MTC
MIDWEST TRANSPORTATION CONSORTIUM

Optimizing Work Zone Road Closure Capacity

tech transfer summary

RESEARCH PROJECT TITLE
Synthesis of Procedures to Forecast and Monitor Work Zone Safety and Mobility Impacts

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MORE INFORMATION
www.ctre.iastate.edu/mtc/projects/2005-01.htm

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Objectives

Improve understanding of the impact of a variety of traffic characteristics, roadway features, and environmental variables on the capacity of work zone lane closures.

Problem Statement

As urban and even rural multi-lane roadways become more congested, the proper timing of lane closures for construction or maintenance work becomes critical. The key is to leave enough capacity and avoid unacceptable delays and waiting lines upstream from the closure. The balance between traffic volume and the number of vehicles that can pass through a work zone determine the delay. For example, if a lane restriction reduces the maximum throughput to 1,300 vehicles per hour (VPH), but 1,500 vehicles arrive in an hour, then we would expect a 200-vehicle-long queue at the end of an hour (1,500 – 1,300 = 200). Assuming the volume of arriving traffic cannot be controlled, the queue length and, hence, the length of delays are a function of the remaining capacity.

Several states have policies, either written or unwritten, regarding when and under what conditions a lane restriction will be allowed for maintenance and/or construction work. These policies are based on an assumption of the capacity remaining when a lane restriction is implemented. Some states have even created manuals or lookup tables that designate when a lane can be restricted so that unacceptable queues are avoided.

Mechanics of Lane Restriction Queuing

Figure 1 illustrates the mechanics of queuing. It shows volume and speed for a work zone lane closure before a queue is formed, during the queue, and after the queue has subsided. On the upper part of the graph is a plot of the traffic volume (in five-minute intervals) passing the lane closure taper, which restricts traffic to one lane immediately before the work area. On the lower part of the graph is a plot of the speeds averaged over the same five-minute intervals. The left vertical line represents the time when the queue first starts, and the right vertical line represents the time when the queue ends.

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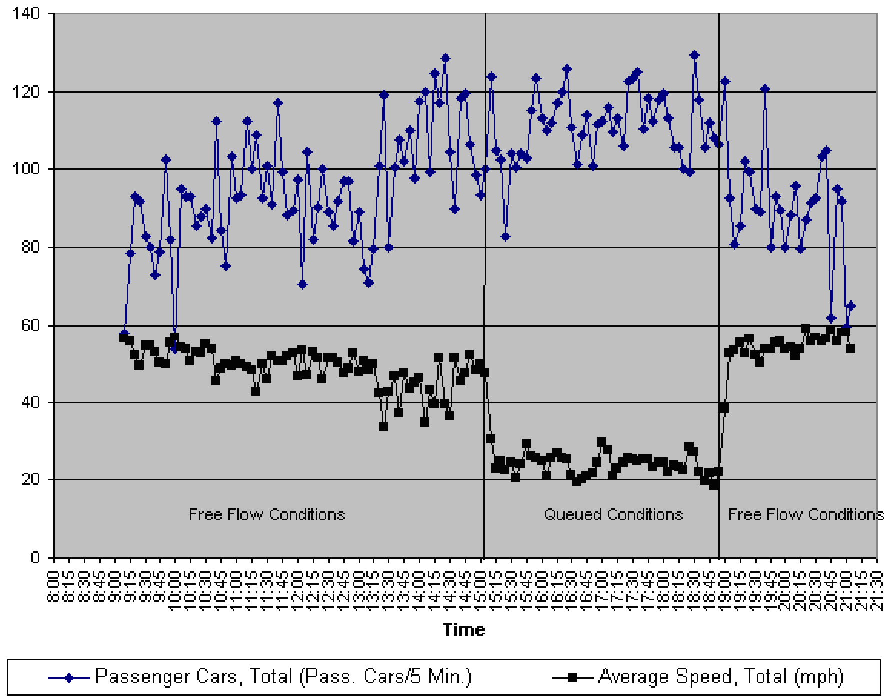

Figure 1. Work zone lane closure flow and speed over time

If the objective of analyzing a restriction is to understand when queuing is likely to begin, free-flow capacity should be used. If the purpose is to calculate queue length and delay after queuing has started, then queue discharge capacity should be used. Methods and computer programs used to estimate the impacts of work zone road closures, such as *Highway Capacity Manual* methods and QUEWZ and its derivative models, including QUEWZ3, QUEWZ-85, QUEWZ-92, and QuickZone, all use queue discharge value for their capacity estimate. If transportation managers are trying to manage traffic volumes so that a queue does not form, then they should focus on the free-flow capacity and seek management strategies that keep traffic volumes below free-flow capacity.

Since the volume of traffic passing the taper before and after queuing occurs varies from one five-minute interval to another, the maximum number of vehicles varies. The average speed drops when queuing begins, and, although it is difficult to tell due to the variation in the volumes, a modest drop occurs in the maximum number of vehicles passing the lane restriction after queuing begins. The maximum flow before the queuing starts is known as the "free-flow capacity," and the maximum flow after queuing starts is called the "queue discharge capacity."

Factors that Impact Lane Closure Capacities

The capacity of a lane closure is dependent on a number of location-specific variables. However, the volumes in Figure 1 illustrate that even when conditions are held constant, maximum throughput (capacity) varies and none of the values specifically represents the capacity of a lane closure. Instead, the maximum throughput is really a distribution of values.

Table 1 lists variables that impact capacity of lane closures. Although many variables are outside of the control of state transportation agencies (e.g., the weather), some variables can be controlled (e.g., the location of merge points relative to grades). The table is intended to provide work zone managers insight into factors that cause the capacity of work zone lane restrictions to vary from location to location.

Benefits of Implementation

- Developers of work zone traffic control plans will understand how a variety of traffic characteristics, roadway features, and environmental variables can impact the capacity at work zone lane restrictions.
- Designers may be able to avoid features that negatively impact the capacity of lane closures.

Table 1. Variables known to impact work zone capacity

Variable impacting capacity	Attributes associated with variable	Known characteristics
Work zone lane closure configuration	The capacity of a lane closure is dependent on the number of lanes left open and closed and the location of the lane or lanes closed.	When one or more lanes are closed, the remaining open lane(s) have less capacity than normal through lanes. For example, when one lane of a two-lane segment is closed, the open lane has less capacity than one normal lane due to merging. Also, right lane closures result in lower capacity than left lane closures because the right lane generally carries more traffic, resulting in more vehicles merging into the open lane.
Intensity and location of work	The capacity of the open lane will be impacted by visible construction work in proximity to the open lane(s).	Even when there is a concrete barrier between the driver and the construction activity, drivers will slow when the work is in close proximity to the open lane. Intensity and location of work have been found to negatively impact capacity by 1.85%–12.5%.
Percentage of heavy vehicles	Due to their poor speed change performance, high percentages of heavy vehicles will reduce capacity of the through lanes.	Because of poor speed change performance, trucks have a greater impact on capacity after queuing than during free flow. On level terrain and in work zone merge areas, trucks equal 2.4 passenger cars and buses equal 1.5 passenger cars.
Driver characteristics	Drivers that have experience with the work zone are likely to select shorter headway, and capacity will increase.	Commuters making routine trips are familiar with the work zone and are more likely to reduce headways through the work zone. During off-peak hours, capacity reduces by approximately 7% and, during the weekends, by 16%.
Entrance ramp locations and volumes	Ramps in the area of the work zone are likely to create more turbulence in the traffic flow and reduce capacity.	The capacity of the open lanes should be reduced by at least the volume of the ramp within or downstream of the taper.
Grade of lane closure	Positive grades will diminish the capacity of open lanes, particularly where there is a high proportion of heavy vehicles.	At only a 3% grade, passenger car equivalent factors for trucks increased from 2.4 to the range of 2.7–3.2. Positive grades are likely to have the greatest impact if they are located at the lane closure merger point.
Duration of work	As the work zone duration increases, drivers are more likely to be familiar with the work zone and reduce their headways, thus increasing the capacity of the work zone with time.	See comments above for driver characteristics.
Weather conditions	The *Highway Capacity Manual 2000* contains reductions in maximum volumes due to weather.	During trace rainfalls, urban freeway capacity is reduced by 1%–3%; in rainfalls of 0.01–0.25 inches per hour, capacity is reduced by 5%–10%; and for rainfalls above 0.25 inches per hour, capacity is reduced by 10%–17%.
Work time	When work is scheduled at night to avoid peak travel times, traffic control presents significant challenges. Drivers are more frequently impaired by drugs or fatigue and generally behave differently due to lower visibility and glare caused by roadway lighting.	Significant differences in traffic flow exist for nighttime work zones and for daytime work zones.
Location of merge point and enforcement	Merging upstream from the taper point of a lane closure increases capacity more than late merging. However, when using early merge, drivers not following expected merge discipline skip to the head of the queue and force themselves into it, creating a crash risk and turbulence, thus diminishing any efficiency gained through an early merge.	Very little is known about the benefits of enforcement, and most studies of enforcement focus on safety benefits, as opposed to traffic flow efficiency benefits. It is believed that using enforcement personnel to support smooth behavior improves traffic flow.

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