GIS USE IN PAVEMENT MARKING AND SIGN MANAGEMENT: AN INTEGRATED APPROACH

Omar Smadi[1], Zachary Hans[2], and Neal Hawkins[3]

ABSTRACT

Geographic information system (GIS) technology is a key component of all phases of the sign management and pavement marking management systems. These programs, like most large-scale infrastructure management programs, are temporal in nature and highly data intensive. Since all pertinent data elements possess a spatial component, e.g. a distance from a known marker or a discrete coordinate, GIS serves as the perfect means by which to manage these data. Additionally, support of multiple referencing methods by GIS better facilitates inventory and quality assurance activities. For example, upon completion of a field inventory, GIS is immediately used to assess the extent and completeness of the infrastructure element collected.

Beyond general data management, GIS is utilized for condition monitoring, performance assessment and general data integration. Basic query and thematic mapping capabilities are employed to graphically present existing conditions and highlight locations of possible concern. Moreover, through integration of multiple periods of condition data, the performance of different infrastructure elements, treatment strategies and materials is assessed and conveyed. The effects of other exogenous factors, such as traffic volumes, pavement type and condition, and historic weather patterns, on condition and performance are also assessed through GIS-based data integration.

This paper will present examples on how GIS is utilized for the different functions to develop, implement, and operate a sign management and pavement marking management systems. The work is being carried out for the Iowa Department of Transportation.

KEY WORDS

GIS, signs, pavement marking, management, tools

INTRODUCTION

The Iowa Department of Transportation (Iowa DOT) is committed to infrastructure management and understands the significant potential benefits from implementing a pavement marking and sign management systems. The importance of pavement markings and signs is reinforced by the Federal Highway Administration (FHWA) and other

1 Research Scientist, Center for Transportation Research and Education, Iowa State University, 2901 S. Loop Dr, suite 3100, Ames, IA 50010, Phone +1 515 294-7110, FAX 515 294-0467, smadi@iastate.edu

2 Research Engineer, Center for Transportation Research and Education, Iowa State University, 2901 S. Loop Dr, suite 3100, Ames, IA 50010, Phone +1 515 294-2329, FAX 515 294-0467, zhans@iastate.edu

3 Associate Director, Center for Transportation Research and Education, Iowa State University, 2901 S. Loop Dr, suite 3100, Ames, IA 50010, Phone +1 515 294-7733, FAX 515 294-0467, hawkins@iastate.edu

governmental agencies for its close relationship to driver safety issues and providing a safe environment for the users of the highways system.

Given the diverse range of driver needs within the state, the Iowa DOT has established an agency goal of developing both management systems that accomplish the following goals:

- Improves the quality of pavement markings and signage on the entire roadway network
- Improves the ability to manage all aspects of pavement markings and signage from materials, request, ordering, fabricating, installing, maintaining, and ultimately removing or replacing
- Improves the ability to budget for these key assets on a statewide basis
- Provide tools for techincal staff to allow them easy access to the inventory information, decisions regarding maintenance or replacement of the exisiting assets, and querrying and reporting functions that they can use in their daily operations
- Provide tools for decision makers to do scenario planning in terms of resources (staff and funding) for the long term maintenance of these important assests. These tools should allow for integration with other asset data at the Iowa DOT to allow for integrated decision making among the different infrastructure assets that the DOT maintains

The paper addresses the different components of each system covering the database side of the management system, the application side, and then offers some conclusions to set up the agenda for future work in this area. The database and application sections will be divided into two parts. The first covers pavement marking and the second covers signage.

DATABASE

This section covers a brief discussion of feature mapping (geocoding) of both the pavement marking and signage data. The use of location referencing tools and GPS to accomplish that is also discussed. Finally, the structure of the database for each management system is covered.

FEATURE MAPPING

Signs and pavement markings, like most transportation-related features, inherently possess a spatial component. They are located on, over, along and adjacent to roadways tied to known locations on the earth's surface. The location of signs and pavement markings may be referenced by discrete coordinates, such as geographic coordinates obtained through a GPS receiver, or to a position/extent along a roadway, such as the distance from the beginning of the route or a known marker. Therefore, collecting and referencing pavement marking and sign data in a manner that facilitates the mapping (geocoding) of these features is critical for effective use of GIS.

Currently in Iowa, the primary method employed for referencing locations of both signs and pavement markings is known marker-based. A known marker is a readily, and uniquely, identifiable feature in the field with a known position along a route and defined geographic location. This information, in conjunction with a feature's route of occurrence, unique reference marker identifier and longitudinal offset(s), the feature may be mapped.

Given the appropriate data, the known marker referencing method can be readily implemented, requiring little field training and no sophisticated data collection equipment (e.g. GPS receivers). Additionally, if a set of markers are used repeatedly for condition assessment, this method facilitates integration and evaluation of temporal data. However, it does possess several shortcomings. The spatial accuracy of features will be limited by the accuracies of the underlying road network, marker location, and linear measurements in the field. It can also be prone to user entry errors, such as inaccurate recording of route and marker identifiers. These errors may result in features not being properly mapped or mapped at all.

In the future, the spatial accuracy of features may be improved through use of a coordinate-route referencing method. With this method, a user records the route of the feature, while a GPS receiver obtains the pertinent coordinate data. Before implementing such a referencing method, equipment costs and temporal data integration procedures for common "test" sites should be considered.

PAVEMENT MARKINGS

The pavement marking management system utilizes reflectivity data from Iowa DOT LaserLux van and handheld reflectometer-based fall/spring assessments as well as paint crew (application) records. Currently, both Laserlux and handheld reflectivity are provided by the Iowa DOT as point-based data. LaserLux reflectivity data are collected continuously and summarized to one-mile increments, while handheld reflectivity data are summarized to five-mile increments. Paint application data are provided as project-level, linear extents.

The common components of all three pavement marking data sets are: route number, reference marker(s) and offset(s), line type, direction of travel, reflectivity and date of collection. The handheld data contains a few additional pertinent attributes such as contractor and material type. The paint application records also include these supplemental attributes, as well as detailed application-related data, including project number, date, material type, paint quantity, paint and bead rates and other work codes.

Upon acquisition of the reflectivity and paint application data, several attributes are added to each data set to enhance data processing and analysis functionality. The LaserLux and handheld reflectivity data sets are also merged. A multi-step process is employed to geocode (map) these data based on the reported route and reference marker(s). In cases where the route-marker combination can not be directly related to a comprehensive list of known markers, the accuracy of these attributes is evaluated. This process includes both visual inspection and a hierarchical assessment of adjacent, known markers. The manner in which the reflectivity data are ultimately mapped is recorded as additional database attributes. Other supplemental, derived attributes include Iowa DOT district, county, data source (LaserLux, handheld), general data collection period (spring, fall) and year of data collection. The combined LaserLux/handheld reflectivity data and paint application data can then be analyzed within a GIS environment or the Pavement Marking Management System Tool.

Lastly, mapping of these data need not be limited to their longitudinal location/extent along a roadway. Using other GIS functionality, and the reported line type and direction of travel, these data can be perpendicularly offset to represent the position of the line within the road cross-section. While this can be challenging to effectively present on small scale maps (e.g. statewide), it can be particularly effective when evaluating the condition of all lines on more finite portions of highways.

SIGN INVENTORY

While the comprehensive Iowa DOT sign management system is still in its infancy, the existing sign inventories of several districts are referenced in the same manner as the pavement marking data, i.e. route and known marker. However, since Iowa DOT districts undertook these inventory efforts independently, much of the existing data has been collected, recorded and maintained in different manners. Attributes observed among those inventories reviewed include: county, route, reference marker, direction of travel, sign face direction, side of road, number of signs, sign type, sign message, sign size, stock number, MUTCD number, general sign condition, post size, number of posts, date inspected, date installed and comments/remarks.

As with the pavement marking data, a multi-step process is employed to geocode (map) these data based on the reported route and reference marker, and the manner in which the sign locations are ultimately mapped is recorded as additional database attributes. These data can then be analyzed within a GIS environment. The presentation of these data can also be further enhanced by more refined mapping through use of other database attributes. For example, using the direction of travel and side of road, signs can be perpendicularly offset from centerline in the proper direction. Furthermore, through use of different symbol styles in GIS, the direction of the sign face may also be conveyed. (See Figure 1)

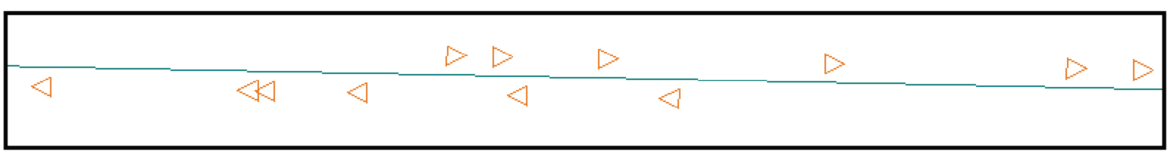

Figure 1. Attribute-based Presentation of Sign Locations, Side of Road, and Direction of Sign Face

APPLICATION

PAVEMENT MARKING MANAGEMENT SYSTEM TOOL

The Pavement Marking Management System (PMMS) Tool was developed to provide the Iowa DOT staff the ability to analyze pavement marking data within an easy-to-use GIS environment.

At the most basic level, a user may view a thematic map of the marking condition (good, fair, poor) for a specified line type, year, time of year (spring, fall), and direction of travel. In Figure 2, the statewide reflectivity of white edge line (in the primary direction of travel) is displayed as well as the approximate mileage in poor, fair and good condition. The red points on this map indicate locations where the white edge line was in poor condition. Using this information, a plan for summer painting activities could be developed. Figure 3 presents locations where the white edge lines were actually painted in the summer of 2005. These locations generally correspond to areas that were in poor condition in the spring.

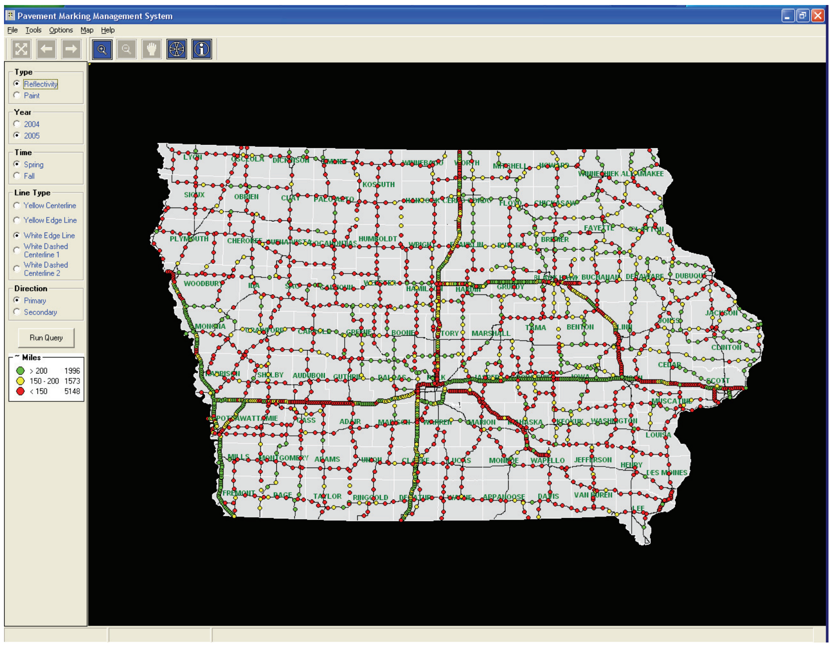

Figure 2. Spring 2005 White Edge Line Reflectivity Ranges

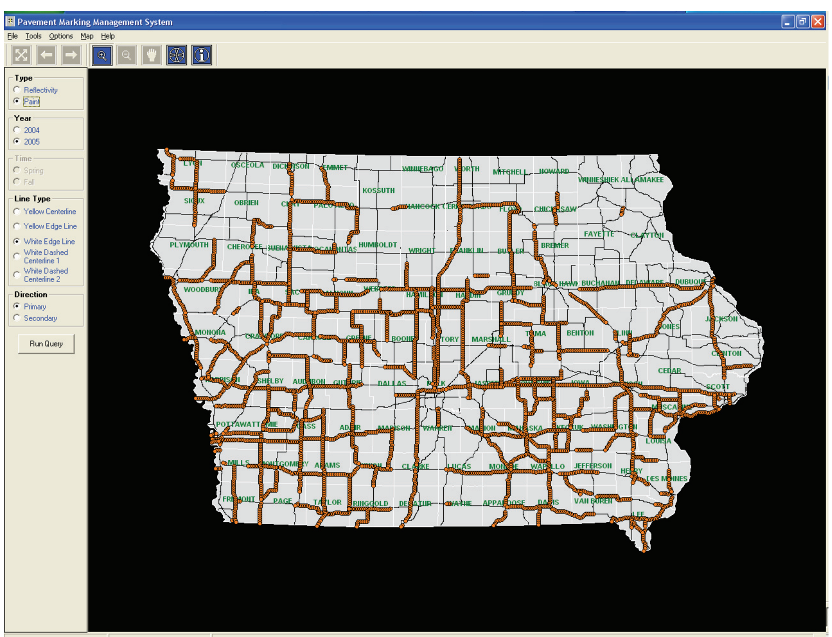

Figure 3. White Edge Line Painted in Summer 2005

Since the primary users of the PMMS Tool will likely be at the district level, the tool allows users to refine the analysis area (Figure 4). Users may then focus on areas that are pertinent to them, where they have knowledge, responsibility and control. For example, the last series of figures (Figure 5 - Figure 9) present analysis of yellow centerline for a localized area through a calendar year, including spring assessment (Figure 5), summer painting activities (Figure 6) and fall assessment (Figure 8). Additionally, Figure 7 presents the ability of the user to investigate more details about specific data, in this case summer paint application. Figure 9 shows the user's ability to track a location over time, through all data collection and paint cycles available.

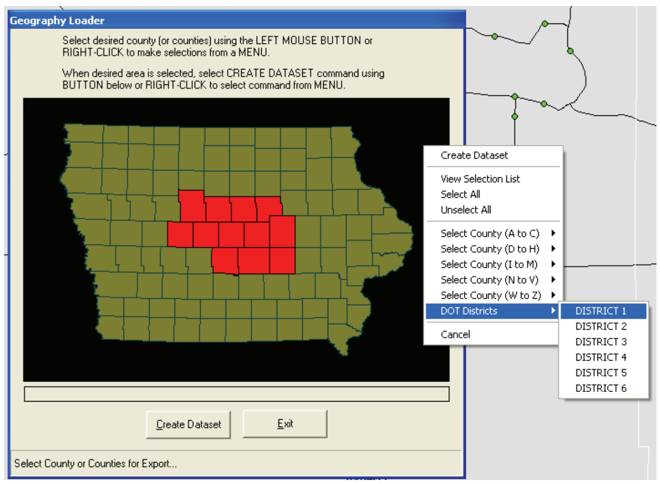

Figure 4. Limiting Analysis Area Extent (DOT Districts)

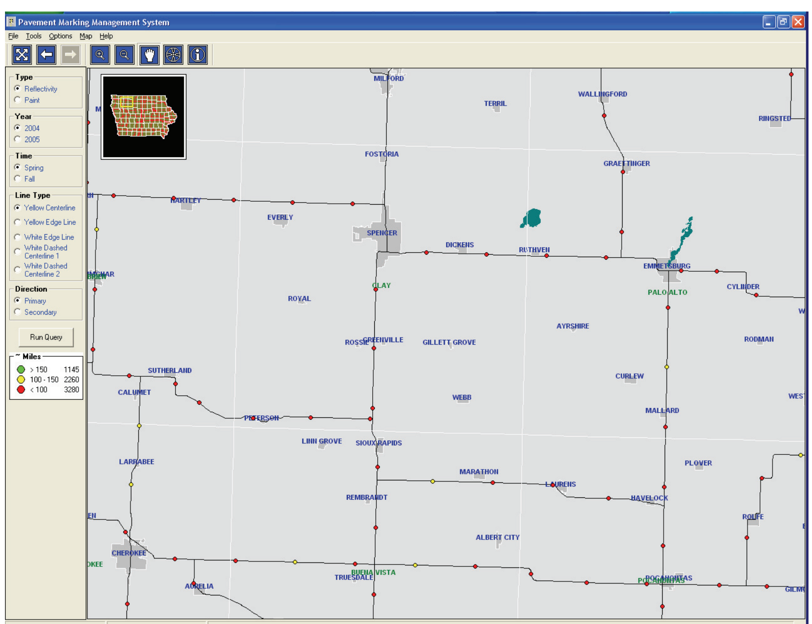

Figure 5. Spring 2004 Yellow Centerline Reflectivity Ranges

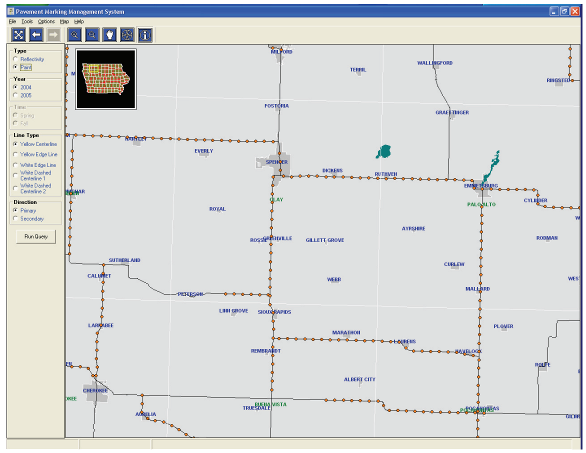

Figure 6. Yellow Centerline Painted in Summer 2004

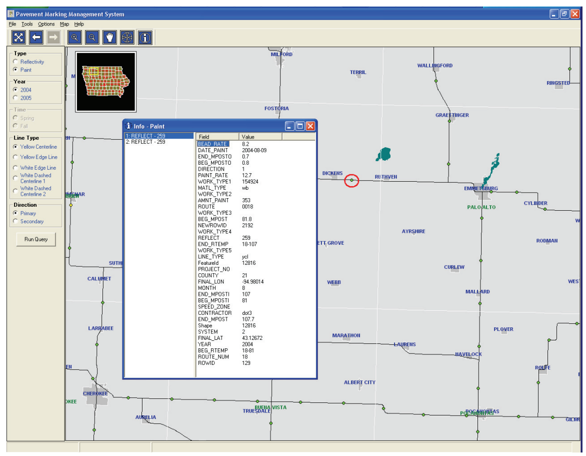

Figure 7. Project Specific, Yellow Centerline Paint Crew Details (Summer 2005)

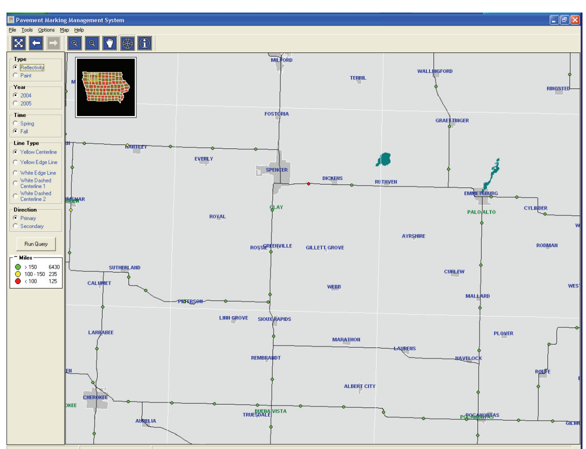

Figure 8. Fall 2004 Yellow Centerline Reflectivity Range

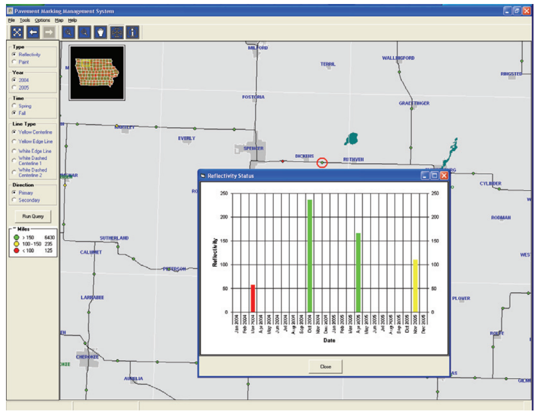

Figure 9. Site Specific, Yellow Centerline Reflectivity over Time

Sign Management

Given the early stages of the sign management system, only preliminary results may be provided. To date, the primary benefits of mapping the sign inventory data have been in the area of quality control and assurance. For example, Figure 9 presents all Iowa DOT District 3 signs that were mapped from their December 2003 inventory. Apparent from this figure is that several routes either had not yet been collected or that an issue existed with the manner in which the signs were referenced. Such a problem could be related to user error or inaccuracies in the underlying route-reference markers. At that time, approximately 6% of over 29,000 signs could not be located.

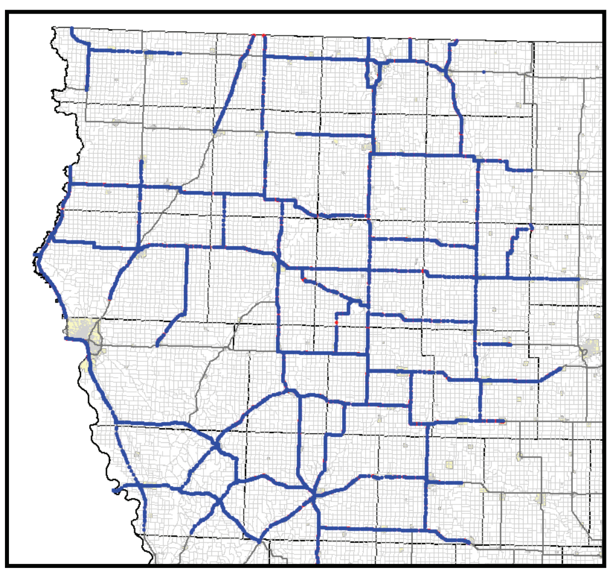

Figure 10. Iowa DOT District 3 Sign Inventory (December 2003)

In April 2004, the sign inventory of District 3 was mapped again (Figure 11). When compared to Figure 10, the total system coverage is much greater, while a portion of one route still appears to be missing data. This inventory included several thousand more crashes (approximately 35,000) with 7% not being located. By looking at the map and reviewing the route and reference markers reported in the database, it can become clearer whether the un-located signs are a systemic or random problem.

Ultimately, the primary benefit of mapping the sign inventory data will be the ability to not only better manage and analyze these data but to integrate the data with other databases, such as crashes, within GIS. A simple example of the former is displaying all locations of stop signs with a district (Figure 12).

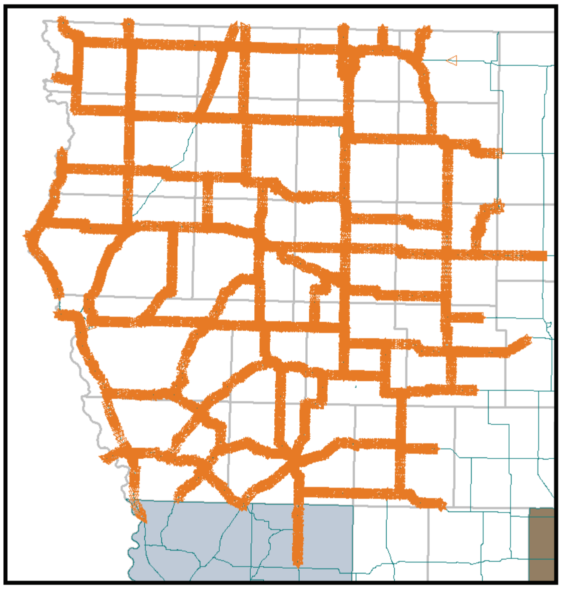

Figure 11. Iowa DOT District 3 Sign Inventory (April 2004)

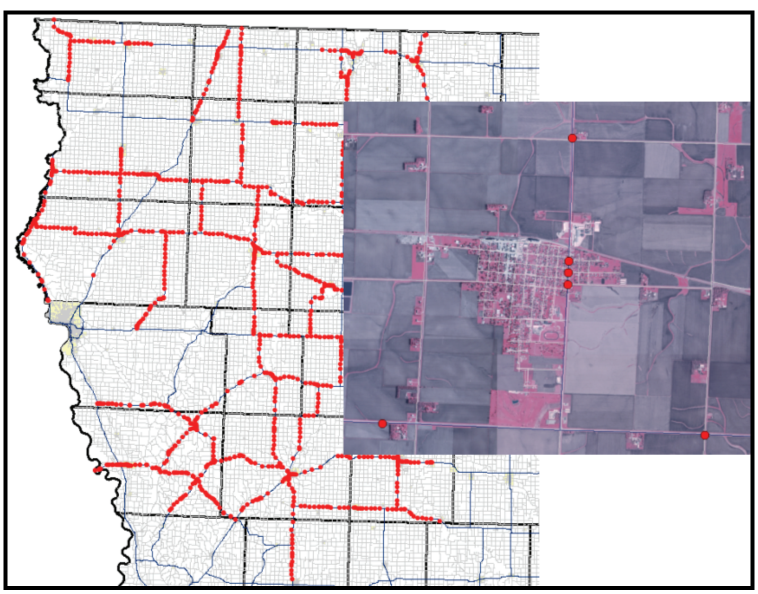

Figure 12. Iowa DOT District 3 Stop Sign Locations (December 2003)

CONCLUSIONS

The tools presented in this paper highlight the importance of providing easy access to the inventory and management data so that consistent, objective, and cost effective decisions can be made regarding the maintenance of pavement marking and signage assets. Even though this work is in the initial phases of development and implementation, the tools developed so far have provided tremendous benefits to the Iowa DOT field, technical, and management staff. Further work is being completed to enhance these tools and develop a frame work for an integrated management system for multiple asset categories that the Iowa DOT maintains. Future work in these two areas includes:

- Data collection tools to help field staff collect sign and pavement marking inventory and condition information. The tools will run in an environment that allows for full integration with the exiting tools and that utilize GIS and GPS functionality.
- Management tools that allow decision makers to develop future needs (resources and funding) to satisfy certain performance goals.
- Training and system maintenance and support.