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Abstract

Assessing the safety and mobility impacts of work zones across the project development phases of road construction and maintenance projects is an emphasis area of the Federal Highway Administration's Final Rule on Work Zone Safety and Mobility[1] (Final Rule). Specifically, the design phase of developing traffic control plans requires performing a traffic analysis to estimate queue lengths, travel times, and delays to determine lane closure times. State departments of transportation (DOTs) must comply with the requirements of the Final Rule by October 2007. To this end, this study was conducted to provide the Virginia Department of Transportation (VDOT) with the state-of-the-practice tools that are available and used by other state agencies for estimating the traffic impacts at work zones.

The researcher found that all models based on the *Highway Capacity Manual* (HCM) assume capacity as an exogenous variable that is given as input to the model; delay and queue length are dependent on capacity. A good estimate of the capacity of a work zone bottleneck is essential to obtain an accurate estimate of traffic impacts. The capacity charts in HCM 1994 were determined for work zones in Texas based on studies conducted before 1982. Based on the recommendations in HCM 2000, it is clear that the 1994 capacity charts significantly under-predict the capacity values at short-term freeway work zones. However, it is possible to obtain realistic capacity estimates from HCM 2000 by using base capacity values specific to the state and applying the necessary adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Data intensiveness, level of effort, and accuracy of the estimates are the key elements state DOTs use to choose the tools for traffic impact analysis. It can be safely assumed that most of the HCM-based tools are easy to use, are not data intensive, and generate quick results, with the exception of QuickZone, which could be data intensive and might require greater user effort. Many state DOTs use the size of the project as an element. Comprehensive tools such as QuickZone and microscopic simulation that are highly detailed and incorporate traveler response to the prevailing traffic conditions might be suitable for use for large projects. There is evidence that simple spreadsheet models and the QUEWZ model produce more accurate estimates of traffic impacts than do QuickZone and microscopic simulation. The inability of many available traffic simulation models to model the oversaturated conditions at work zone bottlenecks is one reason for the erroneous estimates.

The conclusions in this study should help VDOT choose the appropriate tool(s) for estimating the traffic impacts in and around work zones. This is a very high priority for VDOT's Traffic Engineering Division as it works on the development of an agency-wide plan to comply with the Final Rule for roll out by the end of 2006.

FINAL REPORT

ESTIMATION OF TRAFFIC IMPACTS AT WORK ZONES: STATE OF THE PRACTICE

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(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

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ABSTRACT

Assessing the safety and mobility impacts of work zones across the project development phases of road construction and maintenance projects is an emphasis area of the Federal Highway Administration's Final Rule on Work Zone Safety and Mobility[1] (Final Rule). Specifically, the design phase of developing traffic control plans requires performing a traffic analysis to estimate queue lengths, travel times, and delays to determine lane closure times. State departments of transportation (DOTs) must comply with the requirements of the Final Rule by October 2007. To this end, this study was conducted to provide the Virginia Department of Transportation (VDOT) with the state-of-the-practice tools that are available and used by other state agencies for estimating the traffic impacts at work zones.

The researcher found that all models based on the *Highway Capacity Manual* (HCM) assume capacity as an exogenous variable that is given as input to the model; delay and queue length are dependent on capacity. A good estimate of the capacity of a work zone bottleneck is essential to obtain an accurate estimate of traffic impacts. The capacity charts in HCM 1994 were determined for work zones in Texas based on studies conducted before 1982. Based on the recommendations in HCM 2000, it is clear that the 1994 capacity charts significantly under-predict the capacity values at short-term freeway work zones. However, it is possible to obtain realistic capacity estimates from HCM 2000 by using base capacity values specific to the state and applying the necessary adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Data intensiveness, level of effort, and accuracy of the estimates are the key elements state DOTs use to choose the tools for traffic impact analysis. It can be safely assumed that most of the HCM-based tools are easy to use, are not data intensive, and generate quick results, with the exception of QuickZone, which could be data intensive and might require greater user effort. Many state DOTs use the size of the project as an element. Comprehensive tools such as QuickZone and microscopic simulation that are highly detailed and incorporate traveler response to the prevailing traffic conditions might be suitable for use for large projects. There is evidence that simple spreadsheet models and the QUEWZ model produce more accurate estimates of traffic impacts than do QuickZone and microscopic simulation. The inability of many available traffic simulation models to model the oversaturated conditions at work zone bottlenecks is one reason for the erroneous estimates.

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FINAL REPORT

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INTRODUCTION

Assessing the safety and mobility impacts of work zones across the project development phases of road construction and maintenance projects is an emphasis area of the Federal Highway Administration's (FHWA) Final Rule on Work Zone Safety and Mobility[1] (Final Rule). Specifically, the design phase of developing traffic control plans requires performing a traffic analysis to estimate queue lengths, travel times, and delays to determine lane closure times. State departments of transportation (DOTs) must comply with the requirements of the Final Rule by October 2007. Traffic impact analysis can be carried out based on the experience with similar projects, by the use of analytical queuing models, or through microscopic simulation. FHWA has developed the QuickZone[2] program, an analytical model, to facilitate this type of analysis by DOTs. Several DOTs have developed their own analytical tools, mainly spreadsheet based, that are easy and efficient to use.

PURPOSE AND SCOPE

The purpose of this study was to provide the Virginia Department of Transportation (VDOT) with the state-of-the-practice tools that are currently available for estimating traffic impacts at work zones. The scope of this project included a review of the relevant literature, the identification of available tools, and a survey of the VDOT districts and the 49 other state DOTs regarding the state of the practice.

The different tools available for estimating traffic impacts were not evaluated quantitatively using field data.

METHODS

Three tasks were carried out to achieve the purpose of the study:

1. *A review of the relevant literature.* An extensive literature review of the traffic impact analysis tools used to estimate the traffic impacts at work zones was conducted. Studies that have documented the use of analytical and simulation approaches were obtained and reviewed from the following sources: TRISOnline,

Virginia Transportation Research Council Library, the TLCat and TRANSPORT databases, and the University of Virginia Library.

2. *Identification of tools to assess the traffic impacts of work zones.* The work zone traffic impact analysis tools were identified mainly through the literature review and the survey of current practices in state DOTs.

3. *A survey of VDOT districts and the 49 other state DOTs regarding the state of the practice with regard to estimating the impacts of work zones on traffic.* A questionnaire (Appendix B) was developed to focus on (1) tools/approaches used for capacity estimation and (2) tools/approaches used for queue length and delay estimation. The questionnaire was sent by email to the district traffic engineers in the nine VDOT district offices. Then, the questionnaire was emailed to state traffic engineers in the remaining 49 states. Telephone calls were made to the respondents who did not respond to the survey initially, and the questionnaire was sent to them again by email.

RESULTS

Literature Review

Roadway capacities at work zones are lower than the capacities under normal operating conditions. Dudek and Richards[3] reported the findings of capacity studies at 37 sites in Texas. The ranges of observed work zone capacities for six lane closure combinations (3→1, 2→1, 5→2, 4→2, 3→2, and 4→3, where notation $\alpha \rightarrow \beta$ means out of α total lanes, β lanes are open for travel) were reported. These data were used to develop a chart showing the cumulative distribution of the work zone capacities. The *Highway Capacity Manual* (HCM) 1994[4] (and the 1985, 1987, 1993, 1998 editions) incorporated this chart (see Figure A-1, Table A-1, and Table A-2 of Appendix A) as a procedure to determine the capacity at work zones. The HCM also shows the capacity values for different types of work at the work zones, adapted from the same study by Dudek and Richards.[3]

Krammes and Lopez[5] conducted research on work zones in major urban areas in Texas (Austin, Dallas, Houston, and San Antonio) where extensive frontage roads running parallel with the freeway function as an alternative to bypass the congested freeway conditions. Data were collected at 33 sites between 1987 and 1991 to update the capacity values for short-term freeway work zone lane closures. The researchers found that the new capacity values of short-term freeway work zone lane closures of 2→1, 3→2 lane closures were significantly higher than the values reported in HCM 1994. HCM 2000[6] incorporated these findings. Unlike the capacity charts used in HCM 1994, a base capacity value of 1,600 pcphpl is used for capacity computations in HCM 2000. This base value is adjusted (through the application of adjustment factors), using professional judgment and simple empirical equations, for conditions that influence work zone capacity: intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Dixon and Hummer[7] conducted capacity studies at North Carolina work zones as they believed that the capacity values reported in HCM 1994 were applicable only to Texas. They collected capacity data at 24 short-term freeway work zones during 1994 and 1995. They found that North Carolina work zone capacities were higher than the HCM capacities by at least 10 percent (see Table A-3 of Appendix A).

Karim and Adeli[8] developed a neural network-based tool for the estimation of capacity and delay at work zones. The model considers 11 parameters in the estimation of capacity including number of lanes, number of open lanes, layout, percent trucks, grade, and intensity of work. The justification for using neural networks for this problem is that the functional form of the relationship between capacity and the identified independent variables is not known. This model is incorporated into a decision support system, IntelliZone (Jiang and Adeli[9]), which is easy to use and quick in estimating the results. After estimating the capacity, IntelliZone uses a deterministic queuing model to predict the queue length and delay.

Al-Kaisy and Hall[10] studied freeway capacities at six long-term work zone sites in Ontario, Canada. They found that all six sites had base capacity values lower than the HCM base capacity value. A generic capacity model having a multiplicative form was proposed for capacity estimation at long-term work zones, as it produced better estimates for the effect of heavy vehicles when compared to the estimates of the additive form model.

Sarasua et al.[11] conducted a study to determine the base capacity of short-term freeway work zones in South Carolina and eventually to determine the work zone capacity using equations derived from HCM 2000. Traffic volume, speed, and queue length data were collected at 22 sites on four interstates over a 1-year period. A straight line was fitted between speed and density based on linear regression. Using this equation along with the speed-flow-density relationship, the maximum value of flow, i.e., base capacity, was obtained. This base capacity value (1,460 pcphpl) was much higher than the threshold lane volume (1,230 pcphpl) currently used by the South Carolina DOT for deciding lane closure times. They also conducted a survey of 11 state agencies and found that the South Carolina DOT's threshold value was significantly lower than the value used by all 11 agencies (see Table 1).

Schnell et al.[12] evaluated traffic flow analysis tools applied to work zones. Highway Capacity Software (HCS), Synchro, CORSIM, NetSim, QUEWZ 92, and the Ohio DOT spreadsheet were used to estimate the capacity and queue length at four work zones on multilane freeways in Ohio. The results were compared with the field data. The simulation models could

Table 1. Threshold Lane Volumes Adopted by DOTs to Determine Periods When Short-Term Work Zone Lane Closures Can Be Allowed[11]

State	Threshold Lane Volume	Threshold Lane Volume Determination
Connecticut	1,500 vphpl to 1,800 vphpl	Experience and HCM
Missouri	1,240 vphpl	HCM and management decisions
Nevada	1,375 vphpl to 1,400 vphpl	Experience
Oregon	1,400 pcphpl to 1,600 pcphpl	Experience, observations, and *Transportation and Traffic Engineering Handbook*
South Carolina	800 vphpl or 1,230 pcphpl	HCM
Washington	1,350 vphpl	QUEWZ
Wisconsin	1,600 pcphpl to 2,000 pcphpl	HCM

not be calibrated for oversaturated conditions that existed at the work zones, and even after calibration, these models consistently underpredicted the queue lengths. QUEWZ 92 was the most accurate in estimating the work zone capacity. When this capacity estimate was used in the Ohio DOT spreadsheet, it produced the most realistic estimates of queue lengths as compared to the estimates from other tools.

Chitturi and Benekohal[13] compared the performance of QUEWZ 92, FRESIM, and QuickZone with field data at 11 freeway work zone locations in Illinois. Some of these work zones did not have queues. The results of the study showed that none of these models gave an accurate representation of real field conditions. QUEWZ 92 overestimated the capacity and underestimated the queue lengths, mainly because of its use of an outdated speed-flow relationship. FRESIM consistently overestimated the speeds under queuing conditions, overestimated the queue lengths for half of the cases, and underestimated the queue lengths for the other half of the cases. QuickZone consistently underpredicted the queue length and delay as compared to the field data.

Kim et al.[14] developed a multiple regression model to estimate the capacity at work zones as a function of several key independent variables such as number of closed lanes, percentage of heavy vehicles, grade, and work intensity. To develop this model they collected data at 12 work zone sites in Maryland. They found that their regression model produced better estimates as compared to the HCM model.

Work Zone Traffic Impacts Assessment Tools

This section summarizes the tools identified through the literature review and surveys for estimating work zone traffic impacts. The important aspects of each tool and the strengths and weaknesses of the tools based on ease of use, input data requirements, and accuracy of the produced estimates are described. The references provide detailed descriptions. A summary of the tools is given in Table 2. In this report, work zone lane closure by default means a short-term lane closure unless otherwise stated.

HCM-Based Tools

HCM 1994

HCM 1994[4] (and 1985, 1987, 1993, 1998 editions) reports the range (see Appendix A) of observed capacities and the corresponding average capacities of freeway work zones in Texas. It then illustrates a graphical technique to estimate the number of vehicles in the queue and the queue length. Cumulative plots of demand and supply versus time-of-day show how much of the demand is satisfied and how much is backed up as queue. It is important to note that the capacity charts in HCM 1994 were determined for work zones in Texas and that the studies were conducted before 1982. Based on the more recent data collection efforts that resulted in the HCM 2000 recommendations, it is clear that the HCM 1994 capacity charts significantly underpredict the capacity values at short-term freeway work zones, at least for 2→1 and 3→2 lane closures. There is no change in the capacity values of long-term construction sites in HCM 1994 and HCM 2000.

- *Strengths:* Low input data requirement, quick results, and ease of use.

- *Weaknesses:* Outdated capacity values. Since the capacity values were obtained for Texas work zones, these values may not be realistic estimates of capacities at work zones in other states. Due to the simplistic nature of the input, it is not possible to account for the effects of traffic diversion at work zones. Ullman and Dudek[15] contend that this inability of analytical models could lead to significant overestimation of traffic impacts.

HCM 2000

For short-term work zones, HCM 2000[6] suggests using a base capacity value and applying adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in the vicinity of the work area. The proposed base capacity value of 1,600 pcphpl is obtained from Texas work zone studies (studies conducted in late 1980s to early 1990s). Long-term work zone capacities are still the same as those reported in HCM 1994. HCM 2000 however does not provide any approach for estimating the queue lengths.

- *Strengths:* Low input data requirement, quick results, and ease of use.

- *Weaknesses:* Determining adjustment factors could be complicated. All other weaknesses of the HCM 1994 are applicable except the "outdated capacity values."

Spreadsheets

Several DOTs use spreadsheet-based tools to estimate the traffic impacts at work zones. The spreadsheets basically estimate the output (delay and queue lengths) using the graphical procedure explained in HCM, along with analytical equations. Calculations can be carried out in a spreadsheet such as Microsoft Excel®, for example, the New Jersey DOT spreadsheet,[16] and the Ohio DOT spreadsheet.[17] Inputs to the spreadsheet include vehicle demand for every time interval, number of open lanes, roadway capacity, percentage of trucks, etc.

- *Strengths:* Minimal input data, quick results, and ease of use.

- *Weaknesses:* Determining adjustment factors could be complicated. All other weaknesses of HCM 1994 are applicable except the "outdated capacity values." Since they do not include the effect of traffic diversion at work zones, at best, only a percentage of diverted traffic could be subtracted. Therefore, these tools tend to overestimate the queue lengths and delays. The issue of traffic diversion is not as important for rural roads as it is for urban high-volume roads (Ullman and Dudek[15]). Urban areas have closely spaced freeway interchanges, and a significant portion of drivers take the ramps or use alternate routes to avoid the work zone queues. In addition, the demand at entrance ramps upstream of the bottleneck will not be the same as the demand under normal conditions; it would be lower. The result of these traffic diversions is that the queue lengths do not continuously increase with time; instead they stabilize after sometime.

QUEWZ

Queue and User Cost Evaluation of Work Zones (QUEWZ)[18] is a DOS-based analysis tool developed by the Texas Transportation Institute that can be used for estimating the traffic impacts of work zone lane closures. Input data include hourly traffic volumes, percentage of trucks, capacity values under normal conditions, lane closure hours, work zone configuration, etc. QUEWZ-98 uses the capacity calculation equation shown in HCM 2000 to come up with a value for the work zone capacity. There is also an option for changing the base capacity value. It has a diversion algorithm to adjust traffic demand based on the vehicles that may switch to alternate routes. This algorithm is based on observations of freeway work zones in Texas where parallel frontage roads are available. For the calculation of queue length, it uses the procedure illustrated in HCM 1994.

- *Strengths:* Slightly more data intensive than earlier methods. Ease of use and the capability to produce quick estimates. Application does not require the user to have a spreadsheet program to run the model; it is a stand-alone program.

- *Weaknesses:* The diversion algorithm is simplistic and does not necessarily produce the exact percentage of diverted traffic because it is based on atypical freeways with frontage roads.

QuickZone

QuickZone[(2,19)] is an analytical tool that can be used for estimating the traffic impacts of work zones. It was originally developed by Mitretek Systems for FHWA to be an easy-to master tool that allows for fast and flexible estimation of work zone traffic impacts. It is written as a program within Microsoft Excel. This platform was selected to provide ease of use for practitioners already familiar with spreadsheet-based tools. QuickZone is an open-source software enabling DOTs to customize it as they deem applicable to the conditions in their state (MD-QuickZone[20] is an example of Maryland's customization of QuickZone). The data input requirement for QuickZone is greater than that for the simple HCM-based approaches discussed earlier. Network data describing the mainline roadway under construction and the available alternative roadways in the corridor need to be given as input to the model, along with the hourly traffic volumes (travel demand) and capacities of the roadway sections (normal conditions and restricted conditions). QuickZone compares expected travel demand with proposed capacity by facility on an hourly basis to estimate delay and mainline queue length.

- *Strengths:* Comprehensive and highly detailed tool that incorporates various factors that have an impact on the delays occurring at work zones. Traveler response to the prevailing traffic conditions such as route changes, peak-spreading, mode shifts, and trip losses are applied while estimating the queues and delays.

- *Weaknesses:* The application of QuickZone would involve more time and effort than the application of the simple spreadsheet models.

DELAY Enhanced 1.2

DELAY Enhanced 1.2[21] is an application developed by Martin Knopp of FHWA's Utah Division to estimate the traffic impacts of incidents quickly. This model could be applied to short-term work zone lane closures as well. It also uses the same deterministic queuing model used by other tools described earlier. The program has a good graphical user interface, which makes it easier for the user to input the data and visualize the queue length (the plot of demand versus time).

- *Strengths:* Minimal input data, quick results, and ease of use. Application does not require the user to have a spreadsheet program to run the model; it is a standalone program.

- *Weaknesses:* All the weaknesses listed earlier for HCM-based analytical models are applicable here.

Microscopic Simulation Programs

Microscopic simulation programs such as CORSIM, VISSIM, SimTraffic, etc., can be used to estimate the traffic impacts at work zones. The user must code the roadway network, input the traffic volumes, and run the traffic simulation. Instead of estimating the capacity based on analytical equations (such as that of HCM 2000), in simulation it can be obtained as the maximum throughput past the bottleneck location under queue conditions or based on any other definition of capacity. Similarly, queue lengths and delays at desired time points can be obtained as outputs from the model. Simulation models need to be calibrated and validated to the network in question to produce realistic results during analyses.

- *Strengths:* Flexibility to model complex work zone projects. Ability to estimate system-wide traffic impacts, not just near the work zones, attributable to lane closures.

- *Weaknesses:* More time and effort required than with any other available methods. Literature has consistently mentioned the inability of microscopic simulation in modeling saturated conditions accurately.[12,13]

Table 2. Tools Available for Estimating Work Zone Traffic Impacts

<table>
<tr><th>Tool</th><th>Description</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>HCM 1994</td><td>• Reports range of observed capacities and corresponding average capacities of freeway work zones in Texas
• Illustrates graphical technique to estimate queue length</td><td>• Low input data requirement
• Quick results
• Easy to use</td><td>• Outdated capacity values
• Overestimates traffic impacts due to inability to account for effects of diversion</td></tr>
<tr><td>HCM 2000, Spreadsheet, QUEWZ, Delay Enhanced 1.2</td><td rowspan="2">• Proposes using base capacity value and applying adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in vicinity of work area
• Queue estimation technique is same as graphical method in HCM 1994</td><td>• Low input data requirement
• Quick results
• Easy to use</td><td>• Determining adjustment factors could be complicated
• Overestimates traffic impacts due to inability to account for effects of diversion</td></tr>
<tr><td>QuickZone</td><td>• Comprehensive and highly detailed, incorporates various factors that impact delays at work zones
• Traveler response to prevailing traffic conditions, e.g., route changes, peak-spreading, mode shifts, trip losses, are applied while estimating queues and delays</td><td>• High input data requirement (detailed roadway network coding of mainline and alternative roadways)
• Greater time and effort required from user</td></tr>
<tr><td>Microscopic Simulation</td><td>Traffic simulation programs used for operational analysis are used for simulating work zone traffic</td><td>• Can estimate system-wide traffic impacts
• Can model complex projects</td><td>• High input data requirement (detailed roadway network coding of mainline and alternative roadways)
• Greater time and effort required from user
• Cannot model saturated (and oversaturated) traffic conditions</td></tr>
</table>

Survey of the State of the Practice

VDOT Districts

Eight of the nine VDOT districts responded to the survey. The results for these districts are summarized in Table 3.

Most of the districts used a combination of HCM guidelines and experience to obtain capacity estimates. In general, HCM, Synchro, and CORSIM were used for estimating traffic impacts. The Richmond, Salem, and Staunton districts have developed an easy-to-use spreadsheet program to estimate the traffic impacts. The Richmond District further develops lane closure charts (see Appendix C consisting of lane closure schedules that have the minimum impact on traffic.

Table 3. Responses of VDOT Districts Regarding Practices for Assessing Work Zone Traffic Impacts

District	Tools Used for Estimating Capacity	Tools Used for Estimating Traffic Impacts: Queues and Delays
Bristol	ADT and experience	Experience
Culpeper	QUEWZ-98	QUEWZ-98
Fredericksburg	Did not respond to survey	Did not respond to survey
Hampton Roads	Experience and HCM	Highway Capacity Software (HCS) (implements HCM 2000 procedures), Synchro, CORSIM
Lynchburg	Experience	Experience
Northern Virginia	Traffic counts from VDOT database	None currently
Richmond	HCM	Synchro and CORSIM
Salem	HCM and experience	Experience and CORSIM
Staunton	HCM when needed	HCM (Spreadsheet), HCS, Synchro

Other State DOTs

Nineteen states responded to the survey. Their results are summarized in Table 4. Information related to 10 more states shown in Table 5 was obtained through related literature.

The most common tool for determining the capacity value at work zone bottlenecks appears to be the experience of the DOT personnel. The HCM (1994 version[4] or 2000 version[6]) is used on a limited basis, and a few states use no formal procedure to arrive at the capacity value. For traffic impacts estimation, HCM-based tools, especially spreadsheets, are the most popular among DOTs. QuickZone, microscopic simulation, and planning tools are used rarely, if at all. However, a few states are considering using QuickZone for future projects.

DISCUSSION

All models for estimating the traffic impacts of work zones based on the *Highway Capacity Manual* (HCM) assume capacity as an exogenous variable that is given as input to the model; delay and queue length are dependent on capacity. A good estimate of the capacity of a work zone bottleneck is essential to obtain an accurate estimate of traffic impacts. The capacity charts in the 1994 HCM were determined for work zones in Texas based on studies conducted before 1982. Based on the recommendations in the 2000 HCM, it is clear that the 1994 capacity charts significantly underpredict the capacity values at short-term freeway work zones. However, it is possible to obtain realistic capacity estimates from the 2000 HCM by using base capacity values specific to the state and applying the necessary adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Data intensiveness, level of effort, and accuracy of the estimates are the key elements state DOTs use to choose the tools for traffic impact analysis. It can be safely assumed that most of the HCM-based tools are easy to use, not data intensive, and generate quick results, with the exception of QuickZone, which could be data intensive and require greater user effort. Many

Table 4. Responses from State DOTs Regarding Current Practices for Assessing Work Zone Traffic Impacts (survey conducted in December 2005 through January 2006)

State	Tools Used for Estimating Capacity	Tools Used for Estimating Traffic Impacts: Queues and Delays
Colorado	Guidelines in the "Lane Closure Policy" document	Synchro/Sim Traffic and HCS
Delaware	HCM	Delaware Transportation Model, HCS, Synchro, CORSIM
Florida	Chapter 10 of FDOT's Plan Preparation Manual[22] and HCS 2000	Chapter 10 of FDOT's Plan Preparation Manual[22] and HCS 2000
Hawaii	HCM	• HCM and experience • QuickZone in the future
Kansas	None Experience, if any	None
Kentucky	Experience, no formal procedure	• No formal procedure • Rare use of CORSIM
Maine	Experience and HCM 1994	• Spreadsheet and Synchro/SimTraffic for partial closures • TRIPS (Travel Demand Model) for full closures of bridges or highways
Massachusetts	Start with base capacity value and apply adjustment factors for lane widths, truck percentages, grades, etc. (similar to HCM)	• Spreadsheet model (BASICQUE) based on 'Planning and Scheduling Work Zone Traffic Control' publication of FHWA (Chapter 2, page 15), published in 1981 • Also use QuickZone, TRANPLAN for complex projects
Montana	No estimation	HCM, if used
Nevada	HCM 2000	• Currently Synchro, CORSIM, HCM • QuickZone in the future
New Jersey	HCM 1994	Spreadsheet based on HCM
Ohio	QUEWZ-98	Ohio DOT Spreadsheet[17]
Oregon	• Currently experience • Actual traffic counts in future	• Currently CORSIM • Aim to develop graph from CORSIM results and validate it with field data
Rhode Island	HCM 1997	• Mostly HCM and experience • Occasionally QuickZone
Tennessee	Mix of actual traffic counts and HCM procedures	Web-based Queue/Delay Prediction Model under development
Texas	QUEWZ	QUEWZ and CORSIM
Washington	Mix of actual traffic counts and HCM procedures	• Primarily QUEWZ • Limited use of QuickZone
Wisconsin	Experience and literature	Mainly spreadsheet based on HCM, but occasionally CORSIM and QuickZone
Wyoming	HCM and Synchro	HCM and Synchro

state DOTs use the size of the project as an element. Comprehensive tools such as QuickZone and microscopic simulation that are highly detailed and incorporate traveler response to the prevailing traffic conditions might be suitable for use for large projects. There is evidence that simple spreadsheet models and the QUEWZ model produce more accurate estimates of traffic impacts than do QuickZone and microscopic simulation. The inability of many available traffic simulation models to model the oversaturated conditions at work zone bottlenecks is one reason for the erroneous estimates.

Table 5. Current Practices for Assessing Work Zone Traffic Impacts in Selected DOTs

State	Tools Used for Estimating Capacity	Tools Used for Estimating Traffic Impacts: Queues and Delays
Alabama		Oklahoma DOT Spreadsheet[23]
Arizona		(QUEWZ)[24]
Arkansas		(QUEWZ)[24]
California	Experience and HCM	Spreadsheet based on HCM
Illinois	(HCS 2000, SIG/Cinema, HCM, and QUEWZ) [25]	(HCS 2000, SIG/Cinema, HCM-based Spreadsheet, QuickZone, and QUEWZ)[25]
Indiana	(Past data, HCM)[21]	(QUEWZ, QuickZone, Synchro, CORSIM)[21]
Maryland	MD-QuickZone (modified QuickZone) using HCM Value or University of Maryland Model or any user defined value[20]	MD-QuickZone (modified QuickZone)[20]
Oklahoma		Spreadsheet based on HCM[23]
Pennsylvania		Actively using QuickZone[24]
Utah		DELAY Software for small projects, MINUTP (comprehensive planning model) for large projects[21]

The conclusions in this study should help VDOT in choosing the appropriate tool(s) for estimating the traffic impacts in and around work zones. This is a very high priority for VDOT's Traffic Engineering Division as it works on the development of an agency-wide plan to comply with the Final Rule for roll out by the end of 2006.

CONCLUSIONS

- *From this study, it is not possible to conclude if one tool is better than the other at determining the impact of work zones on traffic; however, different tools might be appropriate in different situations in the same state.*

- *HCM 1994 capacity charts significantly underpredict the capacity values at short-term freeway work zones.* HCM-based models assume capacity as an exogenous variable that is given as input to the model and assume delay and queue length to be dependent on capacity. A good estimate of the capacity of a work zone bottleneck is essential to obtain an accurate estimate of traffic impacts at work zones. Capacity charts shown in HCM 1994 were determined for work zones in Texas based on studies conducted before 1982.

- *Few state DOTs have conducted capacity studies to determine capacity estimates at work zones in their states and obtained capacity values that were different from the HCM values.*

- *Realistic capacity estimates can be obtained from HCM 2000 by using base capacity values specific to the state and applying the necessary adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.*

- *It can be safely assumed that most of the HCM-based tools are easy to use, not data intensive, and generate quick results, with the exception of QuickZone, which could be data intensive and require greater user effort from the user.*

- *Many state DOTs decide on which tool to use based on the size of the project.* Comprehensive tools such as QuickZone and microscopic simulation are highly detailed and incorporate traveler response to the prevailing traffic conditions and might be suitable for use in large projects. Though QuickZone and microscopic simulation are detailed methods, some literature shows that the simple spreadsheet models and the QUEWZ model produce more accurate estimates of traffic impacts than the former ones. The inability to model the oversaturated conditions occurring at work zone bottlenecks was mentioned as one reason for the erroneous estimates obtained from simulation models.

SUGGESTIONS FOR FURTHER RESEARCH

1. *VDOT might want to consider conducting a quantitative evaluation of the different tools used to determine the impact of work zones on traffic.* Such tools would include QUEWZ, the HCM-based spreadsheet, QuickZone, and microscopic simulation programs. In such a study, the capacity, queue lengths, and delay estimates would be compared using field data collected across several work zones in Virginia. Evaluation criteria could include accuracy of results, ease of use, and time required to obtain results (which would be mainly dependent on input requirements, network coding, and model run time). Capacity values obtained in this way would be more applicable to work zones in Virginia than the base capacities reported from studies conducted in other states.

2. *VDOT might want to consider asking all districts to use a single methodology/tool to estimate the impact of work zones on traffic.* Alaska, Delaware, Florida, Kansas, Kentucky, Maine, Massachusetts, Montana, Nevada, New Jersey, Ohio, Rhode Island, Wisconsin (soon), and Wyoming have a standardized method. A study determining the advantages and disadvantages of such an approach might be appropriate.

COSTS AND BENEFITS ASSESSMENT

This report should help VDOT in choosing the appropriate tools for estimating the impacts of work zones on traffic in Virginia. Estimating traffic conditions in and around work zones is a high priority for VDOT’s Traffic Engineering Division, as they work to develop an agency-wide Final Rule plan for roll out by the end of 2006.

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APPENDIX A
WORK ZONE CAPACITY ESTIMATES

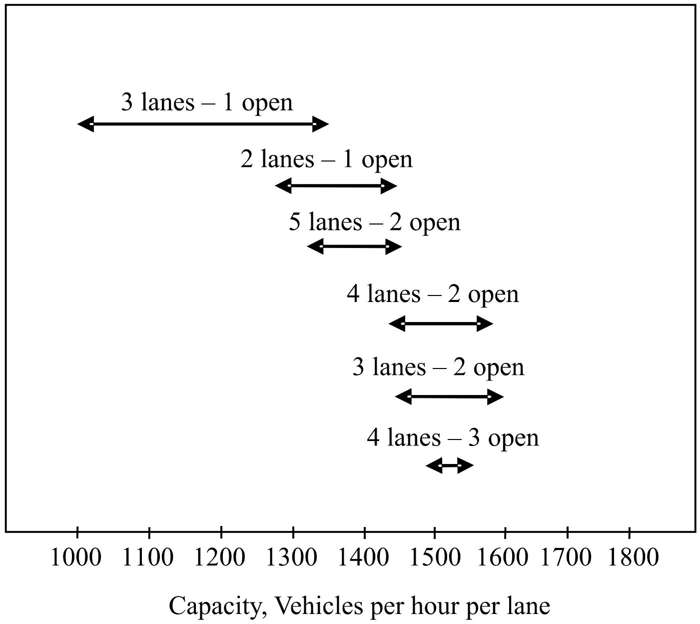

Figure A-1. Range of Observed Short-Term Work Zone Capacities Reported in HCM 1994[4]

Table A-1. Measured Average Short-Term Work Zone Capacities Shown in HCM 1994[4]

No. of Lanes		No. of Studies	Average Capacity	
α (normal)	β (open)		vph	vphpl
3	1	7	1,170	1,170
2	1	8	1,340	1,340
5	2	8	2,740	1,370
4	2	4	2,960	1,480
3	2	9	2,980	1,490
4	3	4	4,560	1,520

Table A-2. Capacity of Long-Term Work Zones as Reported in HCM 1994[4]

No. of Lanes		No. of Studies	Capacity Range (vphpl)	Average Capacity	
α (normal)	α (normal)			vph	vphpl
3	2	7	1,780-2,060	3,720	1,860
2	1	3	-	1,550	1,550

Table A-3. Comparison of Short-Term Work Zone Capacities in North Carolina and Texas[7]

No. of Lanes		North Carolina	Texas
Normal	Open	End of Taper Capacity (vphpl)	End of Taper Capacity (vphpl)
2	1	1,690	1,575
3	1	1,640	1,460

APPENDIX B
SURVEY QUESTIONNAIRE

Q) How do you estimate the Capacity at Work Zones?
A) ____
____

Q) What tools/software programs do you currently use for estimating the Traffic Impacts, mainly Queues and Delays, at Work Zones?
A) ____
____

Q) If different districts within the state are using different techniques, then please list each procedure separately?
A) ____
____

Q) Please provide us with any documentation/reports about these tools (e.g. if using Spreadsheet, please attach copies for our reference/review).
A) ____
____

APPENDIX C
LANE CLOSURE CHART

Table C-1. VDOT's Richmond District Sample Lane Closure Chart

I-64		
Exit 220 to Exit 214 2-lanes		
	WB Take 1 Lane	**EB** Take 1 Lane
12:00am	Work	Work
1:00	Work	Work
2:00	Work	Work
3:00	Work	Work
4:00	Work	Work
5:00	Work	Work
6:00	No Work	No Work
7:00	No Work	No Work
8:00	No Work	No Work
9:00	No Work	No Work
10:00	No Work	No Work
11:00	No Work	No Work
Noon	No Work	No Work
1:00	No Work	No Work
2:00	No Work	No Work
3:00	No Work	No Work
4:00	No Work	No Work
5:00	No Work	No Work
6:00	No Work	No Work
7:00	No Work	No Work
8:00	No Work	No Work
9:00	No Work	No Work
10:00	Work	Work
11:00	Work	Work
12:00	Work	Work

Source: http://insidevdot/C3/Traffic/Document Library/Richmond District Lane Closure Timing Guidance/Lane Restriction time chart All.xls.