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RESEARCH PAPER

Modeling fire station establishment of industrial area using geo-spatial science

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Abstract

Fire stations have to be situated carefully; in an emergency situation, the fire department should be able to reach its destination within time. The study exasperated to integrate Analytical Hierarchy Process (AHP) with Weighted Overlay analysis (WOA) in GIS to present a model for fire station location planning. The case study is carried out in the Asansol Sadar Subdivision of Paschim Bardhaman District, West Bengal, India. The study shows that there are 364.569 km^2 of High-Risk Areas (most congested Settlements, industrial areas, and Coal Mining), 59.62 km^2 of Moderate Risk, and 422.348 km^2 of Low Risk. The results of this research introduce five sites that are most appropriate for establishing the new stations, which cover all the areas based on the fire response time, rules, and regulations. This analytical process considered densely populated shares of the cities and also the industrial neighborhoods in the Jamuria, Kulti – Barakar, Burnpur, Chittaranjan, and Churulia as mostly suitable zones for the new fire departments. The major advantages of the new proposed sites are accessibility to the accident-prone areas as per response time, setting in the most populated area of the zone, and the high potential for interventions, which can reduce the risk and loss of life and wealth.

Keywords: Fire hazards and safety; Site selection of Fire stations; Geographic Information Systems (GIS); Analytical Hierarchy Process (AHP).

1. Introduction

Fire stations are one of the significant and the dynamic land uses in the urban areas that have to assurance the life and safety of urban residents. With the increasing level of the urban growth especially in the Asansol and its suburbs some of the urban zones challenged shortages of urban amenities like fire stations. Many variables, including staffing, training and equipment, are considered in determining whether coverage is adequate. Location selection of fire stations is a crucial decision for decision makers of industrial areas due to the potential risk of fires and the potential danger to society [1]–[3]. Accordingly, city governors or decision-makers must take precautions against fires or service fire areas in minimum time to avoid being in such a rough situation [4], [5]. Thus, decision-makers should minimize the risks by the increasing of the importance level of fire station positions which attracts researchers' interest in the emergency location selection. Fire location selection is a subtopic of the emergency service location selection and there are numerous studies for the selecting optimum fire station location [6]–[10]. Most researchers chose to create the response area as a straight-line or Euclidean buffer rather than a network buffer because of computation time [8] or since the necessary network datasets were unavailable [11]. There are numerous approaches and lots of the problem types in location science to determine the most proper location in alternatives. Nevertheless, many of these location selections are done by simple analysis in terms of rudimentary calculation, past experience, or even predilection. Taking the advantage of information technology, the Geographic Information Systems (GIS) enable the management of both spatial and non-spatial data, leading to its specific roles in data management and integration, data query and analysis, and data visualization [12], [13]. The number and location of fire stations in a community are usually based on the distance between stations, the population served, and the hazards at particular locations [14]. During the past few decades, the Asansol industrial areas and its surrounding areas have experienced population growth, increased residential housing, and expansion in the commercial business and retail sales sector, and of course, being an industrial zone, many industries have set up in Asansol Sub Division [15]–[17]. Many researchers were applied AHP, MCDA and WOA approaches for the decision making purpose and analysis the appropriate location for highly suitable locations of the earth's surface like fire station hospital sites, groundwater, agricultural lands and many more [3], [18]–[20].

Only the GIS can help prioritize alternative site positions and measure the expected performance of the new fire stations. At this time GIS is the maximum important application for the site selection. Everyone knows that selecting an appropriate location is measured an important decision since poor site selection would be costly and hard to reverse. An inaccurate choice can lead to higher transportation costs and loss of the qualified labor. This study area targets that the problems of fire hazard zones and how to recuperate this problem. ArcGIS software has been applied to build a geo-database that covers all of the collected data for this application. Five recommended locations for the new fire station location were successfully determined through using GIS as a tool for decision-making. There is a growing body of literature that is advancing the use of GIS as a part of a multi-participant, multi-criteria framework that takes into account multiple views and consensus [1], [13], [18], [21], [22]. Some researchers used AHP in conjunction with GIS in order to find suitable sites for the landfill for an island in Greece using 10 suitability criteria taking into account both environmental and social variables and individual site constraints [23]. Again the relative importance of the criteria was assessed by experts-in this instance, the scientific advisors responsible for the sitting study. Although the study showed the benefits of MCDA- GIS approaches, the final site was selected on the basis of local non-quantifiable factors such as public opposition highlighting the potential to incorporate public opinion from the outset. Another research group developed spatial modeling procedures for an MCDM analysis using compromise programming (Co-Pr) integrated with a raster GIS [24]. Five sets of information, as noted above, are used to undertake an optimal spatial decision analysis for land use planning purposes. As the analysis deals with conflicting objectives (minimizing and maximizing) in a spatial context, a Co-Pr technique is used and integrated with a raster GIS in the assessment procedures. It often reaches the ears that the fire brigade comes when the house is fully burnt.

Integrating multiple disciplines results in finding a better solution since it uses a wide range of perspectives and analyses more criteria than a single approach and this increases the certainty of the study. In this study, GIS and multi-objective mathematical modeling were selected for determining the optimum solution. Spatial analysis and network analysis were used in GIS to find the attractiveness values of grids and to find the coverage table of alternatives respectively. Mathematical modeling is the other technique that was used for finding the best solution integrated with GIS analysis. The results of GIS analysis were accepted as input for the mathematical model, and the model was built on these inputs. To find the optimum solution, the model was built as a multi-objective model; since there is more than one objective. The objectives of the study are minimizing the total cost and maximizing the total coverage. Identify the fire station using AHP, MCDA, and GIS methods. The ultimate goal is for the station to increase its services in other region. The stations objectives are important for the community since the people can benefit from the wide range of services that will ensure less property destruction from fires. Also, there will be a quick response to hospital emergencies, harmful material accidents, abnormal disasters, and other situations that require emergency response.

2. Materials and Methods

2.1 Study area

The spatial extension of the study area is present between $2341'30''N$ to $2353'30''$ N and $8647'41''$ E to $8714'04''$ E (Figure 1). Asansol subdivision has 4 community development blocks, 4 Panchayat Samitis, 35 Gram Panchayats, 181 Mouzas, 165 inhabited villages, and 1 municipal corporation – Asansol Municipal Corporation (AMC). Asansol Sadar Subdivision is the Administrative Subdivision of Paschim Bardhaman District in the state West Bengal, India. It lies between the Ajay-Damodar River Basin. It is the part of the extended Chota Nagpur Pleatu Region. Asansol sub-division is lying on the Western part of the Asansol Durgapur Planning Area (ADPA). It occupies 831.89 km^2 areas and had a population of 16.72 lakhs in 2011, having $2000/km^2$ Population Density. The test area is experienced by tropical monsoon climate with high temperatures in the summer and dry winter season. The average rainfall in this area is 1408 mm. Situated within Paschim Bardhaman Division, Asansol Sadar subdivision is surrounded by the two mighty rivers; the Damodar River and the Ajay River. It is bordered by the district of Dhanbad (of Jharkhand) on the west. On the eastern side lies the Durgapur sub division of Paschim Bardhaman districts. The region is bounded on the north by the Dumka (of Jharkhand), Birbhum and Murshidabad districts. To the south, lies the Hooghly, Purulia and Bankura district, across the Damodar River. Asansol Sadar Suvdivision experiences on the whole, four main seasons: Summer, Autumn, Monsoon and Winter. Asansol's climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. According to Köppen and Geiger, this climate is classified as Cwa. The temperature here averages 25.3 °C | 77.6 °F. In a year, the rainfall is 1294 mm | 50.9 inch.

2.2 Data used

The remotely sensed data sets were derived from the USGS earth explorer website for data download (https://earthexplorer.usgs.gov/). One satellite data were used for this study (Path 138 and row 044). 2021 Landsat TM OLI/TIRS data were used to identify the land use and land cover of the study area. SRTM Cartosat DEM data of 2014 data were used to generate Elevation, Slope and Aspect map. Google Earth Pro and Survey of India Toposheet were used to delineate communication and existing fire station map. At first toposheet map was geo-referenced in ArcGIS 10.8 Software. Then create road and rail line layer by polyline (Table 1).

Table 1: *The details about data sources used in this study*

Data Type	Data source	Time Period	Spatial data or Map
SRTM DEM	USGS Earth Explorer	2014	Slope, Elevation, Aspect
Landsat 4-5, 7 & 8 LISS-III	(https://earthexplorer.usgs.gov/)	3rd November 2021	LULC
Toposheet (73M/1)	Survey Of India	2005 - 2006	LULC, Communication, Water body

2.3 GIS analysis

To illustrate the fire stations position site selection approach, a case study was carried out using the Asansol Sadar Subdivision geo-database in the GIS environment, ArcGIS 10.8 which is an integrated family of GIS software products for building a complete GIS. The fundamental application tools in the ArcGIS Desktop are designing and building geographic databases, creating geographical analysis, making maps and performing geo-processing. Some of the layers of the Asansol Sadar

Subdivision geo-database were used for fire station location selection. These layers are soil types (formations), hydrographic objects, major and arterial roads, residential streets, railroads, residence and industrial buildings, hospitals, fire stations, educational buildings (elementary school, high school and university) and cultural facilities (cinema, theatre etc.).

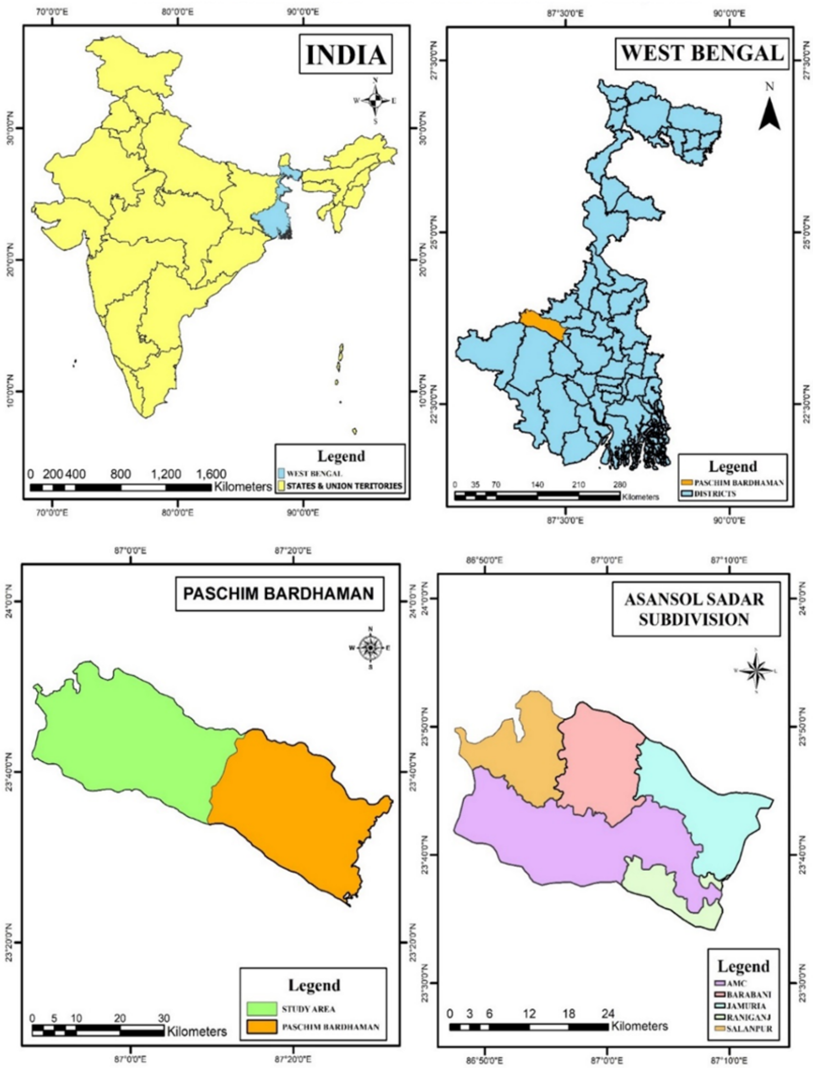


Figure 1: *Locational map of Asansol sub-division.*

2.3.1 Slope

Asansol Sadar Subdivision have positioned in the Ajoy & Damodar river basin. The study area is highly flood plain and low elevation region. The figure 2 showing the study areas slope complaint. The increasingly high values indicate the increasing high slope and low value indicate low slope condition of the study area. In steeper slopes, the intensity of heat generated and the rate of advancement of fire can be considerable higher than on horizontal levels. The lateral migrations in addition to the uphill and downhill movement of fire are also influenced through slope. Steep slopes in the windward side enhance the intensity of fire, especially due to the generation of strong upward convective movement of extreme hot air. The slope of this area is grouped into four classes.

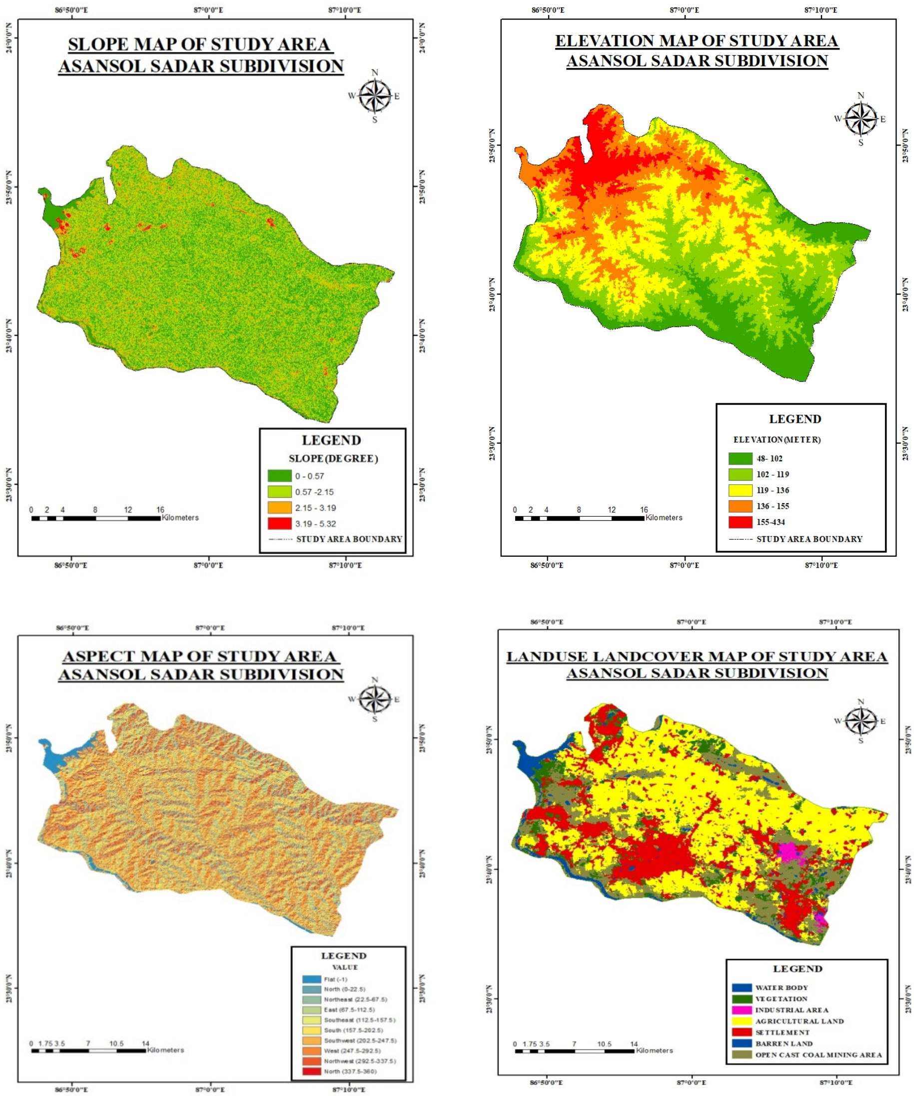


Figure 2: *Criteria maps of the study area.*

2.3.2 Elevation

The forests of this study area, (mainly near the Maithon Dam, near the Ocps) located at higher elevation are additional prone to fire disaster. At high elevation areas, hours of sunshine increase greatly during summer with high intensity of heating resulting in frequent fires. Also, in the regions with a higher elevation the frequency of lightning strikes is higher, which can activate forest fires. The elevation of this area is grouped into five classes. The increasingly high values indicate the increasing high elevation and low value indicate low elevation of the study area. The average elevation of Asansol subdivision is 111 Meter (364 ft) from mean sea-level. The maximum elevation of this region is 434 m and minimum elevation is 48 m. The rocky undulating topography with laterite soil found in this Subdivision is a sort extension of the Chota Nagpur plateau. So there is a Hilly region in the western part of the subdivision and flood plains at the edges of the River Ajay-Damodar. So this region has gradually a high elevation from the western Part to the lower elevation of the rice plains of the agriculturally rich Purba Bardhaman district.

2.4 GIS-based Fire Hazard and Risk Analysis

The risk of fire in urban areas has increased over the years and the rising cost of fire losses would seem to indicate that they are increasing at a greater rate than the measures devised to control them. Cities are growing in size and complexity day by day; therefore, they need to be managed more efficiently. The GIS is a significant and efficient tool that can be used by local administrations to minimize natural disasters. Although there are many formal definitions of GIS, for practical purposes GIS can be defined as a computer-based classification to aid in the collection, maintenance, storage, analysis, output and distribution of spatial data information (Figure 3). Thus, GIS technologies have been used in fire analysis related to the optimum location of Fire Stations. For example, many researchers has made spatial analysis of urban Fire Stations in Tehran, using an analytical hierarchy process and GIS. Others researchers also carried out studies concerning the selection of Fire Station locations using GIS. Unlike a flat paper map, a GIS-generated map can represent many layers of different information. This representation provides a unique way of thinking about geographic space. By linking map databases, GIS enables users to visualize, manipulate, analyze and display spatial data. GIS technology based approach is cost-effective and provides accurate solutions in an expanding range of applications.

2.4.1 GIS Data Compilations

GIS Map based fire hazard and risk analysis is one of the main tasks of this obligation. In order to undertake hazard and risk analysis, various GIS layers and other associated thematic maps have been fashioned for this study that forms the basis for risk ranking. The following is a list of selected GIS layers as base administrative layers and other dependent layers that have been used in GIS based fire risk analyses.

1. Sub divisional administrative boundary layers 2. Rail network 3. Major (highways) and main road networks 4. Minor roads/ street road networks 5. Locations of cities, and major towns with their names 6. Land use land cover map 7. Demarcation of residential, commercial and industrial built-up areas 8. Geographical locations (latitude, longitude) of operational Fire Stations 9. Other collateral data such as information from city development plans (if available), and demarcation of fire-station jurisdictional areas.

2.4.2 Risk Zone Mapping

The study area, Asansol Sub-division was delineated from the Survey of India topographic maps of 1:50,000 scale. The thematic maps required for this study were prepared using ArcGIS v9.3 and ERDAS Imagine v9.2 software tools. The land cover type map was derived from the Landsat 8 image of 30 m resolution. The ERDAS Imagine software was applied for the supervised classification of the Landsat 8 OLI/TIRS image. The road networks and the human settlements were digitized from the topographic maps and Google Earth. The distance from road and distance from settlement maps were prepared from the digitized data using ArcGIS spatial analyst tools. The contour data was generated from the Cartosat 1 DEM of 30 m resolution. ArcGIS spatial analyst and 3D analyst tools were employed to prepare the slope and elevation and aspect maps. A FRI model was developed for the demarcation of fire risk zones (Table 2). These thematic map layers were reclassified using the Natural breaks (Jenks) method (Table 3). Rank was assigned to each class of the thematic map layers

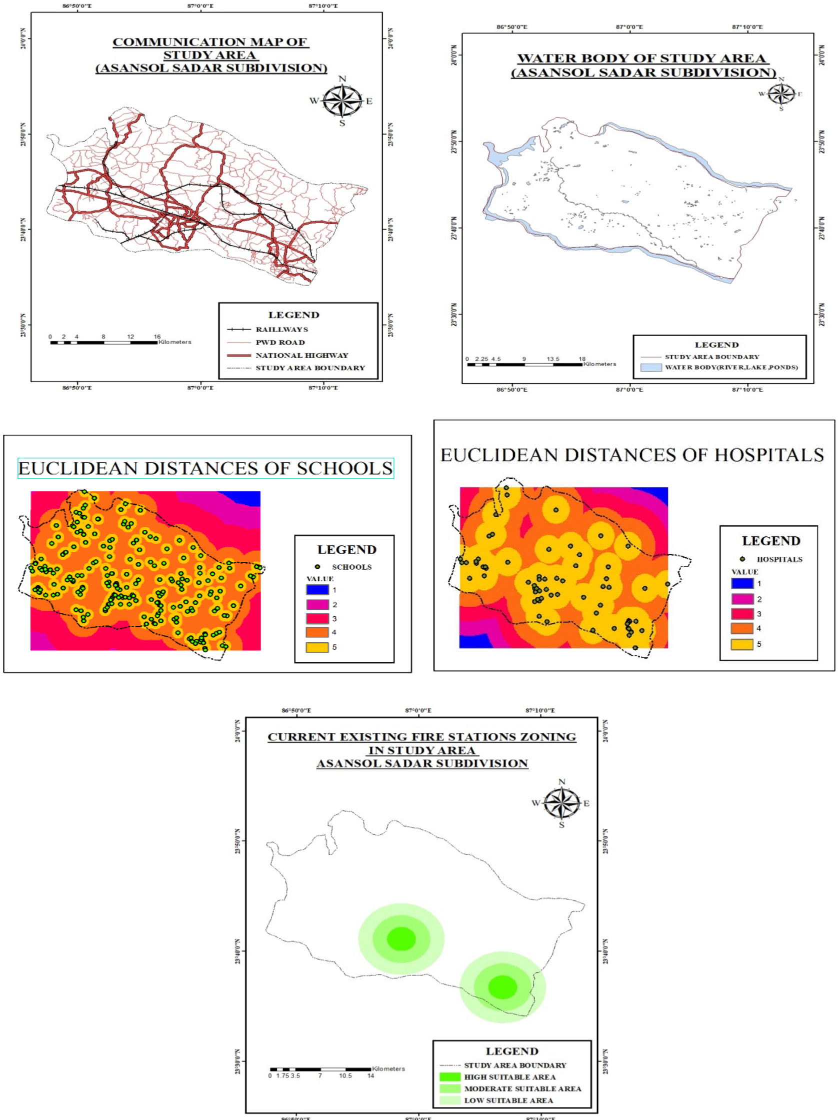


Figure 3: *Criteria maps for fire station estimation.*

and weight was assigned to each thematic map layer according to their capacity on fire ignition and spreading. The Index was derived from the weight and rank (Index = Weight x Rank). The fire risk zone map was prepared by overlaying the index map layers using ArcGIS tools. Finally, the risk zone map was validated with the fire incidence points.

The study has been focused on new fire stations allocation through remote sensing (RS) and GIS techniques. The study of encouraging new fire station in an industrial area like the Asansol Subdivision catchments involves AHP to find the appropriate zones for the construction of required new fire station. The RS with conventional datasets sources played a significant role in Site Suitability Analysis. Combinations of satellite data and other collateral dataset were used to identify the problems of the regions based on the observation of thematic information. Thematic layers were incorporated

Table 2: *The details about Risk Zone Mapping Technique used in this study.*

Factor	Class	Reclassify	Calculator
LULC	Water body	High –Settlement, Industrial Area, Open Cast Coal Mining Area	
	Vegetation	Moderate – Vegetation, Agricultural Land	
	Industrial Area	Low – Water body, Barren Land	Raster Calculator
	Agricultural Land		RC_LULC +
	Settlement		RC_Slope +
	Barren Land		RC_Elevation +
	Open Cast Coal Mining Area		RC_ Aspect =
Slope (Degree)	0 – 0.57	High Risk – 3.19 – 5.32	Fire Risk Zone
	0.57 – 2.15	Moderate – 2.15 – 3.19	
	2.15 – 3.19	Low Risk – 0 – 2.15	
	3.19 – 5.32		
Elevation (Meter)	48 – 102	High Risk – 434 - 136	
	102 – 119	Moderate – 102 - 136	
	119 – 136	Low Risk – 48 - 102	
	136 – 155		
	155 – 434		
Aspect	South, South-west	High Risk – S, SW	
	South-east, East, West, Flat	Moderate – SE, E, W, Flat	
	North, North-east, North-west	Low Risk – N, NE, NW	

Table 3: *Fundamental scale of absolute number of criterion.*

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	Experience and judgment strongly favor
5	Strong importance	one activity over another
6	Strong plus	An activity is favored very strong over
7	Very strong or demonstrated importance	another; its dominance demonstrated in practice
8	Very, very strong	The evidence favoring one activity over another
9	Extreme importance	is of the highest possible order of affirmation

Table 4: *Fundamental scale of absolute number of criterion.*

Development the Pair-wise Comparison Matrix						
Factor	Risk Zone	Road	Hospital	Education	Water	Existing fire station
Risk Zone	1	3	3	5	5	5
Road	0.33	1	3	3	5	5
Hospital	0.33	0.33	1	1	3	3
Education	0.2	0.33	1	1	3	2
Water	0.20	0.20	0.33	1.00	1	1
Existing fire station	0.20	0.20	0.33	0.5	1	1
Total	2.27	5.07	8.67	11.50	18	17

into GIS environment for the purpose of performing multi-criteria analysis such as AHP method. The AHP technique was applied to generate the pairwise comparison matrix for the geo-system parameters and to examine the geometric mean and normalized weight of each parameter. Entire criteria are combined through applying a weight to each followed by a summation of the result to yield a suitability map. The methodologies followed in different phase of the present study are designate in the detailed procedure is summarized as follows (Table 4 - 6).

Table 5: *Computation of Criterion.*

Factor	Risk Zone	Road	Hospital	Education	Water	Existing fire station	Criteria Weight
Risk Zone	0.44	0.59	0.35	0.45	0.31	0.29	40
Road	0.15	0.2	0.35	0.27	0.31	0.29	25
Hospital	0.15	0.07	0.12	0.09	0.19	0.18	13
Education	0.09	0.07	0.12	0.09	0.06	0.12	11
Water	0.09	0.04	0.04	0.09	0.06	0.06	6
Existing fire station	0.09	0.04	0.04	0.02	0.06	0.06	5
Total	1	1	1	1	1	1	100

Table 6: *Estimation of Consistency Vector.*

Factor	Risk Zone	Road	Hospital	Education	Water	Existing fire station	Consistency Vector
Risk Zone	0.40	0.75	0.39	0.55	0.30	0.25	6.66
Road	0.13	0.25	0.39	0.33	0.30	0.25	6.55
Hospital	0.13	0.08	0.13	0.11	0.18	0.15	6.30
Education	0.08	0.08	0.13	0.11	0.18	0.10	6.45
Water	0.08	0.05	0.04	0.11	0.06	0.05	6.44
Existing fire station	0.08	0.05	0.04	0.06	0.06	0.05	6.32

2.4.3 Euclidean Distance

Existing Fire Stations, main roads, water bodies, hospitals, educational Buildings in the study area were applied to perform Euclidean distance analysis of the spatial analyst tools in ArcGIS v10.8 software. The Euclidean distance model is mostly applied in suitability analysis for selecting an optimum site, and the model calculates straight line distance from every cell to a source cell. The operation was performed by inputting the source data and the output file specified. For effective utilization of this data in weighted overlay analysis, it was reclassified from the reclassify tool into different classes of equal interval. The classes are ranked, areas further from road or water bodies (< 100 meter) are not suitable, while closer to this are highly suitable areas. This condition applied because we want suitable site for new fire station that will be closer or easy accessible to roads and water bodies.

2.4.4 Analytical Hierarchy Process (AHP)

The AHP is a research methodology developed and designed by Tomas Saaty in 1980 [25]. Analytical Hierarchy Process is one of the best and most widely used multi-criteria analysis approaches. This approach is characterized by helping the researchers to evaluate the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner [25]. The main objective of using this approach is to help multi-criteria decision-making. This technique is converting the pairwise comparisons between the standards in to weights and numbers showing the relative importance of these criteria and prioritized. The basic steps for the application of AHP in this study [26]–[28]. The foremost objective of this study is to solve the weak coverage and an unplanned distribution of fire departments in the Asansol Sadar sub-division and the need to choose suitable areas for new fire departments according to international standards and national factors. Number of criteria has been chosen hierarchically to identify suitable areas for the new fire departments.

Estimation of lambda (λ) = (6.66+6.55+6.30+6.45+6.44+6.32) = 38.716

Estimation of Consistency Index: $CI = ((\lambda - 1))/((n - 1))$ $CI = ((38.716 - 1))/((6 - 1))$ CI = 0.0905 where, λ = Lambda, n = Number of Criteria Estimation of Consistency Ratio (CR) = (CI/RI) CR = 0.0905/1.24, = 0.073

Table 7: *Estimation of Consistency Vector.*

No of Observation	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	0.12	1.24	1.32	1.41	1.45	1.49

The pairwise comparison matrix was calculated using 1–10 score [26], [28], where 10 indicates highly significant and indicates equal significance. The comparison matrix is the criterion which is mathematically delivered as: n=((n–1))/2 for n numbers of site selection criteria in the pairwise comparison matrix. After calculating the pairwise matrix, weights are calculated using the Saaty method. Analytical hierarchy process is estimated by the consistency ratio (CR) which is measured by Eq. 1. This equation helps to identify the corrected logical contradiction of the pairwise comparison matrix established based on experience or expert judgment. CR=(CI/RI) (1) Where CI indicates the consistency index and RI indicates random index. $CI=(\lambda_{max}-n))/((n-1))$ (2) Equation 2 indicates the consistency index (CI) when λ_{max} is the highest eigenvector of the computed matrix and n denotes the number of criteria. Random index (RI) is the mean value of consistency index depending on the matrix order given by Saaty [29]. The RI value for the 6 criteria is 1.24 (Table 7). The CR value is >0.10, and then the weight value of the AHP method may not give the proper results. In this study calculated CR is 0.073, which is under acceptable limits and calculated weighted values usable for aquaculture site selection. The MCDA method, the basis of which is the analytic hierarchical process is adopted for building an evaluation framework in this study MCDA method can be used for quantifying benefits, risks and uncertainties in natural resource management and spatial explicit land use models. Implementation of MCDA support the decision set of criteria and their relative importance under a fully transparent process, while Involving a wide range of stakeholder views to express a more societal perspective.

2.4.5 Weighted Overlay Analysis

Weighted overlay is one method of modeling suitability. Pairwise comparison generally is a process of comparing entities in pairs to judge which of each entity is preferred, or has a greater amount of some quantitative property, or whether or not the two entities are identical. In this study, different thematic layers Elevation, Slope, Aspect, LULC, and Water bodies were integrated in GIS environment using a set of logical conditions, for identifying the suitable zones of new fire station sites. To make comparisons, the weights of the different themes were assigned on a scale of 1 to 5 based on their influence on the fire station site suitability process.

3. Results and discussion

The suitability model identified and classified suitable areas to build new fire departments depend on standards identified. Generally, land suitability for fire departments in the Asansol Sadar Subdivision decreases from the center of the cities toward the suburbs this is because the population density and built up areas decreases from the center of the city toward the suburbs as well. The less suitable areas for locating fire departments are situated in far from suburb of the cities particularly, in the Mining areas.

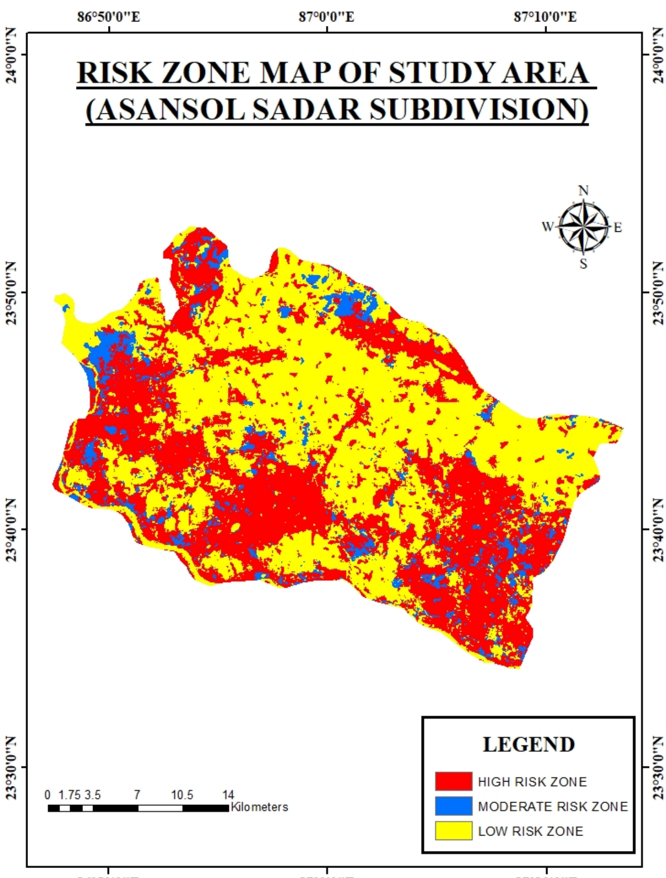


Figure 4: *Fire Risk Zone Map of The study area.*

The model considered densely populated parts of cities and industrial neighbourhoods in Jamuria, Kulti – Barakar, Burnpur, Chittaranjan, and Churulia as high suitable areas for new fire departments. The model results show that two existed fire departments (Asansol Fire Station and Raniganj) are located in between the most suitable and less suitable classes, which means that the planners for fire department services didn't take into consideration the growth of the city; in order to move the location of these two fire departments. The fire department of West Bengal hadn't considered suitability model; because the advanced techniques hadn't developed those days and the growth of the cities is not so much higher.

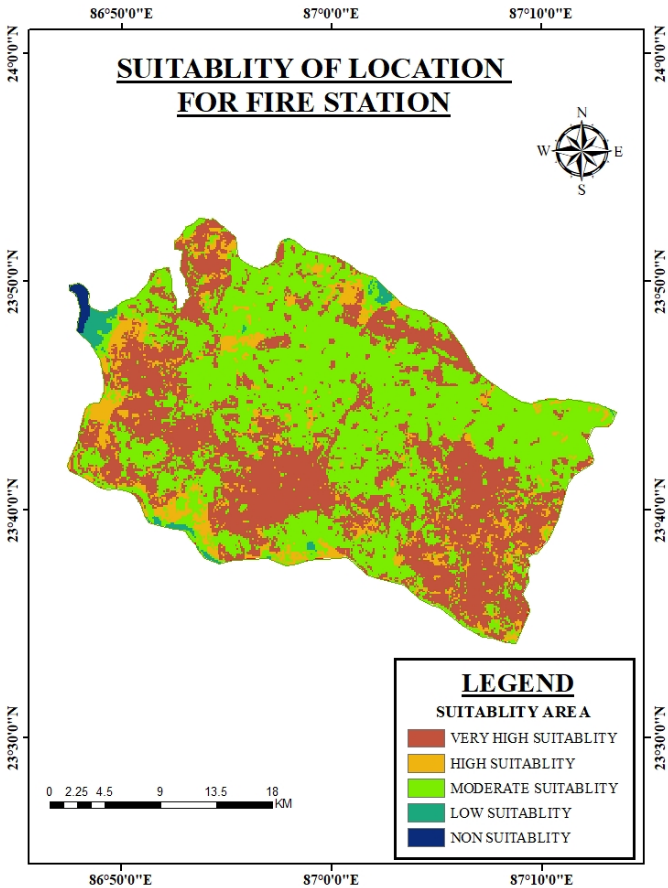


Figure 5: *Suitability Map for new fire stations of the study area.*

The study successfully applied Analytic hierarchy process and geographic information systems (GIS) capabilities in modelling site selection suitability for fire departments. The GIS-based model provided accurate estimations for identifying suitable areas to establish new fire departments. The model provided layer overlay capabilities that could improve the process of decision making and site suitability analysis for locating new fire departments. The model provided layer overlay capabilities that could improve the process of decision making and site suitability analysis for locating new fire departments. The model made several results available for decision makers in the Study Area.

1. Quick and easy assessment to see if a particular area could be suitable for fire department.

2. Exclusion of areas that are not suitable to build fire stations (even if there is a land available).
3. Ability to rank areas in terms of suitability for fire department services.
4. Identification of model inputs at any given site.
5. The possibility of applying the model and its results in any other regions or cities.

Table 8: *The Calculated Area of Risk Zone used in this study*

Sl. no	Risk Zone Type	Area (km^2)
1	High Risk Zone	364.569
2	Moderate Risk Zone	59.6165
3	Low Risk Zone	422.348

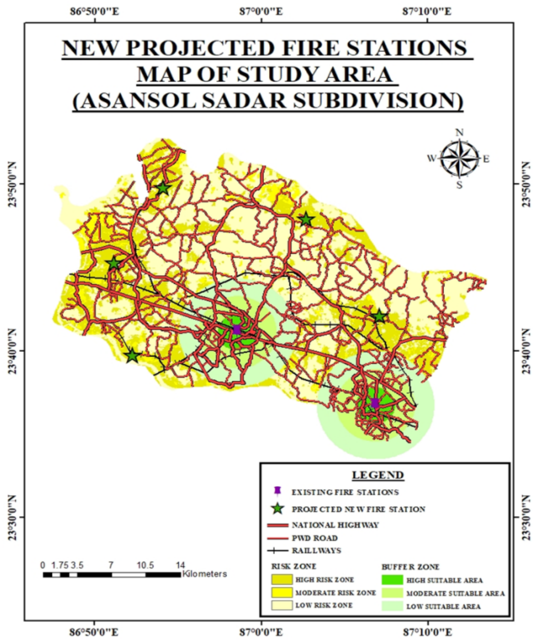
The current response coverage by fire department services of the subdivision (40%) is very low and reflects the need for finding solutions to cover the other (48%) of the areas with fire department services. The current coverage of fire departments of the subdivision (40%) is a small percentage, reflecting the need to find solutions to cover the rest of the areas with this service . Previous studies showing that the accepted percentage for coverage of the city by fire department services based on international standards is (80%) (Figure 4). The coverage areas of existing fire stations was taken as 5 km, 7 km, and 9 km. Areas within 5 km gets the best quality of fire service, 7 km gets moderate quality service and 9 km gets very poor service. As per the recommendation of SFAC which is 5 to 7 minutes in urban areas and 20 minutes in Rural areas this norms were taken. Depending on the results of this study, in order to achieve the optimal distribution of fire departments and ideal coverage for the Asansol Sadar Subdivision with fire department service the study proposes the following scenarios:

First: redistributing of existing centers to achieve a better coverage and larger area of the subdivion. Redistributing these centers geographically depending on the suitability model results of this study, could lead to increased coverage of the city with this service increase; Advantages of this scenario is more economic and lowers the cost because there is no establishment of new centers, But it is Cost Affectively So we cannot take it as our consideration.

Second: Creating additional new fire department centers, in order to insure the most optimal coverage of the Asansol Sadar Subdivision. This scenario will cost more compared to the first scenario, because new fire department centers will be created. By adding five new fire department centres to the existing centers depending on the land suitability map in this study, the coverage area for the city increased from (52%) to (81.8%) (Table 8). This coverage is more acceptable and closer to the ideal coverage and achieve the main objective of this study (Figure 5).

The first of those issues was defining demand. Since there were existing fire stations, as there would be in nearly any practical situation, demand could not be defined as simply any location that could possibly need a fire truck. For a realistic answer to the Emergency Manager's question, demand had to be defined as any location that could possibly need a fire truck and did not have one within the acknowledged standard distance that was also in the same fire district as the location itself. Other variables could have come into play as well, depending on the circumstances. For example, in this case study every mandate point had the same weight, but that may not be reasonable if one of 43 the demand points represents a school or factory while the others represent unoccupied utility sheds or barns (Figure 6).

The second issue that had to be addressed was defining potential fire station sites. Since the Subdivision had no potential sites in mind, they were represented by a continuous plane, but it is unreasonable to define that plane as everything inside the study area boundaries. Some areas are additional and less suitable for building, and there is nothing "optimal" about a site that covers all unmet demand but requires a huge financial support of new infrastructure before it is viable. By using building the site recommendations from the subdivision's of comprehensive plan, reaching an optimal solution that was also viable was simplified. If it had not been available, the introduction of several variables may have been required to produce a practical solution.



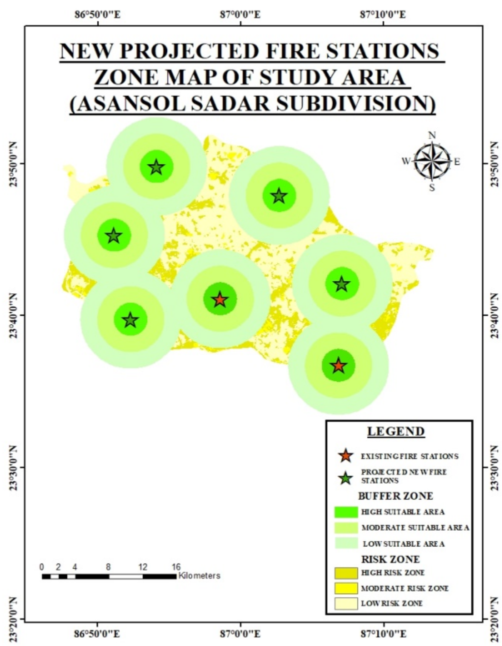


Figure 6: *Projected new Fire Station Map and service zone of the Study Area.*

4. Limitations and recommnedation

Detailed Survey could not be carried out due to lack of time. Sample size depends on the nature of the research problem. If sample size is too small, statistical tests would not be able to identify significant relationships within data set. The importance of sample size is greater in quantitative studies compared to qualitative studies. Sample Sizes of a large area could not be collected due to lack of time and finance. Lack of an extensive experience in primary data collection, there is a great chance that the nature of implementation of data collection method is flawed. Lack of Previous year Fire incidents data, case study bounded in limits. Non-availability of a uniform level of fire statistics of all the fire events in the past 5 years. In fire hazard and risk analysis, fire-load of specific industry has not been taken into consideration. However, weightage has been given to the size of industrial area in the fire hazard and risk analysis of the base unit. An attempt has been made even in the present assignment to go further down at lower levels. Providing special weightage of type of industry will require building level survey including estimation of fire-load for each industry, which is out of scope of present assignment.

To have a Computerization of West Bengal Fire and Emergency Services, training of fire personnel in use of computers is required, which is very important from the modernization of point of view. This study finds that the GIS tool is very valuable tool for combining various information to identify a proper location for the accident area. Online Vehicle tracking through GPS and development of a fully computerized response system is another area for improvement. This helps the Fire Fighters to locate the exact location of incident and to find out the shortest route to reach as soon as possible. The WBFES should have audit by a central authority to ensure good finance mechanism for capital, and O&M expenditures for this Station Set up. The initial investment in software and training is an obstacle to implementation. The possibility of providing this type of analysis to other local fire departments of similar size to cover the investment for software and data should be investigated. This approach can be applied into other industrial areas to delineate the future risk zones and for a pre-planned city designing. More work be carried out to improve the model and to include other percent ancillary data like environmental and socioeconomic factors.

5. Conclusion

As a conclusion, the objective of this study was successfully achieved. This paper studied the locating new fire stations in Asansol Sadar Subdivision in West Bengal, India. The Project based on the defined layers and criterion by using GIS maps and the GIS software. GIS is one of the most significant decision-making locating processes for site suitability analysis. New fire station location was successfully determined by using GIS as a tool for decision-making. This paper is prepared by GIS model based on directing study area. Then this problem is solutions by GIS model. Remote Sensing and GIS is ideally suited for various criteria analysis and management. This study shows a simple and cost effective way to use remote sensing & geographical information system for creating new fire management plan from the available data base. It is recommended to use study construction of fire stations as well as applying this model on a more complex problem such as measuring the merits of locating. This study shows a simple and cost effective way to use remote sensing & geographical information system for creating buffer zone based. Now the fire services of the study area will be fully available. New fire station location planning should consider the socio-economic cost in the old and high density areas of the study area. In the present research by using the weighting logic and overlaying in GIS the different criteria were analysed in relation to the intervention potential.

Finally this case was determined in different sites and the most appropriate sites for AHP analysis selected to locate the new fire stations. The number and location of fire stations significantly influence the efficiency of emergency response during fire accidents. The fire stations have to be found at the most appropriate location in Asansol Sadar Subdivision to reach the scene as fast as possible considering the increasing population and traffic jam. This presentation is inclined towards disaster management. This paper has presented an approach to optimally selecting fire station location by integrating the GIS. This process serves as a prototype for the development of a decision support system combining GIS with multi-objective AHP Model. Such a system will be valuable in decision making for the emergency facility location and other real-life spatial optimization problems. It has been concluded that there are many external factors affecting the site selection and layout preparation of fire stations in the cities. To guarantee the scientificity of fire station locations, factors such as the transit time of fire trucks, and scale cost of fire stations, social services, environment and climate should be taken into consideration comprehensively. . This paper first identified potential fire station locations based on GIS, and then it introduced the preliminary knowledge about AHP and MCDA. This paper regarded the site selection in the subdivision as a multi-criterion decision-making process considering different influencing factors. After that, the weighted values was integrated into the AHP, and the suitability of candidate locations was comprehensively evaluated and scored to obtain the fire station layout that is most suitable for the study area. Follow-up studies in the future will focus on the numerical scale selection rules and optimization of this method so as to facilitate the modification of the proposed method and apply it to the site selection and layout planning of other municipal buildings.

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References

[1] B. Feizizadeh, P. Jankowski, and T. Blaschke, "A GIS based spatially-explicit sensitivity and uncertainty analysis approach for multi-criteria decision analysis," Computers & geosciences, vol. 64, pp. 81–95, Mar. 2014, doi: 10.1016/j.cageo.2013.11.009

[2] A. H. Ahmed, H. Mahmoud, and A. M. M. Aly, "Site Suitability Evaluation for Sustainable Distribution of Hospital Using Spatial Information Technologies and AHP: A Case Study of Upper Egypt, Aswan City," Journal of Geographic Information System, vol. 08, no. 05, pp. 578–594, 2016, doi: 10.4236/jgis.2016.85048.

[3] D. Nsangou et al., "Urban flood susceptibility modelling using AHP and GIS approach: case of the Mfoundi watershed at Yaoundé in the South-Cameroon plateau," Scientific African, vol. 15, p. e01043, 2022.

[4] X. Niu, "Research on the relationship between ecological industry and sustainable development of industrial park," Civil Engineering and Urban Planning IV. CRC Press, pp. 51–54, 2016. doi: 10.1201/b19880-11.

[5] B. Halder, T. Tiyasha, S. Shahid, and Z. M. Yaseen, "Delineation of urban expansion and drought-prone areas using vegetation conditions and other geospatial indices," Theoretical and Applied Climatology, pp. 1–19, 2022.

[6] D. Valinsky, "Symposium on Applications of Operations Research to Urban Services—A Determination of the Optimum Location of Fire-Fighting Units in New York City," Journal of the Operations Research Society of America, vol. 3, no. 4, pp. 494–512, 1955, doi: 10.1287/opre.3.4.494.

[7] A. Okabe, K.-I. Okunuki, and T. Suzuki, "A computational method for optimizing the hierarchy and spatial configuration of successively inclusive facilities on a continuous plane," Location Science, vol. 5, no. 4, pp. 255–268, 1997, doi: 10.1016/s0966-8349(98)00035-7.

[8] N. Liu, B. Huang, and M. Chandramouli, "Optimal Siting of Fire Stations Using GIS and ANT Algorithm," Journal of Computing in Civil Engineering, vol. 20, no. 5, pp. 361–369, 2006, doi: 10.1061/(asce)0887-3801(2006)20:5(361).
[9] X. Dong, Y. Li, Y. Pan, Y. Huang, and X. Cheng, "Study on Urban Fire Station Planning based on Fire Risk Assessment and GIS Technology," Procedia Engineering, vol. 211, pp. 124–130, 2018, doi: 10.1016/j.proeng.2017.12.129.
[10] L. Yang, B. F. Jones, and S.-H. Yang, "A fuzzy multi-objective programming for optimization of fire station locations through genetic algorithms," European Journal of Operational Research, vol. 181, no. 2, pp. 903–915, 2007, doi: 10.1016/j.ejor.2006.07.003.
[11] S. Doocy, A. Daniels, S. Murray, and T. D. Kirsch, "The human impact of floods: a historical review of events 1980-2009 and systematic literature review," PLoS currents, vol. 5, 2013.
[12] B. Halder, A. M. S. Ameen, J. Bandyopadhyay, K. M. Khedher, and Z. M. Yaseen, "The impact of climate change on land degradation along with shoreline migration in Ghoramara Island, India," Physics and Chemistry of the Earth, 2022, doi: 10.1016/j.pce.2022.103135.
[13] B. Halder et al., "Land Suitability Investigation for Solar Power Plant Using GIS, AHP and Multi-Criteria Decision Approach: A Case of Megacity Kolkata, West Bengal, India," Sustainability, vol. 14, no. 18, p. 11276, 2022.
[14] K. Habibi, S. Lotfi, and M. J. Koohsari, "Spatial Analysis of Urban Fire Station Locations by Integrating AHP Model and IO Logic Using GIS (A Case Study of Zone 6 of Tehran)," Journal of Applied Sciences, vol. 8, no. 19, pp. 3302–3315, 2008, doi: 10.3923/jas.2008.3302.3315.
[15] D. Choudhury, K. Das, and A. Das, "Assessment of land use land cover changes and its impact on variations of land surface temperature in Asansol-Durgapur Development Region," The Egyptian Journal of Remote Sensing and Space Science, vol. 22, no. 2, pp. 203–218, 2019, doi: 10.1016/j.ejrs.2018.05.004.
[16] D. Choudhury, A. Das, and M. Das, "Investigating thermal behavior pattern (TBP) of local climatic zones (LCZs): A study on industrial cities of Asansol-Durgapur development area (ADDA), eastern India," Urban Climate, vol. 35, p. 100727, 2021.
[17] B. Halder, J. Bandyopadhyay, K. M. Khedher, C. M. Fai, F. Tangang, and Z. M. Yaseen, "Delineation of urban expansion influences urban heat islands and natural environment using remote sensing and GIS-based in industrial area," Environmental Science and Pollution Research, pp. 1–24, 2022.
[18] J. H. Danumah et al., "Flood risk assessment and mapping in Abidjan district using multi-criteria analysis (AHP) model and geoinformation techniques, (cote d'ivoire)," Geoenvironmental Disasters, vol. 3, no. 1, 2016, doi: 10.1186/s40677-016-0044-y.
[19] B. Halder, J. Bandyopadhyay, and P. Banik, "Assessment of hospital sites' suitability by spatial information technologies using AHP and GIS-based multi-criteria approach of Rajpur–Sonarpur Municipality," Modeling Earth Systems and Environment, vol. 6, no. 4, 2020, doi: 10.1007/s40808-020-00852-4.
[20] E. Dodangeh, A. A. Ewees, S. Shahid, and Z. M. Yaseen, "Daily scale river flow simulation: hybridized fuzzy logic model with metaheuristic algorithms," Hydrological Sciences Journal, 2021, doi: 10.1080/02626667.2021.1985123.
[21] B. Halder and J. Bandyopadhyay, "Potential sites' selection of groundwater zones using AHP and GIS-based multi-criteria approach of Kolkata Municipal Corporation," International Journal of Energy and Water Resources, pp. 1–18, 2022.
[22] B. Halder, J. Bandyopadhyay, and P. Banik, "Assessment of hospital sites' suitability by spatial information technologies using AHP and GIS-based multi-criteria approach of Rajpur–Sonarpur Municipality," Modeling Earth Systems and Environment, vol. 6, no. 4, pp. 2581–2596, 2020, doi: 10.1007/s40808-020-00852-4.
[23] T. D. Kontos, D. P. Komilis, and C. P. Halvadakis, "Siting MSW landfills with a spatial

multiple criteria analysis methodology," Waste management, vol. 25, no. 8, pp. 818–832, 2005.
[24] S. Baja, D. M. Chapman, and D. Dragovich, "Spatial based compromise programming for multiple criteria decision making in land use planning," Environmental Modeling & Assessment, vol. 12, no. 3, pp. 171–184, 2006, doi: 10.1007/s10666-006-9059-1.
[25] T. L. Saaty, "A scaling method for priorities in hierarchical structures," Journal of Mathematical Psychology, vol. 15, no. 3, pp. 234–281, 1977, doi: 10.1016/0022-2496(77)90033-5.
[26] T. L. Saaty, "Decision making with the analytic hierarchy process," International Journal of Services Sciences, vol. 1, no. 1, p. 83, 2008, doi: 10.1504/ijssci.2008.017590.
[27] T. L. Saaty, "The Analytic Network Process – Dependence and Feedback in Decision-Making," Business Applications and Computational Intelligence. IGI Global, pp. 360–387, 2006. doi: 10.4018/978-1-59140-702-7.ch018.
[28] T. L. Saaty, Theory and applications of the analytic network process: decision making with benefits, opportunities, costs, and risks. RWS publications, 2005.
[29] T. L. Saaty, "A scaling method for priorities in hierarchical structures," Journal of Mathematical Psychology, vol. 15, no. 3, pp. 234–281, 1977, doi: 10.1016/0022-2496(77)90033-5.