

### **Project Title**

Exploration of Alternative Spatio-Temporal Methods of Traffic Safety Network Screening

### **University**

South Dakota State University

### **Principal Investigators**

Michael D. Pawlovich, Ph.D., P.E.  
Assistant Professor  
South Dakota State University  
Phone: (605) 688-6936  
Email: michael.pawlovich@sdstate.edu  
ORCID: 0000-0001-9659-0348

### **Research Needs**

The roadway system represents a major investment, both public and private, and a valuable resource that enables mobility and accessibility to users (1, 2). The roadway system is comprised of streets, highways, and access points and the system should operate safely and efficiently (1, 2). Due to degradation of aging infrastructure and increasing traffic, transportation agencies are seeking to effectively update or improve the system (3, 4, 5, 6, 7). With rising costs, tight budgets, and limited land resources, agencies are seeking effective techniques for identifying critical mobility and safety concerns.

Specific to safety concerns, the Highway Safety Manual (HSM) (8) was recently (2010) published to promote a more effective and efficient application of safety analysis. The HSM process involves cyclical steps of network screening, diagnostics and countermeasures, economic appraisal, and evaluation. Though these steps are not new, the HSM is a nationally recognized consolidation of the ideas and an attempt to encourage consistent analysis stemming from increasing interest in safety and data analysis. This interest is manifested through several federal transportation bills (9, 10, 11, 12) and federal agency encouragement (13) for state agencies to increase safety data collection, analysis, and implementation.

Many network screening methods exist, since at least the 1970s and the more widespread inception of computing resources (14, 15). These methods have advantages, primarily relative simplicity and comprehensibility. These methods have several shortcomings as well, as detailed by several sources including the HSM (8, 15, 16, 17, 18, 19, 20, 21, 22). Instead, the HSM and other sources promote methods which address these shortcomings (8, 15, 16, 18, 19, 20, 21, 22, 23, 24), including Empirical Bayesian (EB) and hierarchical Bayesian (HB) methods. All the methods rely first on some manner of connecting crashes to the roadway network.

Historically, assignment of crashes to portions of the network, whether segments or intersections, has been the primary manner to connect crashes and road elements (8, 14, 15). These networks are then screened, often with additional differentiating criteria (e.g., volumes, road classification) for sites meeting certain defined thresholds to generate a list of candidate sites for further review. However, more recently with the use of Geographic Information Systems (GIS) and spatial and temporal analysis, alternative methods for connecting crashes to the roadway network have been developed (18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33). Using these tools, initial efforts were based on crash assignment to the network using a “sliding window” approach, with variations (20, 21, 23, 26, 24). Beyond that, other efforts utilized the power of GIS to analyze spatial clustering of crashes including the development of continuous risk profiles (CRP) (18, 23, 26), point pattern analysis (PPA) (25, 27, 28, 29, 30), and kernel density estimation (KDE) (27, 28, 31, 32, 33). These methods typically analyzed the spatiotemporal nature of crashes without regard to the network and then later connecting the resultant clusters to the network for further analysis of diagnostics and countermeasures. Because these methods either rely on a typology that divides the network arbitrarily or essentially ignore the network, they may not result in cohesive screening results which are directly connected to the roadway.

Instead, we intend to explore the application of GIS and spatiotemporal analysis techniques which rely on the crash locations and densities but with a coincident network connection. Rather than simply analyzing for crash clusters, our effort will examine spatial proximity constrained by network links (segments) and nodes (intersections) without regard to the typology to form individual, network-based crash distributions. Additionally, we intend to analyze these individual, network-based crash distributions for distributional clustering. Using the connection to the network, we will explore the inclusion of traffic and roadway characteristics during distribution and cluster development. The primary goal would be to explore whether this method produces a more efficient and effective means of developing roadway connected crash cluster identification results as an input to network screening and diagnostics. Beyond this, using the data linkages, we intend to explore crash typology (e.g., severity, collision type) distributions and clusters with respect to network (traffic and roadway) characteristics.

## **Research Objectives**

There exist two primary sets of research objectives related to this effort. The first set relates to the application of GIS and spatiotemporal analysis techniques relying on the crash locations and densities but with a coincident network connection. Specific goals within this set of research objectives include:

- 1) Examine spatial proximity constrained by network links (segments) and nodes (intersections) without regard to the typology to form individual, network-based crash distributions.
- 2) Analyze these individual, network-based crash distributions for distributional clustering.
- 3) Explore inclusion of network characteristics during crash distribution and cluster development.

The second set relates to the examination of these crash distributions and clusters applied to specific typologies of wide interest (34, 35, 36), including the following:

- 4) Develop and analyze crash distributions and clusters related to crash severity.
- 5) Develop and analyze crash distributions and clusters related to roadway departure crashes.
- 6) Develop and analyze crash distributions and clusters related to intersection-related crashes.

Assessment of these objectives will be based on a comparative analysis of the developed methodology against existing methodologies. Network screening rank lists from each will be compared and contrasted to identify advantages (positives) and disadvantages (negatives) of each, including verification evaluations for individual highly ranked sites.

### **Research Methods**

The research objectives will be met through execution of the work plan below. Crash, roadway geometrics, and traffic data currently readily available to the research team will be used; however, additional datasets may be used as available. The research team will familiarize themselves with the data, producing standard descriptive statistics to assess quality and reliability of the data. The research team will also explore GIS capabilities, coding options, and current methods for spatiotemporal analysis. Following this, development of processes to generate results from existing methodologies will commence simultaneous with development of the proposed methodology. The results of the rank lists from each will be compared and contrasted. Additionally, using the base developed method, crash typologies will be explored both to explore validity and applicability to network characteristics and to develop some practical examples of use. Throughout the effort, the team will seek input from transportation officials familiar with these disciplines.

### **Expected Outcomes**

The primary outcome of this research is the development of a new method of generating distributions and clusters of crashes along a roadway network for use in traffic safety screening. The development will include code to facilitate spatiotemporal analyses for application to provided network data inputs of crash, roadway geometrics, and traffic and enable crash typologies to be explored. Future research could include further refinement of the methods and both broader and extended applications of the crash typologies to explore traffic safety topics of interest. Practitioners should be able to utilize the process to develop network screening related to their jurisdictions, given sufficient and appropriate input data. Initially, the developed code will be prototypical with a future intent for broad applicability. Guidebooks or instructional manuals will initially be in the form of detailed research notes for operation of the software by the research team.

### **Relevance to Strategic Goals**

The expected outcomes of this project are directly related to the following primary goal: Safety. Traffic safety is of paramount concern to citizens and professionals that serve these citizens. However, traffic safety is one of many competing needs that vie for funds and, additionally, within solely the traffic safety area, potential problem sites compete for funds. Thus, having a method which efficiently and effectively identifies sites of most concern, directly impacts the provision of safe roadways and allocation of funds.

## **Educational Benefits**

This project will provide valuable learning opportunities for multiple graduate students related to traffic safety and data use and analysis, particularly with regard to the use of Geographic Information Systems (GIS) and statistics. Student project efforts will directly support thesis work and lead to authoring of peer-reviewed journal and conference articles. It will also provide opportunity for the students to travel to a conference to present the research and interact with future colleagues. Students enrolled in the following courses will directly benefit from this research as knowledge and findings are incorporated into the curriculum: Surveying and Geomatics (CEE 106/CEE 106L), Highway and Traffic Engineering (CEE 363), Traffic Engineering Design (CEE 467), Highway Engineering Design (CEE 492).

## **Technology Transfer**

Technology transfer will initially be in the form of web pages, seminars, and interactions with interested safety professionals as the research progresses. Additionally, journal articles and conference presentations will be produced as compelling findings are realized. The intent is to develop a prototype process which then could later be further developed into software for broader application.

## **Work Plan**

Months 1-3: Literature review. The research team will perform a literature review to document methods for network screening and spatiotemporal analyses with a specific focus on development of spatial distributions and clusters.

Months 3-4: Obtain and explore data. The research team will obtain the data and generate descriptive statistics to assess quality and reliability. Data subsets for development and validation purposes will be developed.

Month 5: Develop methodology. The research team will develop the framework of the crash distribution and clustering methodology. This framework will serve as the basis for code development.

Month 6: Explore GIS capabilities and coding options. The research team will explore GIS capabilities and coding options, specifically with regard to the data available and methodology to be developed.

Months 6-13: Develop crash distribution and clustering code. The research team will develop the code to implement the developed methodology and develop separate processes to implement existing methods for comparative purposes.

Months 13-17: Generate rank lists to compare/contrast. The research team will generate rank lists using existing and developed methodologies and compare these lists, including verification evaluations for highly ranked sites.

Months 18-21: Explore crash typologies. The research team will explore application of the developed methodology and code to specific crash typologies.

Months 22-24: Report generation. An initial report will be written for MPC in accordance with guidelines. Papers will be developed for submission to peer-reviewed journals and presentation at a national conference.

### **Project Cost**

Total Project Costs: \$144,906  
MPC Funds Requested: \$ 70,803  
Matching Funds: \$ 74,103  
Source of Matching Funds: South Dakota State University

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