Calibration of INTRAS for Simulation of 30-sec Loop Detector Output

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Since its inception in the early 1980s, the Integrated Traffic Simulation (INTRAS) model has been used in many studies involving freeway corridor traffic simulation. The model was originally calibrated with data collected in the 1970s in Los Angeles. In view of changing traffic conditions during the past decade, the validity of the parameter values as calibrated in the original setting is questionable. In several recent studies that used INTRAS as an evaluation tool, the model has been recalibrated with recent data. However, because of the different applications of the INTRAS model in these studies, the calibrations were made with output averaging at longer time intervals and for different output variables. To simulate traffic operation on Southern California freeways consistent with surveillance data currently being collected by the California Department of Transportation in traffic operations centers, INTRAS has been calibrated with respect to loop detector data at 30-sec intervals. The calibration process involved traffic during conditions with and without incidents, based on data collected along a 5-mi section of a major freeway in Orange County. Key parameters calibrated in this study include car-following sensitivity constants, minimum car-following distance, vehicle lengths, effective detector lengths, and the INTRAS "rubbernecking factor." The calibrated model has been used to simulate detector data for evaluating incident detection algorithms and for training artificial neural network models to detect freeway incidents.

INTRAS is a microscopic freeway traffic simulation model designed for freeway corridor traffic simulations. It is structured to facilitate evaluation of different incident detection algorithms and ramp metering strategies (*1*). During program development, detector output in INTRAS was calibrated with data collected in the 1970s at a freeway in Los Angeles (*2*). The validity of the parameter values as calibrated in the initial setting are questionable in view of changing traffic conditions and vehicle performance characteristics that have occurred during the past decade. In several recent studies using INTRAS as an evaluation tool (*3–5*), the model has been recalibrated with more recent data. However, these evaluations were made with model output averaging at longer time intervals, and with variables of different interest, than required for INTRAS to produce meaningful detector output consistent with typical 30-sec field data collected by traffic operations centers (TOCs) in Southern California. For this application, several parameters in the model should be calibrated in more detail.

In this paper, the authors describe the process of calibrating 30-sec station average volume and occupancy at loop detector stations located on a 5-mi section of the westbound SR-91 Riverside Freeway in Orange County, between the SR-57 and Interstate 5 freeways. The calibration process consisted of two parts. First, parameters related to car-following and loop detector operations were calibrated against incident-free data. Once the appropriate combination of the nonincident parameters had been found, incident-related parameters were calibrated against incident data sets. The objective of the calibration was to adjust the input parameters of INTRAS to produce volume and occupancy consistent with field data while maintaining the integrity of the engineering bases of the parameters, which are fundamental to the simulation model. It is hoped that the calibration process discussed in this paper may serve as a useful basis for future calibration with INTRAS or similar simulation models in order to produce detector output at relatively short intervals.

In the following section, the calibration procedure is described in more detail. Important deterministic inputs to the simulation model are featured including network coding, input volume, and free-flow speed. The next section discusses the calibration of nonincident parameters with an incident-free data set. This section also includes validation of the calibrated parameters with an independent data set. The calibration of incident-related parameters, in particular the "rubbernecking factor," is presented next. The results are discussed, and the calibration study is summarized.

CALIBRATION PROCEDURE

For this calibration, 3 days of field data collected by Caltrans were used. The first day of data (Data Set 1) was collected on June 8, 1987 (Monday), from 7:00 a.m. to 7:00 p.m.; it contained incident-free loop data. This was the only data set available for calibration when the study began. Two subsequent data sets (Data Sets 2 and 3) were later obtained from Caltrans for the completion of this work. These data sets contained volume counts and occupancy values at each loop detector on freeway lanes aggregated at 30-sec intervals. Loop detector data at the same counting station were aggregated to station average values in this study.

The latest version of INTRAS source code was obtained from FHWA and made operational for a Sun Sparcstation. The section of program code that processes loop detector data was modified to simulate the actual data accumulation process occurring in the field. Deterministic input data such as network geometry and input volume were coded into the input file. Key parameters thought to influence vehicle travel were adjusted. At each adjustment, the volume and occupancy values at each INTRAS station were compared with the actual field data. The optimal combinations were ascertained after repeated trials.

The adjustment of parameters was divided into two parts. In the first part, parameters that influence vehicle movement during incident-free conditions were calibrated with the incident-free data set (i.e., Data Set 1). After necessary adjustments had been made, the adjusted parameters were validated against an incident-free portion of Data Set 3. In the second part of the calibration, the rubbernecking factor was calibrated against the incident portions of Data Sets 2 and 3.

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SIMULATION INPUT

Network Coding

The entire study section of the SR-91 Freeway in the westbound direction was coded into an INTRAS input file, following the striping plan supplied by the local Caltrans district. The striping plan provided information on mileposts of on- and off-ramps, lane configurations, and detector locations. The coded nodes and links, along with a schematic of the study section, are displayed in Figure 1. The entire section was also videorecorded from a vehicle moving at a constant speed. The video recording helped to both validate the information provided by the striping plan and provide additional information on the location of exit signs, length of acceleration lanes, and other information input to the INTRAS simulation model.

There are eight detector stations in the study section, and each station has three inductance loops. The detector locations and their post miles are shown in Figure 1. These detectors are either circular loops 6 ft in diameter or squares 6 by 6 ft. Hence, an initial effective length of 6 ft was assumed for all the loops.

Traffic Volume

To ensure that nonincident parameters were calibrated for a variety of flow conditions, simulations were performed for three different flow levels (i.e., at low, moderate, and heavy flows). The field data was divided into 15-min intervals. For this study section, the daytime average 15-min volume ranges from 1,200 to 1,960 vehicles per hour per lane (vphpl). In Data Set 1, the 15-min periods beginning at 6:15 p.m., 8:45 a.m., and 4:45 p.m. were selected to represent typical low, moderate, and heavy flow levels in the day. The corresponding average volumes were 1,443, 1,681 and 1,858 vphpl, respectively. For incident simulation, the input volume was governed by the 15-min volume measured immediately before the occurrence of the incident.

In INTRAS, input volumes at all on-ramps must be specified in the data file. The off-ramp volumes are specified as the percentage of vehicles turning off from the freeway links. Within the study section, most of the detector stations are located near major cross streets, and there is always an on-ramp and an off-ramp between the two stations (see Figure 1). The data files provided by Caltrans did not include ramp volumes. Traffic volumes at the on-ramps were thus deduced from Traffic Accident Surveillance and Analysis System (TASAS) data base (*6*). The off-ramp volumes were computed using the principle of continuity of flow, based on the volume count obtained at the detector stations and the ramps.

The vehicle composition in the simulation runs was as follows:

Vehicle Type	*Percentage*
Low-performance passenger cars	46
High-performance passenger cars	47
Buses	0
Single-unit trucks	2
Truck trailers	5

A truck percentage of 6.8 to 7.1 percent in total bidirectional flow was estimated at Milepost 3.26 (near Harbor Boulevard) in 1982 (*7*). For the simulation, a value of 7 percent was used, assuming the percentage of truck in total traffic has remained relatively constant over the years. This figure was divided further into single-unit trucks and truck trailers. The distribution of truck type has been reported in a separate study (*8*) at several freeway-to-freeway connectors in the Los Angeles area. These figures were rounded to 2 percent for single-unit trucks and 5 percent for truck trailers. Since information on the percentage of buses was lacking, it was assumed that the proportion of buses was insignificant compared with the total volume, and a value of 0 percent was used. The remaining 93 percent of the traffic was arbitrarily split equally into the two passenger car categories.

Free-Flow Speed

The free-flow speed on the freeway was deduced from a speed-density relationship fitted to field data. The 30-sec volume and occupancy data from individual loop detectors were used to established the speed-density relationship. Assuming that there was a uniform

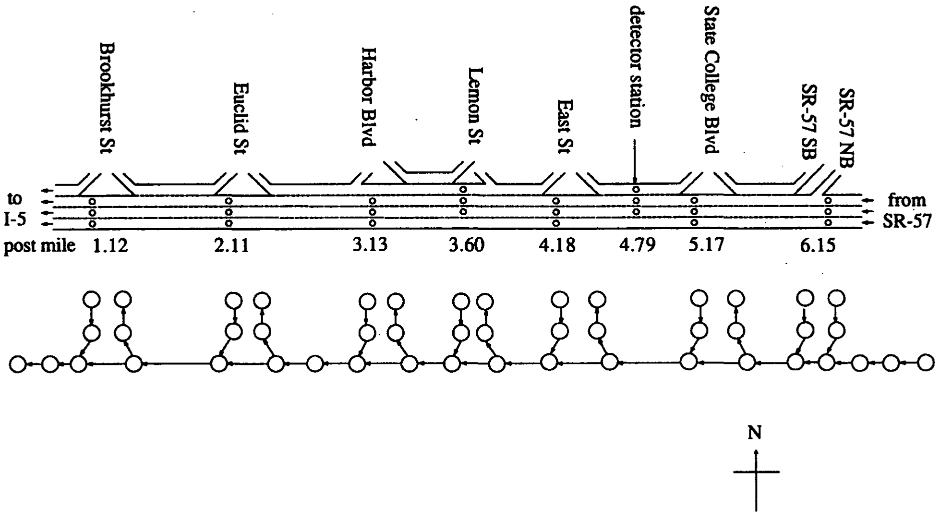

FIGURE 1 Schematic of freeway site and INTRAS nodes and links.

speed-density function represented at all locations within the study section, 100 loop-specific data points were randomly selected from Data Set 1. The average speed and density were deduced from volume and occupancy, using an average vehicle length of 19 ft computed from the aforementioned vehicle composition and the default vehicle lengths in INTRAS. An effective loop length of 6 ft was used in the computation. The data points followed the form of the Greenshields model. The free-flow speed, estimated from linear regression, was 81 mph. It should be noted that the lowest daytime freeway volume at the study section was about 1,200 vphpl (under incident-free conditions). At this volume the fitted Greenshields model gives a space-mean speed of 69 mph, which is close to the actual driving speed on the freeways in Southern California.

Output Data

The objective in calibrating INTRAS included making it produce output similar to the Caltrans 30-sec station average detector data. Correspondingly, the detector output interval was set at 30 sec. For incident-free conditions, a 15-min simulation was conducted for each volume level. The detector output at all stations during simulation runs at low, moderate, and heavy flow levels were combined and plotted in two graphs for evaluation: INTRAS output volume versus Caltrans field volume (volume plot) and INTRAS-measured occupancy versus Caltrans field occupancy (occupancy plot). For illustration, the volume and occupancy plots for INTRAS runs with default parameters are shown in Figures 2 and 3, respectively. The correlation coefficients (*r*-values) and slopes of fitted straight lines that pass through the origin derived from these plots were used as performance measures. In addition, the speed-density, volume-density, and volume-speed plots between field data and INTRAS output were compared.

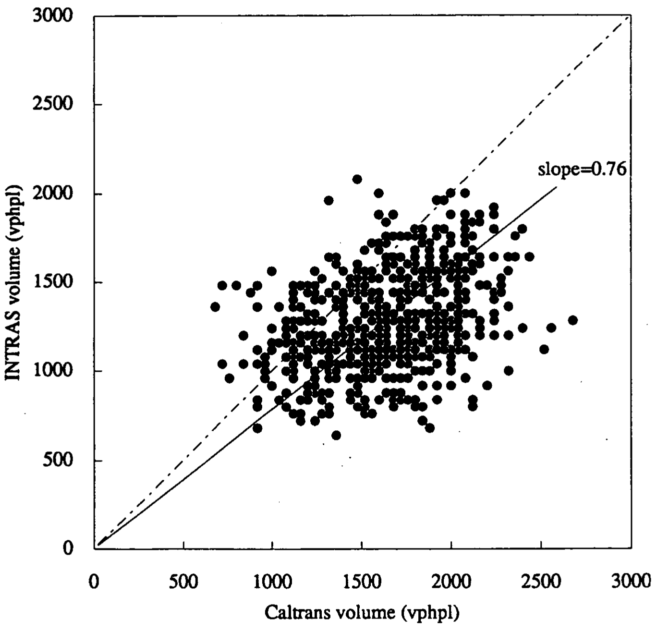

FIGURE 2 Volume plot of INTRAS runs with default parameters.

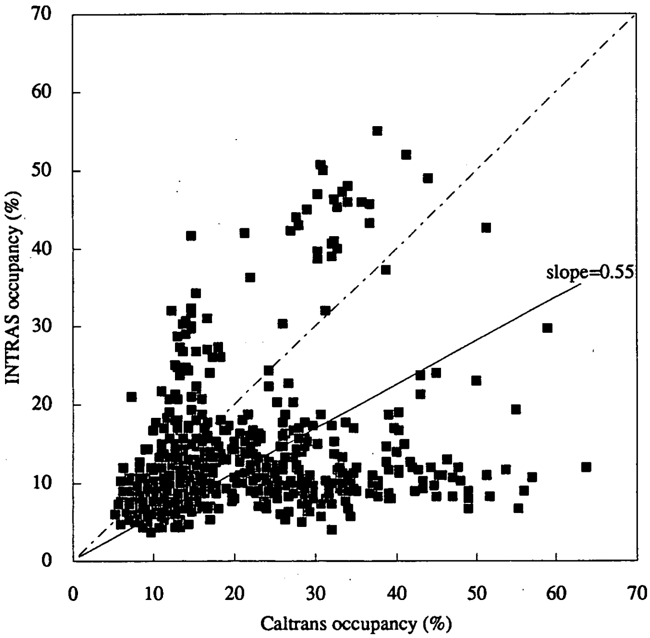

FIGURE 3 Occupancy plot of INTRAS runs with default parameters.

CALIBRATION OF NONINCIDENT PARAMETERS

Parameters thought to affect vehicle movement and detector operation during incident-free traffic simulation were calibrated as described in this section. Important car-following parameters were first identified: (a) car-following sensitivity constant, (b) minimum car-following distance, and (c) vehicle lengths. To reduce the number of possible combinations of parameter values in this calibration, these parameters were calibrated sequentially (i.e., at any time, only the value of one parameter was varied); while the optimum value of any particular parameter was being calibrated, the remaining parameters were treated as constants. For this part of the calibration, the parameters were adjusted to bring the volume and occupancy produced by INTRAS closer to the field data, with emphasis placed on volume count. Initially, the effective length of all loop detectors was set at 6 ft. Although the loop length does not affect volume count, it does affect the occupancy value. After the car-following sensitivity constants, minimum car-following distance and vehicle lengths were calibrated, the effective loop length could still be adjusted to fit occupancy close to actual data. The calibration of incident-free parameters made use of Data Set 1. The model with the calibrated parameters was then validated using the incident-free portion of Data Set 3.

Car-Following Sensitivity Constant

The movement of individual vehicles in INTRAS is governed by the car-following equation (*1,9*):

$$h(t) = L + m + kv(t) + bk[u(t) - v(t)]^2 \tag{1}$$

where

$h(t)$ = spacing headway at time t (ft);

L = length of lead vehicle (ft);
$v(t)$ = speed of following vehicle at time t (ft/sec);
$u(t)$ = speed of leading vehicle at time t (ft/sec);
k = sensitivity constant;
b = relative sensitivity constant, which is set to 1 if $u(t) > v(t)$ and 0 otherwise; and
m = 10 ft of minimum spacing.

The car-following sensitivity constant (k) in Equation 1 was first calibrated. The default values of k are from 10 to 19 at increments of 1, each corresponding to a particular type of driver. To check the sensitivity of INTRAS output with different k-values, simulation runs with three different series of k-values were carried out. The first series contained the default values of k. Series 2 and 3 consisted of k-values from 5 to 14 and 15 to 24, respectively.

A simulation run with each series of k-values was repeated three times, each with a different random number seed. For each set of simulation results with a random number seed, the slopes of the fitted straight lines and r-values of the volume and occupancy plots were computed. The average slopes and r-values obtained from the three random number seeds were examined.

With the reduction of sensitivity in Series 2, drivers followed each other at at higher speed, keeping the same distance. The average slope of the fitted lines and r-values in the volume plots remained approximately the same as those obtained with Series 1. The average slope of the fitted lines in the occupancy plots fell from 0.45 to 0.38. The low occupancy resulted in a very small average r-value of 0.04 in Series 2, not significantly different from 0 at $\alpha = 0.01$, based on Fisher's r-to-z transformation test (*10*).

The Series 3 of the k-values corresponded to more sensitive (or more conservative) car-following behavior. The resulting volume plots had an average slope of only 0.65 (compared with 0.79 obtained with Series 1), while that for the occupancy plots had a higher value of 0.74. Sensitive drivers tend to have greater following distance; therefore, the volume count was lower than the field measurement. They also tend to slow down more with increasing volume, giving rise to higher occupancy. This type of car-following behavior tends to produce unstable conditions that belong to the right-hand side of the volume-density plot.

From the results, it was obvious that efforts to increase the slope of the volume plot caused a decrease in the slope of the occupancy plot and vice versa. Since INTRAS input and output volume at the ramps were computed from actual data, the simulation model should produce a volume count close to the actual value. Among the three series, the default values gave the highest average r-value and slope in the volume plots. Consequently, the default k-values in Series 1 were retained as a good compromise among the three sets of attempted values.

Minimum Car-Following Distance

The m-value in Equation 1 sets the default minimum car-following distance at 10 ft. This distance may be too large, considering that drivers are observed to queue up bumper to bumper when traffic comes to a complete stop. An alternative of 0-ft minimum following distance was tested to study the effect of shortening this value. Simulation runs were performed with $m = 0$ combined with the three series of car-following sensitivity constants.

Series 1 and 3 had high slopes and r-values in volume plots but very low r-values in occupancy plots. The r-values of the occupancy plots for Series 1 and 3 were not significantly different from 0 at $\alpha = 0.01$. Series 2 had relatively higher r-values for occupancy plots to compromise for lower r-values in volume plots. None of the results here was superior to that obtained with Series 1 of sensitivity constants and with 10 ft of minimum following distance. The default minimum following distance of 10 ft therefore was kept unchanged.

Vehicle Lengths

The next step of the calibration involved changing the default vehicle lengths. The default vehicle lengths in INTRAS are as follows:

Vehicle Type	*Length (ft)*
Low-performance passenger cars	17
High-performance passenger cars	17
Buses	40
Single-unit trucks	23
Truck trailers	50

To test the sensitivity of volume and occupancy plots with different vehicle lengths, three series of simulations were carried out: with (a) the default vehicle lengths, (b) the default length plus 5 ft, and (c) the default length minus 5 ft.

By putting shorter vehicles into the simulation model, it is possible to increase the volume in INTRAS or to reduce the occupancy. The results showed that the average slope of the volume plots remained the same while there was a reduction in the average slope of occupancy plots from 0.45 to 0.37. Setting the vehicle lengths to 5 ft longer than the default values brought the slope of the occupancy plot closer to unity. However, data points in the volume plot scattered in a circular region rather than showing a trend of a straight band. Using the default vehicle lengths gave a better match between the simulation results and field data. The vehicle lengths therefore were not adjusted.

Effective Length of Loop Detectors

With the default car-following constants, in order to keep the same INTRAS detector volume but increase the occupancy value, it was necessary to increase the effective length of the detectors. The lane width of the freeway is 12 ft. Assuming 1 ft of minimum clearance on both sides of the lane striping, the maximum size of a square or circular loop is 10 ft. INTRAS simulations at low, moderate, and high volume were made with all the detector lengths set at 10 ft. This brought the average slope of the fitted straight lines in the occupancy plots from 0.45 to 0.49. Since this step involved changing the vertical values of data points in the occupancy plots, the r-values remained the same.

Although the physical size of the loop is 6 ft and its effective zone may be slightly larger, practically it should not be as large as 10 ft. However, to bring the INTRAS occupancy values closer to the field data without changing the form of the car-following model, it was decided to make the numerical adjustment here.

Adjustment of Free-Flow Speed

The free-flow speed of 81 mph on the freeway links was estimated using an effective loop length of 6 ft. Since the effective loop length was increased to 10 ft, it was necessary to reestimate the free-flow speed using the new loop size. The same 100 data points (lane-specific volume and occupancy) used earlier were used to recompute the density and speed, assuming a 10-ft loop length. The fitted Greenshields free-flow speed was 95 mph. The speed of 95 mph was then set for all the freeway links in another set of INTRAS runs, and the results were compared with those obtained with a free-flow speed of 81 mph and loop length of 10 ft.

The average slope of the volume plots, with a free-flow speed of 95 mph, was 0.77. This was closer to the 0.79 obtained with the free-flow speed of 81 mph. But the data points with the higher free-flow speed were more scattered, as reflected in the reduction in *r*-value, from 0.34 to 0.28. The occupancy plots had an average slope of 0.61, which was an improvement on the 0.49 obtained with the free-flow speed of 81 mph. The average *r*-value of the occupancy plot increased from 0.15 to 0.31.

None of the free-flow speeds was distinctly superior. The free-flow speed of 81 mph was closer to the actual driving speed on the freeway and gave better *r*-values in the volume plots. The free-flow speed of 95 mph produced better matched data in the occupancy plots. For free-flowing traffic, it is more important to match volume than occupancy, especially when the actual field volume was used as part of the simulation input. The free-flow speed of 81 mph was thus retained.

Validation of Calibrated Parameters for Incident-Free Conditions

The calibration process changed the freeway free-flow speed to 81 mph and the effective loop length to 10 ft. Another set of detector data (Data Set 3), collected on December 12, 1990 (Wednesday), from 5:00 a.m. to 10:45 p.m. was acquired to validate these adjusted parameters. After excluding time segments encompassing incidents and the period after which detector data appeared to be influenced by them, the remaining segments were divided into 15-min intervals. Three 15-min incident-free periods starting at 10:30 a.m., 5:30 p.m., and 7:00 p.m. were selected to represent moderate-, high-, and low-volume conditions. The average station volumes at these periods were 1,527, 1,771, and 1,264 vphpl, respectively.

This validation data set gave average slopes of 0.87 and 0.54 for volume and occupancy plots, respectively. The corresponding average *r*-values were 0.46 and 0.39. These values were higher than their respective values obtained with Data Set 1. The volume-density curve of field data and that obtained by INTRAS simulations were inspected, and they matched very closely. The calibrated parameters were thus retained.

CALIBRATION OF INTRAS RUBBERNECKING FACTOR

After the nonincident parameters were calibrated and validated, the rubbernecking factor in INTRAS was calibrated with incident Data Sets 2 and 3, collected on February 4, 1991, and December 12, 1990, respectively.

Calibration of Rubbernecking Factor with Data Set 2

Data Set 2 included an incident that occurred at 6:21 a.m. between Harbor Boulevard and Euclid Street, and lasted for 810 sec. This incident resulted in Lane 2 being blocked by a single vehicle, but the exact location within the 1-mil section between the two cross streets was unknown. Repeated simulation runs were performed, placing the incident at different locations between the two stations. In each simulation run, the 15-min actual average volume before the occurrence of the incident was used as the input volume in INTRAS. Five minutes of free-flowing traffic were simulated before the incident. By comparing the time at which a sharp increase occurred in the occupancy of the upstream station at the onset of the incident for the different runs against the trend of increments in actual data, the location of the incident was deduced to be 300 ft downstream from the on-ramp at Harbor Boulevard.

The INTRAS user's manual (*9*) recommends that a rubbernecking factor of 10 be used with each incident simulation. In the calibration, values of 5, 10, 20, 30, and 40 were considered in five simulation runs. Initially, the rubbernecking effect was set at the incident location for the rest of the lanes that were not blocked as well as for all the lanes immediately downstream of the incident as recommended. A second set of five simulation runs was performed with these factors, without the rubbernecking effect downstream of the incidents. Another run with no rubbernecking was made, bringing the total number of simulations to 11.

For each simulation run, the upstream and downstream occupancy and volume at the incident location were plotted against time. Among the four variables, the upstream occupancy was found to be most sensitive at onset, during, and at termination of the incident. Since the upstream occupancy during and after the incident was affected by the rubbernecking factor, the root mean square (*RMS*) error between INTRAS occupancy and actual occupancy during this period was used as a performance measure. The 11 simulation runs were repeated three times, each with a different random number seed. The average *RMS* error of the runs without rubbernecking was computed to be 9.69 percent, and the *RMS* errors from all the remaining runs with rubbernecking were all greater than 18 percent. From the results, apparently no rubbernecking factor is necessary for incident specification. The fluctuation of upstream occupancy with time for the field data and from the simulation run with the default random number seed is shown in Figure 4. INTRAS was capable of generating occupancy values comparable to the field data.

To test (a) the stability of INTRAS in producing occupancy values that were closely matched with the field data, and (b) the hypothesis that the data points produced by INTRAS, such as those in Figure 4, were not significantly different from the actual values collected in the field, the following experiment was conducted. First, 30 simulation runs (without the rubbernecking effect) were performed with different random number seeds. At the end of each 30-sec interval, the occupancy values extracted from the these simulations were taken to compute the mean and standard deviation of the simulated occupancy of that interval. Assuming that the simulated occupancy value at a particular time interval fluctuates about the sample mean and follows a normal distribution, the 95 percent confidence interval was constructed. Successive confidence intervals were plotted against simulation time to form a confidence envelope and superimposed with actual data obtained from the field. All the actual data points fell within the 95 percent confidence envelope, indicating that the actual data points were not significantly different from the values generated by INTRAS.

Calibration of Rubbernecking Factor with Data Set 3

Data Set 3 had an incident that occurred at 10:56 a.m. between Euclid Street and Brookhurst Street. This incident, caused by a six-vehicle collision, resulted in Lane 1 (the leftmost lane) being

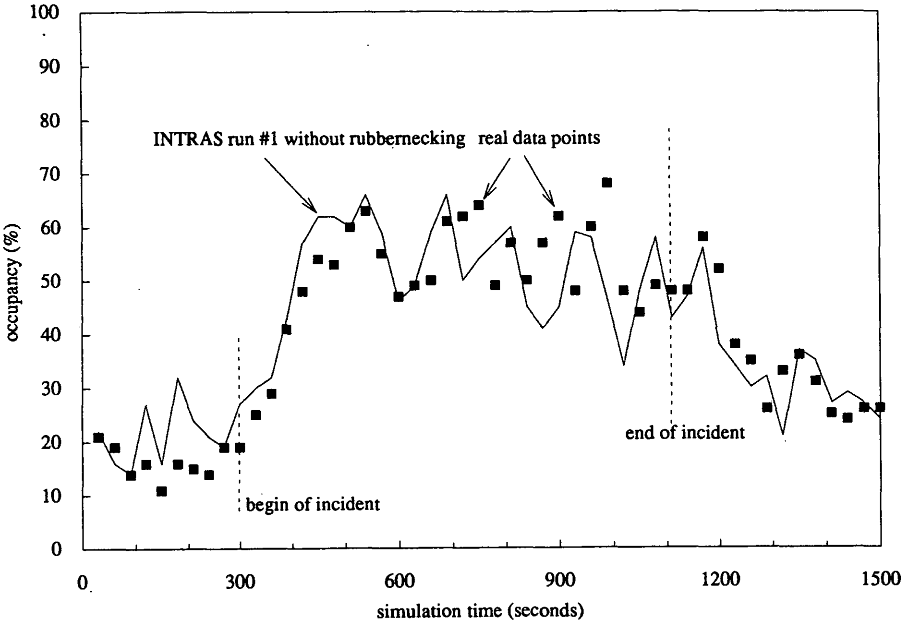

FIGURE 4 Upstream occupancy without rubbernecking factor for incident in Data Set 2.

blocked from 10:56 to 11:33 a.m. From 11:33 to 11:36 a.m., the entire freeway section was closed for the incident management team to move the vehicles involved in the collision from the left lane to the shoulder, after which all the lanes were opened to traffic.

The following 1-h incident scenario was simulated in INTRAS: 5 min of incident-free traffic, incident with Lane 1 blocked for 37 min, followed by a full blockage of 4 min and 14 min of clearance time after the removal of the blockage. Since this incident had been split into two parts and INTRAS permits only two blockage specifications per simulation run, no rubbernecking factor was assigned downstream of the incident. The length of incident was set at 140 ft (for six vehicles) according to the guideline provided in the INTRAS user's manual. By means of trial and error, the upstream end of the incident was placed 500 ft downstream from the on-ramp at Euclid Street.

The same rubbernecking factors used for the Data Set 2 incident were tested here. The average RMS error of upstream occupancy was found to be 14.32 percent without rubbernecking, compared with at least 34 percent with the rubbernecking factors. Similar to the earlier finding, no rubbernecking was required to produce a closer match between INTRAS output and field data. The minimum average RMS error of 14.32 percent was of higher magnitude than the 9.69 percent found in the Data Set 2 incident. The larger difference is caused by the magnitude of the random fluctuation of the field data during the incident as well as by consistent bias in INTRAS output after the incident. For illustrative purposes, the upstream occupancies from INTRAS Run 1 with no rubbernecking and with the default random number seed are plotted against field data in Figure 5.

Simulation runs without the rubbernecking effect were repeated 30 times, each with a different random number seed to construct the 95 percent confidence envelope. Twenty-three of 120 actual data points fell outside the 95 percent confidence envelope. It should be noted that 17 of the 23 outliers occur 4 min after the removal of the incident. INTRAS is good in simulating queueing situations during incidents, but it may underestimate the occupancy during free-flow conditions as well as the recovery periods after incidents. These phenomena were reflected in all the occupancy plots (see Figure 3). Except for this apparent shortcoming, INTRAS is capable of simulating incidents and producing reasonably accurate detector output.

DISCUSSION OF RESULTS

The car-following equation in Equation 1, if used to derive a macroscopic traffic stream model, results in a speed-density function that slopes downward. This function corresponds to the high-density region (rightside) of the commonly used bell-shaped volume-density curve. This is understandable because car-following occurs only when traffic density has reached a certain level. The left side of the volume-density curve is constrained by the free-flow speed imposed on the freeway links.

In general, the car-following equation gives satisfactory results. The only apparent drawback is that it fails to simultaneously produce volume and occupancy high enough to match with the actual data collected in the study section. There may be some combinations of input parameters that can give better results but have not been tested in this limited study. Alternatively, there may be different forms of car-following models that can better represent the behavior of drivers in the study area. Since human driving behavior is complex, one should not expect that the same form of equation would apply to all drivers. One suggestion for improvement may be to replace the car-following model with a series of artificial neural network models, one for each type of driver. The primary advantage of neural network models is that no car-following rules and associated parameter values need to be specified explicitly. Such a neural network model could receive input such as speed, relative speed, vehicle spacing, and vehicle length and produce output indicating acceleration and lane changing responses. An initial attempt to use an artificial neural network model to mimic elements of driver behavior has been performed with laboratory-simulated data in a

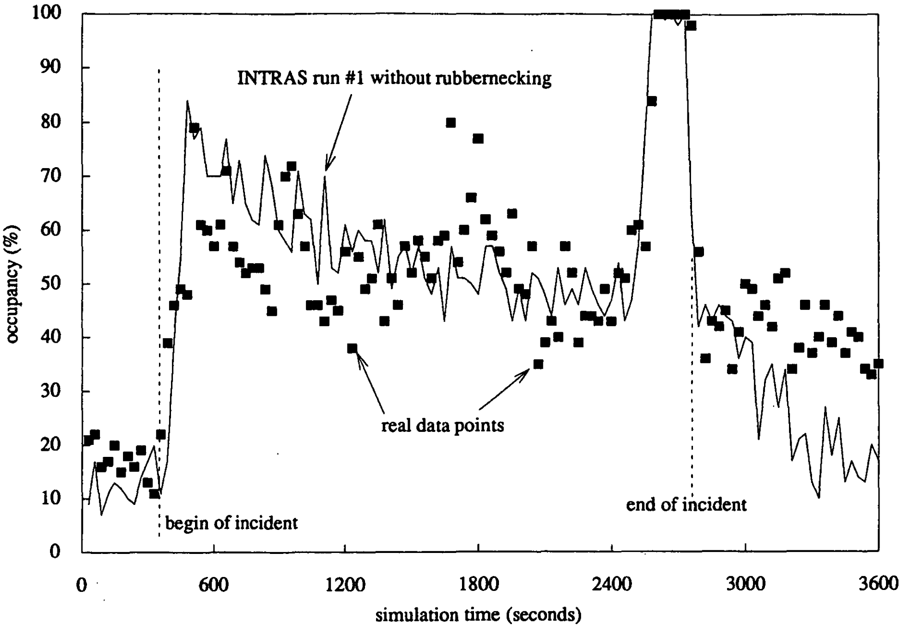

FIGURE 5 Upstream occupancy without rubbernecking factor for incident in Data Set 3.

simplified driving environment (*11*), and the result has demonstrated the potential of such an application.

Two principal limitations in INTRAS could affect data generation for incidents:

1. INTRAS does not permit placement of loop detectors at on- and off-ramps. If such provision existed, one may be able to use ramp volume and occupancy to simulate real-time ramp metering as well as to provide additional inputs to incident detection algorithms.
2. INTRAS permits coding of the rubbernecking factor only in the three rightmost lanes on a freeway (excluding any auxiliary lane). This may not affect simulation runs, as the calibration results have shown that it is not necessary to assign a rubbernecking factor at any incident location. However, if the calibration results at other freeway sites necessitate the use of a rubbernecking factor and the freeway section has more than three lanes, appropriate subroutines in the INTRAS program code would have to be modified.

Despite these limitations, INTRAS is still the most widely used and most readily available microscopic freeway simulation model that can produce detector data at 30-sec intervals. The calibration procedure described in this paper should also apply to the successor of INTRAS, namely, the FRESIM model currently under development, which is believed to have the same fundamental structure as INTRAS. The INTRAS model, with the calibrated parameters, has been used to simulate hundreds of incidents in the study section. The 30-sec station average volume and occupancy output has been used to train artificial neural network models for detection of incidents on the freeway(*12*).

SUMMARY

On the basis of the data sets available, the following input values were used in the INTRAS data file to produce simulation output that closely matched the calibration data:

1. The free-flow speed of the freeway study section was estimated at 81 mph.
2. The default car-following constants were the best among the attempted values in describing driver behavior. With these car-following constants, INTRAS was capable of "moving" vehicles at volumes very close to the actual count made on the freeway. However, the loop detector occupancies were always lower than the values collected in the field. To artificially increase occupancy value, it was necessary to increase the effective loop length to 10 ft.
3. To simulate traffic operation during the incidents considered, it was not necessary to assign any rubbernecking factor in the incident specification. Putting only the actual lane blockage at the incident location on the freeway was enough to produce an occupancy pattern closely resembling the actual traffic operations during incidents.

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