Project Title

Safety Support System for Highway-Rail Grade Crossing

University

North Dakota State University

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Research Needs

Highway-rail grade crossing safety (and the prevention of accidents) is a priority in terms of both highway and railroad safety. Highway-rail crossing accidents often cause severe impacts in terms of fatalities, personal injuries and property damage. The damage cost and disruption to both roads and railroads are often significant (Evans, A. W., 2011; Salmon, Paul M., 2013). In 2014, there were 1,873 crashes reported at highway-rail crossings across the U.S., and those accidents resulted 239 deaths and 703 injuries (Federal Railroad Administration (DRA), 2015). Concerns about crashes at highway-rail crossings have increased for different agencies because it is commonly agreed that both highway and rail traffic levels increase the occurrence and severity of accidents (Hu, Shou-Ren, Li, Chin-Shang, and Chi-Kang Lee, 2010; Austin, Ross D, and Jodi L. Carson, 2002). In results, increasing highway and rail traffic poses a greater risk of crashes at those crossings (Zhang, Yunlong, Xie, Yuanchang, and Linhua Li. 2012). There are many studies focus on accident/ severity prediction, and accident/severity influencing factors identifications (Konur, Dincer, Golias, Mihalis M., and Brandon Darks, 2013; Oh, Juntaek, Washington, Simon P., and Doohee Nam, 2006; Ogden, Brent D. and et al.2007; Eluru Naveen and et al, 2012). These studies agree that highway traffic crossing protection devices, rail traffic, and train speed have positive effects on HRCs' accident rates and on crash severity. All of these studies shed light on understanding HRC accidents and provide foundation support for resource allocation for upgrading HRCs safety performance which is critical for the ultimate goal of "zero tolerance" for rail-related accidents/incidents established by FRA. However, to aggregate the

knowledge of crash frequency and crash severity likelihood into the crossing safety performance measurement is under researched. Moreover, little research has been conducted focusing on resource allocation for HRCs safety improvement by taking both hazard and improvement effectiveness into account, despite the importance of the issue (Konur, Dincer, Golias, Mihalis M., and Brandon Darks 2013).

Research Objectives

1. Prepare data for the safety support system development including digitizing
2. Develop forecasting models to estimate crash and severity likelihood
3. Develop algorithms to calculate aggregate hazard measurement index
4. Conduct countermeasure effectiveness analysis
5. Optimization model to help decision maker to select right countermeasure and right crossings

A systematic method for identifying and ranking crossings for safety or operational improvement is necessary for an explicit decision making process to improve HRGC. The most common approaches to identify the crossings for safety improvement is the hazard index technique. A hazard index is utilized to calculate a value that ranks crossing in relative terms with a higher index associated with a more hazardous crossing while evaluating mainly on fixed effects of traffic exposure factors, travel speed factors, and accident history. Few existing formula also looked at train tracks and lane count factor. Protection factors. None of the existing formulae takes into consideration of both crash frequency estimates and the severity of crashes. Moreover, the existing hazard index approach could not truly identify the most dangerous crossing with limited site indicator factors and could not identify the crossings, which will benefit the most from available improvement activities. In other words, few research aggregate frequency and severity forecasts to estimate crossing hazard. Even with the aggregated hazard measure, hazard alone cannot help decision maker to allocate resources effectively and efficiently. To understand how effective each engineering countermeasure to improve safety performance and reduce hazard at grade crossings is very critical for safety improvement decision-making. Therefore, analyze the potential effectiveness of crossing devices treatments based on specific attributes of each crossing is another critical research focus of the study.

Research Methods

With consideration given to data size and needs for local RGC crash analysis for North Dakota (ND), data for this investigation was extracted from public RGC for ND. Data to support the research came from four resources: (1) the FRA's Office of Safety accident/incident database (2) the FRA's Office of Safety highway-rail crossing inventory (3) countermeasure installation profile from ND DOT and (4) digitized data collected by Amin Keramati, a PhD student of North Dakota State University. A new data set was generated by using the highway-rail grade crossing identification number in all datasets to include data elements in all datasets for each crossing such as highway-rail crossing location, traffic conditions, other geometric factors, accident history, accident-related information, roadway offsets/curves, crossing proximity to nearby intersection and crossing, and countermeasure upgrade information.

Non-parametric algorithms will be looked at for forecasting models such as decision tree algorithms. Decision tree is a hierarchical tree-based prediction model. Generally, development

of a decision tree involves three steps. The first step is tree growth. At the beginning, all data concentrates in the root node. Then, the dataset is broken down into child nodes by applying a series of splitting variables (splitters). Each child node will be treated as parent node for a further splitting. The principle behind splitting is to ensure each child node is as homogeneous as possible after splitting (Zheng, Lu, and Tolliver, 2016). The ID3 algorithm measures entropy, expected entropy, and information gain to decide if a variable should be chosen as the splitter and whether the node can be further split or not (Seyed, 2015). Entropy measures the amount of unpredictability in an event. The higher the entropy value, the harder it is to predict the outcome of an event. If a sample is completely homogeneous, the entropy value is zero. Moreover, traditional statistical methods will be selected for countermeasure effectiveness analysis and optimization models will be developed for decision making process.

Expected Outcomes

The expected outcomes will be educational benefits, workforce development, and technology transfer to advance the state of the art of the railroad industry. Towards the educational benefits and work force development, this project will include one PhD student: Amin Keramati. The student will invent and explore the impacts of different methods of crash frequency forecasting, crash severity forecasting, marginal effect analysis, countermeasure effectiveness analysis and optimization decision-makings. The broader educational benefits will be knowledge products and tools that feed into curricula development and laboratories in rail transportation system.

Towards the technology transfer, the research team will utilize the research methods developed and the system solution to prepare publications and outreach material that would encourage further adoption and further development to refine the technology for deployment. Other methods of technology transfer will include journal papers, conference presentations, project reports, and other outreach materials. All publications will acknowledge this award. The PIs will notify the progress-reporting system (PPPR) of any publications generated from this project, as well as technology transfer activities.

Relevance to Strategic Goals

Transportation Safety – Developed modules and knowledge will directly enhance transportation safety improvement for highway-rail grade crossings. Students trained will be prepared to enter a workforce that to enhance railroad safety.

State of Good Repair – The safety-improvement decision support system intend to help decision makers to allocate their infrastructure improvement funding effectively and efficiently.

Educational Benefits

As noted in the expected outcomes, a PhD student will work with the PIs to conduct research that he will incorporate into journal papers and his PhD dissertation. The PIs intend to incorporate knowledge and models from this research into curricula focused on rail transportation system.

Tech Transfer

As noted in the expected outcomes, the research team will utilize the project findings and models to prepare publications and outreach material that would encourage further adoption in the real world. The team will utilize traditional methods such as journal papers, conference presentations,

project reports, and other outreach materials. In addition, the team will engage railroad representatives throughout the project to provide guidance and to achieve buy-in. All publications will acknowledge this award. The PIs will notify the progress-reporting system (PPPR) of any publications generated from this project, as well as technology transfer activities.

Work Plan

Task 1: Literature review (Jan. 2018 – May 2018)

- A complete national literature review will be conducted will cover journal articles and government reports

Task 2: Data preparation (Jan. 2018 – Jul. 2018)

- Public available data will be downloaded and cleaned
- Collect data profile from NDDOT and digitize and clean them into the format that can be used for research
- Digitize all the data points to the GIS on their correct locations and calculate related distances and angles for each crossing
- Integrate data into one complete data format

Task 3: Forecasting module development (Aug. 2018 – Jul. 2019)

- Crash frequency forecasting model development
- Crash severity forecasting model development
- Marginal effectiveness analysis for both types of models
- Integrated hazard estimation model development
- Develop journal papers

Task 4: Counter measure effectiveness analysis (Aug. 2019 – Dec. 2019)

- Counter measure effectiveness significant test
- Counter measure effectiveness analysis in terms to reduce hazard index
- Develop journal papers

Task 5: Crossing ranking module development(Jan. 2020 – Aug. 2020)

Task 6: Optimization decision module development (Sept. 2020 – Jan. 2021)

- Optimization decision model development
- Sensitivity analysis
- Journal paper development

Task 7: Develop final research full report (Dec. 2020 – Jan. 2021)

Project Cost:
Total Project Costs: $150,336
MPC Funds Requested: $ 75,168
Matching Funds: $ 75,168
Source of Matching Funds: NDSU/UGPTI/TL

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