GeoLink® Maps Mexico’s Highways

¡Adelante, Sí!
GPS and GIS Map Mexico’s Roads and Highways

From the highlands of Chihuahua to the coastline of the Yucatan Peninsula, Mexico has put each of its 32 states’ highway divisions to work using GPS and GIS. With the aid of these advanced technologies to inventory more than 91,000 kilometers of highways, the country expects the resulting data to help in the maintenance and the expansion of its national road network.

Dr. José Luis Palacio is the head of the physical geography department for the Institute of Geography at the National University of Mexico in Mexico City. He has a Ph.D. in geography and has completed postgraduate courses in geographic information systems (GIS) and remote sensing at ITC-Eindhoven in The Netherlands. Laura Luna is a geographer and research assistant at the Institute of Geography. She is a masters candidate and has completed courses in GIS.

During the past five years, Mexico has increased the length of its asphalt road network (mostly four-lane roads) by more than 5,000 kilometers. None of these new roads nor secondary (nonasphalt) roads have been recorded on any maps or by any digital means. Creating a new database to show the location and condition of the roads in Mexico has become an urgent priority; with the data, the highway department, other government agencies, and private utilities will be able to coordinate road maintenance and continued expansion of the country’s newly enhanced highway system.
To develop such a database, a nationwide inventory of the roads and associated attributes is being coordinated by the Mexican Institute of Transportation (Instituto Mexicano del Transporte or IMT), with the academic guidance of the Institute of Geography at the National University of Mexico (Instituto de Geografía–Universidad Nacional Autonoma de Mexico or IGG-UNAM) and the cartographic expertise of the National Institute of Geography, Statistics, and Informatics (Instituto National de Estadistica Geographic Informatic or INEGI) located in Aguascalientes City, Aguascalientes.

At the end of January, about 90 percent of the entire network was registered in a digital format, with a February completion date set for the entire project. After this phase of road registration, information will be transferred to a geographic information system (GIS) in preparation for printing. As of last month, the state maps of Querétaro, Nuevo León, and San Luis Potosí were finished. All 32 state maps should be ready by August 1995, including the road maps and the attribute database.

TRANSPORTATION NET
IMT is a research division of the Ministry of Communications and Transportation (Secretaría de Comunicaciones y Transportes or SCT). Among its responsibilities, SCT manages the administration of federal, state, and secondary roads. Road administration entails organizing three-person SCT brigades from each of Mexico’s 32 states to travel the entire 91,000 kilometers of asphalt roads and to evaluate the condition of paved surfaces, signals, bridges, culverts, and signage (see Figure 1). In this way, the whole road network is visited by qualified state SCT personnel on an average of every two months. Qualified personnel include at least one civil engineer per brigade; sometimes all three members are civil engineers or technicians trained in road construction and/or maintenance. Participants average at least 10 years’ experience, and in some cases have as many as 25 years.

To take advantage of the activities of the SCT brigades, and build upon a joint study carried out previously with IGG-UNAM in the Mexican state of Querétaro, IMT proposed a nationwide inventory of roads and related infrastructure showing the applicability of GPS technology in road mapping. The joint study, *GPS Technology for Road Inventory*, was produced as a nonpublished internal report on road maintenance. The first steps of the road maintenance program are to record each road’s length and its attributes, such as
In notebook computer, a moved far away from the shows the trace of paved sometimes positions were

On Set. =11

obstacle to signal reception. distortion (top photo).

equipment package

general direction of the road.

Figure 1. A portion of the road map of the city of Querétaro shows the trace of paved roads with their corresponding attributes.

Displayed on the hood of the SCT vehicle (this page), each brigade used a compact equipment package consisting of a magnetic antenna, a notebook computer, a GPS receiver, and batteries.

On page 24, along the main roads, big trucks were sometimes a cause for GPS signal distortion (top photo).

Vegetation, more than mountains or hills, was the main obstacle to signal reception. In some cases (such as the street scene pictured on page 24), the trace was lost and sometimes positions were moved far away from the general direction of the road.

culverts, bridges, signals, and so on. We believe that this is the first attempt in the world to use GPS to record a complete national road network.

TRAINING

For the national study, each of the 32 states designated a three-member brigade to be trained at IMT headquarters in the small town of San Fandila, Querétaro, located about 20 kilometers from the state capital. In October 1994, the 96 SCT employees completed a 40-hour course on the fundamentals of GPS and GIS. The hands-on training included surveying approximately 350 kilometers of federal and state paved roads and associated infrastructure in the surrounding areas of San Fandila.

Thirty-two six-channel, L1 C/A-code GPS receivers were used, one for each training brigade. Each receiver was connected to a notebook computer using automated GIS mapping software to capture the data (at 1-second intervals) and to manipulate the information. Manipulating the information includes:
- data logging
- defining function keys to capture attributes
- designing the database
- visualizing road traces and attributes
- transforming data for exporting in a GIS-compatible format in both graphic and tabular information.

Simultaneously, other descriptive data of the surrounding environment were collected by predefining “hot keys” on the keyboard for different attributes. The attributes were as follows: road description and survey (code, date, number of lanes, and so on); culverts; intersections with secondary roads; towns and cities (name); gas, toll, and SCT stations; changes in the number of lanes; bridges (size and type); airports (name and type); bus and truck stops and railroad crossings.

The training sessions were designed to provide strong practical experience, but could not totally prepare participants for the unique conditions they would face once the actual inventory got under way. Querétaro is a semiarid region, but Mexico has six main land regions, ranging from vast open plains to rugged mountain systems with sharp relief to dense rain forest. Consequently, the nation’s environmental diversity could not be represented in the training.

As a result, the participants’ new skills were quickly put to the test when they returned to their corresponding states to collect data. For example, brigades in the states of Chiapas and Yucatan encountered strongly contrasting conditions to those present in Querétaro. In both states, high-density tropical forest, rather than mountains and hills, was the main cause for GPS signal degradation. Because of the effect of vegetation in masking or attenuating satellite signal reception, short stretches of roads could not be registered. To avoid gaps in the final road maps, previously published topographic maps were used to complete the traces, and the existence and position of attributes had to be estimated.

FIRST PHASE

The first phase of data collection was mainly devoted to obtaining a base map of the country that shows the network trace and other general reference features.
Although work was performed in predominantly mountainous terrain, the trace of roads is clear and continuous. (Original scale 1:250,000.)

By late November, 12 of the 32 states had completed the phase of data collection and sent their data to IMT for further processing. This data phase represented more than 26,000 kilometers (about 29 percent) of the entire network.

For this project, postprocessing will include the exporting of data into a layered format. The data will then be joined in a workstation environment and printed as maps in various scales, depending on the size of each state (see Figure 2). No differential postprocessing was performed during the first phase because the hard copies ranged from 1:100,000 to 1:1,000,000, and the cartographic accuracy was less than the stand-alone GPS positioning accuracy. In other words, at these mapping scales, the maximum GPS errors, which averaged 150 meters, were either practically negligible or were absorbed by the sizes of the map symbols themselves.

However, because the advanced phases of the project may use differential GPS, information for postprocessing was collected during the first phase. The later phases will use reference data from 14 sites of INEGI's National Geodetic Active Network (NGAN), which consists of high-precision dual-frequency GPS receiver stations. Originally designed to support a national land regulation program, the NGAN network's GPS receiver stations, which record information at 15-second intervals, are distributed throughout the country to ensure nationwide coverage. Each NGAN site covers a radius of 500 kilometers.

The road trace database will contribute greatly to IMT's other current research programs, including a GIS for planning asphalt road maintenance. In this GIS, IMT is considering both technical and environmental data, such as traffic density, slope, climate, precipitation, and temperature, to model the need to renew the asphalt cover, accident prevention, and so on. Beyond Mexico's countrywide highway-mapping application, GPS will be used to survey 130,000 kilometers of unpaved secondary roads and the country's railroad network.

The second phase is estimated to take eight or nine months, beginning next month, although Mexico's economic problems may postpone the April starting date. The SCT brigades will likely use GPS for more routine activities such as asphalt surface evaluations, signalization, accident location and prevention, maintenance, and other projects yet to be determined by the state highway department. Routine SCT activities are permanent and involve the maintenance of road surfaces, culverts, and other attributes recorded. Other activities include calculating the number and type of signals needed, damages to the road, and accidents.

The above national roadway mapping project utilized the GeoLink GPS/GIS Mapping and Vehicle Tracking System. For product information contact:

GeoResearch, Inc.
Phone: (406) 248-6771
Fax: (406) 248-6770
1-800-GEOLINK

Figure 2. A detail of the road map of the state of Querétaro in the Sierra Gorda. Although work was performed in predominantly mountainous terrain, the trace of roads is clear and continuous. (Original scale 1:250,000.)