Research Journal of Environmental and Earth Sciences 4(10): 907-911, 2012
ISSN:2041-0492

Submitted: August 07, 2012 Accepted: September 24, 2012 Published: October 20, 2012

Computer Application in Routing of Road using Least-Cost Path Analysis in Hillside Development

Imtiaz Ahmed Chandio, Abd Nasir B. Matori, Khamaruzaman B. WanYusof, Mir Aftab Hussain Talpur, Shabir Hussain Khahro and Munirah Radin Mohd Mokhtar
Department of Civil Engineering, University Teknologi Petronas, Malaysia

Abstract: The aim of this study is to determine accessibility (road) with application of Geographic Information Systems (GIS) by using spatial data in hillsides for development. Optimal road planning is a challenging problem of the environment and economic development in high mountain areas that requires the most sophisticated scientific methods of path analysis. In planning the most suitable route for the road, the topography has always acted as an important role as a constraint. The Least-Cost Path Analysis (LCPA) method provides a way to find a route (the cheapest) best from the start and end in two locations that can be easily calculated by considering several criteria in GIS. To find a route with the lowest cost for a road, GIS technology has enabled the implementation of a wide range of linear infrastructure, such as the best route for the road. This study aims at the analysis of best route for a road by using integrated Multi-Criteria Decision Analysis (MCDA) and LCPA approaches in GIS. This analysis used topography and functions related to the slope, land use and the cost data layers. The study found that the road should be kept away from the unnecessary slopes. LCPA model was tested in the form of examples for the most suitable route planning in the development of mounting sites using ArcGIS 9.3.

Keywords: GIS, LCPA, MCDA, most suitable, optimal route planning

INTRODUCTION

Today, many developments in Peninsular Malaysia have encroached into the hills areas which are characterized by steep terrain and dense forest towards. One of the most important issues in the uneven topography is that the excessive slope often occurs when building the roads in the mountains. Extreme slopes should avoid steep and uneven topography to the hillsides (Ismail and Jusoff, 2009). In order to minimize environmental hazards, least-cost path for linear features such as road access is helpful in the application of Geographic Information Systems (GIS) (Yu *et al*., 2003). Methods for optimal route planning for roads and other linear features are being developed in current computer technology. In this case, a GIS technique provides planners and engineers the opportunity to straightforwardly determine the halls of the most suitable land. Along with the Least Cost Path Analysis (LCPA) is particularly important GIS-based spatial analysis approach for this purpose.

LCPA provides identification of the best way from one to another point on the cost surface or raster. To identify the cost of the travelling through each of the cell that gives the cost and determines how expensive the cost of the route is, it is to pass that cell (Bagli *et al*., 2011). LCPA for the route plan can be generated by the accumulated cost or thematic cost surface in GIS, which determines a line that goes from the source to a destination.

The accumulated cost surface consists of a number of criteria, where the value at each pixel gives the estimated relative (neighboring cells) cost of route planning through the pixel. The accumulated cost surface is generated from the cost surface by computing the cumulative cost of each cell from the starting point. The procedure is performed by an algorithm that searches; among the starting point's neighboring cells for the one with the lowest value (Bagli *et al*., 2011; Lee and Stucky, 1998). In this study, the classical (Dijkstra, 1959) algorithm, named after its inventor, the Duetch computer scientist Edsger Dijkstra, has been applied for the implementation of the LCPA in a raster based GIS (Xu and Lathrop, 1995) to identify the least cost path between source and destination points. The algorithm is specially written for a node-based network. To employ this algorithm in a raster GIS based analysis, the centre point of each pixel has been considered as a node in the network (Saha *et al*., 2005).

The accumulation cost surface can be computed by considering all the required criteria of the road planning and incorporate their concerns through a multi-criteria approach using a Weighted Summation Model (WSM) (Chandio *et al*., 2011a). The accessibility (Chandio *et al*., 2011b) criteria in terms of road must be discussed before the planners and engineers to accomplish objectives of minimizing the environmental hazards caused by the development to the uphill sides.

Corresponding Author: Imtiaz Ahmed Chandio, Department of Civil Engineering, University Teknologi Petronas, Malaysia

Application of LCPA has been described in various literatures. Currently, the LCPA is a powerful tool available in most GIS software's is implemented and applied extensively in linear route planning features. LCPA application of the real-world problems has made it possible to find the most suitable route between locations. Therefore, it has been applied by the current intelligent fastest computers in the world (Lee and Stucky, 1998). The IDRISIPATHWAY function was developed in 2003 by Eastman (2003) to determine the least expensive route for the pipeline of future water supplies between the reservoir to a town in Malaysia implemented (Yusof and Baban, 2004).

The least-cost path algorithm was also applied to find the best route from the starting location and ending at the canal road design given the topography, slope and costs (Collischonn and Pilar, 2000).

In this case, least-cost, a conventional method was improved for road planning in the GIS (Yu *et al*., 2003). Yu *et al*. (2003) also presented an overview of the network pattern and the algorithm called Smart Terrain (ST), which is used for bridges and tunnels into consideration the location of the contour information. An integrated approach to view shed analysis to determine the lowest cost path is applied (Lee and Stucky, 1998). The results of the integrated technique are very useful for civil engineering, military activities and management of environmental resources. A GIS-based cost path analysis method was used for the calculation of the time-saving route in the trackless mountains to visit all the rain gauges in a single round trip from base camp (Balstrøm, 2002). A GIS-based Multi-Criteria Evaluation (MCE) methodology was adopted in finding the cheapest route all the way from cold weather to the mining area of Contwoyto Lake, Nunavut (Atkinsona *et al*., 2005).

This study demonstrates the GIS-based methods are most suitable for the accessibility of road in the hilly regions to reduce their future environmental consequences and economic development of regions. Accessibility modeling in GIS has achieved the development of many possible applications by using the LCPA to find the best routes for roads and other linear infrastructure. The results of this study can be a useful contribution in determining the best "cheapest" route to the accessibility of roads using GIS-based integrated multi-criteria decision analysis approach promises the least-cost path spatial analysis function in GIS.

MATERIALS AND METHODS

The study area is located on Kulai Senai Town, Johor Bahru, Malaysia and is conducted in 2012. The LCPA is tested by using the spatial analyst function in Arc GIS 9.3. This is an important spatial analysis tool in GIS and applied to the shortest route spatial referenced in determining the most suitable site for the hillside development for the cheapest route for the road to the hillside development. GIS is a decision making tool that solves the problem of geographic and

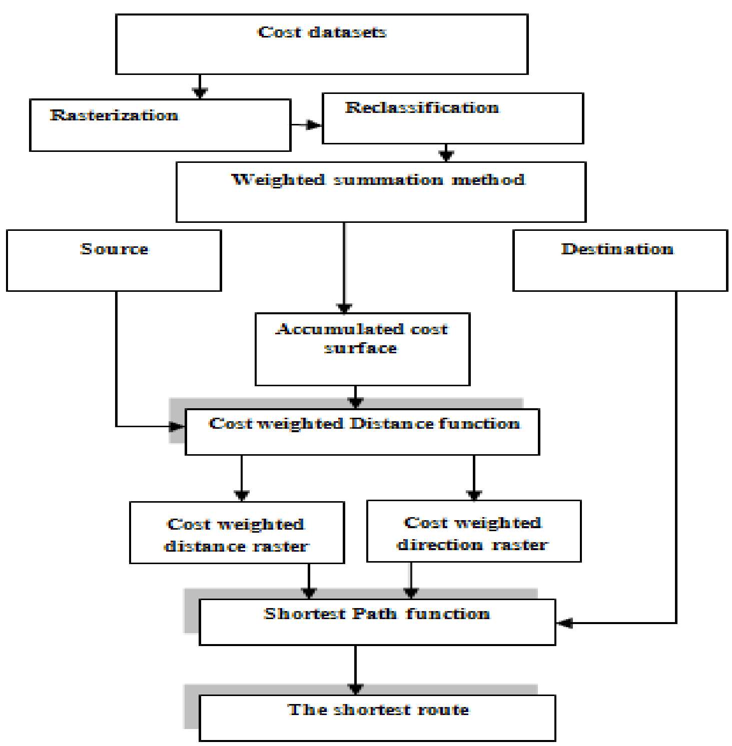


Fig. 1: The methodology for the generation of the least-cost path

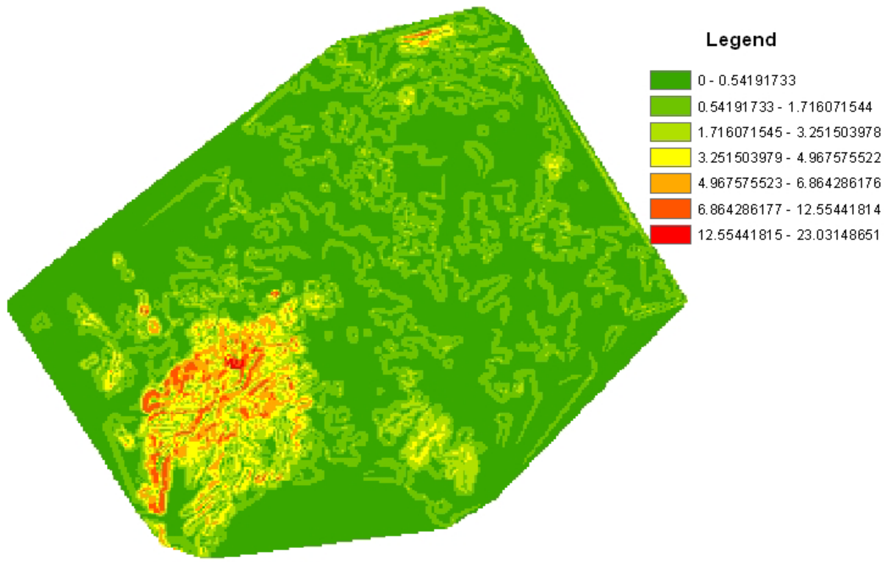


Fig. 2: Slope dataset

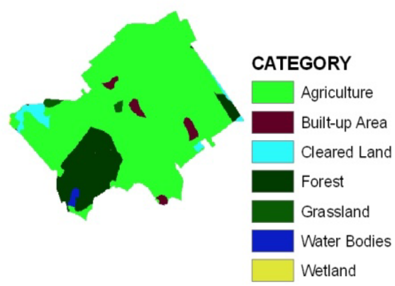


Fig. 3: Land use dataset

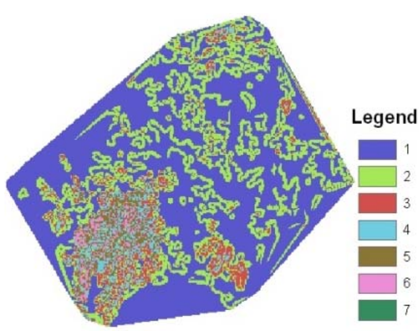


Fig. 4: Reclassified slope dataset

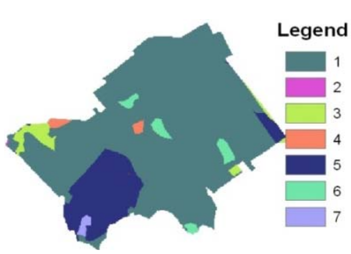


Fig. 5: Reclassified land use dataset

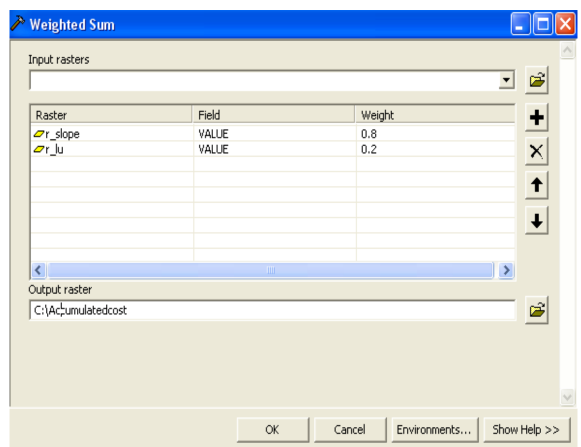


Fig. 6: Weighted summation model in ArcGIS

environmental planning. To find the best "cheapest" route for new hillside development, the following steps be followed to produce the least-cost path based on spatial analysis functions of Arc GIS 9.3 and illustrated in Fig. 1.

The source is the starting point of the proposed feature for the analysis. The cost datasets or cost raster determines the cost of travelling through each cell. Although the cost raster is a single dataset, it is often used to represent several criteria such as slope Fig. 2 and land use in Fig. 3.

Each cost dataset was reclassified to a common scale in Fig. 4 and 5. The next step in generating the accumulated cost raster surface is to add the reclassified datasets together by multiply given weights according to the importance of the cost datasets. The summation of the weights must be 100%. Nevertheless, the Weighted Summation Model (WSM) was applied to

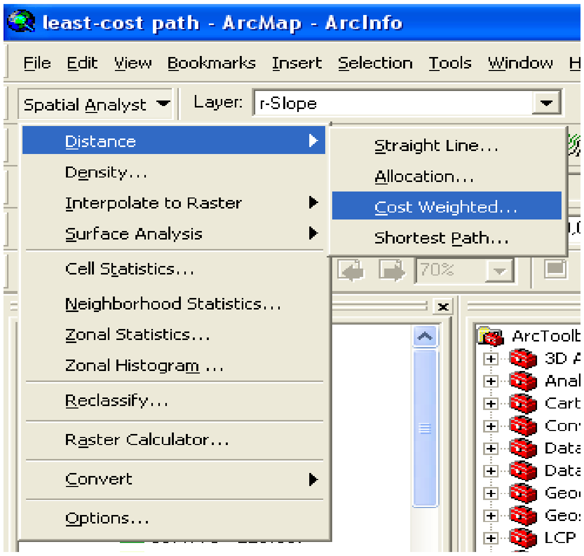


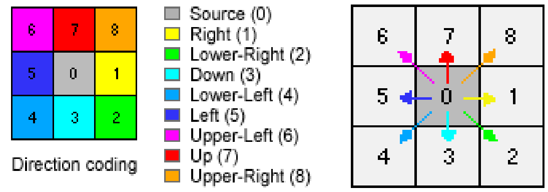
Fig. 7: Cost weighted function in spatial analyst

produce the accumulated cost surface spatial analyst tool of the GIS as shown in Fig. 6. Finally, the cost weighted distance function was used from spatial analyst tool that generated two cost distance and direction (back-link) raster surfaces are depicted in Fig. 7.

RESULTS

The cost distance function (or cost weighted distance) uses the source and accumulated cost surface and produces an output raster where each cell is assigned a value that is the least accumulative cost of travelling from each cell back to the source i.e., the lower the value, the lower the cost represents in Fig. 8. Every cell in the cost-weighted raster is given a value that corresponds to the total of the least travel costs which would be incurred by traveling back along the path to the cheapest way to the nearest source. The cost-weighted distance function produces the two costs i.e. the cost weighted distance raster and the cost weighted direction raster (back-link raster) (Iqbal *et al*., 2006).

The cost distance raster indicates the least accumulated cost for each cell to the nearest source, but it does not tell how to get there. The output back-link raster provides a road map to identify the route to take from any cell, along with the cheapest path, back to the nearest source. The algorithm for calculating the direction of the raster to each cell to determine the code is identical to the neighboring cells is the best way back to the nearest integer numbered 0 to 8. The value 0 is used to represent the source locations. If the least costly path is to pass from the existing cell location to the lower right diagonal cell, the existing cell will be



(a) (b)

Fig. 8: Direction (back-link positions) coding

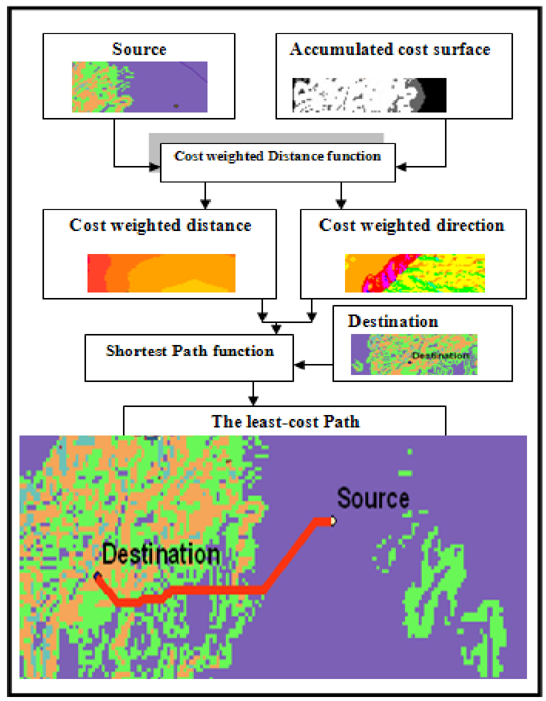


Fig. 9: Least-cost path results

assigned 2; if traveling directly down or south, the existing cell would receive the value 3 and so forth (ESRI Arc GIS 9.3-HelpDesk). The back link is used to reconstruct the least-cost path from every cell of a raster. The values from 1 through 8 encode the direction, clockwise from the right as shown in Fig. 8.

The last step in performing the least cost path function identifies the shortest route between the source and the selected destination by using input cost distance and back-link raster datasets.

The LCPA is a cost effective modeling technique in the GIS which gives the least-cost paths for roads, canals and all other linear features. The LCPA as a spatial function of the GIS was used to generate the best route using a 629 feet elevation (contour) data layer. The contour data layer was converted into a Digital Elevation Model (DEM) to produce a slope data layer. The slope was considered to be <30° in determining the least-cost path to the uphill site. The summarized results of the LCPA are shown in Fig. 9.

CONCLUSION AND DISCUSSION

The least-cost path analysis function is a useful approach in finding the best route (path) for new hillside development, as it provides rapid and important applications in finding all kinds of linear features for the planning of water supply lines, sewer pipes, gas pipes and electrical cables. It is a powerful GIS tools to integrate user information and replaces the conventional method of path planning. It can minimize costs (Delavar and Naghibi, 2003) and project time (Iqbal *et al*., 2006). Environmental constraints are involved in hillside development such as forest clearing, landscape and natural water bodies. This requires a sustainable approach to find a route in the development of the hillside. The method which is based on LCPA has been applied in considering the environmental and economical aspects of the road with integration of GIS and MCDA approach. In fact, LCPA is successfully implemented from (sources) of a predetermined point and the end (goal). It could be concluded that LCPA is a cost effective application of GIS-based intelligent approach in planning for the route that leads to a method, sustainable planning faster and cheaper (Iqbal *et al*., 2006). It is recommended for the environment and economic development in developing countries to use this LCPA in linear route planning features.

REFERENCES

Atkinsona, D.M., P. Deadman, D. Dudych and S. Trayno, 2005. Multi-criteria evaluation and least cost path analysis for an arctic all-weather road. Appl. Geograp., 25: 287-307.

Bagli, S., D. Geneletti and F. Orsi, 2011. Routeing of power lines through least-cost path analysis and multicriteria evaluation to minimise environmental impacts. Env. Impact Assess. Rev., 31: 234-239.

Balstrøm, T., 2002. On identifying the most time-saving walking route in a trackless mountainous terrain. Geografisk Tidsskrift, Danish J. Geograp., 102: 51-58.

Chandio, I.A., A.N. Matori, D.U. Lawal and S. Sabri, 2011a. GIS- based land suitability analysis using AHP for public parks planning in Larkana city. Modern Appl. Sci., 5(4): 177-189.

Chandio, I.A., A.N. Matori and D.U. Lawal, 2011b. GIS-based accessibility analysis using suitable land for public parks in Larkana city Pakistan. Res. J. Appl. Sci. Eng. Technol., 3(6): 553-557.

Collischonn, W. and J.V. Pilar, 2000. A direction dependent least cost path algorithm for roads and canals. Int. J. Geograph. Inform. Syst., 14(4): 67-77.

Dijkstra, E.W., 1959. A note on two problems in connexion with graphs. Numer. Math., 1: 269-271.

Eastman, J., 2003. IDRISI Kilimanjaro Guide to GIS and Image Processing. ESRI ArcGIS (9.3), Redlands, 1999-2001, USA.

Iqbal, M., F. Sattar and M. Nawaz, 2006. Planning Least Cost Gas Pipeline Route A GIS & SDSS Integration Approach. In Advances in Space Technologies, Islamabad, Pakistan IEEE.

Ismail, M.H. and H.K. Jusoff, 2009. Planning of access road using satellite technology and best path modeling. Mod. Appl. Sci., 3(3): 83-95.

Lee, J. and D. Stucky, 1998. On applying viewshed analysis for determining least-cost paths on Digital Elevation Models. Int. Geograph. Inform. Sci., 12: 891-905.

Saha, A.K., M.K. Arora, R.P. Gupta, M.L. Virdi and E. Esaplovics, 2005. Gis-based route planning in landslide prone areas. Int. J. Geograph. Inform. Sci., 19 (10): 1149-1175.

Xu, J. and R.G. Lathrop, 1995. Improving simulation accuracy of spread phenomena in a raster-based geographic information system. Int. Geograph. Inform. Sci., 9: 153-168.

Yu, C., J. LEE and M.J. Munro-Stasiuk, 2003. Extensions to least-cost path algorithms for roadway planning. Int. J. Geograph. Inform. Sci., 17(4): 361-376.

Yusof, K.W. and S. Baban, 2004. The integration of GIS and remote sensing in finding the Least-cost pipeline path for a proposed pipeline in Langkawi Island. Malaysia in International Symposium and Exhibition on Geoinformation, PWTC, Kuala Lumpur, Malaysia.