Site Suitability Evaluation for New Health Facilities Using Geospatial Technologies in Bharatpur, Nepal

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1. Abstract

This study aims to evaluate suitable locations for new healthcare facilities in Bharatpur, Nepal, using Multi-Criteria Spatial Decision Analysis (MC-SDA) and geospatial technologies. The analysis incorporates factors such as population density, road accessibility, slope, proximity to existing hospitals, and land use/land cover. Despite challenges with manually extracting population density data from local ward sources and the absence of standardized road classification, the study developed a composite suitability map to highlight optimal sites. The findings reveal spatial imbalances in existing healthcare services, emphasizing the need for new facilities in underserved areas to improve accessibility and healthcare delivery.

2. Introduction

Unreliable spatial distribution of population, healthcare services, and transportation roads can lead to spatial disparities and poor accessibility to required healthcare facilities [1]. The World Health Organization (WHO) [2] reports that half of the world's population struggles to access health services, leading to 100 million people experiencing extreme poverty annually due to high healthcare costs and inadequate accessibility [3]. Significant disparities in access and availability also exist in developing regions like Southern Asia, including Nepal, where growing urban areas like Bharatpur face increasing pressure on their healthcare infrastructure. Factors such as population density, uneven healthcare distribution, and transportation networks influence healthcare accessibility and affect the success rate of people receiving timely and appropriate health services.

Geospatial technology analysis helps understand the spatial arrangement of healthcare services, their connection to access, and health outcomes, while providing insights for improving medical service delivery [4]. The Government of Nepal is committed to providing free Basic Health Services (BHS), including promotional, preventative, diagnostic, curative, and rehabilitative services. Despite these efforts, inadequate health infrastructure, particularly in growing urban areas like Bharatpur, highlights the urgent need for new facilities to meet increasing healthcare demands [5].

This study aims to address methodological gaps by examining healthcare facility access in both rural and urban settings in Bharatpur, Nepal, including distance, time, and site selection criteria. It explores new sites for healthcare facilities by leveraging geospatial technologies to measure service distribution and accessibility. The analysis revealed that the current distribution of healthcare centers lacks strategic planning, with a high concentration of facilities in well-developed areas, leaving other regions underserved. This has resulted in significant coverage gaps, particularly in the expanding urban environment of Bharatpur.

3. Methods and Materials

3.1 Study Area

The Study area is Bharatpur, located in central Nepal's Chitwan District, covers an area of 433 km^2 and sits at an elevation of 208 meters above sea level. Geographically positioned at 27.6766° N latitude and 84.4402° E longitude, Bharatpur has rapidly urbanized, with a population of 369,377 as of the 2021 census. The city serves as a major commercial and administrative hub, linked by the East-West Highway and Bharatpur Airport, making it a vital transportation center.Despite its growth, Bharatpur faces challenges in healthcare accessibility. Existing health facilities are concentrated in central, well-developed areas, leaving peripheral and rural regions underserved. The uneven spatial distribution of healthcare services, combined with the city's expanding population, underscores the need for strategically planned new health facilities.

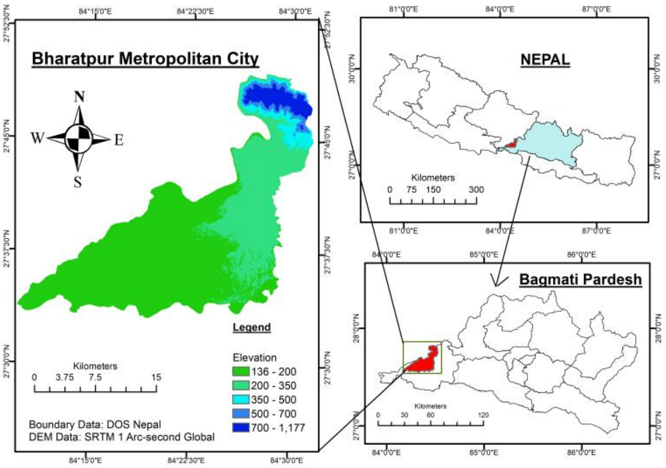

Figure 1. Study Area Map of Bharatpur

3.2 Data Sources and Software

For this study, an experimental research design was employed, focusing on spatial data processing using geospatial technology-based analysis. Sentinel-2A imagery (dated 2024-03-05) with a 10-meter spatial resolution from Copernicus data space ecosystem and a DEM (Digital Elevation Model) were obtained from Earth Explorer to produce the Land Use Land Cover (LULC) and slope maps, respectively. Data on roads and existing hospitals were sourced from the Humanitarian Data Exchange. Population density data was collected from the official Bharatpur website, providing ward-wise population number, which were then converted into a population density map.

All the GIS tasks like data cleaning and analysis were done in ARCMAP.

3.3 Methods

To identify the optimal hospital location using Multi-Criteria Decision Analysis (MCDA) in ArcMap, key factors such as Population Density, Slope, Proximity to Existing Hospitals, Proximity to Roads, and Land Use/Land Cover (LULC) were selected. Relevant spatial data was collected for each criterion, and a pair-wise comparison matrix was created using the Analytic Hierarchy Process (AHP) to assess their relative importance, assigning values from 0 to 4.The criteria were then overlaid in ArcMap using a weighted sum approach, multiplying each layer by its corresponding weight to create a composite suitability map. The final analysis highlighted areas with the highest suitability scores, ensuring accessibility and service coverage were prioritized for effective hospital site selection.

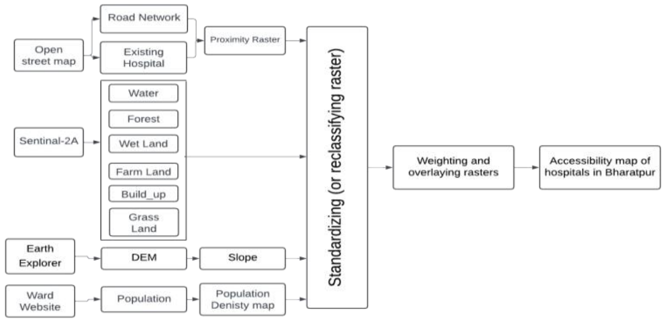

Figure 2. Methodology Flowchart

4. Results and Discussion

4.1 Description of Criteria used

4.1.1 Suitability of Slope

Slope data, assigned a weight of 10%, affects the feasibility of construction and the long-term stability of the hospital site. Gentle slopes, typically less than 5 degrees, are preferred to avoid issues related to erosion, water logging, and high construction costs. The slope influences drainage and site preparation, impacting both initial construction and ongoing maintenance. Proper slope assessment ensures the site can support the structure and minimizes future operational challenges [6].

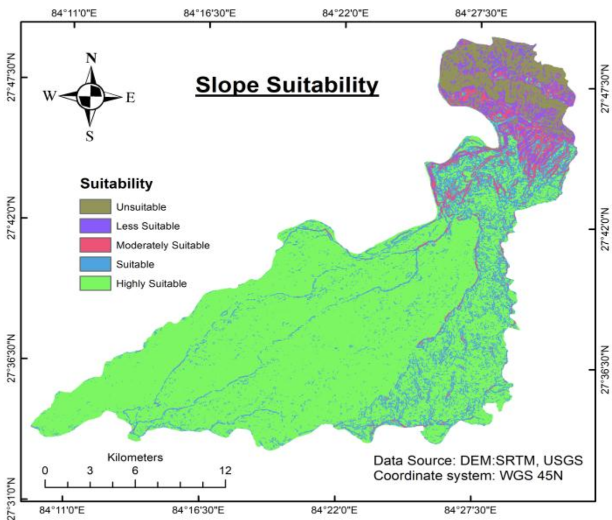

Figure 3. Suitable areas for hospital site according to slope criteria

Slope	Suitability	Area (in m^2)	Area (in %)
>25	Unsuitable	23659268.95	5.51
15-25	Less Suitable	15722334.78	3.66
8-15	Moderately Suitable	16781172.16	3.91
3-8	Suitable	59334858.63	13.82
<3	Highly Suitable	313981039.9	73.11

Table 1. Area and Percentages of slope Suitability

4.1.2 Existing Hospital

The presence of existing hospitals in the vicinity is another important factor to consider, with a suggested weight of 15%. A new hospital should complement the health care landscape by filling gaps in service provision rather than duplicating resources. If the selected site is too close to an existing hospital, it could result in overlapping catchment areas and competition, which may strain both facilities and lead to under-utilization of resources. On the other hand, if there are no hospitals nearby, the new facility could become a crucial health care provider for undeserved populations. Proximity to an existing hospital network can also facilitate the referral of patients in critical conditions [7].

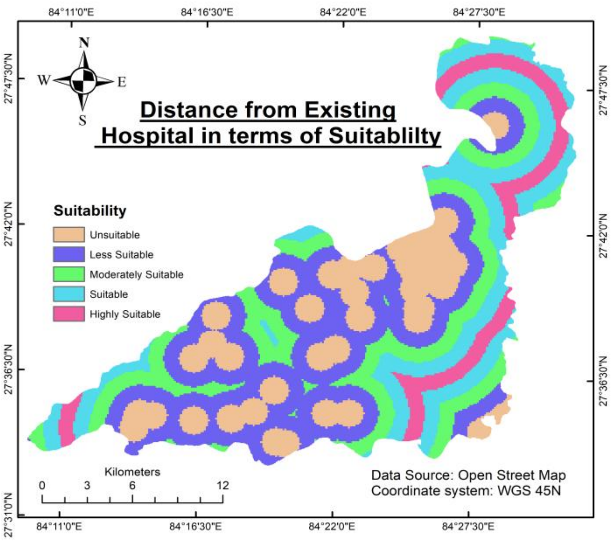

Figure 4. Reclassified distance from existing health center

Distance(m)	Suitability	Area (in m^2)	Area (in%)
<1000 and >1000	Unsuitable	95993767.76	22.15
1000-2000 and 8000-9000	Less Suitable	129785252.5	29.95
2000-3000 and 7000-5000	Moderately Suitable	86211087.85	19.89
3000-4000 and 6000-7000	Suitable	83326800.77	19.23
4000-6000	Highly Suitable	38045500.13	8.78

Table 2. Area and Percentags of distance from existing hospitals

4.1.3 Land Use and Land Cover (LULC)

Land Use and Land Cover (LULC) data is essential in determining the suitability of a hospital site by analyzing how the land is currently being utilized. Urban, residential, and commercial areas are preferred for hospital construction due to their proximity to the population and established infrastructure. On the other hand, agricultural or forested areas may present development challenges such as the need for extensive land clearing or restricted land use policies. LULC data helps in ensuring that the selected site can be converted for hospital use with minimal environmental disruption while aligning with urban development plans. Proximity to developed areas ensures that utilities like water, electricity, and telecommunications are readily available. This factor can have a weight of around 15%, as it plays a pivotal role in determining how seamlessly the hospital can be integrated into the existing urban framework [8].

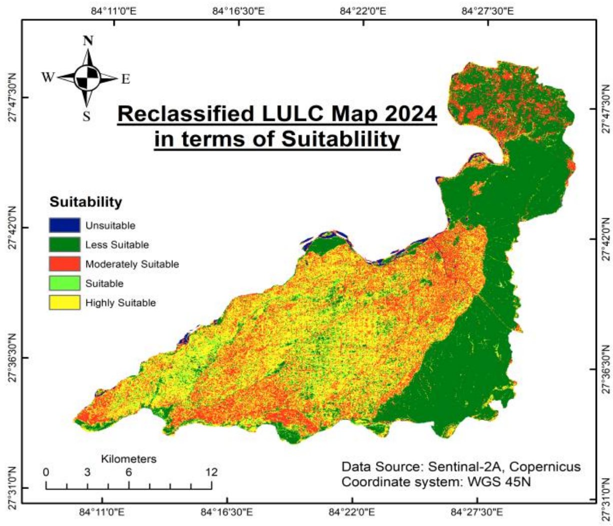

Figure 5. The study area's land use/cover suitability map

Class	Suitability	Area (in m^2)	Area (in %)
Water or Wet Land	Unsuitable	4003342.106	0.93
Forest	Less Suitable	171124902.2	39.71
Build_up	Moderately Suitable	93257362.09	21.64
Grass_land	Suitable	18301376.23	4.25
Open Land	Highly Suitable	144235335.5	33.47

Table 3. Presents the classifications of land use suitability classes and their area coverage

4.1.4 Population Density

Population density is one of the most crucial factors in hospital site selection, typically carrying a weight of around 30%. Areas with high population density tend to have a greater demand for healthcare services, making it essential to place hospitals near these regions. A higher density (generally over 2,000 people per square kilometer) indicates a significant patient base, ensuring that the hospital will be adequately utilized and provide timely care to a larger community.Choosing a location in an area with increasing population trends can future-proof the hospital against rising healthcare demands [9]. 500,1500,3000,5000

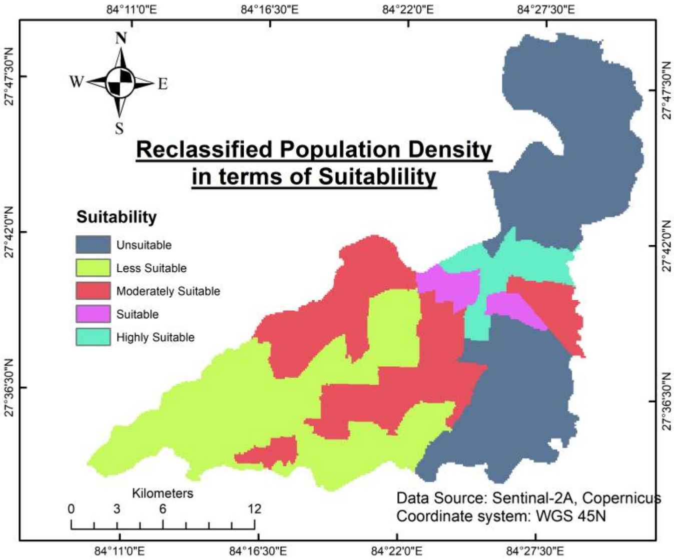

Figure 6. Population Density Map

Range	Suitability	Area (in m^2)	Area (in %)
<500	Unsuitable	165927054.1	38.27
500-1500	Less Suitable	127064228.1	29.31
1500-3000	Moderately Suitable	103918235.8	23.97
3000-5000	Suitable	13429927.84	3.10
>5000	Highly Suitable	23212211.8	5.35

Table 4. . Population density suitability ranges and areal coverage

4.1.5 Road

Road access is essential for both emergency services and routine hospital operations, accounting for a weight of 25% in site selection. Proximity to major roads or highways ensures that patients, ambulances, and hospital staff can reach the facility quickly and efficiently. A hospital located within 1-2 kilometers of a major road provides the accessibility needed for both day-to-day operations and emergency situations, where time is a critical factor. Road networks also support the delivery of supplies, medications, and equipment, ensuring that the hospital functions smoothly. Furthermore, good road access enhances the visibility of the hospital, making it easier for patients from surrounding areas to locate and utilize the services [10].

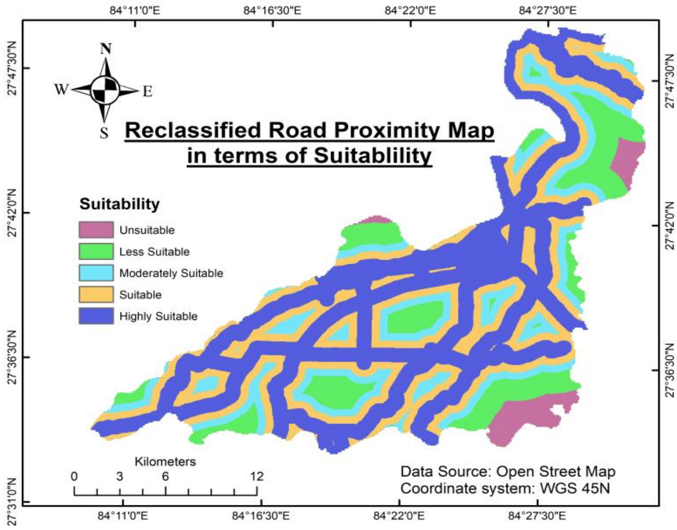

Figure 7. . Road suitability map

Distance	Suitability	Area (in m^2)	Area (in%)
<500	Unsuitable	16803203.75	3.88
500-1000	Less Suitable	59610670.15	13.75
1000-1500	Moderately Suitable	61871201.63	14.27
1500-3000	Suitable	111140412.2	25.63
>3000	Highly Suitable	184136284.6	42.47

Table 5. . Presents road suitability classes and their area coverage in the study area

4.2 Overlay of Criteria

The overlay method in GIS integrates multiple layers such as Population Density, Slope, Proximity to Existing Hospitals, Proximity to Roads, and Land Use/Land Cover (LULC) to evaluate potential hospital sites. Using Analytic Hierarchy Process (AHP), a pair-wise comparison matrix is constructed to assess the relative importance of each criterion, assigning numerical values to prioritize them.

Criteria	PD	SL	EH	PR	LULC	Weights
Population Density (PD)	1	7	5	3	3	0.435
Slope (SL)	1/7	1	1/5	1/7	1/5	0.086
Existing Hospitals (EH)	1/5	5	1	3	3	0.242
Proximity to Roads (PR)	1/3	7	1/3	1	5	0.298
LULC	1/3	5	1/3	1/5	1	0.23

Table 6. presents a pair-wise comparison matrix of criteria and weights

In this matrix, the values from 1 to 9 represent the relative importance of one criterion over another:

1 indicates equal importance,**3** means moderately more important,**5** indicates strongly more important,**7** signifies very strongly more important,**9** represents extremely more important

4.3 Final Suitability Map

After weightage and overlaying on standardized raster, final overlay raster is obtained.This is the required final suitability map.

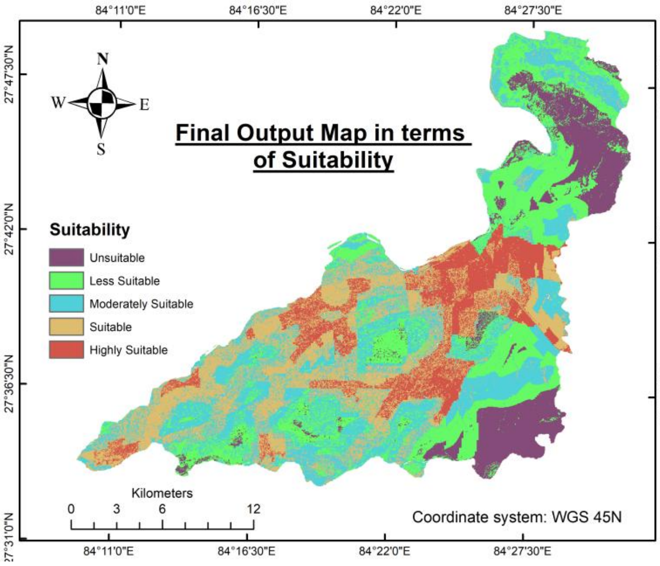

Figure 8. Displays the final outputs of suitable areas for a new health facility

Suitability	Area (in m^2)	Area (in %)
Unsuitable	56540271.21	13.25
Less Suitable	106846215.2	25.04
Moderately Suitable	111390003.2	26.10
Suitable	99132334.77	23.23
Highly Suitable	52845195.68	12.38

Table 7. Final suitablility area and percentages for new health facility

The study found 13.25% of the study area as low-suitable for healthcare facility sites, failing to meet criteria from organizations like FAO[11] and EFMHACA[12]. However, 12.38% was highly suitable, meeting accessibility, environmental, and topography criteria. Although moderately suitable sites may not meet the most suitable standards, they can still serve as alternative healthcare facility service areas.

4.4 Conclusion and Recommendation

The study utilized a geospatial-based decision-making strategy to evaluate healthcare accessibility and distribution, identifying suitable locations for new centers and public services. It aimed to reduce spatial imbalance among healthcare institutions by considering factors like road proximity, infrastructure, population density, and residential areas.

The project faced challenges with population density data and road classification. Manual extraction of population data was time-consuming and inaccurate. The absence of clear road classification made it difficult to assess accessibility and transport efficiency. To improve data collection, collaboration with local authorities, automated extraction techniques, and standardized road classification partnerships with urban planners or national datasets are recommended.

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