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Comparison of Criteria Used by State Transportation Agencies to Evaluate Proposed Lane Closures in Planned Work Zones

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COMPARISON OF CRITERIA USED BY STATE TRANSPORTATION AGENCIES TO EVALUATE PROPOSED LANE CLOSURES IN PLANNED WORK ZONES

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DEDICATION

I dedicate this thesis to my parents, who have always provided me with their unconditional love and support.

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ABSTRACT

The purpose of this thesis was to compare the specific performance measures used by various state transportation agencies across the United States to evaluate the impact of proposed lane closures on the interstate system and decide whether the impact is acceptable or not, and thus whether or not to approve the proposed lane closure. Information about the policies, processes, and procedures for approving lane closures was obtained through a combination of searching the webpages of individual state departments of transportation, downloading pertinent materials, emailing requests for information, and contacting agency personnel by telephone. The collected documents and notes taken during telephone conversation were reviewed and details about the criteria being used by 41 state transportation agencies for the approval of lane closures were extracted.

A trend analysis was performed to determine whether the use of any criterion was more popular. The use of several criteria was examined across the whole nation, within geographical regions, and finally across the same regions. The results of the analysis revealed that some state transportation agencies use multiple criteria. For the 41 states examined, 23 use volume to capacity ratio, 18 used delay, 6 used queue length, and 4 used level of service. Thus, the most popular criterion used across the nation is the

volume to capacity ratio. The analysis within geographical regions revealed that in the Central and North Central, Northeast and Southeast regions the volume to capacity ratio is the most popular criterion while in the Northwest and Southwest regions a delay criterion is the most popular criterion. The analysis across geographic regions revealed that the delay criterion is most popular in the Southwest region, the level of service criterion is most popular in the Northwest region, the capacity and queue length criteria is most popular in the Central and North Central region. Surprisingly, the queue length, which is probably the easiest of the performance measures to observe in the field is only is only popular in the Central and North Central region.

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CHAPTER I

INTRODUCTION

The topic of this thesis is the comparison of the traffic performance criteria used by state transportation agencies in the United States to make decisions about closing traffic lanes on the interstate system during planned construction and maintenance activities. It builds upon two previous studies that compared various lane closure policies. One study included 7 policies and the other included 15. In this thesis, the lane closure policies of 41 states were compared. Therefore, this thesis will serve as a comprehensive reference for those who develop such policies.

The closure of a single or multiple lanes is done to facilitate roadway construction and maintenance activities. The lane closure provides access to and egress from the work area and provides a protective buffer between the work area and the active traffic lanes. There are two types of single-lane closures, namely left-lane closures and right-lane closures. A left-lane closure occurs when the work is done on or adjacent to the left or inside lane of the traffic lanes in one direction. A right-lane closure occurs when the work is done on or adjacent to the right or outside lane. When additional space is needed for construction activities, multiple left or right lanes may be closed.

According to the Manual on Uniform Traffic Control Devices (MUTCD) a work zone is categorized as either a short-term work zone or a long-term work zone depending on the duration of the work (FHWA 2009). A work zone lasting one to three days is considered a short-term work zone. In short-term work zones, lane closures are identified through the use of traffic cones and construction barrels. These regulate traffic by guiding drivers past the lane closure and through the work zone. Long-term work zones, on the other hand, last anywhere from three days to several months and even years. In long-term work zones, concrete barriers are used to separate the work area from the active traffic lanes. Temporary lane closures within the long-term work zone may be needed to facilitate a particular phase or activity of the project.

Although closing one or more traffic lanes has the benefits of providing access to and egress from the work area and providing a buffer between the work activities and the active traffic lanes, the resulting reduction in roadway capacity has the potential to impact traffic operations in the immediate and surrounding areas. When the traffic demand is greater than the reduced capacity at the lane closure, congestion will occur. Traffic will build up upstream of the lane closure. The queuing of vehicles results in delays to the traveling public and the movement of goods. Additionally, adjacent roads may also experience congestion as drivers choose alternate routes to avoid the work zone.

There are a variety of traffic performance measures that can be used to evaluate the impact of the lane closure on traffic conditions and thus a variety of criteria can be established to guide decision making in this regard. Possible measures include the reduction in the carrying capacity of the road segment, the number of vehicles queued, the length the queue propagates upstream of the lane closure, the amount of delay experienced by the vehicles, and the level of service of the road segment. Criteria used to decide whether or not the impact of the lane closure is acceptable can be defined as a threshold value or a specified change in one or more of these measures.

In September 2004, the Federal Highway Administration (FHWA) published the Work Zone Safety and Mobility Rule (DOT, 2004). As part of this update to the work zone regulations, 23 CFR 630 Subpart J, state transportation agencies are required to develop their own work zone safety and mobility policies. Such policies must include procedures for addressing the anticipated impacts of individual projects that are expected to cause significant disruption. The rule recommends that work zone operational and safety data be used to track the impacts of specific projects and that work zone reviews be included in the process. Such policies will help state transportation agencies to systematically implement and manage work zones and thus better mitigate the impacts of work zones on the traveling public and goods movement. Transportation agencies were required to comply with the provisions of the rule no later than October 12, 2007.

In 2007, Maze and Wiegand (2007) published their review of survey results from 7 state transportation agencies. The review compared the agencies' lane closure policy development, use of exceptions to the policy, and enforcement. The review of the lane closure policy development showed that states used a variety of threshold to determine whether or not to allow a lane closure. These thresholds were defined as a specific lane capacity, queue length, or road user delay time.

In 2010 Bourne, et al (2010) published their best practices document in response to a request from the American Association of State Highway and Transportation Officials (AASHTO). The document details the work zone assessment, data collection and performance evaluation practices of 15 state transportation agencies. As part of their review on assessment practices, they found 12 state transportation agencies had established thresholds for work zone mobility and operational performance, which would be applied throughout the project development process, including the evaluation of proposed lane closures. These thresholds defined allowable lengths on lane closures, queues, delays, and level of service ratings.

Now that more time has passed since the update of 23 CFR 630 Subpart J, and state transportation agencies have had an opportunity to live with and use their work zone lane closure policies, a comprehensive review is needed to understand whether any consistency has formed about the use of specific traffic performance measures and decision criteria for approving proposed lane closures.

1.1 PURPOSE AND OBJECTIVES

The purpose of comparing the current lane closure policies, used by state transportation agencies is to identify the most commonly used practices across the nation. The results will be useful to such agencies to better understand how each compares to the group and what range of practices are being used. To complete this comparison, three study objectives were established.

The first objective of this study was to gather information about the policies, procedures and processes from the various state agencies. The goal was to collect information from all 50 states, however a retrieval rate of 50%, or 25 states was deemed acceptable and certainly an improvement over the two previous studies which reviewed the policies of 7 and 15 state transportation agencies.

The second objective was to catalogue details about the different policies. The key interest was on the specific performance measures and associated criteria used to evaluate the impact of proposed lane closures.

The third objective was to conduct an analysis of the various lane closure policies. Again the focus was on the different performance measures and criteria being used. The data extracted from the state policies was compared to examine:

- Whether there was any similarities across the nation;
- Whether there was any similarities within geographic regions; and
- Whether there were any similarities between pairs of geographic regions.

It was believed that as state transportation agencies participate in peer exchange programs, disseminate information about their policies, processes and procedures, and learn about what each other state is doing, that a set of performance measures would gain greater acceptance and use within the transportation community. It was also believed that this transfer of knowledge would be more likely to occur between adjacent states and within geographic regions, as these agencies participate in professional organizations with similar district boundaries.

1.2 METHODOLOGY

The study was broken down into four major tasks: 1) the review of relevant literature; 2) the gathering of policy documents; 3) the cataloguing of the performance measures and criteria used; and 4) then a comparison of the criteria across the nation, and between and among regions. These tasks are discussed in the following paragraphs. Satisfactorily completing these tasks ensured that the objectives of the study would be met.

1.2.1 Review Literature

The first task was to conduct a literature review. The purpose was to first understand the recommended methodology for analyzing the impact of lane closures on traffic flows in work zones and the factors that contribute to this impact, and then establish what is already known about the various state transportation agencies' policies, processes and procedures.

1.2.2 Gather Documents

The second task was to collect relevant documents from the various state transportation agencies. Given the requirements and recommendations contained within the Work Zone Safety and Mobility Rule, it was expected that the various state transportation agencies would have lane closure approval processes and procedures described within approved policies. It was also expected that much of the information would be readily available on-line.

1.2.3 Catalogue Details

The third task was to extract and catalogue the relevant details about the gathered lane closure policies, procedures, and processes. With a focus on the performance measures and criteria being used, the minutia of the procedures for calculating the impact and the processes for approving or denying proposed lane changes was reviewed. The details about the performance measures and criteria were extracted and catalogued.

1.2.4 Compare Details

The fourth task was to compare the details of the lane closure policies, procedures and processes collected from the various state transportation agencies. It was expected that a small number of criteria used to evaluate proposed lane closures would be consistent across a geographic region, perhaps between pairs of regions, and even possibly across the nation.

1.3 ORGANIZATION

This thesis is organized into five chapters. Chapter I introduces the topic of comparing the criteria used by state transportation agencies to evaluate proposed lane closures in planned work zones. The purpose of the study and the research objectives are provided along with a brief description of the research tasks. Chapter II provides background information on analyzing the impact of lane closures in work zones, including the current Highway Capacity Manual (HCM) recommended methodology and various performance measures, along with a review of previous policy reviews. Chapter III describes the document gathering and cataloguing activities and results. Chapter IV presents the various comparisons of the criteria extracted from the policies and the results of those comparisons. Chapter V highlights the key findings to draw some pertinent conclusions and offer some useful recommendations with regard to decision criteria for approving proposed lane changes in planned work zones.

CHAPTER II

BACKGROUND

This chapter first describes the various input measures needed to calculate the impact of lane closures in work zone on the traffic operations of the freeway segment. This is followed by a discussion of the resulting output performance measures describing the impact. The input and output measures are based on the 2010 Highway Capacity Manual (HCM) recommended methodology. The chapter concludes with a review of two previous studies that examined the lane closure policies of a sample of state transportation agencies.

2.1 INPUT MEASURES

The Highway Capacity Manual (TRB 2010) methodology for freeway facility analysis includes procedures for calculating a variety of measures that describe the operating characteristics of the facility. These measures include the capacity of the freeway segment, work zone area and lane closure.

2.1.1 Freeway Capacity

The HCM definition of capacity is "the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period, under prevailing roadway, traffic and control conditions." The HCM includes a series of speed-flow curves that depict the relationship between speed and flow for freeways. The free flow speed is the average speed observed at very low flows. Freeways sections with a free flow speed of 55 mph are expected to have a capacity of approximately 2,250 passenger cars per hour per lane (pcphpl). Likewise those with free flow speeds of 60 mph, 65 mph, 70 mph, and 75 mph are expected to have capacities of 2,300 pcphpl, 2,350 pcphpl, 2,400 pcphpl, and 2,500 pcphpl respectively (TRB 2010).

While the free flow speed can be observed in the field, it can also be estimated using the following 2010 HCM equation:

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}$$

where,

FFS = free flow speed, mph;

f_{LW} = adjustment for the lane width, mph;

f_{LC} = adjustment for lateral clearance, mph; and

TRD = number of ramps per mile located between 3 miles upstream and 3 miles downstream of the midpoint of freeway segment under study.

To apply this equation to an existing or future freeway segment, the condition of the freeway segment is compared to a base condition, described by 12 foot lanes, with at least 6 ft of lateral clearance on the right side of the road, and no interchanges. Smaller lane widths, reduced lateral clearances, and the presence of interchanges are expected to decrease the free flow speed and thus the capacity of the segment.

2.1.2 Base Capacity for Work Zone Lane Closures

For short-term work zones, the HCM recommends a base capacity is 1,600 pcphpl. This base capacity value was drawn from the research findings by Krammes and Lopez (1992), who found the average capacities for five lane closure configurations ([3,1], [2,1], [4,2], [5,3], [4,3]) ranged from 1,588 to 1,629 pcphpl. The configurations are denoted as [A, B], where A is the number of normal lanes in one direction and B is the number of open lanes in the work zone. Krammes and Lopez found that the differences between the different lane closure configurations were not significant at the 0.05 significance level and hence recommended a base capacity of 1,600 pcphpl for all lane closure configurations.

For long-term work zones, lasting a few weeks or more, default capacity values are given for different lane closure configurations, although the HCM recommends using a capacity value based on local data and experience.

The HCM methodology for evaluating freeway facilities includes a procedure for adjusting a base capacity for work zones to account for the type of work activity, the presence of on-ramps and the composition of the traffic. Additional adjustments can be made to account for the lane width, and weather and environmental conditions.

2.1.3 Adjustment for the Intensity of Work Zone Activity

The HCM acknowledges that the impact of a temporary lane closure within a work zone is also due to the type of work activity within the work zone and the proximity of the work to the active lanes of traffic. Krammes and Lopez (1992) found below average capacities occurred when there were unusual or intense work activities. They conjectured that the more unusual activities cause rubbernecking, thereby reducing the capacity, as compared to more common activities. The lower than average capacities were observed for work zones with larger numbers of workers, amount of equipment, amount of dust and noise, and those with activities closer to the open travel lane. The HCM recommends adjusting the base capacity value by up to ±10 percent for the intensity of the work activity.

Examples to describe the differences in the intensity of work zone activities were previously defined by Dudek and Richards (1981) and later elaborated upon by Batson et al (2009). The resulting examples are provided in the following Table 1.

2.1.4 Adjustment for the Presence of On-Ramps

Krammes and Lopez (1992) found below average capacities when there was an entrance ramp in the taper area of the lane closure or immediately downstream of the lane closure. This observation is taken into account in the HCM methodology. An adjustment for the presence of an on-ramp is applied, not to exceed the volume on the ramp. The rationale is that the on-ramp traffic generally finds its way into the mainline traffic lanes which reduces the amount of mainline traffic that can be handled, and the merging of the on-ramp and main line traffic flows may slightly reduce the capacity.

Table 1. Intensity of Work Zone Examples.

Intensity	Work Type Examples
Lightest	Guardrail repair/installation, median cleanup
Light	Pothole repair, bridge deck patching, bridge deck inspection and maintenance, barrier wall erection
Moderate	Resurfacing/asphalt removal, paving (w/light equipment activity), milling (w/light equipment activity)
Heavy	Stripping/slide removal, paving (w/heavy equipment activity), milling (w/heavy equipment activity)
Very Heavy	Pavement marking, final striping, concrete paving (w/heavy equipment activity), bridge widening (w/light equipment activity)
Heaviest	Bridge repair, bridge widening (w/heavy equipment activity)

2.1.5 Adjustment for Traffic Composition

The base capacity is also adjusted for the different types of vehicles in the traffic stream. Larger vehicles such as heavy trucks, buses and recreational vehicles have poor acceleration and deceleration capabilities compared to passenger cars and can be described in terms of passenger car equivalents. These equivalents are used to define the following heavy vehicle factor:

$$f_{HV} = \frac{1}{1 + P_T\,(E_T - 1) + P_R\,(E_R - 1)}$$

where

f_{HV} = heavy vehicle adjustment factor;

P_T = proportion of trucks and buses in the traffic stream;

P_R = proportion of recreational vehicles in the stream;

E_T = passenger car equivalence (PCE) for trucks and buses; and

E_R = passenger car equivalence (PCE) for recreational vehicles.

The HCM includes various tables of passenger car equivalents for trucks and buses, and for recreational vehicles. Specific tables are given for general terrain (i.e. level, rolling, and mountainous) as well as specific grades of the road segment.

2.1.6 Adjusted Capacity

The adjusted capacity is calculated as the base capacity of 1,600 pcphpl, adjusted for the intensity of the work zone, the composition of the traffic, the number of lanes and the presence of on-ramps such that:

$$c_a = \{[(1{,}600 + I) \times f_{HV}] \times N\} - R$$

where,

c_a = adjusted mainline capacity, vph;

I = adjustment factor for type, intensity and proximity of work activity (-160 for light to +160 for heavy), pcphpl;

f_{HV} = heavy vehicle adjustment factor;

N = number of open lanes through the work zone; and

R = manual adjustment for the presence of on-ramps, vph.

2.1.7 Additional Factors

The 2010 HCM also acknowledges that the adjusted capacity of the lane closure may be further adjusted to account for narrow lane widths and adverse weather and environmental conditions. The base lane width is given as 12 feet, which corresponds to that used for basic freeway sections. Narrower lane widths are expected to reduce capacity.

2.2 OUTPUT MEASURES

The operational impact of a lane closure is the difference between how the freeway segment operates with and without the lane closure. This impact can be described using a number of different performance measures that reflect the utilization of the freeway segment, the extent of any congestion, and the delay experienced by users.

Any of these output measures could be used to establish criteria for deciding whether to allow a proposed lane closure to occur in a planned work zones. A criterion could be defined by a minimum or maximum threshold value, a minimum or maximum change in value, or an allowable difference from a benchmark value. The suitability of these measures for use in establishing decision criteria is discussed.

2.2.1 Volume to Capacity Ratio

The volume to capacity ratio (i.e. v/c ratio) is a measure of the utilization or degree of saturation for sections operating under capacity. The greater the value of the v/c ratio, the more the available capacity is being used. When the v/c for a section of freeway reaches

1.0, the capacity of the section has been reached. Theoretically, the v/c ratio cannot exceed 1.0. Additional vehicles cannot be served and will begin to queue upstream.

The volume to capacity ratio cannot be directly measured in the field as it is a composite value, comprised of the volume and the capacity. The capacity of the lane closure needs to be established under congested conditions, while the volume of traffic is only meaningful under non congested conditions. Thus they can both be measured, just not at the same time.

Under congested conditions, the v/c ratio can be deceiving. The volume of traffic will be less than the capacity, resulting in a v/c ratio less than 1.0. However, the low utilization reflects the impedance of vehicles to move and not the available space to accommodate more vehicles.

The volume to capacity ratio is a reasonable performance measure for comparing uncongested conditions and identifying when congestion occurs. However comparing the v/c ratios between uncongested and congested conditions is not appropriate.

2.2.2 Demand to Capacity Ratio

An alternative to the volume to capacity ratio is to evaluate the ratio between demand and capacity. The demand is the number of vehicle wanting to travel the segment and can be significantly larger than the volume of vehicles being serviced. The demand to capacity ratio is equivalent to the volume to capacity ratio when there is no congestion. However, when there is congestion, the demand includes all of the vehicles serviced and all the vehicles queued, waiting to be served. As such, the demand to capacity ratio is a suitable performance measure to capture the relative differences in the amount of congestion or queuing.

The demand to capacity ratio cannot be captured directly in the field, as it is a composite measure, comprised of the demand and the capacity. The capacity must be observed at the lane closure under congested conditions, while the demand must be observed upstream of the tail end of the queue. Thus they can both be measured, just not at the same location.

2.2.3 Number of Vehicles Queued

The amount of traffic that is in excess of the capacity does not get serviced. These vehicles queue and wait to be served. The number of vehicles that queue is a valuable performance measure under congested conditions. The greater the impact of the lane closure, the more vehicles queue.

The number of vehicles queued can be counted in the field, when there are only a few vehicles; however as the number of queued vehicles increases, observing this measure directly in the field becomes impractical. Instead, the number of vehicles queued is estimated as the net accumulation of vehicles, equal to the number of vehicles arriving upstream and the number of vehicles served through the lane closure, during the same time interval. The upstream observation location to capture the volume arriving must be upstream of the tail end of the queue, while the volume served must be observed at the lane closure. Thus, both the number of vehicles arriving and the number of vehicles served can be measured, but not at the same location.

2.2.4 Length of Queue

The length of queue is the distance upstream of the lane closure (i.e. bottleneck) to the tail end of the queue. The length of queue is calculated as the product of the number of vehicles in queue and the average headway (i.e. spacing) of those vehicles. The headway is dependent upon the type of vehicle and the speed of the vehicles within the queue. Larger vehicles require greater distance headway. At lower speeds, vehicles are spaced more closely together while at higher speeds vehicles tend to spread out more. A rough estimate is made by using the distance headway under stopped conditions.

The length of queue is observable in the field, so long as one can access a location that has an adequate sight line to the tail end of the queue. Mile marker posts are a convenient reference to use to determine the difference between the lane closure location and the location of the tail end of the queue.

2.2.5 Total Delay

The total delay is the summation of the additional time experienced by all vehicles over the freeway segment and analysis time period, as compared to the time it would normally take to travel the freeway segment. The delay includes the additional time caused by adherence to work zone speed zones and the time spent in queue.

There are methods to capture the travel speed of individual vehicles in the field. For instance probe vehicles can be driven in traffic and timed between a set of reference points to get a general idea as to the average travel time. Technology such as blue tooth receivers can be used to match the occurrence of vehicles with blue tooth enabled devices (i.e. cellular phones) at specified points along the road. While one reference or data collection point would be at the start of the lane closure, the location of the point upstream is less obvious. Ideally the reference points should contain the congestion to compare the travel times with and without the lane closure.

2.2.6 Average Delay

The average delay is the delay experienced by each vehicle, on average. It is calculated by dividing the total delay by the total number of vehicles served during the analysis period. The same discussion about the travel time applies.

2.2.7 Level of Service

For freeways, the level of service is a performance ranking based on the density of the traffic flow. The letter ranking ranges from A for low densities through to F for densities equal to or greater than that at capacity. Under non congested conditions, a change in the level of service reflects the difference in the speed to flow ratio. However, the ranking is coarse, with only 6 levels and as such similar changes in the ratio may not produce similar changes in ranking. For instance, if the current density reflects a level of service B but is very near to the threshold between levels of service B and C, then a small increase in density will cause a change in ranking to C but if the current density is not near the threshold between B and C, the increase will not cause a change in ranking.

Under congested conditions, the level of service is F. The F ranking indicates that the freeway facility is operating beyond capacity and that queuing is occurring. Regardless of the extent of the queuing, the level of service will remain at F. Therefore, the level of service does not provide any relative measure of performance for congested conditions.

2.3 QUEUE ANALYSIS TOOLS

There are a variety of analysis tools available for the analysis of freeway operations, some specifically to analyze the impact of work zone lane closures. These tools range from simple, deterministic tools to complex, simulation tools.

2.3.1 Deterministic Tools

The simple tools require a small amount of data to perform a deterministic, demand and supply analysis. Specific to work zones, this category of tools includes the HCM methodology and the various spreadsheet based, queue analysis tools. These tools use traffic volumes and work zone capacity to calculate the number of vehicles during each time interval that remain in queue upstream.

The HCM provides a seven step methodology to evaluate the traffic operations of freeway segments. An overview of the methodology is as follows:

1. The geometry of the basic, merging, diverging and weaving sections that make up the freeway segment are defined as well as the amount of traffic entering and exiting the freeway segment in each time interval being analyzed.
2. The traffic demand for each section and 15 minute time interval is defined, based on the overall traffic entering and exiting the facility.
3. The capacities of the different basic, merging, diverging and weaving sections are calculated.
4. Capacity adjustments are made for work zones. Adjustments account for the type of work activity, the presence of on-ramps and the composition of the traffic.

Additional adjustments can be made to account for the lane width, weather and environmental conditions.

5. The demand to capacity ratio for each freeway section and time interval is computed. A demand to capacity ratio greater than one indicates that the specific section is congested. The results are checked to ensure that any queue is contained within the freeway segment and time period.
6. When the demand to capacity ratio indicates that the section is congested, the traffic in the upstream and downstream sections are adjusted to reflect how the congestion regulates the flow of traffic. The time interval is reduced and the freeway segment is reanalyzed.
7. The performance measures of the individual sections are combined into a measure for the entire freeway segment under analysis.

The HCM acknowledges that this methodology is difficult and time consuming to implement, even for non congested conditions, and recommends the use of FREEVAL-2010. Although the software will identify which sections are congested, it will not provide an estimate of the amount or extent of queuing, or an estimate of the delay experienced by users.

A variety of spreadsheet based tools have been developed. Malaghan (2014) compared several spreadsheets and found that those developed and/or used by the state transportation agencies in Oklahoma, Alabama, Missouri and Pennsylvania include older HCM work zone capacity values or some variation of the HCM capacity equation to calculate the work zone capacity. The spreadsheets developed and/or used by Ohio and New Jersey require the user to define the work zone capacity. Each of these tools performs a supply and demand analysis to arrive at the number of vehicles in queue. A vehicle length or headway value is then used to translate the number of vehicles in queue to a queue length.

The category of deterministic tools also includes two more complicated spreadsheet tools; Quick Zone and CA4PRS. These tools consider details about the scheduling of work activities and construction costs to estimate the queues, user delay and travel costs.

2.3.2 Stochastic Tools

When deterministic tools are insufficient for analyzing the dynamics of the traffic operations, there is another category of tools available that estimate performance through simulation. These tools take into account the stochastic nature of traffic to either model the dynamics of traffic streams or the dynamic movement of individual vehicles. These tools are not specifically designed for modeling work zones but the parameters can be adequately adjusted for this specific application. Both macroscopic and microscopic traffic simulation tools can provide a range of traffic performance measures.

Macroscopic traffic simulation tools model the movement of traffic flow through flow rate variables and other general descriptors. Macroscopic models are generally based on deterministic relationships of the flow, speed, and densities of the traffic stream developed through research on highway capacity and traffic flow for freeway sections. The movement of traffic streams is simulated from freeway section to freeway section over sequential time steps.

Microscopic traffic simulation tools model the movement of individual vehicles making up the traffic stream, based on theories of car following and lane changing. These models contain processing logic, which describes how vehicles behave including acceleration, deceleration, lane changes, passing maneuvers, turning movement execution, and gap acceptance. Typically, vehicles are input into the freeway section using a statistical arrival distribution and are advanced on a second-by-second basis.

2.4 PREVIOUS REVIEWS

Since the release of the Work Zone Safety and Mobility Rule in 2004, two reviews of state work zone policies have been conducted. The focus of these reviews differed from the purpose of this thesis however, some of the review results are valuable to this thesis and thus presented in the following paragraphs.

In 2007, Maze and Wiegand (2007) conducted a review of work zone policies from California, Colorado, Indiana, Minnesota, Missouri, Ohio, and Wisconsin. These agencies were chosen because they were believed to have ideal policies. Each of the seven agencies was surveyed about the details of its policy. The survey concentrated on questions about the lane closure policy development, exceptions to the policy, and enforcement. Table 2 summarizes the thresholds different state agencies had established for allowing or not allowing a lane closure.

Table 2. Thresholds found by Maze and Wiegand (2007)

Agency	Thresholds
California, Caltrans	Road user delay time 30 minutes or delay threshold set by District Traffic Manager, whichever is less
CDOT (Region 1)	Lane capacity 1,600 vphpl minus other factors 1,100 vphpl for certain mountainous regions
INDOT	Queue length and road user delay Queue>1 mile for longer than 2 hours Queue>1.5 miles for any period of time, or 10 minute road user delay
Mn/DOT Metro	Lane capacity 1,800 vphpl
MoDOT	Lane capacity 1,240 cphpl for one of two lanes open 1,430 vphpl for two or three lanes open
ODOT	Lane capacity and queue length 1,000-1,490 vphpl (varies by truck percentage and terrain) Queue>0.75 miles for longer than 2 hours Queue>1.5 miles for any period of time
WisDOT	Lane capacity Generally 1,500-1,600 vphpl Limited to 1,200-1,300 vphpl in certain regions

In 2010, Bourne et al (2010) prepared a scan of the best practices in work zones. The scan was focused on the assessment, data collection and performance evaluation practices. Transportation agencies from California, Florida, Illinois, Indiana, Maryland, Michigan, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Oregon, Washington and Wisconsin were included in the scan. Out of these 15 participating agencies, 12 had established mobility and operational performance thresholds. These thresholds would be used throughout the project development process including for the evaluation of proposed lane closures.

Table 3. Thresholds found by Bourne et al (2010)

Agency	Threshold
California DOT	Delay time 0 minute delay for most freeway projects < 15 minute delay if aggressive TMP is being used <30 minute delay on complex projects On other highways, <20 minute delay for flagging operations
Florida DOT	Queue length <2 miles on interstates or speed limits >55 mph
Indiana DOT	Queue length >6 continuous hours or 12 hours per day 0.5 miles<queue<1.0 miles limited to 4 continuous hours 1.0 miles<queue<1.5 miles limited to 2 consecutive hours Queues >1.5 miles are not permitted

Agency	Threshold
Maryland DOT	Queue length, delay Queue<1.0 lime acceptable on freeways 1.0<queue<1.5 miles limited to 2 hours on freeways Queue>2.0 miles not acceptable on freeways Delays<15 minutes on arterials Signalized intersections: C<LOS<A, loss of LOS to D, max. control delay of 30 seconds LOS=D, max. control delay increase is 30% LOS=E, max. control delay increase is 30% up to 50 seconds LOS=F, no control delay increase is acceptable Unsignalized intersections: C<LOS<A. loss of LOS to D, max. control delay of 45 second LOS=D, max. control delay increase is 30% LOS=E, max. control delay increase is 30% up to 80 seconds LOS=F, no control delay increase is acceptable
Michigan DOT	Delay time Delays<10 minutes Volume/capacity<0.8 Drop in LOS 2 levels LOS no worse than D
Missouri DOT	Delay time Delays>15 minutes are considered excessive

Agency	Threshold
New Hampshire DOT	Delay time 0<delay<5 minutes are acceptable 5<delay<10 minutes are not preferable Delays>10 minutes are undesirable; field staff will consider suspending work
New Jersey DOT	Delay time Delays<15 minutes
Ohio DOT	Queue length and duration Queue<0.75 miles acceptable 0.75<queue<1.5 miles limited to 2 hours Queues>1.5 miles are not acceptable
Pennsylvania DOT	Delay time Delays<15 minutes are acceptable 15<delay<30 minutes limited to 2 consecutive hours
Oregon DOT	Delay time Project delay<10% of the peak travel time Corridor delays (all projects combined)<10% of peak travel time
Wisconsin DOT	Delay time Max. of 15 minutes of added delay between major city nodes (all projects along route combined)

Together, the results of these two previous studies show that state transportation agencies were using a variety of performance measures and threshold values. These reviews were published within 5 years of the state agencies needing to comply with the updates to the work zone regulations. More time has passed and it is possible that specific performance measures and criteria for deciding whether the impact of a proposed lane closure have become more popular and widely used. This idea is examined in the following chapters.

CHAPTER III

DATA GATHERING AND CATALOGUING

This chapter first describes the approach used to acquire the various documents from state transportation departments across the nation. This description is followed by the results of these efforts. The results are organized by the criteria state transportation agencies use in deciding to approve a proposed lane closure.

3.1 DATA GATHERING

One of the main objectives of this study was to gather data regarding the lane closure policies, processes and procedures from state transportation agencies from across the nation. The goal was to collect documentation from each of the 50 states, although a success rate of 50% was deemed sufficient, and certainly an improvement over the previous two reviews which examined the policies from 7 and 15 states.

As part of this research, all 50 state departments of transportation were contacted, by examining their webpages and downloading pertinent materials, as well as emailing requests for information, and contacting agency personnel by telephone. This effort produced documents pertaining to lane closure approval processes and procedures for 41 state transportation agencies. This represents a success rate of 82%. The following table is a record of the sources of information. Where applicable the website address is included.

Table 4. Information Sources for 41 State Transportation Agencies

State of Agency	Date of the manual	Web link or phone/email
Alabama	2009	Personal communication
Alaska	2012	Personal communication
Arizona	2009	http://www.azdot.gov/docs/business/work-zone-safety-and-mobility-implementation.pdf?sfvrsn=0
Arkansas		Personal communication
California		Personal communication
Colorado (Region-6)	2010	https://www.codot.gov/library/traffic/traffic-manuals-guidelines/lane-close-work-zone-safety/lane-closure-strategies/R6_Lane_Closure_Report.pdf
Connecticut	2010	Personal communication
Delaware	2010	http://deldot.gov/information/pubs_forms/manuals/de_mutcd/pdf/final_rule_9_10_2007.pdf

State of Agency	Date of the manual	Web link or phone/email
Florida	2012	http://www.dot.state.fl.us/rddesign/PPMManual/2012/Volume1/Chap10.pdf
Georgia	2012	http://mydocs.dot.ga.gov/info/gdotpubs/Publications/6863-12.pdf
Hawaii	-	-
Idaho	2012	http://www.itd.idaho.gov/manuals/Manual%20Production/Traffic/600Const.pdf
Illinois	2012	http://www.illinoistollway.com/documents/10157/30214/ILLINOIS+TOLLWAY+LANE+CLOSURE+GUIDE_2010.PDF
Indiana	2013	http://www.in.gov/indot/files/TrafficSafety_InterstateHighwayCongestionPolicy_2013.pdf
Iowa		Personal communication
Kansas	2008	http://www.ksdot.org/PDF_Files/KANSAS%20WORK%20ZONE%20SAFETY%20AND%20MOBILITY%20POLICY%20MASTER.pdf
Kentucky	2008	http://transportation.ky.gov/Construction/Documents/workzonepolicy.
Louisiana		Personal communication
Maine	-	-

State of Agency	Date of the manual	Web link or phone/email
Maryland	2006	http://www.marylandroads.com/OOTS/WorkZoneAnalysisGuide_Sept08.pdf
Massachusetts	2006	http://www.massdot.state.ma.us/Portals/8/docs/designGuide/CH_17.pdf
Michigan	2012	Personal communication
Minnesota	-	http://www.dot.state.mn.us/metro/trafficeng/laneclosure/index.html
Mississippi		Personal communication
Missouri		Personal communication
Montana		Personal communication
Nebraska	-	-
Nevada	2012	http://www.nevadadot.com/uploadedFiles/NDOT/About_NDOT/NDOT_Divisions/Planning/Work%20Zone%20Safety%20and%20Mobility%20Implementation%20Guide%20March%202012.pdf
New Hampshire	2007	http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/WorkZoneSafetyPolicy.pdf
New Jersey	2011	Personal communication
New Mexico	-	-
New York		Personal communication

State of Agency	Date of the manual	Web link or phone/email
North Carolina	-	-
North Dakota	2007	http://library.nd.gov/statedocs/Transportation/WorkzoneSafetyMobility20100806.pdf
Ohio	2000 2006	http://www.dot.state.oh.us/Divisions/Engineering/Roadway/TrafficControl/MOTDocuments/516-003_Policy_071800.pdf http://www.dot.state.oh.us/Divisions/ConstructionMgt/Admin/Innovative%20Contracting/InnovativeContractingManual04102006.pdf
Oklahoma		Personal communication
Oregon	2010	Personal communication
Pennsylvania	2014	ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/Pub%2046.pdf 2013 PA.pdf
Rhode Island		Personal communication
South Carolina	2007	http://www.scdot.org/doing/technicalpdfs/publicationsmanuals/trafficengineering/rulesscdot.pdf
South Dakota	-	-
Tennessee	2007	http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/TDOTWorkZoneSafetyMobilityManual.pdf
Texas	2009	Dallas 81-05LaneClosures.pdf

State of Agency	Date of the manual	Web link or phone/email
Utah	2005	http://www.udot.utah.gov/main/uconowner.gf?n=10487328146579237
Vermont		Personal communication
Virginia	2011	http://www.virginiadot.org/business/resources/wztc/Virginia_WAPM_2011_web.pdf
Washington	2014	http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1010.pdf
West Virginia	-	-
Wisconsin	-	http://transportal.cee.wisc.edu/closures/devel/
Wyoming	2011	Personal communication

It was expected that lane closure policies, or documents containing details about the lane closure approval process and/or procedures for obtaining approval would be readily available on-line. Each of the webpages for the 50 state department of transportation was scoured looking for such documents, resulting in one or more pertinent documents for 25 agencies. The web sources for these documents are provided in Table 4.

The remaining 25 state departments of transportation were contacted by email and/or telephone. Details about the lane closure policies for an additional 16 states were collected. For those states which could not produce a written document, responses to several questions were recorded. The questions asked about the criteria used to determine when to approve a lane closure, and what lane capacities were assumed. Two agencies reported not having a policy, such as Alaska which reported applying engineering judgment to determine whether to allow a lane closure. Seven agencies did not respond to the requests for information.

3.2 CATALOGUING

The documents and responses received from the state departments of transportation were reviewed. Details about the criteria used to decide whether or not to allow a proposed lane closure was extracted and catalogued. In addition, details about assumed capacity values were recorded. Considering the HCM capacity calculation for basic freeway segments and the calculation for the adjusted capacity for work zones was updated in the 2010 HCM, it was expected that some of the policies would not be up to date is this regard.

3.3 DECISION CRITERIA

The decision criteria are the specific performance measures used to evaluate the impact of the lane closure and decide whether the impact is acceptable or not, and thus whether or not to approve the proposed lane closure. Although the criteria are specific, as in a defined threshold value, a defined allowable change, or a defined difference from a baseline value, strict adherence may not be practiced. Exceptions may be applied based on the unique characteristics of the roadway project, the activities of the work zone, and the judgment of those responsible for approving requests for lane closures.

3.3.1 Capacity Criteria

The simplest of the evaluations is to compare the traffic volume to the expected capacity with the lane closure. If the volume is greater than the capacity, then the lane closure is expected to cause congestion, and result in additional delay to the road users. Using the capacity itself as a threshold value in this manner is the same as using a v/c ratio of 1 as a decision criterion. If the v/c value is greater than one, then the lane closure is expected to cause congestion.

Of the 41 policies reviewed, 24 state departments of transportation use a capacity criterion. Table 5 includes the various capacity values being used as criteria. As shown, there is a wide range of assumed lane capacities ranging from 800 vphpl on a hilly region in South Carolina to 2,500 vphpl in Colorado.

Table 5. Capacity Criteria by State DOT.

State DOT	Capacity Criteria
Alabama	1,500 vphpl
California	1,600 pcphpl reduced for traffic composition and terrain 1,100 vphpl for hilly terrain
Colorado	1,800 and 2,300 vphpl 2,500 vphpl in Denver
Connecticut	No specific capacity mentioned
Delaware	1,170 vphpl to 1,520 vphpl
Florida	1,800 vphpl
Georgia	Arbitrary capacity, as determined by the Traffic Engineer

State DOT	Capacity Criteria
Illinois	1,500 -1,600 vphpl generally 1,200- 1,300 vphpl in some cases If V/C< 0.85 they can close the lane
Indiana	<1,300, 3 lanes are allowed to close <3,740, 2 lanes are allowed to close <5,600- 1 lane is allowed to close >5,600 not allowed.
Iowa	1,350 vphpl
Louisiana	No specific capacity mentioned
Maryland	1,170 vphpl 1,600 pcphpl
Massachusetts	1,170-1,520 vphpl
Michigan	Arbitrary Capacity
Minnesota	1,400 vphpl
Mississippi	Arbitrary Capacity
Missouri	Arbitrary Capacity 1,240 vphpl for [2, 1] lane configuration 1,430 vphpl for [3, 2] lane configuration
New Hampshire	No specific capacity mentioned
New York	No specific capacity mentioned
North Dakota	1,300 vphpl

State DOT	Capacity Criteria
South Carolina	1,000 vphpl 800 vphpl in some hilly areas
Texas	2,000 vphpl
Vermont	No specific capacity mentioned
Wisconsin	1,500-1,600 vphpl 1,200-1,300 vphpl

3.3.2 Permitted Lane Closure Schedule

An extension of the capacity criteria is the development and application of a permitted lane closure schedule. These schedules indicate the times and days when the closure of a lane is allowed on a particular segment of the road, based on when the volume will not exceed the capacity. The permitted lane closure schedule is essentially a screening tool. If a proposed lane closure falls within the permitted times, the lane closure is allowed. Florida, New Jersey and Ohio prepare permitted lane closure schedules.

The Ohio Department of Transportation determines its permitted lane closure schedule by comparing the hourly volumes to a theoretic capacity of the freeway segment (ODOT 2000). The theoretic capacity is calculated as:

$$c_a = 1{,}600 f_{HV} N$$

where,

c_a = adjusted mainline capacity (vph);

N = number of open lanes through the work zone; and

f_{HV} = heavy vehicle adjustment factor.

If the hourly volume is greater than the theoretic capacity, the lane closure is not allowed without further analysis. Additional lane closure restrictions are in place for holidays and special events.

3.3.3 Delay Criteria

The delay is the additional travel time experienced by a vehicle due to the closure of the lane(s). Eighteen of the 41 policies reviewed include a delay criterion for approving proposed lane closures. The delay criterion is usually defined as a minimum acceptable value. This means that if motorists experience delays more than the defined minimum time then the lane closure will not be permitted. Table 6 presents the various delay thresholds used by the state DOTs. Some states, such as California, Georgia and Rhode Island also allow the value for the delay criterion to be set by the district traffic manager.

Table 6. Delay Criteria by State DOT.

State DOT	Delay Criteria
Arizona	minimum delay compared to travel when no work zone is present
California	30 minutes
Georgia	30 minutes
Idaho	15 minutes for Individual traffic delay
Indiana	10 minutes
Kansas	30 minutes
Michigan	10 minutes
Nevada	20-30 minutes delay
New Hampshire	No fixed time

State DOT	Delay Criteria
North Dakota	15 minutes delay
Pennsylvania	20 minutes
Rhode Island	15 minutes delay
Tennessee	30 minutes
Texas	20 minutes
Utah	Delay should not exceed the base line delay
Virginia	No fixed time
Washington	20 minutes
Wisconsin	No fixed time

3.3.4 Queue Length Criteria

The length of the queue or the extent of the build-up of traffic is the distance upstream of the lane closure where vehicles are being stored. For 7 of the 41 policies reviewed, the state department of transportation identifies the length of queue as the decision criterion. Details are provided in Table 7. Missouri, Oklahoma and Wisconsin do not actually specify the maximum acceptable length. Indiana, Maryland and Ohio qualify the length of queue with an acceptable duration. For instance, the Ohio Department of Transportation defines a queue length of 0.75 miles as acceptable, queues greater than 0.75 miles but less than 1.5 miles are acceptable if they do not exceed two hours; and queues longer than 1.5 miles and queues between 0.75 and 1.5 miles lasting for more than two hours are unacceptable.

Table 7. Queue Length Criteria by State DOT.

State DOT	Queue Length Criteria
Indiana	Queue > 1 mile for longer than 2 hours Queue > 1.5 miles for any period of time
Kentucky	Queue should not be more than 3 miles
Maryland	Queue below 1 mile are acceptable Queues between 1 and 1.5 miles are acceptable for less than 2 hours. Queues more than 1.5 miles are not acceptable
Missouri	No particular length was mentioned
Ohio	Queues less than 0.75 miles are acceptable; Queues greater than 0.75 miles but less than 1.5 miles are acceptable if they do not exceed two hours Queues longer than 1.5 miles and queues between 0.75 and 1.5 miles lasting for more than two hours are unacceptable
Oklahoma	User specified acceptable queue length
Wisconsin	No particular length was mentioned

3.3.5 Level of Service Criteria

Level of service (LOS) is a qualitative ranking that assigns letter grades based on some quantitative performance measure. For freeways, the density is used to assign the LOS. The letter grade of A is assigned when the density is less than 11 passenger cars per mile per lane (pcpmpl) and letter grades B, C, D, and E are assigned for densities less than 18, 26, 35 and 45 pcpmpl respectfully. Densities greater than 45 pcpmpl are assigned the letter grade F and represent congested conditions.

Four of the 41 policies reviewed include the use of a LOS criterion. The details are shown in Table 8. Two policies do not specify what constitutes an acceptable or unacceptable LOS or change in LOS.

Table 8. Level of Service Criteria by State DOT.

State DOT	LOS Threshold
Michigan	If LOS is D or lower part of C
Idaho	No specific grade mentioned
Nevada	No specific grade mentioned
North Dakota	LOS should not be less than 2 grades

CHAPTER IV

ANALYSIS

This chapter examines the differences in the popularity of the various criteria used to evaluate proposed lane closures. The data gathered from 41 state transportation agencies is analyzed to provide the frequency of use across the nation. This is followed by an analysis of the criteria used within each geographic region, and comparisons between regions.

4.1 CRITERIA USED ACROSS THE NATION

Table 9 presents the breakdown of the 41 lane closure policies of state transportation agencies, which use one or more of the criteria for determining whether a proposed lane closure is approved. It is important to note that some state transportation agencies use multiple criteria in their decision process. Hence, the cumulative frequency exceeds the number of policies reviewed.

Table 9. Popularity of Criteria across the Nation

Criteria	Frequency
V/C	23
Delay	18
Queue length	6
LOS	4
Other	2

4.2 CRITERIA USED WITHIN REGIONS

This section examines whether lane closure policies have similarities within geographic regions. The thought is that these state transportation agencies may compare themselves to their neighbors, share information, and learn what works best from their neighbors To examine this idea the criteria used by the state transportation agencies in each of the five regions of the nation were compared. The five regions are: 1) Northwest; 2) Southwest; 3) Central and North Central; 4) Northeast and 5) Southeast as shown in Figure 1.

Figure 1. Regions within the USA

4.2.1 Northwest

The Northwest region includes Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, South Dakota, and Alaska. The data collected for these state transportation agencies were aggregated and the use of specific criteria is shown in Figure 2. The lane closure criteria most used in this region is delay.

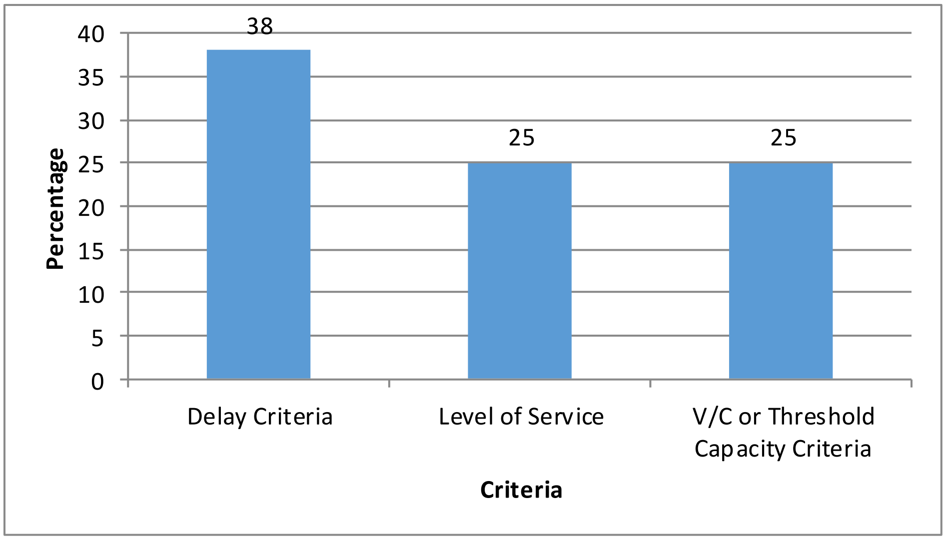

Figure 2. Criteria used in Northwest Region

4.2.2 Southwest

The Southwest region includes California, Nevada, Utah, Arizona, Colorado, New Mexico, Texas, and Oklahoma. The data collected for these state transportation agencies were aggregated and the use of specific criteria is shown in Figure 3. The delay criterion is dominant in this region. It is used by 63% of the state transportation agencies within the Southwest region.

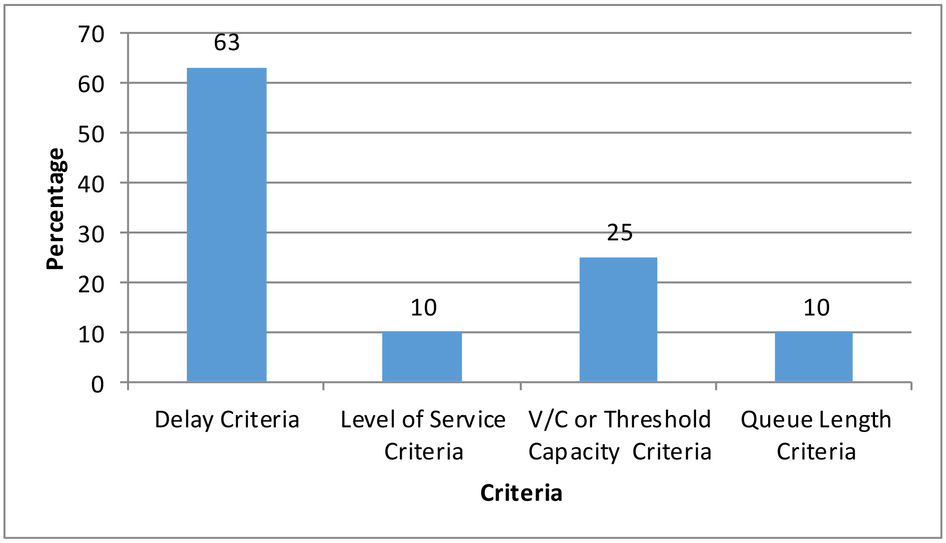

Figure 3. Criteria used in Southwest Region

4.2.3 Central and North Central

Minnesota, Wisconsin, Michigan, Ohio, Kentucky, Indiana, Illinois, Iowa, Missouri, Kansas, and Nebraska are in the Central and North Central region. The data collected for these state transportation agencies were aggregated and shown in Figure 4. The volume to capacity ratio or threshold capacity criteria is predominently used in this region. This criterion is used by 64% of the state transportation agencies in the Central and North Central region.

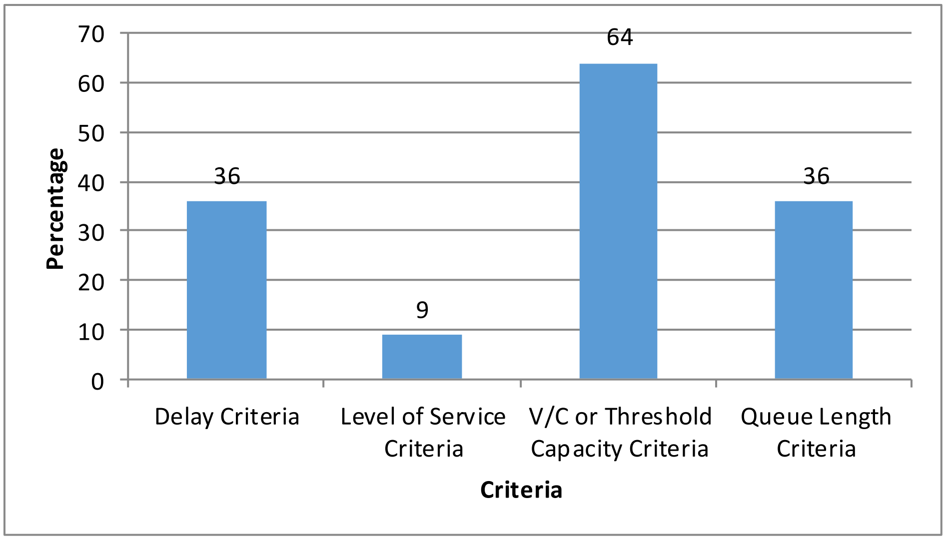

Figure 4. Criteria used in Central and North Central Region

4.2.4 Northeast

Maine, New Hampshire, Vermont, Massachusetts, New York, New Jersey, Rhode Island, Connecticut, Delaware, Maryland, Washington D.C, West Virginia, Pennsylvania, and Virginia are in the Northeast region. The data collected for these state transportation agencies were aggregated and are shown in Figure 5. The volume to capacity ratio or threshold capacity criteria is predominently used in this region. This criterion is used by 50% of the state transportation agencies in the Northeast region.

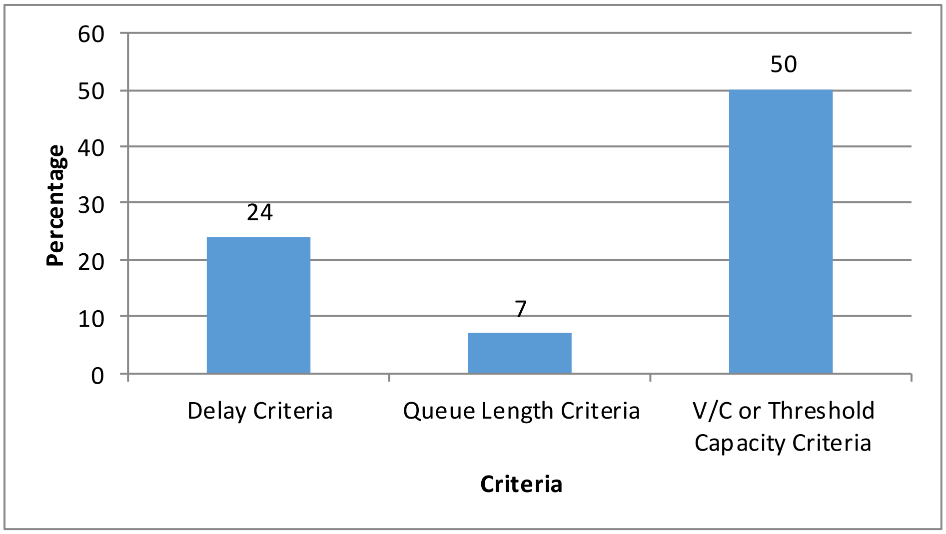

Figure 5. Criteria used in Northeast Region

4.2.5 Southeast

North-Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana are in the Southeast region. The data collected for these state transportation agencies were aggregated and are shown in Figure 6. The capacity criterion is dominant. This criterion is used by 56% of the state transportation agencies in the Southeast region.

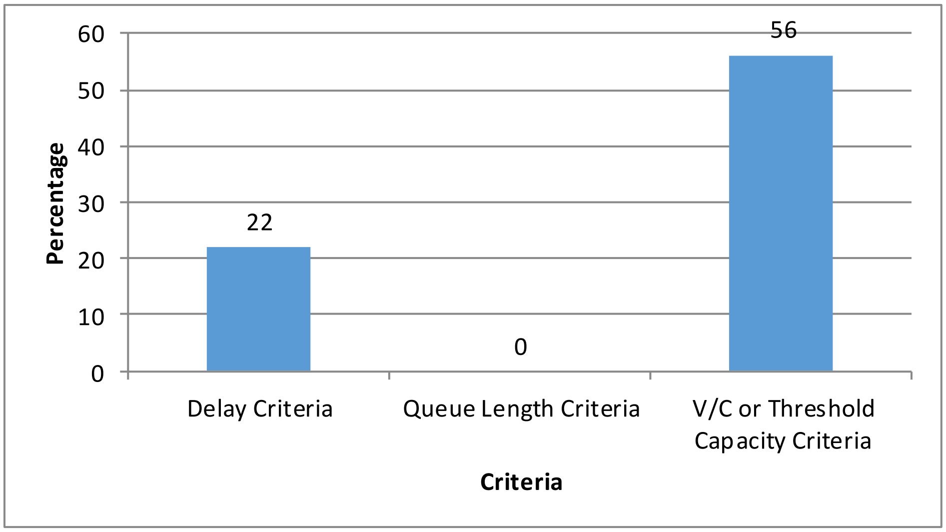

Figure 6. Criteria used in Southeast Region

The analysis of criteria used within regions shows that the volume to capacity (v/c) ratio or capacity criterion is dominant in the Central and North Central, Northeast and Southeast regions, while the delay criterion is dominant in the Northwest and Southwest regions.

4.3 CRITERIA USED ACROSS REGIONS

To explore the differences in the popularity of criteria being used across regions, the use of the delay, level of service, volume to capacity ratio, and queue length criteria is plotted separately. The results are shown in Figure 7 through Figure 10 and discussed in the following paragraphs.

The delay criterion was found to be dominant in the Northwest and Southwest regions. Figure 7 shows that this criterion is especially popular in the Southwest region with 63% of the state transportation agencies using this criterion for approving proposed lane closures. The popularity of the delay criterion is not as strong in the Northwest region.

Interestingly, the delay criterion was not found to be the dominant criterion in the Central and North Central region but is used almost as much as in the Northwest region.

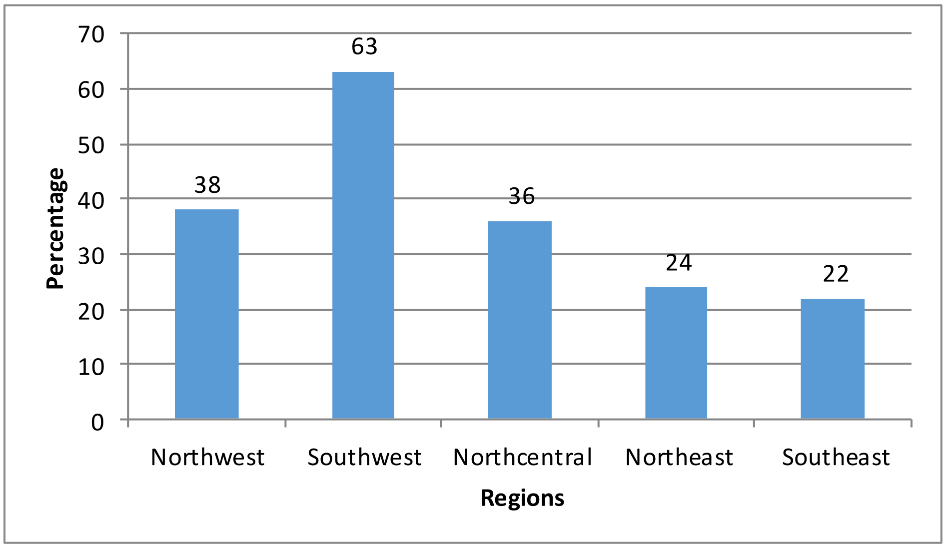

Figure 7. Use of Delay Criterion across Regions

The level of service criterion was not found to be dominant for any region. Taking a side-by-side look at its popularity across regions, Figure 8 shows that the level of service criterion is mainly used in the Northwest region. This criterion is not used in the Northeast or Southeast regions.

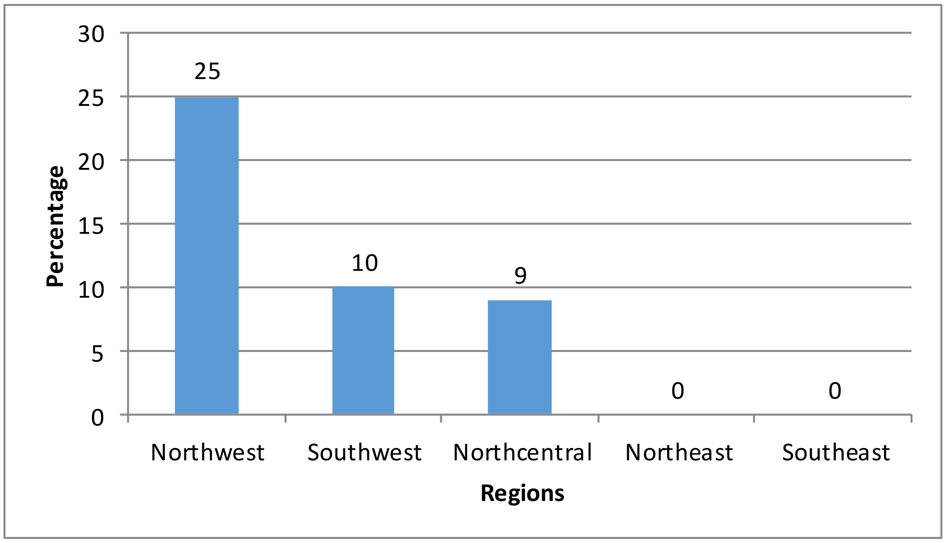

Figure 8. Use of Level of Service Criterion across Regions

The capacity criterion was found to be dominant in the Central and North Central, Northeast and Southeast regions. In each of these regions, at least half of the state transportation agencies use the capacity criterion. Figure 9 shows that capacity criterion is popular with 25% of the state transportation agencies in the Northwest and Southwest regions.

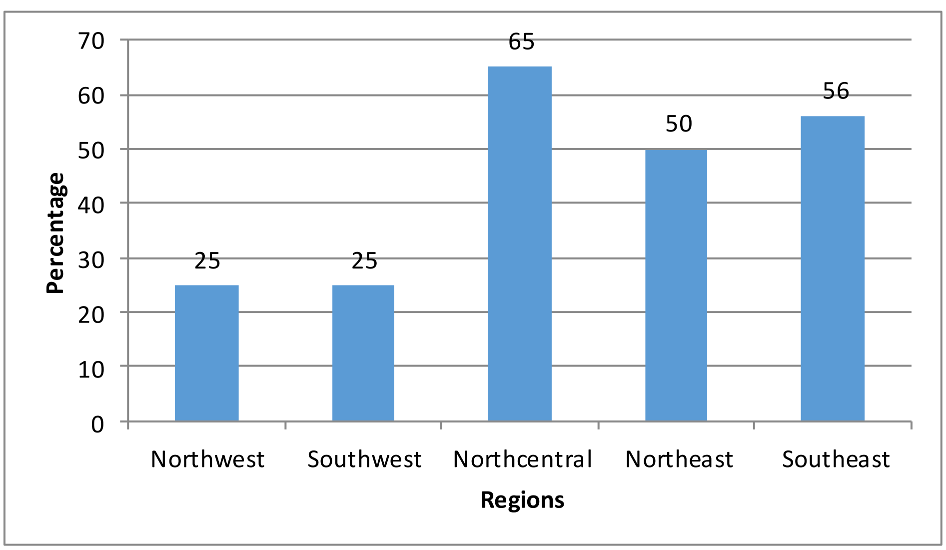

Figure 9. Use of Capacity Criterion across Regions

The queue length was not found dominant in any region. The side by side comparison in Figure 10 shows that this criterion is only popular in the Central and North Central region. The state transportation agencies in the Northwest and Southeast regions do not use this criterion

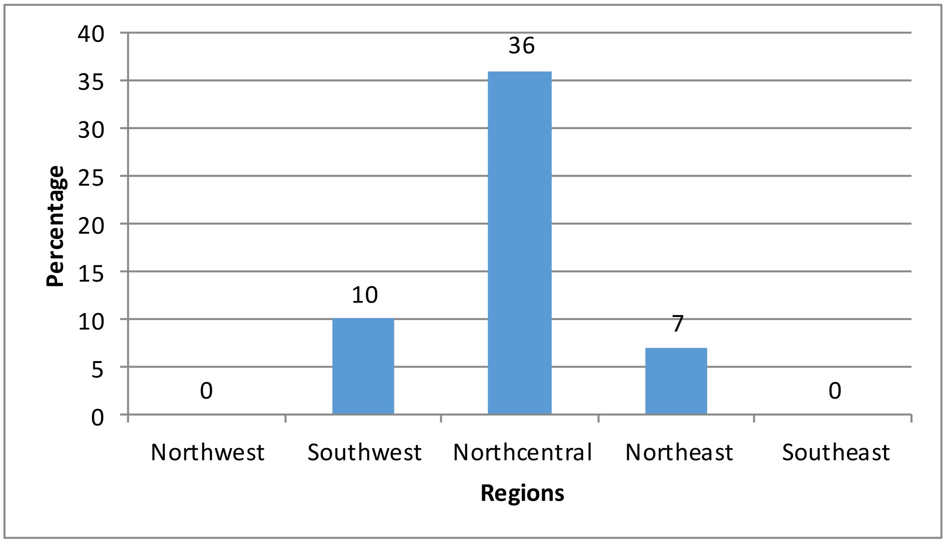

Figure 10. Use of Queue Length Criterion across Regions

CHAPTER V

CONCLUSIONS AND DISCUSSION

The use of different criteria by state transportation agencies across the nation to determine whether or not to approve proposed lane closures has been examined. These criteria include the following performance measures: delay, volume to capacity ratio, level of service, and queue length. Each of these criterions is defined in Chapter II along with a discussion about its appropriateness as a decision criterion. The data collection and cataloguing effort to obtain details about the use of these criteria by the state transportation agencies is described in Chapter III. The collected data was examined to determine whether any criterion has become popular across the nation, within geographic regions or across geographic regions. The results are provided in Chapter IV. In this chapter, the results from the previous section are used to draw some conclusions about the use of these criteria by state transportation agencies.

5.1 CONCLUSIONS

Applied to the problem of whether or not to allow a lane change to occur, a useful criterion is one that defines a particular threshold value, allowable change in value, or allowable difference from a reference value, for a specific performance measure. When considering the impact of a lane change on traffic operations, the volume to capacity measure, and the level of service ranking can be used to indicate whether congestion is expected to occur but cannot provide an estimate of the extent of that congestion. Measures such as the queue length and delay describe the extent of queuing.

Documentation about lane closure policies, procedures, and processes were acquired for 41 of 50 state transportation agencies. Information from 25 was readily available on-line. For the remaining 25, requests were made by email and/or telephone. Not all states had a defined work zone policy that dealt with the impacts of closing lanes. This is rather surprising finding given that the update to the work zone regulations, 23 CFR 630 Subpart J, require state transportation agencies to develop their own work zone safety and mobility policies and these policies must include procedures for addressing the anticipated impacts of individual projects that are expected to cause significant disruption.

The acquired documentation was reviewed and the criteria used for making decisions about allowing lane closured was extracted and catalogued. These data were then examined for trends across the nation, within 5 geographic regions, and across those same regions. From the analysis of 41 state transportation agency lane closure policies, it was found that the predominant criterion in use across the nation is the volume to capacity criterion. The conclusion drawn from this result is that more state transportation agencies are concerned about identifying whether congestion will occur than determining the extent of that congestion.

The popularity of these measures was examined within each of the following 5 geographic regions: Northwest; Southwest, Central and North Central, Northeast; and Southeast. In the Central and North Central, Northeast and Southeast regions, the volume to capacity criterion was found to be most popular while in the Northwest and Southwest regions the delay criterion was found to be most popular.

The popularity of the different criteria across the 5 regions was examined. The results showed that the delay criterion is most popular in the Southwest region, the level of service criterion is most popular in the Northwest region, and both the capacity and queue length criteria are most popular in the Central and North Central region.

The most surprising result was that the use of a queue length criterion is popular only in the Central and North Central region. This result is surprising given that the queue length is probably the easiest performance measure to see in the field. If the queue length is not being used to determine whether a lane closure is allowed, it is unlikely that the queue length is being used to determine whether allowed lane closures are performing as expected.

5.2 DISCUSSION

As mentioned earlier, the studies by Maze and Weigand (2007), and Bourne et al. (2010) compared the lane closure policies of seven and fifteen states respectively. One of the objectives of this study was to improve upon those two studies by cataloging and comparing the lane closure policies of all 50 states. While information could not be gathered from all of the states, this study managed to compare the lane closure policies of 41 states, a significant improvement on the previous studies. In that sense, this paper adds to the current understanding of the variety of criteria being used and their popularity across the nation, within regions and across regions.

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