Project Title:
A Comprehensive Safety Assessment Methodology for Innovative Geometric Designs

University:
Utah State University

Principal Investigators:
Ziqi Song, Ph.D.
Research Assistant Professor
Civil & Environmental Engineering
Utah State University
4110 Old Main Hill
Logan, UT 84322-4110
Phone: 435-797-9083
Email: ziqi.song@usu.edu

Anthony Chen, Ph.D. (Co-PI)
Professor (Utah State University)
Department of Civil & Environmental Engineering
4110 Old Main Hill
Logan UT 84322-4110
(435) 797-7109
Email: anthony.chen@usu.edu

Research Needs:

Innovative geometric designs are often considered as a solution to the challenge of meeting the increasing travel demands with limited recourses (FHWA, 2009). This study focuses on one such design, the diverging diamond interchange (DDI), which aims to improve traffic flow and reduce congestion at highway junctions (Schroeder et al., 2014); but the methodology proposed is transferable to other geometric designs. Utah was among the first states to consider the DDI as a viable interchange option. The state opened its first DDI at the intersection of American Fork Main Street and I-15 in August 2010. Empirical studies have demonstrated the operational and cost benefits of DDIs (Bared et al., 2006; MoDOT, 2011; UDOT 2012; Yang et al, 2014); however, the safety impact remains inconclusive. Theoretically, the DDI design offers a safety benefit because it reduces the number of conflict points in comparison to other interchange options, which can lead to fewer crashes in general. Moreover, the lower design speeds in DDIs may also result in fewer and less severe crashes. One major safety concern with DDIs is that drivers may stay to the right at the crossovers and accidentally enter the opposing lanes. Despite the theoretical safety benefits, little research has been undertaken to quantify the safety impact of DDI using real-world crash data, primarily because of the limited accident history available. A preliminary safety study (MoDOT, 2011) directly compared the crash rates before and after the
construction of a DDI in Missouri and concluded that total crashes dropped by 46% in the first year of operation. However, the simple before-and-after method assumes that any changes to the safety performance can be attributed solely to the DDI design. In reality, confounding factors that change continuously, such as traffic flow, traffic composition, and weather conditions, can also affect the safety performance. Therefore, we propose an alternative approach to deal with possible confounding factors by comparing the safety performance of DDIs with that of a group of reference sites.

In addition, most existing safety studies on novel geometric designs only investigate vehicle crashes. Nevertheless, to fully understand the overall safety impact, we also need to take pedestrian and cyclist safety into consideration. Since a DDI usually attracts more traffic to the interchange, pedestrians and cyclists may feel intimidated by this increase and they may take detours to avoid the interchange. Hence, pedestrian and cyclist crashes may migrate from the interchange to nearby intersections. As a result, we also propose to examine all crashes involving pedestrians and cyclists within a one- to three-mile radius of the interchange and comprehensively evaluate the true safety effects of DDIs.

Utah has been a pioneer and leader in adopting innovative interchange and intersection designs. Currently, the state has six operating DDIs and more are under construction or planned. Four DDIs in the state have been opened to traffic for more than two years, which provides sufficient accident data for a comprehensive safety study. This study will be one of the first independent studies in the nation to investigate the overall safety impact of DDIs. The results will be useful in evaluating DDI construction and retrofit projects in Utah as well as other states. The research is expected to have a broad and significant impact on the implementation of innovative interchange and intersection designs.

**Research Objectives:**
The proposed study will accomplish the following three objectives:
1. Conduct a comprehensive before-and-after study to assess the overall safety impact of DDIs;
2. Propose a methodology to quantify the safety effects of DDIs on different crash and road user types; and
3. Develop a generic framework for before-and-after safety studies that applies to other types of facilities in the state.

**Research Methods:**
This study is an observational evaluation study investigating the overall safety impact of innovative geometric designs. One of the most common study approaches involves a before-and-after study with a comparison group. Conventional methods, such as the simple before-and-after method, often produce questionable results (Persaud and Lyon, 2007). The most serious threat to the validity of the results of studies employing this design is lack of control of potentially confounding variables. A confounding variable is any exogenous (i.e., not influenced by the road safety measure itself) variable that affects the number of accidents or injuries and its impacts can be mixed up with impacts of the measure being evaluated (Elvik, 2002). Variables that are
commonly regarded as potentially confounding in observational before-and-after studies of road safety measures include (Hauer, 1997; Elvik, 2002):

1. Regression-to-the-mean;
2. Long term trends affecting the number of accidents or injured road users;
3. General changes of the number of accidents from before to after the road safety measure is introduced;
4. Changes in traffic volume; and
5. Any other specific events introduced at the same time as the road safety measure.

Recent developments in statistical modeling have provided us several theoretically sound methodologies to tackle the above mentioned issues, e.g., the empirical Bayes (EB) approach (Hauer, 1997; Persaud and Lyon, 2007) and the full Bayes (FB) approach (Lan et al., 2009; Persaud et al., 2010).

The major tasks to accomplish the research objectives are as follows:
1. Perform a literature review on before-and-after study methodology as well as safety studies on DDIs;
2. Identify a group of diamond interchanges that have not been converted to DDIs for comparison;
3. Collect crash and traffic flow data of both operating DDIs and the comparison group; and
4. Develop appropriate statistical models that can account for confounding factors based on data availability.

**Expected Outcomes:**
The study will provide an in-depth understanding of DDIs from the safety perspective. UDOT will be able to use the results to compare safety benefits of the DDI design to other interchange options and to justify the implementation of DDIs at future locations. The results will also help UDOT develop future geometric design policy and guidelines, and the information and recommendations can be shared with other DOTs, FHWA, and AASHTO. Additionally, the methodology developed provides a generic framework for before-and-after studies in Utah. UDOT can use the framework for safety assessments of existing and potential DDIs, as well as other innovative geometric designs, such as continuous flow intersections (CFIs) and ThrU-Turn Intersections (TTIs). The results of this study will be presented at conferences, published in professional journals.

**Relevance to Strategic Goals:**
Safety is a critical aspect of evaluating the validity of innovative geometric designs. The proposed study is directly relevant to the theme of the MPC, “transportation infrastructure and operations to support sustainable energy development and the safe movement of people and goods”, and it will also contributes to one of the strategic goals of MPC, i.e., safety.

**Educational Benefits:**
One graduate student will be involved in the research and receive training in transportation safety analysis, traffic operations, and statistics. The research results will provide fresh materials and case studies to expand the transportation curricula at USU.
Work Plan:

The proposed research will be conducted in a period of 18 months with a starting date of July 1, 2015, and an ending date of December 31, 2016. Tasks will be carried out according to the following schedule:

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Project Cost:
Total Project Costs: $80,000
MPC Funds Requested: $40,000
Matching Funds: $40,000
Source of Matching Funds: LTAP

TRB Keywords:
Innovative geometric design, alternative intersection, diverging diamond interchange, safety, before-and-after safety study.

References:


UDOT, 2012. *Diverging Diamond Interchange (DDI) Observations and Experience*, UT-12.05, Utah Department of Transportation, Salt Lake City, UT.