Calibration of Work Zone Impact Analysis Software for Missouri

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16. Abstract:
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Disclaimer

Abstract

This project calibrated two software programs used for estimating the traffic impacts of work zones. The WZ Spreadsheet and VISSIM programs were recommended in a previous study by the authors. The two programs were calibrated using field data from two work zones in Missouri. Both work zones involved a single lane closure on a three-lane section of roadway. The I-44 work zone was a long-term work zone, while the I-70 work zone was temporary, lasting only a few hours. The capacity values required for calibration were nearly identical for the two programs: 1,575 veh/hr/ln for the WZ Spreadsheet and 1,514 veh/hr/ln for the VISSIM program. The VISSIM driving behavior parameters *CC1*, *CC2*, and *SRF* were also computed. The study found that a calibration based on delay or travel time exhibited better overall performance than a calibration based on queue length. In the future, additional case studies could be added to further calibrate the two models for different work zone lane configurations, such as a one-lane closure on a two-lane segment or a two-lane closure on a three-lane segment.

Chapter 1 Introduction

The Missouri Department of Transportation (MoDOT) is interested in improving the accuracy of methods used to assess traffic impacts due to work zones. In 2008, MoDOT sponsored the first phase of a research effort that evaluated several software programs for work zone traffic impact analysis. The University of Missouri-Columbia (MU) conducted the research and evaluated three software programs—QuickZone, VISSIM, and CA4PRS—also developing a WZ Spreadsheet program customized for work zone capacities observed in Missouri. The first phase of the research effort was geared toward the goal of identifying appropriate analytical tools for different types of work zones. These tools quantify travel delay, queue length, and road user costs, and can hence be used to plan, design, and schedule work activity so as to minimize user costs.

The MU study (Edara 2009) presented the results of a literature review of software available for quantifying work zone traffic impacts; a state DOT survey of current practices in assessing traffic impacts; an analysis of the aforementioned three software programs; a discussion of advantages and disadvantages of each program; and an illustration of the application of programs on three hypothetical work zone case studies. One main contribution of the study was the development of a Custom WZ Spreadsheet based on the deterministic queuing approach. The WZ Spreadsheet produces queue length and delay estimates with minimum input data. The ease of use of the WZ Spreadsheet has contributed to its acceptance and use by MoDOT engineers and consultants. The study also made recommendations for the most appropriate tool for different work zone configurations. For rural interstates, divided roadways, and multilane undivided highways in Missouri, the WZ Spreadsheet model was recommended. For work zones in urban areas where lane closures on a roadway may impact the traffic on neighboring roadways, the use of the microscopic simulation program VISSIM was recommended. The study also provided guidance on driver behavior parameter values in VISSIM that produce observed work zone capacities in Missouri. For two-way one-lane work zones with flaggers, the programs Quick Zone and VISSIM were recommended.

Since the publication of the first phase report, MoDOT engineers and consultants have used both the WZ Spreadsheet and VISSIM driver behavior parameter information to estimate traffic impacts at work zones in Missouri. Given this widespread use, a follow-up study calibrating the WZ Spreadsheet and VISSIM programs using field data from work zones in Missouri was initiated. This report presents the results of the proceeding calibration of the two software programs. Field data from two work zone sites in Missouri were collected. One site was located in an urban area, and the other site was located in a rural area. Calibrations were performed using work zone capacity, travel delay, and queue length values. The parameter values producing the lowest errors were obtained and recommended for future calibration.

A framework was proposed to calibrate work zone software programs. The framework shown in figure 1.1 consists of three steps. The first step determines the performance measure(s) to be calibrated and the associated calibration parameters. For example, delay is a performance measure, and capacity is a parameter that, when altered, affects the delay measure. Input data requirements of the software program and the observed performance measure values are acquired and processed in the second step. Using least squares error estimation, the parameter value that minimizes the error in the chosen performance measure is calculated in the third step.

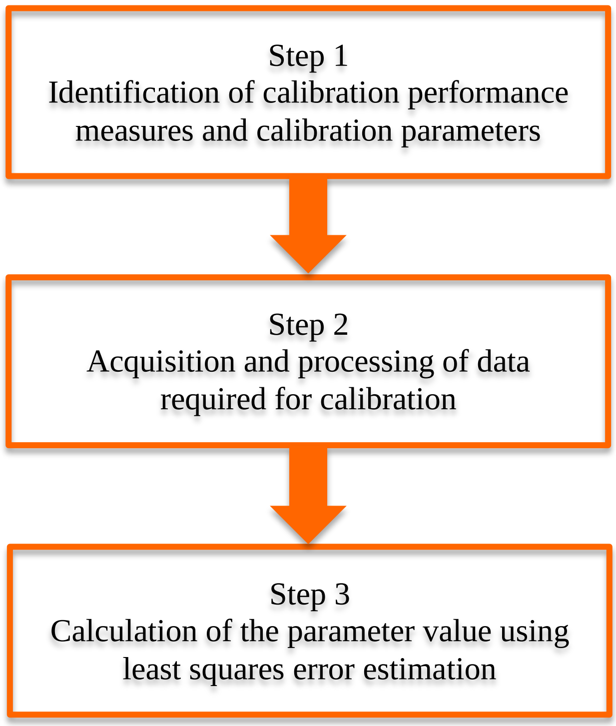

Figure 1.1 Framework for calibrating work zone software programs

This report is organized as follows. The details of the performance measures, data collection, and processing tasks are presented in chapter 2. A brief description of the WZ Spreadsheet program and the VISSIM program, as well as input data requirements and output measures, are presented in chapter 3. Chapter 4 presents the calibration results for the two studied work zone sites. Conclusions and recommendations for the application of the calibrated parameter values are provided in chapter 5.

Chapter 2 Data and Performance Measures

Two main work zone issues were essential for the calibration of the software programs: oversaturation and performance monitoring. Oversaturation states that travel demand must exceed work zone capacity in order to generate queues and delays. Both the WZ Spreadsheet and VISSIM are designed to capture delay and queue length for oversaturated conditions. The second issue, performance monitoring, requires that there be some form of traffic monitoring, either permanent or temporary, that collects the data necessary for calibration. MoDOT's policy is to not close lanes in urban areas for maintenance work during peak period on weekdays. Thus, this study investigated construction work zones and some maintenance work zones that generated oversaturated conditions for at least a few hours during the day or night. Several construction projects were reviewed to identify work zones with the two necessary characteristics. Some projects generated queuing conditions but had no traffic monitoring in the area to collect queue length and delay data. With the assistance of MoDOT and contractors, two work zones that had the necessary characteristics were identified for use in calibration. The details of each work zone are presented next.

2.1 Work Zone 1: I-44 at Antire road.

The first work zone site was located southwest of St. Louis on I-44 between Antire Rd. and Lewis Rd. The work activity involved road resurfacing from June 1, 2012 to October 19, 2012. No alternative routes were available due to the rural setting. The annual average daily traffic (AADT) as of 2011 was 68,181, including 8,020 heavy vehicles (11.8% of the AADT). The original speed limit of 65 mph was reduced to 55 mph in the work zone. This long-term work zone had lane closures in both travel directions. One lane out of three lanes was closed in each direction. Due to high demand in the westbound direction, one additional lane was opened from 3:00 pm to 7:00 pm on weekdays.

A map showing the work zone and the locations of traffic sensors is shown in figure 2.1. Traffic data were extracted from four sensors (Q1 to Q4) deployed in the eastbound direction, as shown in figure 2.1. Sensor Q04 was located at the beginning of the eastbound work zone, and Q01 was the furthest upstream. The distances between adjacent sensors are also pictured in figure 2.1. Travel time and delay values were computed using data obtained from the two Bluetooth sensors that were deployed on I-44 near Rt. 109 and Rt. 141 (gray arrows in the figure). Four portable dynamic message sign (DMS) trailers were used in the work zone to display real-time delay and queue information.

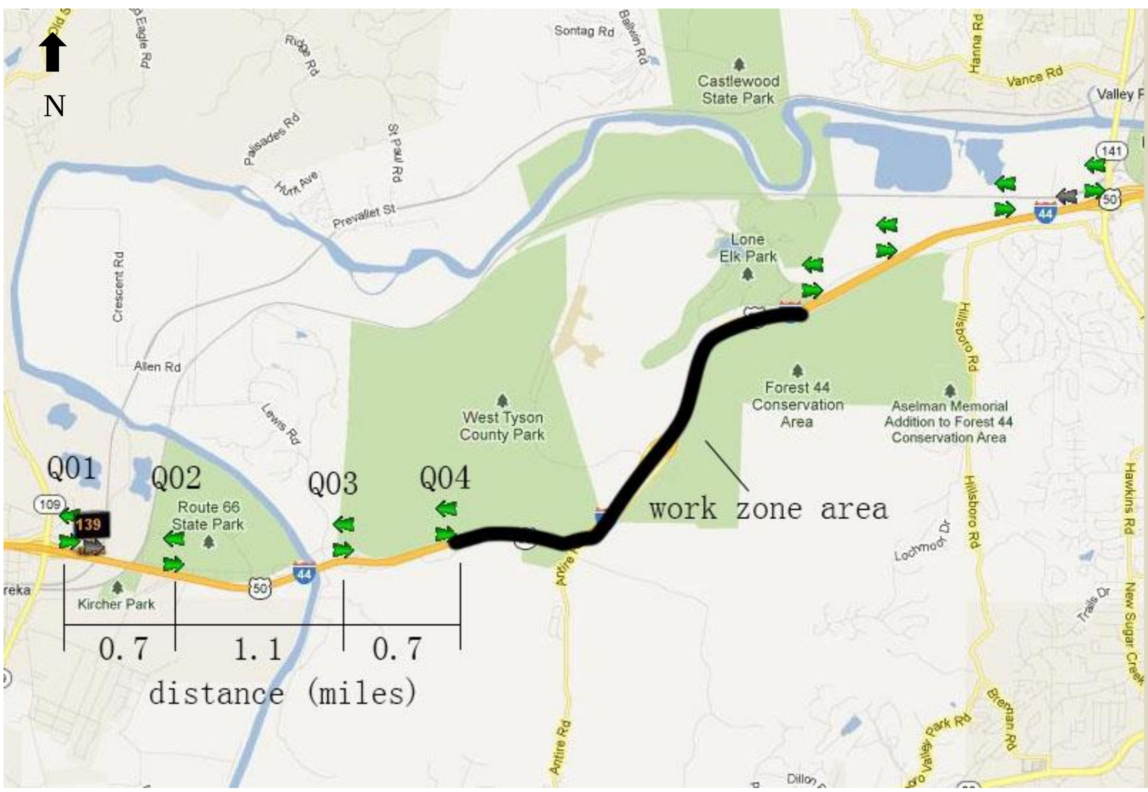

Figure 2.1 Location of work zone and traffic monitoring equipment

Traffic sensor data were available from May 15th, 2012 to October 17th, 2012. There were traffic data missing for two weeks in June; thus, that period was excluded from the analysis. After carefully examining the entire dataset, four days, July 10th, July 12th, July 17th and July 19th, were selected for the calibration process. These days had the highest flow rates and longest queue length (more than 0.7 miles) observed during the entire work zone period. Only eastbound work zone data was used for calibration, since one travel lane remained closed all the time. One lane in the westbound work zone was closed during off-peak hours only, thus there were not many instances of congestion. The hourly traffic volumes for the eastbound direction with and without the work zone are shown in figure 2.2. The non-work zone flow was almost 5,000 vph at its peak.

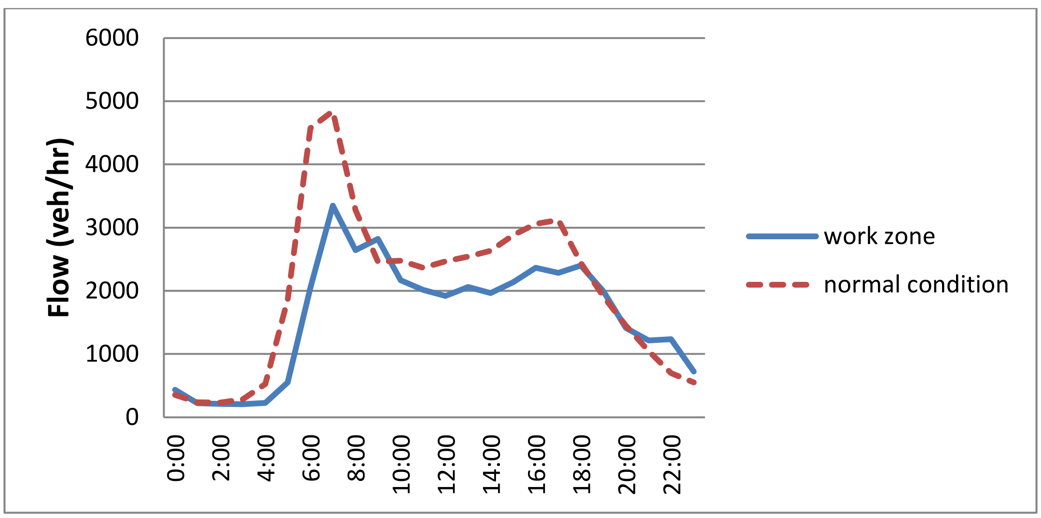

Figure 2.2 Hourly volumes with and without work zone at the eastbound I-44 site

Travel times were calculated using the time stamp information collected by Bluetooth sensors. The two sensors were spaced at 7.3 miles. Travel times, however, did not display any significant delays due to the work zone. This was due to the fact that the placement of Bluetooth sensors was too far away from the work zone, such that vehicles made up for lost time through the work zone by speeding downstream of the work zone. Thus, the Bluetooth data did not capture the delay caused by the work zone. An alternative method was used to capture the work zone delay by using the traffic sensors inside the work zone. The section selected for travel time calculation spanned from sensor Q01 to sensor Q04. The start of the eastbound work zone taper was located at Q04. Free flow travel times were also computed using the free flow speeds determined from speed-occupancy plots. The speed-occupancy plots for the four sensor locations in the eastbound direction are shown in figures 2.3-2.6. Free flow speed was computed by averaging the speed values at low occupancies, <2%. The computed free flow speed values at the four locations were: 68.6 mph at Q01, 66.1 mph at Q02, 64.6 mph at Q03, and 60.4 mph at Q04. Queue length was also determined using the same four sensors, Q01 to Q04. As was shown in figure 2.1, the queue length reached 0.7 mi at Q03, 1.8 mi at Q02 and 2.5 mi at Q01.

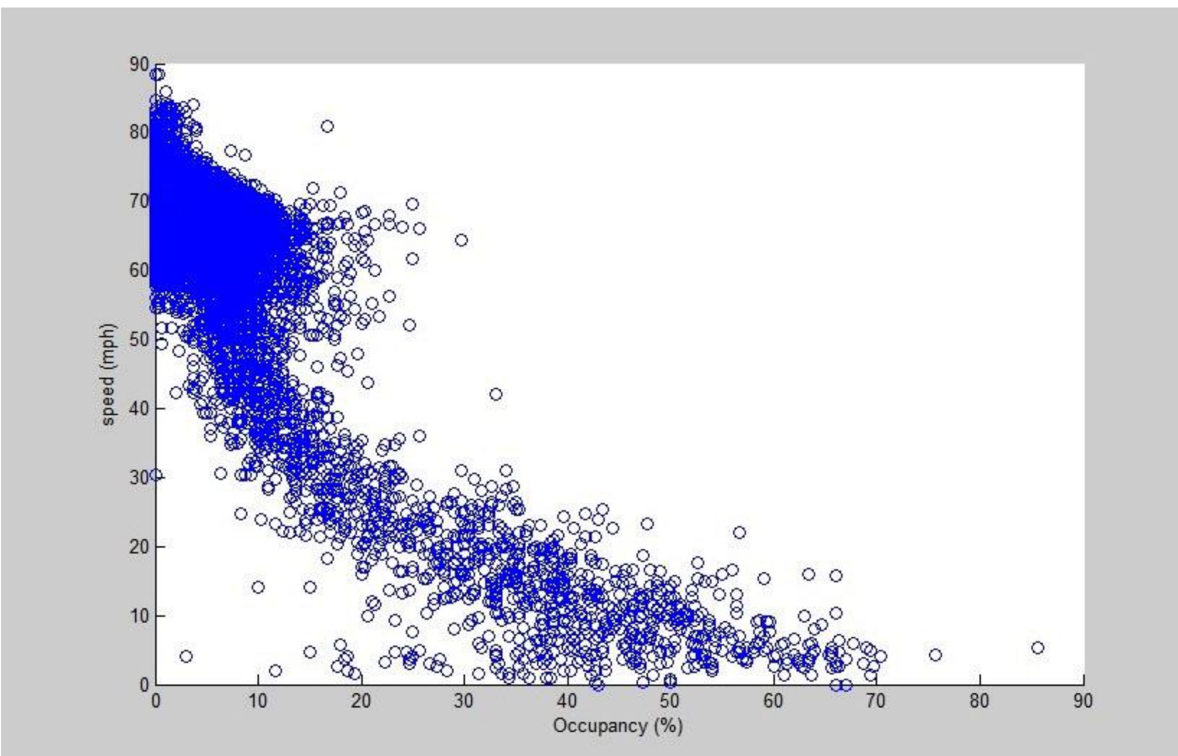

Figure 2.3 Q01: Speed-Occupancy Plot

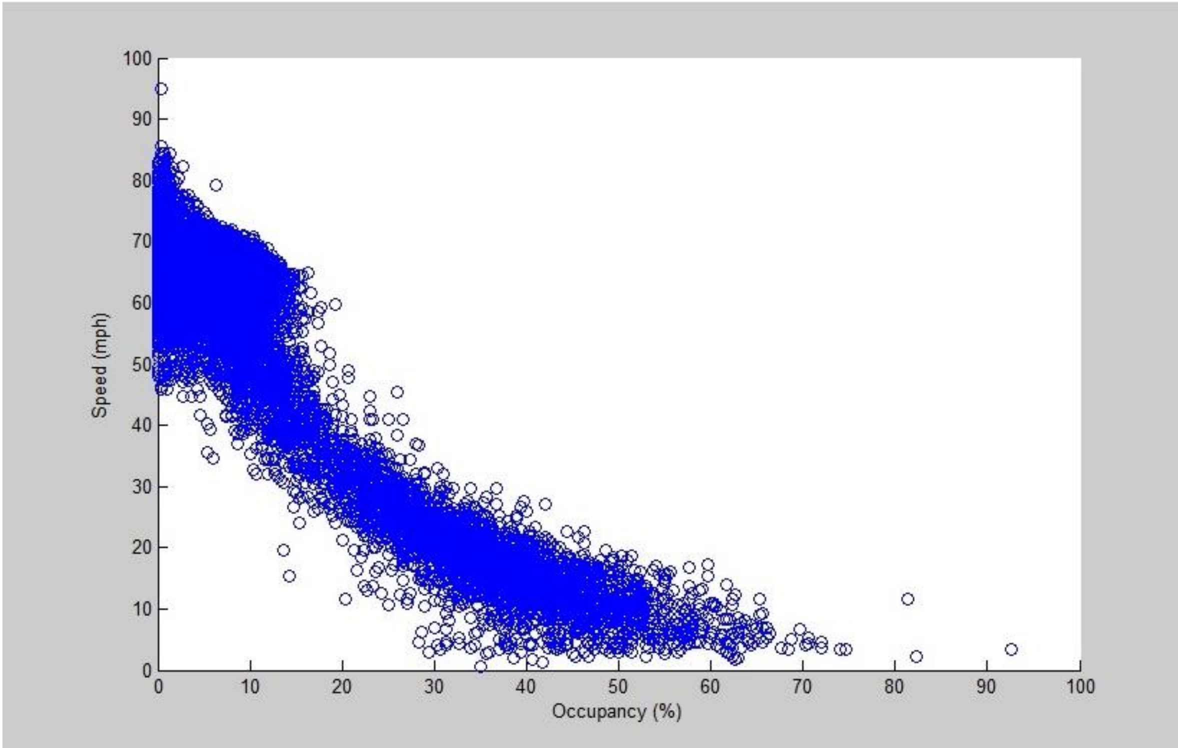

Figure 2.4 Q02: Speed-Occupancy Plot

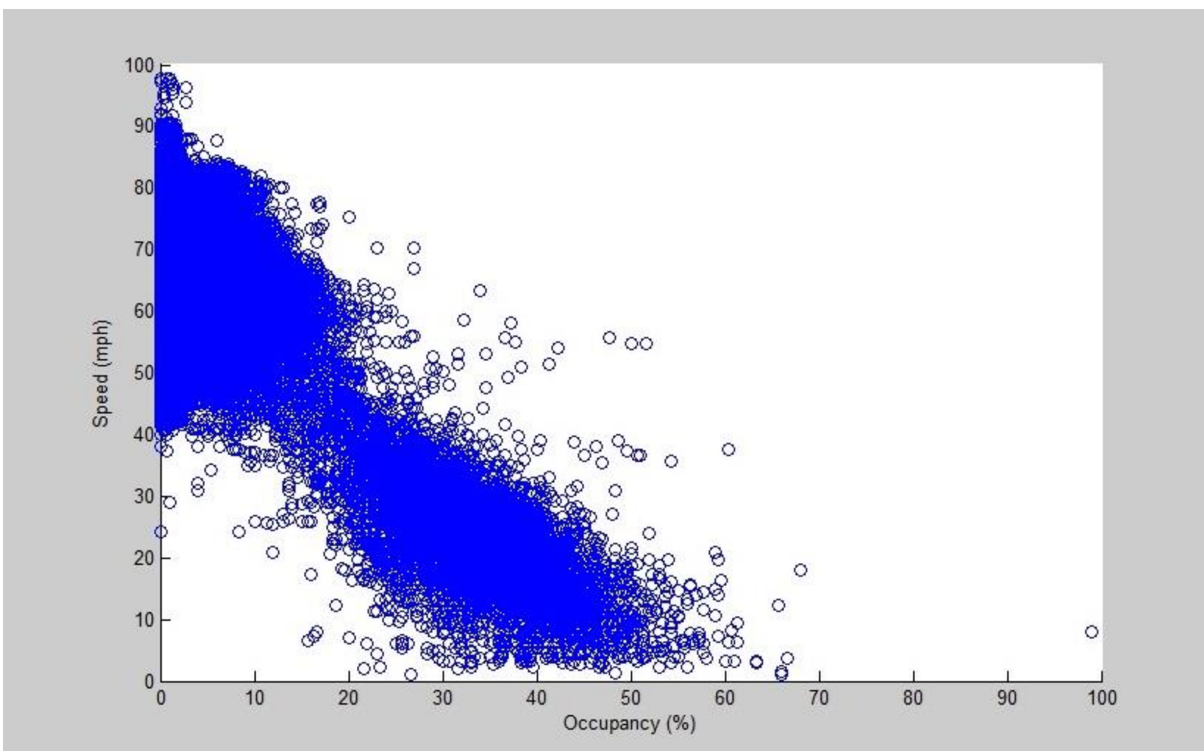

Figure 2.5 Q03: Speed-Occupancy Plot

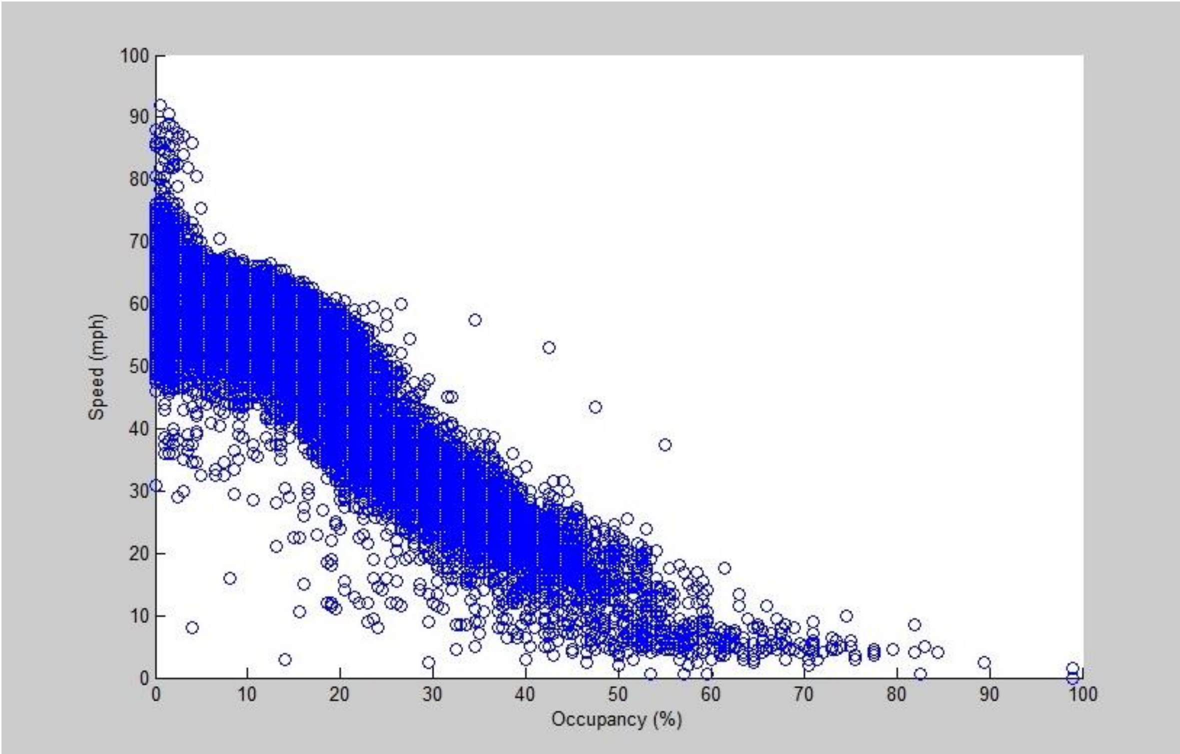

Figure 2.6 Q04: Speed-Occupancy Plot

2.2 Work Zone 2: I-70 Westbound near Blanchette Bridge

The second work zone site was located west of St. Louis on I-70, near the Blanchette Bridge. This short-term work zone was located within a long-term work zone involving a $63 million rehabilitation project of a 54-year-old bridge. The annual average daily traffic as of 2011 was 121,220, including 14,187 commercial trucks (11.7% of AADT). The short-term work involved closing one out of three lanes on August 1st, 2013 between 8:00 pm and 12:00 am. The work zone speed limit was 45 mph.

Traffic data were obtained from permanent sensors deployed on I-70. Two sensors, labeled S01 and S02 (fig. 2.7), captured relevant data. The work zone taper was located 0.602 mi from S01, and the S02 sensor was 0.8 mi upstream of S01.

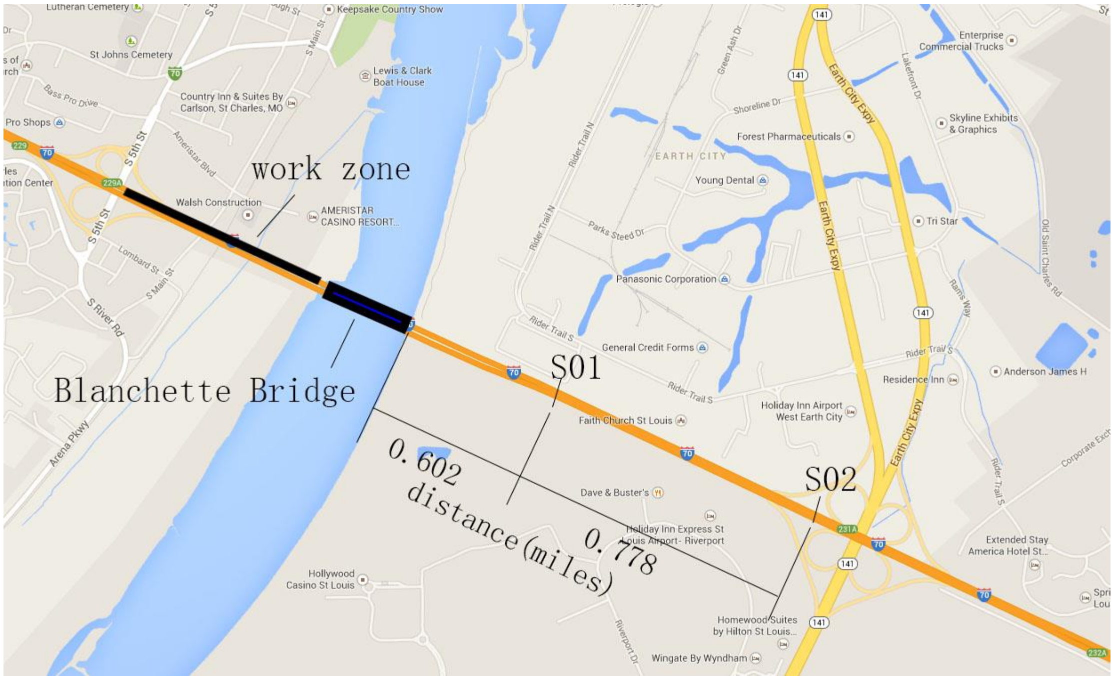

Figure 2.7 Work zone site on westbound I-70

Similar to the I-44 work zone, travel times were computed using speed data recorded at the two traffic sensors. Travel time was computed for the section between sensor S02 and the beginning of taper, a total length of 1.4 mi. Unlike the I-44 work zone, the I-70 work zone lasted for only a few hours. Thus, the speed-occupancy plot was not a reliable approach for determining free flow speed. Instead, free flow speed during the work zone period was assumed to be equal to the reduced speed limit of 45 mph. The hourly traffic volumes with and without the work zone for the westbound direction are shown in figure 2.8.

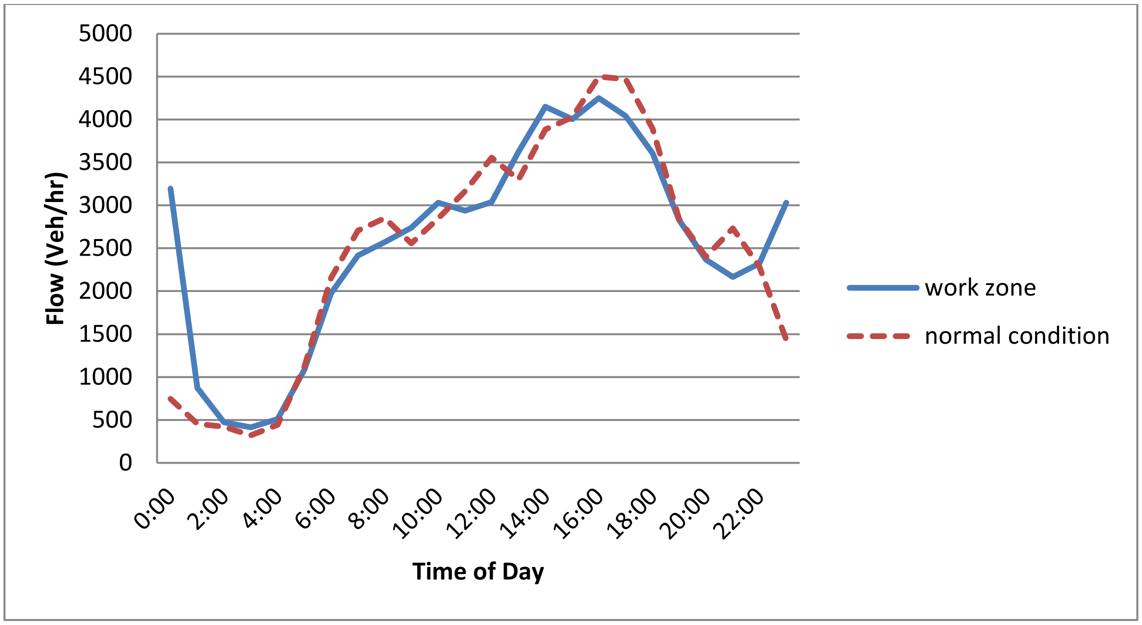

Figure 2.8 Hourly volumes with and without work zone at the westbound I-70 site

Chapter 3 Work Zone Software

Two software programs recommended by Edara (2009) for assessing traffic impacts of workzones in Missouri - VISSIM and the WZ Spreadsheet - are described in more detail in this chapter.

3.1 WZ Spreadsheet

Spreadsheets previously developed and utilized by the California, Virginia, New Jersey, Ohio, Florida, and Illinois state DOTs were obtained and analyzed for the development of the spreadsheet programs utilized in the current study. Several features, including input requirements, output options, an impact assessment algorithm, and cost estimation were analyzed. Next, a new spreadsheet that reflected MoDOT’s capacity values was developed. The resulting spreadsheet used the delay calculation procedure based on the demand-capacity model of the Highway Capacity Manual (2010). A primary goal behind the development of a new spreadsheet was to allow for easy customization to Missouri conditions. A related goal was to minimize user input requirements to allow for the quick estimation of the traffic impacts.

The spreadsheet requires the following inputs: 1) the total number of lanes and the number of open lanes, 2) hourly traffic volumes and truck percentages for each day of the week, 3) the start time and total duration of lane closure, 4) user value of time costs (optional), and 5) base capacity values for normal conditions. A default capacity value of 1,600 vphpl can be used when no data are available. It is not required for the user to enter the reduced work zone capacity values as an input. A built-in function automatically calculates capacity values based on MoDOT's work zone guidelines (MoDOT 2004). A screenshot of the spreadsheet is pictured in figure 3.1. It shows a simple-to-use interface where the user inputs the items in blue. These items include, the hourly demand, start time and duration of the lane closure, number of open lanes, total number of lanes, and truck percentage. Maximum delay, average delay, and user costs are computed based on the user inputs. Graphical representations of delay versus time and queue length versus time are also obtained as outputs, as shown on the right side of the screen.

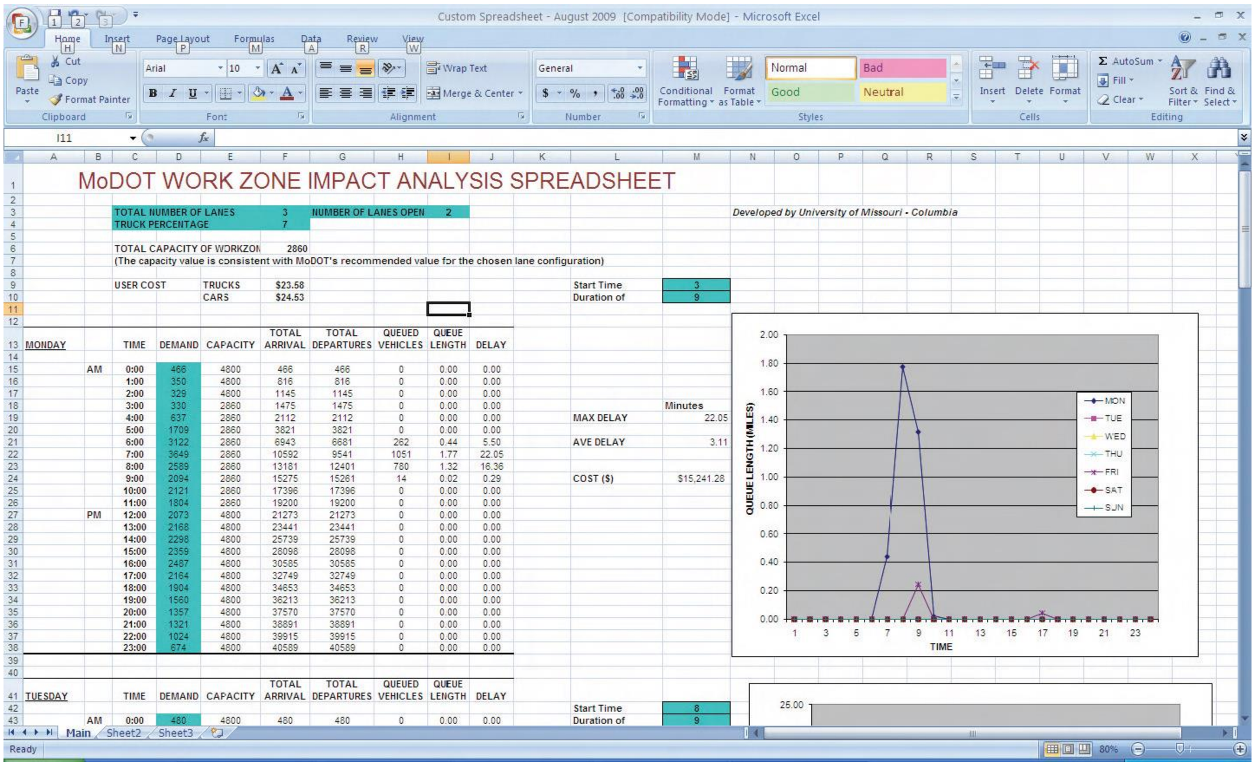

Figure 3.1 Screenshot of the WZ Spreadsheet

Since the WZ Spreadsheet was developed in 2009, MoDOT has made a few updates. One primary update entailed the use of capacity values recommended by the new HCM (2010). Adjustments to base capacity values depending on work intensity and grades were also made. Delay and queue length computation equations remain unchanged.

3.2 VISSIM Simulation Program

Traffic simulation tools have the capability of modeling individual vehicle and driver behavior at a high level of detail to assess traffic performance. In order to accurately utilize simulation models for work zone traffic analysis, it is necessary to calibrate the models to match field conditions, such as lane capacity and queue lengths, by adjusting driver behavior parameters. A previous study (Edara 2009) utilized the VISSIM microscopic simulation program, developing driver behavior parameter values for different work zone capacities observed in Missouri. Parameter values were recommended for different work zone lane closure configurations.

VISSIM is a microscopic, stochastic, discrete time-step based simulation software where individual vehicles represent the most basic elements of a simulation. It is based on the Wiedemann "psycho-physical" car-following and lane-changing models. The characteristics and behavior of individual drivers (i.e., vehicles) affect performance measures such as speed, throughput, and queue length. One user goal is to attempt to duplicate field performance measures using simulation. The car-following model that represents freeway conditions—the Wiedemann 99 car following model (W-99)— has 10 user-defined driving behavior parameters: CC0, CC1, CC2…, CC8, CC9 (PTV America 2008). In the model, a driver can be in one of four driving modes: Free driving, Approaching, Following, or Braking. In W-99, a driver either accelerates or decelerates to change from one driving mode to another, as soon as some threshold value, expressed in terms of relative speed and distance, is reached. Thus, the entire car following process is based upon the repetitive acceleration or deceleration of individual vehicles, with drivers having different perceptions of speed difference, desired speed, and the safety distance between two successive vehicles. The following is a brief description of the 10 driver behavior parameters used in the W-99 car following model:

CC0 is the standstill distance or desired distance between two consecutive vehicles at a stopped condition. The default value is 4.94 ft.

CC1 is the desired time headway for the following vehicle. Based on these values, the safety distance can be computed as $dx_{safe} = CC0+CC1* v$, where v is the speed of the vehicle (PTV 2007). The default value of *CC1* is 0.9. Higher *CC1* values represent less aggressive drivers.

CC2 defines the threshold that restricts longitudinal oscillations beyond the safety distance in a following process. The default value is approximately 13 ft.

CC3 characterizes the entry to the "following" mode of driving. It initiates the driver to decelerate upon recognizing a slower leading vehicle. It defines the time at which the driver starts to decelerate before reaching the safety distance.

CC4 and *CC5* control the speed oscillations after the vehicle enters the "following" mode of driving. Smaller values represent a more sensitive reaction of a driver to the acceleration or deceleration of the leading vehicle. *CC4* is used for negative speed difference, and *CC5* is used for positive speed difference. The default value of *CC4/CC5* is -0.35/0.35.

CC6 represents the dependency of speed oscillations on distance in the "following" state. Increased values of *CC6* result in an increase of speed oscillation as distance to the preceding vehicle increases.

CC7, CC8, and *CC9* are parameters that control the acceleration process.

The lane changing model in VISSIM is based upon driver response to the perception of the surrounding traffic. It uses a gap acceptance criterion where a driver changes lanes provided the available gap is greater than the critical gap. The decision to change lanes depends upon the following hierarchical set of conditions: the desire to change lanes, favorable driving conditions in the neighboring lanes, and the possibility to change lanes (gap availability). Based upon these conditions, the lane changing phenomenon is broadly classified into two types: 1) discretionary lane changes, which include drivers who want to change from slow moving lanes to fast moving lanes, and 2) necessary lane changes in case of any lane closure due to work zones, incidents, etc. A detailed description of the lane changing algorithm is presented in Wiedemann and Reiter (1992).

A necessary lane change depends upon the aggressiveness of a driver in accepting/rejecting gaps in adjacent lanes. A necessary lane change is represented by parameters such as the acceptable and threshold deceleration values of lane changing and trailing vehicles, and the safety distance reduction factor (*SRF*). The safety reduction factor refers to the reduction in safety distance (dx_{safe}) to the trailing and leading vehicles on the desired lane and the safety distance to the leading vehicle in the current lane. The default value of *SRF* is 0.6, which implies that the safety distance during lane changing is reduced by 40%. A lower *SRF* value, for example, of 0.4, would entail that the safety distance for lane changing is reduced by 60%, meaning drivers are more aggressive and accept shorter gaps.

Chapter 4 Work Zone Software Calibration

4.1 Calibration of Work Zone 1 on I-44

The raw traffic data obtained from the work zone contractor were of one-minute resolution. The data included speeds, volumes, and occupancies at the four sensor locations described previously. The WZ Spreadsheet was designed to utilize hourly traffic volumes as inputs. Thus, one-minute data was aggregated to obtain hourly traffic volumes. The raw data contained missing values and outliers that needed to be addressed to create the one-hour dataset. One problem with the data was that each one-minute data entry was not exactly 60 seconds. This meant a one-hour interval could include fewer than or more than 60 data entries. One way to avoid this aggregation problem was to compute the equivalent one-hour volume using the exact number of seconds included in the data entries. For example, if 60 entries added up to only 3,300 seconds and contained 1,000 vehicles, the equivalent one-hour volume was computed as,

$$\frac{3600 \times 1000}{3300} = 1091 \text{ vehicles} \tag{4.1}$$

This normalization technique allowed for consistency in deriving one-hour volumes.

4.2 Calibration of WZ Spreadsheet

The calibration of the WZ Spreadsheet involved identifying the calibration parameter and finding its optimal value that generated the most accurate delay and/or queue length estimates. The calibration parameter for the WZ Spreadsheet was work zone capacity. Two forms of calibration were conducted. First, calibration was conducted in order to minimize error in the estimated delay values. Least squares estimation was used to determine the capacity value that produced the minimum total delay error, computed as the summation of absolute values of the difference in estimated and actual delays. Estimated delays were obtained from the spreadsheet, and actual delays were obtained, as discussed previously, using traffic sensor speeds and free flow speeds. The second calibration approach was to calibrate for queue length instead of delay. The results of both approaches were compared, and the best approach was recommended.

The least squares estimation procedure for data obtained for July 10th is illustrated in table 4.1 and figure 4.1. Hourly demand volumes were input into the WZ Spreadsheet, and the capacity values varied between 2,600 veh/hr and 3,400 veh/hr (for two open lanes). This range was determined based on the typical capacities observed at similar work zones in Missouri. The total delay error values computed for different capacity values are shown in table 4.1. Error decreased as capacity increased from 2,600 to 3,200, then increased again. These values were plotted in figure 4.1. A second order polynomial regression was fitted to the data, as shown in figure 4.1. Based on the error values, 3,200 veh/hr resulted as the calibration parameter value with the least error.

Table 4.1 Delay error values for I-44 work zone data for July 10, 2013

Capacity (veh/hr)	Total Delay Error (minutes)
2600	69.6
2700	44.7
2800	26.5
2900	13.1
3000	8.2
3100	6.0
3200	3.9
3300	5.0
3400	5.9

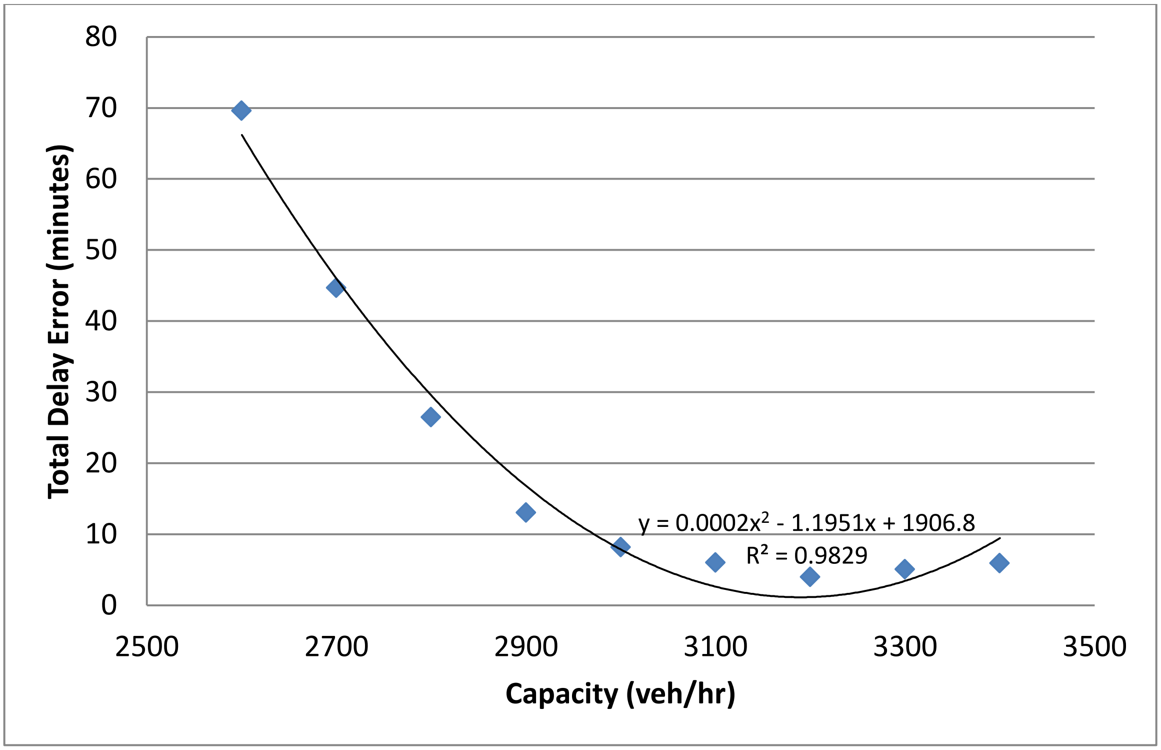

Figure 4.1 Delay error vs. capacity and least squares regression fit for July 10th work zone data

The calibrated capacity value was then used in the spreadsheet to determine the queue length and delay estimates for every hour, as shown in table 4.2.

Table 4.2 Using the calibrated capacity value in the WZ Spreadsheet for July 10th

TIME	DEMAND	CAPACITY	TOTAL ARRIVALS	TOTAL DEPARTURES	QUEUED VEHICLES	QUEUE LENGTH (mi)	DELAY (min/veh)	Actual Queue Length (mi)	Actual Delay (min/veh)	Absolute Queue length Error	Absolute Delay Error
0:00	434	3200	434	434	0	0	0	0	0.10	0.00	0.10
1:00	220	3200	654	654	0	0	0	0	0.04	0.00	0.04
2:00	212	3200	866	866	0	0	0	0	0.04	0.00	0.04
3:00	207	3200	1073	1073	0	0	0	0	0.08	0.00	0.08
4:00	227	3200	1300	1300	0	0	0	0	-0.03	0.00	0.03
5:00	552	3200	1852	1852	0	0	0	0	-0.06	0.00	0.06
6:00	2048	3200	3900	3900	0	0	0	0	0.43	0.00	0.43
7:00	3349	3200	7249	7100	149	0.28	2.79	1.8	2.37	1.52	0.43
8:00	2642	3200	9891	9891	0	0	0	1.8	1.76	1.80	1.76
9:00	2819	3200	12710	12710	0	0	0	0	0.08	0.00	0.08
10:00	2169	3200	14879	14879	0	0	0	0	0.08	0.00	0.08
11:00	2016	3200	16895	16895	0	0	0	0	0.24	0.00	0.24
12:00	1920	3200	18815	18815	0	0	0	0	0.09	0.00	0.09
13:00	2060	3200	20875	20875	0	0	0	0	0.10	0.00	0.10
14:00	1966	3200	22841	22841	0	0	0	0	0.08	0.00	0.08
15:00	2135	3200	24976	24976	0	0	0	0	0.07	0.00	0.07
16:00	2364	3200	27340	27340	0	0	0	0	0.06	0.00	0.06
17:00	2285	3200	29625	29625	0	0	0	0	0.02	0.00	0.02
18:00	2400	3200	32025	32025	0	0	0	0	0.01	0.00	0.01
19:00	1990	3200	34015	34015	0	0	0	0	0.03	0.00	0.03
20:00	1414	3200	35429	35429	0	0	0	0	0.03	0.00	0.03
21:00	1216	3200	36645	36645	0	0	0	0	0.07	0.00	0.07
22:00	1234	3200	37879	37879	0	0	0	0	0.07	0.00	0.07
23:00	721	3200	38600	38600	0	0	0	0	0.01	0.00	0.01
Total Absolute Error										3.32	4.00

The calibration procedure was repeated for another day, July 19th, for the I-44 work zone. The results are shown in table 4.3 and figure 4.2. The capacity of 3,100 veh/hr was determined as the calibration parameter value. Table 4.4 shows the use of the capacity value in the WZ Spreadsheet for estimating hourly delay and queue length values.

Table 4.3 Delay error values for I-44 work zone data for July 19, 2013

Capacity (veh/hr)	Total Delay Error (minutes)
2600	85.9
2700	51.9
2800	28.6
2900	13.6
3000	4.0
3100	3.2
3200	5.1

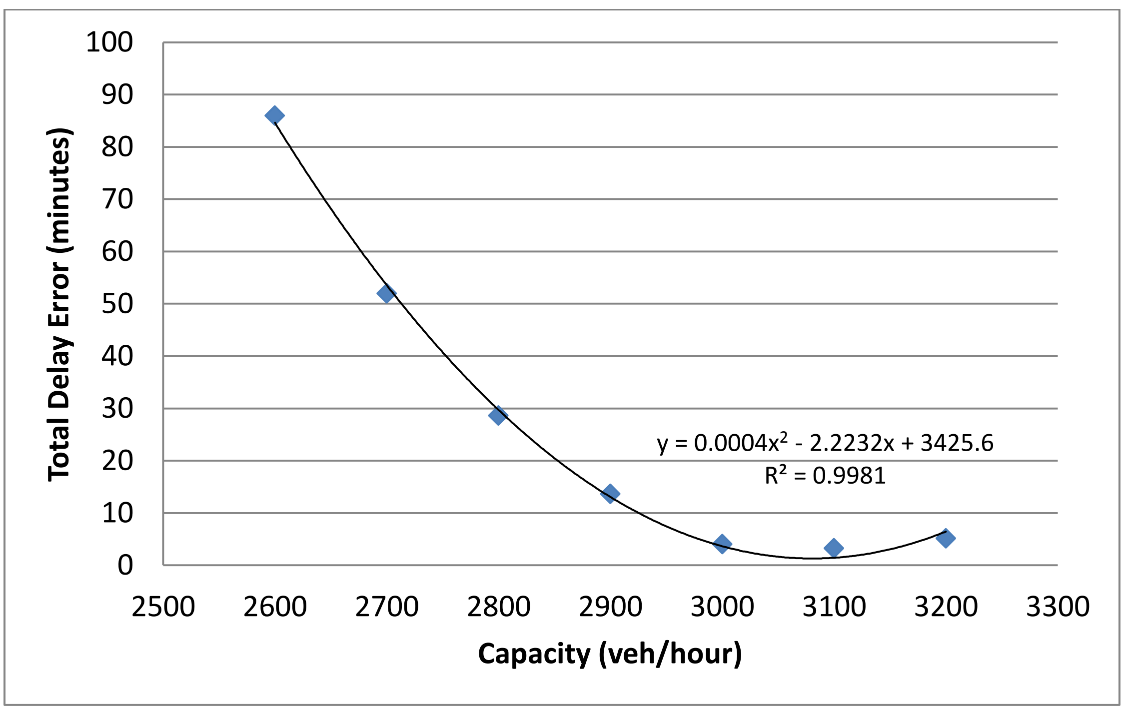

Figure 4.2 Delay error vs. capacity and least squares regression fit for July 19th work zone data

Table 4.4 Using the calibrated capacity value in the WZ Spreadsheet for July 19th

TIME	DEMAND	CAPACITY	TOTAL ARRIVALS	TOTAL DEPARTURES	QUEUED VEHICLES	QUEUE LENGTH (mi)	DELAY (min/veh)	Actual Queue Length (mi)	Actual Delay (min/veh)	Absolute Queue length Error	Absolute Delay Error
0:00	496	3100	496	496	0	0	0	0	0.06	0.00	0.06
1:00	304	3100	800	800	0	0	0	0	0.04	0.00	0.04
2:00	245	3100	1045	1045	0	0	0	0	0.07	0.00	0.07
3:00	233	3100	1278	1278	0	0	0	0	-0.03	0.00	0.03
4:00	305	3100	1583	1583	0	0	0	0	-0.01	0.00	0.01
5:00	623	3100	2206	2206	0	0	0	0	-0.04	0.00	0.04
6:00	2092	3100	4298	4298	0	0	0	0	0.56	0.00	0.56
7:00	3198	3100	7496	7398	98	0.18	1.90	0.7	2.33	0.52	0.43
8:00	2821	3100	10317	10317	0	0	0	0.7	1.00	0.70	1.00
9:00	2905	3100	13222	13222	0	0	0	0	0.09	0.00	0.09
10:00	2360	3100	15582	15582	0	0	0	0	0.10	0.00	0.10
11:00	2099	3100	17681	17681	0	0	0	0	0.13	0.00	0.13
12:00	2108	3100	19789	19789	0	0	0	0	0.07	0.00	0.07
13:00	2164	3100	21953	21953	0	0	0	0	0.13	0.00	0.13
14:00	2267	3100	24220	24220	0	0	0	0	0.05	0.00	0.05
15:00	2350	3100	26570	26570	0	0	0	0	0.04	0.00	0.04
16:00	2487	3100	29057	29057	0	0	0	0	0.04	0.00	0.04
17:00	2614	3100	31671	31671	0	0	0	0	0.01	0.00	0.01
18:00	2457	3100	34128	34128	0	0	0	0	0.05	0.00	0.05
19:00	1984	3100	36112	36112	0	0	0	0	0.00	0.00	0.00
20:00	1556	3100	37668	37668	0	0	0	0	0.05	0.00	0.05
21:00	1391	3100	39059	39059	0	0	0	0	0.04	0.00	0.04
22:00	1222	3100	40281	40281	0	0	0	0	0.08	0.00	0.08
23:00	800	3100	41081	41081	0	0	0	0	0.05	0.00	0.05
									Total Absolute error	1.22	3.19

The capacity calibration values obtained previously were validated using data from the same day of the week. Delay and queuing occurred in the work zone on July 17th, the same day of the week as July 10th for which a capacity of 3,200 veh/hr was determined. The field data showed that delays and queues occurred only between 7:00 am-8:00 am. A delay of 1.52 minutes per vehicle and a queue length of 0.7 miles were observed during this period. The WZ Spreadsheet with a 3,200 veh/hr capacity value produced a delay of 1.71 minutes per vehicle and a queue length of 0.2 miles, both very close to the actual field values. Validation could not be conducted for the second day, July 19th, since queues and/or delays did not occur again on the same day of week during the work zone period.

The calibration procedure discussed above aimed to minimize error in the estimated delay. The same procedure was used to minimize error in the estimated queue length value. The results showed that the calibration based on queue length generated high delay errors. The delay-based and queue length-based calibration results are shown in table 4.5. Based on these values, it was concluded that the delay-based estimation produced acceptable values for both delay and queue length.

Table 4.5 Comparison of delay-based and queue length-based calibration

	Capacity (veh/hr)		**Total Delay Error (minutes)**	**Total Queue Length Error (miles)**
July 10th work zone	Delay-based	3200	3.3	3.9
	Queue length-based	2900	2.6	13.1
July 19th work zone	Delay-based	3100	1.2	3.2
	Queue length-based	2900	0.8	13.6

4.3 Calibration of VISSIM Simulation Model

The calibration of the VISSIM simulation model involved identifying the most appropriate calibration parameters and determining their optimal values. Optimal, in this case, means the most accurate delay and/or queue length estimates. Unlike the WZ Spreadsheet, capacity is not an input to the VISSIM simulation model. Instead, several driving behavior parameters control capacity, and are provided as model inputs. This section describes the calibration approach utilized for the I-44 work zone case study.

A base VISSIM model of the I-44 work zone was obtained from Crawford Bunte Brammeier (CBB), who provided support services to MoDOT during the planning stages of the I-44 project. Several changes were made to the base model, including updating traffic volumes, desired speeds, traffic composition, and other input variables. A screenshot of the VISSIM model is shown in figure 4.3. The section highlighted in brown displays the work zone.

Figure 4.3 I-44 segment containing the work zone in VISSIM

The desired speed distributions were developed using posted speed limits and the operating speeds obtained from traffic sensors. Two uniform distributions were used: a non-work zone speed distribution ranging from 60 mph to 70 mph, and a work zone speed distribution ranging from 50 mph to 60 mph.

Hourly traffic demand at the I-44 work zone is given in table 4.6. The morning peak period was the only time during which the demand approached capacity. Thus, only the morning peak period between 5:00 am and 11:00 am, highlighted in green in the table, was simulated. A warm-up period of 900 seconds at the beginning of the simulation was used prior to initiating data collection. The traffic was composed of 93% passenger cars and 7% trucks.

Table 4.6 Hourly demand for the I-44 work zone

Time	Demand (veh/hr)
0:00 to 1:00	434
1:00 to 2:00	220
2:00 to 3:00	212
3:00 to 4:00	207
4:00 to 5:00	227
5:00 to 6:00	552
6:00 to 7:00	2048
7:00 to 8:00	3349
8:00 to 9:00	2642
9:00 to 10:00	2819
10:00 to 11:00	2169
11:00 to 12:00	2016
12:00 to 13:00	1920
13:00 to 14:00	2060
14:00 to 15:00	1966
15:00 to 16:00	2135
16:00 to 17:00	2364
17:00 to 18:00	2285
18:00 to 19:00	2400
19:00 to 20:00	1990
20:00 to 21:00	1414
21:00 to 22:00	1216
22:00 to 23:20	1234
23:00 to 24:00	721

Three performance measures—capacity, travel time, and queue length—were derived from the simulations. Each parameter set was run five separate times to account for randomness in the simulation, and results were averaged across the five runs. Travel time and queue length values were used to calibrate driving behavior parameters. Travel time was used in lieu of delay, since the accurate estimation of travel time also results in the accurate estimation of delay. Based upon a previous study (Edara 2009), three driving behavior parameters were selected for calibration. These parameters were *CC1, CC2,* and *SRF*, and were the most relevant parameters.

A description of these parameters was provided in chapter 3 of the current report. The range of values for each parameter were recommended in a previous study (Edara 2009), and are shown in table 4.7.

Table 4.7 Ranges of driving behavior parameter values

Parameters	Minimum	Maximum
CC1	0.9 sec	1.8 sec
CC2	10 ft	55 ft
SRF	0.15	0.6

After testing various combinations of parameters, the combination of *CC1* =1.3 sec, *CC2* = 35 ft, and *SRF* = 0.3 produced the lowest total travel time error of 2.02 minutes. The corresponding total queue length error was 2.1 miles. This combination resulted in a capacity of 3,034 veh/hr.

4.4 Calibration of Work Zone 2 on I-70

The raw traffic data obtained from the Missouri DOT database was of one-minute resolution, similar to the I-44 work zone. The data included speeds, volumes, and occupancies at the two sensor locations of interest. The one-minute data was aggregated to obtain hourly traffic volumes for use in the WZ Spreadsheet. The one-hour dataset was developed using the normalization technique previously described for the I-44 site in section 4.1 of the current report.

The least squares estimation procedure used for the I-44 case study was applied again to calibrate the WZ Spreadsheet for the I-70 work zone. The delay and queue length errors for different capacity values are shown in table 4.8. A quadratic least squares fit was plotted for the capacity and delay values, as shown in figure 4.4. A capacity value of 2,900 veh/hr was selected as the calibration parameter based on the smallest delay error.

Table 4.8 Calibration of WZ Spreadsheet for I-70 work zone

Capacity (veh/hr)	Total Delay Error (minutes)	Total Queue Length Error (miles)
2300	39.3	0.5
2500	23.6	1.4
2700	16.7	1.9
2800	14.3	2.1
2900	12.8	2.3
3000	14.9	2.5
3100	17.0	2.7
3200	17.7	2.8
3300	17.7	2.8

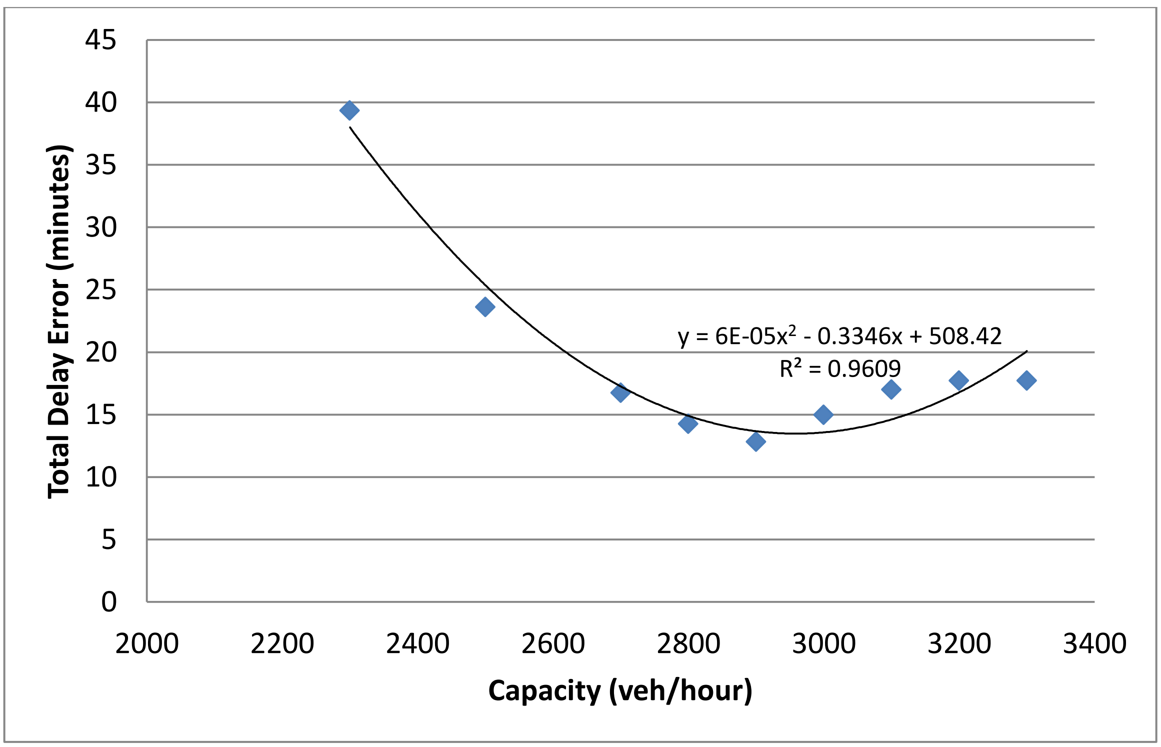

Figure 4.4 Least squares estimation for I-70 work zone

4.5 Calibration of VISSIM model for Work Zone 2

A map of the I-70 work zone was used as background to create the VISSIM model. A screenshot of the VISSIM model with the background is shown in figure 4.5. The hourly traffic demand at the I-70 work zone is shown in table 4.9, with the peak hour being between 16:00 and 17:00. The demand during the entire 24-hour period was simulated. A warm-up period of 900 seconds at the beginning of the simulation was utilized prior to collecting results for the performance measures. The traffic was composed of 88.3% passenger cars and 11.7% trucks.

Figure 4.5 I-70 segment with the work zone in VISSIM

Table 4.9 Hourly demand for the I-70 work zone

Time (In Hour)	DEMAND
20:00 to 21:00	2493
21:00 to 22:00	2164
22:00 to 23:20	2322
23:00 to 24:00	3137
0:00 to 1:00	3194
1:00 to 2:00	887
2:00 to 3:00	472
3:00 to 4:00	421
4:00 to 5:00	521
5:00 to 6:00	1088
6:00 to 7:00	2080
7:00 to 8:00	2416
8:00 to 9:00	2707
9:00 to 10:00	2740
10:00 to 11:00	3137
11:00 to 12:00	3388
12:00 to 13:00	3646
13:00 to 14:00	3747
14:00 to 15:00	4150
15:00 to 16:00	4140
16:00 to 17:00	4250
17:00 to 18:00	4181
18:00 to 19:00	3608

The same performance measures collected for the I-44 work zone, i.e. capacity, travel time, and queue length, were collected from the simulations. Each parameter set was run five separate times to account for the randomness of the simulation, and the results were averaged across the five runs. Several combinations were tested by varying the *CC1*, *CC2,* and *SRF* parameters, as described in table 4.7. The combination of *CC1* =1.4 sec, *CC2* = 35 ft, and *SRF* = 0.4 produced the smallest total travel time error of 18.0 minutes. The corresponding total queue length error was 2.9 miles. The resulting capacity was 3,022 veh/hr

Chapter 5 Conclusions

The WZ Spreadsheet and VISSIM models were calibrated using data from two work zones in Missouri. Both work zones involved a single lane closure on a three-lane section of roadway. The I-44 work zone was a long-term work zone, while the I-70 work zone was temporary and lasted only a few hours. The capacity values required for calibration were nearly identical for both models. The WZ Spreadsheet produced the best results when the average capacity was 1,575 veh/hr/ln, while the VISSIM model performed best when the average capacity was 1,514 veh/hr/ln. Case study calibration based on delay or travel times performed better than queue length. The total error in queue length (or delay) was computed by summing the error values over the entire 24-hour observation period.

In the future, additional case studies could be added to further improve the two models. Such studies could involve different work zone lane configurations, e.g., a one-lane closure on a two-lane segment, a two-lane closure on a three-lane segment, etc. Obtaining the data needed for calibration can be challenging. In order to avoid congestion in urban areas, MoDOT makes an effort to close lanes only during off-peak hours or at night. Thus, finding work zone sites that result in queuing and delays is a challenge. To facilitate future calibration efforts, the current study makes the following recommendations:

1) When travel time monitoring equipment, such as Bluetooth, is deployed, the travel time upstream of the work zone taper should be measured if possible. Work zone analysis software compute queuing and delays as a result of capacity reduction starting at the taper. Thus, software can be calibrated only if data are available upstream of the work zone taper. However, it is recognized that the primary purpose of using Bluetooth monitoring is to inform drivers of the travel time through the work zone or between two points of interest near the work zone—not

necessarily to report travel time to reach the taper. In such situations, deploying one additional Bluetooth unit near the taper is recommended to obtain the data necessary for calibration.

2) The use of private sector data (e.g., INRIX) for travel times and queue length could generate a sufficiently large sample of work zones that could be used for calibration. However, such data should first be validated using ground truth, since such data are still relatively new and have not been fully validated.

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