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Hospital Location Allocation in Murshidabad District by GIS-Based MCA and Analytical Hierarchy Process

Sakti Mandal [a++*]

[a] *Sripat Singh College, Jiaganj, Murshidabad, W.B., India.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Hospitals are one of the most important infrastructural objects. The increasing population, especially in developing countries, amplifies the demand for new hospitals. Identifying the best locations for new hospitals is an important issue due to the fact that selecting suitable locations will help the government to optimize the allocation of medical resources, simplify social contradictions and control the health care development in rural and urban areas.

The district Murshidabad is situated in the bank of Padma and Bhagirathi River. Only 135 primary health centers are there, which provide very basic health services and they are randomly located in the district. No emergency health supporting facilities are present in those health centers and some of them are not opened for 24 hours in a day. Even the block primary health center is also very poor to take admissions of serious patients. Most of the times these health centers ask patient-parties to shift the patient Murshidabad medical college hospital. This is a very tuff job for emergency patients. Sometimes, patient-parties fail to shift the patient to a good hospital for very limited ambulance facility.

To solve the problem, it is very necessary to establish new hospitals or improve the services provided by the existing health centers. And as hospitals are one of the most important health

[++] *Assistant Professor of Geography;*
**Corresponding author: E-mail: tomblo.sakti@gmail.com;*

services needed for the whole society, so they must be located in a rational manner so that we can maximize the accessibility of healthcare.
In this paper, we built site suitability analysis for selecting the optimal site for building new hospitals based on using MCA, AHP and Pair wise comparison method.GIS tool and techniques are employed to analyze the list of identified criteria in hospital site selection. These criterion are Population density, Distance from existing health centers, Proximity to road, Distance from railway track, Distance from river, Distance from industrial zones, Proximity to settlement, Proximity to educational institutions, Proximity to rail stations.
The results shows that though suitable areas are scattered over the entire region but most of the suitable areas are situated in the northern part of Murshidabad as national highway and railway enhance the accessibility of the region. And also the result shows that the southern part some area is very unsuitable for building new hospital. And it is also true that some existing hospitals were not built in the suitable place.

Keywords: Multi Criteria Analysis (MCA); Analytical Hierarchy Process (AHP); site suitability analysis; proximity analysis.

1. INTRODUCTION

Hospitals are one of the most important infrastructural objects. The increasing population, especially in developing countries, amplifies the demand for new hospitals. Identifying the best locations for new hospitals is an important issue due to the fact that selecting suitable locations will help the government to optimize the allocation of medical resources, simplify social contradictions and control the health care development in rural and urban areas [1,2]. On the other hand suitable site selection for hospital will help people to reach hospitals easily, reduce the time of rescue and improve the quality of life [3-6].

Murshidabad district is one of the Muslim dominated districts of West Bengal with more than 63% residential Muslim population (District statistical handbook 2014). Murshidabad was the capital of Bengal during the Mughal period and important district town during British India. The district was once the home of Nawabs and royal families are now the house of migrants, rickshaw pullers, agricultural laborers and Masons (Falahi 2009). Now, it is known as one of the eleven districts in West Bengal that presently receiving funds from the Backward Regions Grant Fund Programme (BRGF) (Ministry of Panchayati Raj 2009). The Ministry of Panchayati Raj declared Murshidabad as one of the country's 250 most backward districts out of a total of 640 in India (Ministry of Panchayati Raj 2009). The planning commission, Ministry of Rural Development identified Murshidabad district as a backward district with district rank order of 300 throughout India (Ministry of Rural Development 2014) [7,8]. So, Murshidabad is a backward district and that is the main reason to select it as a study area for analyzing the spatial extension of backwardness [9,10].

Geographical information system (GIS) functions as a common tool for merging multi-criteria to offers spatial result (Malaperdas, G., & Zacharias, N. (2019). Therefore, the present study aimed to apply the GIS technique by assessing spatial data and tool for estimating spatial backwardness of Murshidabad district. To achieve such aim GIS-based Geospatial technique i.e. Analytical Hierarchical Process (AHP) and weight sum model as a multi-criteria decision approach was applied to show the site suitability of hospital in the study area (Akgun & Bullut, 2007; Malaperdas & Zacharias, 2019).

1.1 Research Aims and Objectives

The aim of the article is to assess the location of existing health centers and identifying the potential areas for establishment of new hospitals. To fulfill this aim some objectives have been followed during this research. The objectives of this research are:

i. Evaluation of location of the existing health centres.
ii. Identification of the potential location for developing new hospitals using Analytical Hierarchical Process (AHP).

1.2 Research Question

i. Which of the main Suitable zone of new hospital location?
ii. What are the expected in future and where?

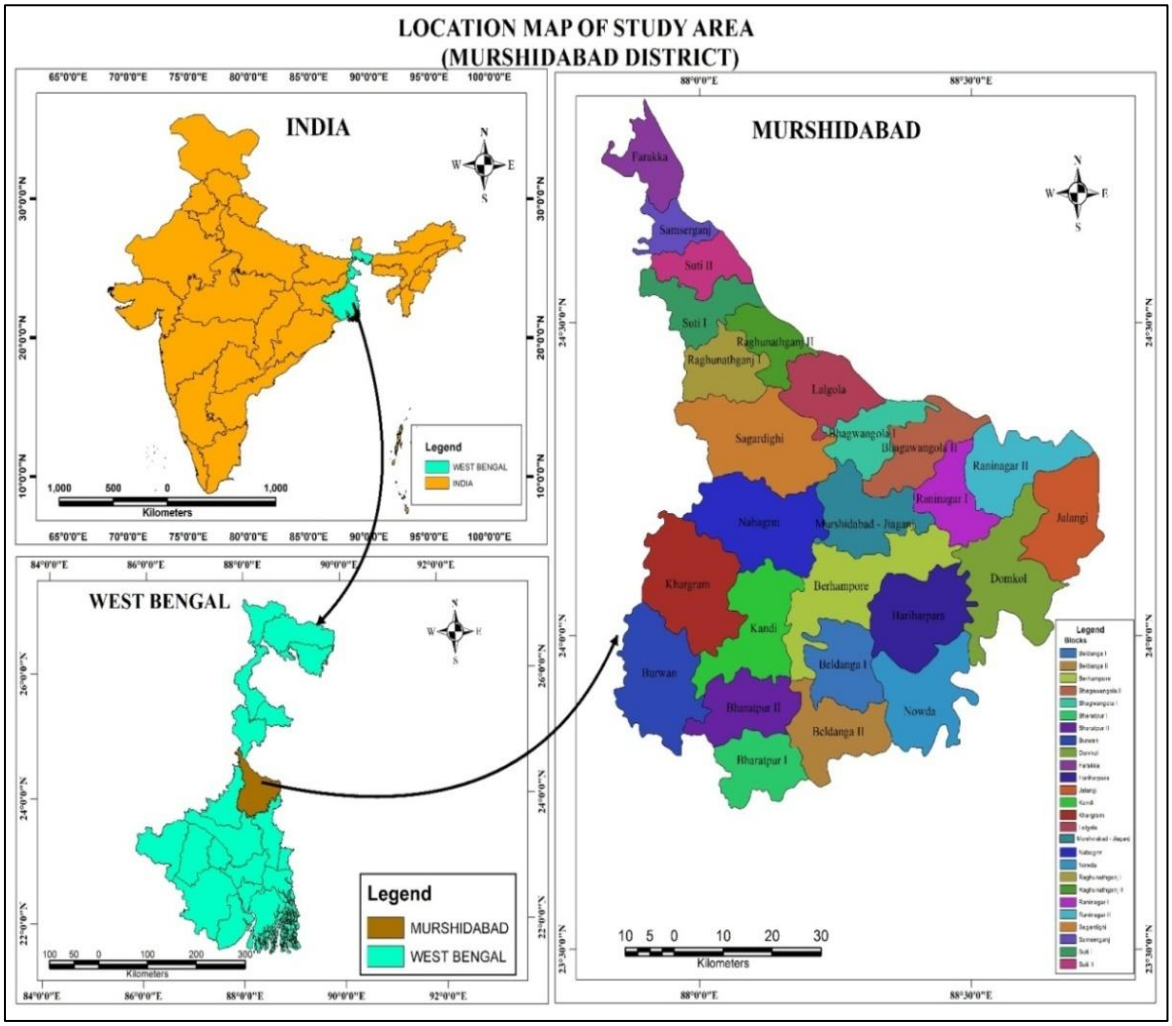

Fig. 1. Location map of the study area

1.3 Study Area

Murshidabad is a community development district in the Indian state of West Bengal. The district is in the middle of west Bengal lying between 23º43'N and 24º52'N latitude 88º44'E longitude with Head Quarter at Berhampore. The district has an area of 5341sq.km. It has 26 block and 1886 village. The river Bhagirathi and river Padma flows through the area. The region has alluvial soil of recent origin (Fig. 1). Maximum temperature of the region during summer is approximately 44^0 C and minimum temperature during the winter is approximately 8^0 C. The average annual temperature is 26.8^0 C. Maximum rainfall occurs during the monsoon season in the month of July, August & September. Average rainfall is 140.8 cm. As per the 2011 Census of India Murshidabad had a total population of 7103807 all of which were rural and urban. There were males 3476243 and 3627564 females. Population below 6 years was 1013392. As per the 2011 census the total number of literates in Murshidabad was 4055834 out of which males numbered 2177187and females numbered 1878647.

2. MATERIALS AND METHODS

2.1 Data and Material Used

Most of the data used for the study are secondary. Only the locational data of existing health centers was recorded during field survey with cell-phone GPS. Population data was collected from Census of India report, 2011. Details of health centers, information about industrial zones (brick-field & rice mill) and educational institutions of the district were collected from Berhampore DM office, BLRO and police station. Road network, railway track network, industrial zones and settlement patches were extracted from Google earth pro map.

Generally, geospatial data are those which have locational information; more elaborately, these are geographic data in the form of location and coordinates. The geospatial data were stored from GPS, Google Earth, satellite imagery and Geo-tagging. The selection, gathering, accumulation, and store of such dataset were due to geospatial analysis (Fig. 2).

2.2 Software Used

Arc Map version 10.8, Erdas Imagine 2015 and QGIS version 3.18.25, Google Earth Pro 10.3, Were used to prepare the data, to analyse image and to map results. Microsoft Excel & Word was used to produce tables, writing, graphs and charts.

2.3 Methodological Orientation

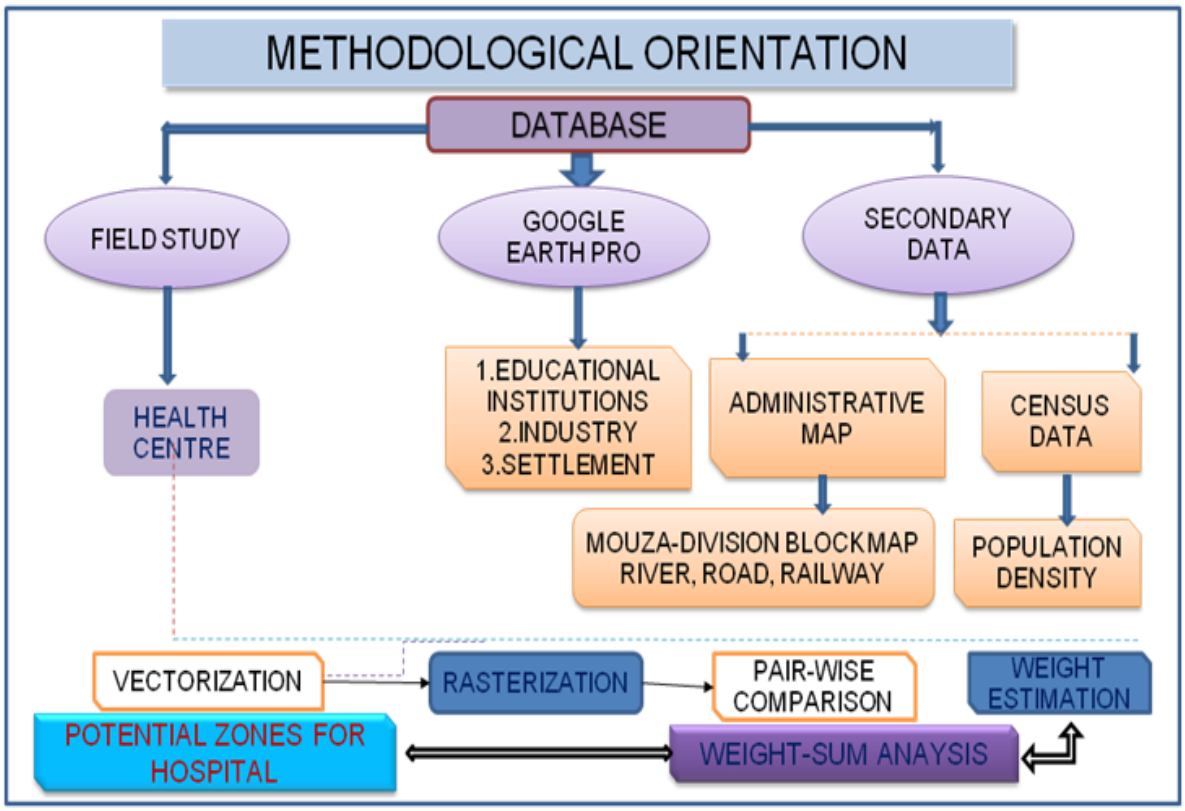

Fig. 2. Methodological orientation

3. RESULTS AND DISCUSSION

Selection of suitable zones to establish new hospital is a very critical process as it depends on many criterion and decisions. Multiple criterions have been adopted to address this issue.

This criterion are- Population density, Distance from existing health centres, Proximity to road, Distance from railway track, Distance from river, Distance from industrial zones, Proximity to settlement, Proximity to educational institutions, Proximity to rail stations.

3.1 Population Density

Population density has been calculated by dividing the number of people who settled in every block by the area of that unit. Accordingly, more populated areas got higher priority compared other areas. The raw score of population density has been standardized from 0 to 1. The result is Fig. 3.

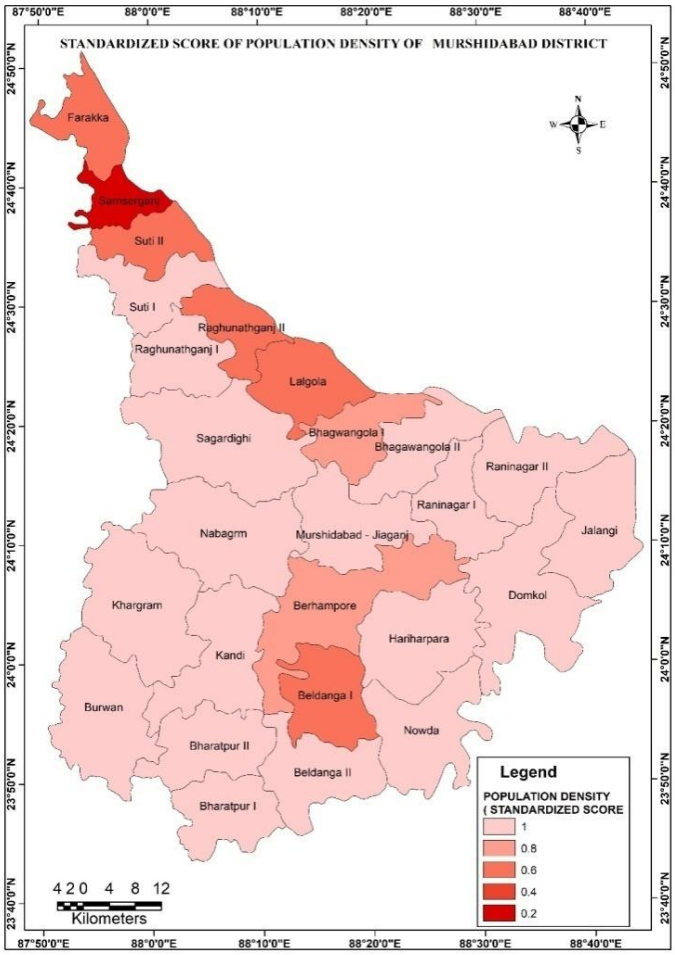

Fig. 3. Standardized score of population density of the study area

3.2 Distances from Existing Health Centre

In order to establish new hospitals in a rational manner we should not allocate them in a close distance to each other. If we do so it will minimize the potentiality of the hospitals. On the other hand if we allocate the away from the existing health centers patients from every parts of the CD -block can access the hospitals easily. So, those regions which are far away from the existing health centres will get more priority. The raw score of distance from health centre has been standardized from 0 to 1 (Figs. 4 & 5).

3.3 Proximity to Road

Hospitals should be located in a closer distance to road. Because, it will be easier to the patients to reach hospital. But we also should keep in mind the problem of noise pollution. Closer distance to road means more noise and unwanted sounds of vehicles. So, a distance of 3 km from the roads is not suitable for hospital allocation. But, after the buffer of 3 km the region will get highest priority to allocate hospitals. The raw score of distance from road has been standardized from 0 to 1.2 km buffer around roads is assigned 0 as this region is not suitable to allocate hospital (Figs. 6 & 7).

3.4 Distances from Railway Track

Hospitals should be allocated by maintaining a safe distance from 5 km meter to railway track. Because, the rail service has produces loud noise. The raw score of distance from railway track has been standardized from 0 to 1.5 meters buffer area around railway is assigned 0 as this region is not suitable to allocate hospital and the rest of the area is assigned with 1 as this region is free from noise pollution produced by rail service (Fig. 8 & 9).

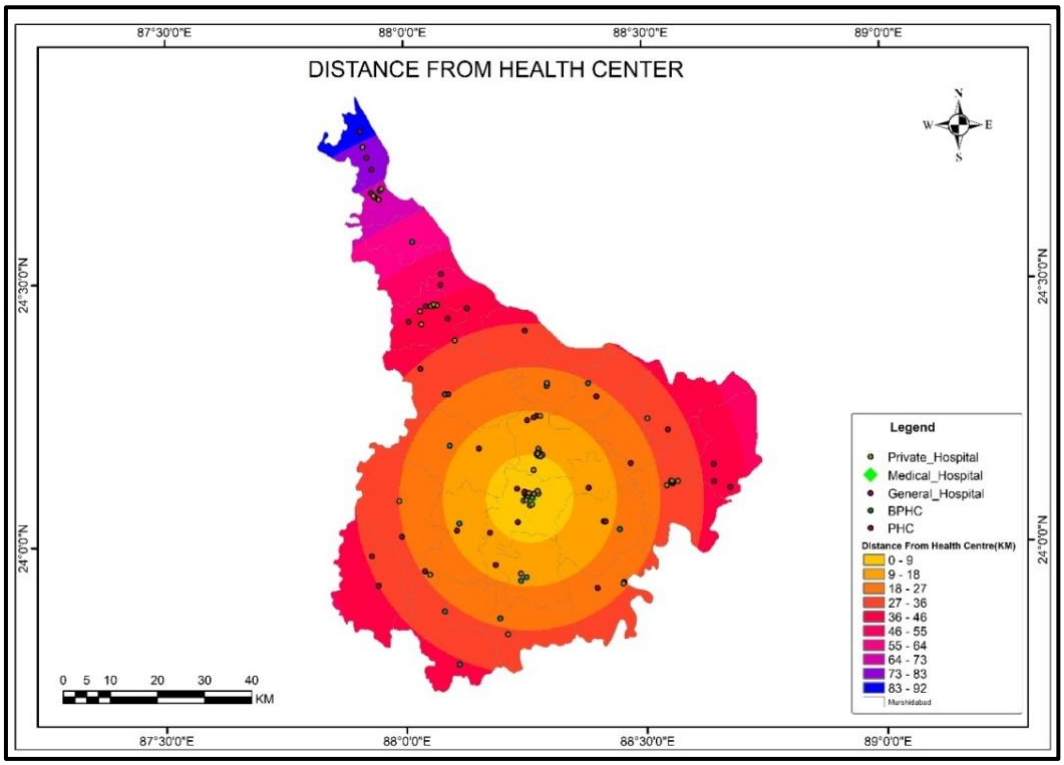

Fig. 4. Distances from health center of study area

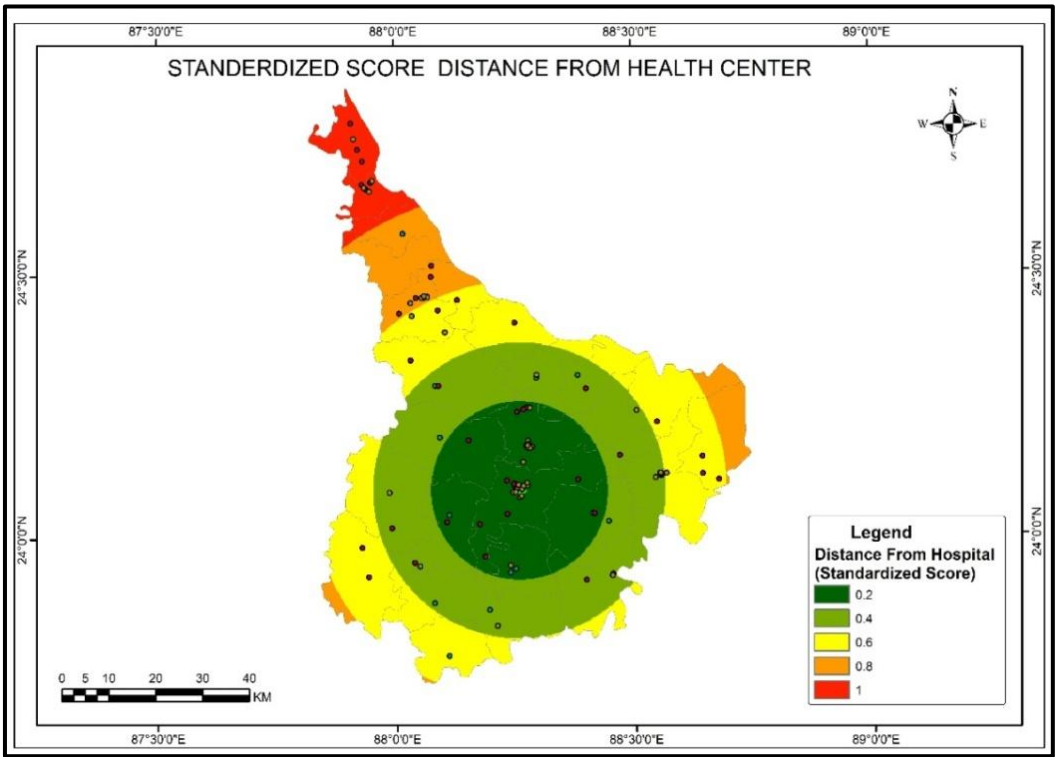

Fig. 5. Standardized score distances from health center

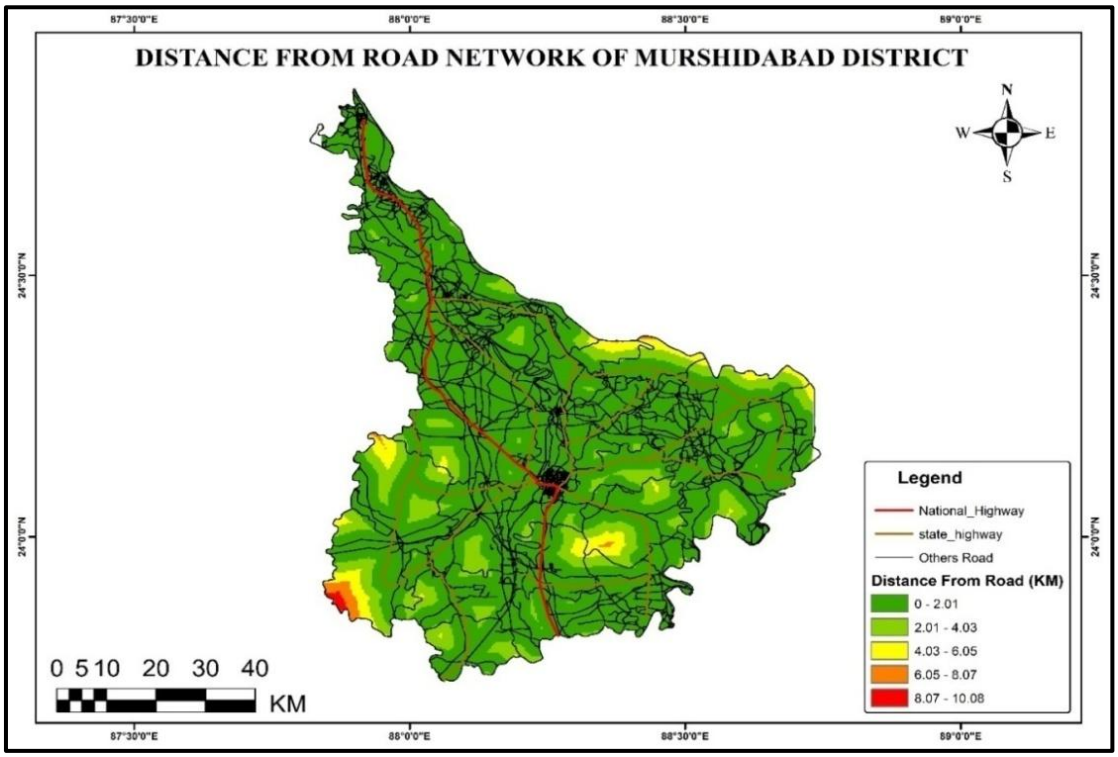

Fig. 6. Distances from road network of study area

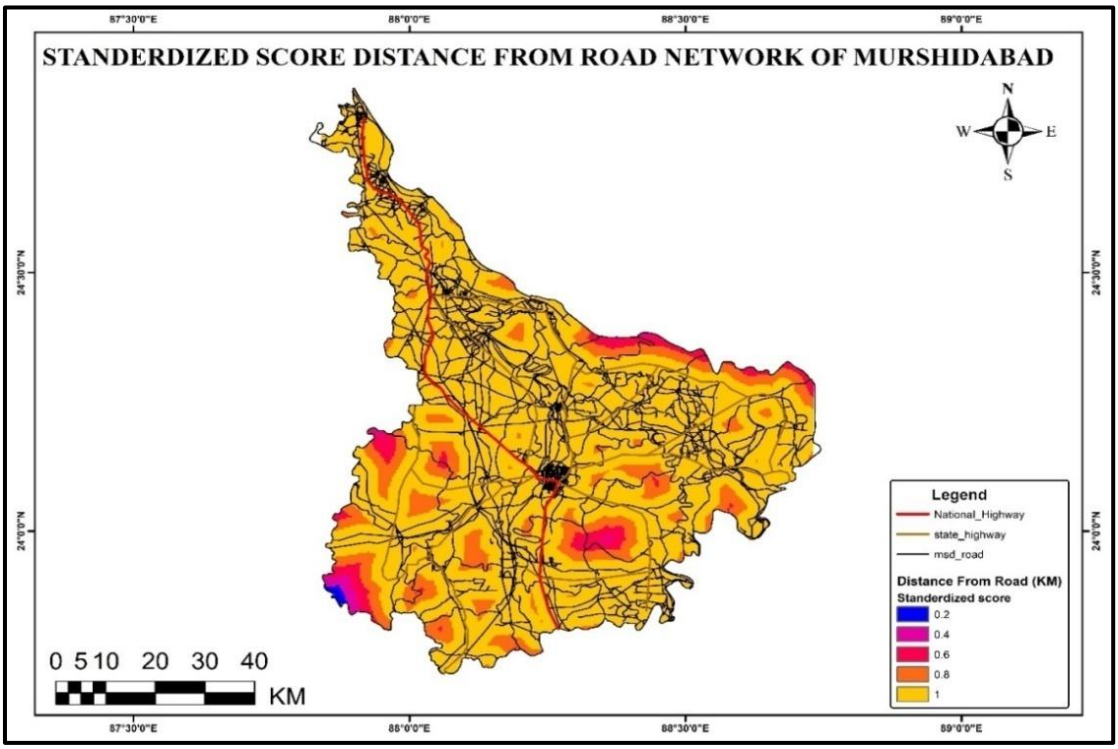

Fig. 7. Standardized score distances from road network

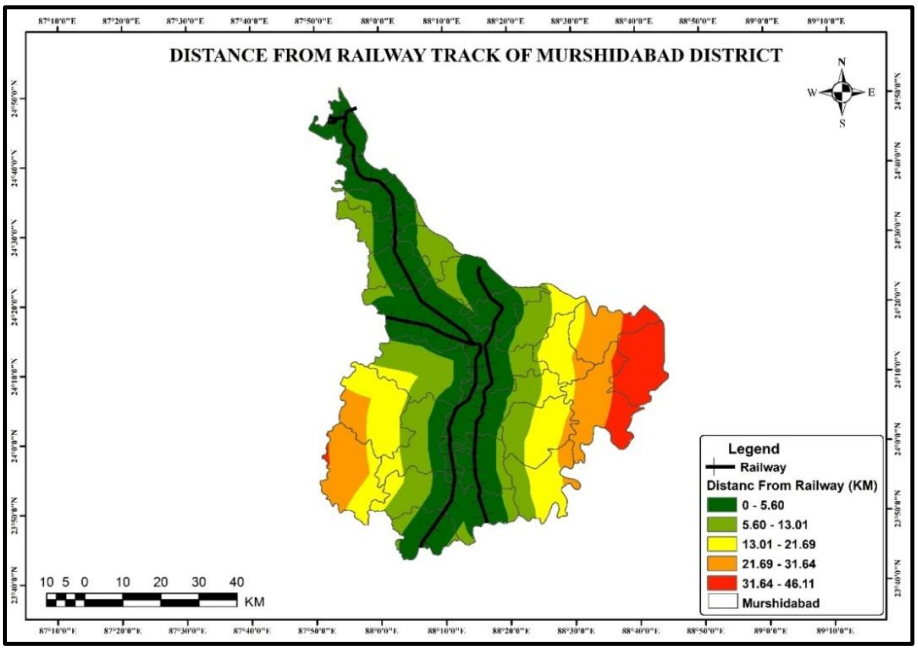

Fig. 8. Distances form railway track of the study area

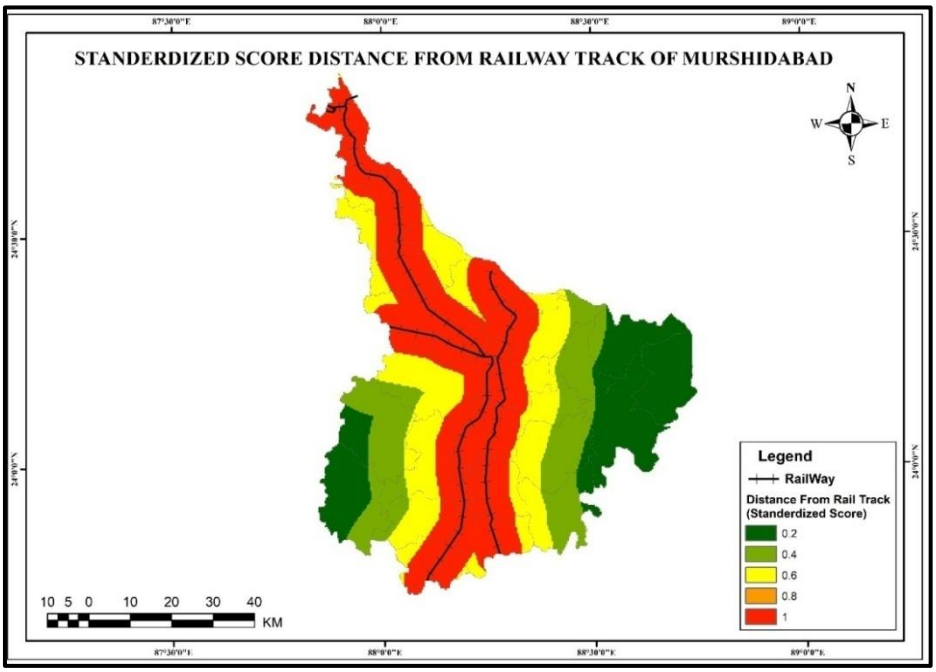

Fig. 9. Standardized score distances from railway track

3.5 Distances from Industrial Zones

There are many brick fields and private shops in murshidabad. They pollute the environment in various ways. They emit a lot of smoke and small dust particles during production, which cause air pollution. Hospitals should not be located in a closer distance to these industries. The raw score of distance from industry has been standardized from 0 to 1.2 meters buffer are around industry is assigned 0 as this region is not suitable to allocate hospital and the rest of the area is assigned with 1 as this region is almost free from pollution produced by industry (Figs. 10 & 11).

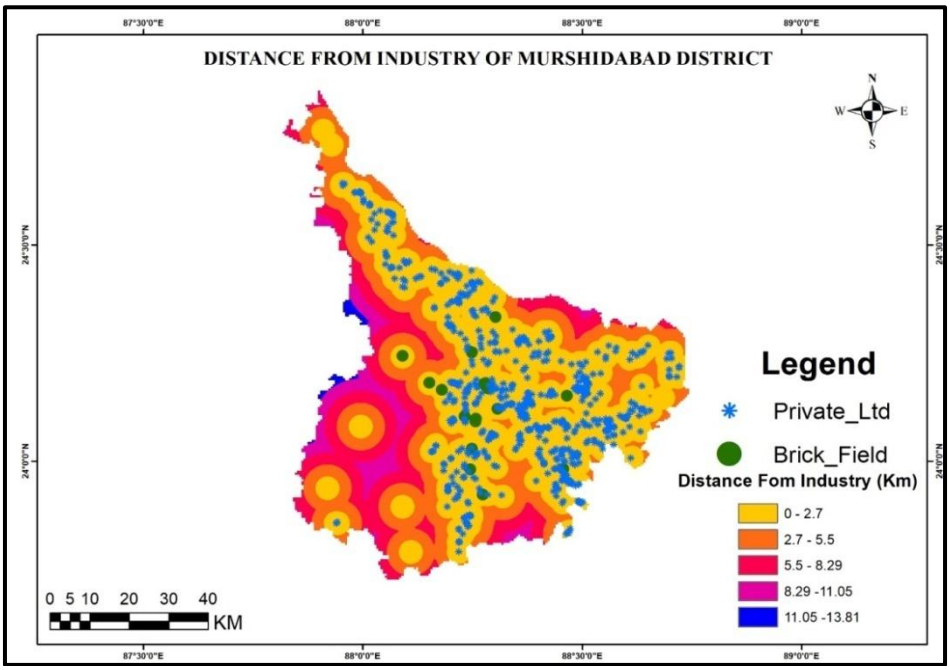

Fig. 10. Distances from Industry of the study area

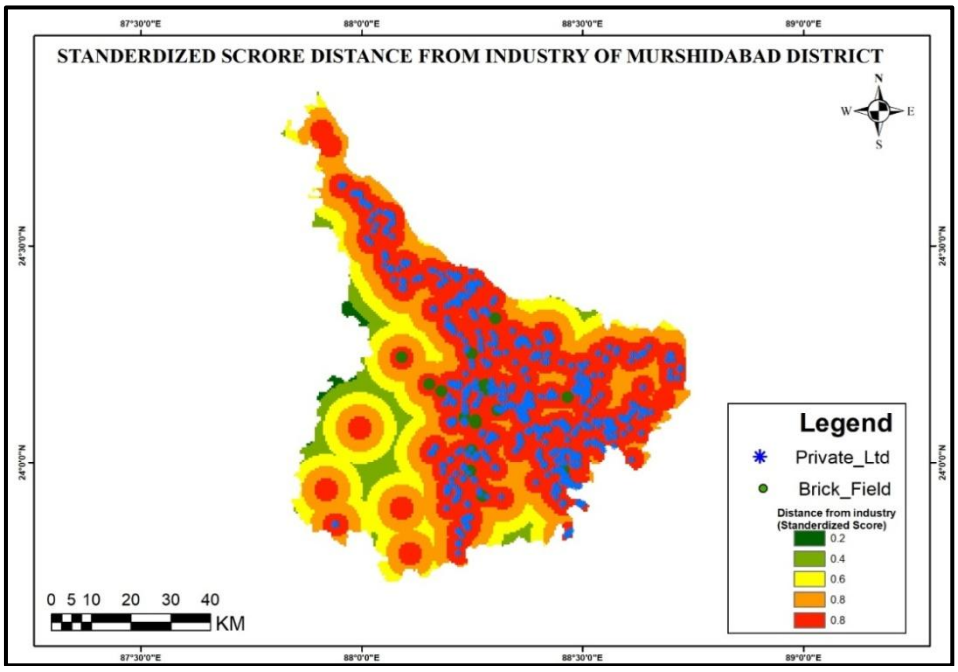

Fig. 11. Standardized score distances from industry

3.6 Proximity to Settlement

Hospitals should be located in a close distance to settlement, so that patients can be transferred to the hospital quickly in emergency. But we should also maintain a safe distance of approximately 100 meters to avoid the problem of contamination and infectious diseases. The raw scores of distance from settlement has been standardized from 0 to 1. 100 meters buffer area around settlement patch is assigned 0 as this region is not suitable to allocate hospital (Figs. 12, 13 & 14).

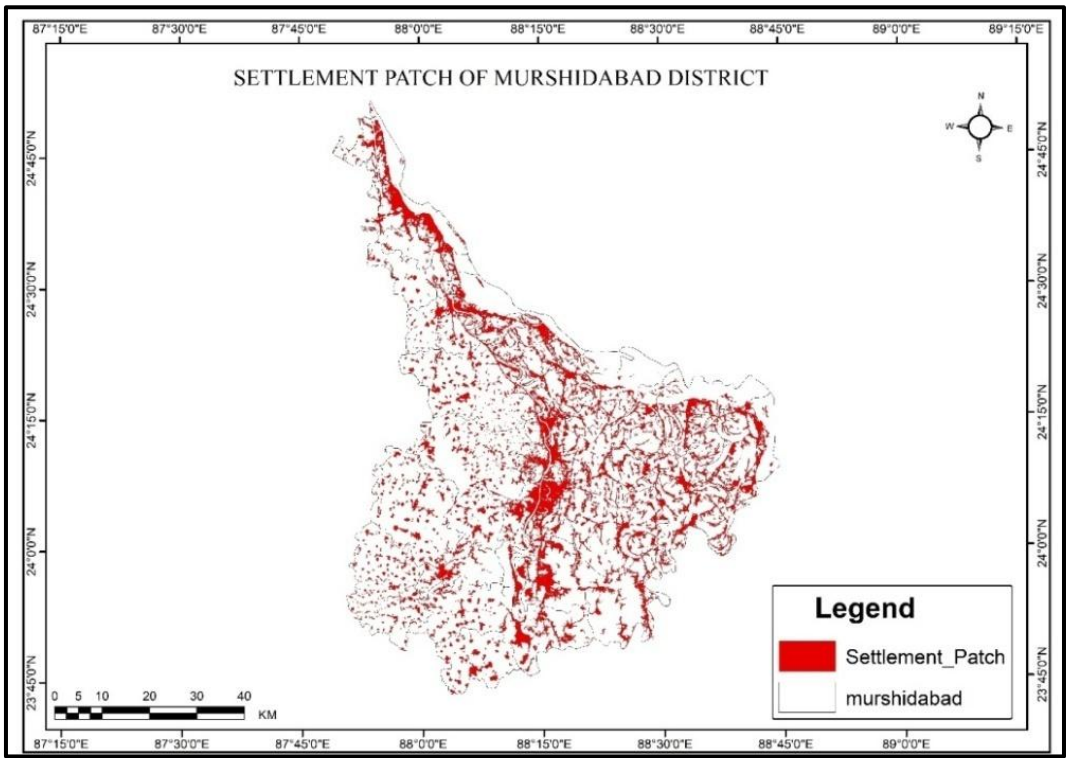

Fig. 12. Settlement patch of the study area

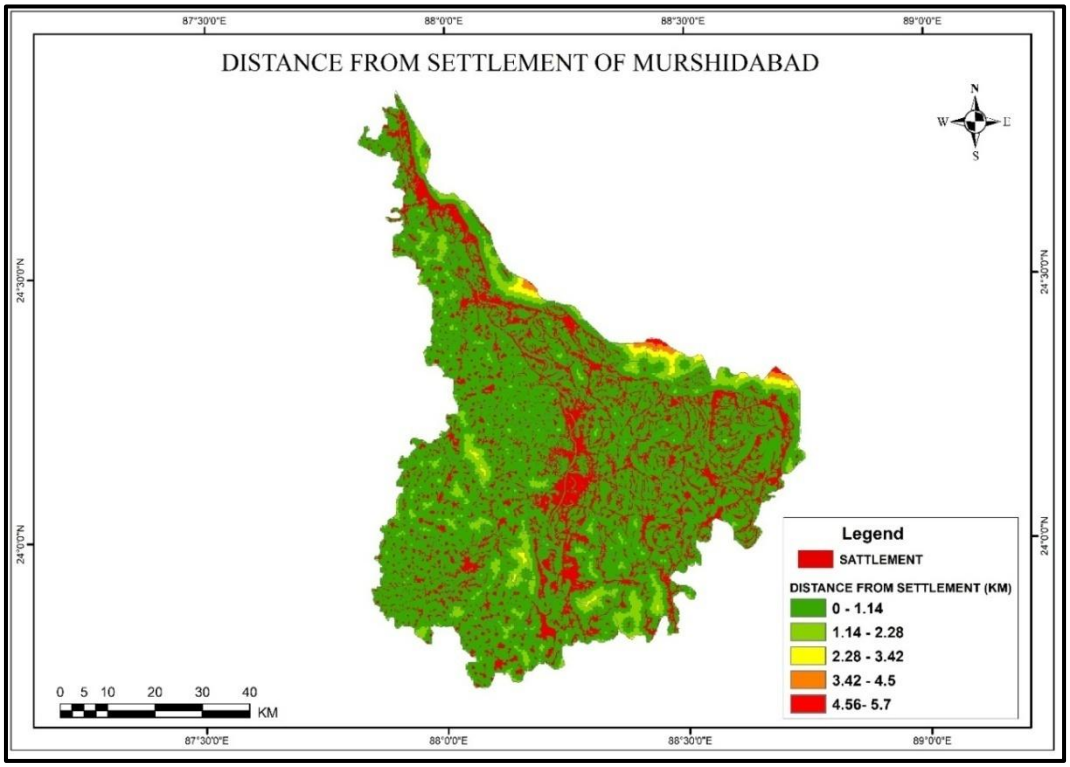

Fig. 13. Distances from settlement of the study area

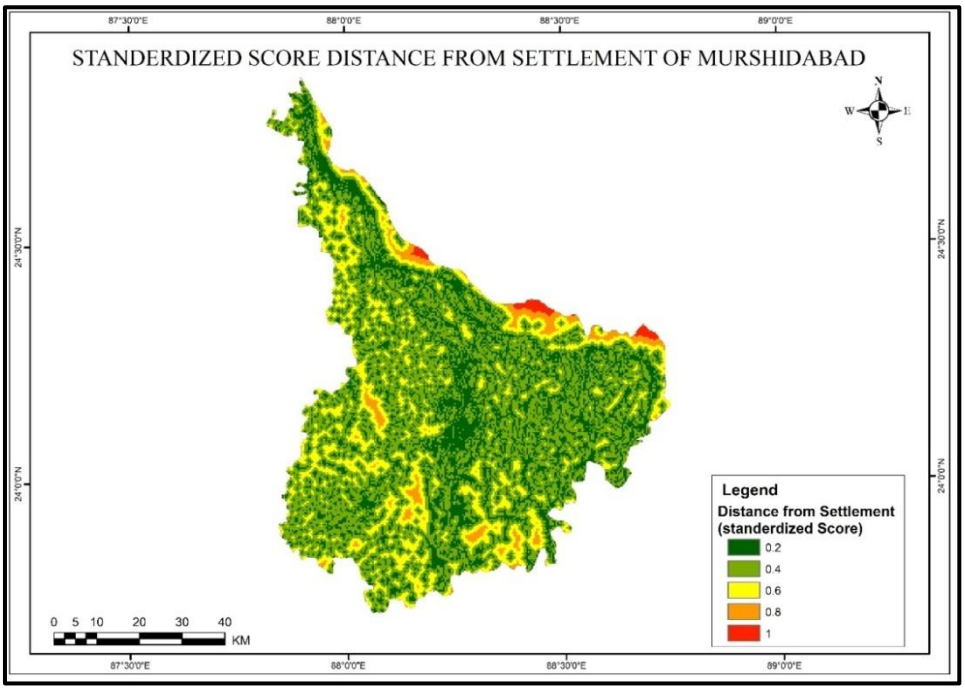

Fig. 14. Standardized score of distances from settlement

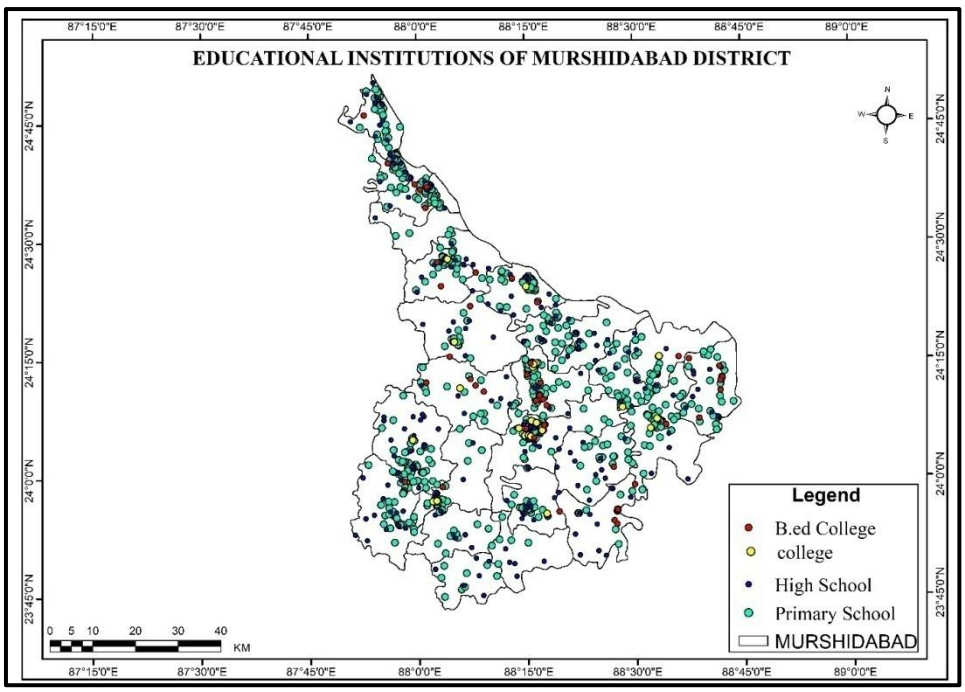

Fig. 15. Spatial pattern of educational institutions of the study area

3.7 Proximity to Educational Institutions

Hospitals should be located by keeping a safe distance of 100 meters from educational institutions to reduce the problem of infectious diseases and contamination. Because, a lot of people gathering in these places. So the most suitable area to construct new hospital is the surroundings of 100 meters buffer region around educational institution.

The raw score of distance from educational institutions has been standardized from 0 to 1.200 meters buffer area around institution is assigned 0 as this region is not suitable to allocate hospital (Figs. 15, 16 & 17).

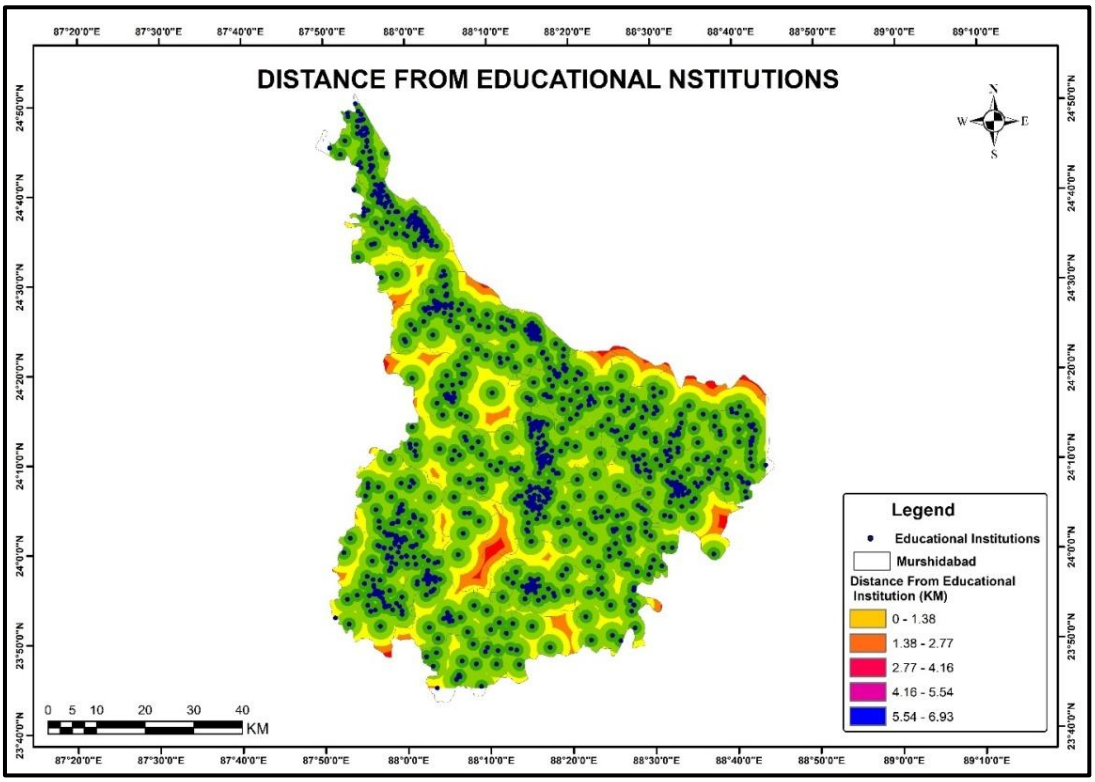

Fig. 16. Distances from educational institutions of the study area

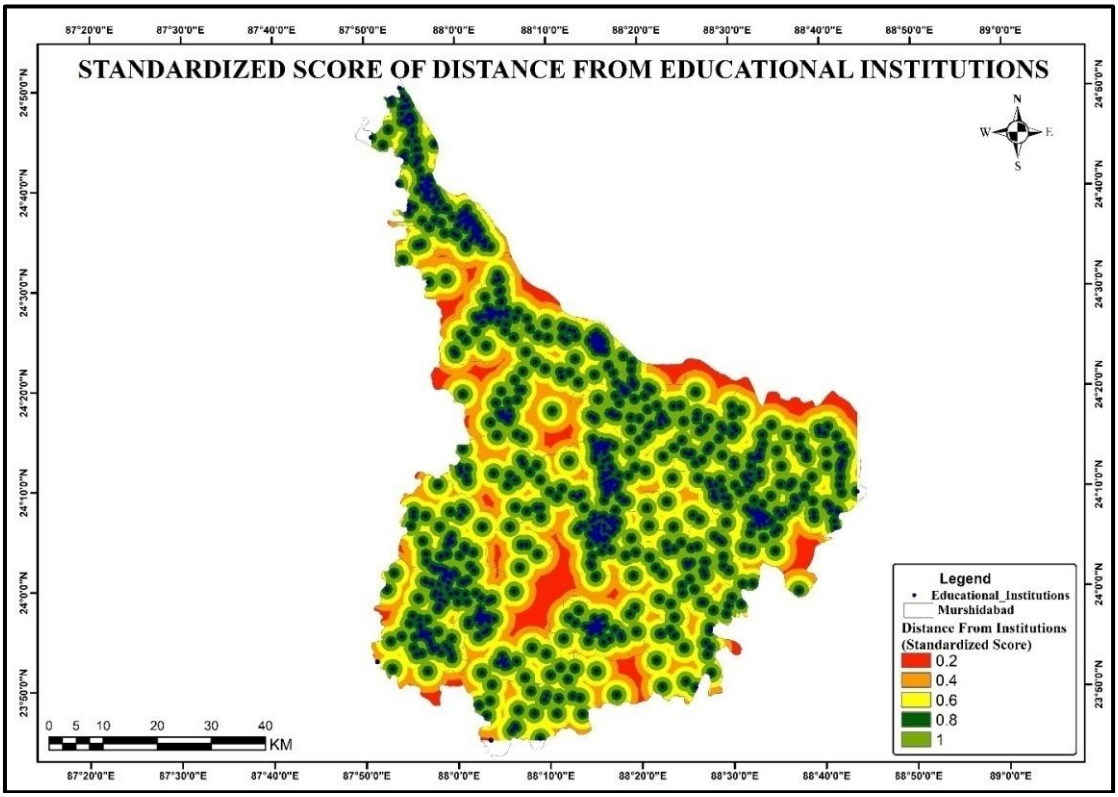

Fig. 17. Standardized score of distances from educational institutions

3.8 Proximity to Rail Stations

We should allocate the location for hospital construction near to railway station, as this will increase the level of accessibility of hospitals and maximize the quality of health care. However, a safe distance of 600 meters should be maintained to reduce the effect of noise pollution produced by rail services. The raw score of distance from rail station has been standardized from 0 to 1.6 meters buffer area around stations is assigned 0 as this region is not suitable to allocate hospital (Figs. 18 & 19).

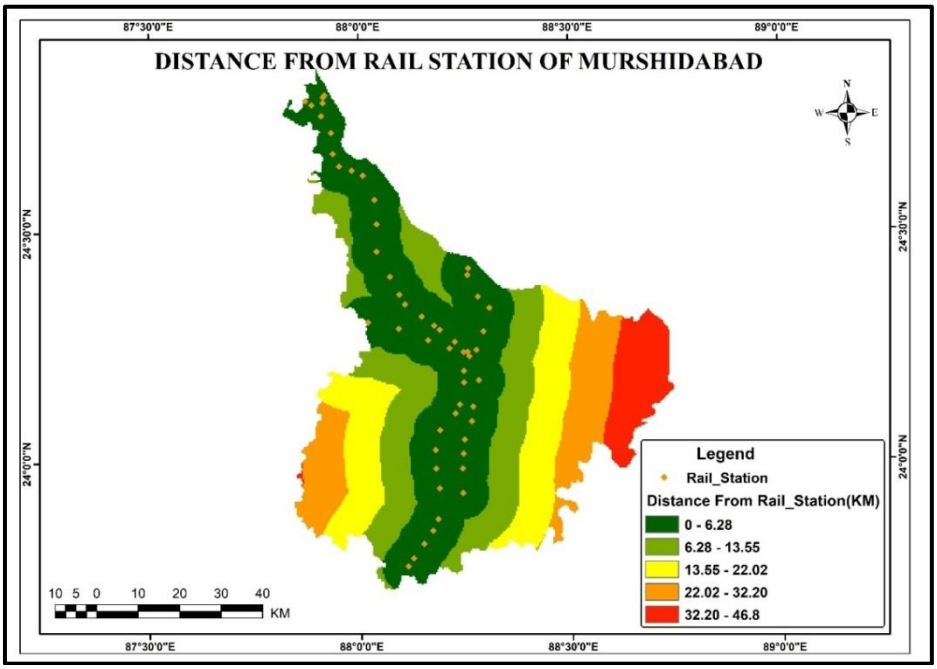

Fig. 18. Distances from railway station of the study area

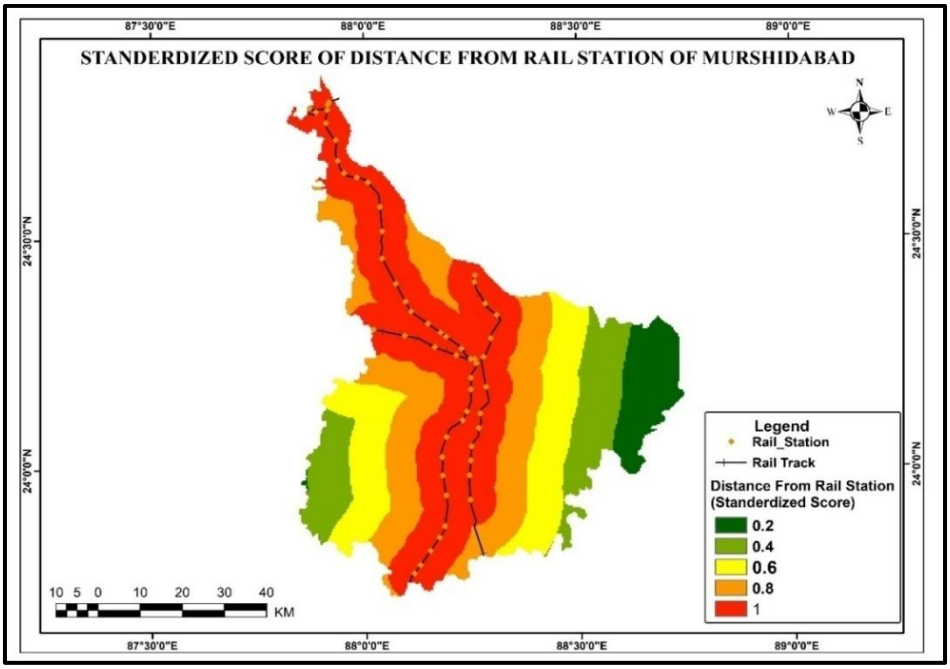

Fig. 19. Standardized score of distances from railway stations

Table 1. Major index values

Lambda	**9.72**
Inconsistency (lambda-N)	2.72
Consistency Index(CI)	0.45
Consistency ratio(CR)	0.06

Table 2. Pair-wise comparison matrix

Criterion	**Population density**	**Distance from Health Centre**	**Proximity To Road**	**Distance From Industry**	**Proximity To Settlement**	**Proximity To Educational Institute**	**Proximity To Rail Station**
Population density	1.000	9.000	8.000	6.000	6.000	7	8
Distance from Health Centre	0.111	1.000	7.000	6.000	5.000	6	4
Proximity To Road	0.125	0.143	1.000	5.000	6.000	7	3
Distance From Industry	0.167	0.333	0.200	1.000	6.000	5	4
Proximity To Settlement	0.167	0.200	0.167	0.167	1.000	3	4
Proximity To Educational Institute	0.143	0.167	0.167	0.200	0.333	1	2
Proximity To Rail Station	0.125	0.250	0.333	0.250	0.250	0.5	1
Total	**1.837**	**11.093**	**16.867**	**16.617**	**24.583**	**29.5**	**26**

Table 3. Normalized pair-wise comparison matrix & relative weight estimate

Criterion	Pop. density	Dist. from Health Centre	Proximity To Road	Dist..From Industry	Prox.. To Settlement	Prox.. To Educational Institute	Prox.. To Rail Station	SUM	Relative weight
Population density	0.544	0.811	0.475	0.384	0.244	0.237	0.308	3.004	0.429
Distance from Health Centre	0.060	0.090	0.416	0.192	0.203	0.203	0.154	1.319	0.188
Proximity To Road	0.068	0.013	0.059	0.321	0.244	0.237	0.115	1.058	0.151
Distance From Industry	0.091	0.030	0.012	0.064	0.244	0.169	0.154	0.764	0.109
Prox.. To Settlement	0.091	0.018	0.010	0.010	0.041	0.102	0.154	0.425	0.061
Prox..To Educational Institute	0.078	0.015	0.010	0.010	0.014	0.034	0.077	0.237	0.034
Prox..To Rail Station	0.068	0.023	0.020	0.020	0.010	0.017	0.038	0.196	0.028
Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table 4. Estimation of consistancy vector

Criterion	Pop. density	Dist. from Health Centre	Proximity To Road	Dist. From Industry	Prox. To Sett.	Prox. To Edu.l Institute	Prox. To Rail Station	Total	Consistancy vectore
Pop. density	0.429	1.696	1.209	0.655	0.364	0.237	0.224	4.814	11.217
Dist. from Health Centre	0.048	0.188	1.058	0.655	0.303	0.203	0.112	2.567	13.625
Proximity To Road	0.054	0.022	0.151	0.546	0.364	0.169	0.084	1.389	9.194
Distance From Industry	0.072	0.063	0.030	0.109	0.364	0.169	0.112	0.919	8.417
Prox. To Settlement	0.072	0.038	0.025	0.018	0.167	0.102	0.112	0.533	8.775
Prox. To Edu. Institute	0.061	0.031	0.025	0.022	0.036	0.034	0.056	0.266	7.856
Prox. To Rail Station	0.054	0.047	0.050	0.027	0.027	0.017	0.028	0.251	8.964

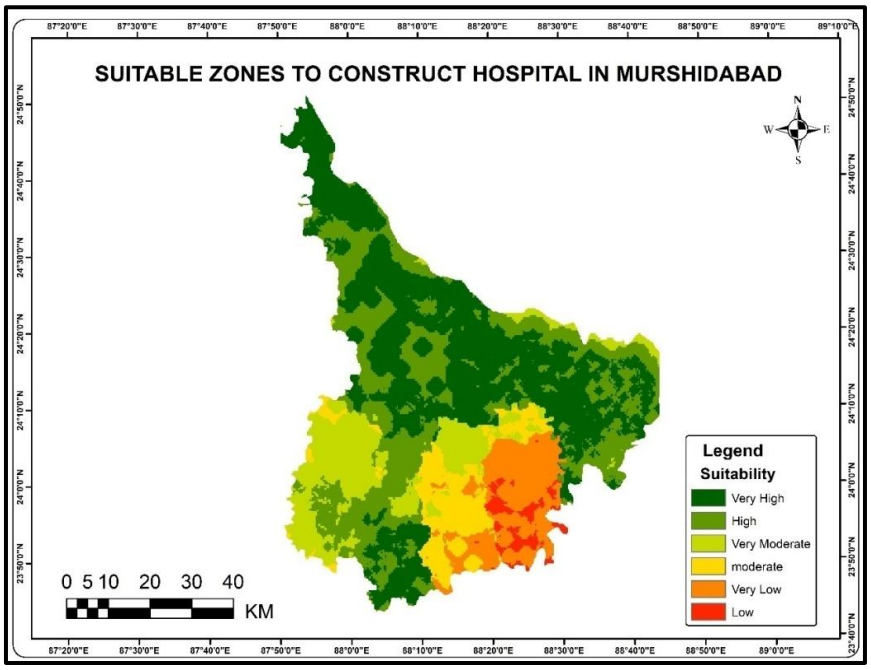

Fig. 20. Suitable site for construction of new hospitals in the study area

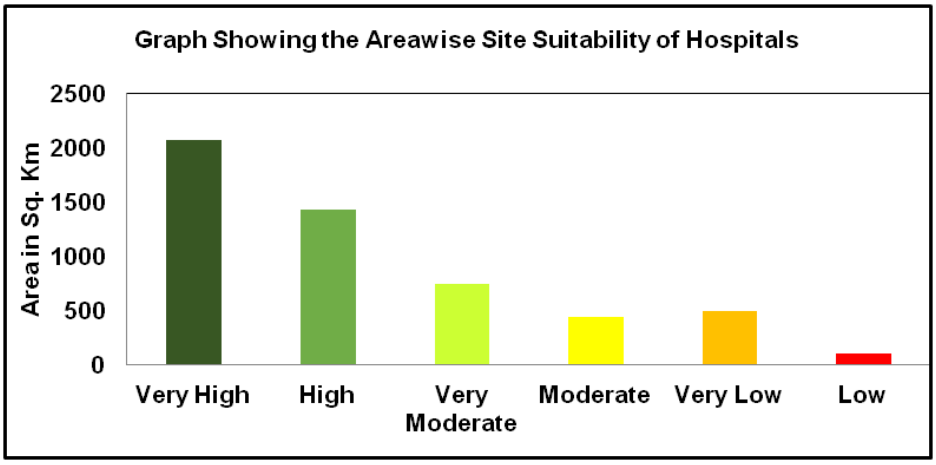

Fig. 21. Area-wise suitable site of new hospitals in the study area

3.9 Site Suitability Analysis to Establish New Hospital

Review of the literature revealed 9 criteria, including population density, distance from existing health centers, proximity to the main roads, being far from railway track, not being located near to river, being far from industrial centers, proximity to educational institution & settlement and being close to rail station. Site suitability analysis has been done by using Analytical hierarchy process (AHP) and Pair wise comparison method. The results of calculating the criteria's weights have been presented in the Tables 2, 3 & 4. As the table depicts, the calculated Consistency Ratio CR is less than 0.1.Therefore, there is no need for revising the comparison matrix.

In the Figs. 20 & 21 the potential zones to establish new hospitals have been shown. This map has been classified into five major zones i.e. very high, high, very moderate, moderate, low and very low suitability zones. Very high, high, moderate, low and very low zones are covering 2067.24, 1425, 747.64, 435, 495, and 97.55 sq.km are respectively.

Most of the least important areas to establish new hospital are situated in the Eastern part of

the study area. The low suitable zones in the Eastern part of murshidabad are situated in a far distance from settlement. The northern part of the study area is highly suitable because of good road network and railway service.

4. CONCLUSION

In this article, we built a suitability model for selecting the optimal site for building new hospitals based on coupling GIS-based MCA and AHP. GIS tool and techniques are employed to analyze the list of identified criteria in hospital site selection. The analysis process incorporates assigning weights for the identified criteria based on AHP. And at the end of the analysis process, the optimal site for building new hospitals is identified. The results shows that though suitable areas are scattered over the entire region but most of the suitable areas are situated in the northern part of murshidabad as national highway and railway enhance the accessibility of the region. And also the result shows that the southern part of some area is very unsuitable for building new hospital. And it is also true that some existing hospitals were not built in the suitable place.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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