International Journal of Applied Geospatial Research
Volume 8 • Issue 3 • July-September 2017

Least-Cost Pipeline using Geographic Information System:
The Limit to Technicalities

Matthew Biniyam Kursah, Geography Department, University of Education Winneba, Winneba, Ghana

ABSTRACT

Increasing demand for water in Wapuli and its environ led to a proposal to construct a pipeline to link the town to an existing water plant. This paper developed a geospatial model incorporating multi-criteria analysis involving technical factors such as slope, landcover, watercourses, distance to roads and soil types to determine a least-cost path for the pipeline. However, the first least-cost path passes through a tiny sacred grove near Moadani dam, necessitating the generation of a second least-cost path by considering sacred groves as constraint. The result showed that the least-cost path avoided steep slopes, and runs through relatively levelled grounds. This analysis showed the importance of cultural factors in route planning. It is recommended that in route planning attention be given to cultural factors much in the same way as the technical factors.

KEYWORDS

Cost Distance, GIS Application, Least-Cost Path, Multi-Criteria Analysis, Saboba

INTRODUCTION

The capital of Saboba district, Saboba, lies at the north-eastern part of the district, near Oti river, which is the source of pipe water supply in the district. Saboba was connected to the pipe water system about three decades ago and major extension occurred in the early 2000s.

After Saboba, the next larger town in the district in terms of population and area is Wapuli. The main sources of water to the people in this town include boreholes, intermittent streams, dugout pits and both natural and artificial wells. These sources are not reliable. The only flowing water body nearby is a stream flowing through Gbenja, about five kilometres from Wapuli on the Saboba-Wapuli road. However, this stream is intermittent in nature and cannot serve as a source of pipe water supply. The town thus experiences water crisis situation. For example it has been found that of the larger towns in the district, aside reporting on inadequate clean water, only residents of Wapuli clearly stated shortage of water as a pressing problem facing the community (Kursah, 2009). The planned construction of a new Senior High School in Wapuli will further increase the population in the town as it will not only facilitate influx of students but will also set a path for the expansion of the town. This is expected to increase water demand and worsen the water crisis situation in the town.

DOI: 10.4018/ijagr.2017070101

Therefore, the demand for a reliable source of water in Wapuli and its environ is high and is expected to increase soon. This situation has influenced a proposal for the construction of a pipeline to link the town to an existing water plant in Saboba. This demands a generation of the least-cost path for the pipeline from Saboba to Wapuli taking into consideration the varied landscapes. Therefore, the determination of least-cost pipeline is a multicriteria problem with conflicting objectives that need balancing (Macharia & Mundia, 2014). Thus, in planning a least-cost path, planners may consider factors such as slope, landuse type, soil type and built environment, ecologists may be concerned about protecting the ecosystems while political elites may also be considering governmental and political interest. Such different considerations make planning processes complex and decision making difficult. It also makes manual planning extremely difficult (Saha, Arora, Gupta et al., 2005), expensive and protracted (Macharia & Mundia, 2014).

By applying GIS, planners have been able to incorporate multiple factors and thereby allowing different stakeholders to reach an optimal solution (Anavberokhai, 2008; Collischonn & Pilar, 2000; Ismail & Jusoff, 2009; Olaya, 2004) as it is possible to generate a least-cost path between two points using GIS multi-criteria analysis (Anavberokhai, 2008). Incorporating multiple factors into GIS for least-cost determination has been done elsewhere, and it has been found to be more accurate and more useful to planners than the manual method (Saha et al., 2005). In this paper, GIS (ArcGIS) is employed to determine the least-cost path for a proposed pipeline project to transport water from Saboba to Wapuli.

LITERATURE REVIEW

Least-cost path is referred with different names; best path, shortest path, optimal path and cheapest path. In all its usages, it means the route with the lowest cost of construction after factoring all the necessary varying criteria which influence route construction and maintenance (Atkinson, Deadman, Dudycha, & Traynor, 2005; Choi, Park, Sunwoo, & Clarke, 2008; Ismail & Jusoff, 2009; Saha et al., 2005; Yu, Lee, & Munro-Stasiuk, 2003). The least-cost path analysis requires multi-criteria evaluation (MCA) to determine the relative importance or weights of multiple factors (Atkinson et al., 2005). Thus, least-cost path is generated from cost dataset or thematic cost surface. This is a raster map where value at each cell gives the estimated cost of passing through the pixel (Saha et al., 2005). The cost here represents the difficulty, resistance or friction in crossing the cell (Collischonn & Pilar, 2000). Thus, the thematic cost layer or cost dataset provides an estimate of the cost of route construction and maintenance over an area (Saha et al., 2005).

In real world, the shortest route is not necessarily the cheapest to construct. Feldman et al used terrain, geology and landuse factors in the Caspian Sea region to generate a least-cost path and found that the least-cost path was 21% longer (51km) than the straight-line path (42km) but the former was 14% less costly to construct (Feldman et al., 1995). This is because the least-cost path avoided higher-cost industrial and urban cells on the straight-line path. Also, it has been found that although the cheapest road was longer, it was less costly by 3.2% because it was located on areas that do not need cut-and-fill and culverts due to relatively higher elevation, suitable soils, and for avoiding major valleys and problematic landcover (Kursah, 2014). Other examples exist showing the application of least-cost analysis. Some of these include determining the best path for constructing an all-weather road between a mining region and a deep water port (Atkinson et al., 2005), for identifying the best path for an electric transmission line (Berry, 2007) and the fastest path with the least slope-gradient (Stefanakis & Kavouras, 1995).

Since the late 1970s, the analytical hierarchy process (AHP) developed by Saaty (1977) has been a popular method for multi-criteria evaluation (Malczewski, 2006) which include the least-cost path. The AHP rates the importance of each criterion relative to every other criterion using a nine-point reciprocal scale (Saaty, 1977, 1980). In this method, the GIS model considers multiple factors together and weights the factors using pairwise comparisons. From this, weighted linear combination

Related Content