Application of GIS in Transportation Planning: The Case of Riyadh, the Kingdom of Saudi Arabia

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Abstract

This paper is intended to illustrate applications of Geographic Information System (GIS) in transportation planning in general, and introduce a symbolic case study of Riyadh city, the capital of Saudi Arabia. The study relied on GIS to identify deficient facilities (i.e., tolerable, moderate, moderate to heavy and heavy road deficiencies) in the vital area within Riyadh's ring road. The deficiency analysis process is utilised to highlight streets where demand exceeds capacity. Incorporating the link volumes resulting from the travel demand forecasting into the network attribute table in GIS. For the short range planning, it will illustrate the usage of GIS in identifying projects on the network using dynamic segmentation, and preparing network link tables for travel demand planning. Moreover, the integration of GIS into the travel demands analysis process is to identify future areas of congestion. Shortest path and travel time allocation of major activity centres analyses are also investigated.

Introduction

Riyadh's city municipality is the prime planning organisation. It consists of fifteen sub-municipalities, with a population of approximately four million and covers an area of nearly four thousand square kilometres. The transportation planning departments in large metropolitan areas examine and coordinate issues of planning and related demographics and air quality concerns. Transportation planning councils manage and approve the use of public funds for transportation projects and services in all relevant districts. Transportation planning projects can be managed by either the ministry of transportation, Arriyadh's Development Authority (ADA) or by Arriyadh's Municipality. As decision-makers and high officials mandate, transportation-planning divisions bear the responsibility of maintaining, continuing and coordinating the planning process in all its premises. A travel demand planning process should be utilised in addressing the region's transportation needs to support planners in decision-making. A combined travel demand analysis and emission estimation process ensures conformity of transportation plans with air-quality standards.

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Planning Activities

The region's transportation planning organisations manage allocation of transportation funds through a pre-set planning process provided in a transportation program. The plan coordinates the implementation of roadway improvements, transit and congestion management projects. The transportation plans ensure the improvement of an area's air quality by reducing congestion and improving mobility. This is achieved through an emission estimation process that examines conformity of the plan with high international standards.

Geographic Information System is rapidly being developed and applied in a no-limit list of applications. Planning in general, and transportation in particular, have greatly benefited from some very effective and efficient technology. Some of the specific transportation applications of GIS include road design, highway mapping, and analysis of accident data and traffic volumes (Antenacci J C., et el, 1991). This technology was unavoidable and most notably in the strategic 30-year long term structural plan is also part of ADA and along with Riyadh's Municipality is also part of the organisations' planning responsibilities. This is why a short-range plan is also critical. Both short-term and long-range plans are eminent for planning agencies in taking on responsibilities. Such plans are often the foundation of a continuing, comprehensive, and coordinated planning effort in the urbanised areas receiving public funds for construction, maintenance, and operation of highways and the public transportation system. The plans identify areas of demand and recommend improvement and management policies based on the travel demand forecasting process.

1. Travel Demand Planning

Transportation planning in Riyadh as in any sound transportation planning agency, employs a travel demand modelling process based on production and attraction of travel between activity areas. Travel demand planning generates the data required for planning decisions. Trip Distribution Models are used to examine the regional travel characteristics. Since activities are based on a network of roads and projects, GIS plays a revolutionary role in illustrating and manipulating the analysis of results. The system enables analysis previously considered impossible because of the very large amounts of data involved (Manogue and Hutch, 1987). Various uses of GIS in modelling activities for long and short range planning can be applied to the roadway network and network maintenance and updating.

1.1 Road Network

A digital roadway network with the automated cartography and the complex mathematical models (Dakan, 1987) is the basis for travel demand modelling. The network is an aggregate representation of major thoroughfares classified higher than collector is and projected to planning coordinate system. The network is the input to the travel demand model as an ASCII file, which contains link cards identified by start and end points, A-B nodes. Each link card is a record that represents the different characteristics of a street segment. Prior to GIS, paper maps were the only medium available for visualising the network and identifying coding errors.

Changes to the network were done with the aid of key maps and knowledge of the region. Limited ability in manipulation lowers the network accuracy and the quality of analysis results.

The GIS capability of displaying graphics, while linking features to attribute tables, has become a valuable tool for maintaining and updating roadway network files. Displaying the road network on a computer monitor is a very effective and efficient tool in observing the relationship between the spatial and physical attributes of roadway facilities. Using GIS in displaying the network has facilitated identification of errors in link connections and trips loading from traffic analysis zones.

GIS provides a quick and easy way of monitoring network errors such as channelling, consistency of functional classification along a facility, errors in number of lanes, and other attributes essential for successful travel demand analysis. It also enables the correction of roadway alignment and the updating of node coordinates used in identifying link end points. The ability of GIS to produce coloured maps has provided a visual dimension for travel demand analysis. It has also made the perception of the different planning scenarios impact possible for non-planners. Furthermore, GIS statistical tools provide an interactive analysis mechanism, which assists in delineating the effects of planning decisions. Statistical summaries are used in the analysis of networks, such as identifying the number of links by facility type, number of lanes monitoring changes in network and travel characteristics overtime.

1.2 Network Maintenance and Updating

Riyadh's Municipality has adopted various GIS engines (software) regardless of vendors since they feature a so-called open system, GIS via localised database. Due to its compatibility, this certainly enabled various planning departments to use it. In GIS, a links attribute table, which contains links, characterised is attached to the network map. Using the GIS capability of displaying the network attribute table along with a graphic display, link attributes can be corrected and updated. In addition, results of travel demand analysis are attached and stored in the network attribute tables, such as a link's modelled volume, speed, and impedance. As needed, coloured maps of the roadway network displaying the different kinds of information are developed illustrating spatial relationships, temporal changes in travel needs, or locating facilities based on class, number of lanes, congestion and speed.

2. Short Range Planning (SRP)

The process of preparing the SRP requires identification of projects, which qualify for public funds, designated by decision-makers. Its transportation planning inclusive part deals with immediate needs and improvements. In the case of transit planning, short-range studies usually focus on operational improvements. The scope of such studies includes primarily analyses of existing demand, user characteristics, routes and schedules, equipment needs, fare structure and management. The techniques for carrying out these tasks are straightforward (Smerk G., 1971). The conventional short-range transportation studies will continue to play a significant role in urban areas that have existing transit systems, as they basically focus on the improvement of existing services. However, it must be pointed out the conventional approach does not apply to a small urban area with a transit system, the scope of short-range transit planning must not be limited to the analysis of the existing system only (Transportation Research Board, Report No. 176, 1976). Selection of qualifying projects relies on a project's ranking process. The ranking process estimates the project's impact on congestion, air quality and development. Calculating the travel time saving and emission levels that could result from implementing the project tests and the project's impacts on congestion and air quality.

2.1 Dynamic Segmentation and Networking

In order to determine the spatial attributes of project proposed for inclusion in the SRP, GIS is used to develop a map of projects, which highlights each group of projects, by type. Any of the three main GIS packages would have dynamic segmentation ability to generate a route for arc sections helped in identifying projects where the project limits does not end at a node. This solved the problem of having a limited ability in depicting projects accurately on the street network. Dynamic segmentation also allows for representing overlap projects, which partially or totally share the same road segment.

2.2.a Buffer Analysis

The proper approach followed in analysing added capacity projects is to examine the project’s effects upon congestion and air quality within an impact area based on a selected distance. Calculating the travel time saving and emission levels that could result from implementing the project within the impact area (buffer) then tests the project’s impacts. Using GIS, buffers are created around each project representing the impact area. In GIS, the links located inside the project's impact area (buffer) can be captured, then, travel timesaving can be calculated from the difference in time, before and after the project's construction. This process involves incorporating the travel demand analysis data into the attribute file, which is transferred from GIS to a date base application (i.e., Access, Oracle..etc.) to undertake the calculations required. The benefits of GIS in this process is that it allowed for generating the buffers required for each individual projects and identification of the different roads located inside the impact area. Figure (1) shows the road network for the capital city of Riyadh.

2.2.b Shortest Path Analysis

As part of the ranking process, travel time on alternative was identified for roads to be constructed. The travel time on alternate routes was used to calculate travel timesaving gained from construction of the proposed project. An alternative route is based on the identification of the shortest path between end points where the new roads are to be constructed. Path Finding Module of Arc/info can be used to generate the shortest route between points of the proposed project interactively. The statistical reports of link travel time and link-ids would be generated and used to evaluate the project's potential in reducing congestion and air pollution within the impact area. This can be a done using the link impedance attribute table which contains link's travel time calculated in GIS based on speed, length and access penalty factors. GIS is used to identify links for projects where Vehicle Miles Traveled (VMT) is used as variable for analysis. Arc identifiers can then be used to join the network links in GIS to the VMT data obtained from the travel model output.

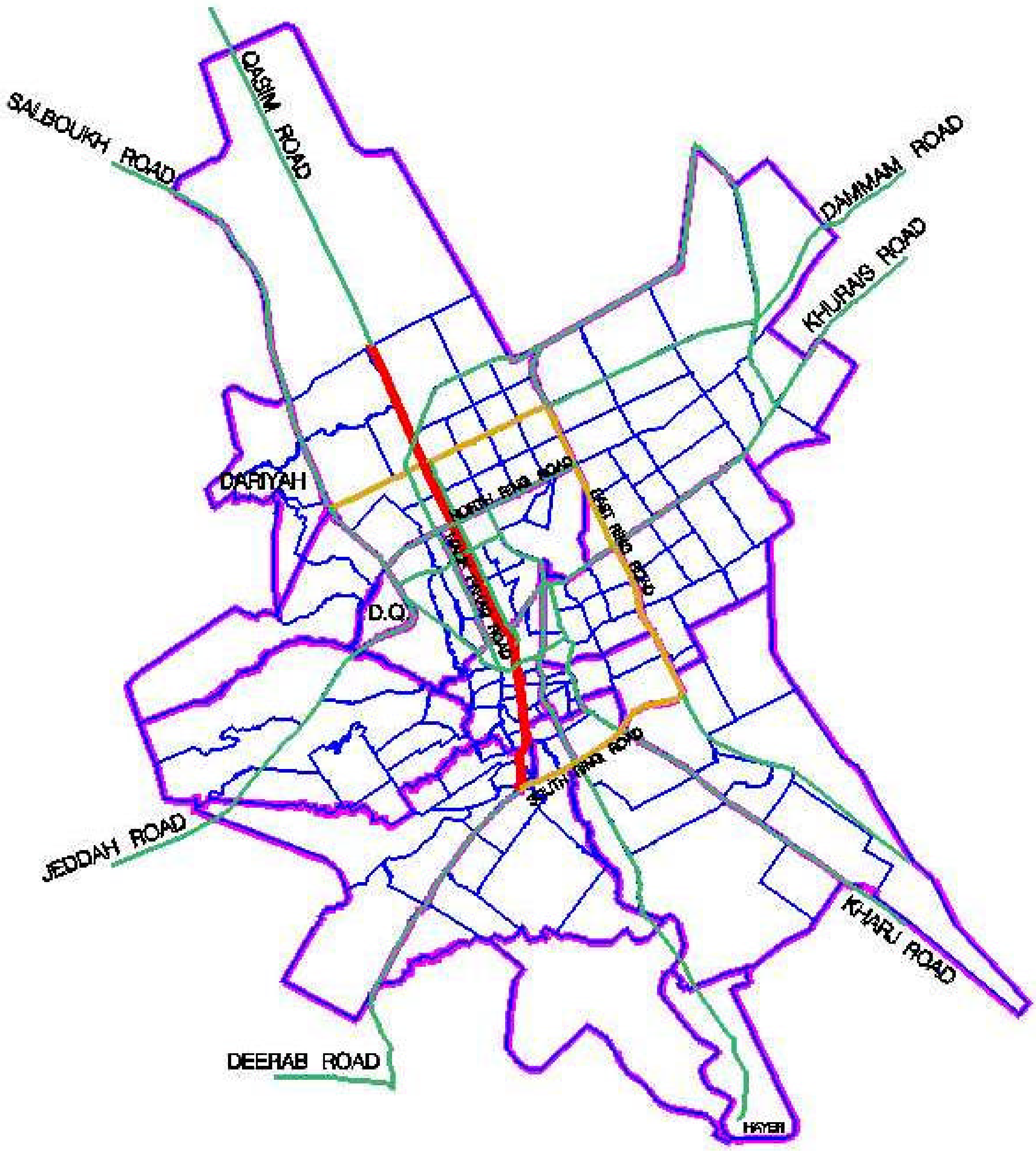

Figure 1 Road Network for the capital city of Riyadh

3. Long Range Planning (LRP)

Current techniques for Long-Range Planning (LRP) are oriented towards network analysis and travel simulation models. These techniques reflect the approach used for highway planning which intrinsically account for transit planning. The long range planning tools, such as GIS, evaluate different laves of services in terms of convenience, frequency, and speed of service and can generate useful information for management purposes. Key elements in the development of long-range transit plans are mode choice analysis and the prediction of future transit use (Chatterjee and Sinha, 1975). Furthermore, any long-range planning is a document that reflects the transportation projects and services needed for improving mobility and access required for regional growth. The plan is developed based on a travel demand forecasting process, which identifies areas of demand. Analysis of travel demand employs a technique, which examines the relationship between the existing streets' capacity and the forecasted traffic volume. This is accomplished through a deficiency analysis process.

4. Deficiency Analysis

The deficiency analysis process is utilised to highlight streets where demand exceeds capacity. GIS is used in identifying deficient facilities. Incorporating the link volumes resulting from the travel demand forecasting into the network attribute table in GIS. Using GIS statistics capability, the relationship between the link's capacity and the forecasted volume can be calculated. Links are then coloured based upon the severity of demand to capacity ratio and presented on maps. These maps can be the basis for identifying roadways that require improvement to accommodate future demand. Figure (2) Shows a sample map used in deficiency analysis.

5. Air Quality Analysis

Air quality planning in the U.S. for instance, involves development of emission estimation inventories to monitor changes in the levels of pollutants that causes the formation of Ozone. MOBILE5a emission model can be used in estimation emission factors. The emission factors are multiplied by the vehicle miles traveled (VMT) on the roadway network associated with each planning scenario to develop emission estimates. Emission estimates are then aggregated to develop county level data. Also emissions are developed for calibration of the urban Airshed Model by a grid overlaid on top of the region’s street network.

6. Allocation of Resources

Facility type that is used in emission estimation utilises the GIS capability of aggregation and representing data in the form of contour lines displaying the distribution of VMT. Networks Allocation module of Arc/info can be used to identify distances and travel times from different attraction points on the street network GIS maps. This technique can also be applied to generate contour lines, which shows travel time on major freeways. These travel times are commonly with respect to distance with activity centres, such as Central Business Districts and medical centres in the metropolitan area. Travel distance maps can be used to represent the air quality benefits of the Employer Trip Reduction Program. Allocation of links' travel time is based on link speed obtained from the travel demand assignment procedure and link length provided in the network attribute tables.

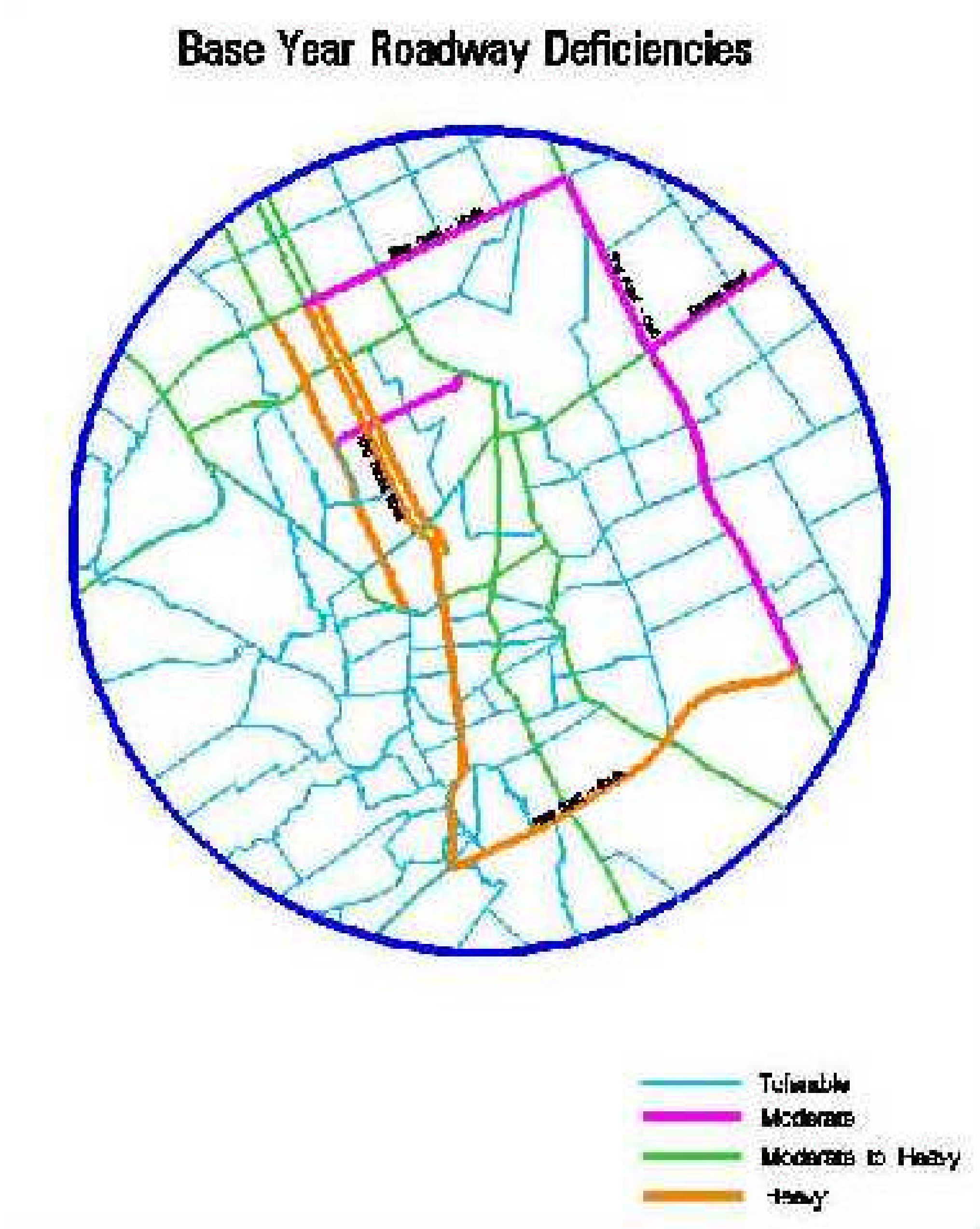

Figure (2): Example Deficiency Analysis Map.

Conclusion

GIS technology has opened up new horizons in transportation planning and especially in travel demand modelling. It provides the tool a transportation planner would need to convey ideas and present implications of planning decision for non-planners visually. GIS provides a means of communication that allows for an interactive understanding between the public and transportation professionals. This technology has developed an essential tool for the most effective use of spatial data yet.

It was evident that GIS in its tracking road deficiencies led to the conclusion that the major highway of King Fahad Road, Olaya main road, Takhassusi road and ring road-south recorded the heaviest traffic. This was based on the observed data, which was linked to a database that enabled the researcher to manipulate it based on the international standards of road capacities. Khurais road on the eastern section of the city indicated a more moderate to heavy road deficiency except of its east of the Ring Road-East where road deficiency was more on the moderate side. The rest of the roads were mainly on the tolerable side.

Recommendations

Since the prime objective of this paper was the illustration of GIS application in transportation, further research needs to be done, emphasising transportation as opposed to GIS applications. This shall certainly illustrate transportation standards rather than the mere results of GIS application. Furthermore, it is recommended that road deficiencies can possibly be examined while removing or adding transportation links to the network via a GIS-Transportation model. Decision makers could then make electronic decisions and thus predict outcomes prior to any actual decision on the ground. This will undoubtedly, lead to more economically optimum decisions and reasonably, predict the consequences.

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