Treating Potential Back-of-Queue Safety Hazards

The purpose of this document is to highlight strategies that can help reduce the work zone congestion that increases back-of-queue crash risk. It is widely recognized that when congestion develops and queues form at the approach to work zones, the risk of crashes increases, especially on major highways where speeds are high and drivers are accustomed to unencumbered travel. Additionally, the problem can be compounded by limited sight distance and roadway curvature. Studies have shown that rear-end crashes in the advance warning area for a work zone are the most common type of work zone crash.[1] Analysis of work zone impacts can help agencies design the appropriate mitigation techniques. Additionally, proper temporary traffic control and the use of congestion mitigating strategies and techniques will help manage the queuing associated with work zones.

Quantifying Work Zone Impacts and Determining Queue Length

Agencies can analyze the potential work zone impacts of implementing a traffic control plan in a number of ways. Analysis can occur at the planning level, which would provide a high-level snapshot of potential impacts. For example, a capacity analysis can help identify congestion issues that may arise from lane closures. A spreadsheet tool can be developed, such as the one used by the Ohio Department of Transportation,[2] to determine the appropriate times to close lanes based on the temporal aspects of the demand for the facility. If lane closures are needed for extended periods of time, capacity analysis may also help designers determine the need for operational treatments.

Analysis includes demand (volume counts and queued vehicles), capacity, and calculation of a ratio of the two (see Figure 1). When this ratio approaches or exceeds 1:0, congestion arises. Figure 1 illustrates the relationship between demand and fixed capacity. When demand exceeds capacity, queuing occurs.

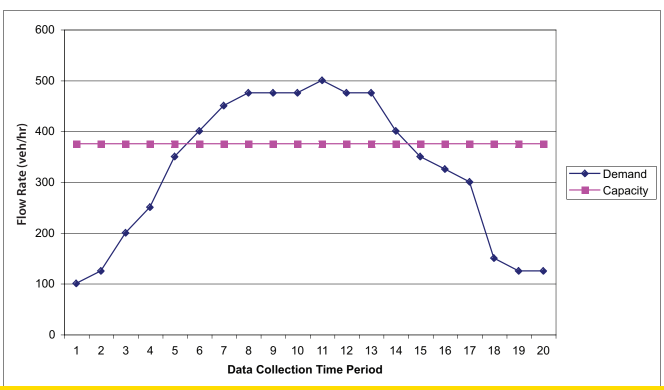

Figure 1. Demand and Capacity by Time Period

When an analysis shows the potential for queuing, especially for extended periods of time, the conditions may negatively impact safety and increase back-of-queue crash risk, especially in locations with limited sight distance to the back-of-queue.

Queues can build very rapidly once oversaturated conditions are present. A recent study showed that backward moving queues can grow at a rate of 30 to 40 miles per hour,[3] adding a mile of queued traffic every 2 minutes.

Capacity analysis can be used to estimate the number of vehicles that are expected to queue. Practitioners can then estimate the length of queue. For stopped queues (such as those observed at signalized intersections), 25 feet is the common spacing (front bumper to front bumper) used to estimate the length of the queue. If there are four vehicles in a stopped queue, the queue length is approximately 100 feet. Rolling queues are more common on freeways as a result of congested conditions, and vehicle spacing may be as high as a few hundred feet. For a queue of four vehicles, the length of rolling queue may be 800 feet.

A second way of analyzing impacts is through the use of traffic simulation modeling tools. However, this more detailed analysis may only be cost effective for significant projects and requires training on the use of the tool selected.

Analysis can help determine if queuing is potentially an issue and may also help agencies include rough budget estimates for traffic management as part of project funds. Table 1 shows planning level data as it is used to calculate a volume (demand or pre-construction undersaturated volume) to capacity ratio. Table 2 highlights estimated capacity for lane closure scenarios. For example, the capacity for a two-to-one lane drop on a four-lane freeway is approximately 1,340 vehicles per hour, and dividing the factored demand by the capacity will produce the ratio of demand to capacity. This ratio provides a general idea of whether the facility will be congested during the peak hour and can be expanded to include other time periods if data are available. The Ohio DOT spreadsheet tool uses this technique to provide guidance on time periods where lane closures are permitted.

[1] Federal Highway Administration, "Work Zone Safety for Drivers," FHWA-SA-03-012 (Washington, DC: 2003), http://safety.fhwa.dot.gov/wz/docs/wzdrive.pdf.

[2] Ohio Department of Transportation, "Permitted Lane Closure" web page, http://plcm.dot.state.oh.us//plcm/plcm_web.jsp (accessed May 2009).

[3] Texas Transportation Institute, *Advance Warning of Stopped Traffic on Freeways: Summary of Project Activities,* Report 0-4413-S, 2005, http://tti.tamu.edu/documents/0-4413-S.pdf.

AADT	Directional Split	Peak Direction	Peak Hour Volume	Capacity	V/C Ratio
15000	0.6	9000	900	1500	0.60
25000	0.6	15000	1500	1500	1.00
35000	0.6	21000	2100	1500	1.40
55000	0.6	33000	3300	1500	2.20

Table 1. Relating Pre-Construction Volume to Capacity

More detailed analysis can be performed as the traffic control plans are developed, the project staging requirements become known, and additional information becomes available. Traffic simulation models provide additional detail by modeling individual vehicle interactions to produce aggregate statistics on operational performance. Other tools[4] such as QUEWZ and QuickZone provide an indication of potential operational issues and can help planners and designers determine impacts and potential safety hazards from queuing. For example, QuickZone outputs show user delay for each traffic control alternative modeled, thereby allowing practitioners to select the best option for scheduling and traffic control.

Number of Lanes		Avg. Capacity	
Normal	Open	vph	vphpl
3	1	1,170	1,170
2	1	1,340	1,340
5	2	2,740	1,370
4	2	2,960	1,480
3	2	2,980	1,490
4	3	4,560	1,520

Table 2. Highway Capacity Manual Work Zone Capacity Estimates

The Importance of Good Data

Traffic detectors (such as loop detectors) count the number of vehicles that pass a given point on the roadway, often expressed as a 15-minute or hourly volume. Demand represents the total number of vehicles attempting to pass that point on the roadway; demand may be higher than volume, especially when non-recurring congestion exists. Additionally, demand varies during the day, and volumes may change drastically within a short time (such as when a school opens or closes or when a factory changes shifts). Understanding data is important in accurately determining potential impacts and designing treatments, and having accurate and timely traffic data, will allow practitioners to understand whether the capacity of the work zone is adequate.

Traffic detectors may not accurately report demand during congested periods due to their inability to count the vehicles in the queue at the end of the reporting period. However, detectors can provide speed and occupancy information, which help determine the level of congestion on the roadway. Agencies should evaluate potential data issues when determining the impacts of a traffic control plan so that mitigation techniques are based on the best possible analysis.

What Are Some Strategies That Can Mitigate Potential Back-Of-Queue Hazards?

Analysis should determine the potential impacts from traffic control alternatives. Designers can use that data to determine the appropriate treatments to mitigate the impacts. Several treatments and good practices are highlighted here.

Treating the End of Queue

For some projects it may be possible to eliminate any back-of-queue issues by maintaining the same number of lanes during construction as prior to construction — by reducing lane widths, for example. Alternatively, shoulder widths can be reduced to maintain the same number of open lanes during construction. These techniques may have less back-of-queue crash risk compared with a lane closure.

If lane closures are necessary, a strategy to help alleviate safety hazards would be to increase the length of taper to help smooth traffic flow at the merge location. Changing the location of the beginning of the taper may also provide benefits if the taper would otherwise be in a location that has limited sight distance. Additionally, greater sign spacing and presence of law enforcement personnel can help provide advance warning to motorists prior to the back-of-queue.

The following strategies can be used as part of the Transportation Management Plan (TMP). Each strategy falls within the Traffic Control Plan (TCP), Transportation Operations component (TO), or the Public Information conponent (PI). Each of these three components is an individual part of the overall TMP.

Proper Design and Installation of Temporary Traffic Control Devices – Proper setup, spacing, and use of traffic control devices are important elements of a safe and efficient work zone. The MUTCD provides minimum standards, and local and State standards and manufacturer's recommendations may also apply. Advance warning signs, advance flaggers, proper taper lengths, device spacing, and other standards are designed to provide maximum safety and mobility for users. When analyzing impacts, designers may identify the need to exceed the MUTCD requirements by locating advance warning signs further upstream before the back of the queue. Agencies may also reduce potential

[4] http://ops.fhwa.dot.gov/wz/resources/final_rule/wzi_guide/appb.htm

queues and back-of-queue issues by increasing the length of taper or changing the location of the beginning of the taper.

Intelligent Transportation Systems (ITS) for Work Zones – Some mobile traffic monitoring and management applications for work zones monitor traffic conditions and, based upon pre-determined thresholds, advise motorists of stopped or slowed traffic ahead, delays, and alternate routes. Portable changeable message signs linked to queue detectors can display delay or speed information in advance. Some systems (such as the CB Wizard) can be used to automatically broadcast work zone safety information to truckers. Traffic analysis can help estimate the potential benefits from the use of ITS. For example, a determination of the volume-to-capacity ratio for a work zone along with analysis of spare network capacity can help determine a plan for implementation of ITS and location of devices. ITS is more commonly used on long-term projects.

Use of Law Enforcement Personnel For Enhanced Driver Attention – Law Enforcement Personnel (LEP) can provide an extra level of notification for traffic queues on higher speed roadways. Some states use LEPs to monitor the back of the queue. LEPs may be parked off the roadway between the second and third advance warning sign and may be facing traffic. They also may move upstream as needed to always provide presence and motorist warning (through flashing lights) in advance of the back-of-queue. FHWA has developed a training course for law enforcement personnel operating in work zones; for more information, contact your local FHWA Division Office.

Reducing/Eliminating the End of Queue

Variable Speed Limit (VSL) Systems – These systems directly target speed variability and back-of-queue conditions. VSL systems vary the posted speed limit upstream of the queue, smoothing traffic flow and indicating to motorists that they should lower their speed because they are approaching slower moving traffic ahead. These systems may also vary the posted speed limit through the work zone in combination with other work zone parameters.

Nighttime Construction – With lower demand during night hours, some agencies perform work at night to avoid generating or compounding congestion that would be likely during the daylight hours. Reducing congestion with nighttime construction can help reduce rear-end crash risk. However, nighttime construction risks should also be considered, including noise, worker safety and fatigue, driver behavior at night, and the glare associated with lighting conditions.

Public Information (PI)

Public Information Campaigns – Many agencies provide advance information to motorists in the form of brochures, websites, 511 information, and other marketing materials. Agencies also use the media to provide public information to motorists on upcoming construction projects and alternate routing, especially projects with lane closures. Information may include travel times, delay, general messages on work zone conditions, and warnings to motorists of potential hazards. It may also include information on alternate routes or alternate means of transportation during the construction period. Part VI of the MUTCD recommends warning signs in advance of the end of queue for incidents.

How Can I Learn More About Back-of-Queue Hazards?

The following links provide more information on impacts analysis and the techniques described in this document:

Work Zone Mobility and Safety Program:
http://ops.fhwa.dot.gov/wz/

Work Zone Peer-to-Peer Program:
http://ops.fhwa.dot.gov/wz/p2p/index.htm

ITS Work Zone References:
http://ops.fhwa.dot.gov/wz/its/index.htm

Work Zone Traffic Analysis:
http://ops.fhwa.dot.gov/wz/traffic_analysis.htm

ATSSA Work Zone ITS Safety and Mobility Solutions:
http://www.atssa.com/galleries/default-file/2008July21_ITS_Safety_and_Mobility.pdf

Work Zone Impacts Assessment Guide:
http://ops.fhwa.dot.gov/wz/resources/final_rule/wzi_guide/wzi_guide.pdf

Manual on Uniform Traffic Control Devices:
http://mutcd.fhwa.dot.gov

SAFER ROADS SAVE LIVES

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