HIGHWAY MAINTENANCE GOES HIGH-TECH: THE GIS/GPS LINK

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GIS

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In 1865, when the first steamboat approached Fort Benton in north-central Montana, waterways were a fast and economic way to transport goods and passengers. But when the state paved its first road in 1923, that all changed, and today nearly 17,000 miles of surfaced highway have been completed throughout Montana's mountainous and rolling terrain.

Despite the advantages it offered, the roadway network had to be updated and maintained, tasks that were unnecessary when using a natural waterway. That responsibility was given to the Montana Department of Highways (MDH), which tracked the highways manually using U.S. Geological Survey (USGS) quad maps as a base. These maps provided about 20 meters of accuracy for latitude and longitude.

USGS maps are fine for an overall perspective of highway monitoring. However, highway features such as road surface changes and passing zones were never scaled to the maps at all because MDH lacked the time and personnel to detail maps to that level. We desperately needed a system to create digital maps with the potential to inventory highway attributes.

Although many state departments of transportation (DoTs) have tried using a computer-aided design (CAD) system for maintaining road data, these systems have inherent shortcomings. For example, a CAD system relies on mathematical parameters to create graphic features, but has no way to incorporate geographic data relating the topological features. Many of the DoTs that originally had automated mapping with CAD are now looking for add-on GIS programs to complete the inventorying tasks that have become so important. The Montana Department of Highways had seen GIS demonstrated effectively by some DoTs and decided that it was the most practical solution for our needs. With that decision, we began seeking the most cost-effective method of building a reliable GIS data base.

PROJECT METHODOLOGY

In January 1990, MDH embarked on a pilot project in cooperation with GeoResearch, Inc., of Billings, Montana, to use GPS and GIS technology. The pilot project was designed to establish the cost benefits and potential of the program, as well as its limitations. The system combines multipurpose computer hardware with GIS software and a GPS receiver to record positional attributes while creating digital maps.

This article describes how an integrated GIS/GPS system was used to create a data base of highway information. Immediate benefits and potential uses for the system in the future are also explored.

![Figure 1: After road attributes have been entered into the computer, plots indicating all locations of a type of attribute may be printed. The printouts above show the locations of overhead utilities (left) and culverts (right) in the pilot project area.](image-url)
At the project's start, MDH developed a data base design to test. The highway inventory data base focused on 104 miles of highway in and around Billings. Approximately 25 road attributes were selected to demonstrate the benefits of the system. These attributes included restricted passing zones, road and railway intersections, surfacing changes, rock slide areas, county lines, irrigation and drainage controls, turning lanes, and major changes in pavement width.

MDH's data base is comprised of two basic layers: linear features, such as the roadway jurisdiction, route number, number of lanes, and guardrails; and point features, such as signs, signals, junctions, drains, mileposts, irrigation structures, and intersections. This design makes it easy for users to visualize characteristics of the road and enter and retrieve data.

Highways are represented by a series of line segments characterized by attributes, as shown in Figure I. Each segment is described by four types of information: highway identification, lane structure, parallel structures such as guardrails, and surface characteristics. The characterized attributes in the various data fields of a computer file characterized are features of the highway, which can be present simultaneously. For instance, a particular stretch of highway can be recorded by any number of attributes — jurisdiction, route number, presence of guardrails, slide areas, and surface condition.

Point features are represented as points with attributes and are connected to linear features by reference to the road jurisdiction, route number, and mile number. Each point feature is identified by type of feature and then described by identification, type, and detail fields. The identification field locates the feature within the highway network according to jurisdiction and route number, while the type field identifies the kind of feature, such as a speed limit sign. The detail field lists specific information regarding the feature. An intersection description, for example, would include cross streets, direction of approach, and turning lanes.

With an established data base design, MDH was ready to apply the GIS/GPS link. We began by having someone drive the designated route and record the attributes of the road with a laptop computer. To log the attributes, the operator pushed a button on the laptop as the structure or point was passed, and the information was recorded into the unit at whatever scale is required. We had predefined these attributes and assigned keys on the keyboard to each to reduce the necessary operator keystrokes. After some experimentation, we found that we could pick up a maximum of 15 attributes at a time while driving at 35 mph. This function varies with the speed of the vehicle. As speed increases, the number of attributes logged decreases. At the end of the day, we had produced a map of the highway with accurately referenced positions and automatically time-stamped coordinate data for clear update histories. All of the attributes along the highway are organized and can be accessed quickly when needed.

As the GPS receiver recorded the position information, the data was run through a conversion program that allowed the user to read the data into a GIS system. This system...
Maps similar to that shown above can be generated using GPS and GIS.

stores the cartographic data and operates the relational data base that becomes the information manager for attribute data.

To obtain accuracies of two to five meters, the receiver required static reference points at known locations. MDH had been working with federal agencies to develop these high-precision control points. By using reference point information in conjunction with the remote file obtained during the highway survey, we created a differentially corrected remote file. Using differential GPS in this manner essentially offset the recorded errors in the field.

RESULTS
After the data base was established, field technicians could locate and track attribute positions on an existing digital map while making updates, thus eliminating postprocessing time. The technology has solved our requirements for position information and digital map data, and we can record and retrieve all of the other highway features that we have never been able to track efficiently before.

MDH’s data base structure allows for uniform treatment of a wide variety of features, future expansion of the system, and extraction of feature classes into subsidiary data bases for specific analysis. The dual structure of the GIS linear and point features does not limit the data base. Queries regarding either one are handled with equal ease and accuracy.

MDH officials may be able to use the pilot project results to answer formerly unanswerable questions such as inquiries on culvert inventories. The project may be useful in fulfilling federal reporting requirements. Queries to the data base can display a layer representing all bridges in the state or in a particular city, depending on which information the user desires.

Moreover, the accuracy obtained by using GIS/GPS projects could reduce MDH labor needs. Departments that traditionally rely on temporary summer help to complete large tasks can now do the jobs with one or two staff members, instead of an entire survey crew. The system has also eliminated the tedious task of finding and digitizing geographic data.

The system’s only limitation has been the small satellite window of less than seven hours, which begins in early evening. But within the next year that window will expand and cover our eight-hour workday.

FUTURE USES
One of the potential tasks of the system might be to inventory no-passing zones. For many years, no-passing zones have been designated by simply painting lines on the highway, which wear off and later must be repainted. A more practical and long-term solution would be to put up signs. With automated GPS/GIS, maintenance personnel could quickly query the data base within a certain highway length, display pertinent information, and develop a maintenance plan to efficiently place signs in appropriate locations. This approach not only would be more cost-effective, but also would allow maintenance personnel to log each task as it is completed. The addition of GPS makes the already sophisticated software of GIS mobile, allowing us to track work as it is being done in the field.

Another task for the new system might be maintaining highway mileage statistics. MDH hopes to further enhance the system in the future by purchasing a department van that will gather data for highway monitoring, aid MDH’s statistics section in tracking highway mileage, and allow our pavement management section to keep track of the deterioration of different highways more efficiently.

The bridge department could use the system to determine more efficiently the beginning and ending points of bridges while more accurately recording latitude and longitude data for federal highway requirements and local highway needs.

With the emphasis changing from building to maintaining highways, such systems are becoming the future of highway inventory programs. They are surely a far cry from the days when the river’s depth or current determined how a transportation route could be traveled.

For information on GeoLink software, used on this project, contact GeoResearch, Inc., 2815 Montana Avenue, Billings, MT 59101, 1-800-829-4474.