SHORT COMMUNICATION

DEVELOPMENT OF A SUGARCANE TRANSPORT ROUTE PLANNING MODEL IN A GEOGRAPHICAL INFORMATION SYSTEM

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Abstract

Route planning involves the determination of a path between any two or numerous points in space, based on design objectives, such as minimum construction cost, maximum travel speed, safety and minimum environmental impact. Because of the significant costs of transport in the sugar industry, a model, named FastTrack, was developed to investigate route planning opportunities in this industry. FastTrack integrates vehicle performance and spatial information to derive optimal pathways for high bulk agricultural transportation in terms of efficiency and economics. The model mathematically incorporates road construction and maintenance costs, topographical terrain, land-use, vehicle performance specifications and annual sugarcane volumes to determine the most cost effective route from a production region to a mill. A small portion of the Noodsberg mill region was selected as a case study area. In this area, approximately 70 000 tons of cane currently travels along the 9 km main road to the mill. A shorter 7 km route that cuts through the current farming landscape, may present a more economical alternative. This case study should sufficiently test and demonstrate the capabilities of the FastTrack model.

Keywords: transport, road trains, GIS, route planning, economics, FastTrack, modelling

Introduction

Route planning involves the determination of a path between any two or numerous points in space. Based on a certain set of design objectives, a straight line between two points may not necessarily be the most efficient path. Typical design objectives may include minimum construction cost, maximum travel speed, safety and minimum environmental impact (Sadek *et al.*, 1999). Route planning has been used successfully to optimally design, *inter alia*, highways (e.g. Sadek *et al.*, 1999), pipelines (e.g. Feldman *et al.*, 1995) and canals (e.g. Collischonn and Pilar, 2000). Because of its ability to overlay and manipulate spatial information, Geographical Information Systems (GIS) are extensively used for route planning.

In South Africa, a large portion of total sugar production cost (20 - 25%) can be attributed to transporting cane (Giles *et al.*, 2007). Bezuidenhout *et al.* (2004) demonstrated successfully how road construction costs could be offset against transport costs to improve overall economics. The aim of this research was to use route planning as a tool to develop a model, named FastTrack, which could integrate spatial information and derive optimal pathways for high bulk agricultural transportation in terms of efficiency and economics. This was done not only by assessing a mill supply landscape, but also by fitting the path's design objectives to specific vehicle configurations. This short communication introduces a methodological framework for the FastTrack model and proposes a suitable case study area.

Route optimisation framework

The FastTrack model mathematically incorporates road construction and maintenance costs, topographical terrain, land-use, vehicle performance specifications and annual sugarcane volumes to determine the most cost effective route from a production region to the mill. The alignment of existing roads and the potential for new specialised roads are simultaneously considered.

Input variables are used to construct a GIS raster that reflects the total cost of transportation, including running costs, infrastructural improvements and annual road maintenance. The capital expenditure repayment period (CERP) is an input variable. A value of five years will be assumed for CERP to support conservative decision making under high market volatility. The constructed cost raster (R/pixel) is used to calculate a least cost path (LCP) based on the optimisation algorithms embedded in GIS. The final output is a road vector that considers not only cost, but also vehicle-specific turning limitations. Figure 1 depicts the model's conceptual framework. Inputs include a digital elevation model (DEM), road construction and maintenance costs, a land use map and vehicle specifications. Several data transformations and calculations are necessary before a final route vector can be produced.

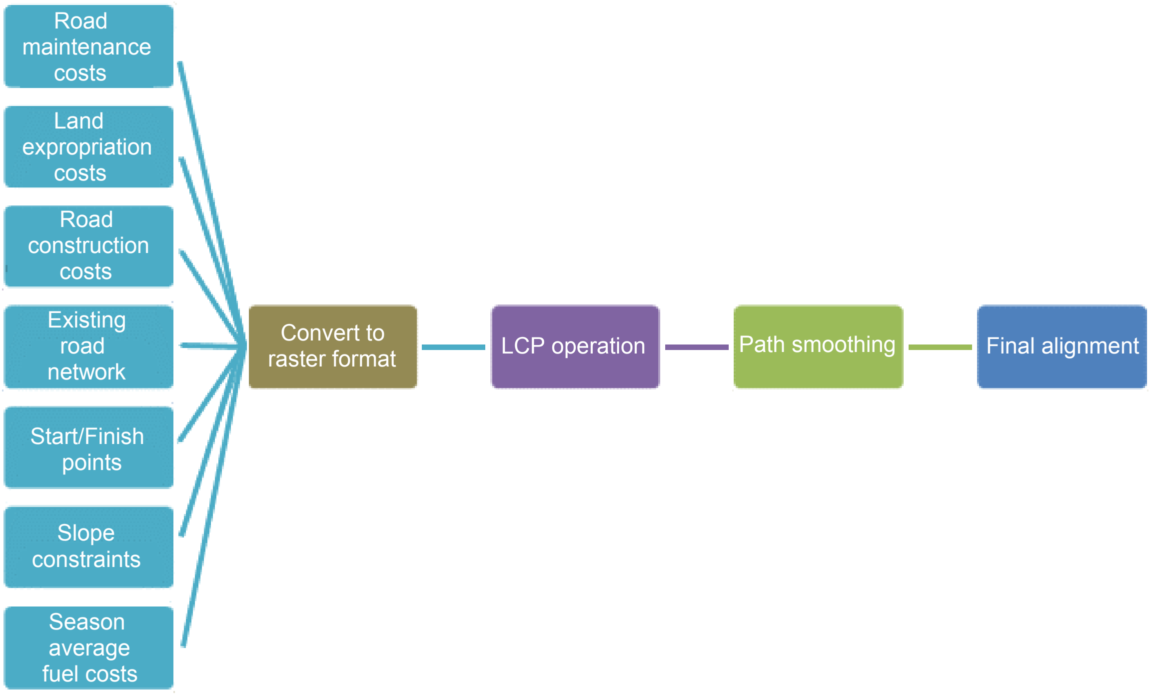

Figure 1. Simplified data flow diagram for the FastTrack model.

Due to the number of variables affecting construction costs, such as soil type, slope, availability and quality of gravel and distance to the quarry, tenders are often made using average road construction costs (personal communication[1]). These include average cut and fill volumes, which would vary only on particularly flat or steep terrain where excessive

[1] P Paige-Green, Council for Scientific and Industrial Research, Pretoria, South Africa (16 January 2008).

earthworks and culverts are required. The FastTrack model makes use of these general figures, which can be modified according to regional averages.

Proposed study area

A relatively small portion of the Noodsberg mill region was selected as a study area. Data capture is a tedious task and involves digitising the many land use features and farm roads in the study area. Figure 2 depicts a land use map of the selected area, showing all main, district and farm roads. The route's starting point and terminal point at the Noodsberg mill are indicated by a circle and a square, respectively. Approximately 140 000 tons of cane is produced south of the study area over a two year period with approximately half of this flowing over the starting point, annually. This volume may justify a more cost effective alternative route through the study area as opposed to using the existing main road. A direct route from the starting point to the mill would be 7 km long, whereas travelling on existing main roads the distance is approximately 9 km. The area has a wide variety of land uses through which a potential new road would have to be constructed. This case study should sufficiently test and demonstrate the capabilities of the FastTrack model.

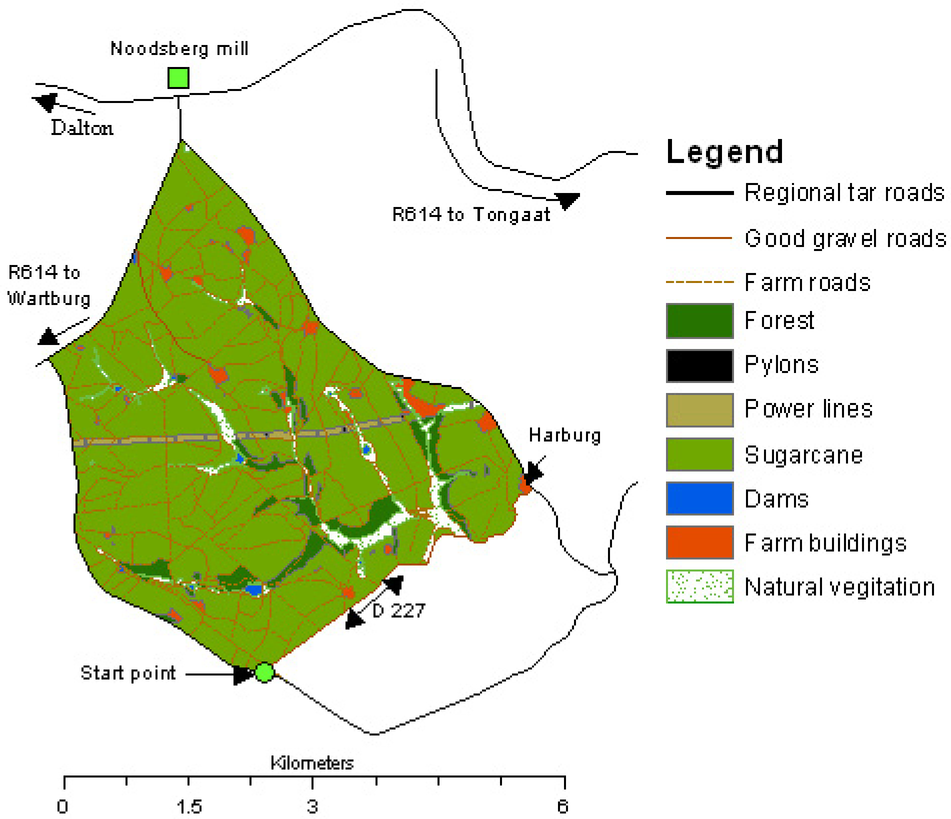

Figure 2. Land use map of the selected study area served by the Noodsberg mill.

Acknowledgements

The Department of Transport is thanked for funding the project. The Noodsberg Cane Growers' Association are thanked for their advice and willingness to provide information and knowledge where required. The School of Geography at the University of KwaZulu-Natal, in particulra Brice Gijbertsen, Ruth Howison and Prof Onisimo Mutanga, are thanked for their advice and guidance pertaining to the use of GIS.

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