USING GIS TO DEVELOP AN INTERSECTION INVENTORY FOR SAFETY

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ABSTRACT

In 2010, there were 30,196 fatal crashes, 23 percent of which were intersection or intersection-related (1). One of the major challenges transportation agencies face when trying to address intersection safety is not having a sufficient enough intersection inventory that provides information on the location, operations, or geometrics of the intersections. The goal of this paper is to demonstrate how agencies can use readily available tools, such as geographic information systems (GIS), and existing transportation datasets to develop a base intersection inventory. This paper will also demonstrate how an agency can conduct a more robust data collection effort by expending only a little more resources. This is based on an effort conducted for the New Hampshire Department of Transportation (NHDOT) to build an intersection inventory of 10,300 intersections. The Federal Highway Administration (FHWA) funded this effort as part of a project to demonstrate the feasibility of collecting Model Inventory of Roadway Elements (MIRE) data and incorporating them into an agency’s safety program.
INTRODUCTION

In 2010, there were 30,196 fatal crashes, 23 percent of which were intersection or intersection-related (1). Intersections create known points of conflict, with turning and crossing movements creating hazards for both vehicles and pedestrians. Improving safety at intersections has become a priority at the Federal, State, and local levels. However, one of the major challenges transportation agencies face when trying to address intersection safety is not having a sufficient enough intersection inventory that provides information on the location, operations, or geometrics of the intersections.

Quality data are the foundation for making important decisions regarding the design, operation, and safety of roadways. With the recent development of more advanced safety analysis tools, such as Safety Analyst (2), Interactive Highway Safety Design Model (IHSDM) (3), and the Highway Safety Manual (HSM) (4), many agencies are seeing the value of better roadway data. The more details a State or local agency knows about its roadways (including intersections), the better it can use its resources to effectively and efficiently identify problem locations, diagnose the issues, prescribe appropriate countermeasures, and then evaluate the effectiveness of those countermeasures. This process can lead to a more successful safety program supported by data-driven decision-making to help improve the safety of roadways and ultimately save lives.

To help support States in improving their roadway data, the Federal Highway Administration (FHWA) Office of Safety recently created the Roadway Safety Data Program (RSDP). This program encompasses a variety of initiatives, with the goal of improving the collection, analysis, management, and expansion of roadway data for safety (5). One of the RSDP initiatives is the Safety Data Capabilities Assessment. In this recent effort, FHWA assessed the ability of the State’s roadway data to support its safety program. FHWA conducted the assessments in 50 States, Washington, D.C., and Puerto Rico (6). During these assessments, many States expressed an interest in collecting intersection data or expanding upon their existing intersection database. However, States also indicated that limited funding is a major barrier to collecting these additional data, especially on non-State-maintained roads. Given the constrained economic environment, States are searching for low-cost, easy-to-implement options to meet their data needs.

Another initiative under the RSDP umbrella is the FHWA Model Inventory of Roadway Elements (MIRE). MIRE is a listing of roadway features and traffic volume elements important to safety management and includes standardized coding for each element. MIRE Version 1.0 currently includes 202 elements grouped into three broad categories: roadway segments, roadway alignments, and roadway junctions (7). Also under the RSDP umbrella are the Fundamental Data Elements for safety (FDE). The FDE, a subset of MIRE, are a list of 38 roadway data elements that FHWA determined necessary for States to collect to support their safety programs.

The next step is the evolution of the MIRE from a listing of elements to a management information system (MIS). FHWA is currently conducting the MIRE MIS project to test the feasibility of collecting, storing, and integrating MIRE data into an MIS and then linking these data with crash and other relevant data for safety analyses.

FHWA chose the New Hampshire Department of Transportation (NHDOT) through an application process as a Lead Agency to participate in the MIRE MIS effort. The objective of the Lead Agency Program was to assist volunteer agencies to collect, store, and maintain MIRE data and to incorporate those data into their safety programs. A secondary objective was to
determine the level of effort and resources necessary to achieve these goals. FHWA did not anticipate that one agency would collect all 202 elements but that each Lead Agency would collect either all or critical elements in one subsection of MIRE (e.g., intersection elements, ramp elements, curve elements, pedestrian elements, etc.) or critical elements from a combination of subsections. Each Lead Agency chose what MIRE elements it wanted to be collected through the program. The NHDOT requested the collection of many critical intersection elements to expand its use of SafetyAnalyst and to improve its overall safety inventory. This paper documents the effort to develop a geographic information system (GIS) based intersection inventory for NHDOT.

OBJECTIVE

The purpose of this project was to develop an intersection inventory for the NHDOT for use in SafetyAnalyst. SafetyAnalyst is set of software tools used by State and local highway agencies for highway safety management. FHWA developed SafetyAnalyst through a cooperative effort. It is available through the American Association of State Highway and Transportation Officials (AASHTO). It is important to note that the effort documented in this paper is applicable to any agency interested in developing an intersection inventory independent of the analysis tool(s) used by the agency.

The objective of this paper is to demonstrate how—based on the effort put forth for NHDOT—an agency can use readily-available tools (e.g., GIS) and existing transportation datasets to develop a base intersection inventory. This paper will also demonstrate how an agency can conduct a more robust data collection effort by expending only a little more resources. Many States already have the existing data needed to develop a basic intersection inventory. According to the Capabilities Assessment, all States indicated they already have an existing basemap of their State-maintained roadways, and many also have local roadways on these maps, as well (6). States are also collecting many of the FDE through the Highway Performance Monitoring System (HPMS) and other data collection efforts. Using their existing basemap and roadway data, this paper demonstrates how State and local agencies can create a base intersection inventory through GIS tools for use in safety analyses and other purposes.

DEVELOPMENT OF THE INTERSECTION INVENTORY

The intersection inventory was developed using the following ten steps:

1) Determine what data to include in the inventory and for what types of intersections.
2) Determine what data are already collected and what remaining data need to be collected.
3) Determine how the data are currently collected, the available data sources, and how to collect the new data.
4) Develop a detailed work plan.
5) Develop or expand the intersection node layer.
6) Develop a model for extracting existing data to pre-populate the intersection inventory.
7) Develop the data collection interface and toolbar.
8) Collect the data.
9) Conduct quality assurance/quality control (QA/QC) reviews.
10) Integrate the new dataset into the current system.
The authors discuss these ten steps in more detail in the following sections, with the primary focus on how the initial node layer (Step 5) and the detailed model (Step 6) were developed using GIS.

**Step 1: Determine What Data to Include in the Inventory and for What Types of Intersections**

The first step in this process was to work with NHDOT to determine what elements it wanted to include in its intersection inventory. Since this project was conducted through the MIRE MIS effort, the starting point was the MIRE listing. NHDOT reviewed the MIRE element listing and provided the project team with a list of the data elements of interest, which included all required and some optional SafetyAnalyst elements for intersections. It included elements related to the overall intersection and each intersection leg, as shown in Table 1. These elements consist of location, operations, and geometric data.

While ultimately NHDOT would like to have detailed information on all intersections on public roads within the State, there was a limited budget available to NHDOT for the collection of data. NHDOT prioritized its intersections based on ownership of the intersecting roadways. Its top priority were the State/State intersections (approximately 1,500), followed by the State/local intersections (approximately 8,800), and then local/local intersections (approximately 30,750). Based on the available funding, NHDOT requested that the project team focus on collecting data at State/State and State/local intersections. This group totaled 10,300 intersections for inclusion in the intersection inventory.
## TABLE 1  Intersection Inventory Elements Requested by the NHDOT

<table>
<thead>
<tr>
<th>Intersection Elements</th>
<th>Intersection Leg Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection ID</td>
<td>Intersection ID</td>
</tr>
<tr>
<td>Location System</td>
<td>Leg ID</td>
</tr>
<tr>
<td>Route Type</td>
<td>Type</td>
</tr>
<tr>
<td>Route Name</td>
<td>Location System</td>
</tr>
<tr>
<td>County</td>
<td>Route Type</td>
</tr>
<tr>
<td>Major Road MP</td>
<td>Route Name</td>
</tr>
<tr>
<td>Minor Road Location System</td>
<td>County</td>
</tr>
<tr>
<td>Minor Road Route Type</td>
<td>Milepost/Distance</td>
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<td>Influence Zone</td>
</tr>
<tr>
<td>Minor Route MP</td>
<td>Direction of Leg</td>
</tr>
<tr>
<td>Agency Site Subtype</td>
<td>Thru Lanes</td>
</tr>
<tr>
<td>GIS Identifier</td>
<td>Left Turn Lanes</td>
</tr>
<tr>
<td>Major Road Name</td>
<td>Right Turn Lanes</td>
</tr>
<tr>
<td>Minor Road Name</td>
<td>Median Type</td>
</tr>
<tr>
<td>Major Road Direction</td>
<td>Left Turn Phasing</td>
</tr>
<tr>
<td>Begin Influence Zone (Major &amp; Minor)</td>
<td>Speed Limit</td>
</tr>
<tr>
<td>End Influence Zone (Major &amp; Minor)</td>
<td>Turn Prohibitions</td>
</tr>
<tr>
<td>District</td>
<td>Operations</td>
</tr>
<tr>
<td>City Town</td>
<td></td>
</tr>
<tr>
<td>Jurisdiction</td>
<td></td>
</tr>
<tr>
<td>Area Type</td>
<td></td>
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<tr>
<td>Intersection Type</td>
<td></td>
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<tr>
<td>Traffic Control Type</td>
<td></td>
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<tr>
<td>Offset Intersection</td>
<td></td>
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<tr>
<td>Offset Distance</td>
<td></td>
</tr>
<tr>
<td>Growth Factor</td>
<td></td>
</tr>
<tr>
<td>Date Open to Traffic</td>
<td></td>
</tr>
<tr>
<td>Corridor</td>
<td></td>
</tr>
<tr>
<td>Comment</td>
<td></td>
</tr>
</tbody>
</table>
Step 2: Determine What Data are Already Collected and What Remaining Data Need to be Collected

The next step was to determine which of the elements NHDOT wanted included in the inventory were already being collected. The State had recently participated in the FHWA Capabilities Assessment, and the corresponding questionnaire included a table of all of the MIRE elements, documenting which elements NHDOT currently collects and in what datasets they reside. NHDOT gave the project team permission to use the information in the questionnaire as a starting point. Over a series of onsite meetings, the project team worked with the NHDOT safety, roadway inventory/HPMS, and GIS staff and reviewed their data collection practices and datasets.

During the review of the information in the Capabilities Assessment questionnaire and in discussion with NHDOT staff, the project team discovered that it was not as straightforward as simply having the data element or not having the data element. The project team determined that there were various categories of data availability:

- **Exist**: The data element exists exactly as it is defined.
- **Derive**: The data element exists in another format and needs to be transformed from the current format or gathered from existing GIS layers. This value may need to be further validated.
- **Assign**: The data element does not exist, but the value can be derived using guidance or coded values provided by NHDOT.
- **Collect**: The data do not exist and will need to be collected.

Step 3: Determine How the Data are Currently Collected, the Available Data Sources, and How to Collect the New Data

Conducted concurrently with Step 2, the project team worked with NHDOT to determine how it currently collects and stores the data. The three primary sources of existing roadway information at NHDOT are GIS layers, roadway videolog, and HPMS.

Currently, NHDOT stores its roadway and intersection data in a statewide road inventory database. The database is maintained using ESRI® ArcGIS version 9.x software. The inventory is a node-based model containing road centerlines and intersections for all Federal, State-maintained, local, and private roads. (This will be described in greater detail in subsequent sections.) The database evolved from NHDOT’s straight-line diagrams that it previously used to maintain the State’s official road mileage for use in HPMS reporting and Highway Block Grant Funding.

In the early 2000s, NHDOT contracted with a private company to update all of the State-maintained roadways in New Hampshire. This involved driving each State-maintained road and recording the mileage using a distance measuring instrument (DMI). The remaining roads (local and private) were inventoried by the State’s nine regional planning commissions. Currently, NHDOT maintains the database using high-resolution aerial photographs with supplemental field verification.

There are over 40 roadway attributes for each road entered into the database. Each road centerline and intersection node has a unique identifier that allows linkage between the attribute information and the corresponding road segment/intersection. Mileposts identify the length of each road segment, representing the distance between each node or intersection. The road centerline attribute table stores the begin and end mileposts of each road segment. In addition,
The road centerline and intersection files use a linear referencing system in which each road segment contains distance value measures along the line. Within the database, the road centerlines are separated into two layers: High Order Routes and Road Anchorsections. The High Order Routes layer represents the entire length of geometry for a route, whereas the Road Anchorsections layer represents the individual road segments (from node to node) that make up a route. NHDOT staff updates the road inventory database on a daily basis, with an annual release made available to the public.

NHDOT also obtains roadway information from a videolog system that utilizes a data collection van. The van includes three cameras for the videolog—front- and rear-facing cameras with a 110-degree field of view and a 360-degree camera mounted on the roof—much like the Google Street View vehicles. The van also tracks global positioning system (GPS) coordinates of intersections and conducts real-time corrections to the GPS, while linked with a GIS map. NHDOT also collects data per the HPMS requirements.

Based on the information obtained from NHDOT, the project team determined how to populate the intersection inventory for each element based on the categories of data availability discussed in Step 2:

- **Exist**: Use values as they currently exist.
- **Derive**: Transform existing data or gather from GIS layer.
- **Assign**: Assign values that are derived using guidance or coded values.
- **Collect**: Collect information that has not yet been collected or validated from GIS, HPMS, or visual imagery.

**Table 2** shows each element to be included in the intersection inventory, where it currently exists (if applicable), and how it will be populated.
TABLE 2 Elements and Primary Method of Data Collection for Intersection Inventory Elements

<table>
<thead>
<tr>
<th>Intersection Elements</th>
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<td>Minor Route MP</td>
</tr>
<tr>
<td>Agency Site Subtype</td>
<td>Major Road Name</td>
</tr>
<tr>
<td>GIS Identifier</td>
<td>Minor Road Name</td>
</tr>
<tr>
<td>Major Road Name</td>
<td>Major Road Direction</td>
</tr>
<tr>
<td>Minor Road Route Name</td>
<td>Begin Influence Zone (Major &amp; Minor)</td>
</tr>
<tr>
<td>Minor Route MP</td>
<td>End Influence Zone (Major &amp; Minor)</td>
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<td>Area Type</td>
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</tr>
</tbody>
</table>

Step 4: Develop a Detailed Work Plan
The next step was to develop a detailed work plan. The work plan included a description of NHDOT’s existing data system, including sources of available data. It also provided an overview of the proposed effort, including timeframe and cost, as well as a detailed data dictionary that NHDOT provided to the project team. The data dictionary included the attributes as well as important considerations for each element.

Step 5: Review or Expand the Node Layer
A crucial step in the development of the intersection inventory was identifying where the intersections are located. NHDOT already had an existing node layer that it developed for use by State and local law enforcement in locating crashes. The State created nodes at intersecting...
roads, where road names or functional classifications changed, and at town limits and county
lines. When created, each node has a unique identifier assigned to it. The node layer is
maintained using NHDOT’s existing road centerline file. Using this node layer as a base,
NHDOT then undertook an extensive manual effort to review and extract the State/State and
State/local intersections using GIS and aerial photography as part of its effort to implement
SafetyAnalyst.

The project team identified several problems with this methodology. Most notably, three
percent of the nodes were not actual intersections as defined by NHDOT. The majority of these
non-intersections were locations where a Class VI road (unmaintained road subject to bars and
gates) intersected with a State road. NHDOT did not want to include these intersections in the
intersection inventory.

As part of this effort, the project team was also tasked with expanding the existing
intersection node layer to include local/local intersection nodes. Based on the identified
problems with the existing methodology, the project team took a different approach to expand
the local/local node layer than the NHDOT had to develop the State/State and State/local node
layer. The existing node layer consists of all the start and end points of each roadway segment in
the road inventory database. These are split at town and county boundaries. To create the
local/local intersection layer, the project team filtered the nodes down to actual intersection
locations of local/local roads. The project team used ESRI ArcGIS 10.0 software to complete all
work. An overview of the process is given below:

1. The local roads were extracted from the State’s road inventory centerline file using a
definition query.
2. Linear referencing tools, specifically the ‘Locate Features Along Routes’ tool, were
used to process the State’s node layer and the local roads extracted from the road inventory
centerline file to identify each local road segment that touched a node. The output is a table
listing each roadway segment, which includes all of the road inventory attributes, coded by the
unique identifier of each node and road segment.
3. A temporary field was added to the table created in Step 2 and populated based on
road legislative class. Each record in the table was scored based on the legislative class of the
road. Another temporary field was created to further select out only the local/local intersections
and to exclude any node locations that represented the intersection of two private roads. In
addition, potential intersection locations could be screened to remove intersections of Class VI
roads.
4. A frequency analysis was used to summarize the legislative class scoring created in
Step 3. The result is a table containing a single record for each node, with the total score of the
legislative class information.
5. A definition query was used to remove any potential intersections with a score of “0,”
which would represent private/private intersections, and Class VI/Class VI intersections.
6. A final spatial selection was used to remove any potential intersections that touch a
State route, which eliminates any State/local intersections from the database.

This methodology provides a way of using GIS tools to screen the nodes down to
local/local intersections without the need for manual interpretation.
Step 6: Develop a Model for Extracting Existing Data to Pre-Populate the Intersection Inventory

The purpose of the model was to automatically extract and transform, where necessary, the data from various existing sources within NHDOT (identified in Steps 2 and 3 of the overall effort) and apply those data to each intersection to “pre-populate” the intersection inventory. In this project, the output from the model needed to be formatted specifically for use in SafetyAnalyst, but it should be noted that it could be formatted for use in any safety analysis tool.

NHDOT had already developed a series of Structured Query Language (SQL) scripts to process its existing GIS road inventory files to create an intersection table that was imported into SafetyAnalyst. SQL is programming language designed for managing data in relational database management systems. Due to inconsistencies in data structure between the NHDOT road inventory files and SafetyAnalyst, it is not possible to directly import NHDOT data into SafetyAnalyst. The NHDOT SQL scripts process the road inventory files to extract existing roadway attribute information based on NHDOT’s roadway data dictionary and transform the information so that data inputs match SafetyAnalyst’s import formats. The scripts have allowed NHDOT to successfully import much of its State system’s inventory data into SafetyAnalyst. Using these data, they have been able to complete network analyses of the State/State and State/local intersections using the required SafetyAnalyst data elements.

Although the SQL scripts help automate the process, there are some limitations with their current methodology. Due to limitations in time and accuracy of some source data, several elements that could have been collected from existing data were not included in their scripting. These data are mostly elements that had to be collected or verified using their aerial imagery or roadway videolog, such as intersection offset distance, intersection type, and traffic control type. Some elements, such as skew angle and school zones, could be derived from existing data but were not required for analysis. In addition, the SQL scripts are run in Oracle SQL Developer, which does not run within the GIS environment. As with any well-maintained GIS, the NHDOT Planning Bureau regularly updates its road inventory database, and, thus, the SafetyAnalyst intersection tables should be able to be updated to reflect those changes. There was a need for a more efficient model.

Using ESRI ModelBuilder software for ArcGIS 10, the project team developed an ArcGIS Toolbox containing a series of geoprocessing models that process the State’s roadway inventory files and generate additional information required by SafetyAnalyst that is currently not available within the roadway inventory database. The project team developed the processes within the models from the steps outlined in the SQL scripts originally developed by NHDOT, but, in several instances, these were modified to make use of existing GIS functions rather than custom coding.

Currently, the toolbox contains an Intersection Update Model, and a New Intersection Model. The Update Model checks the most up-to-date road inventory database and updates the intersection inventory tables for any changes to the database. The New Intersection Model allows the GIS user to identify locations of new intersections. New intersections are intersections where a private road has been accepted as a public road, a new public road has been constructed, or where an intersection has been realigned. Below is a list of some of the key features contained within the model:

- Identifies the major/minor road associated at each intersection based on annual average daily traffic (AADT). Populates the road names of each major/minor road, along with its unique segment identifiers.
• Populates the road route type (Interstate, U.S. route, State route, local road) of each road segment.
• Calculates the milepost location of each intersection referenced to the State’s road inventory database.
• Calculates the approach direction of each roadway segment of the intersection.
• Identifies the number of legs present at each intersection.
• Calculates the intersection type (i.e., tee, four-leg, multi-leg).
• Identifies the city/town, county, NHDOT Maintenance District, State Trooper District, and Regional Planning Commission within which each intersection is located.

The previous import process took several days to complete using the previous SQL scripts. By utilizing the geoprocessing models developed by the project team, this task was successfully completed in less than one hour. In addition to the significant time savings, the geoprocessing models also provide a GIS user-friendly environment and are conducive to more effective troubleshooting should potential issues arise.

Step 7: Develop the Data Collection Interface and Toolbar
The project team used the model described above to pre-populate the intersection inventory with the existing, available data. There was still a need to develop a tool to collect the remaining data elements. It was not within the scope or budget to collect data for over 10,000 intersections in the field, not to mention the safety concerns with field data collection. Therefore, an alternate methodology was used to collect the data. The project team developed an ESRI GIS-based system to populate the intersection inventory that employed both automated and manual methods.

GIS Database Assessment and Setup
The project team requested and obtained from NHDOT a current version of its GIS database. Since NHDOT uses Oracle as the platform for its ArcSDE geodatabase, the data were exported to a file geodatabase. The feature classes in the file geodatabase were imported into a SQL Server ArcSDE geodatabase. The processes were performed in ArcCatalog with an ArcEditor or ArcInfo license.

Once the project team imported the data into ArcSDE, a database assessment was conducted. This involved the following:
1. Confirming that all necessary fields for the data collection were present in the feature classes and named correctly. New fields were created, when necessary.
2. Verifying the required fields were in the correct data type (e.g., integer, text, etc.) and length, referencing the ‘SafetyAnalyst Data Import Reference’ document. Field types were corrected, if necessary.
3. Setting up domains, where necessary, to make sure the data were collected in a consistent manner and in the correct format for use with SafetyAnalyst. The ‘SafetyAnalyst Data Import Reference’ document was used as a guide.
4. Verifying that the feature classes required for the model and the GIS Interface were accounted for and in the proper GIS format.
5. Creating the intersection leg feature class from the existing roads layer. The length of the leg did not matter.
Convert the Existing SQL Scripts into ESRI’s Model Builder

As described in Step 6, once the model pre-populated the intersection and intersection leg feature classes from the roadway inventory datasets, the project team exported the files for use in populating the remaining required SafetyAnalyst attributes.

Develop Data Collection Interface and Toolbar

The project team developed an interface to allow for data entry from the videolog and online mapping sources, such as Google and Microsoft Bing. ESRI’s ArcGIS 10 was the platform used for the interface. The model and data editing (attribute and feature) used were within the ArcGIS 10 desktop environment.

An overview of the GIS Interface task included the following:

- Database review/design: This phase included an assessment of the data as it currently exists so that it could be set up correctly to be used in the GIS interface.
  - Exported data from the file geodatabase provided by NHDOT to ArcSDE.
  - Add fields to feature classes (intersections and legs).
  - Set up domains. Use the ‘SafetyAnalyst Data Import Reference’ document as a guide.

- Building data entry forms: The data entry forms were used to enter remaining attributes not populated by Model Builder, as well as to allow the user to edit any existing attributes.
  - Intersections.
  - Legs.

- Creating a toolbar that includes several custom tools:
  - Run Model.
  - Edit Attributes of a feature (shows custom data entry forms).
  - Export intersection and leg attribute tables for use in SafetyAnalyst.

The team developed a custom data entry form to allow the end-user to enter in the required MIRE attributes for intersection and leg features. Microdesk assisted with the development of the form. The form has built-in checks and validation to ensure that all attributes are accounted for. There is a drop-down box for all attributes that have a domain tied to them so the data entry clerks collect the data in a consistent, accurate manner for use with SafetyAnalyst.

There were several attributes that NHDOT requested be collected but were outside the scope of this project. Therefore, the project team included them in the data entry interface for potential future use by NHDOT. For these attributes, a domain was assigned based on the list of attributes provided by NHDOT; however, the project team did not collect those data elements for them.

There was one data entry form for intersection attributes and one form for intersection leg attributes, as shown in FIGURE 1. The elements that are in light gray text are those that were pre-populated and do not require any additional action. The drop-down boxes have black text, and the empty white boxes are those that require data entry. The gray boxes with no text, such as Lighting Presence and Pedestrian Volume, are the “placeholders” for attributes that NHDOT might collect at a later date.
The initial intent was to link the videolog with the data collection tool. However, the videolog was not compatible with the software, and after working directly with the videolog vendor, the project team determined that the videolog could not connect with the data collection tool. As a result, an alternate approach was taken. The tool included Google Street View and Microsoft Bing Bird’s Eye plug-ins for ArcGIS, which allowed the user to view Google and Microsoft Bing aerial images of an intersection by simply clicking on that intersection on the GIS map (8). This reduced the data entry time, since the user did not have to search for the visual image of the intersection. This process was the primary substitute for the videolog, but the videolog could still be used as a resource if the imagery from Google or Microsoft Bing did not provide the information needed. However, it would not be an automatic connection; the data entry user would need to manually find the location in the videolog. The Google/Bing ArcGIS add-in allowed users to click anywhere on their map in ArcGIS and a small window would appear with that location in Google or Bing. This aided in the data entry process by allowing users to see fairly current aerial imagery and other base data to help determine the attributes of an intersection or leg.

Step 8: Collect the Data
Once the data collection tool was finalized, the next step was to begin data collection. Before data collection could begin, the project team needed to install the data collection tool on each workstation and train the data entry clerks. This was a two-day process. As part of the training,
the project team developed a data entry manual that provided explicit instructions for each of the data entry clerks.

Once the tool was installed and the training was completed, the data entry effort began. The interface allowed the end-user to enter the attributes for overall intersection and individual leg features using existing satellite and aerial images, including Google Street View and Microsoft Bing Bird’s Eye, as well as web map service imagery from a 2011 flyover provided by the University of New Hampshire. The NHDOT GIS database was connected to the user interface and the imagery sources. When the users click on the intersection on the GIS map that they want to populate, the data entry form for that location automatically appears, with the user interface pre-populated. The user then keys in the remaining items. The interface was developed to have the pre-populated items “grayed” out so they could not be edited by the entry clerk. These pre-populated data elements were primarily moved to the bottom of the form so as not to confuse or slow down the data entry process. Only those items that need to be collected can be changed. There are drop-down menus and built in error checks that prevent the user from entering erroneous data, as shown in Figure 2.

![Image of data collection through GIS-based intersection inventory builder.](image)

The GIS data are stored in an ArcSDE geodatabase. This format of geodatabase allows for multi-user editing and multiple versions. Each data entry clerk was assigned a different county in New Hampshire. All users had their own version of the database, which helped with the quality assurance/quality control (QA/QC) process that is described in the following section.

The project team provided NHDOT with a sample of the dataset to test the process of incorporating it into its system. This was to ensure that there were no issues with the data. Once NHDOT approved the sample, data collection was completed.
Step 9: Quality Assurance/Quality Control (QA/QC)

Once a week, all data entry clerks posted their individual database versions to a “Quality” version of the database. An independent reviewer checked a sample of intersections from each data entry clerk and noted any inconsistencies. These were then reported back to each data entry clerk, and they were responsible for fixing those identified issues. They were also responsible for reviewing their data to ensure similar issues did not exist at other intersections. Once each dataset was corrected, it was then posted to a “Master” database.

Step 10: Integrate the New Dataset into the Current System

The final step was to deliver the database to NHDOT and install the data collection tool and model on its system. (As of the date of this paper submittal, this has not yet been completed.) A sample of the dataset was provided to NHDOT and was tested for incorporation into the NHDOT system. Because there were no issues with the sample test, it is not anticipated there will be any significant issues with integrating the completed intersection inventory into NHDOT’s system.

RESULTS

The development of the data collection tools and model began in January 2012 and took approximately three months to complete. The data collection for all 10,300 intersections began in March 2012 and was completed in July 2012. This was under budget and ahead of schedule. The data collection was initially estimated to take six months to complete but only took four months. The data collection itself was estimated to take 2,000 hours but only took 1,600 hours. At any given time over the data collection period, there were three to five data collection stations that were manned almost full-time. The management and QA/QC time took slightly more hours than initially planned but was more than offset by the reduction in the data collection time. The initial estimates were based on 10-12 minutes per intersection, but it took only an average of 9 minutes per intersection.

Throughout the data collection process, the number of intersections completed per hour improved for each data entry clerk. At the start of the data collection it took almost 12 minutes per intersection; however, by the end, it took approximately seven minutes per intersection. Error rates also improved through the data collection period. Since this process is repetitive in nature, the more familiar the clerks became with the process and the data elements, the more efficient they became.

The determination of speed limits was perhaps the largest obstacle during data collection, as it required the most time of any data element. NHDOT does not have a speed limit database, so the speed limits for each approach had to be collected from the speed limit signs. However, the signs were often not right at the approach and the data entry clerks had to “drive” down the street using Google Street View to find the speed limit sign. The data entry clerks were challenged with developing an efficient method to collect this information. The method that was adopted by the majority of the data collectors was to print out a map of the corridor, and then using Google Street View “drive” the corridor all at once, and note on the map the location of the speed limit signs and the posted speed limit. Then, when they went to fill in the data on the approach leg, they could reference the map.

Despite the issues with collecting speed limits, this effort came in under budget and ahead of schedule. There were many factors that contributed to this success, including the following:
1) **Work Plan:** There was a great deal of effort that went into developing the work plan. The work plan provided a clear vision and approach for conducting the data collection. This helped to lay out clear expectations on the part of NHDOT and the project team.

2) **Constant contact/feedback with State DOT:** Throughout the entire process, NHDOT was available to answer questions and to provide clarification and feedback. This constant communication was key to developing a dataset that best meets their needs.

3) **Use of a “Frequently Asked Questions” document.** Since there were multiple data entry clerks simultaneously entering data, there were several similar questions that came up in the beginning of the data collection effort. The project team developed a Frequently Asked Questions (FAQ) document. Each time a data entry clerk asked a question, that question and its response were added to the FAQ document. The data entry clerks were instructed to review the document every morning. This helped to provide a level of consistency among the various staff members.

4) **Flexibility:** Each data entry clerk was given the flexibility to collect the data however they thought was most efficient for them. Some collected all of the speed limits first within a corridor; some did all of the intersections, then all of the legs. By allowing this flexibility, each data entry clerk was able to work in the manner that would be most efficient for them.

5) **Sample dataset:** The project team provided NHDOT a sample dataset to ensure there were no problems with the data. Although none were found, if there had been issues, they could have been resolved before completing the data collection rather than having to go back and correct the data—thus saving valuable time, budget, and resources.

6) **Use of GIS Tools:** The tool was completely GIS-based using ESRI products and did not require any proprietary software. This allowed the project team to install it on NHDOT’s system, allowing NHDOT to continue the data collection effort in the future, if it decides to do so.

**CONCLUSION**

The idea of collecting a comprehensive intersection inventory for over 10,000 intersections would seem daunting for an agency of any size. However, the project demonstrated that existing GIS tools and readily-available transportation datasets can be used to develop a base intersection inventory. As evidenced in Table 2, over half of the requested elements either already existed or could be derived. Even without the data collection effort, the model developed using GIS tools could be used to develop a basic intersection inventory. This effort also demonstrated that, by expending a relatively minimal amount of resources, developing a comprehensive intersection inventory is feasible. Additional future research to track how NHDOT is able to use the inventory, as well as the resulting improvement in safety at intersections, would be a worthwhile effort.
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