GIS-INTEGRATED MULTI-CRITERIA SUITABILITY ANALYSIS FOR HEALTHCARE FACILITIES SITE SELECTION IN RAJOURI DISTRICT, JAMMU AND KASHMIR, INDIA

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Abstract
The study aims to develop a decision support model for the selection of a suitable site to establish a new healthcare center with adequate facilities based on the analytical hierarchy process (AHP) in the Rajouri district of Jammu and Kashmir.
This study utilized AHP and GIS to identify an appropriate location for a new healthcare center. The study employed eight criteria to evaluate potential locations and utilized pairwise comparison to assign weights to each criterion. GIS-based spatial analysis was used to create factor and suitability maps for each criterion. Suitability was evaluated on a scale of 0 to 10 and each factor map was combined using the ArcGIS weighted overlay selection tool.
The final map of the study represents the suitable site for a healthcare center in the Rajouri district and it shows the sites from the highly suitable to the least suitable area. In Rajouri district, mostly the central part can be considered very suitable as the population density of this area is higher compared to other areas of the district. The southwestern parts of the district are moderately suitable or least suitable sites for a new healthcare center.
The study displays the pattern of the existing location of healthcare centers, mostly, the existing locations are not proper and suitable. Therefore, in the future, the allocation of healthcare centers must be in more adequate areas. Policymakers and healthcare professionals can be benefitted from this study in selecting suitable locations for future hospitals, which could ultimately improve access to healthcare services in the region. Additionally, the study can be contemplated in developing new policies for better transportation system in the study area.

Keywords: Analytic Hierarchy Process, Geographic Information System, Weighted Overlay Approach (WOA), Hospital, Healthcare Site Suitability

1. Introduction

Healthcare facilities have emerged as the foremost essential establishments where individuals seek medical assistance and strive to enhance their health status. Healthcare site selection is a matter of major importance to many governments and institutions. Choosing an appropriate location for a healthcare in any given area, considering specific predetermined criteria, is an exceedingly complex process. The concerns encompass not just the technical aspects, but also environmental, social, and conflicting political factors. The determination of the placement of a new service, such as a healthcare facility, is a substantial challenge for both urban planners and decision makers. Selecting the best appropriate place among multiple alternative sites is a challenging and intricate task. Site selection is a cognitive process that involves assessing criteria and appraising and categorizing possibilities (Ibrahim et al., 2011; (Hopkins, 1977)

Across the world, there has been a natural growth in the need for healthcare facilities over time (Pantzartzis et al., 2017; Velez et al., 2021). Healthcare services play a crucial part in the socio-economic development of any nation. The primary objective of medical services is to meet the healthcare needs of individuals at any given moment, as required by healthcare facilities (Tripathi et al., 2021; Murad, 2007; Kushwaha et al., 2020). The demand for medical services is rising in urban areas as a result of ongoing migration from rural regions, resulting in disparities in the provision of these services (Dell'Ovo et al., 2018; Razzak et al., 2023).

It is important to develop more healthcare in order to augment healthcare capabilities. To begin this process, the first step is to choose the locations for establishing the hospitals. Selecting hospital sites is a multifaceted matter. The process requires the involvement of several stakeholders, including patients, physicians, healthcare personnel, and real estate developers. It also necessitates effective coordination among authorities, urban planners, and policymakers in the health sector (Mokhtar et al., 2023; Reanto et al., 2023). The strategic placement of a hospital will optimize its operational efficiency and improve the quality of healthcare services provided. Choosing a location without being asked frequently leads to increased expenses and decreased client satisfaction. To meet the increased demands for healthcare facilities, it is essential to designate additional appropriate hospital sites.

The health facility is the most significant part of the welfare of individuals and communities. Hence, the allocation of a healthcare facility should be in a way that the accessibility to the center will not be troublesome or an obstacle for people (Soltani & Marandi, 2011). It is important to ensure that the allocation of a healthcare facility is based on the requirements and demands of the population and not just based on financial or economic considerations (Todorov & Todorova, 2023; Gul & Guneri, 2021; Khosravi Kazazi et al., 2022). It is crucial to prioritize the necessity over financial stability for optimal site selection of a healthcare center (Li et al., 2022; Yu et al., 2023). The stipulation for new healthcare facilities is magnified with the expanding population of the country (Desta et al., 2023; Tripathi et al., 2022; Zhou and Wu, 2012). Although many private and public healthcare facilities provide services, those are demarcated to a certain group of people in society (Rabiei-Dastjerdi et al., 2021; Ali et al., 2023). Although some sections of society are benefit from these healthcare facilities, some underprivileged sections of society are often excluded from such facilities (Mourato et al., 2023; Das et al., 2023; Shafii et al., 2023). It is highly and often challenging for the underprivileged section in accessing good healthcare facilities due to the lack of proper and nearby healthcare centers (Liburd et al., 2013; Banks, 2012). Moreover, in remote and underprivileged areas lack of good transportation facilities are another obstacle that diminishes the chance of access to a healthcare centre. In addition to that, lack of awareness and literacy rate among the underprivileged sections of society plays a significant role in accessing healthcare facilities (Silalahi et al., 2020; Rahimi et al., 2017; Youzi et al., 2018). Often, these people tend to take medication traditionally or cope up with some home remedies available at their houses.

This study accentuates the necessity of

new and proper healthcare facilities to be constructed by public and private health organizations, NGOs, etc. These facilities should be especially available and accessible to financially unstable sections of society who cannot spend a large amount of their income on healthcare (Soltani & Marandi, 2011; Zhou and Wu, 2012). The major difficulty lies in the selection of a hospital site regardless of who is offering these facilities (Rabiei-Dastjerdi & Matthews, 2021). Accessibility should be optimum to the target population and should be close proximity to residential areas (Ampofo et al., 2023; Mitab et al., 2023). In addition, the hospital location should also take into account the availability of transportation, proximity to emergency services, and the availability of qualified healthcare professionals (Cobos-Mora et al., 2023). Other factors that need consideration for the selection of a site for a new healthcare facility, are population density, demographics, disease prevalence, and existing healthcare facilities (Halder et al., 2020; Cheng et al., 2020; Triantaphyllou & Mann, 1995). Site selection also involves careful consideration of zoning regulations, environmental impact, and the availability of utilities (Jordan et al., 2004; Rahimi et al., 2017). The selection of suitable sites can bring a significant impact on the sustainability of a new hospital. The proper allocation of a hospital can serve patients well, reduce transportation costs, and improve the overall health of the community (Soltani & Marandi, 2011; Chatterjee & Mukherjee, 2013). Therefore, it is essential that all stakeholders involved in the establishment of a new hospital carefully consider the location of the facility not only to ensure its long-term success but also to observe the impact on the community (Soltani & Marandi, 2011; Chatterjee & Mukherjee, 2013). Overall, it is important to carefully consider the potential impacts of establishing a hospital in a specific location and to work to mitigate any negative consequences that may arise (Soltani & Marandi, 2011; Javad & Sadeghi, 2013). To reduce the negative impacts in the selection of hospital sites, one should be rational. So, the primary purpose of this research is to decide the selection of suitable sites for healthcare facilities in the Rajouri district of Jammu and Kashmir to construct a new hospital by utilizing GIS based Analytical Hierarchy Process. Taking into account a wide range of constraint criteria and factor criteria, there should be a healthy equilibrium between the available medical resources.

In addition to that the existing locations of healthcare centers in the district are not optimal and suitable, leading to accessibility challenges for the population, especially in underprivileged and remote areas. The goal of this study is to determine and recommend a more efficient method to decide the allocation of new medical facilities by taking into account factors such as population density, demography, disease prevalence, accessibility, and the availability of trained medical personnel. The study also intends to look into how choosing a location for a hospital affects the long-term viability of local healthcare infrastructure, as well as transportation costs and the health of local residents.

There's a lack of focused research on the geographic distribution of healthcare services for the people of Rajouri district, hindering efficient policymaking and resource allocation. Hence the study specifically points out the inadequacy of existing healthcare facilities in the district and the need for a systematic and data-driven approach to select optimal sites for new healthcare centers. The study emphasizes that the current locations of healthcare centers are often not suitable, leading to difficulties in accessibility, especially for underprivileged sections of society. The gap lies in the absence of a comprehensive decision support model that integrates Analytical Hierarchy Process (AHP) and GIS to guide the selection of suitable sites for healthcare facilities.

This research focuses on determining the optimal approach for selecting suitable sites for healthcare care facilities in Rajouri District.

It also aims in the allocation of efficient hospital, utilizing GIS-based Analytical Hierarchy Process. This research focuses on answering the following questions:

1. What are the key criteria and factors considered in the selection of suitable sites for establishing a new healthcare center in the Rajouri district of Jammu and Kashmir?
2. How does the population density influence the suitability of locations for healthcare centers in different parts of the Rajouri district?
3. What is the existing pattern of healthcare center locations in the Rajouri district, and how effective are they in terms of suitability?

2. Study Area

Rajouri district is one of the 20 districts in the Indian Union territories of Jammu and Kashmir. It is located in the western part of the state, bordering Pakistan to the west. The district covers an area of 2630 square kilometers and has a population of approximately 642,415 people. Access to healthcare facilities in Rajouri district varies depending on location. In urban areas, healthcare facilities are relatively more accessible and better equipped than in rural areas. Some remote and difficult-to-reach areas may have limited access to healthcare services. In terms of healthcare workers, Rajouri district has a shortage of healthcare professionals, particularly physicians and specialists. The availability and accessibility of healthcare facilities in Rajouri district can be measured in terms of the number of healthcare facilities per capita and the distance from the facilities. According to government data, there are 42 PHC and 4 CHCs in the district, which translates into an average of 1 PHC for every

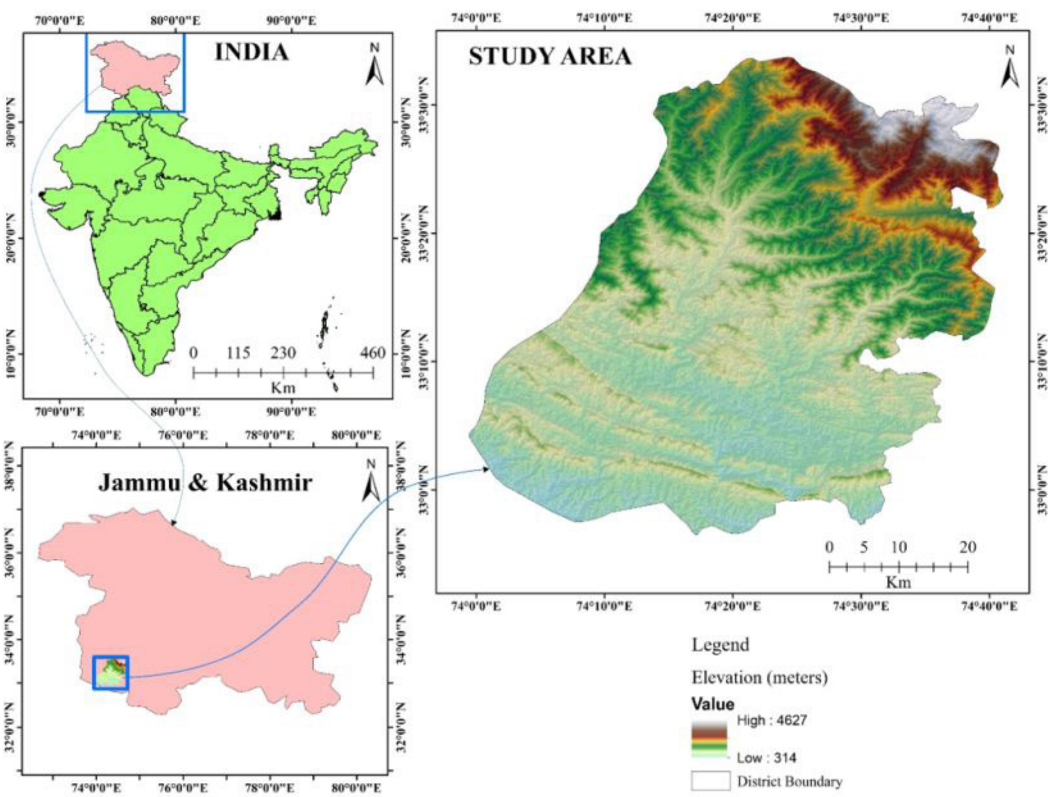

Fig. 1a. Location of the study area

15,238 people and 1 CHC for every 160,000 people. However, despite the relatively high number of healthcare facilities, access to healthcare remains a challenge for many people in the district. This is due to several factors, including the hilly terrain, poor road infrastructure, and the high cost of health services in private facilities.

3. Materials and methods

This study used GIS and the AHP to identify suitable sites for healthcare facilities in the Rajouri district of Jammu and Kashmir, India. Different GIS datasets were collected from various sources, such as land use land cover (Figure 3d), rivers (Figure 2b), roads (Figure 2c), agricultural land (Figure 3c), population (Figure 2a), existing healthcare facilities (Figure 2d), and digital elevation models (Figure 3b); (Sentinel-2A, Geofabrik Open-Source Data Portal, Census of India and Google Earth Pro). We prepared elevation and slope maps using the Shuttle Radar Topography Mission (SRTM) DEM with 30 m resolution. We developed a multi-criteria site suitability model, selecting criteria based on their significance in selecting healthcare facility sites Table 1. We used the pairwise comparison method to establish the weights of each criterion and to come up with an appropriate hospital suitability map (Figure 1). To standardize the units of different criteria, converted them to the same units using standardization methods. We converted the vector layer of all criterion maps into a raster layer and reclassified it using the weighted overlay method. The criteria were ranked on a scale of 0-10, where 0 indicates the least suitability and 10 indicates the highest suitability for healthcare facilities site selection (see Table 3).

The Conditioning factor refers to a set of parameters such as value, conditions, or data that favor the selection of a suitable location for facilities (Rizeei, 2018). This study depicts the association among conditioning factors and hospital sites to examine their aptness for appropriate healthcare facilities. To accomplish this, a spatial database consisting of the conditioning factors was chosen from the works (Rizeei, 2018; Chapi et al., 2017;

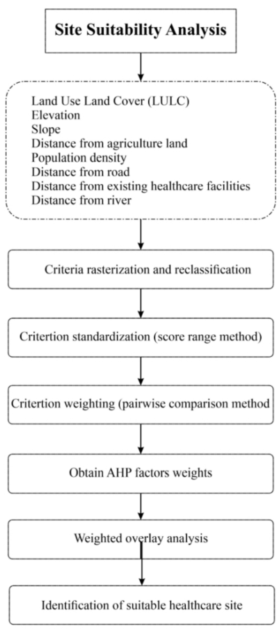

Fig. 1b. Conceptual flow chart of methodology applied in the present study for suitability of healthcare facilities site selection in the Rajouri district

Table 1. Parameter used for suitability of healthcare facilities site selection in the Rajouri districts

Parameters	Type of Data	Details of the data	Sources
Population	Non-Spatial		Census of India, 2011
Existing hospital	Spatial		Digitized feature
LULC, agricultural land	Spatial	Spatial Resolution: 10 m	Sentinel-2A, 2020
DEM	Spatial	Spatial Resolution: 30 m	SRTM DEM
Slope	Spatial	Spatial Resolution: 30 m	SRTM DEM
Road	Spatial		Geofabrik Open-Source Data Portal
River	Spatial	Spatial Resolution: 30 m	SRTM DEM

Table 2. Conditioning factors used for the suitability of the site of healthcare facilities

S. No	Conditioning Factors for suitability Healthcare site
1	Population density
2	Existing healthcare facilities
3	Land Use Land Cover (LULC)
4	Distance from road
5	Agriculture land
6	Digital Elevation Model
7	Slope
8	Distance from river network

Mojaddadi et al., 2017; Kalantar et al., 2018). To produce the independent variables, all of the crucial conditioning factors taken into consideration in the study were listed (Table 2) and analyzed as data layers for the Rajouri district.

Population Density

The density of population is interlinked with the necessity for healthcare facilities and significant performance. Using census data as the basis for the spatial unit of analysis, the following method (Equation 1) calculates the population density of a given area in terms of individual kilometers or per square metre.

$$Population\ density = \frac{Number\ of\ people}{Land\ area}$$

The suitability analysis is provided in Table 3 which consists of the suitability rating of each conditioning factor. These factors are reclassified into different suitability levels based on the results of the AHP, a tool of decision making used to evaluate alternatives by considering multiple criteria.

River

The distance from rivers is indeed an essential factor to consider when selecting a site for a healthcare facility. During the monsoon season harsh weather conditions and excessive rain can lead to flooding in adjacent areas, particularly at descending elevations and slopes. Therefore, it is important to incorporate the possible location interval from rivers and streams into the hospital site suitability criteria. Hence from 0 – 100 m is not preferable for the establishment of a hospital due to the higher risk of flooding, whereas from 100 – 1000 m is most suitable for the selection of the hospital site as it provides a reasonable distance from the rivers and streams to minimize the risk of flooding while still being easily accessible. 1000-2000 m is moderately preferable, and 2000-3000 is less suitable for the hospital site. More than 3000 m is the least preferable among all Table 3.

Distance from the main roads

The construction of a new healthcare facility near roads is significant in terms of the availability and accessibility of healthcare facilities for people. To evaluate this, the input layers for the criteria related to roads were downloaded from the Geofabrik Open-Source Data Portal and converted into a raster layer. The resulting raster layer was then reclassified with a scale value of 0-10, areas within 300 meters radius from the road are given the highest preference and ranked as 10th with the highest suitability. On the other hand, areas up to the <2300-meter buffer zone were considered the least suitable and ranked as 1 Table 3.

Existing healthcare facilities

In Rajouri district, one district healthcare center and some primary and community healthcare centers are available in terms of adequate healthcare facilities. According to the Hospital site suitability calculations, areas within the 2 km radius of the existing healthcare site are considered less suitable,

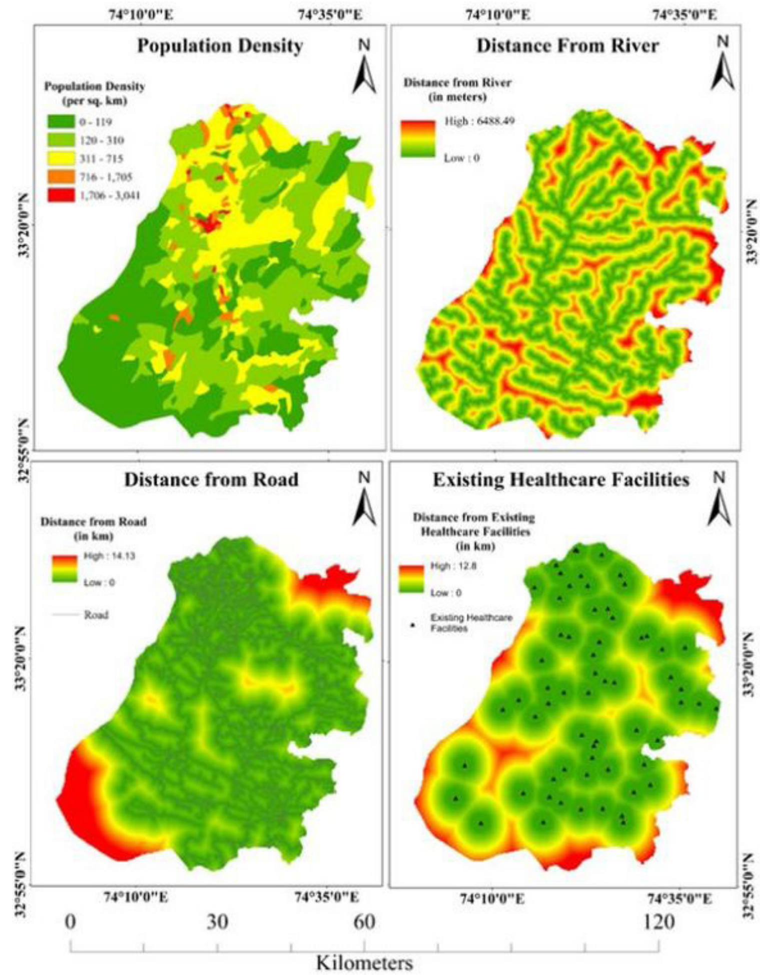

Fig. 2. Conditioning factors for healthcare facilities site selection of Rajouri district: (a) Population density (b) Distance from river (c) Distance from road (d) Distance from existing healthcare facilities

whereas areas beyond this radius are highly preferable for the construction of a healthcare facility. Distance to other healthcare facilities is displayed in (Table 3) where the preference is given to the place away from the currently existing healthcare facilities in the area.

Land Use Land Cover

The LULC map utilized in the study encompasses various types of land, including water, trees, crops, built-up areas, barren ground, snow/ice, and rangelands. The researchers used high-resolution Sentinel-2A imagery with a resolution of 10 meters to classify the different land use categories. From an economic perspective, built-up areas are considered very suitable for the construction of new healthcare facilities because they can provide the necessary infrastructure and resources for healthcare facilities. The study assigns built-up areas as highly suitable and ranks them as the 10th, which is the most significant area for hospital site selection (Table 3).

However, other land use categories, such as water, snow / ice and rangeland areas, were considered unsuitable for the construction of new healthcare facilities. In agricultural land, within the 250-meter radius area around the hospital site was considered unsuitable,

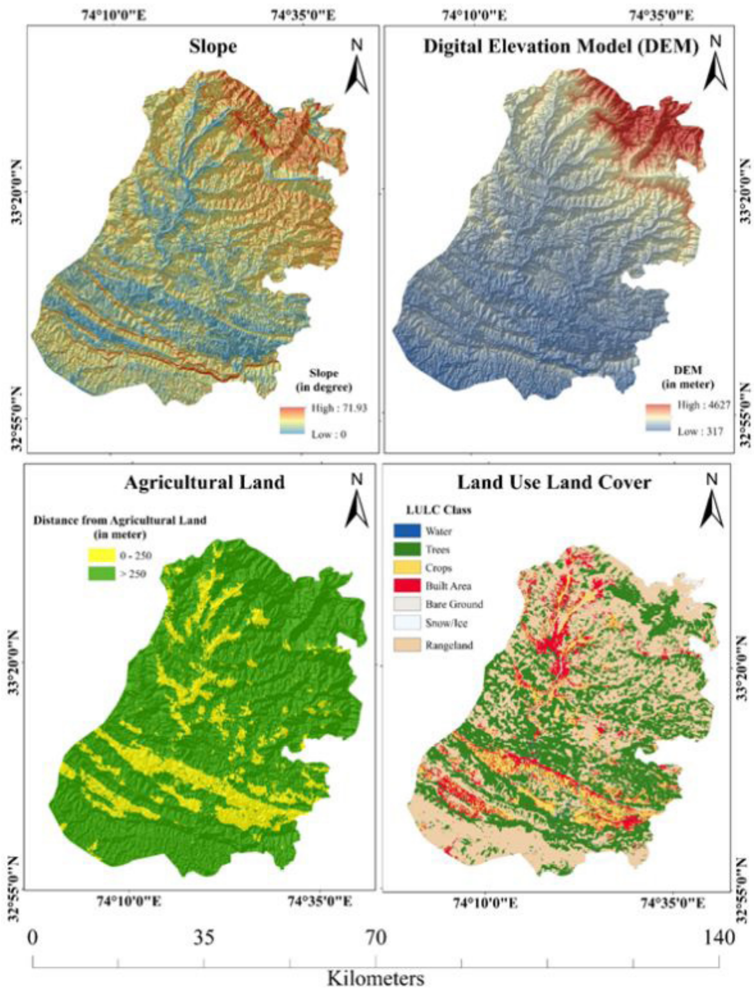

Fig. 3. Conditioning factors for healthcare facilities site selection of Rajouri district: (a) Slope (b) DEM (c) Agriculture land (d) Land Use Land Cover

while other parts beyond this radius of agricultural land were considered most suitable for hospital construction.

Elevation (Altitude)

Elevation is a significant element for the consideration of appropriate areas for a healthcare facility. Higher elevation makes a less appropriate site for the construction and operation of healthcare facilities. The elevation in Rajouri district ranged above 317 to 4627 meters from mean sea level (MSL). The elevation values of the study areas were divided into five categories and assigned rank values based on their height, and rank values were assigned for the suitability of the healthcare facilities site

Table 3. Ranking values for the selected criteria

Criterion	Weight	Influence (%)	Sub-criteria/ alternatives Rajouri	Suitability index (ranking)	Suitability
Population density	0.366	36.6	0-127	2	Least suitable
			127-314	3	Less suitable
			314-674	5	Moderately suitable
			674-1713	8	Suitable
			1713-3040	10	Very suitable
Existing healthcare facilities	0.213	21.3	0-209	3	Less suitable
			209-384	10	Very suitable
			384-588	8	Suitable
			588-868	6	Moderately suitable
			868-1485	0	Unsuitable
Land use land cover	0.156	15.6	Built areas	10	Very suitable
			Rangelands	8	Suitable
			Crops	5	Moderately suitable
			Trees	3	Less suitable
			Water	0	Unsuitable
			Baren Ground	0	Unsuitable
			Snow ice	0	Unsuitable
Distance to Roads (m)	0.104	10.4	0-300	10	Very suitable
			300-800	8	Suitable
			800-1300	6	Moderately suitable
			1300-2300	3	Least suitable
			2300-16418	0	Unsuitable
Distance to Agricultural land (m)	0.70	7.0	0-250	0	Unsuitable
			>250	10	Most suitable
Elevation (m)	0.041	4.1	317-820	2	Less suitable
			820-1262	10	Very suitable
			1262-1910	8	Suitable
			1910-2848	6	Moderately suitable
			2848-4627	0	Unsuitable
Slope (^{o})	0.029	2.9	0-9	0	Unsuitable
			9-16	10	Very suitable
			16-24	8	Suitable
			24-33	5	Less suitable
			33-71	3	Least suitable
Distance to River (m)	0.020	2.0	0-100	0	Unsuitable
			100-1000	10	Very suitable
			1000-2000	8	Suitable
			2000-3000	6	Moderately suitable
			3000-7370	2	Less suitable

selection. The highly suitable areas in Rajouri district were those with elevations between 820 to 1262 m, which were assigned a rank value of 10. The elevation ranges from 317 to 820, 1262 to 1910, 1910 to 2848, and 2848 to 4627 m were given rank values of 2, 8, 6, and 0, respectively, and were considered least preferable areas suitable for selection of healthcare facilities.

Slope

The estimation of land morphology can be determined in a study area by utilizing slope gradation, which is measured in degrees or percent. A higher degree of slope is considered less suitable for the establishment of healthcare facilities as the population in such areas is less and scattered. The slope layer map was prepared using SRTM DEM data of the study area in a GIS environment, and the slope was reclassified into different categories ranging from very steep areas to plane areas based on their degree of slope (Table 3). The most suitable areas for the selection of a healthcare facilities site were identified as the plain areas with a slope of less than 9o, which were assigned a rank of 10. In contrast, areas with a slope of more than 33o were considered least suitable.

Euclidean Distance

The Euclidean distance tool is commonly used in spatial analysis to measure distances between vector features. The tool calculates the distance from each cell to the nearest feature of a specified type, such as rivers, roads, or healthcare facilities. The resulting distances can be categorized based on different criteria, such as proximity to a road or healthcare facility. The classification is dependent on specific application requirements, which may vary based on factors unique to the analysis.

Reclassification of the criterion

The process of reclassification of raster data to analyze the selection of suitable hospital sites based on different criteria. The criteria maps are reclassified based on their suitability for hospital site selection, and different levels of suitability are established based on threshold values. The resulting criteria are then classified as integer rasters, each representing a different level of site suitability. To calculate the final site suitability map, all criteria maps are placed on the same scale and with the same units, and a weighted score is used to measure the levels of hospital site suitability. The study compares a highly preferable location for hospital site selection against a less preferable site, presumably to assess the effectiveness of the reclassification method.

AHP-based weight calculation for each criterion map

The AHP is a multicriteria decision-making technique that has been widely accepted

Importance rank	Verbal judgement
9	Extremely important
8	Very to extremely strong important
7	Very strongly more important
6	Strong to very strong important
5	Strongly more important
4	Moderate to strong important
3	Moderately more important
2	Equal to moderate
1	Equal important

Table 4. Scale for pair-wise comparison matrix. Source: (Saaty, 1980)

by researchers and practitioners (Saaty, 1980; Eastman et al.1995; Jankowski, 1995; Al-Shalabi et al. 2006; Uyan, 2014). This approach is used to estimate the hierarchical structure of criteria and sub-criteria in the decision-making process (Improta et al., 2019). The AHP approach provides weight values for each criterion or sub-criterion, enabling decision-makers to make informed decisions (Shahin & Mahbod, 2007; Németh et al., 2019). The AHP methodology involves a pairwise comparison matrix to quantify the design criteria and elements, which is then used to detect the individual weighted score for each criterion. The sum of the components is normalized to unity to provide a consistent and reliable result (Saaty 1980; Malczewski 1999; Rezaei-Moghaddam & Karami, 2008; Feizizadeh et al., 2014).

In this study, the AHP approach was used to calculate weight scores for site selection criteria. A pairwise comparison matrix was created using a 1-9 scale to indicate the level of significance for each criterion (Table 4). The number of comparisons needed for n number of criteria was calculated using the formula n (n-1)/2 (Saaty, 1980; Ozcan et al., 2011; Vahidnia et al., 2009; Sisay et al., 2021). The AHP was employed to derive weights for each criterion through pairwise comparisons. The consistency ratio (CR) was calculated using Equation 2 to ensure the logical coherence of the pairwise comparison matrix. The CR helps to identify any inconsistencies that need to be corrected.

$$CR = CI/RI$$

In this decision-making process, the consistency ratio (CR), consistency index (CI), and random index (RI) are used. The random index is determined using the index table provided by Saaty in Table 5.

$$CI = (\lambda_{max} - n)/(n-1)$$

In order to assess the reliability of the weight values generated by the AHP method for selecting a healthcare facility site, several metrics were used. The consistency index (CI) was computed using Equation 3, which involves dividing the difference between the highest eigenvector of the computed matrix (λ_{max}) and the number of criteria (n) by (n-1). The random index (RI) was determined as the average value of the consistency index based on Saaty's matrix order (1997), and for eight criteria, the RI value was found to be 1.41 (as shown in Table 5). The consistency ratio (CR) was obtained by dividing the CI by the RI. If the CR value exceeds 0.10, it indicates that the weight values generated by the AHP method may not be reliable.

In the present study, the calculated CR value was 0.09977, which falls within the acceptable range. Hence, it can be concluded that the weight values obtained through the AHP method are reliable for selecting a healthcare facility site.

Utilization of Weighted Overlay Analysis for the Suitability of the Site Selection

Weighted overlay analysis is a crucial approach for the selection of a suitable site in terms of any study area. The Weighted Overlay Analysis performed in the Analytic Hierarchy Process to discover the main factors (Awad & Jung, 2022; Almansi et al., 2022). To apply the WOA, thematic layers were integrated in the GIS approach (Girvan et al. 2003). For a suitable outcome, the weighted overlay method in ArcGIS requires that all rasters be integer units (Table 3). The weighted overlay analysis tool computes the suitability index of a pixel by multiplying the site suitability

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 5. Random inconsistency indices (RI). Source: (Saaty, 1980)

score with the weight assigned to each pixel. The resulting values are added together to generate a suitability map, which is obtained using Equation (4). This methodology has been employed in several studies (Pramanik 2016; Yalew et al. 2016; Cengiz and Akbulak 2009).

$$S = \sum w_i x_i$$

The equation for calculating the total suitability score (S) is given by summing the product of each site suitability factor's weight w_i with its assigned criterion score *i*, and x_i. Thus, the equation can be represented as $S=\sum w_i x_i$, where i represents each selected site suitability factor.

4. Results

The reclassified raster data were used in the GIS analysis for the hospital site selection. This analysis also made use of the AHP weighted and pairwise computation correspondingly. In the AHP method, the CR was the primary indicator of judgment that was used. The CR for this particular outcome was 0.09977, and it is an important aspect of the site selection technique. The study used the analytic hierarchy process to calculate the weighted values of selected criteria, and the scores of sub-criteria were analyzed using the weighted overlay method to determine the most suitable site for a healthcare center in Rajouri district (Table

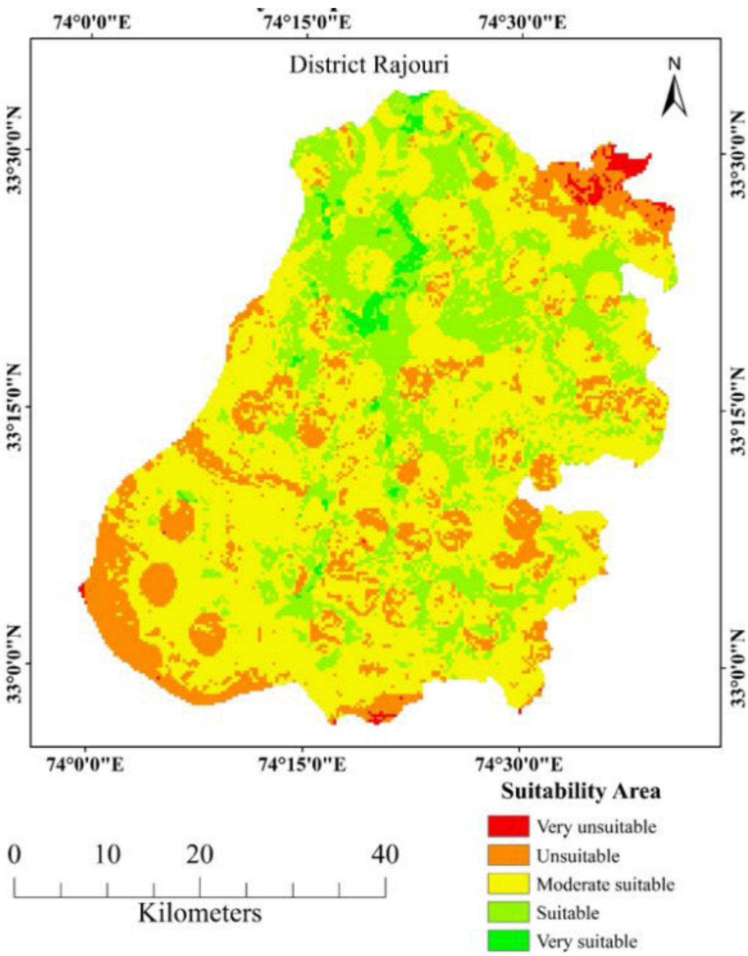

Fig. 4. Suitability of Healthcare Facilities Site Selection in Rajouri District

3). The suitability map was divided into four categories: 1. Very suitable, 2. Suitable, 3. Moderately suitable, and 4. Unsuitable and very unsuitable areas (see Figure 4). The appropriateness levels were determined based on this categorization.

5. Discussion

The increasing population has led to a greater demand for improved facilities, including healthcare, education, and transportation. Figure 4 illustrates the location for selecting healthcare facilities based on specific criteria. The AHP and pairwise comparison technique were utilized to calculate the weightings for each criterion (as shown in Tables 6 and 7). The consistency ratio (Table 8) and the RI (Table 6) were also determined according to Saaty (2003) for the selected criteria. Each criterion was further divided into various scores and weighted (Table 5) to prioritize the analysis.

The results clearly indicate that the green areas on the map (Figure 4) are highly suitable for healthcare facilities. Factors such as population density, transportation systems, and land availability play significant roles in influencing an effective healthcare system. With the population growing rapidly day by day, the existing government hospital alone cannot adequately cater to the healthcare needs of this area. Additionally, private hospitals and a few health centers are insufficient to meet the healthcare requirements of the substantial population.

6. Conclusion

The primary objective of this study is to select suitable healthcare sites in the Rajouri district of Jammu and Kashmir. The district is experiencing rapid urban development due to population growth. This population increase leads to challenges such as limited land availability, high land values, and the construction of new buildings, which in turn results in the degradation of open spaces. It is crucial to enhance urban facilities to improve the quality of life for the district's residents, while also curbing horizontal expansion and encouraging vertical expansion. These measures can help address issues such as land scarcity, degradation of open spaces and vegetation, and so on. Additionally, the district faces problems related to poor road conditions and limited availability of public transportation, which increase the likelihood of road accidents. To mitigate these issues, the district authorities should prioritize road repairs and improvements to ensure safer travel conditions.

In the Rajouri district, there is currently only one district hospital and few existing government health centers are insufficient to meet the healthcare demands. It is imperative that the government takes action to address this issue, particularly to provide accessible and affordable healthcare services to the lower-income population (Table 3).

The AHP and GIS is employed to identify a suitable site for a hospital in the study area. This method facilitates the calculation of weighted values for each criterion chosen. In this study, the suitability of areas in the study area is categorized as very suitable, suitable, moderately suitable, unsuitable, and very unsuitable (refer to Figure 4). The challenge with unsuitable areas in this study is their distance from densely populated areas.

Ideally, a hospital location is considered more favorable if it is situated in a populated area with good transportation access and an environmental suitable location. The pairwise comparison method relies on expert opinions, which significantly contribute to the decision-making process. The result is based on the integration of the GIS and AHP methods. Field survey was conducted to further support the site selection process. It is essential to verify the identified areas on the field or ground level, taking into account other local parameters such as the availability of public toilets, ambulance services, and road conditions, as well as regional factors like administrative conditions and density of population, before the final implementation of the healthcare facility site selection.

Table 6. Pairwise comparison matrix

Criteria	Population Density	Hospital	LULC	Road	Agricultural land	Elevation	Slope	River
Population Density	1	3	5	5	7	7	9	9
Hospital	0.33	1	3	3	5	7	7	7
Settlement	0.20	0.33	1	3	5	5	7	7
Road	0.20	0.33	0.33	1	3	5	5	5
Agricultural land	0.14	0.20	0.20	0.33	1	3	5	5
Elevation	0.14	0.14	0.20	0.20	0.33	1	3	3
Slope	0.11	0.14	0.14	0.20	0.20	0.33	1	3
River	0.11	0.14	0.14	0.20	0.20	0.33	0.33	1
Total	2.24	5.30	10.02	12.93	21.73	28.67	37.33	40.00

Table 7. Utilizing a Standardized Matrix and weighted distribution in the Case of Multicriteria Decision Analysis

Criteria	Population Density	Hospital	LULC	Road	Agricultural land	Elevation	Slope	River	Weight
Population Density	0.446	0.567	0.499	0.387	0.322	0.244	0.241	0.225	0.366
Hospital	0.149	0.189	0.299	0.232	0.230	0.244	0.188	0.175	0.213
LULC	0.089	0.063	0.100	0.232	0.230	0.174	0.188	0.175	0.156
Road	0.089	0.063	0.033	0.077	0.138	0.174	0.134	0.125	0.104
Agricultural land	0.064	0.038	0.020	0.026	0.046	0.105	0.134	0.125	0.070
Elevation	0.064	0.027	0.020	0.015	0.015	0.035	0.080	0.075	0.041
Slope	0.050	0.027	0.014	0.015	0.009	0.012	0.027	0.075	0.029
River	0.050	0.027	0.014	0.015	0.009	0.012	0.009	0.025	0.020
Total	1	1	1	1	1	1	1	1	1

Table 8. Estimation of the consistency ratio

	Population Density	Hospital	LULC	Road	Agricultural land	Elevation	Slope	River	Total	Cr
Population Density	0.366	0.640	0.782	0.521	0.487	0.290	0.258	0.181	3.525	9.623
Hospital	0.122	0.213	0.469	0.313	0.348	0.290	0.200	0.141	2.097	9.834
LULC	0.073	0.071	0.156	0.313	0.348	0.207	0.200	0.141	1.510	9.657
Road	0.073	0.071	0.052	0.104	0.209	0.207	0.143	0.101	0.961	9.212
Agricultural land	0.052	0.043	0.031	0.035	0.070	0.124	0.143	0.101	0.599	8.602
Elevation	0.052	0.030	0.031	0.021	0.023	0.041	0.086	0.060	0.346	8.340
Slope	0.041	0.030	0.022	0.021	0.014	0.014	0.029	0.060	0.231	8.077
River	0.041	0.030	0.022	0.021	0.014	0.014	0.010	0.020	0.172	8.533
										8.985

$$Maximum\ eigenvalue\ (\lambda_{max}) = 8.985$$

$$n = 8$$

$$Consistency\ index\ (CI) = (\frac{\lambda_{max} - n}{n - 1}) = 0.14068$$

$$Random\ index\ (RI) = 1.41$$

$$Consistency\ ratio\ (CR) = (\frac{CI}{RI}) = 0.09977$$

$$Maximum\ eigenvalue\ (\lambda_{max}) = 8.985$$

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