## SPR 4218: Performance of Right-turn lane designs at intersections

## Focus Group: Traffic, Mobility and Safety (TMS)

## INDOT Primary Contacts:

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## Background & Problem Statement:

Intersection-related crashes are one of the main contributor to total crashes. In 2014, intersection-related crashes contributed to 47% and 28% of all crashes and fatal crashes in the US, as reported by the National Highway Traffic Safety Administration (NHTSA). Within Indiana, they contributed to 33% of total crashes and 28% of fatal crashes (INDOT 2014). In addition, the Federal Highway Administration (FHWA) estimated the annual economic and societal costs of intersection-related crashes were close to $50 billion (FHWA 2015).

Although intersection-related crashes are in general reducing annually, the decrease is modest. Different intersections based on their design, traffic volume and location have varying levels of crash risk. Therefore, engineers and researchers have been looking for alternative ways to improve the safety and operations at intersections. Researches commonly focus on examining the relationships of the intersections’ geometry designs and types of crashes. A recent concern is safety impacts at intersections with right-turn lanes. Right turn lanes provide space for deceleration and storage for right turning vehicles. Since they separate the turning movements from through traffic they have been known to improve safety and operations at intersections. Depending on the traffic control methods and design elements used, right-turn lanes can be designed in different forms. However, each form has its own advantages and disadvantages. Constructing appropriate right-turn lanes will improve traffic safety, increase travel speed, reduce delay, and reduce congestion.

Numerous districts have realized that large yield controlled, channelized right-turn lanes often have high crash rates.  The problem appears to be that driver expectancy varies between the vehicles that yield, and those following.   Also, the driver yielding must turn to check oncoming traffic almost 180 degrees behind them.  Additionally, it has been discovered that right-turn lanes may actually be contributing to higher crash rates due to blocking visibility of approaching vehicles in the adjacent through lanes. Figure 1 and Figure 2 show these issues and highlight the design issues at SR-43 and US 40 respectively.

Some states have explored the issue of safety of right turn lanes. Georgia, Illinois and Texas are primary examples where crashes at intersections with right turn lanes were analyzed (Fitzpatrick, K., Schneider IV, W., & Park, E. (2006)). Illinois Department of Transportation has implemented a modification to the right-turn lanes approaches to improve the line of sight of the right-turning passenger vehicles in the Peoria area. The analysis of data of three years before (i.e. 2003) and three years after (i.e. 2016) the modification of right-turn lane designs provide insights of safety impacts. As such, the results reveal a statistically significantly reduction for both younger and older driver right-turn crashes at 66% and 70%, respectively. In addition, these experiments provide a set of modification factors for the right-turn lane designs which are a good reference to extend the experiment to other areas.

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| **Figure 1** |

Within Indiana, there are multiple intersections which have high crash rates. Figure 1 is an example located on SR-43 at the northbound I-65 off ramp, in Tippecanoe County. This intersection had 66 WB to NB Right Turn Rear End crashes in a 3-year period (7/1/2012 to 6/30/2015).

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| **Figure 2** |

Figure 2 is an example located at the eastern intersection of US-40 with SR-267/Quaker Blvd, in the Town of Plainfield. It includes an EB right turn lane to SB SR-267/Quaker Blvd. There were 17 NB to EB Right Turn Rear End crashes in a 3-year period from 2013-2015, and there were 10 EB to SB Right Turn Rear End crashes in a 3-year period from 2013-2015.

Therefore, to figure out the design configurations that result in higher crash rates, there is a need to evaluate the safety and operations at right-turn lanes.

There are various factors that influence on the decision on whether right-turn lanes should be used, and if yes, which right-turn lane design should designers follow. A systematic analysis of the safety issues related to right turn lanes is critical to understand: (1) current limitations; (2) identify factors that contribute to crashes at these intersections and (3) provide recommendations for design. Currently, the INDOT does not have the guidelines for use of alternative turn-right lane designs. It is critical to have guidelines for designers so they can quickly narrow down options for consideration. A tool is needed to diagnose high crash intersections and provide recommendations to improve safety.

The objective of the proposed research project is to (1) collect data from INDOT and conduct data analysis of the crashes at right turn lanes; (2) identify factors that contribute to the crashes at right turn lanes; (3) identify geometric design variables that correlate with right turn crashes and (4) provide recommendations to mitigate crashes and develop guidelines for use of alternative intersection designs, to improve safety. The guidelines are suggested based on the combination of performance measures obtained from the data at candidate intersections and analysis that will be conducted.

**Proposed Scope of Work**:

This study is divided into seven tasks. Task 1 primarily focuses on synthesis of existing body of knowledge and best practice about right-turn lane. Based on the findings in Task 1, a report will be submitted to INDOT. A presentation will be given in the SAC meeting and input will be obtained from the SAC on finalizing candidate intersections for the next tasks. Data will be obtained from INDOT for the candidate intersections and analysis and recommendations will be based on the modeling.

**Task 1: Studying Literature and best Practice**

The existing literature on intersections with free right-turn lanes and islands will be studied. Best practices will be gathered from other states, and local governments. The data requirements and design practices will be summarized in a document.

**Task 2: Selecting the candidate intersections**

The focus of this study is on all situations with existing right turn lanes intersections. Based on the input from the SAC, candidate intersections will be selected so that a diversity of right turn lane intersections can be considered in the analysis. Different right turn lanes including right turn lane with lane pavement marking, shared lane with island, channelized right turn lane, right turn lane with island and dedicated downstream lane will be considered. In addition intersections at interstate ramps, local roadways and state road intersections. Medium to high volume intersections will be selected as candidate locations. The number of intersections will be decided based on discussions with the SAC.

**Task 3: Data Gathering and Cleaning**

The data will be obtained from INDOT for the candidate intersections. The data will be verified for any errors and clean to make sure there are no redundant information, no missing information and all intersections have variables that will be considered in the analysis. This include the right turn lane length, width, turning radius, downstream lane width, corner radius, island dimensions when present, island size, acceleration lane etc. At the end of this task, the research team will deliver a clean dataset that will be used in the future tasks.

**Task 4: Statistical Modeling and Analysis**

We will utilize advanced statistical models to develop models that determine the factors that correlate with crashes at the right turn lane intersections. In the models, the factors, which are generally considered by designers for the right-turn lane designs including the design variables of the right turn lane, presence of an island, presence of a dedicated downstream lane, line of sight will be considered. Then, the set of variables which are related to the safety performance will be identified. The models will clearly show which variables – design, traffic flow, time of day, environmental variables impact the safety at the right turn lanes.

**Task 5: Recommendations for Intersection Safety and Design**

Based on the developed quantitative safety effectiveness measures, guidelines for design improvements involving alternative right-turn lane designs will be developed. The project team will recommend the measures that should be taken from a design stand point and from traffic control perspective to reduce the crashes at right turn lane intersections. These recommendations will be provided in a document that will be useful reference for INDOT engineers for design of new intersections or redesign of existing intersections

**Task 6: Final Report**

A final report will be developed that documents the data collection, data modeling and analysis of right turn lane crashes. In addition, key recommendations to improve the intersection safety at right turn lanes will be provided in the final report.

**Team Qualifications**

The Purdue research team has significant expertise in conducting research on safety research, traffic operations and planning especially in impacts assessment, pedestrian safety modeling at intersections and network level and developing guidelines for traffic operations and planning. Furthermore, the team has access to various data sources from the federal level that will allow them to test different questions of interest to INDOT. More importantly, the team members are able to keep abreast of the most recent developments in data collection and analysis and methods pertinent to this study, through their academic activities.

Dr. Satish Ukkusuri, Professor of Civil Engineering at Purdue University, will lead the project. Dr. Ukkusuri has extensive experience with intelligent transportation systems, safety modeling, connected/autonomous vehicle research, transportation planning, operations and logistics based on his work in the last 15 years. He has worked on pedestrian safety modeling both at the facility level and intersection level and his published work in this area is widely cited at Transportation Research Board and other venues. He has worked on large-scale simulation of dynamic speed limits, signal coordination and congestion impacts by developing new traffic modeling tools that capture a mixed CV environment. He has worked on transportation projects valued at more than $13 million in the last 12 years with various public and private agencies to solve important transportation issues. He has international transportation experience where his research has been used in countries such as China and Colombia. He has published more than 220 peer reviewed journal and conference publications.

INDOT Benefits and Implementation Potential:

INDOT will have significant benefits from this study by implementing this project.

(1) *A list of right-turn lane design alternatives*. A list of right turn lane design alternatives and key factors that correlated with crashes will be provided. The key factors help to select which right-turn lane should be used.

(2) *Guidelines that will serve as a tool to utilize at high crash intersections*. Decision making at right turn intersections with islands is complex. We will develop guidelines that facilitate the identification of high risk intersections, guidelines for data collection and analysis and design guidelines to improve the safety. This guidelines will facilitate the process of analyzing them internally, and summarizing a set of alternatives that guide INDOT's decisions on selection of right-turn lane designs. INDOT engineers can use these guidelines at the design stage and construction stage for new intersections and possibly redesign existing intersections. A hardcopy with clear guidance will be provided.

Implementation Impact on Priority Areas: (select the primary priority area implementation of this project will impact)

***Describe the expected benefits of the research results in the following table and rank\*order the benefits in order of importance (with 1 being the most important).***

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| **Rank** | **BENEFITS** | | **DESCRIPTION OF BENEFIT** |
| **1** | **Cost Savings (avoidance and revenue enhancement)** | | |
|  | *(such as: construction costs, material costs, early project completion, in-house labor and equipment costs, improve design to avoid over design, permit fees, direct revenues, etc.)* |  |
| **2** | **Safety** | | |
| **1** | *(such as: crash mitigation, reducing truck and vehicles conflicts, reducing INDOT’s tort exposure, etc.)* | Reduction in crashes, and meeting driver expectancy. |
| **3** | **Mobility/Reduced Congestion** | | |
|  | *(such as: travel time reliability, customer satisfaction in travel times, congestion relieve, ride quality, maintaining speed limit in construction zones, etc.)* |  |
| **4** | **Quality** | | |
| **2** | *(such as: improved processes/procedures, asset preservation, improved design, updated specifications, extends the life of infrastructure, etc.)* | Future intersection designs will be improved. |
| **0** | **Time Savings** | | |
|  | *(such as: improve construction scheduling, early project completion, quicker maintenance or rehabilitation, etc.)* |  |
| **0** | **Other (other tangible and intangible benefits)** | | |
|  | *(such as: employee development/training, economic development, proof of concept, etc.)* |  |

***\* If there is no benefit in a particular category rank that category as 0.***

**References**

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