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A GIS model of the National Road Network in Mexico

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ABSTRACT

This paper describes a benchmark methodology for building a GIS model of the National Road Network in Mexico. A model of the road network is useful because it can help to calculate the shortest route between any two locations linked to the road system. The model estimates an average speed for every section on the network according to its hierarchy, regional location, toll status and administration. Optimal routes can be estimated in terms of a time-minimisation criterion. The paper presents a statistical test that shows that the model's results have a small bias of +6 percent in comparison to observed travel times from the Mexican Ministry of Transport. This bias can be fixed using a linear transformation of estimated travel time.

1. Mexican sub-system

This paper presents the methodology followed to build the North American GIS Road Network Model, a tool that can be used to estimate optimal routes between any two nodes within the network using travel times as an optimisation criterion. The model uses cartographic data from the Topographic Digital Dataset (TDD) and the Municipal Geo-Statistical Framework, published by the National Institute of Statistics, Geography, and Informatics (INEGI, 2000a, 2000b). This dataset includes comprehensive cartographic data of the National Road System. It classifies each road according to the number of lanes, whether it is a toll or a free road, whether the federal or a state government administrates it, and whether the road is paved or unpaved. The dataset also includes the most important ferry routes and complete information on the rail network.

The Secretary of Communications and Transport (SCT), through the Administration of Federal Roads and Bridges (CAPUFE), offers a service on its website that traces routes between the most important cities in the country. The system, called "*Traza tu Ruta*", provides the user with information on the shortest route between any two cities including a description of the route, its total length, and the estimated travel time. The data is used in the present study to estimate the average speed in each section of the road network.

1.1. Hierarchical classification of the National Road System

According to the SCT, the National Road System in Mexico comprises 14 Federal Corridors with a total length of 17,356 km. The Federal Corridors connect the most important cities in the country across the 31 states and the Federal District. The corridors include 6630 km of four-lane roads (38 per cent of the total length) and 4976 km of toll highways (28 per cent of the total length). The Federal Corridors are managed by the Federal Government. This subnetwork of Federal Corridors has the highest hierarchy in the model. It is shown as '*trunklines*' on Figs. 1–8.

A secondary network connects inner cities with the main corridors and several local roads between the main corridors and their feeders. This subnetwork has an extension of 69,768 km and includes both federal and state roads. The length of the network administered by state governments is 39,635 km, representing 56 per cent of its total length. Almost 95 percent of the secondary network comprises two-lane roads; however, it also includes 1760 km of one-lane roads, which are mainly located in Yucatan State. The secondary network is almost exclusively toll-free; however, it also includes 969 km of toll roads. The road network is completed by 90,965 km of unpaved roads. It comprises 14,744 km and 39,140 km of two and one lane unpaved roads, respectively.

Finally, the network includes two main ferry routes connecting the Baja California Peninsula with the main continental landmass

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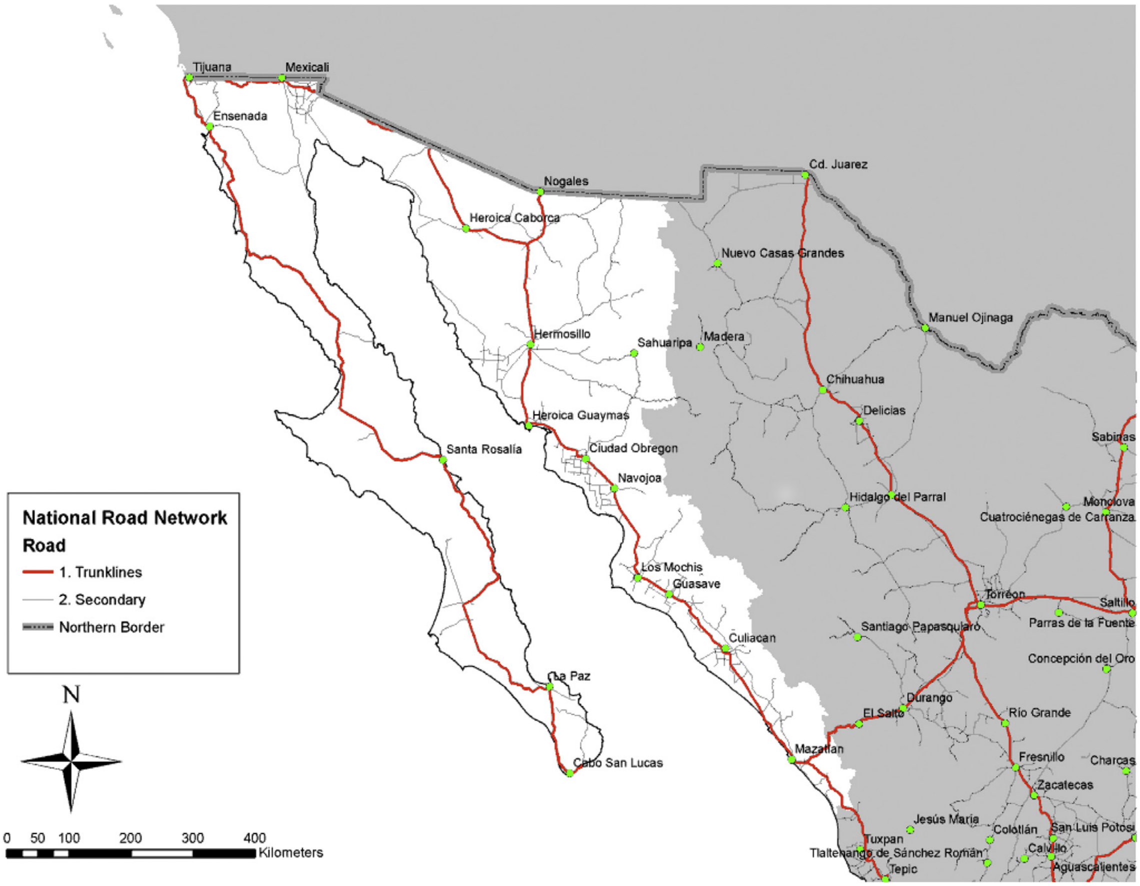

Fig. 1. National Road System: Northwest macroregion I.
Source: Own elaboration (Digital Cartography from the Municipal Geo-statistical Framework and the Topographic Digital Dataset, INEGI).

(La Paz-Mazatlan, and Santa Rosalia-Guaymas), and the Caribbean islands of Cozumel and Isla Mujeres with the Yucatan Peninsula.

1.2. Construction of the model

The objective of the model is to work as a tool to calculate the optimal route between any two locations, which is defined as the route which minimises travel time. In order to do this, the model needs to assign an average speed to each section of the network.

The SCT publishes on its website estimated travel times for routes between selected cities in the country. For each route, average travel time is disaggregated by road section depending on whether the section is toll-free or tolled. The data also includes the state where each section is. This data is extrapolated to the rest of the sections of the road network following a special criterion for each road hierarchy, which is explained below.

1.2.1. Federal Corridors

The SCT presents estimated travel times for all the 14 Federal Corridors on the network. For any corridor, the speed that is allocated to the sections lying in a particular state is equal to the average speed of all the sections in that state. This exercise is performed separately for toll and toll-free roads. For sections that cannot be related to a specific state, the average speed assumed is that of the neighbouring sections within the same corridor.

According to SCT data, the average speed of the Federal Corridors is 107 km/h on toll highways and 85.9 km/h on toll-free roads. Average speed does no present significant variations across toll highways; however, the variances across toll-free sections are significant (Figs. 9 and 10).

1.2.2. Secondary network

The secondary network is divided in eight macroregions.[2] For each macroregion, we select a sample of routes and estimate their travel time and average speed according to SCT data. Due to the fact that the SCT does not present information for all the sections of the secondary network, we extrapolate the data from the sample to the rest of the roads in the region, assigning to each of them the estimated average speed of the routes in the sample.

For each macroregion, we calculate the average speed and standard deviation of its roads. If in any macroregion the standard deviation is higher than an arbitrary threshold, we split it in smaller areas following the NUTS3 division for Mexico as presented in the paper. To each of these regions we assign the average speed of the sampled routes in their respective territories.

a. Sample

The criterion for selecting the sample was to choose for each macroregion, routes that cover the maximum possible area. In particular, we selected feeders crossing through the longest axis of a region, which typically connects the interior cities of a region with the Federal Corridors, local roads, which connect the corridors that

[2] Macroregions are as defined by Bassols-Batalla (1993, 2002).