SWZDI
Smart Work Zone Deployment Initiative

Assessing Driver Behavior at Back of Queues: Implications for Queue Warning System in Work Zones

tech transfer summary

The project studied queue warning systems, their implementation in states, and their effectiveness as well as driver behaviors to offer effective countermeasures to reduce back-of-queue conflicts in work zones.

Objectives

- Identify common types of queue warning systems (QWSs)
- Summarize QWSs used in Smart Work Zone Deployment Initiative (SWZDI) states
- Identify driver behaviors in back-of-queue (BOQ) scenarios
- Make recommendations
- Summarize needs for connected vehicle applications

Problem Statement

QWSs may not be as well targeted to high-risk drivers and are not geared to address some of the behaviors that contribute to BOQ crashes. Thus, one of the main needs to address BOQ situations is to understand what drivers are doing so that QWSs can get a driver's attention. Additionally, driver behavior may indicate that other countermeasures, such as speed management, may be as effective as formal QWSs.

Background

Rear-end crashes are one of the primary crash types in work zones and frequently occur at the BOQ. Some agencies have utilized BOQ warning systems, where real-time sensors are located upstream of stopped or slowed traffic, either to actually detect BOQs or monitor conditions to predict BOQ locations. QWSs then provide notifications of traffic conditions to drivers, which ideally lead to lower speeds and drivers being prepared to react to the BOQ, resulting in fewer crashes and conflicts.

Drivers encounter a work zone BOQ scenario

July 2020

RESEARCH PROJECT TITLE
An Intelligent Video-Based End of Queue Warning System for Work Zones

SPONSORS
Smart Work Zone Deployment Initiative (Part of TPF-5(295))
Federal Highway Administration
(InTrans Project 19-686)

PRINCIPAL INVESTIGATOR
Shauna Hallmark, Director
Institute for Transportation
Iowa State University
515-294-5249 / shallmar@iastate.edu

CO-PRINCIPAL INVESTIGATOR
Anuj Sharma, Research Scientist
Center for Transportation Research and Education, Iowa State University

MORE INFORMATION
intrans.iastate.edu

SWZDI, InTrans, and CTRE
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

Iowa, Kansas, Missouri, and Nebraska created the Midwest States Smart Work Zone Deployment Initiative (SWZDI) in 1999 and Wisconsin joined in 2001. Through this pooled-fund study, researchers investigate better ways of controlling traffic through work zones. Their goal is to improve the safety and efficiency of traffic operations and highway work. The mission of the Institute for Transportation (InTrans) and Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

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QWSs have been noted as effective; however, a driver needs to be properly monitoring the roadway environment to receive the warning and, then, needs to be prepared to take the appropriate actions when necessary. This includes being alert and slowing to a manageable speed. In many cases, drivers are distracted and fail to recognize warnings. In other cases, drivers receive the warning but fail to comply with appropriate speeds.

Project Description

The researchers analyzed BOQ safety critical events (SCEs)—i.e., crashes, near-crashes, or conflicts—to further evaluate which driver behaviors contribute to BOQ conflicts. Two different datasets were utilized:

- BOQ SCEs that were reduced from camera image captures at BOQ locations in work zones in Iowa during the 2019 construction season: Potential SCEs were monitored, and near-crashes or conflicts were manually coded. A total of 68 SCEs were identified and analyzed.
- BOQ events in the second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS): BOQ events including 46 SCEs and 283 normal events, which were used as controls, were identified. Driver behaviors were coded, and type of work zone, roadway type, and type of barrier present were reduced from the forward roadway video. Vehicle speeds were extracted from the time series data, and following behavior in the queue was also noted.

A mixed-effect logistic regression model was developed with probability of a near-crash as the response variable. The best-fit model included glance behavior, following behavior, and average speed.

Key Findings

Iowa Data

- Analysis of these data indicated speeding, following too closely, and forced merges were the primary characteristics associated with BOQ SCEs.
- Almost 40% of drivers who were engaged in an SCE (27 of 68 events) were traveling at a speed that was determined to be too fast for the conditions.
- Drivers involved in an SCE were more likely to be following closely (54%). Following closely was subjectively defined as less than 1 second between the subject vehicle and lead vehicle. Following was defined as approximately 2 seconds between vehicles and accounted for 36.8% of drivers involved in an SCE; drivers who were not following closely made up 8.8% of SCEs.
- In almost 9% of cases, a forced merge occurred, which contributed to the SCE.

SHRP2 NDS Data

- Analysis of these data indicated that following too closely and glances away from the roadway task of 1 or more seconds were statistically significant.

Model Findings

- The odds of being involved in a BOQ SCE is 3.8 times more likely if the driver was engaged in a glance away from the roadway task of 1 or more seconds ($p = 0.0147$). This includes any type of glance away from the roadway task including distractions.
- When a driver is following closely (< 2 seconds), they are 2.91 times more likely to be involved in an SCE ($p = 0.0568$) than when not following closely.
- The average speed of the subject driver was also significant, but the analysis showed drivers were more likely to be involved in an SCE at lower speeds than at higher speeds, which was likely due to most BOQ SCEs occurring during traffic congestion.
- While speed was included in the model, the effects of speeding could not be determined.

Recommendations

- **Speed management countermeasures.** QWSs are likely to be effective for speeding. Other countermeasures, such as dynamic speed feedback signs (DSFSs), also may be effective when combined with QWSs. Enforcement may also be a strategy to reduce speeds in queue areas in work zones.
- **Wayfinding application (app) messages.** Several wayfinding apps have the potential to provide in-vehicle messaging to drivers, which could assist in alerting drivers about the upcoming presence of work zone BOQs. This may be particularly helpful for distracted and inattentive drivers who may not notice on-road messaging. Protocols for providing messages about upcoming BOQ events could be developed using existing tools, and messages could also be tailored to high-risk drivers.
- **Tailgating countermeasures.** Following closely has been noted as one of the main contributors to BOQ events; however, other solutions such as speed management or in-vehicle notifications are not geared to address tailgating. No specific solutions were found to address tailgating besides enforcement.

- **Addressing distraction.** QWSs are less likely to be effective for distracted drivers who may not be paying attention to work zone traffic control. One strategy to address both speeding and distracted drivers is use of portable rumble strips, which have been shown to be effective in conjunction with QWSs; however, it may be difficult to pinpoint a distinct BOQ point to place the devices, and they may not be appropriate for all roadway types. Additionally, a simplistic analysis of the data indicated drivers who were involved in SCEs were twice as likely to be engaged in some cell phone task. Thus, the study found evidence to reinforce laws prohibiting cell phones in work zones.

Recommendations for Future Research

- Further evaluate the effectiveness of DSFSs in conjunction with QWSs
- Identify other audible attenuator countermeasures that may target distracted drivers
- Develop Iowa-specific crash modification factors for QWSs

QWSs in a Connected Vehicles Environment

Connected vehicles have the potential to greatly improve system ability to detect slowed and stopped traffic. Additionally, relay of queue messaging can be delivered through in-vehicle systems rather than relying solely on changeable message systems (CMSs) or other static warnings. However, until a sufficient number of connected vehicles are in use on roadways, developing and maintaining a system that accommodates both regular and connected vehicles may be resource-intensive compared to the benefit.

Another application for connected vehicles is delivering targeted messages about upcoming work zones. Most agencies already monitor traffic conditions including work zones. Information about BOQ situations, crashes, and other work zone information can be conveyed to connected vehicles through basic safety messages.

Implementation Readiness and Benefits

The results of this research confirmed that speed, following too closely, forced merges, and inattention were major contributors to BOQ incidents, and the research offers countermeasures in addition to QWSs to address driver behaviors associated with SCEs in work zones.