Using Public Information and Graphics Software in Graduate Highway Safety Research at Worcester Polytechnic Institute

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ABSTRACT - The adoption of parametric modeling highway design software in the graduate program at Worcester Polytechnic Institute has allowed graduate research to capitalize on publically available information. Recently graduate highway safety research has used AutoCAD Civil 3D (Civil 3D) to harness information from Google Earth and the Massachusetts Geographic Information System to gain an understanding of study area characteristics while minimizing the field time required for data collection. This paper presents the use of Civil 3D in two graduate research projects, the visualization of crash data with Civil 3D, and the use of Civil 3D to save data collection time.

I. Introduction

Tree collisions account for 48 percent of all fatal fixed-object crashes (Figure 1). Utility Pole crashes (Figures 2 & 3) account for 12 percent of all fatal fixed-object crashes. Trees are significant roadside hazards, but they also contribute positively to the roadside environment and aesthetics. “There is a strong movement nationally to maintain and preserve … scenic resources during construction and reconstruction of highways.” (AASHTO, 2008) The American Association of State Highway and Transportation Officials (AASHTO) “…encourages a comprehensive view of the design situation”(AASHTO, 2008) The Roadside Design Guide suggests that “to promote consistency …, each highway agency should develop a formal policy to provide guidance to design, landscape, construction, and maintenance personnel ….” (AASHTO, 2006)

Three particularly prominent studies have been made over the past three decades focused on reducing the occurrence of fatalities due to collisions with roadside fixed-objects: Mak & Mason’s Accident Analysis - Breakaway and NonBreakaway Poles Including Sign and Light Standards along Highways volume II - Technical Report (1980), Fox, Good & Joubert’s Collisions with Utility Poles (1979), and TRB State of the Art Report 9 Utilities and Roadside Safety: Initiatives (2004).

The goal of all of these studies was to determine which road characteristics contribute most significantly to run-off-road crashes and establish the most appropriate location for fixed objects such as utility poles and the maintenance and placement of new trees. Conducting such research requires access to crash records and to the highway characteristics of sections of highway both where the crashes have occurred and where they have not occurred. Collecting large data samples such as tens of miles of roadway characteristics can be time-consuming.
II. Background

Techniques for Highway Surveys

Highway surveys traditionally involve measuring and computing horizontal and vertical angles, elevations, and distances using a variety of data-gathering equipment. Data gathered in the field can be transformed, through a series of calculations and manipulations, into a base map with contour lines and highway alignments.

Recently, more sophisticated survey data collection techniques have been developed. These techniques include either measuring of distances and elevations from a remote location (i.e., airplanes, satellites, etc.) or field data collectors, which can automate some of the post-processing of field data. The accuracy and precision, as well as the amount of data gathered, govern which method is used.

Google Earth (Google, 2008), one of several public domain sources for information gathered through remote sensors, contains geographically referenced images and terrain information of varying degrees of precision and accuracy for location throughout the globe. The precision and accuracy of the information displayed can be varied through the original source of Google Earth's information, noted at the bottom of the screen.

AutoCAD Civil 3D and GIS

The use of AutoCAD Civil 3D (Civil 3D) in conjunction with Massachusetts GIS information and Google Earth, for roadside safety research at Worcester Polytechnic Institute (WPI), has improved the data collection processes, crash data visualization, and expanded research opportunities in the geographically referenced crash database field.

Civil 3D is a suite of software tools which includes AutoCAD, Autodesk Map 3D (Map 3D), highway design tools, and survey tools. Civil 3D creates a model which dynamically links model objects such as the horizontal, vertical, and cross-sectional elements of linear designs or the grading groups and drainage structures for site development projects. For example a Civil 3D model of a highway is developed through objects, 3D representations of your project based on a horizontal and vertical alignment and a proposed cross section (called an assembly). Each object is dynamically linked to each other, allowing the modeler to adjust any object resulting in 3D model updating automatically. This update would also revise proposed contours and earthwork calculations. The parametric properties of the software include a database of design criteria based on established highway design standards.

Map 3D, a geospatial database software tool designed to create and manage large data sets, allows the user to combine and query multiple data sources. (Autodesk, 2008) It supports over 3000 coordinate systems. Map3D reads and writes data in these formats: DWG, DGN, SHP, and MID/MIF. Map 3D reads Spatial Data Files, many raster formats, and many database formats. (Autodesk, 2008) The Civil 3D software suite, capitalizing on its Map 3D platform can import and export available data from many state Geographic Information Systems (GIS) and Google Earth.

III. Graduate Research Using Civil 3D

With this technology, highway safety research of roadside hazards, specifically trees and utility poles was conducted as Worcester Polytechnic Institute (WPI). Both studies had similar methodologies, aimed at identifying the roadway characteristics that seem to lead to roadside crashes with trees or poles.

Phase 1: Study Area Identification

The objective of phase one was to establish a study area, based on an assessment of the location of tree crashes. The 2005 Massachusetts Crash database
includes Massachusetts Mainland State Plane NAD 83 meters coordinates for crashes that have been geocoded to an approximate location based on available crash location data. Crashes were mapped on Massachusetts Geographic Information System (MassGIS) data obtained through Google Earth and viewed in Civil 3D. Upon review of the mapped tree crashes, it appeared tree crashes were occurring more frequently on urban local roads and in small urban neighborhoods. This observation, contrary to previous research (Ivey & Zegeer, 2004), altered the path of the research phases to come.

This altered path included a review of the tree crashes within Massachusetts by functional classification of roadway and the determination of the roadway functional classification with the highest tree crash rate to be studied further. Functional classification is a means by which Civil Engineers distinguish between the level of access and mobility of a road.

Available traffic information was gathered from MassHighway and the regional planning agencies whose boundaries overlap central Massachusetts, including the Montachusett Regional Planning Commission, Metropolitan Area Planning Council, Central Massachusetts Regional Planning Commission, and the Northern Middlesex Council of Governments. Using this data, tree and pole crash rates were calculated. Crash rates are a common way of comparing the number of crashes at different locations with different traffic characteristics.

MassHighway maintains a Geographic Information System (GIS) of the functional classification of roads in the Commonwealth. This GIS database was queried to produce a list of roads by functional classification. This list was cross-referenced with the list of tree crash locations to categorize the tree crashes by functional classification. Crash rates by functional classification were then calculated.

Phase 2

Upon determining that rural collectors experience the highest tree and pole crash rates (the characteristics of a representative rural collector were gathered using a combination of field measurements and publically available information with the goal to link roadway characteristics with tree and pole crash probability. The rural collector chosen was a 9.8 mile section of Route 31 in Spencer, Massachusetts. This road was chosen for its varying highway and area characteristics.

An organized method of identifying data points was utilized to allow cross-referencing and the ability to return to the same site if necessary to collect more data along this 9.8 mile route. This method included the use of a field established baseline with stations increasing in a northerly direction along the study route. Initially, stations were measured using a car’s odometer to measure 0.1 mile (121 meters) increments. Station 0+00 was established at the Town of Spencer/Town of Charlton town line for replication and synchronization with the data gathered through Civil 3D.

Data was collected at 0.1 mile segments along the 9.8 mile study roadway and at all crash locations. Field collected data included:
- Lateral offset from the edge of road to the trees and poles,
- Speed limit,
- Location of tree relative to horizontal alignment (i.e., inside or outside of curve or at point of tangency),
- Location of tree relative to the vertical alignment (i.e., at the top, middle, or bottom of the hill),
- Density of trees,
- Diameter of tree,
- Proximity to other fixed objects (e.g., guardrail), and
• Width of road.
  Data gathered using Civil 3D:
• Horizontal alignment (i.e., radius and length of curve) and
• Vertical alignment (i.e., grade).
  Lateral offset, tree diameter, proximity to other fixed objects, and the width of the road were measured using a 100-foot decimal surveyor’s tape. The measurements were taken from the edge of the traveled way to the front of the tree. The edge of the traveled way was defined as the edge of the single white line (SWL) where it existed. If there was no SWL, the front of the curb and/or the edge of the pavement (EOP) marked the edge of the traveled way. If the tree was located behind a guardrail the measurement was taken from the edge of the traveled way to the front of the guardrail (FOG) and another measurement was taken from the FOG to the front of the tree. Measurements were always taken perpendicular to the edge of the road so the minimum lateral offset was recorded.

  The tree density was calculated by counting the number of trees existing in the initial 50 foot-length of each segment, horizontally along the road. Trees located behind other trees were not counted.

  Aerial photographs and contours from Google Earth were imported to Civil 3D for gathering highway characteristics. After importing the images and surface data into Civil 3D, the horizontal alignment of the road was established by creating an alignment object along the road center line. See Figure 4 for an example of a portion of the horizontal alignment. After establishing the horizontal alignment, the existing ground surface was sampled and the existing profile was established. A portion of the existing profile is shown below in Figure 5.

  Alignment and profile data referencing the same stations as the field-gathered data was tabulated. An attempt to correlate roadway characteristics and tree/pole placement to crash frequency and severity was made during this phase using multiple linear regression models. The data collected in Phases 1 and 2 were used.

  Researchers found speed limit and vertical alignment characteristic appeared to be among the more predictive parameters for estimating the crash rate. Conversely, horizontal curvature of the road, surprisingly, was not a very useful predictive characteristic for determination of the tree crash rate.

V. Findings & Conclusion

The visual representation of crashes versus the calculation of crash rates by functional classification shows that visually representing crash data absent of traffic volumes can be misleading when considering roadways with different levels of traffic. Crash rates, a statistical representation of crash data which accounts for variations in traffic volumes, provides a more accurate representation of crash history.

  The inclusion of GIS information and Civil 3D in these research projects saved many hours of field data collection and allowed for a much more realistic representation and visualization of the data. Graduate students were able to gather necessary highway characteristics in one day for this road using Civil 3D, verses what would have taken several weeks using traditional highway survey methods.

VI. Recommendations for Future Research

While conducting this research, opportunities to further this research were identified. The prospect of creating a GIS database which calculates crash statistics such as crash rates should be considered.

  Massachusetts already has much of the information necessary in isolated databases, including a database of the functional classification of the roads,
databases of the traffic volumes, and the geographically references crash data itself.

VI. References


VII. Figures

Figure 1. Distribution of Fatal Fixed Object Crashes by Most Harmful Event (FARS, 2008).

Figure 2. Utility pole struck by Ford Explorer (TAMU, 2008).
Figure 3. Severe car collision with a utility pole (Pennlive, 2008).

Figure 4. A portion of the horizontal alignment and the aerial photographs.

Figure 5. A portion of the vertical alignment.