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A GIS-Based Framework For Sustainable Recreation Planning In Riyadh City

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Abstract :*Recreational services play a pivotal role in supporting the well-being of urban residents by providing spaces to escape the pressures of life and enhancing opportunities for relaxation and social interaction. With the growing global trend toward sustainability, recreational planning is no longer limited to providing activities alone; it now requires adopting a comprehensive sustainability approach that integrates environmental, economic, and social dimensions. This transformation requires the development of innovative planning strategies, such as redistributing recreational facilities to reduce the need for long-distance travel, increasing green spaces to enhance air quality and biodiversity, and designing facilities that rely on energy and water efficiency.*

This paper introduces a new classification framework based on a geographic information system that is focused on interpreting the emerging spatial patterns of recreational facilities within the city of Riyadh. The framework relies on three main components—recreational purpose, community trends, and spatial allocation—as interrelated elements that contribute to understanding how modern recreational phenomena are formed within the city. The framework also integrates the analysis of the population pyramid to clarify age-related disparities and guide the design of facilities and activities in a way that reflects the diverse needs of the population and achieves social sustainability. The framework also enables the analysis of the development of new recreational patterns and their spatial evaluation through the study of planning standards for facilities, including supply, demand, and accessibility, thereby enhancing the achievement of spatial justice principles in service distribution.

The results revealed a clear imbalance between the current demand and supply of recreational services, confirming the need to develop new recreational complexes according to clear spatial standards. The study's derived procedures and standards play a significant role in guiding sustainable recreational planning applications in rapidly growing cities.

Keywords: *Sustainable recreation planning, Framework, Recreation cluster, Planning standards , Modern trends*

1. INTRODUCTION

Sustainable recreational planning is a contemporary trend in urban planning that seeks to balance the needs of residents with resource protection. Effective planning integrates economic, social, and environmental dimensions to establish this approach. The goal is to minimize negative environmental impacts while enhancing the overall quality of life. Nowadays, the demand for outdoor recreation is growing rapidly and establishing a strong community base, which positively impacts human capital while also providing social benefits through opportunities for interaction [1]. This trend is particularly significant for metropolitan cities in light of rapid urbanization. According to the United Nations, statistics estimate that 55% of the world's population is concentrated in major cities, with predictions rising to 68% in the future [2].

Recently, many cities have paid increasing attention to developing recreational activities as an essential part of improving the quality of life and enhancing urban attractiveness. Governments have begun to launch programs aimed at diversifying the economy and increasing the contribution of the recreation sector to sustainable development plans [3]. However, many cities still face issues in this area, such as the lack of infrastructure dedicated to recreation activities and the weak and unfair spatial distribution between neighborhoods. Global comparisons reveal that developing cities often have fewer recreational spaces than developed cities. Local economic growth and the overall quality of life reflect this direction. Other issues, including insufficient per capita green space, excessive energy consumption, and restricted access to public facilities, further exacerbate environmental challenges [4].

In light of these challenges, understanding the limited efficiency of recreation services requires an examination of their fundamental components and the spatial relationships that influence their distribution and quality. These can be categorized into several aspects: availability, accessibility, and type of recreation [5]. Population density affects adequacy and equity in the distribution of recreational locations, such as parks, making availability a crucial consideration [6]. Accessibility is determined by the interaction between transportation options and destinations, encompassing decisions related to transportation modes, routes to reach those locations, and travel time. The gravity of a destination is connected to optimal distribution choices, which influence investment potential and individuals' capacity to access various activities [7]. The type of recreation is shaped by the spatial classification of entertainment and related factors, including area, capacity, and management [8].

The importance of these factors becomes clearer in times of crisis, as the Covid-19 pandemic has demonstrated the urgent need for planning and managing recreation facilities because of their essential role in promoting psychological and physical health, enhancing social interaction, and alleviating the pressures that accompany health crises [9]. The pandemic has revealed a clear shortage in the readiness of many cities to provide sufficient recreational spaces for all segments of the population in terms of spatial distribution or ease of access, despite government efforts to strengthen the recreation sector by raising the per capita share of green and open spaces, improving recreational infrastructure, and expanding access to public facilities. However, challenges still exist in many urban areas. The most prominent challenges are the absence of an accurate spatial classification of services and the weakness of the planning standards adopted for selecting facility locations, which reduces the efficiency of distribution and spatial equity. The limited initiatives related to accessibility and environmental sustainability also emphasize the need to adopt a more integrated approach to sustainable recreational planning.

In light of the challenges presented by the pandemic, the necessity for precise classifications of recreational facilities and activities has become crucial for enhancing recreation planning and ensuring equitable spatial distribution. Accurate classification of recreational facilities and activities is an essential part of the effectiveness of comprehensive planning, as it contributes to improving the distribution of services and achieving the future needs of residents. This included Keppel's (1951) classification of the spatial hierarchy of facilities [10]. Bunusevac (1977) classification of urban and national green spaces [11] Sato (1985) classified Japanese parks based on area levels and user types [12], while the American National Parks and Recreation Association NRPA (1996) classified parks based on facility size [13]. Metin et al. [14] interpret the connection between recreational activities, their goals, functions, and the types of locations that suit them. However, the effectiveness of these classifications is enhanced when combined with the classification of activities according to their nature, as explained by Ikpoku et al. [15], who divided outdoor activities into active activities that require dedicated facilities and spaces and passive activities that can be practiced in facilities that do not require equipment, such as smaller open spaces. This classification enables the establishment of a well-rounded recreation network that effectively and fairly caters to the needs of the residents.

Alongside the significance of spatial classification in sustainable recreational planning, establishing clear standards based on reliable data is crucial for promoting efficient facility provision and ensuring equitable distribution. Developing planning standards is a complex process that relies on integrating available data about the planning unit. In Tanzania, providing effective infrastructure for facilities requires considering controllable factors such as size, population, and lack of tenure security, as they have a direct impact on facility capacity [16]. In the context of achieving equity in access to recreational spaces, Zhang et al. [17] assessed the accessibility of parks within cities by collecting spatial and demographic data, classifying recreational spaces based on indicators of accessibility and spatial equity.

To apply these standards in a practical manner and achieve a fair and effective distribution of the facility. The use of geographic information systems and remote sensing has become vital. Since the 1960s, these tools have been widely used due to the advanced analytical and modeling capabilities that provide in urban planning, including assessing the distribution of green spaces, analyzing accessibility, and understanding social interactions. Multiple studies, such as Ummeh and Toshio [18], Cetin [19], Sotoudehnia and Comber [20], Zainol and Maidin [21], and Murad [22], have shown how to use geographic information systems to evaluate

recreational spaces, identify service areas, analyze population density, and improve fairness in access to facilities that contribute to achieving sustainable urban planning.

Despite these advanced applications, significant knowledge gaps remain regarding the reclassification of recreation places and activities to better address the current and diverse needs of residents in a more sustainable manner. Previous studies have primarily focused on measuring the distribution of green spaces and their accessibility, as well as analyzing population densities and user interactions. However, they have not effectively employed inductive methods to develop a new classification of recreational facilities and activities, nor have they identified appropriate planning criteria that integrate social, economic, and environmental dimensions. Therefore, this paper aims to integrate geographic information systems with inductive methods to create a scientific foundation for a comprehensive classification that ensures effective distribution of recreational spaces and encourages sustainable planning, which preserves environmental resources and minimizes negative impacts on urban ecosystems.

2. MATERIAL AND METHODS

2.1 Study area

The geographic scope of this study concentrates on the city of Riyadh, which is in the Riyadh region. These metropolitan spaces span a total area of 1,973 square kilometers and have a population of 8,591,748. The units of analysis are defined at three levels: city, municipality, and district (Riyadh/Northern Sector/Hattin). Figure 1 provides a detailed overview of the case study.

Figure 1 Map of Riyadh, from left to right the gradation in levels: national, regional, and local level, kingdom of Saudi Arabia, by Authors

2.2 Data acquisition

A database was established to support the evaluation of accessibility and the calculation of demand and supply. The GIS data obtained from the Ministry of Municipalities and Housing (MOMAH) included the primary and secondary road networks, administrative boundaries of the neighborhoods, and population census data. All analyses were conducted using "ArcGIS Pro 3.1.0."

2.3 Analysis methods

The study adopted an inductive approach based on field surveys to identify modern recreational facilities and develop a flexible classification framework. It also included a demographic analysis of population characteristics

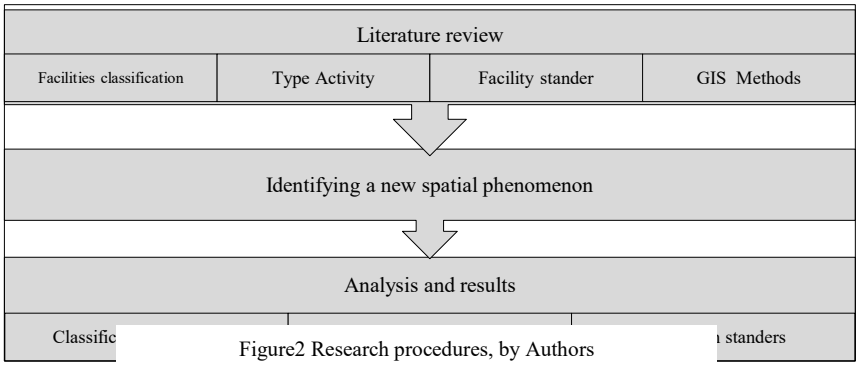

Figure2 Research procedures, by Authors

using a population pyramid to identify segments and groups and understand the relationship with recreational activity patterns. In addition the study sought to formulate suitable planning criteria by analyzing the characteristics of the chosen location.

The methodology included developing an accessibility model based on travel time using a network analysis tool and converting the model into a service area via the Buffer tool and the geometric equation. The demand profile was prepared by integrating the accessibility model with the population layer using Intersect to estimate the expected usage of the facility. The supply size and service adequacy were also estimated through metadata analysis and the application of the market penetration equation to challenge the actual coverage of the facility compared to the demand size. Figure 2 The systematic sequence and analytical procedures adopted in the current study.

3. RESULTS

3.1 Classification of Recreational Services in Riyadh

The results of the spatial and functional analysis reflect that the recreational facilities in Riyadh can be divided into two classes according to the urban usage characteristics and the nature of activities provided. The first category is the traditional facility, which follows the classic approach to recreation and largely falls within the context of the parcels or zones specifically designed for hosting basic recreational activities, such as parks, green areas, and recreation centers. The second category consists of modern facilities, Boulevard City and Boulevard World, which together form an integrated recreational complex within a single spatial block (cluster). Despite being divided by a major roadway, the cable car system facilitates direct connectivity, thereby improving both functional integration and mobility between the two areas. This recreational cluster is depicted in Figure 3, and a comprehensive summary of the available activities is presented in Table 1.

Table 1 Recreation Cluster Characteristics in Riyadh City, by Authors

Characters		**Boulevard City**	**Boulevard World**
District area		850,000	705,000
Plot area (m^2)		637,500	528,750
Per capita (m^2)		0.6 – 0.8	0.6 – 0.8
Max capacity (person)		` 14,166	11,750
Min capacity (person)		10,625	8,812
Duration		permanent	seasonal
Passive recreation	Cafés and restaurants	✓	✓
	Outdoor seating	✓	✗
	Theaters	✓	✗
	shops	✓	✓
Active recreation	Rides	✗	✓
	Battlefields	✗	✓
	Children's games	✗	✓
	Sporting events	✗	✓
Semi-active passive	Hobbies	✓	✓
	Light game	✓	✓

Additionally, Figure 4 presents a proposed framework that defines the relationship between recreational purpose, community trends, and spatial allocation, from general to specific, providing a foundation for analyzing patterns of recreation and guiding recreation planning more effectively. The framework is structured around three primary subjects: recreational purpose, community trends, and spatial allocation. Along with the subject of purpose, activities are classified into general recreation-oriented activities; activities with a specific purpose—such as eating and drinking—which, while essential, may acquire potential

recreational qualities; and mixed activities that combine the previous two types, exemplified by experiences that merge learning and enjoyment, such as museums and amusement parks in one space. The trend divides recreational activities into two categories: traditional recreation, which is associated with traditional places like parks, and modern recreation, which is based on current social trends. Regarding the spatial allocation for recreation spaces, the framework adopts a hierarchical approach, beginning with parcels as small place units within the urban fabric, such as squares and local gardens, followed by zones, representing recreational areas with functional homogeneity, such as public parks, and culminating in clusters, which are high-density composite units encompassing multiple facilities and activities, such as the Boulevard area. Table 2 shows

Figure 3 Recreation Cluster Surround by Residents' Districts, Google Earth 2025, adoubted by Authors

statistics of recreation places in Riyadh based on the classification framework.

Table 2 Recreation services statistics in Riyadh City, adabted from Quality of Life 2018

Spatial allocation for recreation services	Statistics
Recreation parcels	≤ 3533
Recreation zones	≤16506
Recreation cluster	1

3.2 Demography and recreation activities in Riyadh

We can use the functional framework of recreational services to comprehend the recreation patterns of different age groups in cities. From Figure 5, the population pyramid indicates that the total population of 8,591,748 is concentrated in the 20–44-year-old group [23]. which usually tend to semi-active recreation

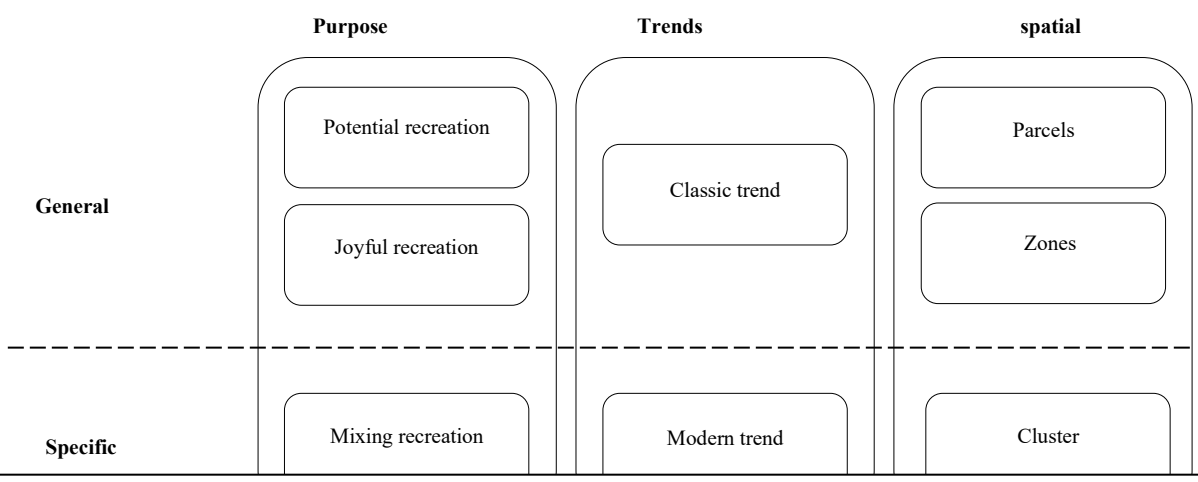

Figure 4 Classifying of recreation services, by Authors

activities like light sports, hobbies, and interactive games. Similarly, the spatial allocation at the plot, district, and cluster levels reflects that the relative correspondence between the various age groups' needs and the nature of the available facilities is directly linked to the leading role of the age distribution in determining the type and intensity of activities that these levels should provide.

For instance, individuals under 18 tend to prefer active activities, such as sports. Large park facilities, serving

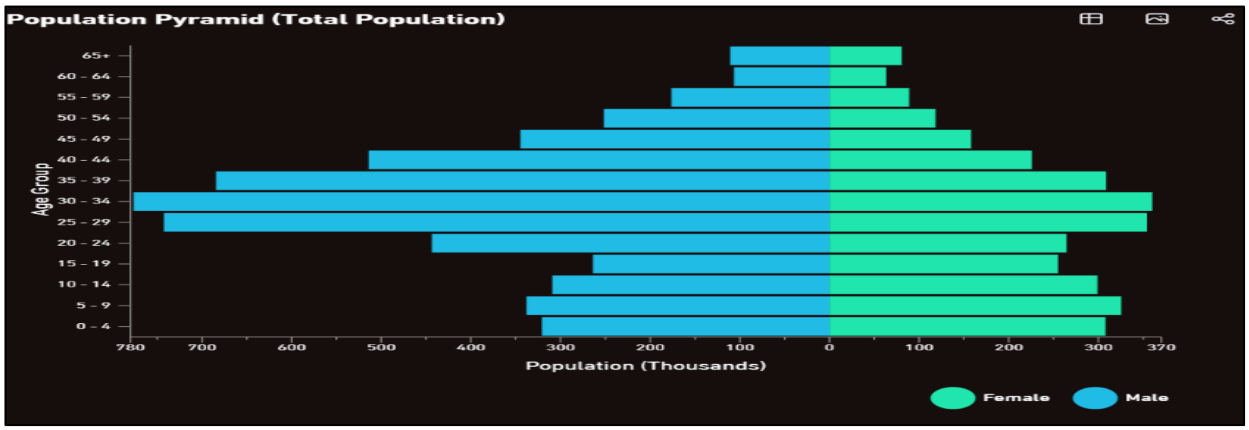

Figure 5 Demography pyramid in Riyadh city, Ministry of economy and planning 2025

multiple neighborhoods, typically provide these activities within designated zones. The 19-55 age group, which engages in semi-active or semi-passive pursuits, aligns with multi-activity recreation centers that are frequently clustered to serve several districts. In contrast, those over 55 years of age generally favor passive recreational activities, such as meditation or relaxation, which can be accommodated within local parks that are allocated within parcels or plots that serve one neighborhood [24] [25].

Therefore, the integration of the spatial and functional framework of recreational activities with the population pyramid indicates that age distribution is a crucial indicator for guiding recreational planning, ensuring it is sustainable and balanced while effectively meeting the needs of the population.

3.3 Recreation Cluster Standards

The results above indicate that the recreational cluster located in Riyadh—Riyadh Boulevard—represents a new phenomenon at the city level and can be evaluated according to established planning standards, considering the spatial and functional framework of the facilities and the needs of residents according to age groups. According to the American Planning Association [26] and the urban local code of the Ministry of Municipalities and Housing [27], which classifies recreational facilities into categories, each variable includes an area, capacity, and service area, as shown in Table 2.

Table 3 Recreation planning standards, Ministry of Municipalities and Housing, 2015

Type	Facility area (ha)	Population	Mobility		Service area	
	High-Low	High-Low	Car	Walk	Min.	km
Mini Park	0.08 - 0.3	1.2 – 0.9	-	✓	5	0.1 - 0.2
Neighborhood Park	0.4 – 0.5	5 - 3	-	✓	5-7	0.2 - 0.35
Distract Park	0.5 - 1	15-10	✓	✓	5-7	0.4 - 0.8
Sector Park	2 - 6	45 - 30	✓	-	15-20	2.5 - 5
City Park	Variable - 7	More than 100	✓	✓		variable
Recreation center	Variable – 0.2	City level	✓	-		variable
Camping	variable	City level	✓	-		variable
Specialized gardens	variable	City level	✓	-		variable
Rural Park	variable	City level	✓	-		variable

The efficiency of the existing recreation cluster in the adequate aspect can be evaluated based on accessibility, capacity, and service adequacy. The goal is to determine whether expansion is needed or if additional similar clusters should be created to meet the requirements of city residents. The following steps outline this process:

A. Building Accessibility Model

The accessibility model estimated the average travel time to recreational destinations by car during peak hours. A 2013 study examining urban planning factors related to traffic congestion found that the average travel time by car to the intended destination during congested periods is about 24.9 minutes [30]. This result was derived from a GIS-based network analysis that applied travel-time thresholds of 5, 15, and 25 minutes. Figure 6 presents the outcomes of the network analysis.

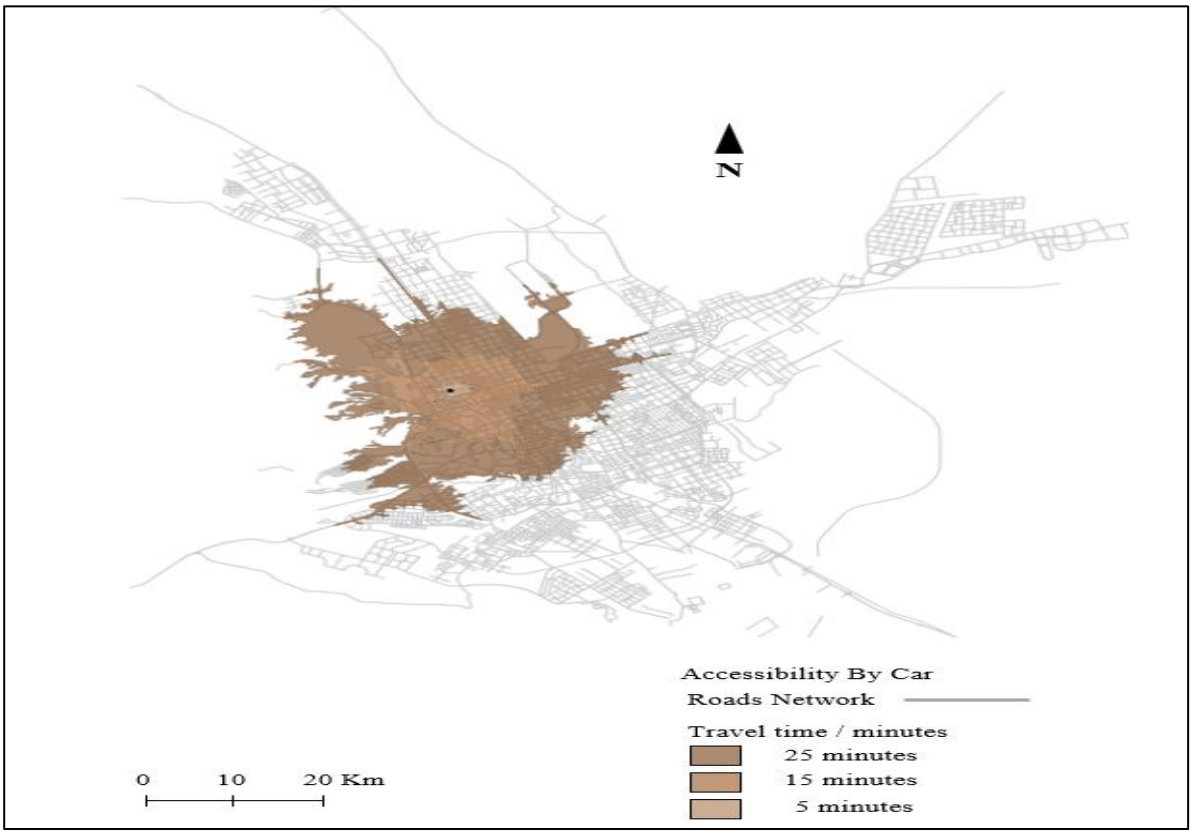

Figure 6 Travel time by car, by Authors

When calculating the travel time area in 25 minutes, which equals 799 km², this represents 40% of the total city area. Consequently, 60% of the city districts require additional recreation clusters to achieve equitable accessibility for residents. In terms of service area calculating for recreation clusters, the irregular shape was converted into a circular service area (Figure 7) using the buffer tool and the area of a circle equation:

$r^2 = A / p$ (1)

Where:

r^2: circle radius

A: travel area

π: Mathematical constant equal 3.14

which corresponds to 31.88 km as a service area.

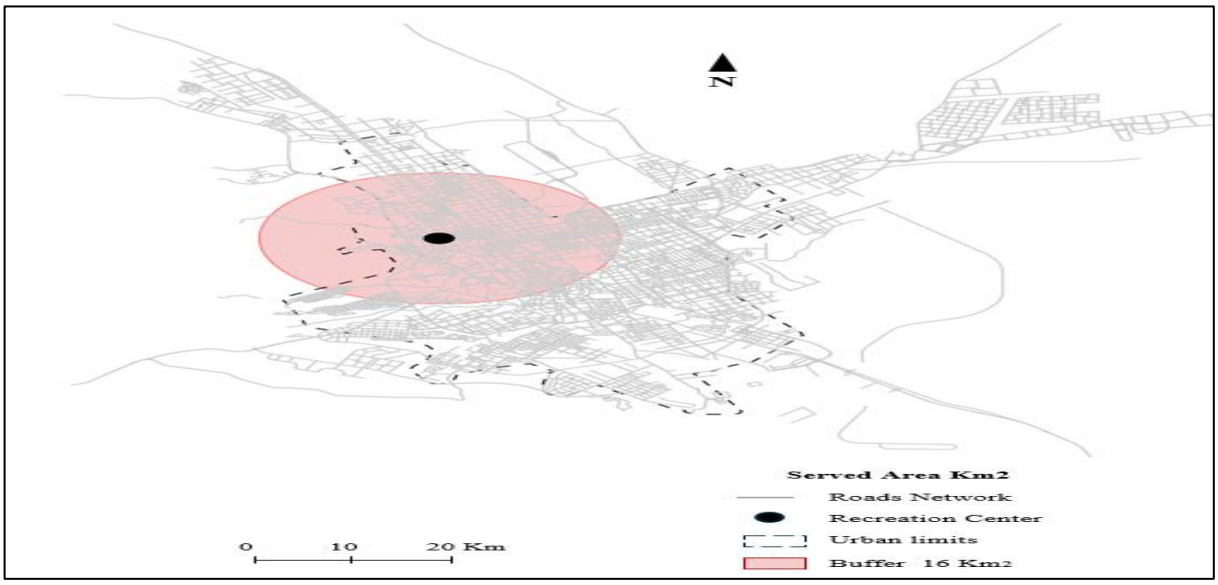

Figure 7 Service area, by Authors

B. Creating a demand profile

The demand size of the recreation cluster is estimated based on population distribution. By utilizing the intersection tool with the travel time layer and appropriate symbology, the demand size is calculated using the attribute table. The population within the served area is 3,541,142. Furthermore, the served area is predominantly characterized by low to medium density, which typically indicates high- or medium-income families who have the purchasing power to rent or own accommodation in the study area. This correlation between low density and real estate value is supported by Amegah et al. [28]. In contrast, high-density areas are located in the far east, west, and south, which are indicative of medium- or low-income families experiencing high density and a relatively decreasing property value. Figure 8 illustrates population density at the city level. While Figure 9 illustrated density in the served area.

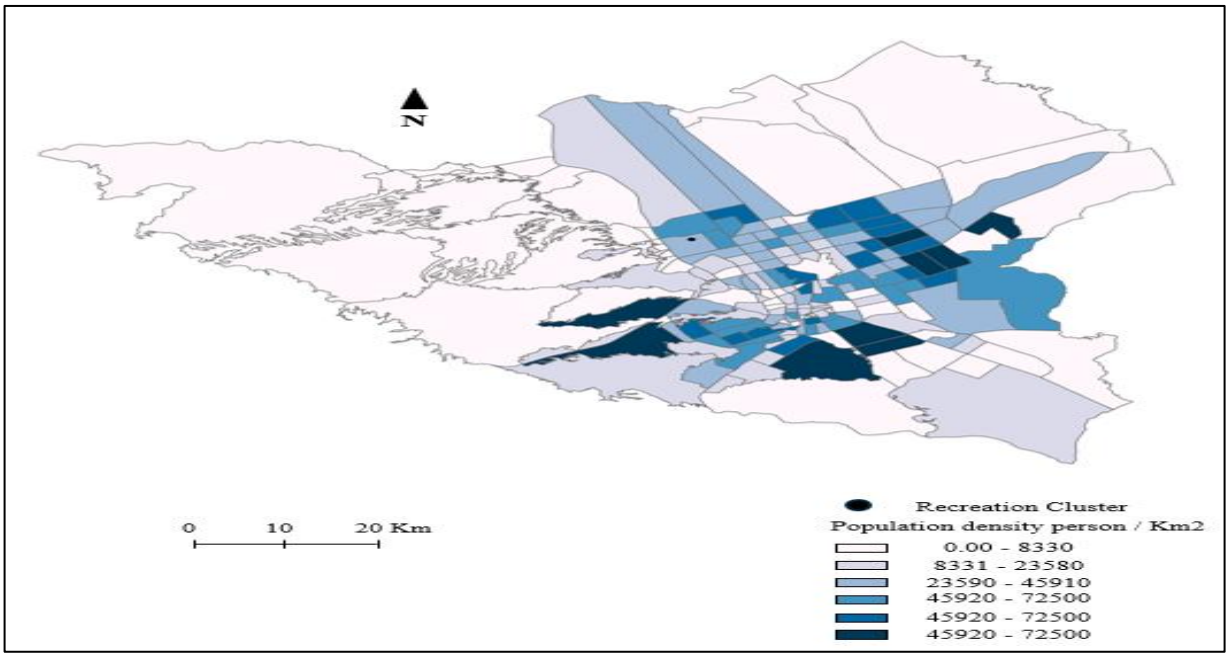

Figure 8 Creating Population density at city level, by Authors

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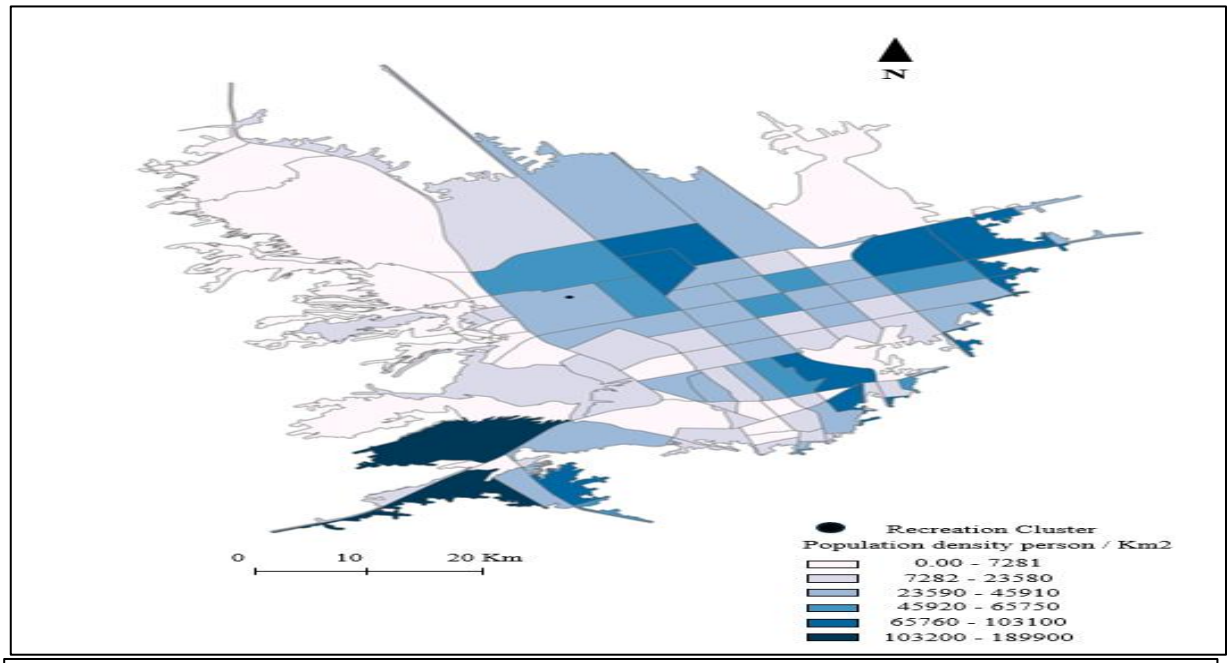

Figure 9 Creating Demand profile in served area, by Authors

C. Creating supply size

This approach assumes that the service level indicated by market penetration is calculated using the following equation:

MPc = (NUc / TPc) * 100 (2)

Where:

MPc = Market penetration for recreation cluster

NUc = Number of users for recreation cluster

TPc = Total population in buildup area

By applying this formula, the number of served individuals equals 3,541,142. Dividing by the population of 8,591,748 reveals that 41% of the city's residents are served, while 59% remain in unserved areas. Figure 10 below illustrates the shortage of recreational clusters in the city.

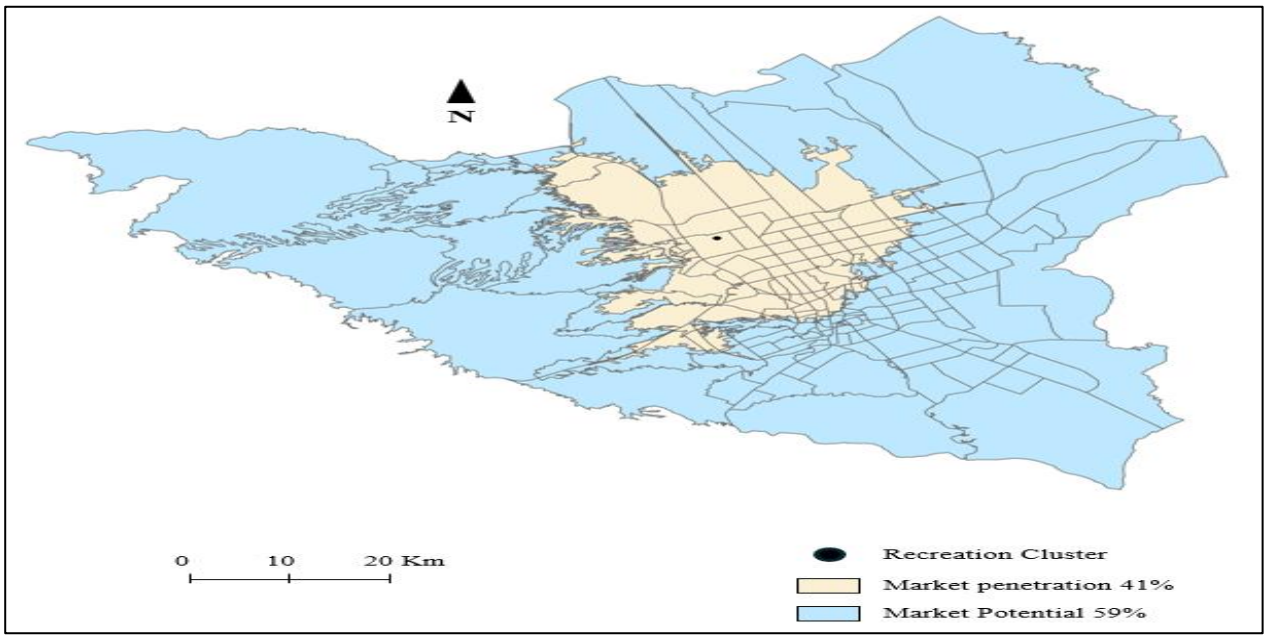

Figure 10 Creating supply size, by Authors

Based on the above, it can be concluded that three criteria are used to determine the spatial feature: service area, population served, and adequacy. The key consideration for the service area is accessibility time. The population served is calculated based on the demand within the service area, while adequacy is assessed by monitoring the existing supply in the city and estimating the service shortfall using the market penetration equation. Figure 11 illustrates the standards for recreation facilities.

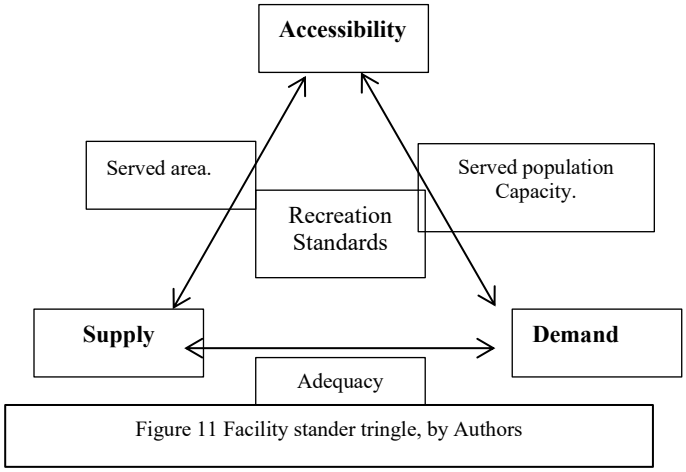

Figure 11 Facility stander tringle, by Authors

4. DISCUSSION

The current paper aimed to integrate Geographic Information Systems with inductive methods to establish a theoretical framework for a comprehensive classification of recreational services that ensures the efficient distribution of recreational facilities and promotes sustainable recreational planning, preserving environmental resources and reducing negative impacts on urban systems. The results demonstrated that the objective was accomplished by creating a dynamic framework for the city's recreational services, concentrated on three primary subjects: activity patterns, community trends, and spatial allocation. Additionally, the integration of spatial analysis and the demographic characteristics of the population contributes to guiding the planning of recreational facilities in accordance to community behavior and in alignment with the city's population pyramid. Which enhances the efficiency and fairness of facility distribution. The results also provided the planning standard for evaluating the recreational cluster Riyadh Boulevard as a new spatial phenomenon in the city, using supply, demand, and accessibility indicators to estimate the service gap and determine capacity and efficiency.

The results indicate that the developed framework contributes to explaining the interaction between the recreational behavior of the population and the urban structure, which improves one's understanding of recreational planning and enables its transition to measurable and testable practical applications. This overlap between spatial and behavioral analysis also allows for the construction of a more accurate predictive model of how recreational patterns form in rapidly growing cities like Riyadh.

The results of the current study are consistent with previous literature that highlighted the role of geographic information systems in evaluating the spatial distribution of recreational facilities. The study by Cetin [19] focused on analyzing accessibility to green spaces within a specified walking distance, which aligns with this paper's reliance on accessibility as a key factor in determining the service area, while expanding the analysis to include behavioral and age dimensions. The methodology of Sotoudehnia and Comber [20], which evaluated actual and perceived accessibility, intersects with the findings of this paper regarding the importance of demographic characteristics and modes of transportation in explaining usage. The current study advances the analysis by incorporating an efficiency assessment and measuring the service gap through market penetration, which has not been addressed in those previous studies.

Similarly, the results of this study align with what Zainol and Maideen [21] proposed regarding the importance of age analysis in facility planning, while this paper provides a more comprehensive framework that links age, behavior, and activity level across different age groups, resulting in a classification that is more generalizable and applicable. This paper also approaches Murad's model [22] in using GIS to estimate demand, but it goes beyond that by developing a planning standard applicable to major recreational clusters, which enhances the

direction of planning decisions and contributes to more accurately identifying service gaps. Thus, these treatments deepen the connection between the results and the theoretical framework and support the transition toward practical models capable of interpreting the formation of recreational behavior patterns in rapidly growing cities like Riyadh.

Although the classification framework enabled a profound understanding of the interaction between recreational behavior and spatial structure, several limitations need to be acknowledged in interpreting the results. First, the demographic data, particularly the income data, are incomplete, which further strengthens the socioeconomic differences in demand and accessibility patterns. Second, the accessibility analysis was restricted to private vehicles, given the dominant transportation patterns in Riyadh. This limited the analysis to exclude alternative modes of transportation, such as walking or public transit, which may become more pertinent as urban development proceeds to newer stages in the future. The results duly demonstrated the applicability of the framework in providing spatial behavioral indicators of this nature. Future research will still need to further improve the model by incorporating additional social variables and diverse access patterns.

Despite the mentioned limitations, this paper fills an important gap in the existing literature by modeling a framework that combines dimensions of behavioral age, spatial analysis, and planning standards. This is especially pertinent to major Saudi cities currently facing rapid changes in urban, social, and economic structures. The new framework has demonstrated its effectiveness as a practical tool for decision-makers while assisting them in guiding investments in recreational facilities, identifying gaps, and establishing priorities, all while promoting sustainability and equity in the distribution of these facilities.

5. Conclusion

The study explored the possibility of developing a comprehensive framework for recreational services in the city of Riyadh, considering recreational activity patterns, community trends related to the population, and spatial allocation. Accordingly, a new spatial phenomenon known as "recreational cluster" was identified. The study relied on inductive methods and a spatial database containing geographical information about the basic infrastructure of recreational facilities, with the aim of analyzing the characteristics of the recreation cluster. Due to the database's capabilities in geometric calculation, a network analysis was conducted to calculate travel time, then converted into a service area using a geometric equation to estimate demand size, followed by calculating market supply efficiency.

The results showed that the district's service area of the recreational cluster reaches 16 km, covering approximately 41% of the city's population, indicating a service deficit of 59%. This indicator highlights the possibility of creating another cluster to enhance accessibility and achieve balance in spatial distribution, contributing to the sustainability of recreational planning.

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