and Regional Planning, Faculty of Architecture and Planning, King Abdulaziz University, Jeddah, Saudi Arabia, ammahbood@kau.edu.sa
Department of Urban and Regional Planning, Faculty of Architecture and Planning , King Abdulaziz University, Jeddah, Saudi Arabia, aalhumaidi0010@stu.kau.edu.sa

Abstract
Outdoor activities play a vital role in sustainable development, significantly enhancing quality of life and social well-being and fostering a healthy urban environment. This paper applies a Geographic Information System-based Multi-Criteria Decision Analysis GIS-MCDA framework to identify a suitable location for outdoor activities in Riyadh that promote a healthier urban environment. Five criteria related to aesthetic quality, equitable accessibility, environmental protection, functional integration, and urban resilience were identified and converted into influence factors. Simultaneously, residents' priorities were gathered through a structured questionnaire, while experts' judgment was obtained via Delphi rounds to integrate experts' and residents' priorities together. Moreover, GIS is used to model the suitability of locations for outdoor recreation. The results indicate that the absolute scenario assigns the highest priorities to aesthetic quality, followed by urban resilience, environmental mitigation, functional integration, and equitable accessibility. The suitability map reveals that highly suitable areas that balance all criteria are primarily located around built-up areas that provide suitable terrains, high accessibility, environment buffer zones, opportunity or untapped assets, and secure and resilient zones. The finding highlights the potential of GIS-MCDA as a spatial decision support tool for urban and recreational planning.
Key words: *GIS-MCDA, outdoor recreation, urban well-being, suitability, criteria, sites*

INTRODUCTION

Outdoor spaces are fundamental components of urban infrastructure that contribute to a healthy urban environment, reducing the incidence of chronic diseases, promoting physical activity, strengthening mental and physical health, supporting social cohesion, and improving quality of life. However, supplying sufficient outdoor space becomes increasingly challenging due to rapid urban expansion and fragmented development patterns. Insufficient and disproportionate distribution of these areas leads to spatial gaps between districts, which restrict access to safe and health-promoting environments and increase health inequality. Consequently, integrating urban well-being considerations into urban planning has become essential for promoting healthy and resilient communities. (Brunyé et al., 2018; Marchment & Gill, 2022; Rebecchi et al., 2025).

From urban perspectives, the efficiency of outdoor spaces is influenced by location and the surrounding context. Selecting appropriate locations for outdoor activities is essential to ensuring equitable access to safe recreational environments, reducing human exposure to environmental hazards, and improving connectivity to urban infrastructure. (Lopez-Haro et al., 2024; Wolch et al., 2014). In addition to preventing chronic diseases such as obesity and diabetes, these areas act as a therapeutic landscape that supports mental well-being. Neuroscientific studies indicate that exposure to open spaces and natural features can regulate neurotransmitters such as dopamine and oxytocin while reducing cortisol levels. (Gascon et al., 2015; Hunter et al., 2019; Organization, 2019; Tost et al., 2019).

Geographic Information Systems GIS enables the systematic integration of urban well-being parameters in recreation planning by prioritizing locations that meet defined standards. Additionally, leveraging spatial decision-making tools minimizes risks associated with pollution, noise exposure, traffic, and land use conflicts. (Malczewski, 2006; Wolch et al., 2014).

Selecting suitable outdoor spaces without a clear approach leads to critical environmental issues, degradation of natural resources, and unsustainable land-use transformation. In this context, geographic information system-based multi-criteria decision analysis GIS-MCDA becomes an effective technique to evaluate potential sites based on a range of environmental, social, and economic criteria to select sustainable locations. Furthermore, integrating the Analytic Hierarchy Process AHP with GIS supports decision makers to systematically derive criteria weights, thereby reducing bias and increasing the objectivity of the analysis, which is aligned with the local context. (Alyousef et al., 2022; Bahadori et al., 2022; Malczewski, 2006).

Public participation in urban planning is essential to achieving social acceptance and long-term sustainability, as it allows the integration of users' needs into the site selection process. (Geertman & Stillwell, 2004). Rikalovic et al. (2014) indicate that GIS-MCDM has advanced into an effective framework for integrating users' priorities into decision input. This mixed method engages groups in defining, prioritizing, and evaluating criteria, while a public participatory geographic information system PPGIS involves public participation in spatial data production. Each approach aims to transform subjective assessments into quantitative values that integrate into suitability models, to ensure that the results are socially acceptable, responsive to the community's needs, and consistent with environmental, social, and economic considerations.

The current limitations of suitability applications underscore the need for a comprehensive approach that specifically addresses healthy urban environments. Therefore, this study utilizes a GIS-MCDA framework in Riyadh to identify suitable locations for outdoor activities that enhance urban well-being and improve quality of life. This paper adds to the existing literature by integrating spatial analysis with the priorities of residents and expert opinions, thereby enhancing the reliability of the suitability assessment. The proposed framework acts as a practical planning tool designed to promote urban well-being and optimize the distribution of outdoor recreation spaces in rapidly growing cities.

Materials and Methods

Study Area

Riyadh is the capital city of Saudi Arabia. It is located on Najd Plateau at an elevation of approximately 600 meters above sea level. The coordinates are between 24°18′ N and 25°11′ N latitudes, and 46°15′ E to 47°19′ E longitudes. (Alghamdi et al., 2021). The Plateau gradual decrease in elevation from 609 meters in the west to 600 meters in the east. (Alqurashi et al., 2016). Riyadh has experienced significant urban growth as the administrative, commercial, and cultural center of the Kingdom of Saudi Arabia, which has affected land use patterns. Rahman, (2016) notes that various case studies monitoring land cover changes have observed a substantial increase in built-up areas within the city's urban growth boundary. Figure 1 below illustrates the area of the case study.

Data acquisition

The spatial dataset sourced from the Ministry of Municipalities and Housing encompasses land use, land covers, primary and secondary road networks, and district administrative boundaries. The digital elevation model (DEM) was acquired from the United States Geological Survey website (USGS). All geospatial analysis performed using ArcGIS Pro 3.1.0 software.

Figure 1 Overview of the baseline map in Riyadh, Saudi Arabia

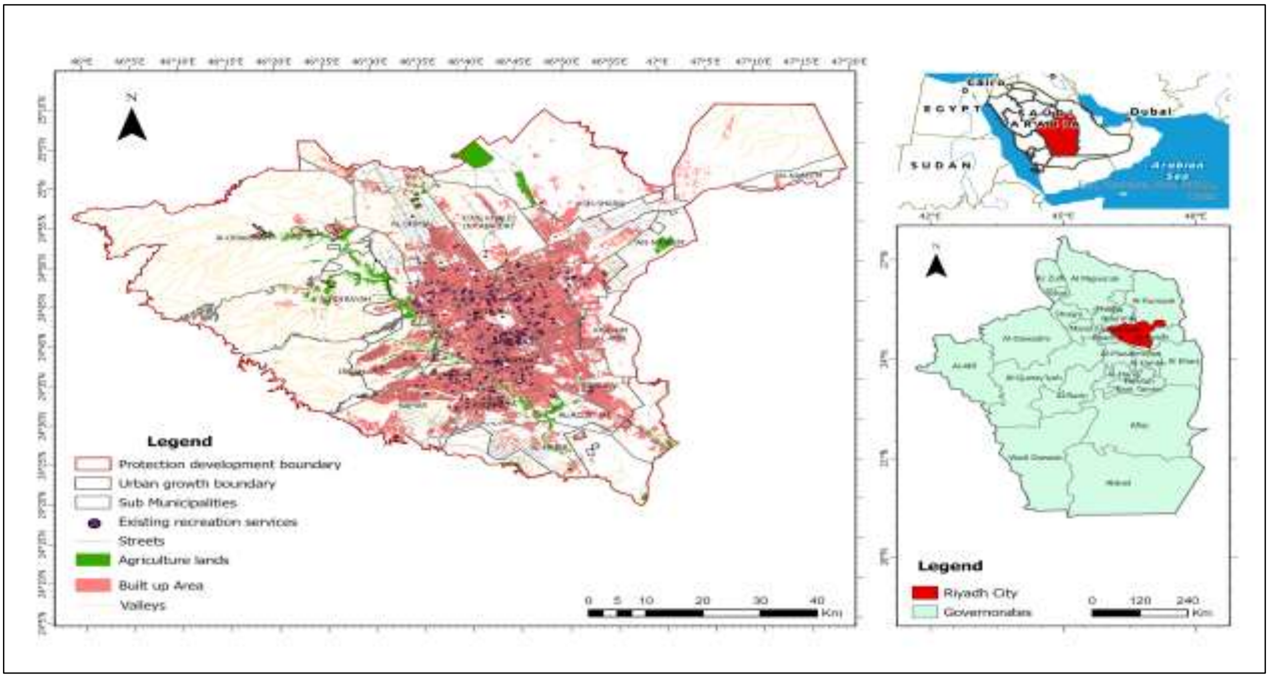


Figure 2 Overview of the baseline map in Riyadh, Saudi Arabia

GIS–MCDA Framework

The framework of the current study flowchart is designed in four phases, as illustrated in Figure 2. In initial phase, a comprehensive literature review is conducted to identify suitability criteria, which validated by experts to ensure local context consistency. In second phase, spatial data is collected to develop a base map that reflects existing conditions. This involves creating factor maps for each criterion, which serve as input for suitability modelling.

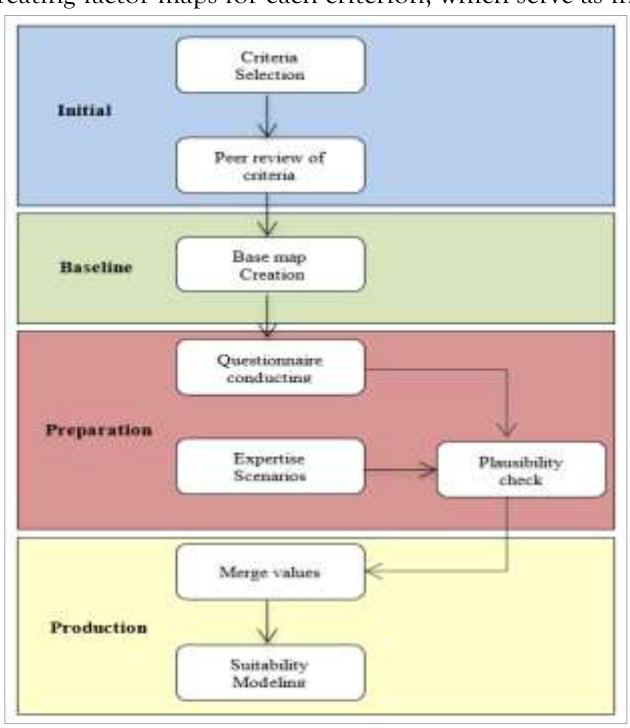


Figure 3 Research plan.

In the third phase, a questionnaire is developed to assess residents' priorities for each criterion, using a five-point Likert scale. (Joshi et al., 2015). Additionally, expert scenarios generated via the Delphi method to align expert judgment with the resident perspective. The relative weight of criteria is determined by the Analytic Hierarchy Process (AHP) and Weighted Linear Combination (WLC) technique by Saaty, (1990). A plausibility check is performed to identify the best scenario that aligns with residents' priorities. (Rabe et al., 2018).
In the fourth step, integrated weight values Rw are calculated by merging experts' and residents' inputs using the following equation:

$$Rw = \frac{\sum(Ws+We)}{Ns} \qquad (1)$$

Where Ws represents the weight values derived from residents' priorities, We represent the weight values derived from expert judgments, and Ns signifies the number of classification groups.
Suitability modeling for outdoor recreation is executed within GIS by overlaying suitability maps. The final output is categorized into five suitability classes: unsuitable, low, medium, high, and absolute suitability.

RESULTS

Thematic Criteria for Outdoor Recreation Suitability

A set of criteria has been identified to incorporate urban well-being aspects into suitable mapping for outdoor activities. These criteria are synthesized based on a systematic literature review, the existing condition of the study area, and expert consultation. The selected criteria include (1) aesthetic quality, related to preserving the natural landform through landscape while minimizing development costs, expressed by the distance from slopes; (2) Equitable accessibility, which ensures effective connectivity by the distance from the transportation network; (3) Environmental Mitigation aims at minimizing exposure to noise and pollutants by maintaining a buffer zone from adjacent districts; (4) Functional integration associated with optimal allocation regarding existing and potential resources; and (5) Urban resilience is defined by the distances from natural and industrial hazard areas, including industrial zones, landfills, and flood-prone areas, while repurposing open spaces for risk reduction (Dhami, 2013; Tims, 2009; Tŭrk, 2009).
Integrating topographical features in landscape planning is pivotal for the success of a recreation facility. Sites with gentle slopes are preferred to avoid soil erosion and decrease construction costs, as natural landscapes improve aesthetic perception and psychological well-being. (Mundher et al., 2022; Yen et al., 2021). Relating to equitable accessibility, proximity to transport networks is important, where a 3-kilometer threshold is recommended to increase user access and promote equitable service delivery (Giles-Corti et al., 2013; Willoughby, 2005; Yan et al., 2024). Conversely, the proximity of outdoor activities to residential areas and other urban functions can have negative environmental consequences. (Lofti & Koohsari, 2009; Nappi et al., 2019; Utami Dewi et al., 2023). Outdoor activities require careful consideration in terms of functional integration, which requires buffer zones between proposed and existing recreation to decrease negative impacts such as noise and congestion, while allocating outdoor areas within vacant assets that provide recreational opportunities (Eagles et al., 2002; Goines & Hagler, 2007; Gospodini, 2006). Moreover, the brown field and vacant facilities provide opportunities through transforming into open spaces and recreational areas, which contribute to the rehabilitation of the urban fabric and improvement of health quality (De Sousa, 2003). To increase the resilience of cities, protect public health, and ensure potential risks to sustainable infrastructure, outdoor areas should have a safety distance of at least 500 meters from dangerous areas such as industrial areas, sewage treatment plants, airports, and flood-prone areas (Cutter et al., 2010; UNISDR, 2015). Conversely, the literature underscores that proactive interaction with natural environments promotes psychological well-being and superior quality of life; outdoor activities must be positioned to existing open spaces for urban resilience and enhancing community adaptive capacity and social-

ecological health. (Bratman et al., 2019). Table 1 presents the criteria along with their respective levels of importance, where one indicates unsuitability and five indicates absolute suitability.

Table 1 Statement of suitability criteria, factors, classes, and preference values

Criteria	**Factors**	**Classes**	**Preference value**
Aesthetic quality	Distance to Slope Area	1	(> 45°)
		2	(30°–45°)
		3	(20°–30°)
		4	(12°–20°)
		5	(< 12°)
Equitable accessibility	Distance to transport networks	1	(> 15 km)
		2	(10-15 km)
		3	(6-10 km)
		4	(3-6 km)
		5	(<3 km)
Environmental Mitigation	Distance to Build-up Area	1	(< 0.50 km)
		2	(> 10 km)
		3	(7-10 km)
		4	(3-7 km)
		5	(0.50 - 3 km)
Functional integration	Distance to the existing recreation area	1	(< 3 km)
		2	(> 12 km)
		3	(9-12 km)
		4	(6-9 km)
		5	(3-6 km)
	Distance to potential resources	1	(>3 km)
		5	(<3 km)
Urban resilience	Distance to hazard area	1	(< 0.5 km)
		5	(> 0.5 km)
	Distance to valleys streams	1	(< 0.5 km)
		2	(> 10 km)
		3	(5-10 km)
		4	(2-5 km)
		5	(0.5-2 km)

Geospatial Criteria Mapping and Normalization

Thematic maps generated to visualize the factors influencing the selection of suitable locations for outdoor areas in Riyadh. maps developed using the Euclidean distance tool to quantify spatial proximity, alongside the Reclassify tool to categorize criteria into distinct suitability values. Figure 3a illustrates the digital elevation model DEM and corresponding slope map, while Figure 3b presents the suitability classification based on slope gradients. The results indicate that the steep slopes and valley streams in the western part of the city are characterized as unsuitable to moderate suitability. Conversely, the most suitable areas for outdoor activities are those with a gentle slope or less than 12 degrees, which are extensively distributed across the city.

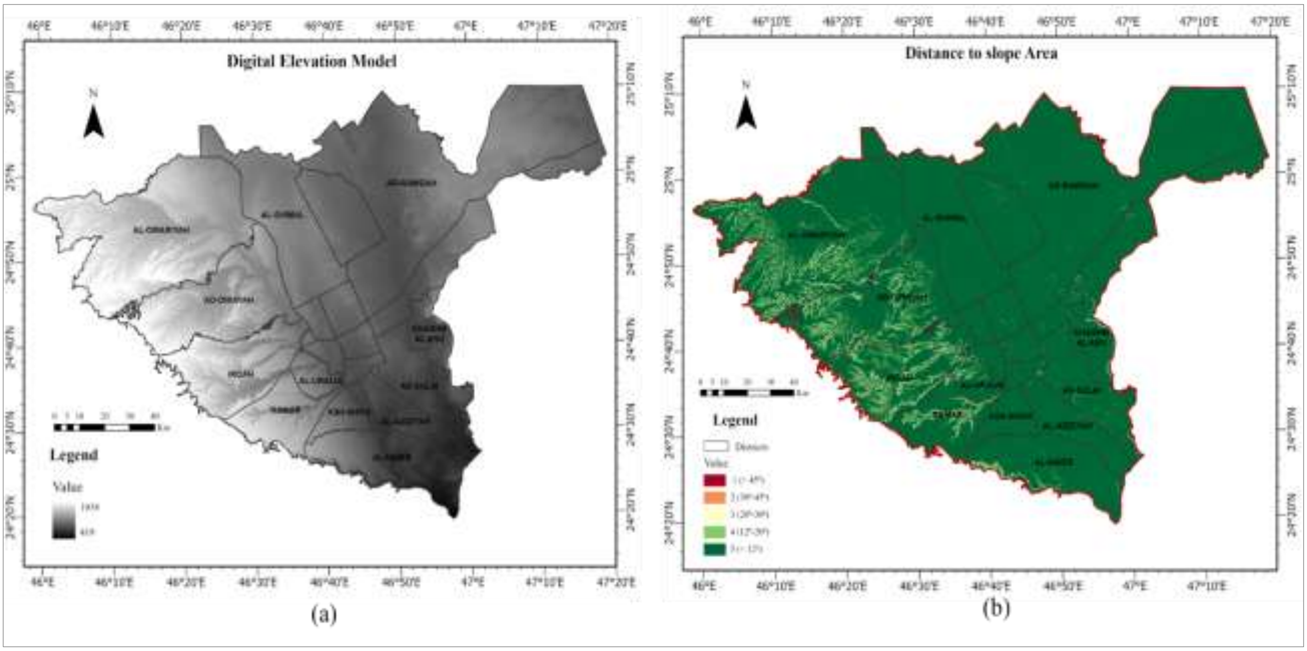


Figure 4 (a) Digital elevation model; (b) Distance to slope area.

Transportation facilities are essential to providing access to various urban infrastructures, especially outdoor spaces. In Riyadh, the road network is classified into highways, arterial roads, secondary roads, and local roads, supplemented by a public transportation system comprising the metro, bus, and railway networks. Figure 4a. illustrate transportation networks. Figure 4b reveals that outdoor sites located within 3 kilometers of transportation facilities are considered suitable sites for easy access to users.

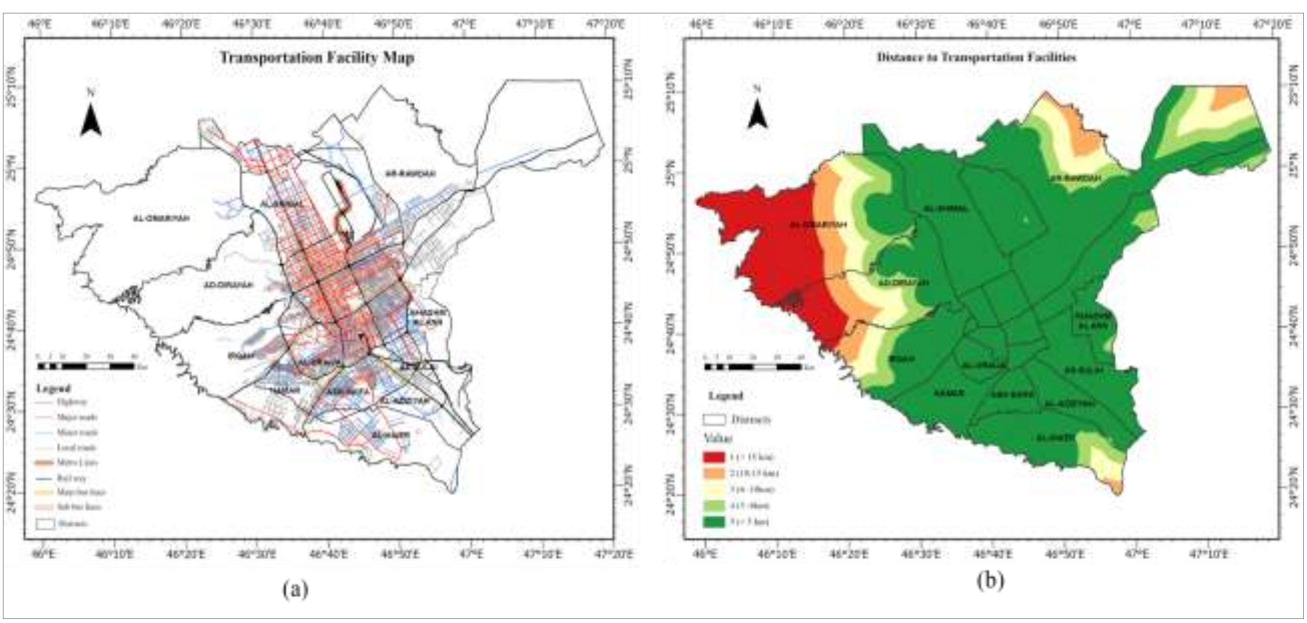


Figure 5 (a) Transportation facilities map; (b) Distance to transportation networks.

The proximity of recreational services to built-up areas, including residential districts, causes environmental issues, noise, and pollution. Therefore, create a buffer zone between outdoor activities and built-up areas to mitigate adverse environmental impacts, enhance the quality of life, and maintain residents' access to these facilities. This spatial benefit is maximized when facilities are situated within 0.5 kilometers of built-up areas to ensure rapid emergency access to healthcare; the suitability gradually decreases as the distance increases, becoming statistically negligible beyond seven kilometers. Figure 5a shows existing built-up areas, while Figure 5b presents the corresponding recreational suitability map.

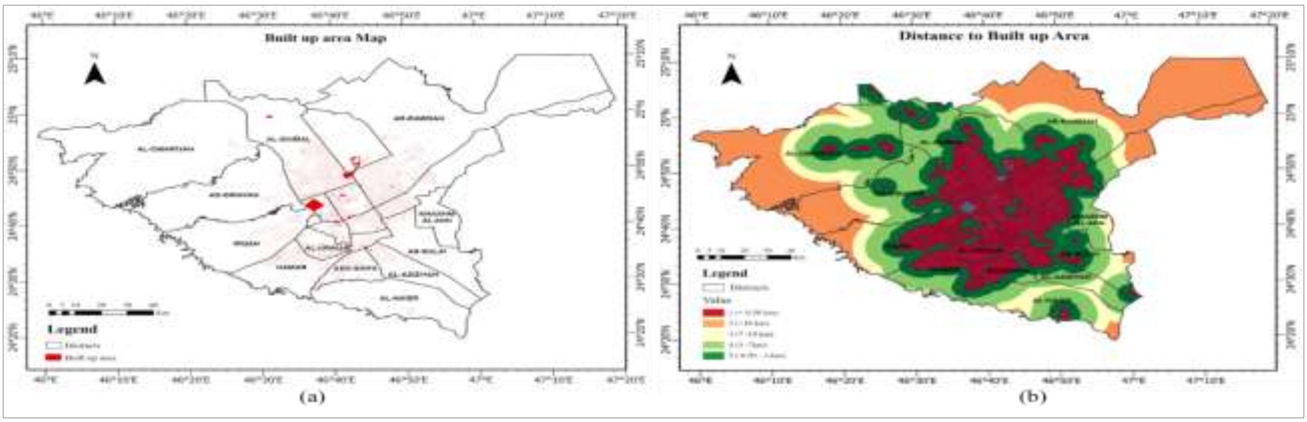
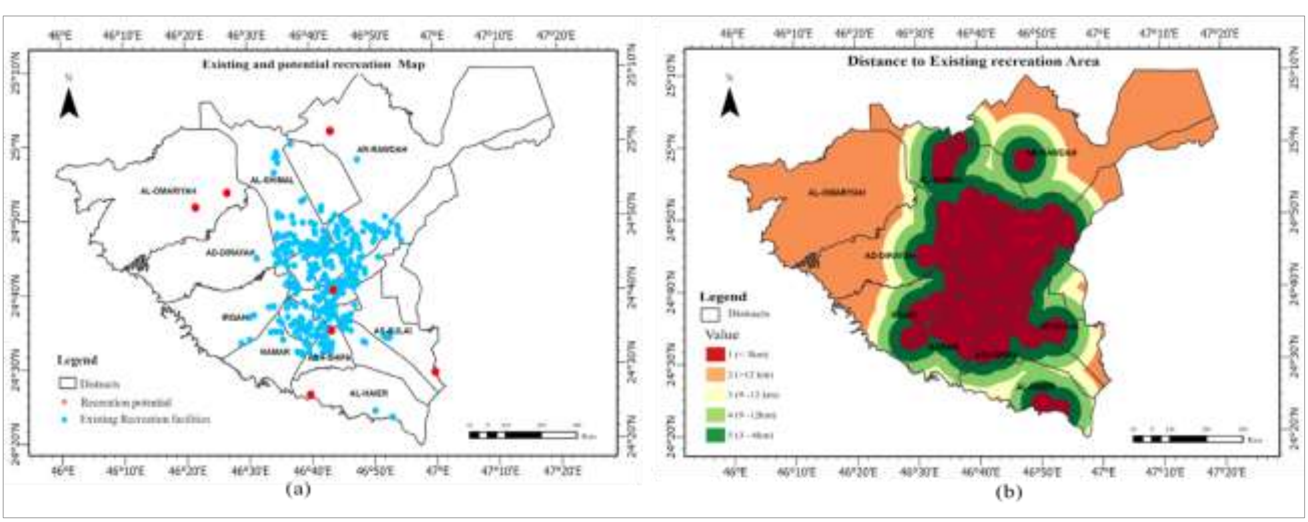


Figure 6 (a) Built-up areas map; (b) Distance to built-up areas

The proximity to existing recreational sites exacerbates functional conflicts and potential congestion issues, particularly in Riyadh, where there is a heavy dependency on private vehicles. Therefore, it is recommended to create a buffer zone of approximately three kilometers between recreation sites. This buffer zone ensures integration between accessibility and tranquil surroundings while providing sufficient spatial separation to minimize noise and functional overlap caused by traffic-related activities. Figure 6a illustrates the spatial distribution of potential and existing resources, while Figure 6b shows the suitability map relative to existing facilities.

Leveraging vacant assets is essential for expanding recreational opportunities in Riyadh. Therefore, proposed recreational sites should be allocated near vacant assets, ideally within a three-kilometer radius, to achieve an effective integration between accessibility and efficient resource management. Figure 6c illustrates the suitability classification for recreation assets.



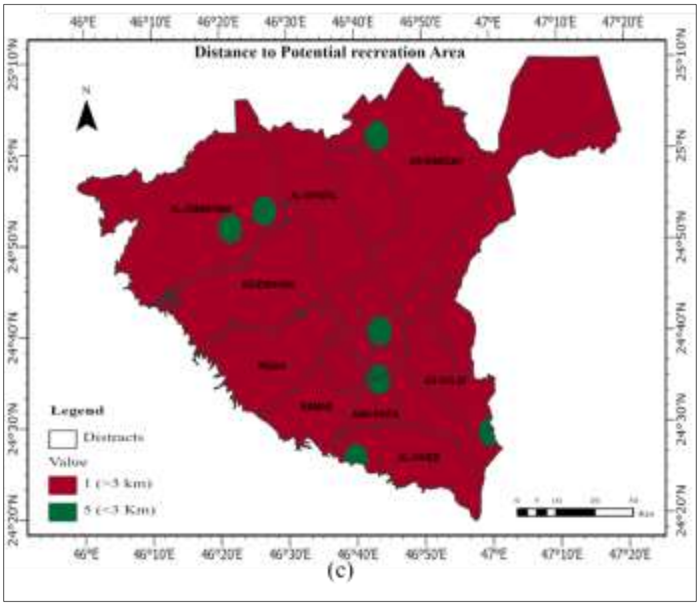
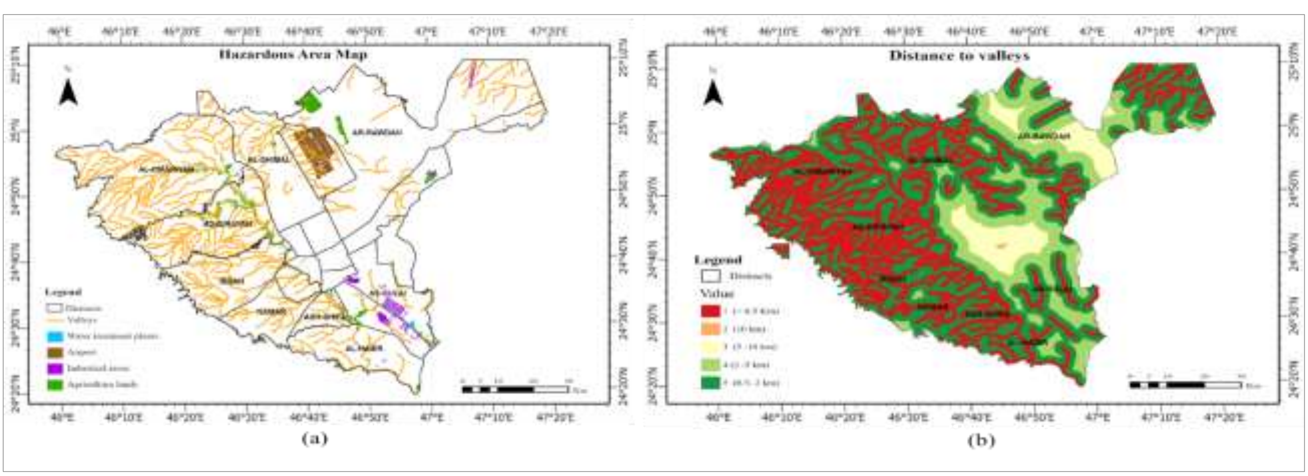


Figure 7. (a) Existing and potential resources; (b) Distance to existing recreation maps; (c) Distance to potential resources.

Figure 7a below illustrates the spatial distribution of natural and industrial hazard areas in Riyadh city. Figure 7b shows the valley streams characterized by high flood risk, particularly in the western parts of the city. The suitability analysis shows the necessity of making a buffer zone of 0.5 kilometers from flood-prone areas when allocating outdoor areas. However, areas located between 0.5 and 2 kilometers from valley streams are considered viable outdoor activities and promote public health through integration with open space. Regarding the proximity to industrial hazardous sources, including airports, water treatment plants, industrial zones, and landfills, Figure 7c below illustrates that increasing the distance beyond 0.5 kilometers threshold significantly improves the suitability of proposed sites and safeguards public health.



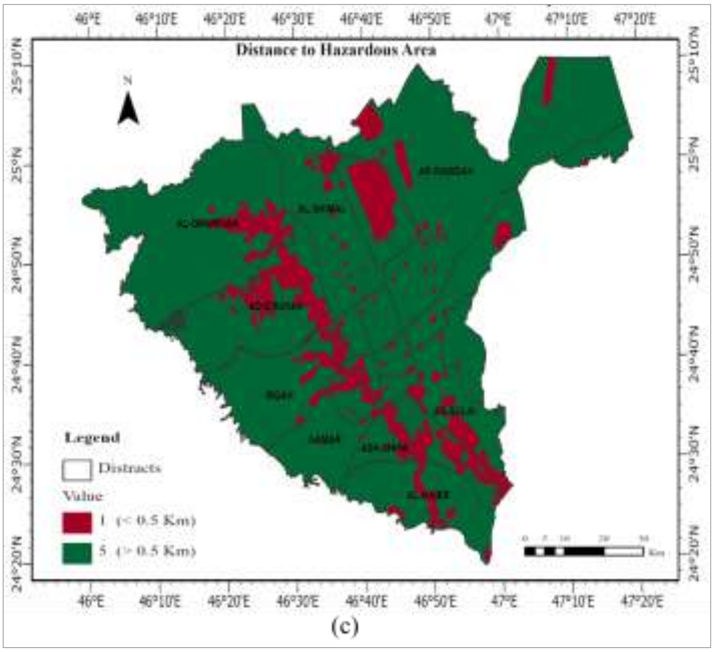


Figure 8 (a) Hazard area map; (b) Distance to valley streams; (c) Distance to hazard area.

Priority assessment from residents' perspectivs

Public participation aimed to reflect the suitability priorities of community through the criteria assessment. data collected via a questionnaire distributed to representative random sample. This sampling method enhancing generalizability of the results. (Taherdoost, 2016). The sample size reached 397 respondents, to evaluate the questionnaire's reliability, the Cronbach's alpha coefficient calculated, yielding a value of 0.72 this value indicates a satisfactory degree of consistency and reliability (Taber, 2018). Participants evaluate the priority of each criterion using a five-point Likert scale, ranging from "Not a priority" to "Absolute priority." (Joshi et al., 2015).

The criteria were evaluated based on the functional dimensions as follows: (1) Aesthetic quality —using topographical features and patterns to enhance the visual quality of a site; (2) Equitable accessibility —improving easy access by locating outdoor areas near transportation networks; (3) Functional integration —identifying and effectively repurposing vacant assets for; (4) Environmental Mitigation —maintaining sufficient distance to isolate built-up areas from negative externalities such as noise and pollution; and (5) Urban resilience —ensuring safety and enhancing healthier urban environmental by mitigate exposure to natural and industrial hazards while optimizing open spaces. After collecting the responses, the relative weight of each criterion calculated using the following equation, which converts the mean ratings into standardized weights:

$$w_s = \frac{\bar{x}_i}{\sum_{i=1}^{n} \bar{x}_i} \qquad (2)$$

Where Ws refers to the relative weight of the criteria, $\bar{x}_i$ represent the mean responses for the criterion, $\sum_{i=1}^{n} \bar{x}_i$ signifies the total mean of all criteria. The results summarized in Table 2 delineate the priority value from the residents' perspective.

Table 2 Residents priorities values

Criteria	**Factors**	**Mean**	**Preference weights**
Aesthetic quality	Distance from slope	3.92	21.2%
Equitable accessibility	Distance from transportation facilities	3.55	19.4%
Environmental Mitigation	Distance from existing and potential recreational resources	3.67	19.9%
Functional integration	Distance from Built-up Area	3.66	19.8%
Urban resilience	Distance to hazard area and open spaces	3.65	19.8%
Total		18.45	100%

Priority assessment from Expert's perspectivs

A concurrent assessment conducted by five local experts from government entities responsible for urban planning and land allocation to confirm that the assessments reflect a comprehensive understanding of the local context and regulatory frameworks. The Analytic Hierarchy Process (AHP) is based on the pairwise comparison used to drive relative weights for each criterion.

To ensure perspective compatibility, the session began with brief notes explaining the five criteria using the same definitions and concepts presented to the residents. which allows experts to make their pairwise comparison on residents reasoning. The Delphi technique employed over multiple rounds to maximize consensus and provide feedback to each expert for evaluation refinement. Table 3 summarizes the scenarios derived from the expert evaluations. While Table 4 presents the correlation values with the residents' assessment, the fifth scenario exhibited the highest correlation with residents' priorities, while the consistency ratio (CR) of AHP matrix was 0.01, which is well below the maximum acceptable value of 0.10 threshold (Saaty, 2013)

Table 3 Six scenarios from experts by pairwise comparison and the analytical hierarchy process AHP

Factors		**Expert's scenarios**					
		Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**
Distance from slope	e1	0.20	0.32	0.53	0.33	0.28	0.22
	e2	0.20	0.32	0.13	0.17	0.28	0.22
	e3	0.20	0.16	0.13	0.17	0.28	0.22
	e4	0.20	0.11	0.13	0.17	0.09	0.22
	e5	0.20	0.11	0.07	0.17	0.07	0.11
Distance from existing and potential recreational resources	e1	0.33	0.25	0.46	0.29	0.33	0.20
	e2	0.17	0.25	0.23	0.29	0.22	0.20
	e3	0.17	0.25	0.15	0.14	0.22	0.20
	e4	0.17	0.13	0.08	0.14	0.11	0.20
	e5	0.17	0.13	0.08	0.14	0.11	0.20
Distance from Built-up Area	e1	0.33	0.33	0.54	0.20	0.26	0.22
	e2	0.17	0.17	0.22	0.20	0.26	0.22
	e3	0.17	0.17	0.11	0.20	0.26	0.22
	e4	0.17	0.17	0.11	0.20	0.13	0.22
	e5	0.17	0.17	0.02	0.20	0.09	0.11
Distance to hazard area and open spaces	e1	0.25	0.38	0.51	0.25	0.26	0.22
	e2	0.25	0.25	0.17	0.25	0.26	0.22
	e3	0.25	0.13	0.13	0.13	0.26	0.22
	e4	0.13	0.13	0.10	0.25	0.13	0.22
	e5	0.13	0.13	0.09	0.13	0.09	0.11
Distance from transportation facilities	e1	0.20	0.38	0.51	0.22	0.33	0.25

	e2	0.20	0.25	0.17	0.22	0.25	0.25
	e3	0.20	0.13	0.17	0.22	0.25	0.25
	e4	0.20	0.13	0.09	0.22	0.08	0.13
	e5	0.20	0.13	0.06	0.11	0.08	0.13

Table 4 Spearman rho correlation of expert scenarios with residents' priorities

	Scenarios	Factors					Spearman's Rho
		F1	F2	F3	F4	F5	
Experts' scenarios	Scenario 1	0.26	0.17	0.17	0.20	0.20	0.00
	Scenario 2	0.13	0.25	0.17	0.33	0.13	0.80
	Scenario 3	0.50	0.08	0.10	0.14	0.18	-0.22
	Scenario 4	0.26	0.20	0.23	0.17	0.15	0.22
	Scenario 5	0.25	0.11	0.25	0.29	0.09	0.91
	Scenario 6	0.22	0.22	0.20	0.22	0.13	0.75
	Participant's scenario	0.20	0.20	0.20	0.21	0.19	-

Collaborative values from Residents and Experts perspectives

The results presented in Table 5 show final priority values for suitable outdoor locations. Aesthetic quality, associated with the integration of terrain and natural features, emerged primarily, which reflects a common recognition of aesthetics as a key component of a recreation experience. Urban resilience ranked secondly, highlighting the imperative of avoiding natural and industrial hazard areas while optimizing public health through allocating outdoor areas in proximity to open areas. Environmental Mitigation occupied the third rank, emphasizing the significance of buffer zones in segregating outdoor activities from built-up areas to minimize potential environmental impacts such as noise and pollution. The fourth priority is Functional integration and resource optimization, which focuses on equitable distribution and investing vacant assets for enhancing opportunities. Finally, equitable accessibility receives the lowest ranking, with a concentration on the proximity of recreational sites to transportation networks.

Table 5 Final preferences of residents and experts

Criteria	Factors	Priorities values
Aesthetic quality	Distance from slope	25.15%
Equitable accessibility	Distance from transportation facilities	14.10%
Environmental mitigation	Distance from existing and potential recreational resources	15.45%
Functional integration	Distance from Buildup Area	22.65%
Urban resilience	Distance to hazard area and open spaces	22.65%
Total		%100

Suitability Modeling of Recreation Outdoor Areas

To generate the suitability map, the integrated weights are reflected using the Model Builder tool in ArcGIS Pro. The resulting map was classified into five ordinal categories: unsuitable, low suitability, medium suitability, high suitability, and absolute suitability. Figure 8 illustrates the distribution of suitability classes across the city. Areas that are unsuitable and have low suitability are primarily concentrated in the city's suburbs and along valley streams, typically characterized by high natural hazards and constraining accessibility. In contrast, medium suitability areas are dispersed throughout built-up areas. High and absolute suitability area distributed around built-up areas that are easily accessible and provide environmental protection and opportunities. Table 6 below illustrates the suitability categories and the calculated areas for each category.

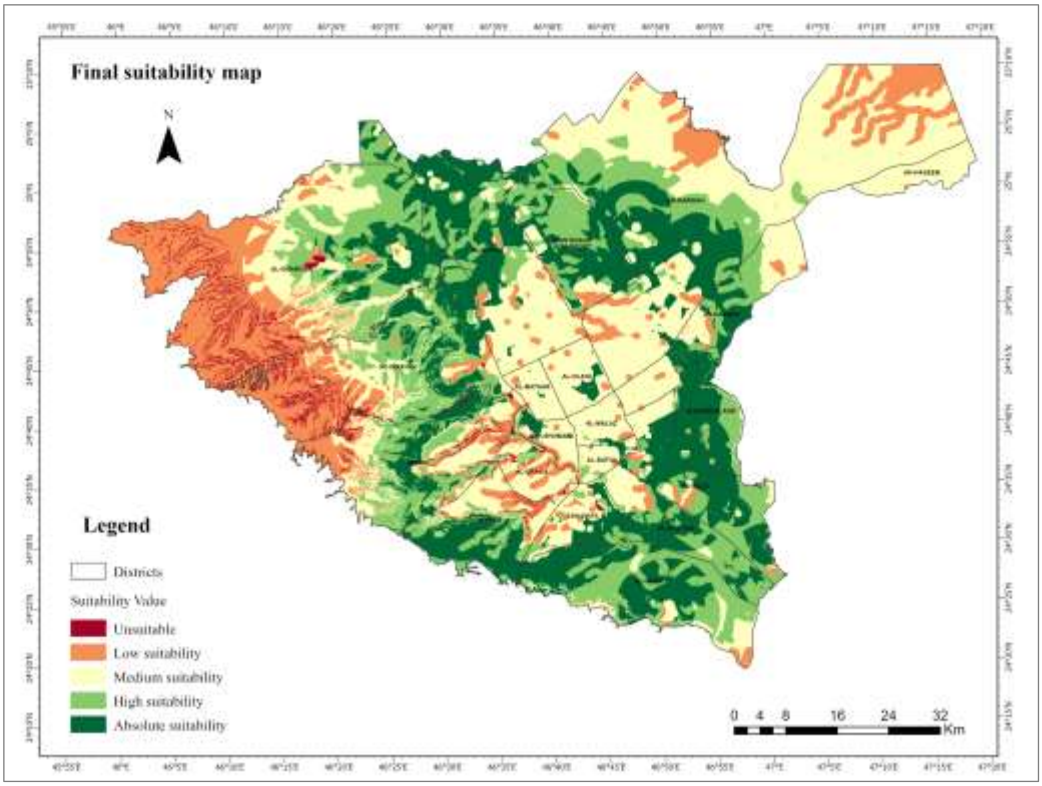


Figure 9 Final suitability map of the outdoor area.

Table 5 Calculating suitability areas in Riyadh city.

Classes	**Area (km²)**	%
Unsuitable Area	117	1.97
Low suitability	1025	17.16
Medium suitability	2039	34.13
High suitability	1366	22.86
Absolute suitability	1426	23.88

These results demonstrate the capabilities of Geographic Information Systems based on Multi-Criteria Decision Analysis GIS-MCDM to generate spatial alternatives. The application of recreational suitability analysis is represented by the following formula:

$$\sum S = \sum_{i=1}^{n} (C_i \,.\, \overline{W}_i)$$

Where $\sum S$ represents a composite suitability score. C_i denote the criteria values, and $\overline{W}_i$ Significantly, the weighted average of expert and residents' priorities. The aggregate raster values are normalized to a range between 0 and 1.

DISCUSSION

This paper aims to implement GIS-MCDA framework in Riyadh to identify a suitable location for outdoor activities that enhance urban well-being and quality of life. The results demonstrate the effectiveness of framework in identifying suitable locations for outdoor areas, prioritizing aesthetic quality, equitable accessibility, environmental mitigation, functional integration, and urban resilience, which reflects awareness among participants of the health consequences associated with pollution, traffic congestion, and land use conflicts. This trend confirms that recreational planning acts as a proactive intervention, reducing exposure to environmental risks and promoting health equity. Significantly, this approach involves expert backgrounds and local experience, which bridges sustainable planning with healthy urban environment goals that appeared particularly in areas surrounding the built-up area in Riyadh city.

Many studies used geographic information systems based on multi-criteria decision analysis GIS-MCDA to identify optimal locations for green and outdoor spaces using different spatial criteria. For example, Bakolo et al. (2024) adopted a technical approach that relies on the environmental and physical parameters of small cities, while Li et al. (2022) used GIS-based Fuzzy Analytical Hierarchy Process (F-AHP) primarily on expert assessment. In contrast, Zhao & Gong, (2024) emphasized social and spatial justice through indicators of accessibility and service coverage. Furthermore, Rabe et al., (2018) demonstrated that incorporating user preferences significantly enhances the credibility and robustness of expert-driven models.

Despite advancing studies, urban well-being aspects are often integrated indirectly into overall criteria. Additionally, participation mechanisms tend to fragment, relying on either experts or residents without a systematically integrated framework. This study addressed this gap by adopting a participatory health-oriented approach that explicitly integrated resident experience with expert knowledge. This dual source reduces the bias associated with a single engagement model. The inclusion of esthetic quality, equitable accessibility, environmental mitigation, functional integration, and urban resilience as core criteria expands previous models to encompass multiple dimensions of health, including environmental exposure and psychological well-being.

The current paper encounters methodological constraints, the most prominent being the reliance on the integrity and accuracy of spatial data, in addition to the challenges associated with the diversity in professional background among experts when determining the criteria. However, involving the residents in assessing the priority of the criteria contributed to mitigating these limitations and enhancing the reliability of the results.

The results confirm that the proposed GIS-MCDA framework provides an effective tool in rapidly growing cities, by providing accurate suitability maps aligned with healthy urban environmental and spatial equity objectives. Therefore, decision-makers and planners can leverage the current model to address spatial gaps, direct investments, enhance urban sustainability, and improve residents' health.

CONCLUSIONS

The study developed a GIS-MCDA framework to identify suitable locations for outdoor recreation in Riyadh. The model integrated spatial data, experts' judgment, and residents' preferences to produce a suitable map supporting urban planning decisions. The results highlight several absolutely suitable zones that support outdoor recreational activities and improve urban livability. The proposed framework provides a practical decision – support tool for planners seeking to allocate recreational spaces in rapidly growing cities. Future research integrates additional environmental and social indicators that apply the framework to another urban context

REFERENCES

1. Alghamdi, A. S., Alzhrani, A. I., & Alanazi, H. H. (2021). Local climate zones and thermal characteristics in Riyadh City, Saudi Arabia. *Remote Sensing*, *13*. https://doi.org/10.3390/rs13224526
2. Alqurashi, A. F., Kumar, L., & Sinha, P. (2016). Urban land cover change modelling using time-series satellite images: A case study of urban growth in five cities of Saudi Arabia. *Remote Sensing*, *8*. https://doi.org/10.3390/rs8100838
3. Alyousef, T., Alshihri, F., Abdellatif, M., Alrawaf, T., & Abdellatif, R. (2022). Integrated Recreation Cities and Sustainable Development in Saudi Arabia: Contributions, Constraints, and Policies. *Sustainability (Switzerland)*, *14*. https://doi.org/10.3390/su14106182
4. Bahadori, M. S., Gonçalves, A. B., & Moura, F. (2022). A GIS-MCDM method for ranking potential station locations in the expansion of bike-sharing systems. *Axioms*, *11*(6), 263.
5. Bakolo, C., Kayitete, L., de Dieu Tuyizere, J., Tomlinson, J., Fawcett, J., & Alfaro, R. F. (2024). Identification

of optimal locations for green space initiatives through GIS-based multi-criteria analysis and the analytical hierarchy process. *Environmental Systems Research*, *13*(1), 46.

6. Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. In *Science Advances* (Vol. 5, Issue 7). American Association for the Advancement of Science. https://doi.org/10.1126/sciadv.aax0903
7. Brunyé, T. T., Gardony, A. L., Holmes, A., & Taylor, H. A. (2018). Spatial decision dynamics during wayfinding: intersections prompt the decision-making process. *Cognitive Research: Principles and Implications*, *3*. https://doi.org/10.1186/s41235-018-0098-3
8. Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. *Journal of Homeland Security and Emergency Management*, *7*(1). https://doi.org/10.2202/1547-7355.1732
9. De Sousa, C. A. (2003). Turning brownfields into green space in the City of Toronto. *Landscape and Urban Planning*, *62*(4), 181–198. https://doi.org/10.1016/S0169-2046(02)00149-4
10. Dhami, I. (2013). *Classification and mapping of recreation and ecotourism areas in West Virginia*. West Virginia University.
11. Eagles, P.-F.-J., Haynes, C.-D., & McCool, S.-F. (2002). *Sustainable Tourism in Protected Areas: Guidelines for Planning and Management* (IUCN; IUCN). IUCN, Gland, Switzerland, and Cambridge, UK, the United Nations Environment Programme and the World Tourism Organization.
12. Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. *International Journal of Environmental Research and Public Health*, *12*(4), 4354–4379.
13. Geertman, S., & Stillwell, J. (2004). Planning support systems: An inventory of current practice. In *Computers, Environment and Urban Systems* (Vol. 28, pp. 291–310). https://doi.org/10.1016/S0198-9715(03)00024-3
14. Giles-Corti, B., Bull, F., Knuiman, M., McCormack, G., Van Niel, K., Timperio, A., Christian, H., Foster, S., Divitini, M., & Middleton, N. (2013). The influence of urban design on neighbourhood walking following residential relocation: longitudinal results from the RESIDE study. *Social Science & Medicine*, *77*, 20–30.
15. Goines, L., & Hagler, L. (2007). Noise pollution: a modem plague. *South Med J*, *100*(3), 287–294.
16. Gospodini, A. (2006). Portraying, classifying and understanding the emerging landscapes in the post-industrial city. *Cities*, *23*, 311–330. https://doi.org/10.1016/j.cities.2006.06.002
17. Hunter, M. R., Gillespie, B. W., & Chen, S. Y.-P. (2019). Urban nature experiences reduce stress in the context of daily life based on salivary biomarkers. *Frontiers in Psychology*, *10*, 413490.
18. Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert Scale: Explored and Explained. *British Journal of Applied Science & Technology*, *7*(4), 396–403. https://doi.org/10.9734/bjast/2015/14975
19. Li, C., Zhang, T., Wang, X., & Lian, Z. (2022). *Site selection of urban parks based on fuzzy-analytic hierarchy process (F-AHP): A case study of Nanjing, China*. International Journal of Environmental Research and Public Health; MDPI.
20. Lofti, S., & Koohsari, M. J. (2009). Measuring objective accessibility to neighborhood facilities in the city (A case study: Zone 6 in Tehran, Iran). *Cities*, *26*, 133–140. https://doi.org/10.1016/j.cities.2009.02.006
21. Lopez-Haro, J., Gómez-Chávez, L. F. J., Pelayo-Zavalza, A. R., & Gómez-Varela, J. F. (2024). Association between active use of urban green spaces and Well-Being in adults aged 18–65 years: A systematic review. *Journal of Health & Pollution*, *12*(1–4), 16002.
22. Malczewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science*, 20, 703–726. https://doi.org/10.1080/13658810600661508
23. Marchment, Z., & Gill, P. (2022). Spatial Decision Making of Terrorist Target Selection: Introducing the TRACK Framework. *Studies in Conflict and Terrorism*, *45*, 862–880.

https://doi.org/10.1080/1057610X.2020.1711588
24.Mundher, R., Abu Bakar, S., Maulan, S., Mohd Yusof, M. J., Al-Sharaa, A., Aziz, A., & Gao, H. (2022). Aesthetic quality assessment of landscapes as a model for urban forest areas: A systematic literature review. *Forests*, *13*(7), 991.
25.Nappi, M. M. L., Nappi, V., & Souza, J. C. (2019). Multi-criteria decision model for the selection and location of temporary shelters in disaster management. *Journal of International Humanitarian Action*, *4*. https://doi.org/10.1186/s41018-019-0061-z
26.Organization, W. H. (2019). *Global action plan on physical activity 2018-2030: more active people for a healthier world*. World Health Organization.
27.Rabe, S. E., Gantenbein, R., Richter, K. F., & Grêt-Regamey, A. (2018). Increasing the credibility of expert-based models with preference surveys – Mapping recreation in the riverine zone. *Ecosystem Services*, *31*, 308–317. https://doi.org/10.1016/j.ecoser.2017.12.011
28.Rahman, M. T. (2016). LAND USE AND LAND COVER CHANGES AND URBAN SPRAWL IN RIYADH, SAUDI ARABIA: AN ANALYSIS USING MULTI-TEMPORAL LANDSAT DATA AND SHANNON'S ENTROPY INDEX. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLI-B8*, 1017–1021. https://doi.org/10.5194/isprs-archives-XLI-B8-1017-2016
29.Rebecchi, A., Mosca, E. I., Capolongo, S., Buffoli, M., & Mangili, S. (2025). How Can We Measure Urban Green Spaces' Qualities and Features? A Review of Methods, Tools and Frameworks Oriented Toward Public Health. *Urban Science*, *9*(12), 544.
30.Rikalovic, A., Cosic, I., & Lazarevic, D. (2014). GIS based multi-criteria analysis for industrial site selection. *Procedia Engineering*, *69*, 1054–1063. https://doi.org/10.1016/j.proeng.2014.03.090
31.Saaty, T. L. (1990). The Analytic Hierarchy Process, RWS. *Publications, Pittsburgh*.
32.Saaty, T. L. (2013). Analytic hierarchy process. In *Encyclopedia of operations research and management science* (pp. 52–64). Springer.
33.Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education*, *48*, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2
34.Taherdoost, H. (2016). *Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research*. Https://Hal.Science/Hal-02546796/.
35.Tims, W. (2009). *GIS Model for the land use and development master plan in Rwanda*.
36.Tost, H., Reichert, M., Braun, U., Reinhard, I., Peters, R., Lautenbach, S., Hoell, A., Schwarz, E., Ebner-Priemer, U., & Zipf, A. (2019). Neural correlates of individual differences in affective benefit of real-life urban green space exposure. *Nature Neuroscience*, *22*(9), 1389–1393.
37.Türk, E. (2009). *Optimum land-use allocation using binary integer programming and geographic information systems: Case of Çesme*. Izmir Institute of Technology (Turkey).
38.United Nations International Strategy for Disaster Reduction (UNISDR). (2015). How to Make Cities More Resilient: A Handbook for Local Government Leaders. In *https://www.undrr.org/publication/how-make-cities-more-resilient-handbook-local-government-leaders-2017* (Issue April 2012).
39.Utami Dewi, N. M. S., Maba, W., & Pandawani, N. P. (2023). Strategies for Overcoming Environmental Noise in Recreational Area (Case Study in Tibubeneng Village, Kuta Utara District, Badung Regency). *International Journal of Multidisciplinary Research and Analysis*, *06*. https://doi.org/10.47191/ijmra/v6-i4-06
40.Willoughby, M. R. (2005). *GIS-BASED LAND USE SUITABILITY MODELING FOR OPEN SPACE PRESERVATION IN THE TIJUANA RIVER WATERSHED*.
41.Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough.' *Landscape and Urban Planning*, *125*, 234–244.
42.Yan, L., Jin, X., & Zhang, J. (2024). Equity in park green spaces: a bibliometric analysis and systematic literature review from 2014-2023. *Frontiers in Environmental Science*, *12*, 1374973.
43.Yen, H. Y., Chiu, H. L., & Huang, H. Y. (2021). Green and blue physical activity for quality of life: A systematic

review and meta-analysis of randomized control trials. In *Landscape and Urban Planning* (Vol. 212). Elsevier B.V. https://doi.org/10.1016/j.landurbplan.2021.104093
44.Zhao, Y., & Gong, P. (2024). Optimal site selection strategies for urban parks green spaces under the joint perspective of spatial equity and social equity. *Frontiers in Public Health*, *12*, 1310340.