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RESEARCH REPORT

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Synthesis of Research on Work Zone Delays and Simplified Application of QuickZone Analysis Tool

By

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16. Abstract

The objectives of this project were to synthesize the latest information on work zone safety and management and identify case studies in which FHWA's decision support tool QuickZone or other appropriate analysis tools could be applied. The results of the analysis showed that QuickZone was an efficient tool to macroscopically analyze traffic operations at work zones. It provides reliable planning-level estimates of delay and queue length that are comparable to that reported by microscopic simulation models. It can be used to analyze work zones in urban freeways, rural freeways, four-lane divided urban arterials and corridors, and two-lane rural highways. QuickZone, provides DOT staff with the opportunity to effectively analyze work zone projects and fully assess their impacts. It also provides DOT staff with a tool that can be used to reliably estimate work zone user cost, in the form of vehicular delay, for different project scheduling, phasing, delivery methods, and other traffic management alternatives. QuickZone, a Microsoft Excel application, is a fairly simple-to-use analysis tool. However, it requires extensive data input to fully represent the traffic flow profile throughout the work zone. QuickZone delay and queue length output are highly sensitive to calibration parameters such as saturation flow headway and lane capacity. Using site specific parameters will improve the model output. Average saturation flow headway and the corresponding lane capacity values for different road types in Idaho are provided in Table 4 in this report. These values are based on field measurements of saturation flow headway at different sites throughout Idaho. Realistic capacity estimates can be obtained using these values as base capacity values with adjustments following the Highway Capacity Manual 2000 procedures. Adjustments to the base value include: duration and intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Table of Contents

List of Tables

List of Figures

Executive Summary

The objectives of this project were to synthesize the latest information on work zone safety and management and identify case studies in which Federal Highway Administration's (FHWA) decision support tool QuickZone or other appropriate analysis tools could be applied. A literature search was performed to document previous work that has been completed on work zone traffic analysis and analysis tools. A survey of selected states Departments of Transportation (DOT) was conducted to determine common practice in the analysis of work zone traffic analysis and operations. The survey results showed that the most common tool for analyzing work zones appears to be the experience of the DOT personnel. The Highway Capacity Manual (HCM) 2000 was used on a limited basis, and a few states used no formal procedure to arrive at the capacity value. (1) For traffic impacts estimation, HCM-based tools, especially spreadsheets, were the most popular among DOTs. Microscopic simulation and macroscopic planning tools were used rarely, if at all. However, a few states, similar to ITD, were considering using QuickZone for future projects.

Existing microscopic and macroscopic work zone analysis tools were reviewed and assessed. The FHWA's QuickZone was used to analyze work zone traffic operations in 3 work zone case studies: an urban freeway work zone, a rural freeway work zone, and a 2-lane, 2-way rural highway work zone. (2) The study included applying the analysis tool to the case studies, documenting the input/output process for each tool, documenting of the results of each analysis, and identifying data necessary to calibrate and validate the models. The VISSIM microscopic simulation model was also used to analyze the operations of the rural freeway and 2-way rural highway work zones. Results of this analysis were used to develop a set of findings and recommendations for possible changes in relevant Idaho Transportation Department (ITD) manuals, best practices, and specifications. Finally, materials that can be used by ITD to train their staffs in how to analyze work zone traffic operations were developed.

The results of the analysis showed that QuickZone is an efficient tool to macroscopically analyze traffic operations at work zones. It provides reliable planning-level estimates of delay and queue length that are comparable to that reported by microscopic simulation models. It can be used to analyze work zones in urban freeways, rural freeways, 4-lane divided urban arterials and corridors, and 2-lane rural highways. QuickZone provides ITD staff with the opportunity to effectively analyze work zone projects and to fully assess their impacts. It also provides ITD staff with a tool that can be used to reliably estimate work zone user cost, in the form of vehicular delay, for different project scheduling, phasing, delivery method and other traffic management alternatives. QuickZone, a Microsoft Excel application, is a fairly simple-to-use analysis tool. However, it requires extensive data input to fully represent the traffic flow profile throughout the work zone. Traffic profile data includes: average annual daily traffic (AADT), hourly, daily, and monthly traffic variation, directional distribution, and percent of heavy vehicles. The data is available and can be obtained from ITD Automatic Traffic Recorder (ATR) data collected, archived and maintained by ITD Planning Division. A macro script to convert ATR data to QuickZone format data can significantly simplify QuickZone data input process for ITD staff.

QuickZone delay and queue length output are highly sensitive to calibration parameters such as saturation flow headway and lane capacity. Using site specific parameters will improve the model output. Average saturation flow headway and the corresponding lane capacity values for different road types in Idaho are provided in Table 4 in this report. These values are based on field measurements of saturation flow headway in different sites throughout Idaho. Realistic capacity estimates can be obtained using these values as base capacity values with adjustments following the HCM 2000 procedures.[1] Adjustments to the base value include: duration and intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Chapter 1
Introduction

Work Zone Safety and Mobility: An Overview

When transportation agencies engage in any type of construction--road preservation, making capacity additions and/or creating new routes--, they must, as a necessity, set up work zones. Work zones have several costs beyond the mere construction costs. Additional costs occur as a result of time lost by travelers, accidents and fatalities, and reduction of customer satisfaction.

According to a study done by the Texas Transportation Institute, motorists encountered an active work zone one out of every 100 miles driven on the national highway system (NHS) in 2001, representing over 12 billion hours of vehicle exposure to work zones. Motorists experienced a lane closure every 200 miles driven, representing slightly more than 6 billion miles of vehicle travel through work zones nationally.[3] A growing portion of highway capital expenditures are being allocated for roadway improvements, preserving existing roads and bridges. In 2004, expenditures for system preservation nationwide reached $36.4 billion; 79 percent of those capital expenditures involved active work zones on existing roads where traffic was present.[4] According to the Federal Highway Administration (FHWA), federal aid roadway improvement projects impacted an average of 23,745 miles per year from 1997 to 2001. In 2001 alone, an estimated 3,110 work zones were present on the NHS during the peak summer roadwork season. It is estimated that these work zones resulted in lost capacity of more than 60 million vehicles per hour per in a single two-week period. The impact of a work zone can also extend beyond the physical location of the construction itself, affecting safety and mobility miles away.[5]

In 1998, FHWA released a report titled *Meeting the Customer's Needs for Mobility and Safety during Construction and Maintenance Operations.*[6] The report stated that the delay costs incurred by road users from work zones typically are not considered when construction zones are planned. Very few state and local highway officials or construction contractors could determine the true cost of a road construction or improvement project, according to the study, even after the project was completed. In the overwhelming majority of cases, officials and contractors calculated only hard costs, such as labor and materials. However, every road project also incurs soft costs—the extra minutes or even hours spent by motorists and their passengers in negotiating the delays caused by work zones. The cost of traveler delay is rarely calculated.[6]

Work zones not only have an impact on capacity and the resulting costs of delay, but they also result in increased risk of accidents. More than 41,000 people were injured in 2003 as a result of motor vehicle crashes in work zones. This grew from 36,000 in 1996, an increase of 14 percent. Additionally, 105 fatal occupational injuries occurred at road construction sites. Based on information from National Highway Traffic Safety Administration’s Fatality Analysis Reporting System (FARS), 835 fatalities resulted from motor vehicle crashes in work zones in 2007.[7]

Work zones also have a negative effect on customer satisfaction. In a survey done in 2000 for FHWA, 32 percent of respondents indicted dissatisfaction with work zones, the second highest rate of dissatisfaction among the attributes of major highways. Customers suggested three improvements to overcome travel delay problems: (1) using more durable paving materials to eliminate the need for repairs; (2) making repairs during non-rush hours; and (3) reducing the time it takes to complete repairs.(8)

With highway improvement projects on the rise across the nation, reducing congestion and improving safety in and mobility through work zones have become more important than ever. FHWA has established programs to provide information on best practices for work zones through its website.(9) The agency also has developed decision support tools to help transportation agencies reduce motorist delays through work zones. Traffic management plans for work zones that minimize the length of time that the work zone is in place can help to significantly reduce crashes and the resulting crash fatalities.

Despite the fact that computer models are available to predict traffic conditions in work zones, state agencies have rarely used modeling for either project planning or design. The agencies have generally limited their use to large, highly visible projects.(6)

Work Zone Safety and Mobility Rule

In September 2004, FHWA published a revised *Work Zone Safety and Mobility Rule.*(10) State and local governments receiving Federal-aid funding were required to comply with the rule no later than October 12, 2007. The rule has three primary components and goals. First, it calls for each state and local DOT to implement an overall policy on work zone safety and mobility to institutionalize the consideration and management of work zone impacts. Second, the rule requires establishment of agency-level processes to support policy implementation, including procedures for assessing the impacts of work zones, analyzing data, conducting training, and reviewing processes. Third, the rule calls for establishing project-level procedures to assess and manage the impacts of individual projects.

The updated rule establishes a category for “significant” projects. A significant project is one that by itself or in combination with other nearby projects is anticipated to cause sustained impacts that are greater than considered tolerable according to state policy and/or engineering judgment. All projects on the interstate system within the boundaries of a designated Transportation Management Area are deemed significant if they occupy a location for more than three days with either intermittent or continuous lane closures. Designation as a significant project triggers the need for further procedures for assessing work zone impacts, which is where work zone analysis tools are needed.

For a DOT, establishing an overall policy is the first step toward institutionalizing the planning, design, and operational strategies that reduce congestion and crashes due to work zones. Formalizing processes and practices helps ensure a consistent way of doing business across projects. Formalized processes also lead to greater consistency and uniformity for highway users traveling through work zones.

Work Zone Congestion Mitigation Strategies

Work zone congestion mitigation strategies can be categorized into five groups:

1. Traffic Management Strategies.
2. Demand Management Strategies.
3. Design Alternatives to Minimize Congestion Cost Strategies.
4. Alternative Project Scheduling and Phasing Strategies.
5. Alternative Contracting and Delivery Strategies to Accelerate Project Completion.

The term traffic management should be taken in the broadest sense. Traffic management strategies include one or more of the followings: traffic calming, traveler information, smart work zones, dynamic message signs, advanced speed information system, traffic conditions displayed on internet, narrowed lanes, increased incident management capabilities, and increased speed enforcement.

Demand management strategies involves making other modes more attractive, using parking pricing and other incentives to shift traffic volumes to non-peak periods, or working with employers to shift times of employee arrival and departure. Other demand management strategies include alternative route improvements, improved pre-construction traveler information, and mass transit improvements.

Design alternatives that minimize congestion costs include: the use of temporary elements, such as temporary pavement, to alleviate congestion or the prefabrication of elements, reduce the duration of reconstruction.

Alternative scheduling and phasing strategies also include nighttime work, weekend only closures, or continuous full closures to reduce the construction duration. Phasing strategies might involve simultaneous work on parts of a project to reduce the duration of closures or alternatively breaking the project in short duration creating less traffic impact in total.

Alternative delivery methods typically involve design-build (private sector designers on the contractor's team) or design-sequencing (use of public sectors designer working with a contractor). Alternative contracting methods involve a variety of incentives and disincentives to expedite project delivery, reduce traffic congestion, and reduce costs. One method that is not widely used but offers promise is setting flexible contract start dates with fixed deadlines for completion.

Project Scope and Objectives

The objectives of this project were: (1) to synthesize the latest information on work zone safety and management, (2) identify case studies in which FHWA's decision support tool QuickZone or other appropriate analysis tools could be applied, and (3) develop training materials to assist ITD staff in using the selected analysis tool. To achieve these objectives, several tasks were conducted. First, a literature search was performed to document previous work that has been completed on work zone traffic analysis and analysis tools. A survey of a selected number of state DOTs was conducted to determine common practice in the analysis of work zone traffic analysis and operations.

Existing microscopic and macroscopic work zone analysis tools were reviewed and assessed. Two of these analysis tools: VISSIM microscopic simulation model and the FHWA's QuickZone were used to analyze work zone traffic operations in two work zone case studies: a rural freeway work zone and a two-lane two-way rural highway work zone. The analysis included applying the analysis tools to each case study, documenting the input/output process for each tool, documenting of the results of each analysis, and identifying data necessary to calibrate and validate the models. QuickZone was also used to fully analyze the operation of urban freeway work zone in the Boise area. Results of this analysis were used to develop a set of findings and recommendations for possible changes in relevant ITD manuals, best practices, and specifications. Finally, materials that can be used by ITD to train their staffs in how to analyze work zone traffic operations and to prepare a set of conclusions that can be used as input for the development of a work zone operations plan were developed.

Report Organization

The report is organized in six chapters. Following the introduction in Chapter 1, Chapter 2 presents an overview of work zone delay and queue length analysis tools. Chapter 3 includes a literature review for previous research on work zone traffic analysis and analysis tools, and Chapter 4 documents current state DOTs practices in work zone analysis. Chapter 5 includes the analysis and results for the three case studies included in the study. Finally, Chapter 6 presents the study conclusions and recommendations.

Chapter 2
Work Zone Delay and Queue Length Analysis Tools

This section describes the characteristics of work zone delay and queue length analysis tools and includes information on input data requirements and the level of accuracy of the estimates. In general, work zone analysis tools can be classified into two groups: 1) macroscopic deterministic queuing theory tools employing methods highlighted in the HCM 2000, and 2) microscopic simulation modeling with dynamic-route assignment capabilities. (1) Macroscopic HCM-based tools range from simple applications of deterministic queuing theory principles using a spreadsheet to more advanced tools employing diversion route algorithms and testing a wide range of mitigation strategy alternatives.

HCM-Based Tools

The HCM 2000 work zone analysis procedure is based on basic macroscopic deterministic queuing theory. (1) Cumulative arriving and departing volumes are compared for each time interval to determine the queue length. The total delay experienced by all vehicles is represented by the area between the cumulative arrivals and departures. The basic principles of the HCM 2000 deterministic queuing theory procedure is illustrated in Figures 1 and 2. (1)

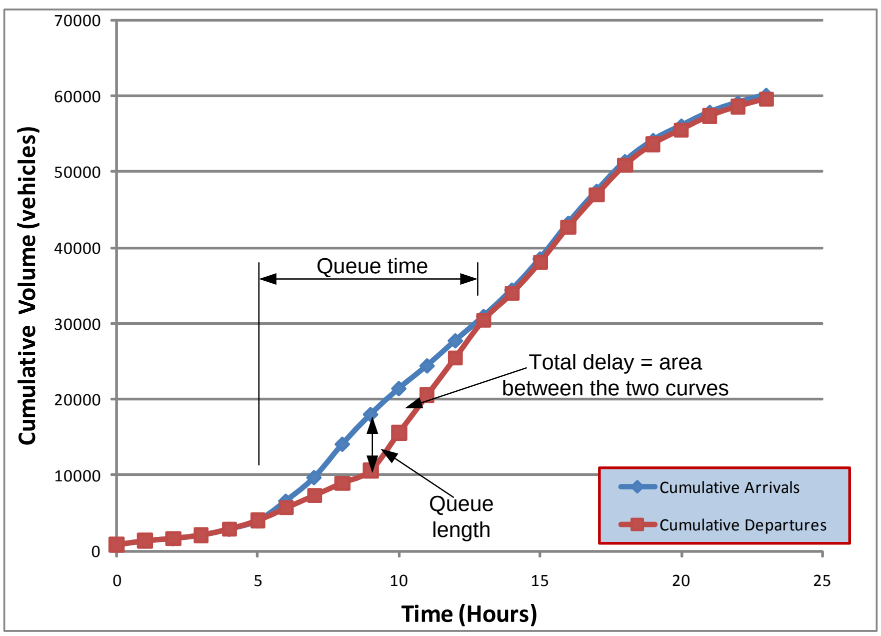

Figure 1. Deterministic Queuing Theory Analysis for Work Zone Delay and Queue Length.

	A	B	C	D	E	F	G	H	I	J
1	Hour	Arriving Volume	Capacity	Excess Volume	Excess Capacity	Queue Length	Departures	Cumulative Arrivals	Cumulative Departures	
2	0	830	4950	0	4120	0	830	830	830	
3	1	520	4950	0	4430	0	520	1350	1350	
4	2	320	4950	0	4630	0	320	1670	1670	
5	3	430	4950	0	4520	0	430	2100	2100	
6	4	820	4950	0	4130	0	820	2920	2920	
7	5	1100	4950	0	3850	0	1100	4020	4020	
8	6	2600	1650	950	0	950	1650	6620	5670	
9	7	3100	1650	1450	0	2400	1650	9720	7320	
10	8	4400	1650	2750	0	5150	1650	14120	8970	
11	9	3920	1650	2270	0	7420	1650	18040	10620	
12	10	3400	4950	0	1550	5870	4950	21440	15570	
13	11	3000	4950	0	1950	3920	4950	24440	20520	
14	12	3300	4950	0	1650	2270	4950	27740	25470	
15	13	3200	4950	0	1750	520	4950	30940	30420	
16	14	3490	4950	0	1460	0	3490	34430	33910	
17	15	4100	4950	0	850	0	4100	38530	38010	
18	16	4700	4950	0	250	0	4700	43230	42710	
19	17	4200	4950	0	750	0	4200	47430	46910	
20	18	3900	4950	0	1050	0	3900	51330	50810	
21	19	2800	4950	0	2150	0	2800	54130	53610	
22	20	1900	4950	0	3050	0	1900	56030	55510	
23	21	1800	4950	0	3150	0	1800	57830	57310	
24	22	1250	4950	0	3700	0	1250	59080	58560	
25	23	1000	4950	0	3950	0	1000	60080	59560	
26				Total Queue =		28500	vehicles			
27				Total delay =		14250	vehicle-hour			
28				delay cost =		$6.50	vehicle-hour			
29				# of working days		10	days			
30				Total delay cost=		$926,250.00				
31										
32	Capacity = 1650 vph for one lane during construction, otherwise capacity is 4950 vph									
33	Excess volume = volume - capacity									
34	Excess capacity = capacity - volume									
35	Queue length: Start from the start of the work schedule = access volume + access volume or access volume - excess capacity									
36	Departures = arrivals (if volume is less than capacity),									
37	departure = capacity (if there is queue present), or departures = arrivals + queue (case of partial queue)									

Figure 2. Deterministic Queuing Theory Worksheet for Work Zone Delay and Queue Length.

One of the major parameters that is needed for work zone delay and queue length analysis is lane capacity throughout the work zone area. A good estimate of the capacity of a work zone bottleneck is essential to obtain an accurate estimate of traffic impacts at work zones. 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. [(1)] HCM 2000 uses different values for capacity reductions based on the duration of construction activities: short-term work zones and long-term construction zone closures.[(1)]

The difference between the short- and long-term closures is the type of diversion barrier used and the duration of their placement. HCM 2000) uses a base capacity of 1,600 passenger vehicle per hour per lane for short-term freeway work zones, regardless of the lane closure configurations. [(1)] The value is based on a research study conducted in 1994.[(11)] This base value should be adjusted for other conditions in the work zone, such as the intensity of work and the number of workers on site. Work zones where rubbernecking is likely to occur will also affect the lane capacity. HCM 2000 [(1)] did not explicitly give guidelines on how to reduce lane capacity based on site specific characteristics, but the manual recommends that the value of 1,600 passenger vehicles per hour per lane be adjusted ± 10 percent based on engineering judgment.[(1)] The heavy vehicle adjustment factor (f_{HV}) should be calculated following the procedure identified in the freeway analysis section of the manual.

The presence of ramps near lane closures affects capacity in two ways. First, entering ramp traffic will merge into the main stream reducing the capacity of the main flow. Second, the added turbulence of merging traffic will also have a negative effect on capacity. The HCM 2000 [(1)] recommends, when possible, full lane closures be placed at least 1,500 feet downstream of a ramp. If this is not possible, the ramp volume should be added to the mainline volume or the capacity should be reduced by the amount of the entering ramp volume.

Lane capacity for long-term construction zones can be estimated based on the total number of lanes and the number of lanes closed. For example, for a three-lane freeway segment with one- lane closed, the average lane capacity would be an estimated 1,860 ± 200 passenger vehicles per hour per lane. For a 2-lane segment with 1-lane closed, the estimated capacity would be 1,550 passenger vehicles per hour per lane. When traffic executes a crossover and uses lanes normally used by opposing traffic, the estimated lane capacity would be approximately 1,550 passenger vehicles per hour per lane. If no crossover occurs, but traffic must merge down to a single lane, the value is typically higher. A lane capacity of 1,750 passenger vehicles per hour per lane could be used. Lane width is also a consideration for long term analysis. Constricting the lane width down to 11 feet or 10 feet would reduce capacity by 10 percent. Reducing the lane width to 9 feet or less would result in a 14 percent reduction.

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 2000 combined with analytical equations. Calculations can be carried out in a spreadsheet such as Microsoft Excel (for example, the New Jersey DOT spreadsheet). [1,12] Inputs to the spreadsheet include vehicle demand for every time interval, number of open lanes, roadway capacity, and percentage of trucks in the traffic stream. Output from the spreadsheet includes delay and queue length reported for each time period.

QUEWZ

Queue and User Cost Evaluation of Work Zones (QUEWZ) is a DOS-based analysis tool developed by the Texas Transportation Institute that is used to predict congestion and associated user costs in work zones.[13] Input data include hourly traffic volumes, percentage of trucks, capacity values under normal conditions, lane closure hours, work zone configuration, and more. QUEWZ-98, the most recent version, uses the capacity calculation equation shown in HCM 2000 to come up with a value for the work zone capacity.[1] The program includes an option for changing the base capacity value. A diversion algorithm can be used 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 were available. For the calculation of queue length, the software uses the HCM 2000 computation procedures.[1]

DELAY Enhanced 1.2

DELAY Enhanced 1.2 is a software application developed by FHWA in 1997 that provides quick estimates of travel delay for incident management, maintenance striping alternatives and limited ITS evaluations.[14] This model is geared to short-term work zone lane closures. It uses the same deterministic queuing theory following the HCM 2000 procedures.[1] The program has a graphical user interface for data input. It also provides graphical representation of the estimated queue length (the plot of demand versus time).

QuickZone

QuickZone is a work zone delay impact analysis tool developed by FHWA. It is a Microsoft Excel-based application with open source code to facilitate software customization. QuickZone is targeted at state and local traffic construction, operations, and planning staff as well construction contractors. QuickZone has the following capabilities:

- Quantifies corridor delay resulting from capacity decreases in work zones.
- Identifies delay impacts of alternative construction phasing plans.
- Supports trade-off analyses between construction costs and delay costs.
- Considers alternate phasing schedules.
    - Location along mainline.
    - Time-of-day (peak vs. off-peak).
    - Season (summer vs. winter).

- Assesses impacts of delay mitigation strategies such as:
  - Variable message sign deployments.
  - Signal retiming on detour routes.
- Allows the establishment of work completion incentives.

QuickZone calculates the average traffic delays and maximum queue lengths that could result from lane restrictions in both urban and suburban work zones. The software also facilitates tradeoff analyses between costs of construction and delays; evaluates how modifying the schedule, such as changing the time of day or season for various construction phases, might affect traffic delays; predicts queues and delays associated with mitigation strategies to reduce work zone impacts; and facilitates calculating incentives and disincentives for construction contractors to reduce user delay. QuickZone is designed to calculate the difference between a roadway network's capacity and the actual number of vehicles using the network. The excess volume is expressed as a queue. The software uses standard deterministic queuing theory and volume-capacity ratios to generate its estimates.

Several mitigation strategies are built into QuickZone, including diversion to a detour route; techniques to manage demand, such as time shifting and trip cancellations; mode shifts to transit; and traveler information services using intelligent transportation systems. QuickZone compares expected travel demand with the proposed capacity hour by hour through the life of a project to estimate delays and queues on the facility. By performing this hourly calculation for each phase of a project, the software takes into account anticipated travel demand throughout the day as well as seasonal variations (such as summer versus winter travel). Data input to QuickZone include the following:

- Data on the roadway facility under construction and adjacent alternative routes in the travel corridor.
- Data on the work zone strategy and phasing plan, including anticipated capacity reductions due to the work zone.
- Data on travel demand, including travel patterns in the corridor prior to construction.
- Data on planned strategies to mitigate congestion during each construction phase, including estimates of capacity changes.

The open source code for QuickZone allows for further customization of the software to provide state and local DOTs with a tool that best meets their needs. Possible customizations includes parameters such as state-specific queue-length estimation, additional mitigation strategies, more detailed detour route volume assessment, custom capacity reduction for work zones, different calculations for user delay, queue estimation or cost analysis, and the ability to import networks from other transportation modeling and simulation packages. State DOTs that currently partner with FHWA to test, validate, and improve the accuracy of QuickZone output include: Maryland SHA, Pennsylvania DOT, Ohio DOT, North Carolina DOT, Wisconsin DOT, Washington State DOT, and Utah DOT.

Simulation Programs

Microscopic and macroscopic simulation can be used to model operations and to estimate the traffic impacts in work zones and surrounding areas. Several of these models employ dynamic route assignment algorithms that enable them to assess the impact of different diversion route plans as well as other mitigation strategies.

Examples of microscopic simulation models with such capabilities are VISSIM, CORSIM, AIMSUN, and Dynasmart-P. Examples of planning-level macroscopic simulation models with dynamic route assignment capabilities include CUBE and VISSUM.

While simulation models provide a very detailed output of the traffic operations, they require extensive data input and a complex model verification, calibration, and validation process. It should be noted that some agencies, primarily in urban areas, maintain updated simulation models for their traffic networks. For example, the COMPASS metropolitan planning organization maintains a CUBE simulation model for the greater Boise traffic network. Such models, if available, can be used to conduct area-wide impact analysis of different work-zone design alternatives. Summary of the characteristics of different work zone analysis tools is presented in Table 1.

Table 1. Work Zone Impact Analysis Tools

Level	Analysis Method	Example Tools	Description	Strengths	Weaknesses
Macroscopic	HCM-Based	Spreadsheets QUEWZ-98 DELAY Enhanced 1.2 IntelliZone	Simple applications. Use base capacity then apply adjustment factors for intensity of work activity, effect of heavy vehicles, and presence of ramps in vicinity of work area.	Very simple and easy to use. Requires little input data.	Determining adjustment factors could be complicated. Tends to overestimate traffic impacts. Cannot account for effects of diversion.
		QuickZone	Incorporates various factors that impact delays at work zones. Model traveler response to different control alternatives and diversion strategies.	Comprehensive and highly detailed output. Models traveler response to prevailing traffic conditions such as route changes, peak-spreading, and mode shifts.	Requires a large amount of input data that including detailed roadway network data for both mainline and alternative roadways.
	Macroscopic Planning Level	VISUM CUBE	Employ dynamic route assignment algorithms and can test a wide range of alternatives including ITS strategies.	Detailed output for network-wide impacts. Link- specific delay and queue length estimates.	Extensive effort In model development, calibration and validation.
Microscopic	Microscopic Simulation Models	VISSIM	Employ dynamic route assignment algorithms and can test a wide range of alternatives including ITS strategies.	Very detailed output for network-wide impacts. Vehicle specific delay and queue length estimates.	Extensive effort in model development, calibration and validation. Model run time could exceed hours for large networks.

Chapter 3
Literature Review: Work Zone Analysis Tools

Dudek and Richards report the findings of capacity and delay at 37 road construction sites in Texas.[15] They analyzed ranges of observed work zone capacities for six lane closure combinations and used the data to develop a chart showing the cumulative distribution of the work zone capacities. Krammes and Lopez conducted research on work zones in major urban areas in Texas (Austin, Dallas, Houston, and San Antonio) where extensive frontage roads running parallel to the freeway function as an alternative to the congested freeway conditions.[16] Data were collected at 33 sites from 1987 and 1991 to update the capacity values for short-term freeway work zone lane closures. The HCM 2000 [1] incorporated findings from these studies. A base value of 1,600 vehicles per hour per lane is used for capacity computations in HCM 2000.[1] This base value is adjusted, using a combination of professional judgment and simple empirical equations, for conditions that influence work zone capacity: intensity of work activity, affect of heavy vehicles, and presence of ramps in close proximity to the work zone.

Dixon and Hummer conducted capacity studies at North Carolina work zones. They collected capacity data at 24 short-term freeway work zones during 1994 and 1995.[17] They found that North Carolina work zone capacities were higher than the HCM capacities by at least 10 percent. Karim and Adeli developed a neural network-based tool for the estimation of capacity and delay at work zones.[18] The model considers 11 parameters to estimate 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, which is easy to use and quick in estimating the results.[19] After estimating the capacity, IntelliZone uses a deterministic queuing model to predict the queue length and delay.

Al-Kaisy and Hall studied freeway capacities at six long-term work zone sites in Ontario, Canada. [20] 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., conducted a study to determine the base capacity of short-term freeway work zones in South Carolina and eventually determined the work zone capacity using equations derived from HCM 2000.[1, 21] Traffic volume, speed, and queue length data were collected at 22 sites on 4 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 vehicles per hour per lane) was much higher than the threshold lane volume (1,230 vehicles per hour per lane) currently used by the South Carolina DOT at the time 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.

Schnell, et al. 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.[22] The estimated results were compared with the field data. The simulation models could not be calibrated for oversaturated conditions that existed at the work zones, and even after calibration, these models consistently underestimated 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 compared the performance of QUEWZ-92, FRESIM, and QuickZone with field data at 11 freeway work zone locations in Illinois.[23] 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 underestimated the queue length and delay when compared to the field data .

Kim, et al. 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.[24] To develop this model, they collected data at 12 work zone sites in Maryland. They found that their regression-based model produced better estimates when compared to the HCM model.

Several states have utilized FHWA’s QuickZone work zone analysis tool. The Maryland State Highway Administration's (SHA) used the software to analyze evening road closures for its ongoing replacement of the Woodrow Wilson Bridge outside Washington, D.C. During one phase of the project, nighttime road closures were planned from midnight until 0400. When the construction began, it became clear that four hours were insufficient when coupled with the required setup and takedown times. The software was used to analyze multiple scenarios for extending the duration of the lane closure and the number of lanes closed. The analysis showed there would be little difference in the impact on drivers if the closures began at 2100 and the opening time was extended to 0500. The contractor made these changes to the schedule, reducing this phase of the project from an estimated six months to two months.

Staff from FHWA’s Central Federal Lands Highway Division (CFLHD) used QuickZone to plan reconstruction of an 18.6-mile section of the Beartooth Highway, just outside Yellowstone National Park in Montana and Wyoming. The software was used to evaluate a series of four planned work zones to provide an estimate of the total delay experienced by motorists. Output from software was used to improve coordination of lane closures.[25]

Chapter 4
Current State Practices in Work Zone Analysis

A survey tool was used to identify and document current state practices in work zone analysis. A total of 19 state DOTs representatives were interviewed by phone as part of this survey. Survey questions included:

1. How do you estimate the capacity at work zones?
2. What tools/software programs do you currently use for estimating traffic impacts?
3. Are different districts within the state are using different techniques? (If the answer was yes, each procedure was listed separately.)

4. Do you have any documentation/reports about these tools?
5. If the DOT uses QuickZone, they were asked the following:
    a. How often do you use it?
    b. What is the best aspect of QuickZone?
    c. What is the worse aspect?
6. If the DOT does not use QuickZone, they were asked to explain why.

Arizona DOT currently uses stock plans and MicroStation Computer Aided Design (CAD) software to estimate traffic impacts, queues and delays for work zones throughout the state. Arizona DOT found stock plans to be more useful and accurate with the type of work being done. QuickZone has not been used for work zone projects because the engineers have not contributed time to it.

California's DOT (CALTRANS) uses a special type of cumulative demand/cumulative capacity curve to help estimate traffic impacts, queues, delays, and capacity. QuickZone is not used because they have made improvements to the demand/capacity curve over the years to customize it to fit the needs of the state. When CALTRANS tried QuickZone out, they thought it was extensive and required very detailed data input.

Colorado Department of Transportation (CDOT) uses a program called CDOT Work Zone-User Cost Program instead of QuickZone. The program is a simple program dealing with single corridors on a 24-hour cycle. Colorado DOT does not use QuickZone because their projects are usually short-term work zones and QuickZone seems more complex than what they need.

The Montana Department of Transportation uses Highway Capacity Software to estimate work zone impacts, queues, and delays. They have looked into QuickZone but did not find it adequate for their needs believing it was too animated and required too much data input.

The Nevada Department of Transportation uses two microscopic traffic modeling software (Synchro and Corsim) to estimate traffic impacts, queues, and delays. Their experience finds that an average number used for estimating work zone capacity is 1,800 vehicles per hour per lane. Nevada DOT investigated QuickZone but felt it had no benefits over the programs currently being used.

The Oregon Department of Transportation uses MicroStation and design sheets to help design work zones. To estimate traffic impacts, queues and delays, Oregon DOT developed a spreadsheet within Excel. Oregon DOT does not use QuickZone because of its intensive data input requirements.

The Washington State Department of Transportation uses QUEWZ-98 to estimate traffic impacts, queues, and delays. On a typical project, 1,350 vehicles per hour per lane is used for estimating capacity. Washington State DOT staffs believe QuickZone requires excessive data input. Washington DOT did like the low level of modeling, the local networks and impacts displayed by QuickZone.

The Wyoming Department of Transportation uses Highway Capacity Software (HCS) to estimate the traffic impacts, queues, and delays throughout the state. They have experimented with QuickZone, but have not used it because they believe they have had no projects that would require its use. In the future, Wyoming DOT will use QuickZone.

Several other states (such as Alabama, Delaware, Colorado, Mississippi, Maine, New Jersey, and Ohio) rely on staff experience to estimate capacity at work zones. The HCM 2000 is used on a limited basis, and a few states use no formal procedures to arrive at the capacity value.[1] 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 (Alaska, Michigan, Montana, and Tennessee) similar to ITD, are considering using QuickZone for future projects

Chapter 5
Case Studies

Three work zone case studies were used in this part of the study; an urban freeway, a rural freeway, and a 2-lane, 2-way rural highway. The three case studies were selected to test how tools like QuickZone work in different situations. The characteristics of the work zone activities for these three projects were provided by ITD. The urban work zone case study was analyzed using the FHWA's QuickZone analysis tool. For the other two case studies, two analysis tools were used: VISSIM microscopic simulation modeling and the QuickZone analysis tool. The following sections describe the experiment process and discuss the results for each respective comparison scenario.

Urban Freeway Work Zone Case Study (I-84)

The urban freeway chosen in this study was a section of I-84 between the Meridian Road and Garrity Boulevard interchanges in the cities of Meridian and Nampa, Idaho. This segment of the freeway is about 8 miles long, has 2 lanes in each direction, and had an AADT of about 38,000 vehicles per day in 2007.[26] The freeway section is being widened to three lanes in each direction. Construction began in January 2008 and is scheduled to be completed by fall of 2010. For modeling purposes, project duration of 120 weeks, from January 6, 2008 to April 25, 2010 was used. This report describes the modeling of the work zone in QuickZone.

The designated detour for this project is Franklin Road, which runs parallel to and is located on the north side of the freeway. Franklin Road is approached by traveling north from the Meridian Road and Garrity Boulevard interchanges. Franklin Road between Meridian Road and Garrity Boulevard is, for the most part, a four-lane urban road that runs in the east-west direction. Some of the roads crossing Franklin Road are signalized; others are either stop-sign controlled or uncontrolled. The QuickZone software, however, does not require traffic control information for the intersections in the detour route. The impact of control on traffic operation was modeled through appropriate capacity reductions on segments of the road network.

Network Development

QuickZone represents the road network in a node-link format. To build the network, the coordinates of the nodes are required. Google Earth was used to determine the physical coordinates, relative to an arbitrary datum, between various points of interest (such as intersections) along the mainline and the detour route. The distances were measured to a precision of one-hundredth of a mile. It should be noted that Google Earth incorporates elevation in its distance measurements, which may affect the accuracy of the measurements, but since the region is mostly flat, these errors are assumed to be negligible. Google Earth was also used to determine the number of lanes along the network links and the number and length of turn lanes for each intersection. This information was then verified through site visits. Figure 3 shows a screen capture from the QuickZone Editor software that was used to build the network. The lists of nodes, including the coordinates of the links are shown in Table 7 in the Appendix A. Nodes 1 through 6 are on the freeway; the remaining nodes are on the detour route. The units for the x-y coordinates are in miles; the coordinates for Node 1 was chosen arbitrarily as 0.0 and 1.0 miles.

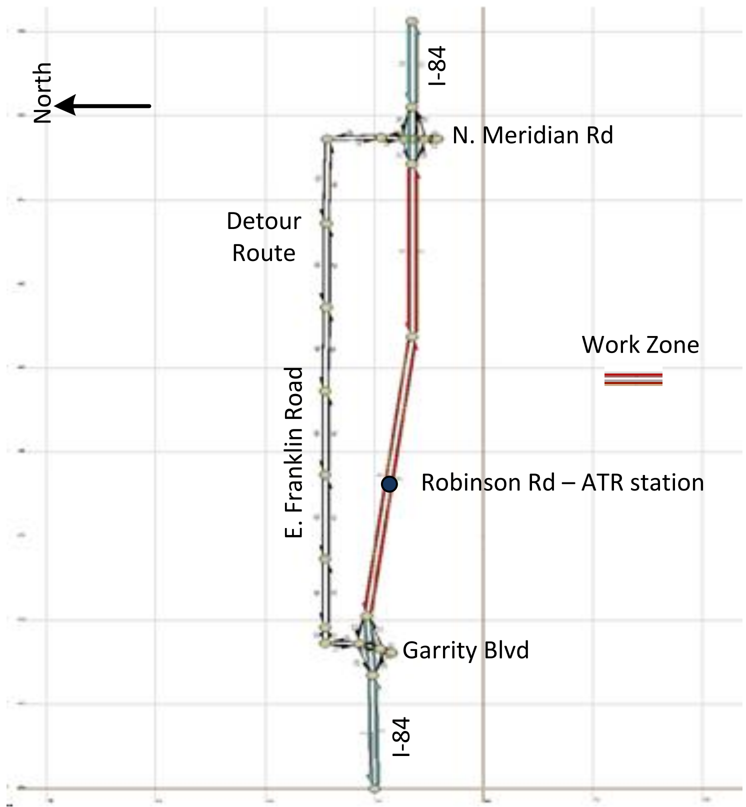

Figure 3. The I-84 Network

Table 8 in the Appendix A lists the links and other parameters used by QuickZone. The parameters include the link capacity, the free-flow speed on the link, the type of link, and the jam density. QuickZone also requires that links be identified as inbound or outbound directions. The inbound direction used in this project was the direction leading to downtown Boise. QuickZone uses the parameter and position for visual display of the network; it does not affect the modeling in any other way.

Figures 4 and 5 are enlarged images of the Meridian Road and the Garrity Boulevard interchanges. The direction from Node 1 to Node 7 (Figure 4) is the eastbound direction on I-84. The segment between Nodes 3 to 5 (Figure 5) is the work zone. In both figures, the direction from the bottom of the page to the top is oriented in the easterly direction.

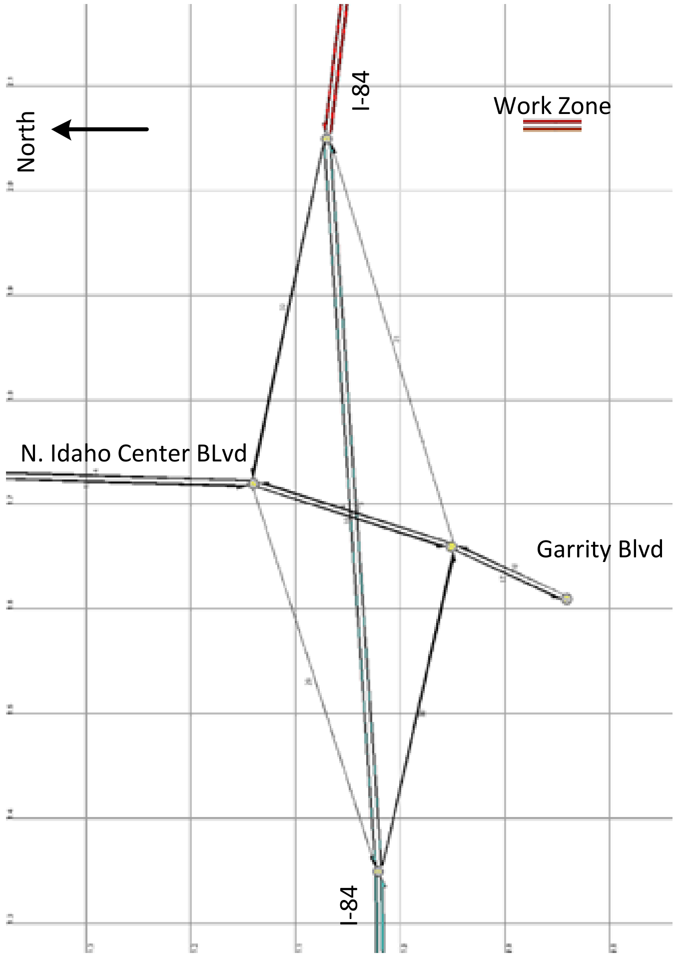

Figure 4. The Garrity Boulevard Interchange

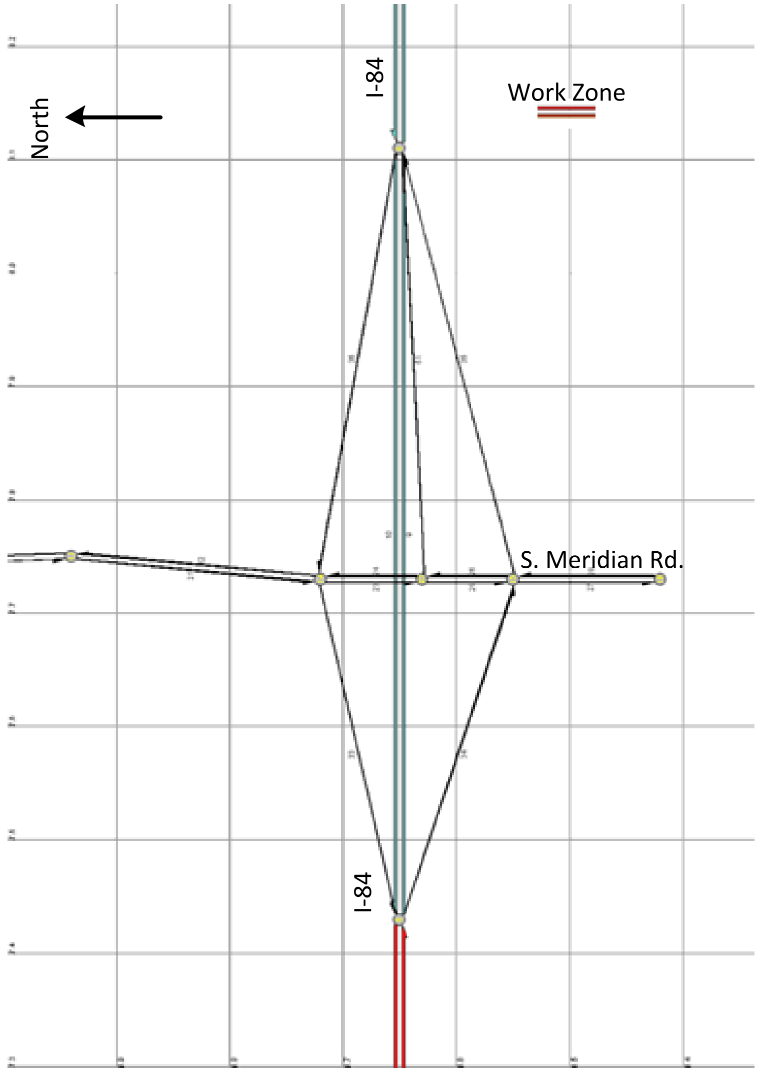

Figure 5. The Meridian Interchange.

Data Acquisition

Data required by QuickZone for each link include capacity; free-flow speed (FFS); jam density; directional hourly, daily, weekly, and annual distribution of demand; truck percentage; and AADT. Average annual hourly volumes can also be used if available. Capacities for freeway links were estimated using Exhibit 23-2 of the HCM 2000 and were based on FFS.(1) The estimated capacity for all freeway links was 2,375 vehicles per hour per lane (vphpl). For non-freeway links, a capacity analysis of the upstream node of a link was performed using theTEAPAC software and the adjusted saturation flow rate for the lane group feeding into the link was used as the capacity for the link.

Free Flow Speeds (FFS) was determined using the Highway Capacity Software (HCS) with the base FFS taken to be the posted speed limit plus 5 mph. Links on surface roads were modeled as multi-lane facilities. For surface roads with a posted speed limit of 35 mph, the FFS was estimated to be 38 mph based on the relationship between the FFS and the posted speed limit for roads with a speed limit of 45 mph. Jam density was calculated using assumed vehicle lengths and headways to be 150 vehicles per mile per lane. Estimation of demand distributions were derived from 2007 data from the Robinson Road ATR, which is located within the study area. These distributions were applied to all links of the network. It was assumed that the demand distributions throughout the region of study were similar, thereby allowing one set of distributions to be used.

The truck percentage was assumed to be 10 percent, taken from the ITD 2008 Highway Needs Report (27). The AADTs for I-84 were obtained from ITD District Three 2007 Rural Traffic Flow Map,[(26)] which includes AADTs for interchanges (including ramps and cross-streets) along I-84 in southwest Idaho. Most of the AADTs for the detours were obtained from daily traffic counts found on Ada County Highway District (ACHD)'s website.[(28)] The rest were estimated using the cross-street AADTs from the District 3 map. (Several links on the west end of Franklin Rd. lacked AADT, the AADT for the nearest links to the east were used.)

QuickZone also requires information on construction phasing and travel behavior. The basic phasing was obtained from the original construction plans for the project. It was supplemented by meetings with ITD and Connecting Idaho Partners staff during the summer of 2008. Ultimately, only one phase was used since no capacity changes between phases were expected.

Travel behavior changes due to construction can also be incorporated in QuickZone model. For this model, it was assumed that there would not be any mode shifts, time shifts, or trip cancellations since no data were available to justify assuming otherwise.

Capacity reduction on the mainline due to construction was estimated using the procedure outlined on pages 22-7 and 22-8 of the HCM 2000.[(1)] The intensity factor was taken to be 160 passenger vehicles per hour per lane. For the ramp adjustment factor, the capacity of the mainline lane in the work zone was reduced by the on-ramp capacity up to a maximum of one half the capacity of the mainline lane. This calculation was done within QuickZone.

QuickZone Output

Once all necessary data were entered into QuickZone, the calculations took about three seconds, which is much faster than estimated by the manual. Many different reports of the results are available. Two graphs from the QuickZone output, showing anticipated queue length, are provided in Figures 6 and 7. Delays and queues were observed in the work zone in the inbound direction on Friday and Saturday evenings as well as on Saturday mornings. The outbound direction experienced more frequent delays and queues, with some degree of queuing occurring on Monday, Tuesday, Wednesday, Friday and Saturday. No queues or delays were observed on Sunday or Thursday mainly due to the relatively low volumes during these two days.

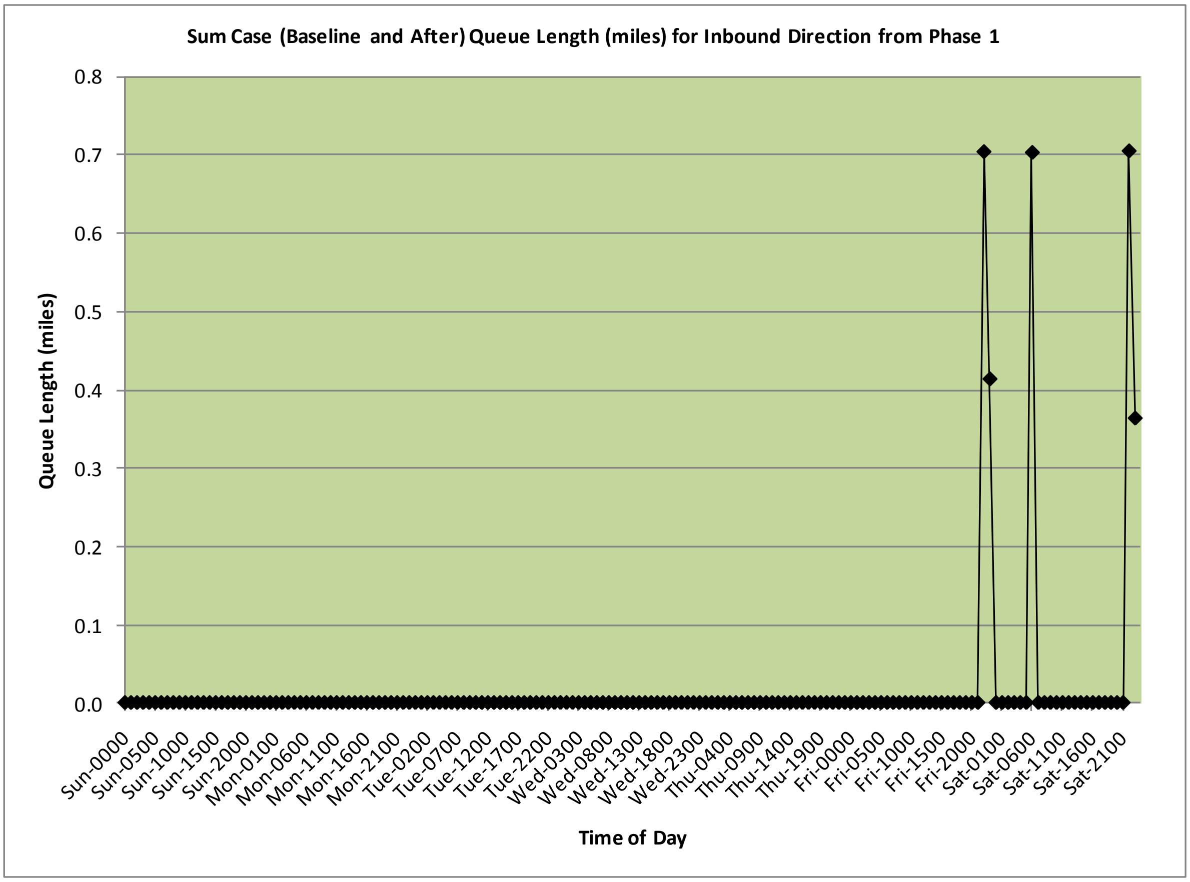

Figure 6. I-84 Case Study Queue Length Weekly Summary (Inbound Direction)

The QuickZone results showed that a total of 850 vehicles took the detour per week. The total for the project duration was estimated by QuickZone to be over 100,000 vehicles

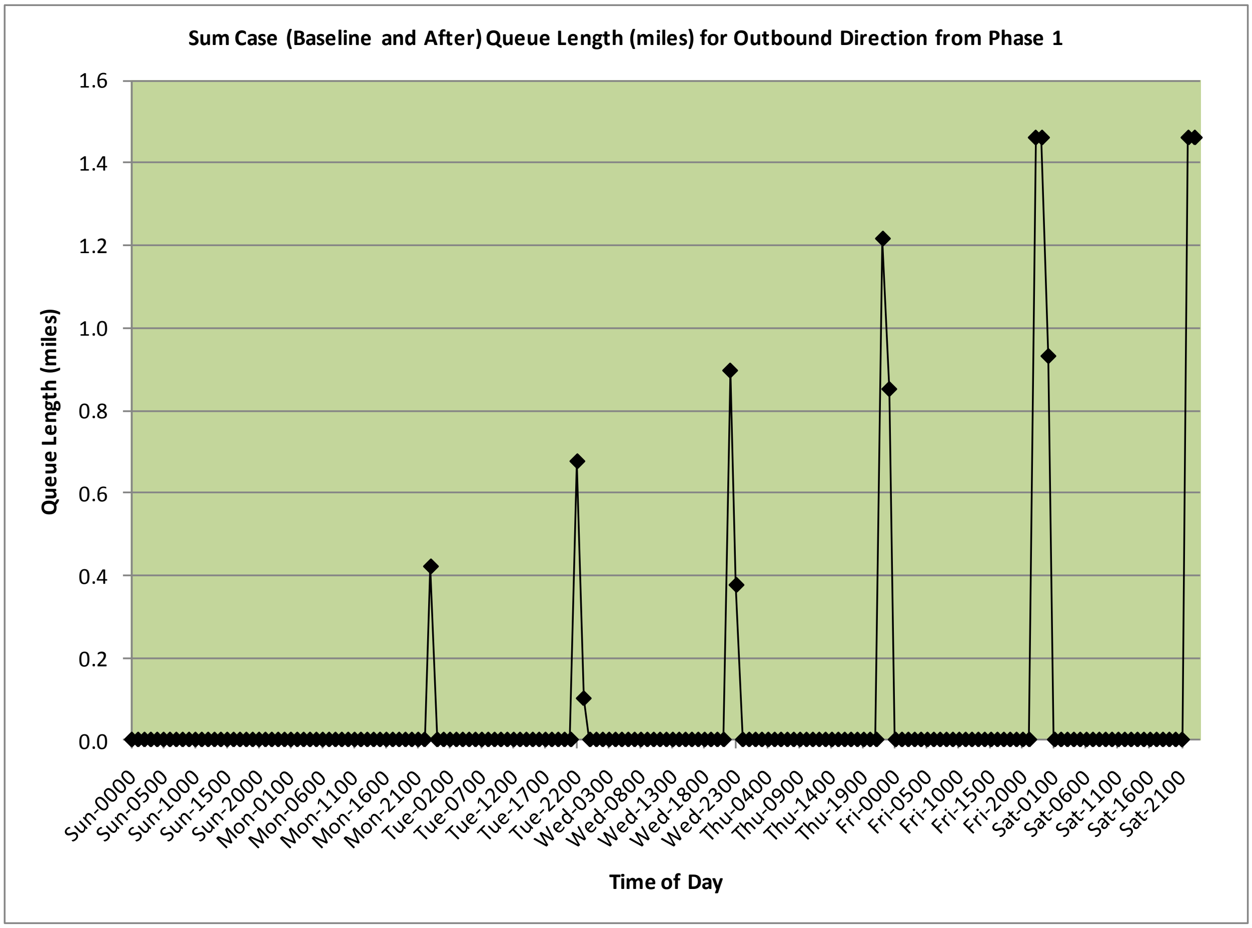

Figure 7. I-84 Case Study Length Weekly Queue Summary (Outbound Direction)

The weekly delay summary is shown in Table 2. The total delay on the mainline during a week was estimated at 3,392 vehicle hours. The maximum user delay was estimated to be more than 31 minutes and this occurred on a Friday. Table 3 summarizes the results for the I-84 project. Since only 1 phase of 120 weeks was modeled, the results for the phase and the project are the same. The total cost due to the widening project is estimated to be over $10 million for the duration of the project.

Table 2. I-84 Case Study Weekly Delay Summary

	Queues				Mainline Delay	
	Max Unsaturated Miles	Max Unsaturated Vehicles	Max Combined Miles	Max Combined Vehicles	Total Delay Vehicles	Max User Delay Minutes
Entire Work Zone	0	0	1.46	439	3,392	31.48
Sunday AM	0	0	-	-	-	-
Sunday	0	0	-	-	-	-
Monday	0	0	0.42	127	127	9.09
Tuesday	0	0	0.67	202	232	14.48
Wednesday	0	0	0.90	269	382	19.29
Thursday	0	0	1.21	363	617	26.02
Friday	0	0	1.46	439	1,156	31.48
Saturday PM	0	0	1.46	439	878	31.48
Phase 1 Project	**0**	**0**	**1.46**	**439**	**3,392**	**31.48**

Table 3. I-84 Case Study Work Zone Delay Cost Summary

				Delay Cost					
		Delay		Mainline Cost		Detour Costs	Inventory Cost		
	Duration	Weekly Total	Phase Total	Cars	Trucks	Cars/Trucks	Mainline	Detour	Total Costs
Phase	Weeks	Vehicle-Hours	Vehicle-Hours	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Phase 1 Project	120	3,659	439,104	$9,232,474	$986,102	$98,354	$17,146	$3,983	$10,338,060

Rural Freeway Work Zone Case Study (I-15)

A section of I-15 in southeastern Idaho (I-15 MP 16.341 to MP 21.339) was selected as a rural freeway work zone case study. Two models were developed for this section of I-15, a VISSIM microscopic simulation model and a QuickZone analysis model, shown in Figures 8 and 9 respectively. The main focus of the analysis was to compare the output from the calibrated VISSIM simulation model with the QuickZone model output, to verify the accuracy and validity of the QuickZone model when used for rural freeway work zone analysis.

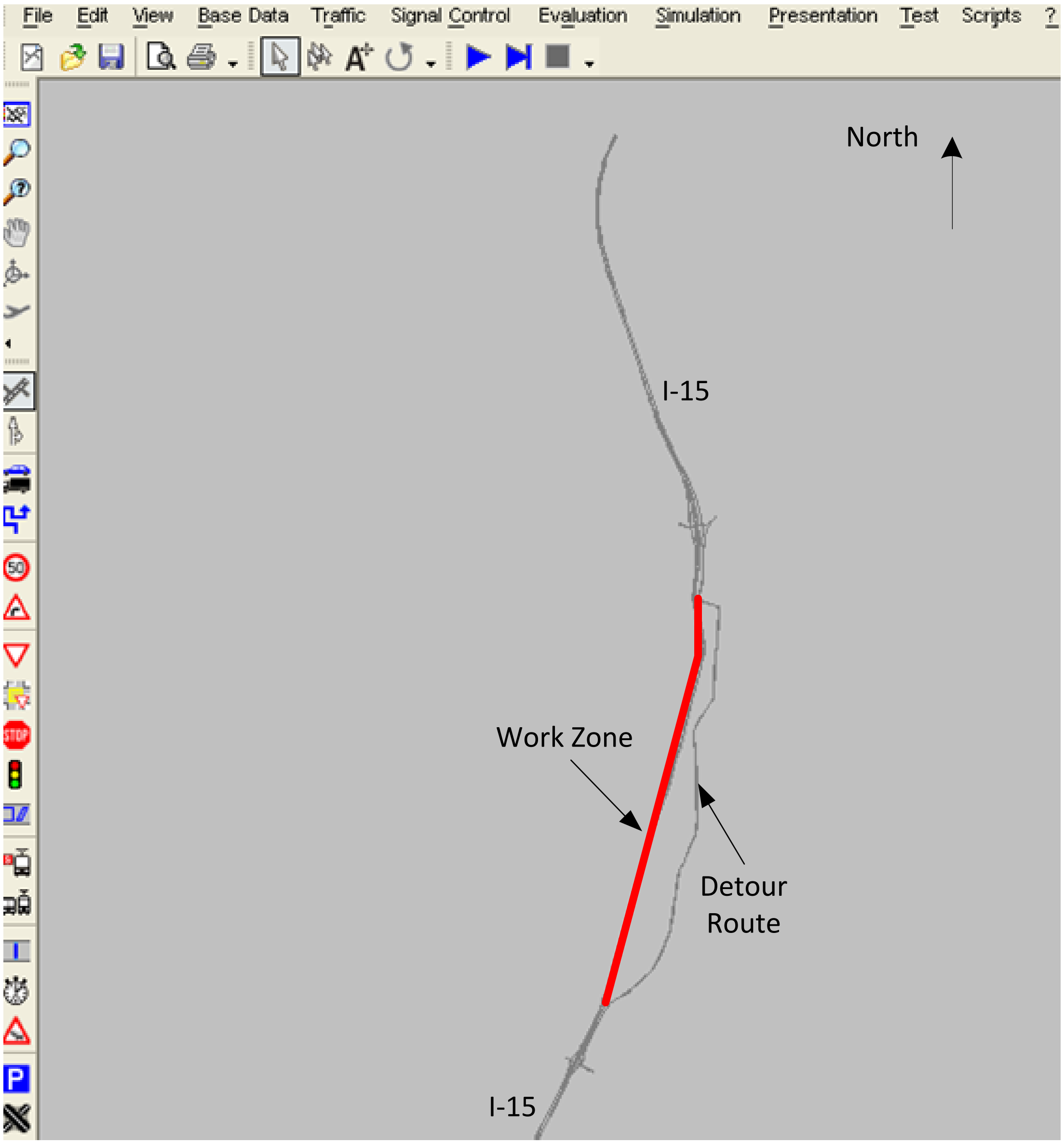

Figure 8. VISSIM Model for the I-15 Work Zone

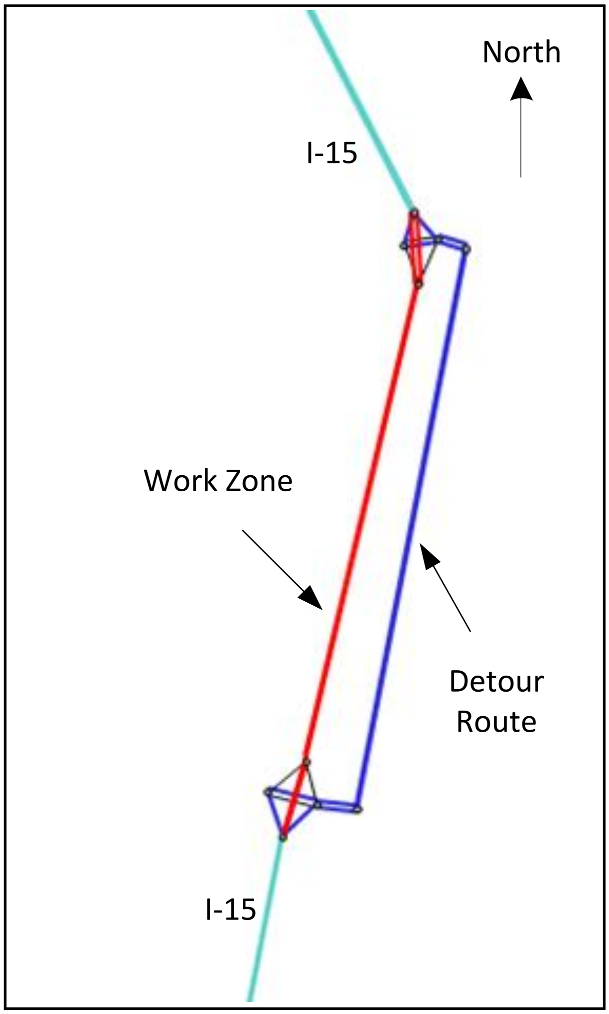

Figure 9. QuickZone Model for the I-15 Work Zone

VISSIM Model Development and Calibration

Geometric data for the I-15 VISSIM model were obtained from Google Earth aerial photos. Traffic flow profile data were obtained from ITD ATR counts published on the ITD website.[29] ATR data were also used to calibrate the VISSIM model using the model calibration procedures suggested by Park and Qi.[30] These procedures are shown in Figure 10.

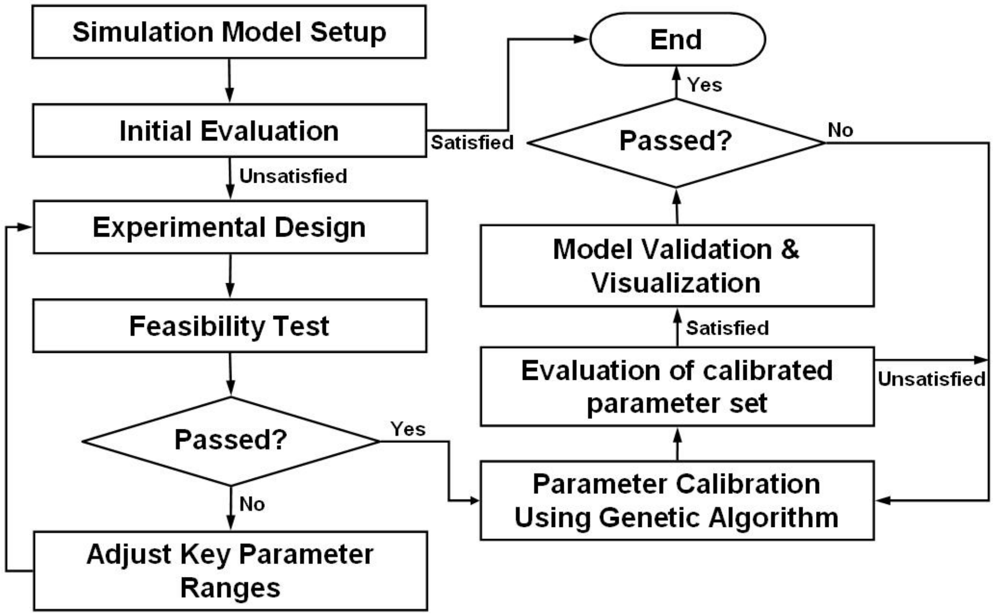

Figure 10. Microscopic Simulation Model Calibration and Validation[30]

QuickZone Model Development

The QuickZone model for the I-15 rural freeway case study was developed using steps outlined in sections 5.1.1 and 5.1.2. Geometric data were obtained from Google Earth aerial photos. Traffic flow profile data were obtained from ITD ATR counts published in ITD website.[29] Full details of QuickZone model development and its data input and output process are also provided in the QuickZone workshop training materials developed by the project team. A copy of these materials is provided in Appendix B of this document.

Saturation Flow Rate Field Data Collection

The saturation flow rate and lane capacity data are very important input parameters that affect the accuracy and quality of delay and queue length data reported by the QuickZone model. To ensure that state-specific saturation flow and lane capacity date were used in the analysis, the project team conducted field data collection at several locations throughout Idaho to collect and document the queue discharge characteristics for different road types in Idaho. Data collection included videos recorded through Closed Circuit TV (CCTV) cameras as well as manual field data collection at different sites. The average saturation headway and the corresponding average lane capacity for different road types are presented in Table 4.

Table 4. Saturation Flow Headway and Lane Capacity for Roads in Idaho

Road Type	Number of Sites	Average Saturation Headway (seconds)	Average Lane Capacity (vehicle/hour/lane)
Urban Freeway	9	2.07	1739
Rural Freeway	4	2.14	1682
4-Lane Divided Highway	4	2.28	1579
2-Lane, 2-Way Highway	2	2.31	1558

Analysis and Results

Table 5 provides a comparison of the maximum queue length and the total delay estimates reported by VISSIM and QuickZone models for the I-15 rural freeway work zone site for both day and night work activities. Data obtained from the calibrated VISSIM microscopic simulation model was assumed to be the true delay and queue length values. QuickZone overestimated both the queue length and total delay for both the day and night work zone activities. The differences between QuickZone and VISSIM queue length values ranged from 17.60 percent for day work zone activities to 44.68 percent for night work zone activities. The absolute error in the maximum queue length estimates was 60 vehicles and 11 vehicles for day and night work zone activities, respectively. The differences between QuickZone and VISSIM total delay values ranged from 14.52 percent for day work zone activities to 22.62 percent for night work zone activities. The absolute error in the total delay estimates was 89 vehicles/hour/day and 19 vehicles/hour/day for day and night work zone activities, respectively. This difference was expected taking into consideration the difference in the analysis level between the microscopic VISSIM model and the macroscopic QuickZone model. Despite these variations, estimates generated using QuickZone seem acceptable for planning level analysis of queue length and delay attributable to work zone.

Table 5. Comparison of Queue Length and Total Delay Estimates for the I-15 Rural Freeway Case Study Using VISSIM and QuickZone

Work Zone Activities Scenarios	Maximum Queue Length (vehicles)		Difference (%)	Total Delay (vehicle-Hours)		Difference (%)
	VISSIM	QuickZone		VISSIM	QuickZone	
Day Work Zone Activities 0800 to 1700	341	401	17.60	613	702	14.52
Night Work Zone Activities 2000 to 0500	47	68	44.68	84	103	22.62

Rural Highway Work Zone Case Study (US-30)

A section of US-30 in southern Idaho (from milepost 449.0 to milepost 454.0) was selected as a rural highway case study. This section of the road is a 2-lane, 2-way highway near the Idaho/Wyoming border. Two models were developed for this section of US 30, a VISSIM microscopic simulation model and a QuickZone analysis model (Figures 11 and 12 respectively).

Model Development

The VISSIM and QuickZone models for the US-30 2-lane highway case study were developed using the same steps used for the other models. Geometric data were obtained from Google Earth aerial photos. Traffic flow profile data were obtained from ITD ATR data published in ITD website.[29]

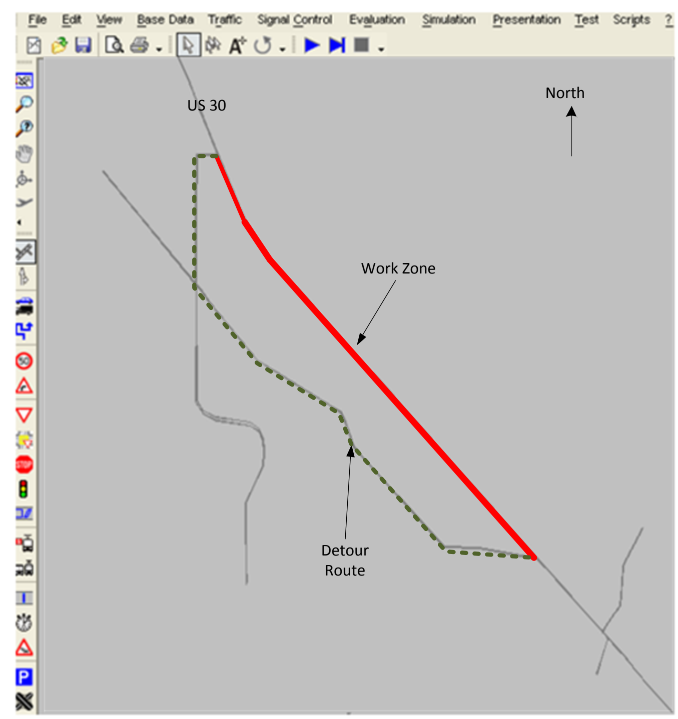

Figure 11. VISSIM Model for the US-30 Work Zone

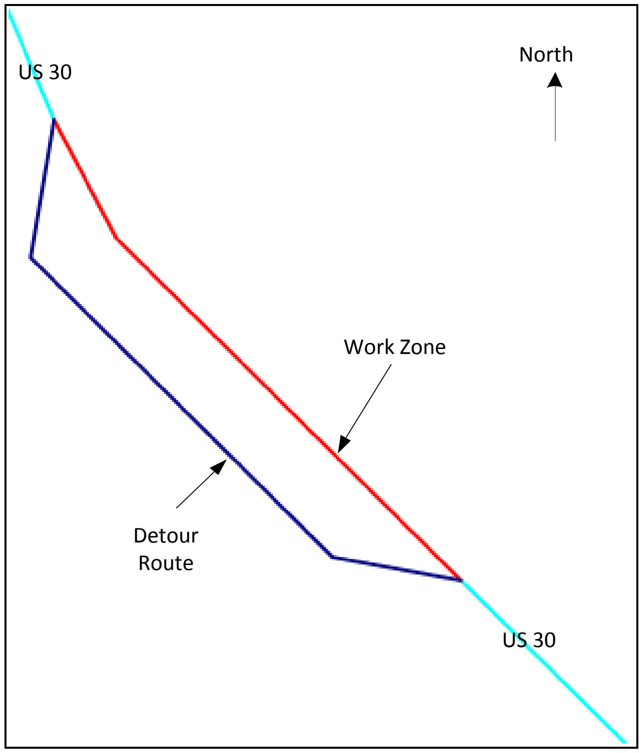

Figure 12. QuickZone Model for the US-30 Work Zone

Analysis and Results

Table 6 provides a comparison of the maximum queue length and the total delay estimates generated by VISSIM and QuickZone for the US-30 2-lane highway work zone site for both day and night work zone activities. The results are very similar to those of the urban and rural freeway work zones. QuickZone provides higher estimated than VISSIM of both the queue length and total delay for both the day and night work zone activities. The differences in maximum queue length estimates ranged from 25.84 percent for day work zone activities to 61.90 percent for night work zone activities. The differences in the maximum queue length estimates were 23 vehicles and 13 vehicles for day and night work zone activities, respectively. The differences in average total delay estimates ranged from 19.50 percent for day work zone activities to 45.45 percent for night work zone activities. The differences in the total delay estimates were 47 vehicle/hour/day and 15 vehicle/hour/day for day and night work zone activities, respectively.

Again, the differences in both maximum queue length and total delay seem acceptable for planning-level analysis similar to those intended for QuickZone model use.

Table 6. Comparison of Queue Length and Total Delay Estimates for the US-30 Rural Highway Case Study Using VISSIM and QuickZone

Work Zone Activities Scenarios	Maximum Queue Length (vehicles)		Difference (%)	Total Delay (vehicle-Hours)		Difference (%)
	VISSIM	QuickZone		VISSIM	QuickZone	
Day Work Zone Activities 0800 to 1700	89	112	25.84	241	288	19.50
Night Work Zone Activities 2000 to 0500	21	34	61.90	33	48	45.45

Chapter 6
Conclusions and Recommendations

Three work zone case studies were used in this study; an urban freeway, a rural freeway, and a 2-lane, 2-way rural highway. The characteristics of the work zone activities for these three projects were provided by ITD. The three case studies were analyzed using the QuickZone model. Additionally, the rural freeway and the two-way rural highway case studies were analyzed using the VISSIM microscopic simulation model. Queue length and delay estimates from the QuickZone analysis tool were compared with those reported in the microscopic simulation output. The results show that while QuickZone generally provided higher estimates of both queue length and total delay in work zones, the estimates for both tools are comparable and sufficient for planning level analysis. Based on the results of the analysis, the following conclusions could be made:

- QuickZone is an efficient tool to macroscopically analyze traffic operations at work zones. It provides reliable planning-level estimates of delay and queue length that are comparable to that reported by microscopic simulation models. It can be used to analyze work zones in urban freeways, rural freeways, four-lane divided urban arterials and corridors, and two-lane rural highways.

- QuickZone, as a work zone analysis tool, can provide ITD staff with the opportunity to effectively analyze work zone projects and to fully assess their impacts. The tool can also be used by ITD staff to reliably estimate work zone user cost, in the form of vehicular delay, for different project scheduling, phasing, delivery method and other traffic management alternatives.

- QuickZone is a fairly simple-to-use analysis tool. However, it requires extensive data input to fully represent the traffic flow profile throughout the work zone. Traffic profile data includes: AADT, hourly, daily, and monthly traffic variation, directional distribution, and percent of heavy vehicles. However, the data is available and can be obtained from ITD ATR data collected, archived and maintained by ITD planning department. With its ease of use, Quickzone is a cost effective tool that can be used to analyze different project scheduling options for work zone activities.

- A macro script to convert ATR data to QuickZone format data could significantly simplify QuickZone data input process for ITD staff.

- QuickZone delay and queue length output is highly sensitive to calibration parameters such as saturation flow headway and lane capacity. Using site specific parameters can improve the model output. Average saturation flow headway and corresponding lane capacity values for different road types in Idaho are provided in Table 6 in this report. These values are based on field measurements of saturation flow headway in different sites throughout Idaho. Realistic capacity estimates can be obtained using these values as base capacity values with adjustments following the HCM 2000 procedures. Adjustments to the base values include: duration and intensity of work activity, effect of heavy vehicles, and presence of ramps in close proximity to the work zone.

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Appendix A
Link/Nodes List for the I-84 Model

Table 7. List of Nodes on I-84

Node Number	X	Y
1	0.00	1.00
2	1.35	1.02
3	2.05	1.07
4	5.38	0.65
5	7.43	0.65
6	8.11	0.65
7	9.13	0.65
8	1.73	1.45
9	1.72	1.14
10	1.66	0.95
11	1.61	0.84
12	7.73	1.43
13	7.75	0.94
14	7.73	0.72
15	7.73	0.55
16	7.73	0.42
17	1.92	1.45
18	2.73	1.45
19	3.73	1.45
20	4.73	1.45
21	5.73	1.44
22	6.73	1.44
23	7.73	0.63

Table 8. Links on the I-84 Network

Link Number	A Node	B Node	Lanes	Capacity (VPL)	Length (miles)	FreeFlow Speed (mph)	Jam Density (V/mi/L)	I or O	Type	Position
1	1	2	2	2355	1.35	66	150	I	M	1
2	2	1	2	2355	1.35	66	150	O	M	2
3	2	3	2	2355	0.702	56	150	I	M	1
4	3	2	2	2355	0.702	56	150	O	M	2
5	3	4	2	2355	3.952	56	150	I	WZ	1
6	4	3	2	2355	3.952	56	150	O	WZ	2
7	4	5	2	2355	2.05	56	150	I	WZ	1
8	5	4	2	2355	2.05	56	150	O	WZ	2
9	5	6	2	2355	1.461	56	150	I	M	1
10	6	5	2	2355	1.461	56	150	O	M	2
11	6	7	2	2370	1.02	67	150	I	M	1
12	7	6	2	2370	1.02	67	150	O	M	2
13	8	9	2	686	0.31	38	150	O	D	2
14	9	8	3	1987	0.31	38	150	I	D	1
15	9	10	2	1524	1.401	38	150	I		2
16	10	9	2	1029	1.401	38	150	I	D	1
17	10	11	2	2262	1.083	38	150	O		2
18	11	10	2	1000	1.083	38	150	I		1
19	12	13	2	425	0.49	38	150	I	D	1
20	13	12	2	321	0.49	38	150	O	D	2
21	13	14	2	985	0.221	38	150	I	D	2
22	14	13	3	1962	0.221	38	150	O	D	1

Table 8 (Cont'd.). Links on the I-84 Network

Link Number	A Node	B Node	Lanes	Capacity (VPL)	Length (Miles)	FreeFlow Speed (mph)	Jam Density (V/mi/L)	I or O	Type	Position
24	23	14	2	1797	0.09	38	150	I		2
25	23	15	2	1448	0.08	38	150	I		1
26	15	23	2	1797	0.08	38	150	I		2
27	15	16	2	2264	0.13	38	150	I		1
28	16	15	2	1000	0.13	38	150	I		2
29	9	2	2	1524	0.389	38	150	O	D	0
30	2	10	2	2370	0.318	38	150	I	D	0
31	10	3	2	1000	0.408	38	150	I		0
32	3	9	2	2155	0.337	38	150	I		0
33	14	5	2	646	0.308	38	150	O		0
34	5	15	1	2155	0.316	38	150	O		0
35	15	6	1	1000	0.393	38	150	I		0
36	6	14	2	2370	0.386	38	150	O	D	0
37	8	17	2	841	0.19	38	150	I	D	1
38	17	8	2	1003	0.19	38	150	O	D	2
39	17	18	1	841	0.81	48	150	I	D	1
40	18	17	1	1003	0.81	48	150	O	D	2
41	18	19	1	841	1	48	150	I	D	1
42	19	18	1	1003	1	48	150	O	D	2
43	19	20	1	841	1	53	150	I	D	1
44	20	19	1	1003	1	53	150	O	D	2
45	20	21	1	1010	1	53	150	I	D	1

Table 8 (Cont.) – The Link List

Link Number	A Node	B Node	Lanes	Capacity (VPL)	Length (Miles)	FreeFlow Speed (mph)	Jam Density (V/mi/L)	I or O	Type	Position
46	21	20	1	516	1	53	150	O	D	2
47	21	22	1	1225	1	48	150	I	D	1
48	22	21	1	1591	1	48	150	O	D	2
49	22	12	2	1678	1	38	150	I	D	1
50	12	22	2	1246	1	38	150	O	D	2
51	23	6	1	1400	0.381	38	150	I	D	0