TRB Paper 05-2751

Evaluation of Traffic Delay Reduction from Automatic Workzone Information Systems Using Micro-simulation

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Word Count: 7210

Submitted to 2005 TRB Annual Meeting

ABSTRACT

Automated Workzone Information Systems (AWIS) have been developed, and some of them have been deployed in the field. Several field operational test studies have been conducted in the past to evaluate system functionality and reliability. However, there were few studies evaluating the effectiveness of AWIS in reducing traffic delays, which is of high interest of transportation agencies. Unlike testing AWIS system functionality, it is neither accurate nor cost-effective to evaluate the effect of AWIS on reducing traffic delay in the field study, particularly when there are diversions to other alternative routes. In this paper we propose a microscopic simulation approach to evaluate the diversion effects in tandem with delay reduction on mainline freeway. Using the traffic data collected from the field, two simulation models are calibrated corresponding to traffic conditions both before and after the AWIS is deployed. By exploiting the special topology of the simulated network (one major freeway with one alternative arterial street), in the simulation model calibration, a two-stage heuristic solution algorithm is used to estimate the origin-destination demand matrices and routing parameters simultaneously. Applying the calibrated demand matrix for the "after" scenario on both "before" and "after" simulation models, the traffic delay and other related system performance measures are obtained, therefore comparisons can be made to evaluate if AWIS has positive effect on the traffic delay reduction. The evaluation results show that AWIS deployed on the Interstate Freeway I-5 workzone in Magic Mountain area of Los Angeles can effectively reduce traffic delay on the freeway mainline and improves the overall performance of the traffic system.

1. INTRODUCTION

Work zones have been a noticeable source of accidents and congestion, and there have been significant efforts to enhance safety and improve mobility in work zone areas. Recently, attention has been paid to applying Intelligent Transportation Systems (ITS) to work zone traffic management. By providing real-time traffic information to the travelers, Automated Workzone Information Systems (AWIS) are expected to assist drivers when they drive through the work zone. AWIS products are available in market and many have already been deployed. Notable instances of AWIS systems include ADAPTIR (Automated Data Acquisition and Processing of Traffic Information in Real-time) by Scientex Corporation, CHIPS (Computerized Highway Information Processing System) by ASTI Transportation Systems, Inc., Smart Zone by ADDCO Traffic Group, and TIPS (Traffic Information & Prediction System) by PDP Associates Inc., etc.

A typical AWIS system usually integrates several traffic sensors and several Portable Changeable Message Signs (PCMSs) with a central controller that automatically determines appropriate messages to be shown on PCMSs according to the detected traffic condition. Because AWIS provides useful real-time traffic information to motorists as they approach or pass through a work zone, its direct benefits include adjusting drivers' speeds, reducing their anxiety and increasing safety for both motorists and construction personnel. A potential benefit of AWIS is that it can enhance the efficiency of traffic system by diverting some motorists who want to avoid delay to an alternative route.

However, it is unknown whether AWIS can indeed provide the above-mentioned benefits when they are deployed in the field. To evaluate AWIS system functionality and reliability, many field operational tests have been conducted, such as ADAPTIR systems in Maryland (1), Iowa, Illinois (2), Kentucky (3), and Nebraska (4), TIPS system in Ohio (5) and CHIPS system in California (6). Due to the technological problems, some early systems were failed to be evaluated. For those evaluation studies that did not go through, system reliability and frequent hardware problems have become an issue that needs to be solved by system manufacturers. Regarding the traffic impact of AWIS, the studies in Kentucky, California and Nebraska investigated if AWIS has any diversion effect.

Among these evaluation studies, there were few studies evaluating the effectiveness of AWIS in reducing traffic delays, which is of high interest of transportation agencies. Although several traffic analysis tools, such as FREQ, QuickZone (7), and QUEWZ (8), can be used to estimate the traffic delays associated with traffic management plan in the work zone planning phase, their capability to analyze traffic delay is limited and may not be realistic due to the difficulty in representing complex traffic congestion phenomena analytically. Unlike testing AWIS system functionality, it is neither accurate nor cost-effective to evaluate the effect of AWIS on reducing traffic delay in the field operational tests because such uncontrollable factors as incidents or variations of demand patterns often make it difficult to fairly compare "before" and "after" results.

As an increasingly popular and effective tool for analyzing a wide variety of dynamic problems not amendable to study by other means, microscopic traffic simulation offers an alternative method for the performance evaluation of a traffic system with AWIS deployment. Microscopic models feature the calculation and prediction the state of individual vehicles in continuous or discrete time-space and offer detailed descriptions of both road and traffic characteristics (acceleration lanes, merging, lane-changing, etc.) that are critical to work zone traffic modeling. Therefore, this paper adopts one of the microscopic simulation models, PARAMICS (PARAllel MICroscopic Simulation), as our evaluation tool.

The remainder of this paper is organized as follows. In the next section, a microscopic simulation method to evaluate traffic delay reduction from an AWIS system is proposed. To calibrate the simulation models, a two-stage heuristic solution algorithm will be used to solve the simultaneous estimation of origin-destination (OD) table and routing parameters problem. In section 3, the proposed method is used to calibrate both the "before" and "after" simulation models. Section 4 offers the evaluation results. Finally the conclusion remarks are presented in Section 5.

2. METHODOLOGY OF SIMULATION MODEL CALIBRATION

2.1 Evaluation Methodology

The evaluation methodology is shown as Figure 1. Using the traffic data collected from the field, two simulation models are calibrated corresponding to traffic conditions both before and after the AWIS is deployed. By exploiting the special topology of the simulated network (one major freeway with one alternative arterial street), the focus of the model calibration is to simultaneously adjust the origin-destination demand matrices and routing parameters to capture the diversion effects. To evaluate the traffic delay reduction with or without AWIS under the same demand pattern, we apply the "after" demand together with both "before" and "after" routing parameters in the calibrated networks. Therefore simulation runs are conducted under two scenarios:

1. Without AWIS: "after" demand pattern together with routing parameters in the "before" model,
2. With AWIS scenario: "after" demand pattern together with routing parameters in the "after" model.

Based on the comparison of the simulation results of Scenario 2 and Scenario 1, the traffic delay reduction from AWIS can be estimated.

2.2 Model Calibration Method

A microscopic traffic simulation model generally includes physical components, such as the roadway network, traffic control systems, and driver-vehicle units, etc., and associated behavioral models, such as driving behavior models and route choice models. These components and models have complex data requirements and numerous model parameters. Although most simulators provide data input guidelines and default model parameters, these models nevertheless need to be calibrated for the specific study network and the intended applications (9).

In the traditional process of model calibration, model parameters are adjusted until reasonable (both qualitatively and quantitatively) correspondence between the model and field-observed data is achieved. Such adjustments with multiple parameters are a time-consuming and tedious process. The trial-and-error method based on engineering judgment or experience is usually employed for model calibration. More systematic approaches include the gradient-based approach and Genetic Algorithms (GA) (10,11). These approaches regard the model calibration procedure as an optimization problem in which a combination of parameter values that best satisfies an objective function is searched. However, most calibration efforts reported in the literatures have focused on either the calibration of driving behavior models (12,13,14,15), or the calibration of a simple linear freeway network (14,15,16,17). In this paper, we propose to estimate the demand matrices and routing parameters simultaneously, as will be introduced in the following.

2.2 Proposed Calibration Method

The traffic network under investigation consists of a major freeway and a parallel arterial street, as will be shown in Figure 2. Based on the special network topology of the study site, the most important parameters need to be calibrated for this network is the route choice model and OD matrix. Therefore our calibration efforts focus on the simultaneous estimation of OD matrix and route choice parameter. Analytically, the problem of the simultaneous estimation of OD matrix and route choice parameters was first addressed by Liu and Fricker (18). They made an attempt to estimate an OD matrix and the travel cost coefficient θ of the logit-based route choice probabilities from link traffic counts on un-congested network. Yang, Meng and Bell further studied on this problem on congested network (19). Similar to the above two studies, the OD table and routing parameter estimation can be formulated as minimizing the difference between modeled and observed flows:

$$Min \;\; L(q^{rs},\theta)=\sum_{a}[\sum_{rs} q^{rs}\cdot(\sum_{k} P_k^{rs}(\theta)\cdot\delta_{ak}^{rs})-x_a^{obs}]^2 \qquad (1)$$

s.t.

$$q^{rs}\geq 0$$

where (r, s) is set of OD pairs; $P_k^{rs}(\theta)$ is the probability of selecting path k from r to s, which is a function of routing parameters θ; q^{rs} is OD flow from r to s; x_a^{obs} is observed link volume on link a; δ_{rs}^{ak} is equal to 1 if link a is on path k between r and s, and 0 otherwise.

Now the question turns to how to solve the simultaneous estimation problem in Equation 1 in order to calibrate the simulation model. Solving such a simultaneous estimation problem is generally difficult because of the high dimension of the parameter space. In the following, a two-stage heuristic search method, assisted by Paramics OD Estimator as the OD estimation tool, is proposed. Paramics O-D Estimator utilizes its simulation engine to obtain an estimate of the O-D demand matrix for each time slice through matching vehicle counts at selected locations. A complete set of link traffic counts is not required in the estimation process, which makes the tool very practical. Other information, such as a historical O-D matrix, cordon flows, turn movements are also helpful for the program to converge faster. Although Paramics OD Estimator does not accept travel time data as inputs, the objectives in our calibration method have included the travel time information, as shown in the Stage 2 of the following.

Stage 1: Generate n sets of OD matrix and routing parameters with Paramics OD Estimator.
(1) Determine reasonable ranges of routing parameters $\boldsymbol{\theta}$. Then orderly choose parameter value from the multiple-dimension parameter space. Note $\boldsymbol{\theta}$ is a parameter vector. Let n be maximal number of iteration. Let i = 1; Set $\boldsymbol{\theta} = \boldsymbol{\theta_i}$ in the simulation model.
(2) Use OD estimator to estimate OD table Γ_i based on traffic counts at selected locations. The objective function is:

$$Min \quad L(\theta) = \sum_{a=1}^{N} (x_a^{sim}(\theta) - x_a^{obs})^2 \qquad (2)$$

where N is the number of selected locations with traffic count data; x_a^{sim} is simulated flow on link a; x_a^{obs} is observed flow on link a.
(3) i = i+1. If i $<$ n, go to step 2; otherwise go to the next stage.

Stage 2: Evaluate these OD matrix and routing parameters with Paramics Modeler.
(4) Let i = 1
(5) Use Paramics Modeler to run simulation with OD table Γ_i and θ_i. Based on the simulation results, a goodness of fit measure, i.e. Mean Absolute Percentage Error (MAPE), is used to evaluate the quality of the estimated OD table and routing parameters.

$$MAPE(i) = \frac{100}{N+M} \left\{ \sum_{a=1}^{N} |(x_a^{obs} - x_a^{sim}) / x_a^{obs}| + \sum_{b=1}^{M} |(p_b^{obs} - p_b^{sim}) / p_b^{obs}| \right\} \qquad (3)$$

where M is the number of selected routes with travel time data; p_b^{sim} is simulated travel time on route b; p_b^{obs} is observed travel time on route b.
(6) i = i+1. If i $<$ n, go to step 5, otherwise go to Step 7.
(7) Compare all MAPE(i), i is from 1 to n and then find the lowest one, corresponding to i = μ. Therefore, Γ_μ and θ_μ are the best calibrated OD table and routing parameter vector. At this time, the simulation model is considered to be well calibrated with an estimated OD table Γ_μ and parameters of the route choice model θ_μ.

3. MODEL CALIBRATION RESULTS

3.1 Study site

As illustrated in Figure 2, the 1.3 mile work zone site is located in the City of Santa Clarita, north of Los Angeles, on freeway I-5 between Magic Mountain Parkway and Rye

Canyon Road. The construction started from July 30th, 2002 and left three lanes in each direction open to motorists after the closure of one southbound lane and one northbound lane on the median side. In case of traffic congestion, the Old Road is the suggested as alternative route. The Old Road is a parallel arterial street to the I-5 freeway and has one lane in each direction,with multiple signalized and non-signlized intersections.

An AWIS system, namely CHIPS, was deployed in the field to manage the traffic for both directions. Because historical data show that southbound I-5 has severe traffic congestion, usually occurred in the weekends and holidays, we only focuses on the southbound direction in this study. The major components of the CHIPS system on the southbound direction include three traffic speed sensors (i.e. RTMS-1, RTMS-2 and RTMS-3) and three PCMSs (i.e. PCMS-1, PCMS-2, and PCMS-3). Based on the detected traffic scenario using speed sensors, the corresponding messages will be shown on PCMSs, as shown in Tables 1 and 2.

3.2 Data collection

Data for the "before" study were collected on May 18th, 2003 when the work zone was in place and the AWIS system was not deployed. Data for the "after" study (with AWIS) were collected on September 1st, 2003 (during the Labor Day Holiday weekend). Tube counters were placed on six specified on-ramps and off-ramps for traffic count collection. Two probe vehicles equipped with GPS device continuously traveled back and forth in the work zone area for collecting travel time data on the mainline freeway and the alternative route. Two personnel collected 30-minute traffic count data at two mainline locations, RTMS-1 and RTMS-3 during traffic congestion. Additionally, traffic count data at the loop detector station of Hasley Canyon Rd were obtained from California Freeway Performance Measurement System (PeMS).

Both May 18th, 2003 and September 1st, 2003 showed a severe congestion in the work zone area. The study time period for this study is from 4 PM to 5 PM in the afternoon, during which the section of freeway between Hasley Canyon and the work zone was full of queued traffic.

3.3 Network coding

The simulation network includes a 6-mile section of freeway (from the north of Hasley Canyon Road junction to the south of Valencia Blvd junction) and a potential alternative route, the Old Road. As shown in Figure 3, the network was built in PARAMICS based on aerial photos and the road geometry and infrastructure maps, which were obtained from California Department of Transportation (Caltrans). Other basic input data to Paramics include vehicle mix by type, vehicle characteristics, traffic control and traffic detection system data. Traffic analysis zone information was obtained from the regional planning model. The driver behavior data, represented by aggressiveness and awareness factors in PARAMICS, were assumed to be the default normal distribution in this study.

3.4 Calibration of driving behavior model

After the coding of a simulation network, the driving behavior model needs to be calibrated first. The purpose of this step is to calibrate the capacity at major bottleneck points of the simulation network. The simulation network has one major bottleneck, caused by the work zone lane closure at Rye Canyon Road. The capacity at this point is the major concern of this step of calibration.

Driving behavior models of Paramics has two key global parameters for the entire simulation network, i.e. mean target headway and driver reaction time. They are used to control vehicle-vehicle interactions during simulation. Because of the traffic queuing in the freeway work zone area, the average headway on mainline freeway will be different with other portions in the network. Consequently, the headway factor on freeway mainline, which is a local parameter to further adjust the headway on mainline links, is the third parameter to be calibrated at this step. A larger headway factor corresponds to a larger time headway between vehicles traveling on the link.

The trial-and-error method is used for the capacity calibration based on an assumed OD table (only for the capacity calibration). It was found that when the mean target headway and driver reaction time were 0.9 and 0.8, and the headway factor of mainline freeway links was 1.2, the simulated capacity could match the capacity measured in the field. A sensitivity analysis was performed in order to show how headway factor of mainline freeway affects mainline capacity at the bottleneck point, as illustrated in Figure 4. In our experiment, a smaller headway often causes frequent vehicle stopping and a higher headway leads to a larger space between vehicles, which in both cases capacity will be decreased.

3.5 Estimation of OD table and routing parameter

For a traffic system with work zone, some familiar drivers who know both freeway and local streets may take an alternative route if there is severe congestion on the mainline. If an AWIS system or CMSs are used to display real-time traffic information, more drivers will know the traffic condition ahead. If strong messages with diversion instructions are shown on CMSs, some aggressive drivers who do not know the local streets may also take the alterative route. These typical routing behaviors of a work zone area can be modeled in Paramics through the use of dynamic feedback assignment, in which travelers with real-time information can switch routes en-route.

The dynamic feedback assignment updates the link costs to include a turning delay cost. The turn delays are calculated at defined feedback periods specified by the user. By default feedback calculations only affect those drivers who are willing to comply to the traffic information and route guidance. As a result, dynamic feedback assignment has two most important parameters, feedback period and compliance rate. In Paramics simulation, the compliance rate is represented by familiarity factor, i.e. percentage of familiar drivers. In order to simplify the estimation problem, the feedback period was set to 1 minute in order to reflect the influence of dynamic traffic information from AWIS on familiar drivers. So, there is only one routing parameter, i.e. familiarity, which needs to be estimated together with the OD table.

In the simultaneous estimation process, a total of six cordon flows (obtained from Caltrans) and five observed link flows are used. The six links having observed flow data include two mainline links (at Hasley Canyon junction and prior to Rye canyon Road off-ramp), two on-ramp links (at Magic Mountain Blvd junction and SR-126 connector to southbound I-5), and one off-ramp (at Hasley Canyon junction).

Based on the stage 1 of the solution algorithm described in Section 2, a set of estimated OD tables were obtained, together with their corresponding familiarity factors. In the before and after simulation models, familiarity has different ranges. Based on the stage 2 of the solution algorithm, simulation using Paramics Modeler is involved in order to provide a goodness of fit measure, MAPE, for sampling scenarios. The simulation time period is from 3:00 to 5:00 p.m. The first one hour of simulation is treated as the "warm-up" period in order to make vehicles queue up on the freeway, which corresponds to the traffic condition at 4:00 p.m. observed in the real world. The second hour's simulation data are used to calculate MAPE.

As shown in Figure 5, the "before" simulation model was calibrated when familiarity is 3%, which corresponds to the lowest MAPE value. Figure 6 shows that when familiarity is 18%, the "after" simulation model has the lowest MAPE. Table 3 compares observed and simulated data from the calibrated "after" model. It shows that the simulated and observed travel times are matched well with each other at most selected locations.

4. EVALUATION

Based on the calibrated "before" and "after" model from Section 3, simulation runs were conducted using the calibrated OD table of the "after" simulation model under the two scenarios:
(a) Without AWIS scenario (baseline scenario): "before" network with 3% familiarity
(b) With AWIS scenario: "after" network with 18% familiarity

Same as the simulation configuration in Section 3, the simulation time period is from 3:00 to 5:00 p.m. and the first one hour of simulation is treated as the "warm-up" period. Because PARAMICS is a stochastic simulation model, which rely upon random numbers to release vehicles, assign vehicle type, select their destination and their route, and to determine their behaviors as the vehicles move through the network. Each scenario needs multiple simulation runs and the median simulation run in terms of vehicle Hour Traveled (VHT) is used to represent the traffic condition of the scenario for performance comparison. The required number of runs is calculated:

$$N = (t_{\alpha/2} \cdot \frac{\delta}{\mu \cdot \varepsilon})^2 \qquad (4)$$

where μ and δ are the mean and standard deviation of VHT based on the conducted simulation runs; ε is the allowable error specified as a fraction of the mean μ; $t_{\alpha/2}$ is the critical value of the t-distribution at the confidence interval of 1-α.

Although traffic delay reduction is the major performance measure of the study, the other related measures are also included. Table 4 shows the performance measures on the mainline. After the deployment of AWIS, average mainline delay was reduced 46.2% and the total mainline delay was reduced 40.7%. The average mainline travel time was reduced from 21.8 minutes to 13.5 minutes (free flow travel time is about 4 minutes), equivalent to a 38.1% reduction.

The reduction of mainline traffic delay corresponds to the increase of traffic delay on the alternative route, as shown in Table 5. Because the speed limit on the Old Road is as low as 30 mph, the average delay on the Old Road was not significant before the AWIS deployment but did show a sharp increase after the use of AWIS. Also, more vehicles traveled on the alternative route and its average travel time increased from 9.1 minutes to 11.1 minutes. 11.1 minutes of travel time on the alternative route is lower than the travel time on the mainline, i.e. 13.5 minutes. This explains that diverted drivers can benefit from the diversion.

Vehicle Hour Traveled (VHT), Vehicle Mile Traveled (VMT), and average network speed are overall system performance measures in this study. As shown in Table 6, the use of AWIS significantly reduced VHT 36.7% and at the same time increased VMT 14.6% due to diversion. As a result, the average network speed increased from 12.1mph to 21.9 mph.

Finally, the diversion rate and volume from the simulation study is shown in Table 7. For the "without AWIS" scenario, the freeway mainline speed is slow because traffic queue has been backed up to the far upstream of the workzone area.. Therefore, even without AWIS, 3.5% travelers diverted from mainline freeway to the Old Road from Hasley Canyon off-ramp. After the AWIS deployment, the diversion rate increased to 7.8%, equivalent to an additional 224 vehicles in the one-hour study period.

5. CONCLUSION

This paper proposes a microscopic simulation method to evaluate traffic delay reduction in a traffic system with AWIS. Using the traffic data collected from the field, two simulation models are calibrated corresponding to traffic conditions both before and after the AWIS is deployed. By exploiting the special topology of the simulated network (one major freeway with one alternative arterial street), in the simulation model calibration, a two-stage heuristic solution algorithm is used to estimate the origin-destination demand matrices and routing parameters simultaneously. Applying the calibrated demand matrix for the "after" scenario on both "before" and "after" simulation models, the traffic delay and other related system performance measures are obtained, therefore comparisons can be made to evaluate if AWIS has positive effect on the traffic delay reduction. The evaluation results show that AWIS deployed on the Interstate Freeway I-5 workzone in Magic Mountain area of Los Angeles can effectively reduce traffic delay on the freeway mainline and improves the overall performance of the traffic system.

The applicability and potential effectiveness of an AWIS solution ought to be investigated during a planning phase prior to any decision on its implementation. Although the proposed microscopic simulation is used for the evaluation of the traffic delay reduction in this paper, the method can also be used as a warranty tool. It can help decision makers to determine if the application of an AWIS system to a specific work zone site will be beneficial.

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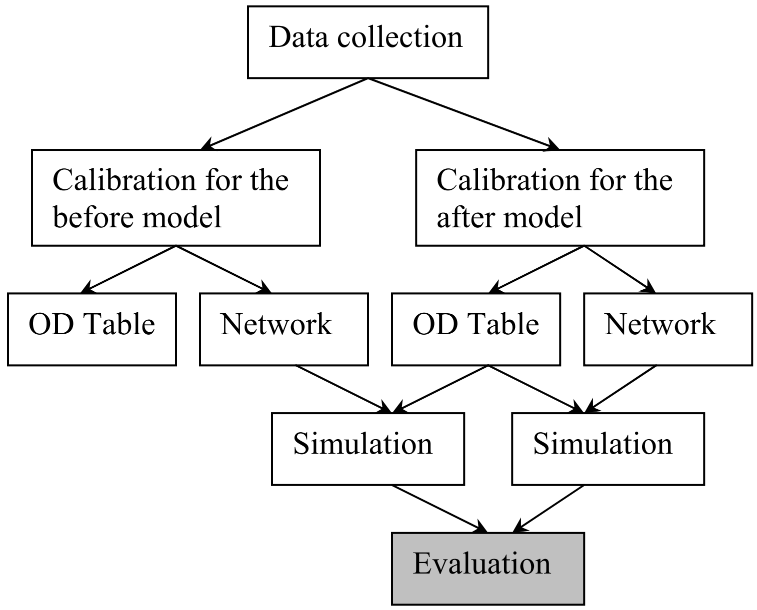

Figure 1 Framework of evaluation methodology

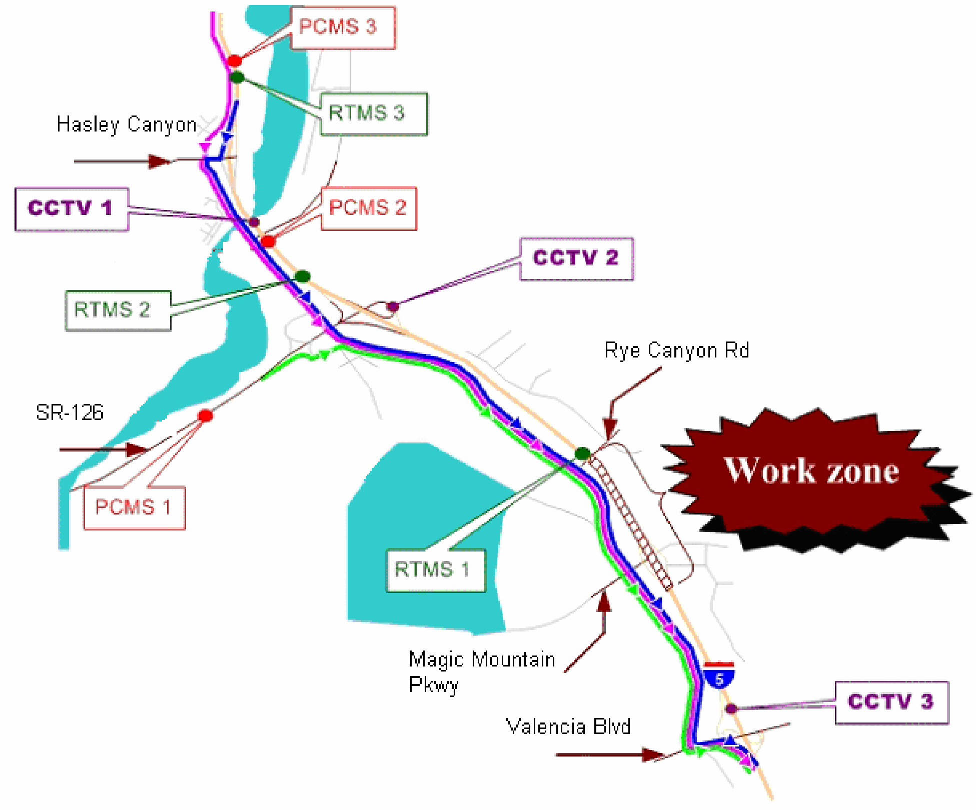

Figure 2 Work zone site with the deployment of the CHIPS system

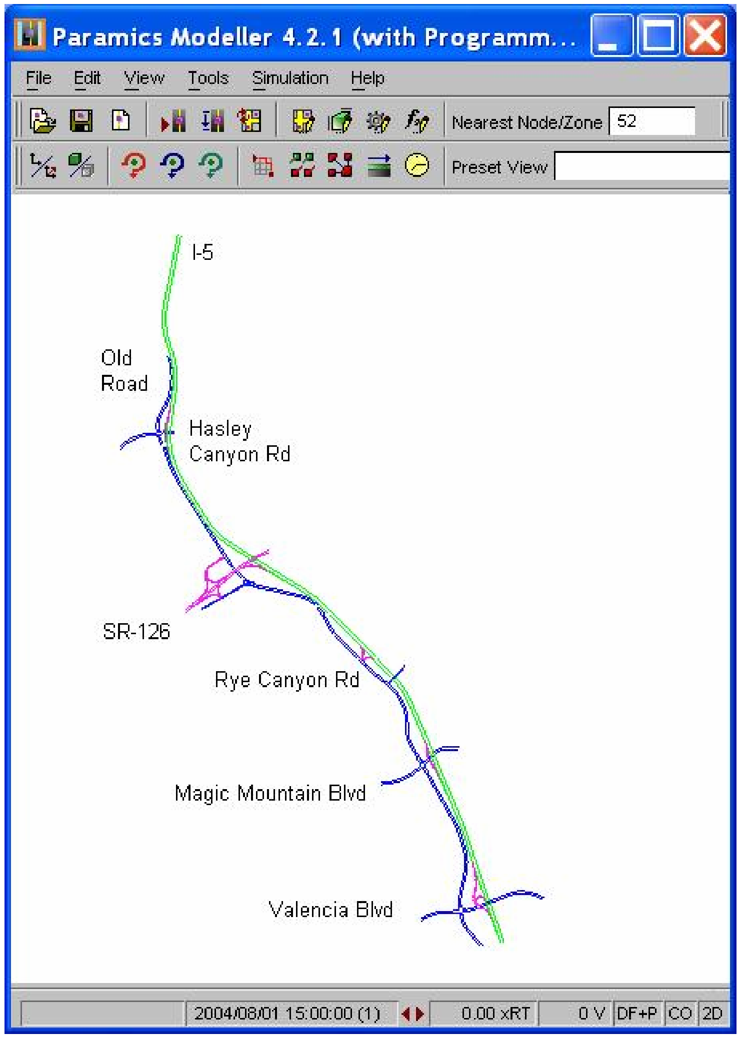

Figure 3 Coded simulation network

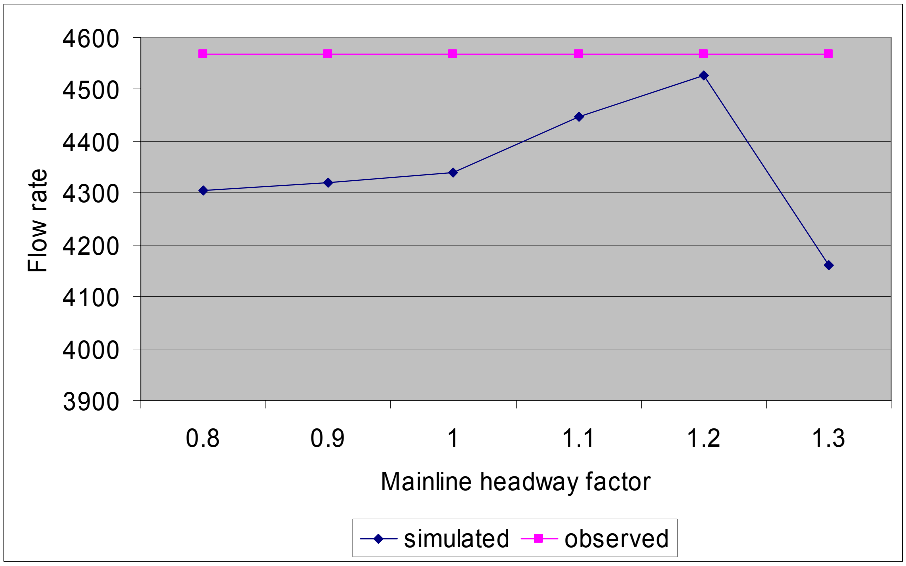

Figure 4 Calibration of headway factor of mainline freeway links

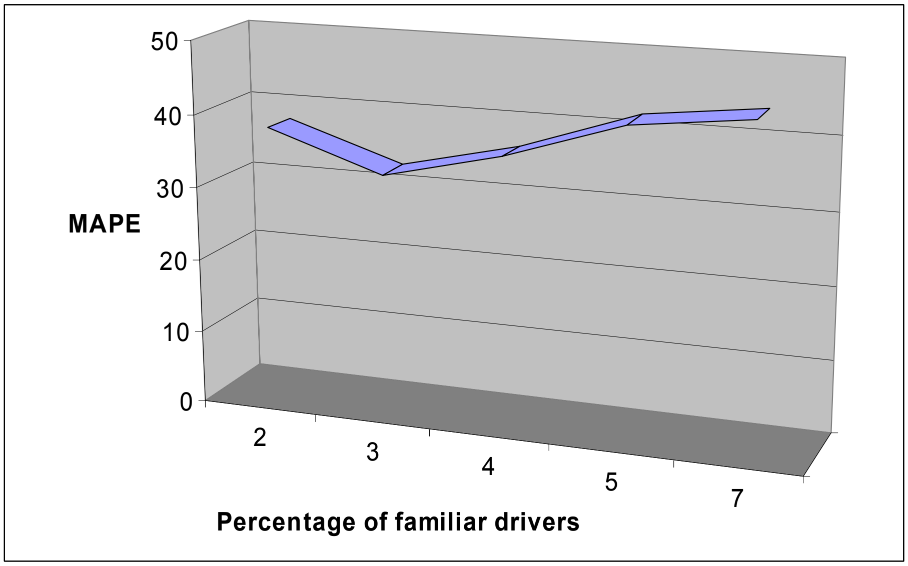

Figure 5 Calibration of the before model

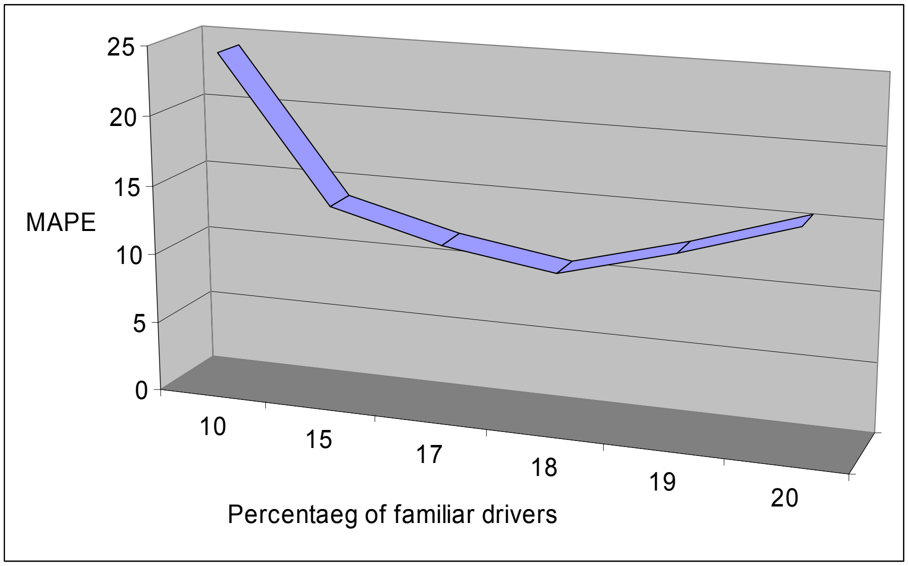

Figure 6 Calibration of the after model

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Table 1 Current Southbound I-5 Message Board Scenarios

Scenario	Queue Detector Tripped			CMS Combo Message		
	RTMS-1	RTMS-2	RTMS-3	PCMS-1	PCMS-2	PCMS-3
SBS0001	F	F	F	CMB001	CMB001	CMB001
SBS0002	T	F	F	CMB002	CMB003	CMB005
SBS0003	T	T	F	CMB006	CMB007	CMB003
SBS0004	T	T	T	CMB006	CMB007	CMB008

Note : T = Queue being detected, F = No queue being detected

Table 2 List of Messages

Message Number	Page 1(1st Flash)	Page 2(2nd Flash)
CMB001	BLANK	BLANK
CMB002	TRAFFIC/JAMMED	SOUTH 5/AT RYE/CANYON
CMB003	SLOW/TRAFFIC/AHEAD	PREPARE/TO/STOP
CMB004	TRAFFIC/JAMMED/NXT 2 MI	EXECT/5MIN/DELAY
CMB005	TRAFFIC/JAMMED/AHEAD	126 FWY/TO MAGIC/MOUNTAIN
CMB006	SOUTH 5/TRAFFIC/JAMMED	AUTOS/USE NEXT/EXIT
CMB007	JAMMED/TO MAGIC/MOUNTAIN	EXPECT/10 MIN/DELAY
CMB008	JAMMED/TO MAGIC/MOUNTAIN	EXPECT/15 MIN/DELAY

Table 3 Comparison of observed and simulated data from the calibrated after model

	Location/Route	Observed	Simulated	APE
Traffic count	main_Hasley	3890	3867	0.59
	main_Rye Canyon	4568	4526	0.92
	off_Hasley	764	813	6.41
	on_SR-126	480	477	0.63
	on_Magic Mountain	713	674	5.47
Travel time	Mainline	13	13.1	0.48
	Old Road	11	11.1	0.92
MAPE				2.20

*: from the Hasley Canyon junction and the Valencia Blvd junction

Table 4 Performance comparison on the mainline

	Without AWIS	With AWIS	Reduction	Reduction Percentage
Average Mainline Delay (min)	17.9	9.6	8.3	46.2%
Total Mainline Delay (hr)	1133.4	672.3	461.1	40.7%
Average Mainline Travel Time (min)	21.8	13.5	8.3	38.1%

Table 5 Performance comparison on the Old Road

	Without AWIS	With AWIS	Increase	Percentage
Average Delay on the Old Road (min)	1.5	4.4	2.9	191.3%
Total Delay on the Old Road (hr)	7.6	29.9	22.3	293.2%
Average Travel Time on the Old Road (min)	9.1	11.1	2.0	22.0%

Table 6 Overall performance of the traffic system

	Without AWIS	With AWIS	Reduction	Percentage
VHT (Vehicle Hours Traveled)	2266.7	1434.7	832.1	36.7%
VMT (Vehicle Miles Traveled)	27357.6	31350.9	-3993.3	-14.6%
Average Speed (mph) = VMT/VHT	12.1	21.9	-9.8	-81.0%

Table 7 Diversion volume and diversion rate

	Without AWIS	With AWIS	Increase
Diversion Volume on Hasley off-ramp	145	369	224
Diversion Rate on Hasley off-ramp	3.5%	7.8%	4.3%