GIS IN ASSESSING TOPOGRAPHICAL ASPECTS OF HILLY REGIONS

Satish Kumar[1], V.K. Bansal [2]

[1]Research Scholar, Department of Civil Engineering, National Institute of Technology Hamirpur, H.P., India
[2]Associate Professor, Department of Civil Engineering, National Institute of Technology Hamirpur, H.P., India

Abstract

Topography helps in identifying the areas of adverse locations that may increase development cost, delay construction besides creating the safety related problems. It further identifies areas that can be developed with minimum resources or to be restricted. Generally, on the basis of their knowledge and experience architects or engineers use 2D contour maps for analyzing hilly regions to locate infrastructure facilities. The applications of geographic information systems (GIS) help in analyzing topographical aspects by modeling topography. It provides 3D view of topographical information of the region where infrastructure facilities were proposed and likely to be located. In the present study various topographical aspects that are crucial for the locating infrastructure facilities were identified. A GIS-based methodology was developed for the analyzing the facilities of the campus of Jawaharlal Nehru Government Engineering College (JNGEC) Sundernagar, India, as a case study.

Key Words: *GIS, topography, site selection, geospatial analysis*

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1. INTRODUCTION

The location of infrastructure facilities depends upon the assessment of topographical information of land where various facilities/utilities are likely to be located. Generally, architects or engineers perform the job of locating various facilities/utilities. Generally, architects or engineers consider the topographical aspects and on the basis of their knowledge locate facilities which result variations.

In hilly regions, topographical analyses are crucial for identifying the facilities that are located in areas of adverse conditions. It is most crucial issue for architects or engineers. The topographical assessment of facilities provides useful solution in analyzing that a facility is correctly located or not, especially when infrastructure facilities are located in an undulating land where topographical aspects have substantial role to play. Considering the topography while locating infrastructure facilities in hilly regions shall be a step towards sustainability [1].

In developing countries, project failure is due to poor assessment of topographical aspects thereby locating facilities at adverse locations [2]. A good assessment shall locate the infrastructure facilities at suitable locations and reduce development costs [3]. Therefore, architects or engineers should understand topographical aspects and their effect on the development of the hilly region.

The process of identifying a proper location for a infrastructure facility is an important issue [4]. It requires a full consideration of topography of a region [5]. Studies [6]; [7] recommended that facility designers can affect facility location by identifying areas of adverse locations. The suitability of the land for any particular facility is not only based on a set of physical parameters but also very much on the economic factors. The assessment of the physical parameters of the land is possible by analyzing the topographical aspects (slope, elevation, and runoff patterns).

The assessment of physical parameters identifies the limitations of the land for locating a particular facility. The limitations are required to be considered with respect to the topography for ensuring sustainability of a region.
Rajendran and Gambatese [8] suggested that to ensure the sustainable development of hilly regions topography must be included. The sustainable growth of a hilly region requires visualization of topography and spatial relationships among existing and proposed facilities [9]. The traditional way of facilities distribution requires efforts of experts from many fields to choose the best alternative by considering the available information. The process depends upon level of experience, knowledge and individual's perspective, which leads to variations in facility location interpretation.

2D maps, and sketches are used while finalizing locations of infrastructure facilities. Architects or engineers' ideas are represented either through solid three-dimensional (3D) models or CAD-based 3D models [10]. CAD-based 3D modeling focuses on the visualization, whereas topographical assessment requires database management, graphical and non-graphical analyses, and geo-spatial analysis where CAD-based systems are lacking. Hence, architects or engineers repetitively organize, interpret, and link graphical and non-graphical information manually to assess the locations of infrastructure facilities.

The locations of facilities in a hilly region where topography plays major role cannot be finalized without modeling topography and geo-spatial analysis capabilities [11]; [12]. Such dependence cannot be easily modeled in absence of GIS. It allows viewing and analyzing the effects of locating a new facility in the neighborhood of existing facilities [13].

Cheng et al. [14] developed a GIS-based decision support system (DSS) to assist the construction engineers. It is GIS integrated with database management system that improves the efficiency of instrumentation programs; integrate location-based and thematic information, graphical displays, and database queries. Bansal [15] suggested that the use of GIS for retrieving the information from database can help architects or engineers in decision making. Manase et al. [16] developed GIS-based accident prevention (GISAP) system and suggested that GIS capabilities can enhance the analysis of fragmented information. Cheng and Ko [5] developed a decision support system (DSS) for monitoring of hillsides safety. The application of this system not only assist engineers in collecting data, managing data, inferring slope stability, and diagnosing the possible causes, but also increase precision and accuracy in decision making.

2. RESEARCH JUSTIFICATION

The majority of the available information is poorly utilized due to the lack of an integrated framework to manage, manipulate, analyze, and present information, thereby failing to locate the facilities more appropriately in the current practices. CAD-based modeling fails to consider the topographical aspects of a region. Also use of CAD-based systems is somewhat difficult and visualization provided by them is also not easily customizable [17].

Computer-aided DSS developed by Cheng and Ko [5] and GIS-based DSS developed by Cheng et al. [15] were used for preliminary investigation of site conditions which did not utilize the full potential of GIS. Cheng and Ko [5] recommended the use of GIS only to improve the graphical visualization of monitoring conditions of hillsides, whereas Cheng et al. [14] used GIS just for integration of location-based and thematic information. Both the studies were based on fuzzy set theory, involving not only lengthy and time consuming process, but also results may vary from experts to experts. Further, GISAP developed by Manase et al. [16] used many software packages which resulted lengthy and time consuming analysis, interpretation, and prediction of fragmented information.

With change in topography, site conditions vary from place to place and there is no integrated framework to locate infrastructure facilities in hilly regions. Literature indicates that there is a minimum knowledge and lack of responsive tools for evaluating locations of proposed facilities in hilly regions. A well defined methodology for identifying areas of adverse conditions and locating potential areas for infrastructure facilities has not been explored much. Therefore, the best way to enhance the sustainability of a hilly region is to consider the topography.

Considering the importance of GIS, architects or engineers, create, store, and share information about 3D models of existing facilities along with surrounding topography [15]. Visualization of existing facilities along with surroundings, database management, and geospatial analysis capabilities on a single platform can help in identifying the effective locations the proposed facilities by using GIS. Kumar and Biswas [18] also suggested that GIS-based evaluation being simple and flexible can be used to analyze the potential sites for identifying the facility location in a hilly region.

GIS-based modeling of existing facilities along with topography shall assist architects or engineers in examining what adverse conditions exist, where? The work envisaged in the present study is an attempt to take advantage of the potential of GIS. A location identified shall be in accordance with topography which will strengthen decision making process and facilitate to formulate suitable framework for sustained development of a region. The proposed framework will not only help in taking corrective measures, but also locate the proposed facilities at more appropriate locations and develops the hilly region more naturally.

3. RESEARCH OBJECTIVES

In order to ensure that the critical aspects influencing the location of infrastructure facilities in a hilly region are not overlooked, a framework has to be evolved. The present study explores the application of GIS taking into account the topographical aspects. It identifies those proposed facilities which are located in areas of adverse site conditions. This facilitates in taking corrective measures and locates the proposed facilities at more appropriate locations. Therefore, the main objective of the present study was to develop the GIS-based framework for locating infrastructure facilities in hilly region accomplished through:

- Identification of aspects affecting site selection decisions,
- Modeling of topographical aspects, and
- Geo-spatial analysis to identify infrastructure facilities located in areas of adverse locations.

The developed framework was used for assessing the infrastructure facilities' in the campus layout of Jawaharlal Nehru Government Engineering College (JNGEC) Sundernagar, India.

4. CRITICAL ASPECTS

The various topographical aspects and existing facilities/ utilities applicable for assessing the infrastructure facilities' in the campus layout of Jawaharlal Nehru Government Engineering College (JNGEC) Sundernagar, India, have been discussed below:

4.1 Topographical Aspects

Topography represents slope, and elevation of the region. The slope instability is caused due to the cutting of a hill; therefore, cuttings shall not be undertaken unless appropriate measures are taken. Topography can be preserved by locating a facility with respect to natural contours of a region. Selection of a location having minimum disturbance to the natural topography reduces retaining works, cut/fill, construction cost, and ultimately enhances location-based safety [15]. The elevation of a location is another important factor associated with location-based decisions. For example, a location on higher elevation is considered suitable for over head tank whereas a location on lower elevation is suitable for rain harvesting water tank. It is also necessary to understand in a hilly region how water flows naturally and after a change in topography.

4.2 Open Space Around

Open space around a facility has significant ecological and environmental importance. It improves inside-out climate of facilities and abates heat-island effect by their ecological-balancer function [20]. Open space left around and in between two facilities provide light, ventilation, and ensures safety during construction by minimizing the risks of spatial and temporal exposure to the existing facility and its users [21].

4.3 Existing Utility Services

Utility services furnish an everyday necessity to the public at large. Public utilities provide water, electricity, natural gas, telephone service, and other essentials. Water supply line laid with respect to the topography ensures proper water supply besides ensuring its safety during catastrophes. A sub-soil dispersion system should be located away from the nearest habitable building as economically feasible [19].

5. GIS-BASED FRAMEWORK

The steps involved in developing the GIS-based framework for locating facilities in the hilly region has been shown in Fig.1 and discussed below:

5.1 Topography Modeling

JNGEC campus, a case study, spreads in an area of more than ten acres. To evaluate the impact of topography, a surface model (digital representation of a surface in 3D), triangulated irregular network (TIN) was developed. The *pdf* file of architectural drawing (showing contours, existing facilities/utilities, and proposed facilities) was converted into an image file and used for digitization in ArcGIS. The contours which were digitized from image file were assigned elevation values in the corresponding rows of the attribute table. The resulting feature class was converted to TIN in ArcGIS. The 2D aerial photograph of campus was draped over the developed TIN to facilitate visualization of the open space and topography of the campus.

5.2 Modeling of Existing Facilities

The existing facilities/utilities were modeled to evaluate their effects in locating the proposed facilities. In the present case study, the existing facilities/utilities include buildings, roads, sub-soil dispersion system, and overhead electrical supply lines. The *pdf* file of architectural drawing converted earlier into image file was used to digitize existing facilities and assign elevation values in ArcGIS. The footprints of existing facilities were exported to Google *SketchUp* for 3D modeling. All existing facilities were modeled in 3D on their respective footprints in G*oogleSketchUp*, and imported back to ArcGIS as 3D *multipatch* in the *geodatbase* [22].

5.3 Integrating Topography with Existing Facilities

Existing facilities/utilities were placed on their respective locations on the topographical model developed earlier. Fig. 3 gives 3D view of existing and proposed facilities/utilities along with topography. The integrated model of surface and facilities helps in measuring horizontal distances, elevation, and slope on a surface. It helps in the visualization of spatial relationships among existing facilities required in assessing proposed infrastructure facilities. Fig. 2 shows the GIS-based framework used for assessing infrastructure facilities in the JNGEC campus.

5.4 Development of Input Datasets

Input datasets are information pertaining to topography and facilities. In order to develop GIS-based framework to identify faulty locations of proposed facilities, input datasets were created for the topographical aspects and existing facilities identified earlier. For the present case study five topographical aspects used as input datasets in ArcGIS as shown in Tab.1, however, numbers of input datasets are variable depending upon type of project under consideration.

Tab. 1: Topographical aspects

Sr. No.	Aspects
1	Topography
2	Existing buildings
3	Sub-soil dispersion system
4	Roads/paths
5	Overhead power supply lines

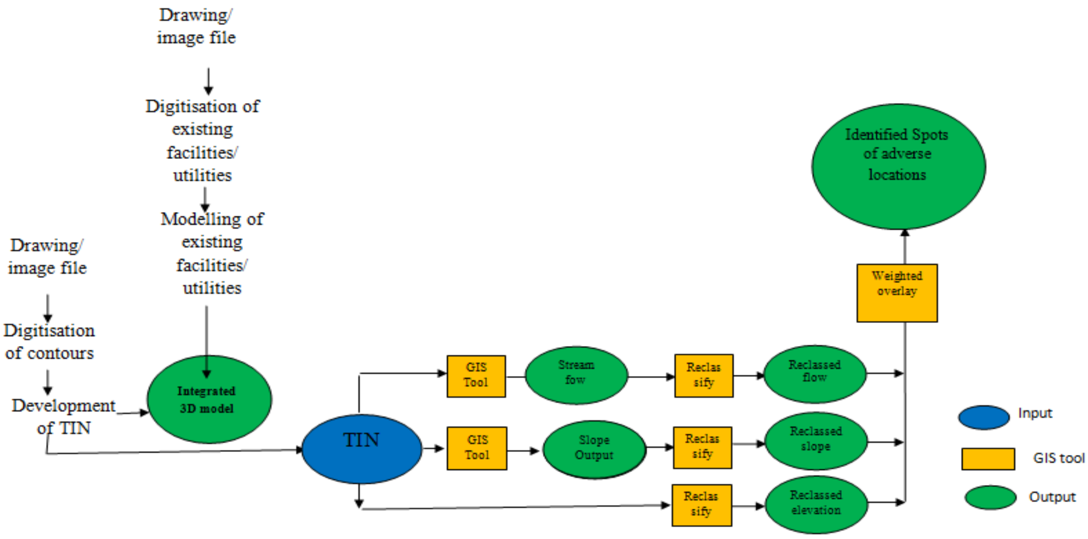

Fig. 1: The GIS-based framework for analyzing infrastructure facilities in the hilly region.

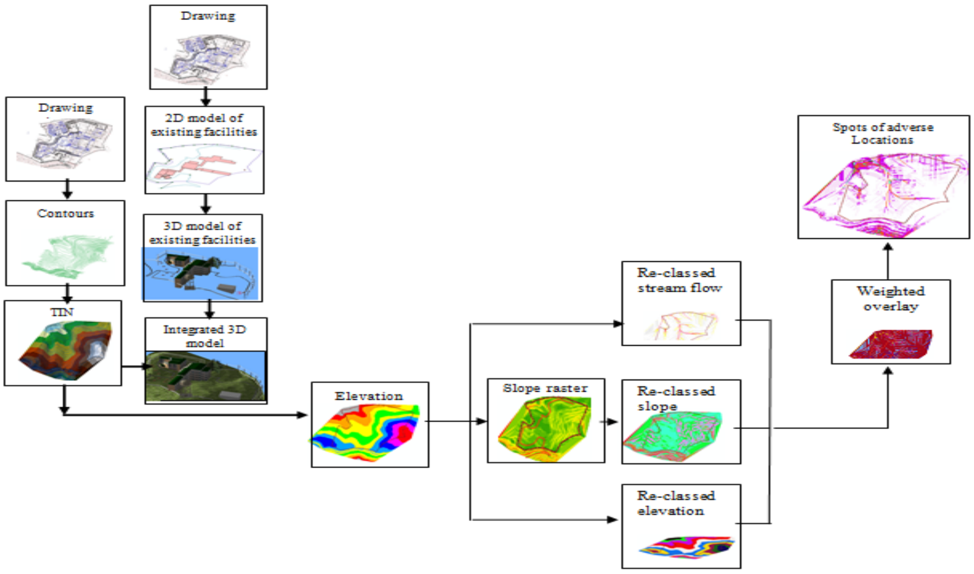

Fig. 2: Various stages of GIS-based framework used for assessing infrastructure facilities in the JNGEC

5.5 Analysis

Elevation raster of the region derived from TIN was used to precisely mark the elevations of various locations on a hilly region, similarly runoff pattern dataset helped in visualizing, how water naturally flows in the region. Slope dataset derived from TIN helped to know steep or flat portion of the region.

• The derived datasets are generally floating points, continuous, and in different ranges. Hence, these were re-classified to a common scale of 1to10. Higher scale values (SV) indicate more suitable attributes whereas lower values give an idea of less important attributes. For example, slope dataset was reclassified into 10 equal intervals. A higher SV was assigned to the almost flat terrain having slope (0-2°) and lower SV to the steep portion having range of slope (29-35°) in the present case.

• Similarly, for re-classified elevation raster, higher SV was given to lowest elevation range (208-223) lower SV to the highest elevation range (313-328) in present case.

• To know the natural flow of water of the study area, re-classed stream order dataset was considered and the highest SV was given to the horizontal surface and lowest SV to the steep sloped area. Tab. 2 shows the details of Scale value (SV), and cell counts assigned to different attributes for re-classed datasets within each dataset.

Fig. 3: 3D view showing infrastructure facilities with topography.

Tab. 2: *Cell counts* and *scale value* for re-classed data sets.

Slope		**Elevation**		**Runoff patterns**	
Count	SV	Count	SV	Count	SV
73	1	616	1	233	1
225	2	1185	2	524	3
539	3	3298	3	1604	6
1021	4	5440	4	6183	8
1599	5	5552	5	21063	10
2819	6	6045	6	-	-
5357	7	3941	7	-	-
8652	8	2028	8	-	-
6333	9	1148	9	-	-
3685	10	1050	10	-	-

6. CONCLUSIONS

Topography plays an important role for locating infrastructure facilities in a hilly region. It affects the development of the region. The various topographical aspects considered provide a unique and precise solution for assessing locations of various infrastructure facilities. The consideration of topography reduces the site development cost and ensures the sustainability of a hilly region. The GIS is used in present case study to consider the topography in developing the GIS-based framework for assessing the locations of various infrastructure facilities. Geo-spatial analysis helped in identifying infrastructure facilities which were located in adverse locations, helped in developing the region more naturally.

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REFERENCES

[1]. Rajendran S. Sustainable construction safety and health rating system. 2006. Ph.D. dissertation, Oregon State University, Corvallis, Ore.

[2]. Ghobarah A. Civil Engineers' role in site-selection studies. Journal of Professional Issues in Engineering 1987; 113:351-359.

[3]. Hinze J, Raboud P. Safety on large building construction projects. Journal of Construction Engineering and Management, 1988; 114:286-293.

[4]. Kumar M, Shaikh VR. Site suitability analysis for urban development using GIS based multi-criteria evaluation technique. Journal of Indian society of Remote Sensing 2013; 41: 417-424.

[5]. Cheng MY, Ko CH. Computer-aided decision support system for hillside safety monitoring. Automation in Construction 2002; 11:453-466.

[6]. Toole TM. Design engineers' responses to safety situations. Journal of Professional Issues in Engineering Education practice 2007; 133:126-131.

[7]. Gambatese J, Hinze J. Addressing construction worker safety in the design phase-designing for construction worker safety. Automation in Construction 1999; 8:643–649.

[8]. Rajendran S, Gambatese JA. Development and initial validation of sustainable construction safety and health rating system. Journal of Construction Engineering and Management 2007; 135:1067-1075.

[9]. Dan L, Guoxin T, Liuyin W, Shujun, Z. "A study for 3D virtual campus navigation system based on GIS", Proc. IEEE conf. on Wireless Communications, Networking and Mobile Computing 2008 Dalian, China.

[10].Waly AF, Thabet, W Y. A virtual construction environment for pre-construction planning. Automation in Construction 2002; 12:139-154.

[11].Bansal VK. Use of Geographic Information Systems in Spatial Planning: a case study of an institute campus. Journal of Computing in Civil Engineering, ASCE 2014; Accepted.

[12].Pettit C, Pullar D. An integrated planning tool based upon multiple criteria evaluation of spatial information. Computers, Environment and Urban Systems 1999; 23:339-357.

[13].Bansal VK, Pal M. Generating, evaluating and visualizing construction schedule with geographic information systems. Journal of Computing in Civil Engineering, ASCE 2008; 22:233-42.

[14].Cheng MY, Ko CH, Chang CH. Computer-aided DSS for safety monitoring of geotechnical construction. Automation in Construction 2002; 11:375-390.

[15].Bansal VK. Application of geographic information systems in construction safety planning. International Journal of Project Management 2011; 29:66-77.

[16].Manase D, Heesom D, Oloke D, Proverbs D, Young C, Luckhurst D. A GIS analytical approach for exploiting construction health and safety information. Journal of Information Technology in Construction 2011; 16:335-356.

[17].Issa RR, A Flood I, O'Brien WJ. Closure. 4D CAD and Visualization in Construction: Developments and Applications. eds., A.A. Balkema Publishers, Tokyo 2003. p. 281-284.

[18].Kumar M, Biswas V. Identification of potential sites for urban development using GIS multicriteria evaluation technique. Journal of Settlements and Spatial Planning 2013; 4:45-51.

[19].National Building Code of India 2005, SP 7:2005Second Revision 2005, Published By Bureau Of Indian Standards, New Delhi 110002.

[20].Carsjens GJ, Ligtenberg A. A GIS-based support tool for sustainable spatial planning in metropolitan areas. Landscape and Urban Planning 2007; 80:72-83.

[21].Sacks R, Rozenfeld O, Rozenfeld Y. Spatial and temporal exposure to safety hazards in construction. Journal of Construction Engineering and Management 2009; 135:726-736.

[22].SketchUp (2012), "Google Sketch Up Plug-in."<http://sketchup. google.com/ intl /en /download/plugins.html> (May 15, 2012).

BIOGRAPHIES

Satish Kumar is HOD Architecture in the Department of Technical Education, Govt. of Himachal Pradesh. Author is pursuing his PhD from NIT Hamirpur.[1]

Dr. Vijay Kumar Bansal is working as Associate Professor in the Department of Civil Engineering, NIT Hamirpur, Himachal, India.[2]