VALIDATING THE PERFORMANCE OF THE FHWA WORK ZONE MODEL VERSION 1.0: A CASE STUDY ALONG I-91 IN SPRINGFIELD, MASSACHUSETTS

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ABSTRACT

Central to the effective design of work zones is being able to understand how drivers behave as they approach and enter a work zone area. States use simulation tools in modeling freeway work zones to predict work zone impacts and to select optimal design and deployment strategies. While simple and complex microscopic models have been used over the years to analyze driver behavior, most models were not designed for application in work zones. Using data collected from an instrumented research vehicle and model components from two PhD dissertations, FHWA created the Work Zone Driver Model and programed the Work Zone Driver Model DLL v1.0, a software that could override car-following in commercial microsimulation software packages so that practitioners can better predict work zone impacts.

This paper demonstrates the capabilities of the FHWA Work Zone Driver Model DLL v1.0, interfaced with VISSIM, and tested on an interstate work zone in Springfield, MA. The DLL's performance is compared to field data collected using an instrumented research vehicle (IRV) and to Weidemann 99 in VISSIM. Performance metrics were selected to align with state DOT work zone management efforts.

Results showed acceptable performance from the DLL, as it predicted queue locations and travel speeds that were near field observations. Limitations of the DLL and interface are discussed, and opportunities for improving version 2.0 are described.

Keywords: work zones, microsimulation, car-following, queue, delay

INTRODUCTION

The Interstate System is comprised of approximately 223,000 lane-miles of pavement, has more than 57,000 bridges, and tens of thousands of other significant structural elements (*1*). Many of these elements are reaching their design life of 50 years and require major rehabilitation or replacement in the near future. Work zone activity has already been increasing over the past several years, and the number of work zones is projected to increase (*2*).

Freeway work zones can create significant delays. They account for nearly 24% of all non-recurring delay, and 10% of total delay annually (*3*). Even during off-peak hours, work zones are a major contributor to delays, averaging 11 hours of delay per non-peak urban traveler (*4*).

To mitigate work zone impacts, states develop Traffic Management Plans (TMPs) with targeted traffic control strategies for significant construction projects. The first step of a TMP is predicting the operational impacts of the work zone (*5*). Engineers and planners have used both microscopic and macroscopic models to predict the queues, delays, and travel times created by work zones within a degree of accuracy, giving them the foresight to design and schedule a work zone that will reduce the total delay (*6*, *7*).

Microscopic models calculate and predict the state of individual vehicles in continuous or discrete time-space, and offer detailed descriptions of both road and traffic characteristics critical for work zone modeling. By modeling the individual reactions of vehicles, microscopic models provide a more precise look as to how network elements impact traffic flow (*8*). If an accurate model were used, the aggregate delays experienced by each vehicle could provide practitioners detailed insight about work zone impacts. While these tools have been used to predict work zones impacts in the past (*9*), their core algorithms were not developed to reflect the specific behaviors observable in work zone driver behavior. Before microscopic models can be used to accurately predict work zone impacts, a work zone driver behavior model needs to be developed.

FHWA developed a work zone microscopic model to simulate car following through a work zone. The FHWA Work Zone Driver Model, which was designed to better predict vehicle responses to work zone elements, was created using field data, and synthesized from two Ph.D. dissertations. The algorithms were calibrated and validated at a microscopic level. So that practitioners could use the model to predict work zone impacts, FHWA developed the Work Zone Driver Model v1.0, which, when interfaced with a commercial microsimulation software package, overrides the car-following logic for work zone segments. The software is implemented as a dynamic link library (DLL).

Before practitioners can use this software, it must be interfaced with a microsimulation software package and tested to validate its performance and accuracy.

The purpose of this research is to test and validate the performance of the FHWA Work Zone Driver Model DLL v1.0 through a case study, so that practitioners can use the software to better estimate the impacts of freeway work zones. Validation performance metrics were selected to align with state and local DOT performance measures often used in TMPs (ex. travel time, delay, back of queue).

For this case study, the FHWA Work Zone Driver Model v1.0 was interfaced with VISSIM 7.0, and tested along the northbound travel lanes of an instrumented work zone on I-91 in Springfield, Massachusetts. The accuracy of the FHWA Work Zone Driver Model DLL v1.0 was tested; results were compared to VISSIM's car-following model, Weidemann 99, and to field data.

LITERATURE REVIEW

States are interested in aspects of work zone performance, and use work zone performance measures for various reasons. Hallmark et al. (*10*) summarize the various work zone performance metrics used by state DOTs. While the list is not exhaustive, it does summarize usage of some of the most popular metrics; total or average delay time was the most common, but other common metrics included queue length and location, number of vehicles that encounter a queue, and maximum per-vehicle delay. Some measures, like user satisfaction or complaint figures, were also common, but can't be modeled with microsimulation.

Each of these metrics is useful for different purposes. For example, it has been suggested that motorists view work zones primarily in terms of delay (*11*, *12*), so states collect delay times to inform road users about potential impacts. Other metrics are used in the planning stages, since states are required to evaluate road construction projects that use Federal funds for mobility impacts throughout the planning and construction process (*5*).

The choice of certain performance metrics often depends on a state's unique circumstances. Rather than suggesting that states track a large number of metrics, Federal guidance recommends a limited number of well-tracked key metrics, provided there are established performance targets for each measure (*13*). For example, Michigan's thresholds for work zone performance include travel time delay of less than ten minutes and a volume-to-capacity ratio of less than 0.80 (*11*).

Many computer models have been developed to predict work zone impacts. Research has, for example, focused on improving capacity predictions (*14*, *15*) or comparing various tools designed to predict work zone performance (*6*, *7*). These tools have had varying levels of success; for instance, Schnell et al. (*7*) noted that the models they tested consistently underestimated queue length, and in some cases were unsuitable for work zone modeling.

Simulation at the microscopic level, in particular, has recently become more common as a tool to evaluate the potential impacts of work zones. Pringle and Nikolic (*16*) cite its utility to practioners as a customizable tool, its ability to capture traffic dynamics over time, and the potential to consider and evaluate multiple underlying elements and factors. They also highlight that the visual element that microsimulation tools provide are useful in presenting results to non-technical audiences or for high-level discussion.

On the other hand, microsimulation requires calibration and validation to elicit useful results—Pringle and Nikolic (*16*) warn of the risk of "garbage in, garbage out". To encourage the proper use of microsimulation, the state of Washington has established a VISSIM protocol (*17*) which defines minimum standards that a model must meet in the calibration and validation process in order to be used in project development in the state. These include performance standards for error in speed and capacity predictions, as well as guidelines for checking model rationality and errors.

These steps are crucial to a model's performance, as reflected by the amount of literature on the topic. For example, research has been done to attempt to calibrate VISSIM's default parameters based on estimated work zone capacities (*18*, *19*). Improvements to capacity values, however, do not necessarily suggest that other estimates will also be improved. Chatterjee et al. (*19*) simulated a wide variety of potential values to develop a set of lookup tables that allow practicioners to choose calibrated parameters based on estimated work zone capacities and lane distribution. While they assume that these calibrated parameters will result in more accurate outputs when it comes to metrics like queue length and delay, such assumptions cannot be taken for granted and must be separately validated (*20*).

A common way to validate any car-following model is to compare its performance with field data other than the data with which it was calibrated. This verifies that a model doesn't overfit the calibration data, but still performs successfully in situations it was intended to model. This review found that, generally, such models are compared to field data by reporting the error in one or more performance metrics, expressed (for example) as percent error (*21*) or root mean square error (*22*, *23*). The lower the error, the better the model is said to have performed, although Hollander and Liu (*20*) note that minor fluctuations are in the nature of traffic, so some level of error is to be expected. From this review, it was determined that a primary concern in validation is that field data are collected and analyzed using the same methods as the model data, so that variances in data collection or data processing proceedures do not influence validation results.

Conclusions from this review include:

1. The performance metrics of speed through the work zone, queue length and location, and travel times through the work zone would align with state and local DOT interests in work zone performance;
2. Validation efforts should directly compare performance metrics from the model to data collected in the field. Field data should be processed using the same methods as model data, for a true comparison.

OVERVIEW OF FHWA WORK ZONE DRIVER MODEL - VERSION 1.0

The FHWA Work Zone Driver Model was developed to better predict car-following through freeway work zones. The model uses the framework and acceleration equations developed in two dissertations:

1. <u>A New Multidimensional Psycho-Physical Framework for Modeling Car-Following in a Freeway Work Zone</u> (*24*). A psycho-physical car-following framework that defines relative-distance (Δx) and relative-speed (Δv) regions with distinctly different driver behaviors;
2. <u>Modified Field Theory (MFT)</u> (*25*). Acceleration equations created for work zones, derived from psychology's Field Theory.

The FHWA Work Zone Driver Model v1.0 calculates car-following behaviors differently based on the segment traversed (freeways, advanced warnings, taper zones, and work zones), the level of congestion (congested vs. uncongested), and classification of the lead vehicle (passenger car, heavy vehicle, motorcycle). In the model, each unique scenario (ex. “advanced warning, congested conditions, following a passenger car”) has a unique framework with its own calibration variables.

Each framework includes seven ‘regimes,’ bounding specific regions in the Δx/Δv space. Figure 1 shows the regimes.

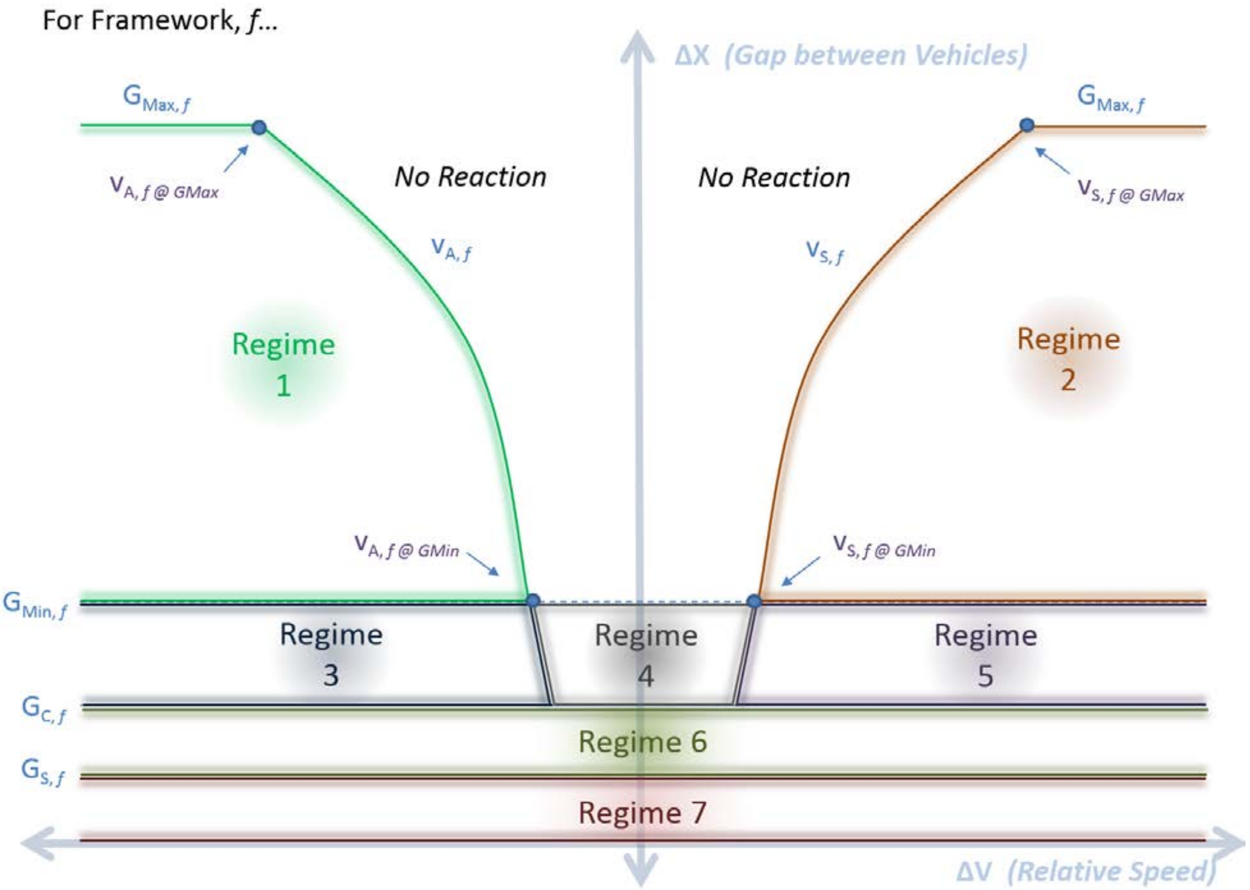


FIGURE 1 Generic Car-Following Framework of the FHWA Work Zone Driver Model.

Within each regime, a combination of force equations are used to compute car-following acceleration response. Relative speed, relative position, following vehicle speed, and parameters describing driver preference (such as desired speed or safe following distance) are factored into force equations to calculate the response. The resulting acceleration / deceleration for each modeled timestep is implemented in the software.

FHWA Work Zone Model DLL v1.0

The FHWA Work Zone Model v1.0 was implemented in a DLL that, when interfaced with a microsimulation software package, overrides the microsimulator’s car-following algorithms for work zone segments. This DLL is intended for use by engineers and planners to predict the impact of freeway work zones.

CASE STUDY - I-91 SPRINGFIELD, MA WORK ZONE

The performance of the FHWA Work Zone Model in VISSIM was tested against an instrumented work zone along Interstate 91 northbound in Springfield, Massachusetts. This 3-lane, 6-mile segment included 5 on-ramps, 7 off-ramps, and a 1+ mile work zone that reduced capacity from 3-lanes to 2-lanes. To evaluate model performance, driver behavior field data were collected using an instrumented research vehicle (IRV) during the weekday AM peak hour (0800-1000) (*26*, *27*). To create and calibrate the VISSIM networks, macroscopic data were collected and summarized by MassDOT using roadside instrumentation (*28*). This work zone was selected because it was a long-term work zone (4+ years) and the segment was heavily instrumented. Figure 2 shows the segment of I-91 examined.

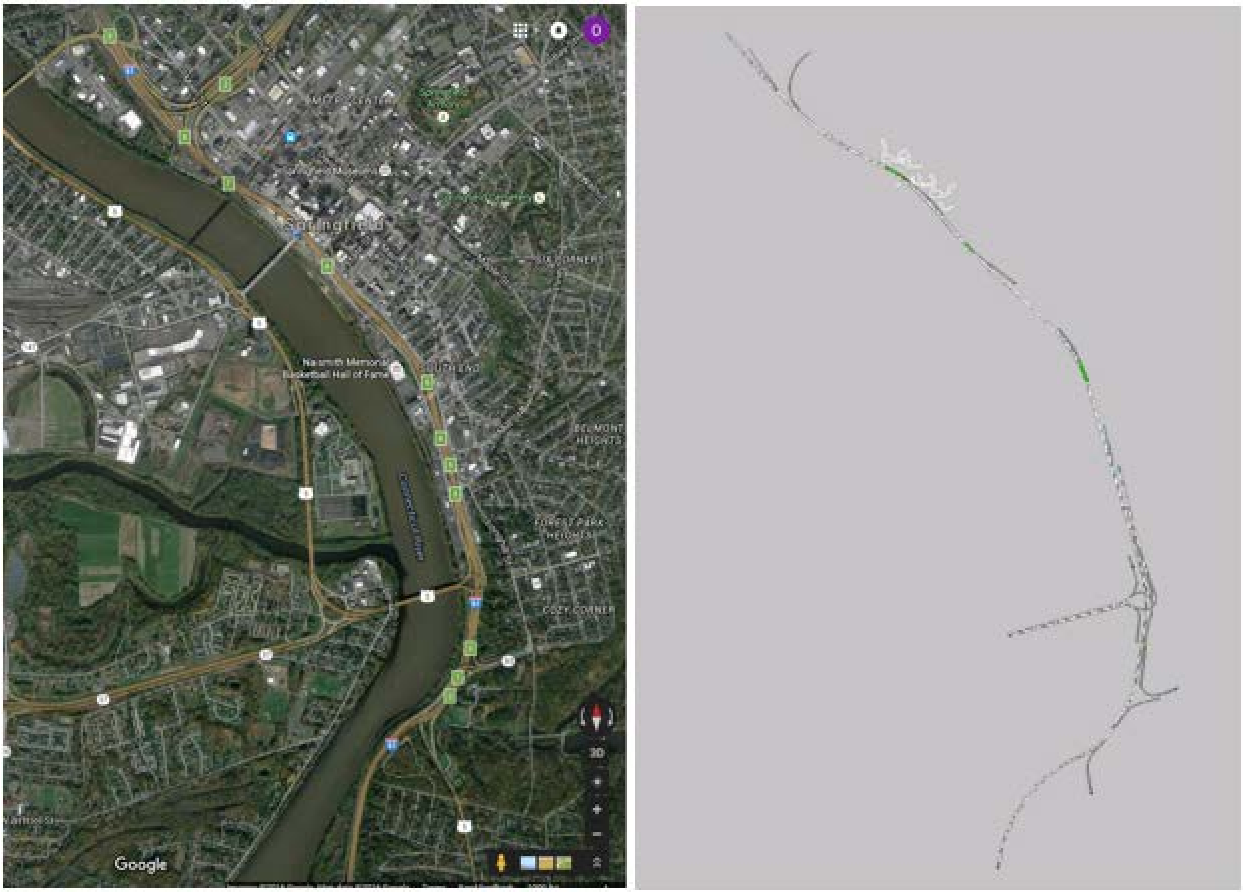
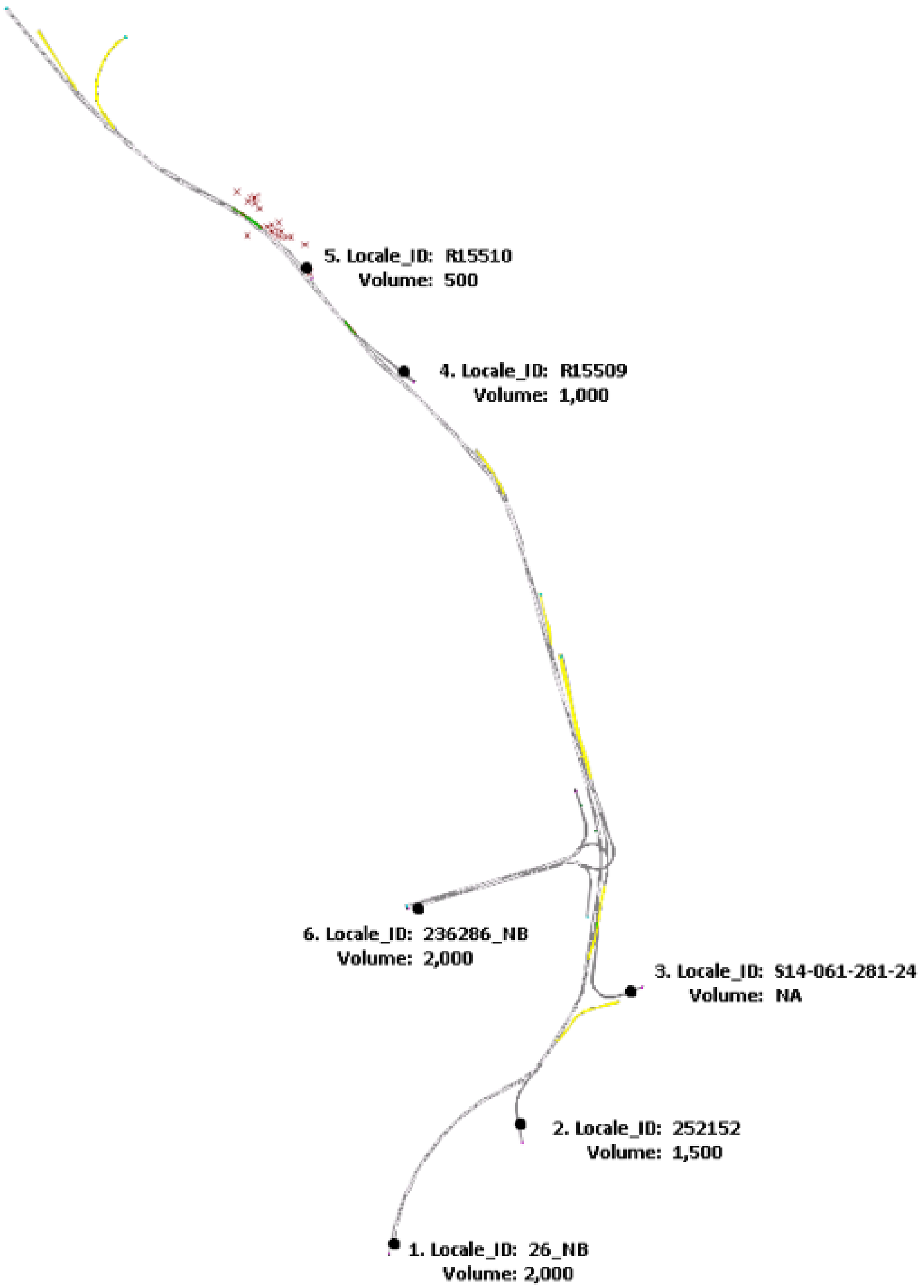


FIGURE 2 I-91 in Springfield, Massachusetts – satellite image (left) and VISSIM network (right).

Network Calibration

Volume

Traffic volumes were defined using count data found on the MassDOT Highway Transportation Data Management System website (*28*). The location of each field data collection point is shown in Figure 3. The vehicle input volumes entered into the VISSIM network are also provided in Figure 3. Volumes are representative of the field data collected July 9, 2016, between 07:30 and 10:00 a.m. The volume for point 3 (exit 2 on-ramp) was estimated due to lack of data.



Point	Locale_ID	Road Name	Volume
1	26_NB	I-91 NB	2,000
2	252152	Exit 1 On-Ramp	1,500
3	S14-061-281-24	Exit 2 On-Ramp	1,500 (estimated)
4	R15509	Exit 3 On-Ramp	1,000
5	R15510	Exit 4 On-Ramp	500
6	236286_NB	US 5	2,000

FIGURE 3 MassDOT data collection points used for vehicle input volumes.

Desired Speed

Speed distributions were created using historical records for I-91, published on MassDOT's Highway Transportation Data Management System site (*28*). The desired speed distribution published to this website is consistent with field data collected using the instrumented research vehicle. The data used for this study were collected July 7, 2016 and are listed in Table 1.

TABLE 1 Desired Speed Distribution for I-91 from MassDOT

Speed Bins (mph)	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84
Midpoint Speed (mph)	42	47	52	57	62	57	72	77	82
Fitted Normal Cumulative NB Distribution	0.0%	0.2%	1.6%	8.4%	26.7%	55.4%	81.4%	95.1%	99.2%

Due to limited number of speed data collection points, the data used to calibrate VISSIM's desired speed distribution was collected at a nearby location outside the 6 mile segment modeled.

Other Consideration

Data limitations – such as number/location of collection points or level of data aggregation – can limit a modeler's ability to accurately recreate a network, thereby influencing the accuracy of a model. There existed minor data limitations for I-91 (such as traffic composition) that may have reduced the accuracy of the VISSIM network created.

Work Zone

The work zone evaluated was a part of the Massachusetts Department of Transportation's I-91 Viaduct Rehabilitation Project near Springfield, MA, which replaces the existing deck of the bridge (*29*). This analysis takes place during Stage 1B of the project (December 2015 to November/December 2016). During Stage 1B, the inside lane (3rd lane) of I-91 NB was closed, starting three quarters of a mile north of exit 6 until the I-291 EB on-ramp (see Figure 4).

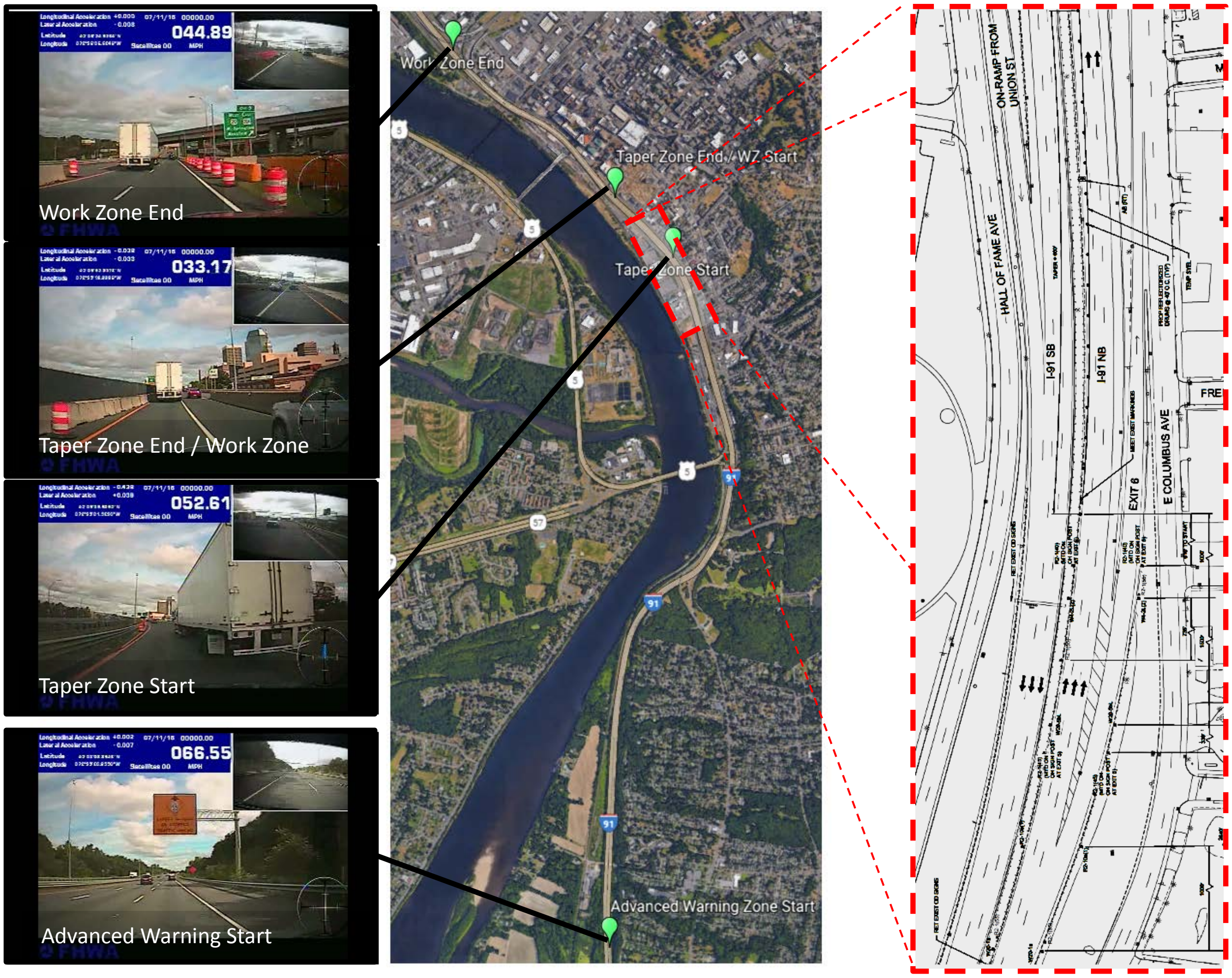


FIGURE 4 The I-91 NB closure, as seen from the Instrumented Research Vehicle (left), satellite (middle), and MassDOT AutoCAD drawings of the lane closure (right).

VISSIM DLL Interface

The FHWA Work Zone Driver Model DLL v1.0 was interfaced with VISSIM using the existing DLL interface in VISSIM. Link numbers for the VISSIM (FHWA) network were changed to designate the links for advanced warning, taper zone, and work zone.

It is important to note that when a car-following DLL is interfaced with VISSIM, it overrides all acceleration/deceleration functions. A DLL cannot be created to override just car-following, nor can it ; a DLL cannot be created to return VISSIM's acceleration/deceleration for other behaviors or scenarios (such as slowing/stopping at a red traffic signal, slowing/yielding to other vehicles in a conflict area, or slowing to accommodate lane changing for route choice or cooperative lane changes). Ergo, if a DLL does not include acceleration/decerleration functions for these interactions, then vehicles will not slow for these scenarios or elements.

The FHWA Work Zone Driver Model v1.0 includes acceleration/deceleration algorithms for car-following only, and does not include acceleration/deceleration algorithms for other behaviors. Future versions of the FHWA Work Zone Driver Model DLL will include algorithms for elements (such as conflict zone) and behaviors (such as lane changes for route choice) commonly found near work zones. However, when using version 1.0, network adjustments should be made to avoid error.

Taper Zone Network Adjustments

Without acceleration/deceleration algorithms for conflict zones, vehicles traversing the closing lane will not slow or yield to vehicles that have the right-of-way; and without algorithms for cooperative merging, all vehicles merge at full speed. In earlier tests of the FHWA DLL, this created unrealistic merging behaviors at the taper zone. This problem is corrected by adding reduced speed zones to the closing lane, adjacent lanes, and the links approaching them (1000 feet prior to lane closure). This solution helps simulate more realistic lane change speeds at the start of the taper zone.

Unfortunately, this solution causes all vehicles to slow uniformly – not just the vehicles yielding during a merge. This may reduce variance in travel time and queue lengths predicted by the FHWA model near the taper zone.

Static Route Network Adjustments

Static routes were used in the I-91 network. In VISSIM, if a vehicle enters a link that isn't along its route, VISSIM deletes the vehicle.

Without deceleration algorithms to accommodate lane changing for route choice, some DLL vehicles failed to slow and change lanes to stay on their route. They missed a required lane change, entered a link that wasn't on their route, and were deleted. This created problems in earlier tests, as over 1500 vehicles were deleted from the network (more than 1/6th the entire volume), drastically reducing volume and placing traffic in near free-flow. To correct the problem, vehicle look back distances were adjusted on each link so that vehicles merge early to stay on their static route. Additionally, on links with disappearing vehicles, vehicle inputs were increased by the number of disappearing vehicles so that the total network volume remained unchanged.

EVALUATION: METHODOLOGY AND RESULTS

The performance of the FHWA Work Zone Driver Model v1.0 was compared to field observations and to the performance of the microsimulation tool's native car-following algorithms (i.e. VISSIM's Wiedemann 99). The VISSIM models (Wiedemann and FHWA) were each run 10 times, generating results. Results were compared to field data collected from 7 runs of the FHWA instrumented research vehicle (IRV), traversing the I-91 northbound network in July 2016.

Three performance metrics were selected: travel time through the work zone segments (i.e. advanced warning, taper zone, and work zone); travel speeds through the work zone segments (i.e. advanced warning, taper zone, and work zone); and the location of the back-of-queue. Performance metrics were selected based on literature review findings, to align with metrics that state and local agencies are interested in, and to ensure that the metrics have been used to compare model performance in similar studies (thereby ensuring scientific validity of the approach).

Performance Measure 1: Travel Time through the Work Zone Segments

Travel time through the work zone segments was selected as a performance metric because: 1. DOTs reported using travel times to estimate work zone delay; 2. the travel time is directly impacted by acceleration/deceleration predicted in car-following models, and is therefore a useful metric for validating model performance. Travel times were collected for: the advanced warning zone, the taper & buffer zone, and the work zone.

Field travel times were collected using the floating car technique in the IRV. Travel times through the advanced warning zone, taper zone, and work zone were recorded for each run. The I-91 NB network was recreated in VISSIM 7.0. The simulation was run ten times using VISSIM’s Wiedemann 99 model and the FHWA Work Zone Driver Model, and travel times through the work zone segments were recorded. The average travel time through each segment was compared (Table 2). Box-and-whisker plots were created to compare the ranges of travel times predicted and observed (Figure 5).

TABLE 2 Summary Table: Travel Time through each Work Zone Segment: Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA).

		Average Travel Time [mm:ss]			
		Advanced Warning Zone	**Taper + Buffer Zone**	**Work Zone**	**Total**
Field	Mean	4:01	0:47	1:29	6:18
	Std. Dev.	1:02	0:07	0:30	1:09
VISSIM (Wiedemann)	Mean	4:27	0:22	1:44	6:33
	Std. Dev.	0:19	0:00	0:02	0:20
VISSIM (FHWA)	Mean	4:18	0:36	2:07	7:02
	Std. Dev.	0:01	0:00	0:01	0:03

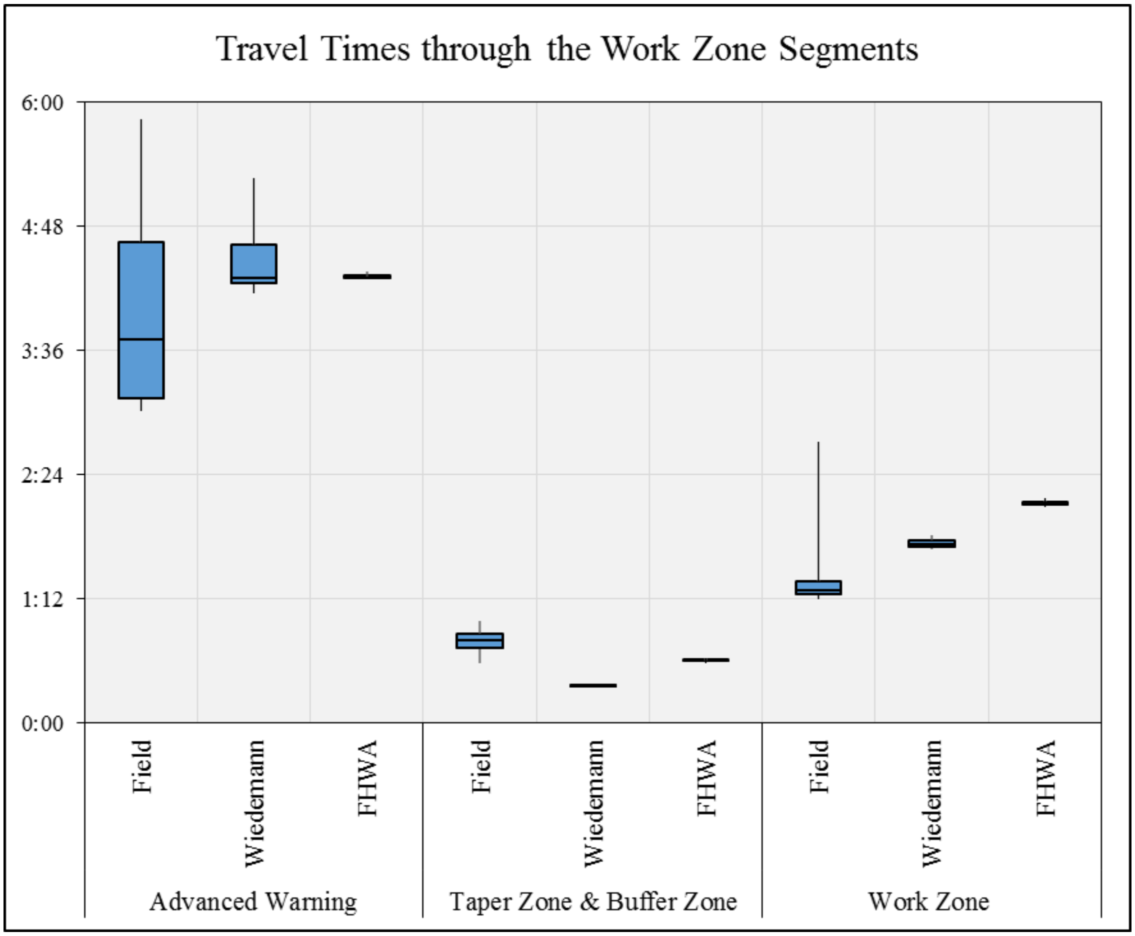


FIGURE 5 Comparison of Travel Times through all Work Zone segments - Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA)

Travel times predicted by both models fell within (or near) the range of field-observed travel times for all three work zone segments, however, neither model reproduced the broad range of travel times observed in the field.

Performance Measure 2: Travel Speed through the Work Zone

The second performance metric, travel speed through the work zone segments, was selected because: 1. DOTs reported using travel speeds to estimate network performance; 2. travel speeds have been used to validate simulation models in prior studies, therefore this is a valid performance metric.

The range of travel speeds through each work zone segment were recorded and compared for the VISSIM simulations and the Field. Travel speeds at specific locations (such as the start of the taper zone) were also recorded and compared for the VISSIM simulations and the Field.

Travel speeds for the field data were collected by recording the range of speeds observed by the IRV as it traversed each work zone segment (i.e. the advanced warning zone, taper zone, and work zone) along I-91 NB in Springfield. The range of speeds were reported on a "per run" basis, and the average low and average high speeds across all runs was calculated The IRV's instantaneous speed at the beginning and end of each work zone segment was also recorded.

In VISSIM, the average speed of vehicles traversing each work zone segment and the average instantaneous speed of vehicles at the beginning and end of each work zone segment was recorded for the Wiedemann and FHWA models.

Summary results were compiled and compared – Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA) – for average speed per work zone segment (Table 3) and average instantaneous speed measured at the beginning and end of each work zone segment (Table 4).

TABLE 3 Summary Table: Travel Speeds Observed along each Work Zone Segment: Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA).

		Travel Speeds [mph]		
		Advanced Warning Zone	**Taper + Buffer Zone**	**Work Zone**
Field	Mean	45.8	27.1	39.4
	Avg. Low	20.9	14.4	28.4
	Avg. High	70.7	39.7	50.4
VISSIM (Wiedemann)	Mean	37.6	17.5	49.6
	Avg. Low	0	0	0
	Avg. High	84.4	84.9	83.9
VISSIM (FHWA)	Mean	47.8	36.5	40.1
	Avg. Low	0	0	12.8
	Avg. High	81.8	74.1	76.1

TABLE 4 Summary table: Travel Speeds at the Beginning and End of each Work Zone Segment: Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA).

		Travel Speeds [mph]			
		Entry Point, Adv. Warning Zone	**Entry Point, Taper Zone**	**Entry Point, Work Zone**	**Exit Point, Work Zone**
Field	Mean	67.3	26.1	37.1	50.6
	Std. Dev.	3.7	14.9	1.9	2.9
VISSIM (Wiedemann)	Mean	65.0	54.8	58.3	54.4
	Std. Dev.	0	1.8	1.1	1.4
VISSIM (FHWA)	Mean	65.0	36.1	29.8	56.0
	Std. Dev.	0	0.7	0.4	0

The FHWA model more accurately predicted average travel speeds, however, both models failed to recreate the variance in travel speeds observed, especially at the taper zone entry point.

Performance Measure 3: Back-of-Queue

The third performance metric, the back-of-queue locations, was selected because: 1. state and local DOTs report using back-of-queue predictions to determine how and where to deploy queue warning (therefore accurate back-of-queue predictions would be important to DOT agencies); 2. queue length has been used in peer-reviewed publications as a performance metric in the evaluation of macroscopic work zone models – such as QUEWZ, QuickZone, and FREEVAL – and in microsimulation to estimate impacts for work zone planning efforts (*9*).

For the purposes of this study, a queue was defined as an instance where vehicles were forced to reduce speed to 25 miles per hour or less due to local congestion, and the queue length was the distance between the first and last queued vehicle.

To estimate the presence and location of queues in the field, IRV GPS data and video recordings were reviewed. Seven queues were observed; GPS coordinates for the back and front of each queue were collected and mapped.

The same method was used to determine presence and location of queues in VISSIM, for the FHWA model and Wiedemann model. Simulations were stopped at 45 minutes. If a platoon of vehicles was slowed to 25mph or less, the coordinates for the platoon were recorded, and the back and front of each queue were plotted. A comparison between field-observed and VISSIM-simulated queues is shown in Figure 6.

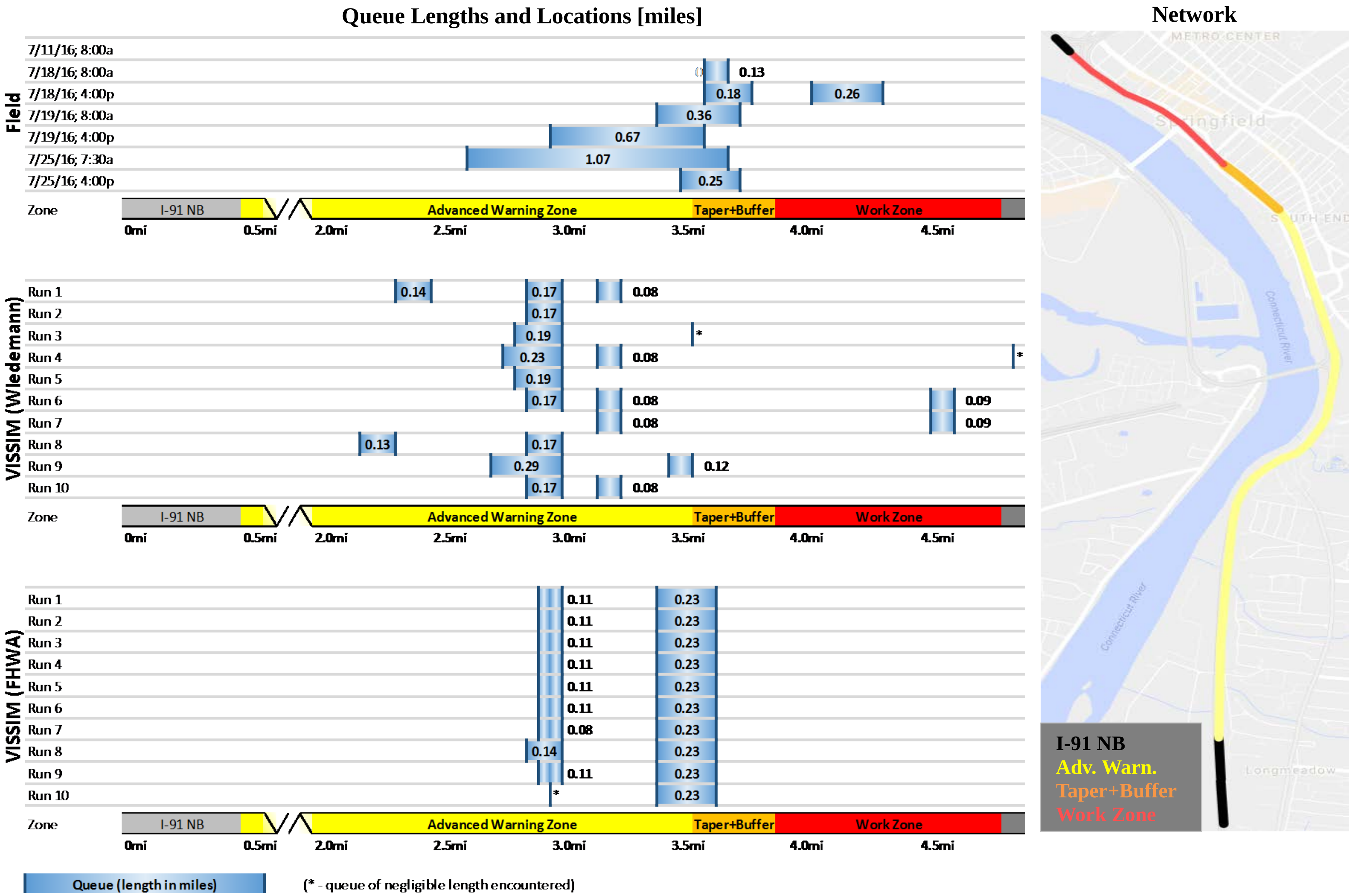


FIGURE 6 Queue Lengths and Locations per Run: Field vs. VISSIM (Wiedemann) vs. VISSIM (FHWA).

Field data showed queues forming in the taper zone. The queues predicted by Weidemann were in the wrong location (they formed in the advanced warning zone), however, it was able to recreate some of the variations in queue lengths observed in the field. FHWA predicted queues that started in the right location, however, FHWA did not predict the variance in queue lengths observed in the field data.

Both Wiedemann and FHWA consistently predicted an upstream queue in advanced warning that was not observed in field data. The queue location corresponded to the US5 on-ramp, and was likely caused by vehicles entering I-91.

SUMMARY AND CONCLUSIONS

Performance

The FHWA Work Zone Driver Model DLL v1.0 performance was acceptable. The average total travel time predicted by FHWA was less accurate than Wiedemann (Table 2), however, travel time per segment was more accurate for both the advanced warning and taper zones. Travel speeds per segment (Table 3) for FHWA were more accurate accross all segments, with average, low, and high speeds closer to those observed in the field. The average instantaneous speed at critical points (Table 4) was also closer to field obsservations for all segments. Queue locations predicted by FHWA were consistent with those observed in the field, with most queues beginning in the taper zone and extending into advanced warning; these queues were not observed in the Wiedemann model.

Both Wiedemann and FHWA failed to reproduce the per-run variance observed in the field data. For FHWA, this could be caused by the missing acceleration/deceleration algorithms, since decelerations from chance encounters at conflict and merge zones often produce shock waves in near-congested or "at capacity" conditions. This could also indicate a need for dedicated lane-changing algorithms, as lane changes sometimes result in disruptions to traffic flow.

Next Steps

Results from this case study demonstrate that both Weidemann and the FHWA Work Zone Driver Model could predict some work zone operational impacts, however, there are opportunities for improvement:

Network Volumes

Daily traffic volume fluctuations were unaccounted for in these models, potentially creating the field variations that neither model could reproduce. Adjusting input volumes "per run" to match volumes of specific days may improve model variance.

Model Improvements (FHWA Work Zone Driver Model DLL v2.0)

The FHWA Work Zone Driver Model DLL v1.0 performed well, but there are opportunities to improve version 2.0 of the DLL.

Althought network adjustments helped correct for the missing algorithms, the DLL should be updated to include acceleration/deceleration algorithms for behaviors other than car-following in

VISSIM. These include decerleration algorithms for:

- Priority rules
- Conflict areas
- Lane change / Gap acceptance
- Route choice (slowing to change lanes)
- Hook following

This may help recreate variances observed in the field, and could make the model easier to use for practitioners.

The DLL could also be upgraded with a work zone lane-changing model, as work zone lane changing is often a specialized behavior.

Optimize Utilization

Since Weidemann includes deceleration algorithms that FHWA is missing (such as cooperative merging and lane change), using the FHWA model and Weidemann model in mixed traffic could optimize results. Weidemann vehicles would introduce decelerations at merge locations, and the FHWA model could improve travel time predictions. Additional model runs and new case studies are required to find an optimal solution for using both models.

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