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Project Title

Impact of Connected Vehicle Technology on Traffic Safety under Different Highway Geometric Designs

University

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Research Needs

According to National Highway Traffic Safety Administration (NHTSA), about sixteen percent of crashes in 2016 were caused by distracted driving and almost ninety percent of crashes were results of human errors (NHTSA, 2017). To mitigate crash severity and reduce crash rate, advanced technologies such as connected vehicle (CV) have shown the great potentials on preventing human-error resulted crashes. During the past few years, CV technology has reached a level of maturity and it can be expected that CVs will soon go beyond testbeds. According to Foley’s Survey (2017), more than 20% of vehicles in transportation networks will be CVs by 2025. Using real-time data collected via vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication platforms, CV technology can greatly support many types of in-vehicle safety applications such as forward collision warning (FCW), intersection movement assist (IMA), bind spot warning (BSW), lane changing warning (LCW), do not pass warning (DNPW) and control loss warning (CLW). Hence, how CV technology can impact highway safety becomes a vital research topic and has attracted great amounts of research efforts during the past few years.

It shall also be noted that crash severity and frequency are strongly related to highway geometric features such as lane width, shoulder width, and vertical/horizontal alignment designs. Although many recent simulation experiments and testbed evaluations have shown CV’s benefits on improving safety, limited efforts have been placed on studying its safety performance under different highway designs. To address such a need, this project will firstly take Salt Lake City as the study site and try to understand the intercorrelations between crash severity/frequency and highway geometric features, based on spatial-temporal analysis of crash data. Then by mapping crash scenarios to CV technologies, our research team will further discuss which types of CV applications can help preventing crash in each scenario. In addition, grounded on a well-calibrated microscopic simulation model, this project will implement V2V and V2I communication technologies to acquire real-time vehicle trajectory data. The collected information will further be used to analyze impacts of CVs on potential crash rate and severity with three types of surrogate measures of safety: standard deviation of speed, standard deviation of headway, and potential rear-end crash rate. The results of this study will facilitate better understanding of CV safety impact and will be useful for supporting future decision-making process in terms of technology and infrastructure investment by government agencies and transportation planners.

Research Objectives

The research objectives of this project are summarized as follows:

1. Studying the intercorrelation between crash severity, frequency and highway geometric characteristics based on statistical analysis of crash data in Salt Lake City.
2. Mapping crash scenarios with CV technology applications and discussing the CV benefits on mitigating crash severity and reducing crash rate.
3. Establishing a microscopic simulation platform for supporting the implementation of various CV applications.
4. Using simulations to evaluate impact of CV technology on highway safety improvement under different highway designs by examining pre-defined safety surrogate measures.
5. Presenting the research outcomes at national level.

In summary, grounded on statistical analysis of crash data, this research will further conduct simulations to study CV safety impact under different scenarios of highway designs. The cases with different CV penetration rates will be compared with the one without CV involved for safety performance assessments. At the conclusion of this project, we will be able to ascertain whether the stated objectives have been achieved.

Research Methods

Research methods of this project are designed to study the intercorrelations between crash severity, frequency and highway geometrical features. Statistical models will be implemented to identify the most significant design factors that may impact traffic safety. In addition, our research team will develop a microscopic simulation platform that can support various CV in-vehicle safety applications and study how it can help prevent crashes caused by improper highway designs.

Using Salt Lake City crash data from Utah Department of Transportation (UDOT) and Utah Department of Public Safety (UDPS), the data analysis will be carried out with the following steps:

1. Perform spatial-temporal analysis to identify crash hotspots on Salt Lake City highway network and study the corresponding crash severity.
2. At those hotspots, use regression model and variable correlation analysis method to study the relations between safety performance and highway geometrical factors such as lane width, shoulder width, and alignment curve degrees.
3. Take additional variables such as population growth rate and social economic factors into account and examine their dynamic relationships to crash rate and severity. Specifically, we can look at both long-run and short-run relationships by using retrogressive

distributed lag (ARDL) bounds testing approach, and vector error correction model (VECM), respectively.

With understanding of highway geometric design's impact on traffic safety, the second part of this project focuses on examining whether CV technology can help reduce the corresponding crash risks. Specifically, it will involve the following activities:

1. Map each type of crashes with potential solutions offered by CV technology. For example, FCW function supported by V2V communication can help prevent rear-end crashes when improper horizontal/vertical alignment design results in short sight distance.
2. Develop microscopic simulation models to support CV technology testing. This project will adopt VISSIM platform as basis and use the VISSIM-COM interface and VB.NET for trajectory data collection and CV controls.
3. Design different simulation scenarios with respect to different lane width, shoulder width, alignment curve design, and CV penetration rate.
4. Define three types of safety surrogate measures (i.e., standard deviation of speed, standard deviation of headway, and potential rear-end crash rate) and compare the safety performance of the cases using CV technology with the one without CV in the traffic.

Expected Outcomes

At the end of this project, the research outcomes will help transportation community better understand how CV technology applications would reduce the crash severity and frequency when highway geometric design plays a key factor in affecting traffic safety. Further, this research can provide an overview of safety-related CV applications. Such information would benefit decision-makers in determining further infrastructure investment for supporting CV operations. More specifically, the expected outcomes of this research project are summarized as follows:

1. A statistical analysis report of intercorrelations between traffic safety and highway geometric features.
2. Discussions of which CV applications can help reduce crash risks under different highway designs.
3. Microscopic simulation platforms in VISSIM for supporting CV applications' experimental tests.
4. Evaluations of various CV applications on improving highway safety when improper geometric designs are the main causes of traffic crashes.

Relevance to Strategic Goals

This project aims to study the effects of highway geometric designs on traffic safety and discuss whether implementing CV technology can help reduce crash risk. Taking Salt Lake City as the study site, the outcomes of this research will offer an overview of highway safety performance and identify the crash hotspots that might be caused by improper geometric designs. This research will assist on improving public safety and reducing transportation-related fatalities and injuries. Moreover, with better understanding of CV applications' benefits on improving highway safety and reducing geometrical-related crash risks, this project would support the longterm urban planning strategic goal in terms of infrastructure investment so as to support CV technology implementations. It would foster the development of livable communities.

Educational Benefits

This project will directly fund one Ph.D. students from Department of Civil and Environmental Engineering at University of Utah. Females and students from underrepresented groups will also be encouraged to participate in the project. The student will be responsible for conducting the research activities under the supervision of the PI. He or she will also lead the writing of peer-reviewed journal and conference articles resulting from this project. The research outcomes will directly support his/her dissertation work as well. In addition, we will foster the integration of research and teaching in transportation engineering. Students enrolled in the following courses will directly benefit from this research: Transportation Engineering (CVEEN 3520), Quantitative Methods in Transportation (CVEEN 6530), Highway Designs (CVEEN 5620), Optimization in Transportation (CVEEN 5920/6920), Traffic Network Modeling (CVEEN 7545), and Transportation Planning (CVEEN 5560).

Technology Transfer

The proposed research will support the highway safety improvement plans of UDOT, UDPS, and Salt Lake County. It will also inform the long-range transportation planning of UDOT on investing CV-related infrastructures. For example, UDOT is leading an effort on operating the first-ever “non-testbed” of CV corridor in Salt Lake City, where more than 30 intersections on Redwood Rd. were installed with DSRC communication devices (Roadside Units - RSUs). Since the current application of CV corridor focuses on improving bus reliability, the expected research outcomes would further imply the benefits of implementing CV applications to address highway safety issues.

The potential audiences of this research would include traffic engineers, traffic safety agencies, transportation asset managers, transportation planners, and policy decision-makers. The following agencies, offices, and committees are those most likely to implement the research results:

- Utah Department of Transportation
- Utah Department of Public Safety
- FHWA Office of Safety and Office of Planning
- TRB Standing Committee on Safety Data, Analysis and Evaluation (ANB20), Highway Safety Performance (ANB25), Vehicle-Highway Automation (AHB30)

The research outcomes will also be published on peer-reviewed journals and conferences such as traffic injury prevention, accident analysis and prevention, ASCE journal of urban planning and development, and Transportation Research Board Annual Meeting. The PI of this project has been actively participated the activities in TRB committees and is serving as member and friend of several standing committees. The PI is also serving as editorial board member of several transportation-related journals. Research findings will be shared with those communities the PI involved on the end of this project.

Work Plan

The proposed research work will take one year to complete. Research tasks with associated work schedules are listed as follows:

- *Task 1: Crash data collection and analysis (3 months)*
  Our research team will collect the crash data from UDOT and UDPS safety database. Then statistical analysis will be placed on studying the effects of highway geometrical features on traffic safety. Each type of crashes will be further mapped with certain CV applications as solutions of crash reduction.

- *Task 2: CV simulation applications development (4 months)*
  Grounded on VISSIM platform, we will develop a set of microscopic models for supporting the simulation of various CV applications.

- *Task 3: CV Safety impact study (2 months)*
  By implementing the simulation models, we will evaluate the safety performance of selected CV applications based on the examination of three pre-defined safety surrogate measures. The simulation-based study will be carried out on scenarios with different highway geometric designs and CV penetration rates.

- *Task 4: Results analysis and discussions (2 months)*
  The safety performance of CV applications with be compared with the case without CV involved. Further discussions will be offered to prioritize CV infrastructure investment so as to mitigate crash severity and reduce crash frequency at hotspot locations.

- *Task 5: Final project report preparation (1 month)*
  All research outcomes and findings will be summarized into the final project report.

Project Cost

Total Project Costs:	$90,000
MPC Funds Requested:	$40,000
Matching Funds:	$50,000
Source of Matching Funds:	Utah Department of Transportation

References

National Highway Traffic Safety Administration, (2017), 2016 Fatal Motor Vehicle Crashes: Overview. Report No. DOT HS 812 456, US Department of Transportation, Washington D.C.

Foley & Lardner LLP, (2017), 2017 Connected & Autonomous Vehicle Survey. Access at https://www.foley.com/files/uploads/2017-Connected-Cars-Survey-Report.pdf