Traffic Management Systems Actively Managing the Display of Queue Warning Messages

Congested travel conditions on freeway facilities present significant safety concerns—particularly with their increased potential for rear-end collisions. Such conditions typically result in unexpected shock waves of unstable traffic flow propagating upstream of incidents, bottlenecks, or other restrictions. Recurring congestion may occur due to bottlenecks or roadway geometry (e.g., heavily used offramps, merge areas with heavy onramp traffic volumes, or reductions in number of lanes), while nonrecurring or unexpected congestion may result from a crash or the existence of a work zone. Traffic management systems (TMSs) can be used to generate and display warning messages that alert travelers to congested traffic conditions before travelers encounter unexpected or unstable traffic flow conditions or stopped or queued vehicles.

TMSs displaying queue warnings and other kinds of messages such as recommended or changed speed limits alert drivers to decrease the likelihood of their having to take actions such as hard braking, abrupt lane changes, or running off the road to prevent rear-end collisions. The capabilities a TMS needs for displaying warning messages associated with areas of unstable traffic flow may include assets to monitor current travel conditions and the ability to analyze data collected about travel conditions, detect the presence of unstable flows and queues, select an appropriate warning message, and identify the changeable message signs (CMSs) on which to post the messages. Important resource issues that agencies should consider so that their TMSs actively manage and display queue warning messages include the need for additional assets to monitor conditions during which queues may form, the ability to analyze traffic data and recommend warning messages to post, and staff to supervise, verify, or override recommended warning messages.

DESIRED OUTCOMES

- Manage traffic actively and display messages alerting drivers of changing conditions and circumstances.

- Improve safety by reducing the potential for and number of crashes due to drivers' encountering unexpected slowed, queued, or stopped traffic on freeways.

- Complement other operational strategies used in the management of traffic and improve the safety of travelers encountering work zones.

- Supplement other traffic management operational strategies such as lane-use control, part-time shoulder use, and variable speed limits to improve safety and mobility on roadways. TMSs monitor traffic conditions and display queue warning messages.

KEY ISSUES TO CONSIDER

- Identification of areas with potential for crashes due to unstable or stopped traffic.

- Sufficient capabilities of a TMS to detect and verify traffic conditions that warrant display of queue warning messages to alert drivers and mitigate safety risks.

- Sources of data used to detect unstable or queued traffic.

- TMSs with capability (e.g., via algorithms and selection logic) to determine the appropriate message to display to alert drivers to unexpected conditions.

- Operation of the TMS to display queue warning messages as conditions warrant.

- Policies, procedures, and staff resources to support the active management and display of queue warning and other messages.

BENEFITS

- An evaluation estimated that the display of queue warning messages on Interstate 94 (I–94) westbound near I–35W in Minneapolis decreased crashes by 56 percent and near crashes by 69 percent.[1] Minnesota DOT (MnDOT) says the benefits may be overstated, because the results pertain only to a specific crash type for a specific time period.

- Pennsylvania DOT (PennDOT) determined that the display of queue warning messages with work zones along a 40-mi stretch of I–78 decreased crashes by 12 percent and the number of injury and fatal crashes by 23 percent.[1]

- Texas DOT found that the display of queue warning messages, coupled with portable transverse rumble strips, upstream of nighttime work-zone lane closures during the widening of I–35 in Central Texas reduced crashes by 44 percent compared with not displaying them.[2]

  Note: Agencies appear to accept the inherent safety benefits of reduced crashes that queue warning provides for relatively small investment. In part because it is usually not deployed as a standalone strategy, few benefits are reported on display of queue warning messages alone. Also, because queue warnings are relatively inexpensive to add on, distinguishing the benefits of displaying queue warnings versus other strategies that are implemented in the same area is difficult and offers agencies little incentive to measure the results and benefits.

LESSONS LEARNED

- Many state DOTs have successfully deployed the use of queue warning messages in work zones and along freeway corridors.

- The display of queue warning messages does not add significant costs to managing and operating TMSs, which use existing assets to display queue warning messages on permanent or portable CMSs.

- The most common sources of data to detect unstable traffic flow or queues are sensors, third-party sources, and crowdsourcing such as via mobile device applications.

- The display of queue warning messages typically does not increase the number of operators managing and operating a TMS.

- The display of queue warning messages is highly automated, with operators generally performing in supervisory roles as a part of their regular duties to monitor roadway systems.

- An agency may need staff or contractor support to integrate field devices deployed to monitor traffic conditions in select work zones and display messages in an agency's TMS to monitor traffic conditions.

- The display of queue warning messages enhances the effectiveness of other operational strategies by providing a rationale related to downstream traffic conditions (slowed or stopped traffic).[2]

EVALUATING TMSs DISPLAYING QUEUE WARNING MESSAGES

- Determine the extent to which the display of queue warning messages uses elements of an existing TMS. The decision may be affected by the type of traffic condition that causes unstable or stopped traffic, such as a work zone or permanent bottleneck. Agencies should evaluate existing coverage of TMS assets needed to monitor traffic conditions, considering sensor type, spacing or granularity, and ability to distinguish among lanes of traffic. Similarly, agencies should assess the availability and locations of permanent or portable CMSs to display needed messages.

- Determine type and source of data from among infrastructure or sensor data, probe or third party traffic data, and connected vehicle data to collect and use for monitoring traffic conditions.

- Determine the analytic requirements for display of queue warning messages, including an algorithm to analyze traffic conditions, detect a queue, and select appropriate messages. Agencies may require additional software incorporated into their TMSs' operating systems to manage the process, along with business rules that accommodate other traffic management functions and TMC operator supervision.

- Identify TMC operator duties. These generally supervisory duties may include confirming queue conditions to ensure a trigger is not a false positive, confirming queue message posting, or overriding a message if a more urgent or alternative event needs to be communicated.

[1]McNary, R. 2023. "Vehicle Probe Data-Driven Queue Protection System."
 Presented at the 2023 Transportation Engineering and Safety Conference, State College, PA.
[2]Palmer, S., and J. Foley. 2018. "US 23 FlexRoute." Presentation. Michigan DOT, University Region Traffic Safety & Operations.

CURRENT PRACTICES

MnDOT

- Developed and deployed TMS assets to display queue warning messages along I–35W southbound approaching Highway 62 and at two locations along I–94 westbound near I–35W. The I–94 locations used traffic speed and distance between vehicles in an algorithm that identifies unstable traffic conditions and predicts potential crashes to determine whether a message should be displayed at specific locations. The software interface for TMC operators enabled the operator to change the messages or the time displayed to avoid messages' being displayed for longer than necessary and risk drivers' not acting in response to messages.[1]

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FIGURE 1. Photo. Full color overhead sign with queue warning message in St. Paul, Minnesota.

- Displays queue warning messages at one location as of late 2024: Highway 52 northbound approaching the Lafayette Bridge, which crosses the Mississippi River into downtown St. Paul (figure 1). An overhead CMS suggests lane assignments and displays a "STOPPED TRAFFIC AHEAD" queue warning message based on downstream speed data in each lane. TMC operator time to provide oversight of message posting is incidental to normal duties to monitor traffic conditions and manage the TMS.

- Includes queue warning as a standard message displayed with work zones. Operators use existing CMSs or portable CMSs to display a "STOPPED TRAFFIC AHEAD" message in advance of select work zones when certain average speed thresholds get met. These applications are managed through a TMC's TMS software.[3]

PennDOT

- Considers the display of queue warning messages when concerns arise about recurring or nonrecurring traffic queues leading to crashes. As of early 2024, PennDOT displays queue warning messages along nearly 30 corridors.

- Says most applications are for corridors that experience queuing conditions on a temporary basis due to work zones.

- Uses vehicle probe data rather than traditional traffic detection equipment to detect the presence and location of a queue. The agency refers to such corridors as "Vehicle Probe Data Driven Queue Protection Corridors."[3]

- Displays queue warning messages along the 12-mi I–76 managed corridor in Montgomery County. The corridor includes other traffic management operational strategies like variable speed limits. PennDOT is designing several other TMS upgrades to display queue warning messages along other corridors as part of larger freeway management upgrades in the Philadelphia and Pittsburgh regions. PennDOT collects traffic data along those corridors by using remote traffic microwave sensors along with vehicle probes.

- Observes that a TMC operator's role is mostly supervisory and incorporated into duties to monitor traffic conditions and alerts and facilitate traffic management decisions and incident and event responses.

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[3]McNary, R. 2023. "Vehicle Probe Data-Driven Queue Protection System."
Presented at the 2023 Transportation Engineering and Safety Conference, State College, PA.

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- Displays queue warning messages regularly in advance of work zones on freeways and ramps.

- Requires assets used to manage and monitor traffic affected by work zones to be integrated with TMS.

- Uses TMS assets to support monitoring traffic and displaying messages in advance of work zones that include both portable and permanent dynamic message signs if available, detectors, and cameras (figure 2).

- Displays messages depending on speed thresholds— typically, 45 mph for a slowdown and 35 mph for stopped traffic ahead.

- Reports no increase in staffing attributable to monitoring travel conditions and displaying queue warning messages, because procedures are no different from those for verifying detected incidents and coordinating responses.
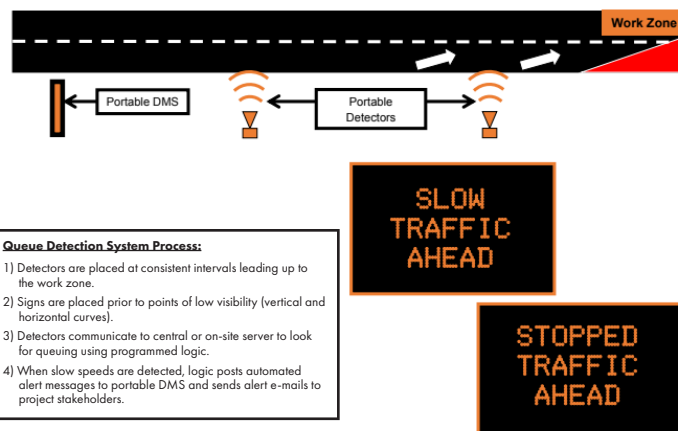
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FIGURE 2. Diagram. Iowa DOT work zone queue warning schematic.

REFERENCES

1. Hourdos, J., and J. Robbennolt. 2023. "Evaluation and Refinement of Minnesota Queue Warning Systems." Report No. MN 2023-05, Mn DOT Office of Research & Innovation, St. Paul, MN. https://mdl.mndot.gov/items/202305, last accessed October 14, 2024.

2. Ullman, G. L., R. E. Brydia, and V. Iragavarapu. 2016. "Safety Effects of Portable End-of-Queue Warning System Deployments at Texas Work Zones." Transportation Research Record no. 2555: 46–52. https://journals.sagepub.com/doi/10.3141/2555-06, last accessed October 14, 2024.

3. Mn DOT Office of Traffic, Safety, and Operations. 2008. "Minnesota IWZ Toolbox: Guide for Intelligent Work Zone System Selection." https://www.dot.state.mn.us/trafficeng/workzone/iwz/MN-IWZToolbox.pdf, last accessed September 10, 2024.

FOR MORE INFORMATION on other TMC practices or the TMC Pooled-Fund Study:

- Traffic Management System Portal (National Operations Center of Excellence): https://transportationops.org/traffic-management-systems-and-centers.

- TMC Pooled-Fund-Study website: https://tmcpfs.ops.fhwa.dot.gov/.

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