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Road Accessibility Analysis of Hillside Development Using Geographic Information System

I. A. CHANDIO[++], M. A. H. TALPUR, T. A. QURESHI, I. A. MEMON

Department of City and Regional Planning, Mehran University of Engineering and Technology, Jamshoro, Sindh.

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Abstract: Encroachment of hillsides for development has become apparent in certain developing countries because of shortage of flat land. This unavailability encourages severe environmental problems where unstable slope exist. This threat results a huge loss of life and resources. Hence, this paper aims to determine the road accessibility of hillsides to be developed. Geographic Information System (GIS) technique Least-Cost Path Analysis (LCPA) gives a platform to determine road accessibility easily from the starting and end point locations. Results found that GIS is an important computer technology which can solve complicated land use planning problems such as accessibility analysis for hillside development. This research focused on possible site accessibility by employing the GIS least-cost path analysis for hillside development of the study area. The purpose was to determine site accessibility in terms of road access in view of its hilly topography. It can be a useful technique for various stakeholders like urban planners, engineers and policy makers. This aspect of the research enriches land suitability analysis and addresses environmental and economic challenges encountered for the foreseeable future of hillside development. This study covers standard procedures for accessibility modelling from the beginning of assessing land suitability and modelling with the acquisition, preparation and computation of spatial data.

Keywords: Geographic Information System, Accessibility, Land Suitability.

1. INTRODUCTION

Any regioncannot be economically developed without road accessibility (Geurs and Wee, 2004; Liu and Zhu, 2004). Any kind of land-use activity cannot be generated without sustainable accessibility. For the land suitability analysis, steps should be taken, such as the GIS based accessibility approach, prior to determining hillside 'access' in the development's analytic process(Talpur, Napiah, Chandio, and Khahro, 2013). Therefore, sustainable accessibility can enhance economic activities in hillsides while also protecting the natural beauty of the hillside environment. Hilly topography is an often issue in development and constructing a road because of uneven steep terrain and dense forest (Taylor, Sekhar, and D'Este, 2006). Risky slopes should be avoided in the uneven topography of the hilly areas (Dai, Lee, and Zhang, 2001; Ismail and Jusoff, 2009). Thus, GIS is a useful tool for the minimization of environmental hazards by using the least-cost path (LCP) technique in the evaluation of road access in the hilly areas (Yu,andMunro-stasiuk, 2003). Computer technology techniques facilitates at present to determine suitable land for laying infrastructure planning (Ahlfeldt and Wendland, 2011). An example is GIS, a technique that gives opportunity to the planners to determine the road most suitable hilly areas. Nevertheless, GIS-based spatial assessment tool called the LCP method is a specifically designed and important approach for this very purpose. In order to minimize the environmental riskscausedbyuphill side's development, the road accessibility criteria should be discussed with environmental specialists and planners to attain the objectives.

It is illustrated in various papers application of LCP. Currently, various GIS software's gives the facility of LCP significant function, which is broadly used in linear path planning problems (Ismail and Jusoff, 2009). It is also used in mountain areas for accessibility analysis. The use of LCP has made it convenient to find out real world problems; the most appropriate routes towards different locations. Therefore, the aforementioned application requires fastest computers in the world. (IDRISIPATHWAY function) one of its practical application was developed by Eastman in 2003, to find the minimum costly routes for future water supply lines between reservoir and town(Iqbal, Sattar, and Nawaz, 2006a). LCP was used to find out the best route from the beginning to end for designing road along with canal by considering variouscriteria (Collischonn and Pilar, 2000).

However, least-cost path for road planning in the GIS was improved as a traditional method (Yu *et al.,* 2003) described the network pattern overview known as 'Smart Terrain' (ST) that implemented for channels and subways locations. Lee and Stucky applied an integrated approach for determining the lowest cost path to view shed analysis (Lee and Stucky, 1998). The outcomes of that technique were beneficial for military land use

[++]Corresponding Author: Imtiaz Ahmed Chandio; Email: imtiaz.chandio@faculty.muet.edu.pk

activities. To calculate a time-saving route, a GIS-based cost path analysis function was applied to find track in mountainous area, to reach in a one round trip from base camp. GIS-based Multi-Criteria Evaluation (MCE) method adopted to discover the low cost route in cold weather regions to the extraction of mining regions(Atkinsona, *et al.,* 2005; Olsson, 2009).

This paper explains the computer based intelligent technologies for example, GIS. GIS methods can be the utmost efficient to improve the economic condition of the region by investigating the possibility of accessibility in hilly regions to reduce future environmental concerns. The results can be a useful contribution for the determination of optimal routes (accessibility) in hillside areas using the GIS-based approach.

2. STUDY AREA

Study area was selected at Penang Island Mountainous region for this analysis. Study area covers 150 square kilometers **(see Fig.1).**

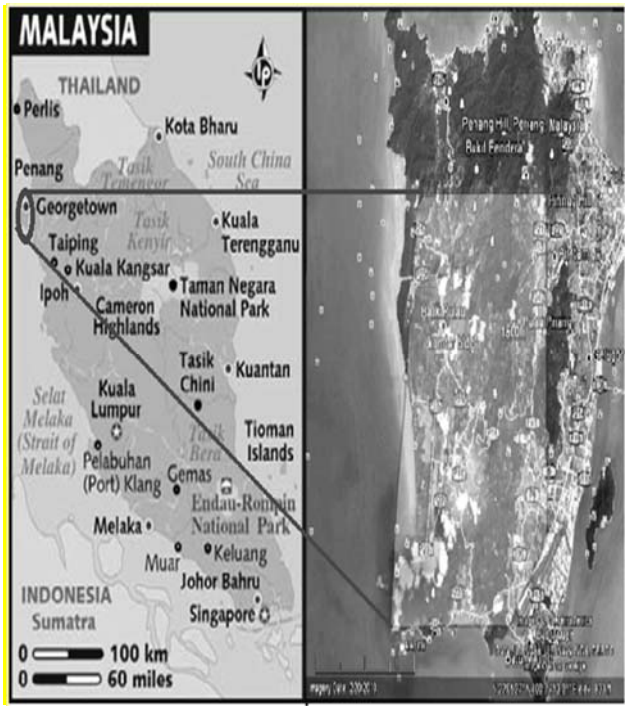


Fig.1. Study area (Penang, Malaysia)

3. METHODS

Road accessibility is the most important aspect of sustainable hillside development. The LCP analysis approach was used to the study area. ArcGIS spatial extension has a capability of prediction and to project possibilities for feasible uphill routes. GIS is a decision-making tool that involves geographically and environmentally referenced spatial problems to help determine the accessibility and most suitable uphill route. The following steps are taken to project the accessibility of route possibilities:

1. To create Source and Cost Datasets;
2. To cost Weighted Distance;
3. To perform Shortest Path.

The detailed process of producing accessibility is depicted in **(Fig.2).**

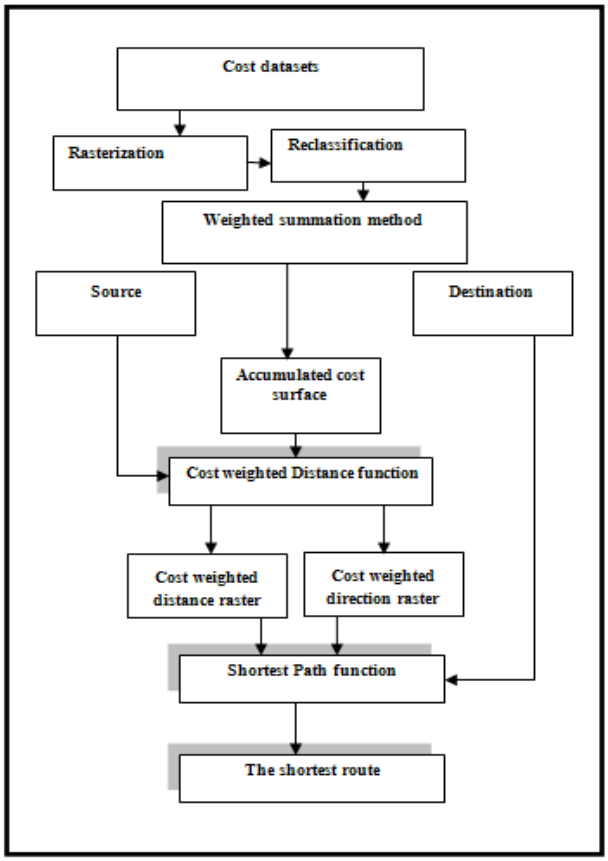


Fig.2.Flow diagram of the generation accessibility (Iqbal, Sattar, and Nawaz, 2006b)

Therefore, three data layers elevation, slope and aspect were used to generate possible accessibility**.**

4. RESULTS AND DISCUSSION

The spatial function of LCP in the ArcGIS is to provide cost effective modelling method in road accessibility. The Least Cost Path (LCP) analysis is used to find out the site accessibility of a given hillside. LCP analysis plays a vital role in hillside development in terms of road access (Liu and Zhu, 2004). To develop an output raster the cost distance function utilizes a source data layer and gathered cost surface in which value are allocated in every cell. This can be called the least accumulative cost of travelling from each cell back to the source; i.e., the lower the value, the lower the represented cost. Every cell in a cost-weighted raster is assigned a number (value) corresponding to a total of the least travel costs incurred when traveling back along the path to the nearest source. The cost-weighted

distance function produces two cost sets; i.e., the cost weighted distance raster and the cost weighted direction raster (back-link raster) (Melbye,*et al.*,2015).

The cost distance raster may indicate the minimum gathered cost for each cell to the nearest source but it does not clear how to reach there. The output back-link raster provides a road map to recognize a route taken from any cell, together with inexpensive route back to the adjacent source. The algorithm for calculating a direction for the raster to each cell in order to find the code is identical to that of the neighboring cells as the best way of return to the integer, numbered 0 to 8 with '0' representing the source's location. If the least costly path is to pass from the existing cell located at the lower right diagonal cell, the existing cell will be assigned 2; if traveling directly down or south, the existing cell would receive the value 3, and so forth (Melbye *et al.,* 2015). The back- link is used to rebuild the least-cost path from every cell of a raster and values from 1 to 8 in clockwise direction from the right.

The last phase in accomplishing the LCP function distinguishes the nearby route between the source and the designated end point with input cost distance and back-link raster datasets. The LCP as a spatial function of the ArcGIS was used to produce road accessibility. As shown in **(Fig.3),** the accessibility model which is overlaid on land suitability model.

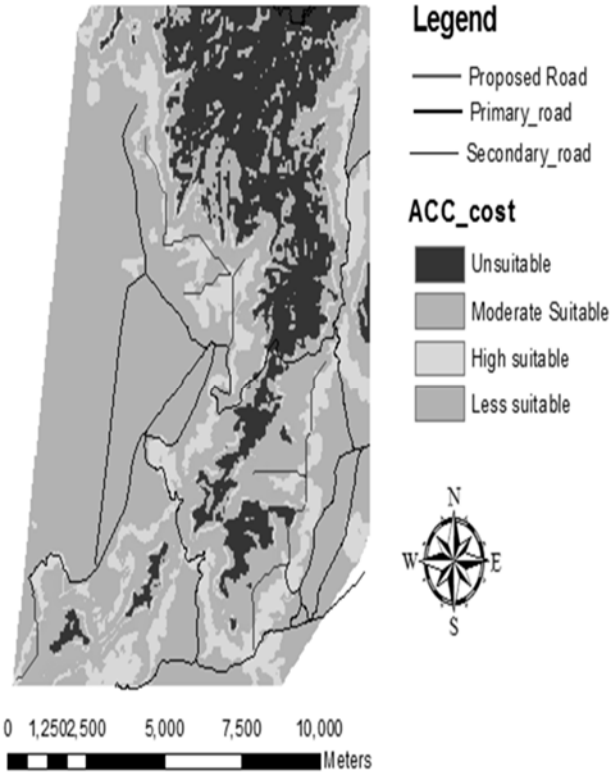


Fig.3.Accessibility model

5. CONCLUSION

This study may also constitute an innovative approach for decision-makers; thus reducing future environmental hazards for hillside developments; especially noting that a site accessibility model is also developed. Road accessibility can boost local economic development activities of any new developing area; economy and environment may deteriorate because of lack of planning concentration. Therefore, in this research, 'least-cost path' (LCP) analysis techniques in GIS is applied as a sustainable approach to determine site accessibility in terms of road for new hillside development. This technique also helps different other type of linear infrastructure planning. GIS is a powerful computer intelligent technology which can minimize the time cost of analysis and replaces conventional methods of road planning. Hillside development has a probability to loose land cover such as trees and landscape. Natural water bodies can exist in mountain areas that need a sustainable methods to develop hilly areas for various kind of development. LCP is successfully implemented from a predetermined starting point (source) through to an end point (destination). This paper describes that computer applications are useful in planning field which has been proved a more efficient and economic method for determining the possibility of accessibility. It (LCP) is herein recommended by the robust results of this study for environmental and economic utilization in developing countries as a tool for linear route planning.

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