GIS Application in Developing a Roadway Feature Inventory Program

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by

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Abstract

In recent years GIS has been applied in many engineering fields, including transportation and highway engineering. This presentation reports on a recent project for the collection and dissemination of roadway feature inventory data. A requirements document was compiled for the development of a Roadway Feature Inventory Program (RFIP) based on the needs and requirements of the roadway feature inventory personnel at the Maryland State Highway Administration (SHA). It was based on information captured through a series of Joint Application Development (JAD) sessions and interviews. The primary focus was to collect and update data using electronic aids, such as a handheld GPS unit, for management to decide on the most efficient manner to allocate scarce resources in the provision of adequate service. Dynamic Segmentation was used for storing the data. This presentation discusses the GIS aspects of the RFIP development.

Key-words: highway maintenance, roadway feature inventory, GIS, dynamic segmentation.

Introduction

This paper is focused on the Geographic Information System (GIS) aspect of a research project that was aimed at developing a Roadway Feature Inventory Program (RFIP), to capture the needs and requirements for better planning and scheduling of maintenance activities for the Maryland State Highway Administration (MSHA). It was based on information captured through a series of Joint Application Development (JAD) sessions and interviews. Some primary objectives of this research, served to outline the potential needs of MSHA users of the roadway feature inventory program, specifically documenting what data needed to be collected and the level of detail in data collection. Of special emphasis was the automation of data collection, and the data updating process, aided by Geographic Information Systems (GIS) and its' interface with other technologies for feature inventories.

The goal of the research was to identify what was the most efficient way to collect data, and what should be the units used for the collected assets. Also considered was how should the database be maintained, and what meaningful conclusions could be derived from the collected inventory for future maintenance, planning and scheduling of its' activities. The research provided some required solutions sought by MSHA during the year 2003, as a core set of requirements were identified from which maintenance activities could be effectively scheduled. In summary, the objectives for RFIP development were:

- To capture the needs of potential MSHA users of the feature inventory program, specifically documenting, what needs to be collected and the level of detail for data collection
- Automation of data collection and the updating process, facilitated by electronic and technological advancements for feature inventory
- To devise methodologies for the future generation of a maintenance management system

- To become better acquainted with the roadway feature inventory process for future planning and budget allocation
- Collect related information with the appropriate tools in an effort to minimize cost
- Specify most critical assets and needs as they pertain to the allocation of financial resources
- To document and communicate data within the administration

The proposed solutions were compatible with the existing architecture, which comprised of the Maryland Department of Transportation (MDOT) IT Security Plan, and the (MSHA) computing environment. Provisions were also made for the storage of data in ORACLE and other standard databases, to be used for other affiliated initiatives. Initiating GIS enabled storage of multiple versions of databases that included the Production, Testing and Development phases. Despite being 'century compliant', data processing had to be done accurately whether used in a stand-alone configuration, or in tandem with other century compliant products utilized by the State of Maryland.

Data Collection

Many technologies exits for field data collection, such as van platform, permanently installed sensors, GPS equipped handheld palm pilots, aerial platform, satellite photography, and hybrid methods. These technologies were discussed in the JAD session and due to the cost-effectiveness and precision requirements, GPS equipped handheld palm pilots were deemed to be the best for data collection. However, a customized program (to be installed on the palm pilots) needed to be developed to ease the data collection efforts by the technicians and download the collected data in a central database.

Model Development

Accessing the RFIP of MSHA would be the Information Technology Division (ITD) at the headquarter office, the office of Maintenance (OOM), district offices, and consultants working for MSHA. Of all the available technologies, GIS was deemed the most appropriate for the collection and storage of data, performing automated functions, and compiling historical and current data. The long-term goal was to develop a mathematical model using Markov Decision Process (MDP) to forecast maintenance Rehabilitation and Reconstruction (MR&R) activities over a planning horizon that could be integrated with the proposed RFIP (see, Jha et al. 2004). Figure 1 shows a conceptual framework of the integrated RFIP and MDP model. Such a model is desirable in order to schedule the most cost-effective series of maintenance procedures. Eventually MSHA would like to develop a comprehensive Integrated Highway Maintenance Management System (IHMMS) with seamless upload and download to and from the integrated RFIP/MDP model. A requirement study for IHMMS development was reported in Jha and Schultz (2003).

The task of optimizing human resources and determining funding allocations for maximum life-cycle of highway assets is of dire importance in an era of shrinking budgets. Of similar significance is the determination of appropriate roadway feature inventory threshold standards, in order to maintain a desired level of service. The series of JAD sessions outlined the units of measure for various physical and non-physical roadway assets that needed to be maintained (see, Table 1).

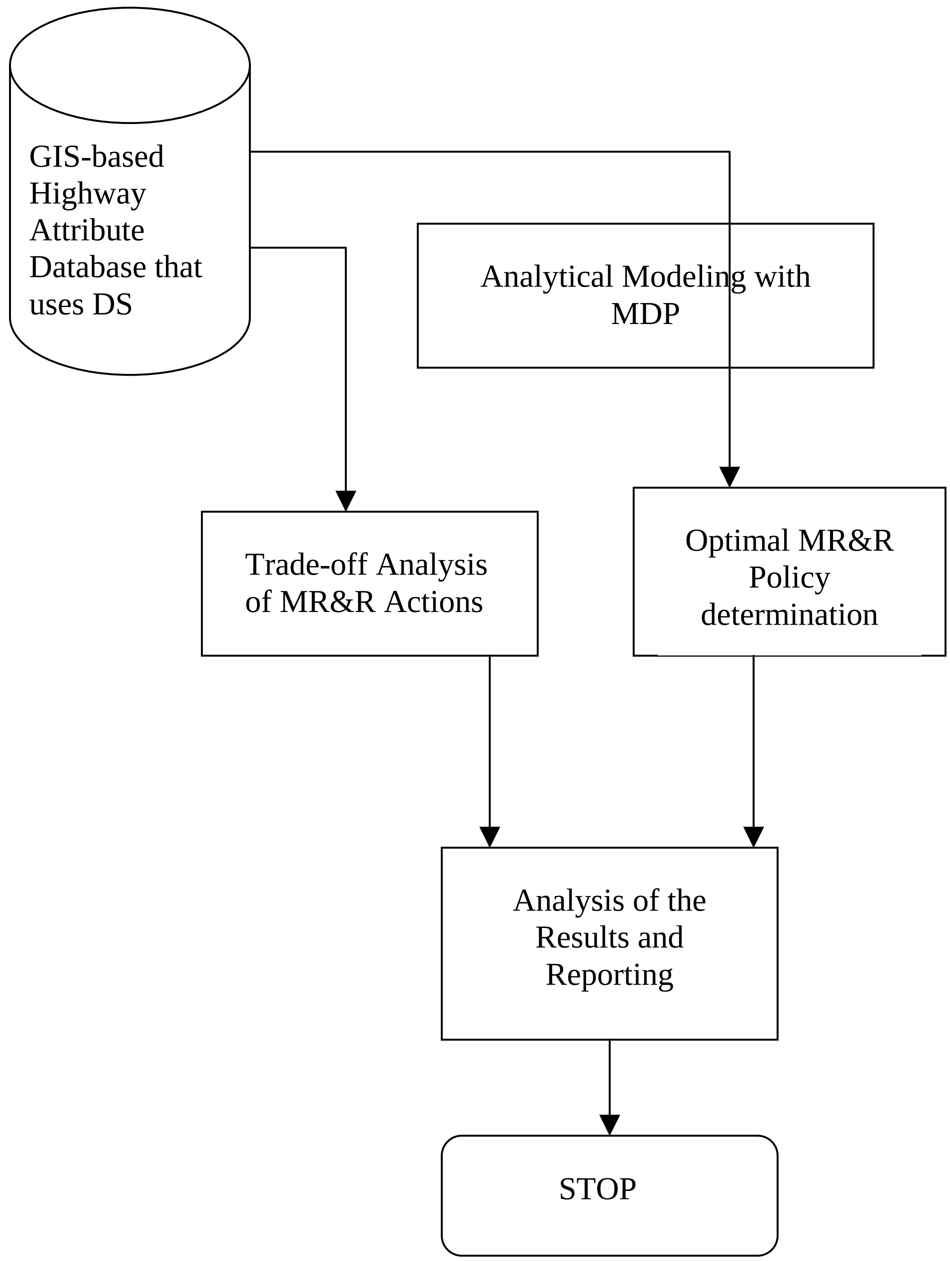

Figure 1. Conceptual RFIP/MDP Model

Table 1. Units of Measure for Physical and Non-Physical Roadway Assets

ASSETS	UNIT OF MEASURE
Sweeping	Miles
Debris	Fence to fence in linear miles
Graffiti	Linear miles
Grass	Number of acres
Litter	Linear miles
Bush/tree	Linear miles
Slope	Linear miles
Landscaping	Acres
Drains (including side, edge)	Not applicable
Storm sewers/inlets	Quantity
Curb/gutter	Linear miles or feet
Cross pipes	Linear feet
Ditches	Linear miles or feet
Box culverts (<20 ft of span distance)	Quantity, size, length
Traffic barrier w-beam	Linear feet
Impact attenuators	Quantity, type
Highway lighting	Not applicable
Signs	Quantity
Pavement markings	Legends, symbols, graphics
Linear striping	Stripe miles
Snowplow able raised pavement markers	Quantity
Paved lanes	Square yard
Paved shoulders	Square miles
Bridge decks/drains/joints	Square yard
Ridge curb/rail/fence	Square yard
Bridge drift	Square yard
Bridge sub/super structure	Square yard
Bridge culvert	Square yard
Bridge end slopes	Square yard
Easements	Number location
Noise walls	Quantity

RFIP System Architecture

The sequential process of acquiring data for the roadway maintenance feature inventory system architecture involves the use of manual and electronic aids such as odometers, sonar and transponders, palm pilots, PC's across servers, scanners, video cameras and laptops. Through these aids, on-time data is acquired and directed to the information technology division at the SHA, to be synchronized with the existing database (NCHRP, 1994). These aids have their own strengths and weaknesses. The JAD sessions identified handheld GPS equipped palm pilots to be most effective in collecting assets in the field. The system architecture consists of three tiers, namely the data tier, application tier, and user tier, as shown in Figure 2.

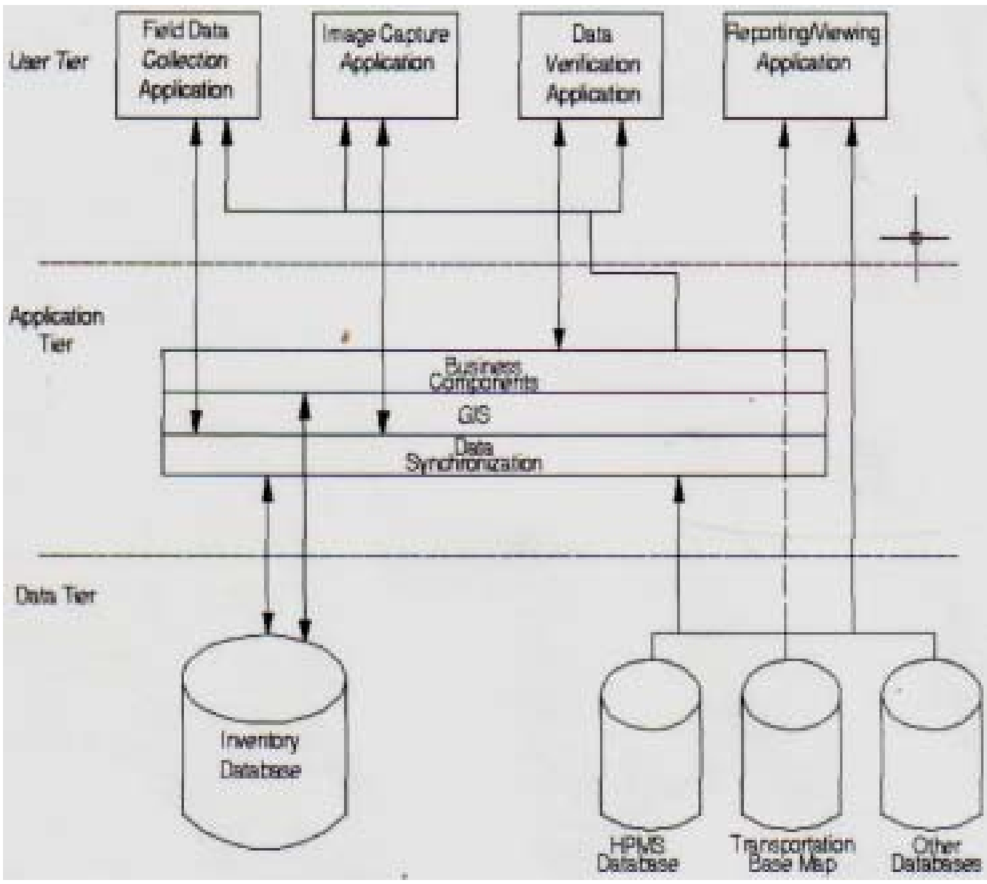

Figure 2. RFIP System Architecture

The data tier manages, stores, and retrieves data. The application tier includes Commercial Off The Shelf (COTS) products which are customized software components that encompasses the logic and rules for the roadway feature inventory. The user tier includes all current work orders, accounting data, as well as accumulated data from the National Pollutant Discharge Elimination System (NPDS).

In figure 2 the data tier shows an exchange of information between historical and recently obtained data that is synchronized and verified before being stored. Within the MSHA database, existing standards and thresholds are contained, thus serving as a reference for new data entering the system from contractual vendors outside the agency.

The transportation base map covered by the MSHA jurisdiction outlines the areas under surveillance, to which workers are dispatched. Other existing databases contain data of a historical nature, also existing inventory, personnel availability, vehicle pool, supplies in storage, and other additional operating data.

In the application tier, the GIS database contains all route data within state limits, with the business components comprising of all consulting and contracting concerns. From this source, on-time field-data along with video images are coordinated with the GIS database. For quality assurance and control, the data verification application is coordinated with the business affiliates to ensure that quality and standards are maintained. An updated database of the base map is sustained by on-site reports and views of present inventory. All field-data in the user tier whether obtained by SHA field technicians or other contracted personnel are verified by the existing GIS database

Dynamic Segmentation

The key to data storage in RFIP is the dynamic segmentation (ESRI, 1995 & 2001) feature, which allows querying the database to obtain attribute condition information for specified mile-point range. A linear mile-point referencing system is used to store the data.

Utilization of Dynamic Segmentation (DS) within the GIS framework integrates the many diverse attribute databases, and would depend on linear referencing methods in order to maintain and manage highway facilities (ESRI, 2001). During the course of operations a particular highway segment could be accessed based on its' location, the number of lanes, shoulder width, whether divided or undivided, or any other pertinent demographic.

Roadway inventories are commonly referenced using the route and milepost as the key to the geographic information file. Other capabilities supported by the GIS platform are map production, interactive query, geocoding, integrate video and photo log data, and three dimensional modeling. (NCHRP, 1994). Figures 3a and 3b show a skid map with its identifying characteristics. This strip map in Figure 3a shows various linear attribute or event data for a road segment from a highway inventory database.

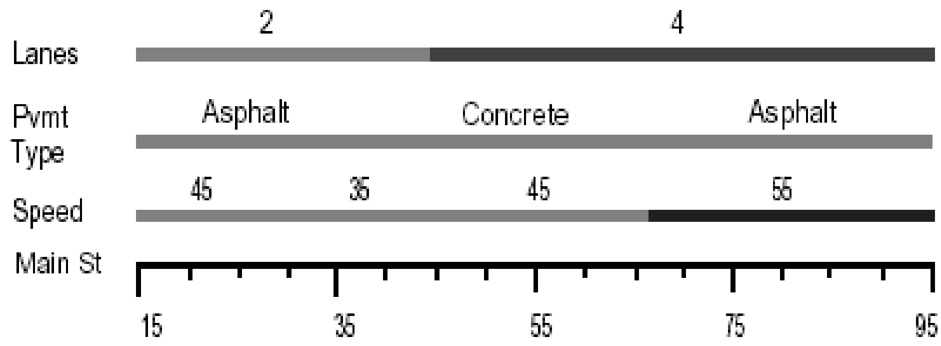

Figure 3a. Highway Strip Map

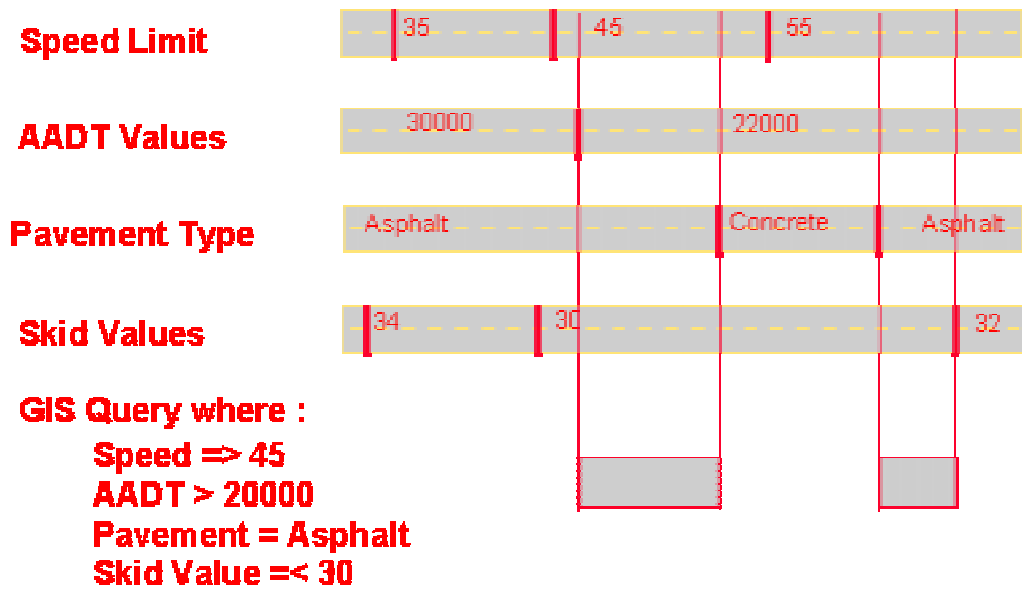

Figure 3b. Dynamic Segmentation Application to a Highway Strip Map

Conversely, certain highway characteristics could be predetermined with the use of GIS, and the particular segment with those features would be highlighted on a map with the surrounding area. Highway agencies standardization of their operational procedures enables the integration of data from different jurisdictions, and with the frequency of inspection, data information quality is enhanced thus providing the ability to make better maintenance decisions. The actual acquisition of data in RFIP occurs within three tiers of operation as shown in figure 2.

Issues with Dynamic Segmentation

Our preliminary experience with dynamic segmentation suggests that TrasCAD may be better suited for dynamic segmentation than ESRI products due to the ease in integration with C/C++ programming language used for developing the Markov Decision Process. A seamless integration is desired for the integrated RFIP/MDP development. This may require dynamic communication through dynamic data exchange or specialized dynamic link libraries, similar to that developed by Jha and Schonfeld (2000) for highway alignment optimization. A cost-effective dynamic segmentation model development for roadway feature inventory program with seamless integration of MDP however, requires more research.

Conclusions

This paper focused on RFIP development with emphasis to lessons learned from GIS-based dynamic segmentation application for the integrated development of the RFIP/MDP model. The findings of the research can be summarized as follows:

1. GIS is the key to developing a RFIP, especially its dynamic segmentation feature
2. Use of electronic aids, especially a GPS equipped handheld palm-pilot is particularly suited for collecting field data.
3. Due to the integration requirement of RFIP with MDP and eventually with an IHMMS, a cost-effective GIS package with easy integration capability with C/C++ programming language is required.

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