Assessing the Potential of Using Traffic Simulation Model Results for Evaluating Automatic Incident Detection Algorithms

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ABSTRACT

Non-recurring congestion is recognised to cause a substantial portion of the congestion experienced on freeways in most urban centres. Automatic incident detection (AID) algorithms have been developed since the mid 1970s in an attempt to detect these incidents quickly and efficiently and a number of AID algorithms are currently in use, however, there is no clear consensus as to which of these algorithms provides better performance. This lack of consensus is primarily a result of the lack of a common independent test-bed, which would enable objective comparisons of different algorithms. A desirable component of such a test-bed would be the ability to incorporate synthetic data produced by a simulation model since these data could examine various incident scenarios in a systematic manner.

This paper examines the simulated loop detector data produced by the INTEGRATION model and compares these data to actual field data at both the macroscopic and microscopic level. On the basis of this analysis, it is concluded that these synthetic data are sufficiently similar in character to the field data as to be useful for the evaluation of AID algorithms.

I. INTRODUCTION

A. Background and Objectives

Most urban freeways in North America experience significant congestion during part, or all, of the morning and evening peak commuting periods. While much of this congestion is a result of demand in excess of the capacity provided by the existing transportation infrastructure, (recurring congestion), a significant portion of delay (non-recurring congestion) is caused by unexpected temporary capacity reducing incidents. Studies in Los Angeles have shown that more vehicle hours of delay result from incident induced non-recurring congestion, than from regularly occurring (recurring) network congestion (Busch, 1991).

Automatic incident detection (AID) has been recognised as an effective means of reducing the impacts of non-recurring congestion and as such, has been incorporated as an element within traffic control systems of many large urban centres. These AID rely on surveillance systems, typically in-ground induction loop detectors, to provide data to the AID algorithms, which attempt to identify the occurrence of an incident by interpreting these data. A number of different algorithms are currently used in practice, however, there does not appear to be consensus among practitioners or researchers that any single algorithm is superior to all others.

A review of the literature (Rakha and Van Aerde, 1996) reveals that few recent objective comparisons have been made between algorithms using common independent test data. In the majority of the literature, individual algorithms are evaluated either off-line or on-line using field data for a particular site. Unfortunately, each algorithm has typically been tested on a unique site with unique roadway geometry, surveillance technologies, surveillance coverage, and traffic patterns, making objective comparisons between algorithms difficult. Furthermore, while the literature cites a number of different performance measures for AID algorithms, including detection rate, false alarm rate, mean time to detect, and mean delay time, not all of these measures are provided for each algorithm.

An opportunity exists to establish a common AID algorithm test-bed, on which all algorithms could be tested and for which common measures of performance could be compiled. This test-bed could consist solely of a compilation of field data, however, this would limit the

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geometric and surveillance system configurations that could be examined. Furthermore, the actual time at which incidents occur and clear are often unknown. Surveillance system inadequacies, such as poor loop calibration, inoperative detectors, erroneous data, and inadequate loop spacing, have a detrimental impact on the AID algorithm performance, but do not necessarily reflect poor algorithm logic.

Synthetic data have several advantages, including the ability to control incident frequency, location, duration, and severity and the ability to explicitly control the location and reliability of loop detectors. This control permits systematic assessment of the capabilities of an algorithm for different flow regimes, incident types, and surveillance levels. However, it must first be shown that these synthetic data have the same character as field data. They must be sufficiently similar in character to field data such that the results obtained from assessing AID on these synthetic data have a strong correlation with the performance of these AID on field data under similar conditions.

The objective of this paper is to compare the simulation results provided by the INTEGRATION simulation model with field data, and to determine whether these synthetic data are sufficiently similar in character to the field data to make the synthetic data useful for testing AID algorithms.

B. Paper Organisation

In the next section, the selected field study site is described and rational is provided for its selection. The surveillance system equipment is described and sample loop detector data are examined. Section III describes the macroscopic calibration of the INTEGRATION simulation model for the study section. This calibration consists of the selection of appropriate speed/flow/density relationship parameters, and the estimation of time varying origin - destination traffic demands.

In section IV, the simulation model results are examined at a macroscopic level. In particular, average 5 minute simulation detector results are compared to the speed/flow relationship input to the INTEGRATION model. Subsequently, the spatial and temporal variations in average 5 minute speeds resulting from INTEGRATION are compared to variations in field data.

Section V examines the model results at a more microscopic level. Three specific aspects of the simulation results are examined, namely the temporal variation of 20-second speeds, the variation of speed as a function of occupancy, and the flow-occupancy relationship.

Section VI illustrates some sample synthetic data for an incident that blocks the shoulder of the study section for 10 minutes. These data serve to illustrate the simulated microscopic changes that result from the occurrence of an incident, and serve as an example of the type of data that could be created for use in testing AID algorithms.

Finally, in Section VII, conclusions and recommendations are made on the basis of the work described in this paper.

II. STUDY NETWORK

A. Description of Study Network

Highway 401 in Toronto, Canada, which experiences an average annual daily traffic flow of approximately 340,000 vehicles, is one of the most heavily travelled roadways in North America. This facility serves as the primary east-west commuting corridor for the Greater Toronto Area (GTA) as well as the primary east-west link for goods movements in the province of Ontario.

The COMPASS freeway traffic management system provides surveillance via single and dual induction loop detectors and closed circuit television along approximately 41 km of the system. Loop detector stations are located at all access and egress points and approximately every 0.6 km along the freeway. The loop detectors provide speed, volume and occupancy data to the COMPASS control centre every 20-seconds. These data are utilised on-line for automatic incident detection (AID) and advanced traveller information systems via changeable message signs, and are also archived for off-line use.

Within the GTA, the freeway is separated into an express and collector facility in each direction. Typically, each facility consists of three or four lanes. For this study, a 5 km long section of the westbound express facility was selected, as illustrated in Fig. 1, for three primary reasons:

1. The section was instrumented and detector stations were operational at all access and egress locations.
2. The section geometry was quite simple, with a single high-speed transfer road to the collector facility and a single high-speed transfer road from the collector facility. A simple section was desired as an initial site, with the expectation that more complex sites could be examined if the results from this initial site were positive. It was also important that the congestion patterns observed within the section resulted from attributes of the section, rather than conditions upstream or downstream of the section, since these effects could not be captured directly by the simulation model. Finally, the results would be expected to be much more transferable to other

locations, if the section geometry consisted of typical freeway elements.

3. The section experienced significant congestion during the AM commuting period, which resulted from the high demands attempting to access the express facility from the collector facility.

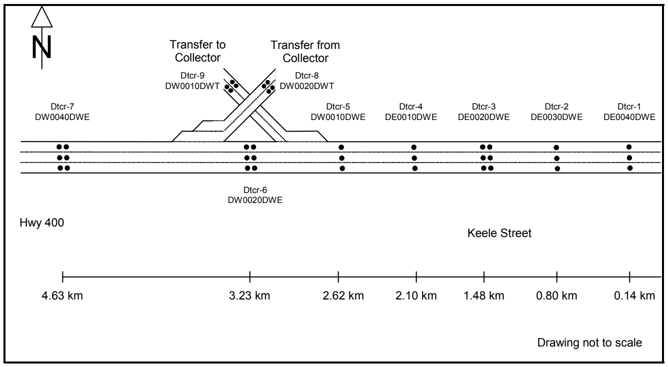

Fig. 1: Section of Highway 401 westbound express used in study.

B. Surveillance Equipment

As indicated in Fig. 1, there exist 7 mainline and 2 transfer detector stations within the study section. Each station is identified by number (i.e. 1 through 9) and the 9 character COMPASS system identifier is also listed. As indicated, detector stations are spaced at approximately 0.6 km intervals with the exception of station 7. In the field, a station is located between stations 6 and 7 (COMPASS reference # DW0030DWE), however, it was inoperative during this study, and as a result, was not considered. All 9 stations depicted in Fig. 1 were operative during this study.

Five of the 9 detector stations are dual loop stations that directly measure vehicle speed, while the remaining 4 stations are single loops that can only estimate speeds on the basis of average vehicle lengths computed from nearby dual loop stations. Previous research reported in the literature (Hellinga and Van Aerde, 1994) has indicated that these speeds should be used with caution, since they may contain considerable error, particularly for low flow conditions.

C. Examination of Field Data

The objective of this paper is to assess the potential for using simulation model results for the testing of AID. In order to perform this assessment, it is required that the characteristics of field data, that are relevant to AID, be examined. It is also necessary that the field data be used to calibrate the input parameters required by the simulation model. In this section, several general characteristics of the field data are identified. Calibration issues are discussed in the subsequent section.

Fig. 2 illustrates the temporal variation in aggregated 5 minute average station speeds for the 7 mainline detectors from 4 AM to 11 AM. These data illustrate 3 characteristics of the system:

1. It is evident from the reduction in speed after 7:15 AM, that the freeway section experiences congestion from approximately 7:15 AM to 9:30 AM.

2. During this time of congestion, station 7, which is located downstream of the merge area, experiences speeds that are greater than those experienced by stations upstream of the merge. This behaviour is consistent with traffic theory predictions for the situation in which merging traffic causes congestion (as opposed to congestion spilling back into the section from a bottleneck downstream of the section).

3. There is a significant systematic variation in speeds between detector stations during low flow conditions (i.e. prior to 6 AM). Station 3 reports speeds between 130 and 135 km/h, station 7 reports speeds between 105 and 110 km/h, and station 5 reports speeds between 65 and 90 km/h. The vertical profile of this section does not contain grades sufficiently steep to cause these extreme differences. Therefore, it is considered likely that the detector stations are not all consistently calibrated and that the speed estimates produced by the single loop detectors could contain considerable error. Consequently, the data are normalisation using Equation 1.

$$S'_t = S_t \cdot \left(S_f \big/ \bar{S}_{5-6AM} \right) \qquad [1]$$

S'_t = normalised speed for time interval t (km/h)
$\bar{S}_{5-6AM}$ = Average of speeds recorded between 5 and 6 AM (km/h)
S_f = assumed free speed of 110 km/h
S_t = observed average 5 minute speed (km/h)

Fig. 3 illustrates the temporal variation in average 5 minute speeds after normalising using Equation 1.

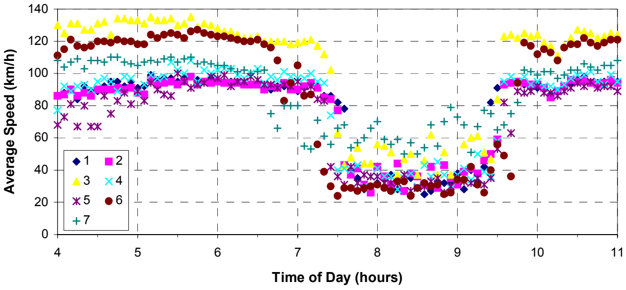

Fig. 2: Observed temporal variation in average 5 minute station speed

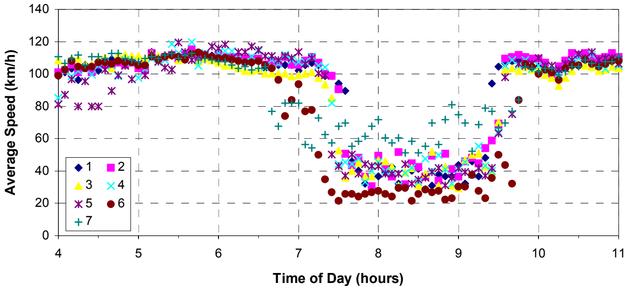

Fig. 3: Observed temporal variation in normalised average 5 minute station speed

III. MACROSCOPIC MODEL CALIBRATION

The INTEGRATION traffic simulation model requires the macroscopic characteristics of the traffic network, such as link length, capacity, jam density, free speed, speed at capacity, and the origin-destination traffic demands, be specified as input data. These characteristics are often highly network dependent and therefore must be calibrated for the specific section being modelled.

A. Speed/Flow/Density Relationships

A methodology for systematically calibrating the parameters of the speed/flow/density relationships (Van Aerde and Rakha, 1995) was utilised to determine parameter values appropriate for the normalised observed data. Using a representative data sample, the appropriate parameter values were estimated to be: free speed = 110 km/h; capacity = 2200 vph/lane; speed at capacity = 80 km/h; jam density = 120 veh/km. The resulting macroscopic speed-flow relationship is illustrated in Fig. 4 along with the normalised observed data.

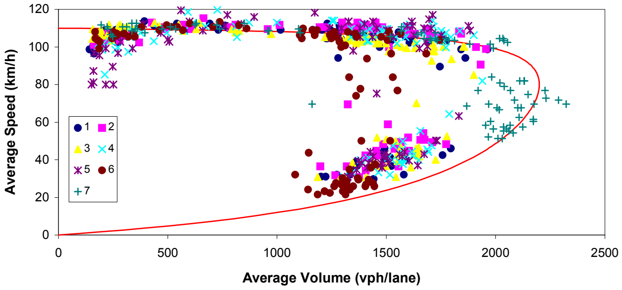

Fig. 4: Calibrated speed/flow relationship and normalised observed average 5 minute station data

B. Origin-Destination Demands

Typically, the estimation of dynamic O-D demands is a process that relies on the inference of the unknown demands from observed link flows, partial or outdated surveys, and assumptions about trip making behaviour. The accuracy of these estimated O-Ds, while rarely known, is often quite poor, which in turn leads to discrepancies between the simulated results and observed field data.

In this study, the freeway section was deliberately chosen to avoid the difficulties inherent in O-D estimation, and the potential errors that might be introduced by such a process. For this section, it is possible to directly measure the O-D flows (mainline to mainline = station 1 minus station 9; collector to mainline = station 8; mainline to collector = station 9).

The distinction between observed flow and actual demand is not critical in the context of this study, since demand stored upstream of detectors 1 and 8 is captured as observed flow when it subsequently enters the network. However, to reflect the un-served traffic demand, rather than the observed traffic flow, demand was increased by 15% above the flow observed at station 1 during the time period when the flow at station 1 is in the congested regime. Dynamic demands were created at the 5 minute level of aggregation on the basis of the observed flows. The temporal variation in these demands is illustrated in Fig. 5.

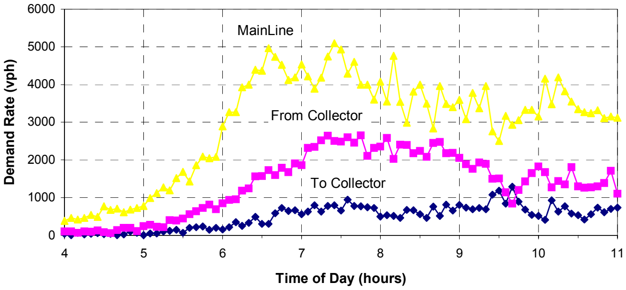

Fig. 5: Temporal variation in estimated 5 minute traffic demands

IV. MACROSCOPIC MODEL VERIFICATION

Having calibrated the INTEGRATION simulation model, the network was modelled from 4 AM to 11 AM with an additional 1 hour of simulation time to permit all vehicles to clear the network. In total, 34950 vehicle trips were modelled, with an average trip length of 4.2 km and an average trip duration of 6.4 minutes.

A two level approach was adopted for assessing the adequacy of the simulation results for testing AID algorithms. At the first level, macroscopic model results were examined for internal consistency and also compared to aggregate field data. At the second level, microscopic characteristics of the simulation results were compared to the field data.

A. Speed/Flow Relationship

Fig. 6 illustrates the macroscopic speed/flow relationship provided as input to INTEGRATION, and the average 5 minute detector station speeds produced as output from INTEGRATION. These data reflect a base case scenario in which no random speed variability is imparted.

On the basis of Fig. 6, three observations can be made.

1. First, while the detector station speeds reported by INTEGRATION follow the general trend of the specified speed/flow relationship, the reported speeds in the uncongested regime consistently lie beneath the curve and exhibit less variance than the field data (Fig. 4).
2. In the congested regime, the reported detector speeds lie directly along the specified speed/flow relationship, but have much less variability than the corresponding field data (Fig. 4).
3. The data points lying internal to the speed-flow relationship, which reflect non-equilibrium traffic conditions, are also evident in the field data.

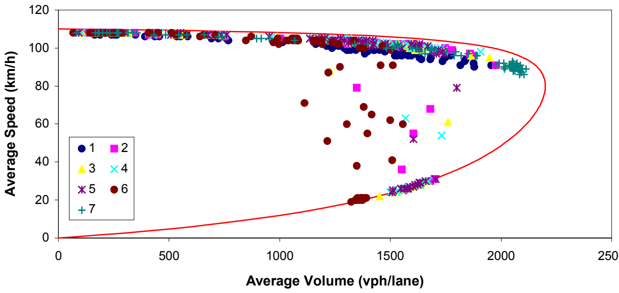

Fig. 6: Average 5 minute simulated speed-flow data when no random variability in speed is imparted

Since much of the challenge of developing AID algorithms lies in coping with the variability exhibited by field data, it is important that synthetic data exhibit similar levels of variability. In an attempt to increase the variability in the detector data reported by INTEGRATION, speed variability was imparted during the simulation. This was accomplished by varying the aggressiveness of individual drivers, such that drivers with different levels of aggressiveness would travel at different speeds for the same volume. All other input parameters were left unchanged. From Fig. 7, which illustrates the resulting detector station speeds reported by INTEGRATION, it is evident that, while the variability of reported speeds has increased, the mean speed as a function of volume has decreased in the uncongested regime. At a flow of 2000 vph, the reported speed is approximately equal to 70 km/h while the macroscopic relationship indicates a speed of approximately 100 km/h.

It is speculated that this discrepancy between the specified speed-flow relationship and resulting speeds arises from the manner in which variation in speed is modelled. Variation in speed is achieved by making some drivers more aggressive than the mean, and some drivers less aggressive than the mean, where the mean is represented by the specified speed-flow relationship. An aggressive driver is one that, for a given speed, accepts a smaller headway than an average driver. However, as volume increases, there is also an increase in the interaction between vehicles. With increased volume there is also a further decrease in the opportunity to make lane changes, so that at higher levels of congestion, the less aggressive drivers, begin to control the speed of the entire traffic stream. Thus, as the volume increases towards capacity, the discrepancy between the specified speed-flow relationship and the resulting speeds becomes larger.

At the current time, a lack of appropriate field data prevents a comprehensive microscopic analysis of the origins of variations in speed and the development of more refined methods for modelling these variations.

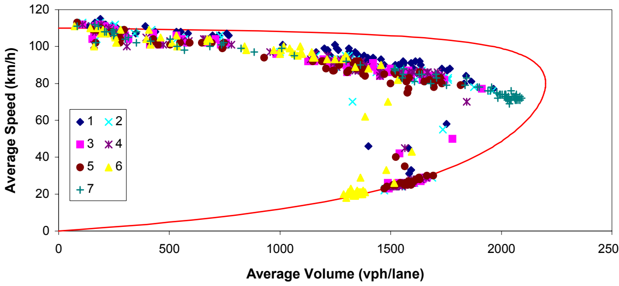

Fig. 7: Average 5 minute simulated speed-flow data when random variability in speed is imparted

B. Temporal and Spatial Variations in Average Speed

As indicated in Fig. 2 and 3, during the AM peak period, the study section experiences substantial variation in speed over both time and space. The calibration of time varying O-D demands captures the temporal nature of the traffic demand, however, it is necessary to examine the traffic conditions that result from these demands. Fig. 8, 9, and 10 depict the temporal variation in observed and simulated average speeds (simulation utilised variability in speeds as discussed in the previous section) at three different locations (detector stations 3, 6, and 7 respectively). These figures confirm a previous observation that traffic is most congested directly upstream of the merge (detector station 6) and that downstream of this bottleneck, speeds are significantly higher.

These figures also indicate that the simulation results correlate very well with the observed data. Congestion within the simulation occurs at approximately the same time, and for the same duration, as is observed in the field data.

On the basis of these comparisons, it can be concluded that, while discrepancies remain between the observed and simulated data, and particularly between simulation speed-flow results and input speed-flow parameters, the model captures the primary macroscopic temporal and spatial trends.

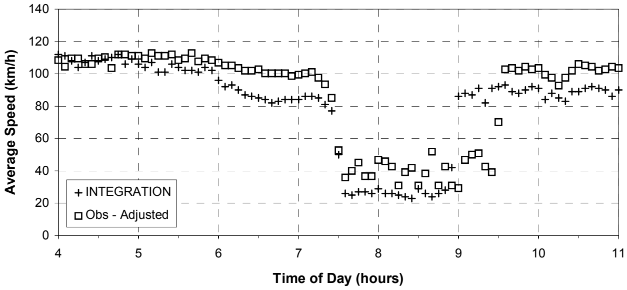

Fig. 8: Average 5 minute simulated and normalised observed speeds for detector station 3

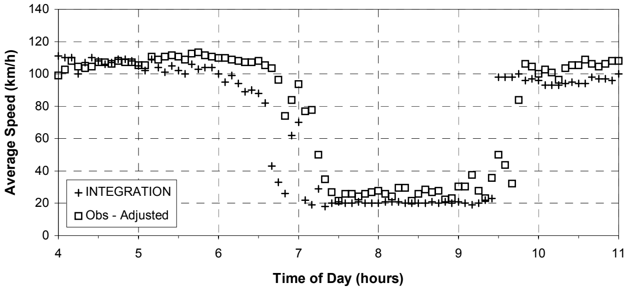

Fig. 9: Average 5 minute simulated and normalised observed speeds for detector station 6

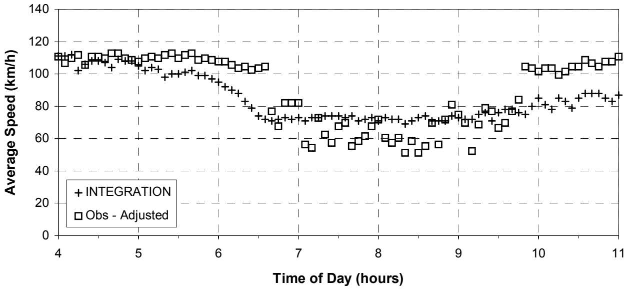

Fig. 10: Average 5 minute simulated and normalised observed speeds for detector station 7

V. MICROSCOPIC MODEL VERIFICATION

Having examined model results at the macroscopic level, and concluded that these results adequately reflect the macroscopic trends observed within the field data, it is necessary to examine the microscopic characteristics of the simulation results. This is done by examining three aspects of the simulation results, namely the temporal variation of speed at the 20-second level of aggregation, the variation of speed as a function of occupancy, and lastly, the microscopic relationship between flow and occupancy.

A. Temporal Variation in Speed

As an initial step in microscopic verification, a qualitative comparison is made of the simulated and observed temporal variation in 20-second speed data.

Consider Fig. 11 and 12 which depict the observed and simulated 20-second speed data for the centre lane at detector station 6. Several observations can be made on the basis of these two figures.

1. The field data display considerable variation in speed in both the congested and the uncongested regimes. The simulation data exhibit much less variation in the congested regime.
2. The field data contain a number of speed observation that seem to be erroneous (e.g. at 7:45 AM, a 20-second speed of 150 km/h is reported while the average speed at this time is approximately equal to 25 km/h). These suspect data are likely a result of measurement error and do not reflect actual conditions. The simulated data, which are not affected by measurement errors, do not exhibit these suspect observations.
3. The simulated data indicate a more rapid transition from the uncongested to the congested regime than is indicated by the field data. Similarly, the simulation data indicate a more rapid recovery from the congested regime to the uncongested regime. These rapid transitions are particularly evident at 7 AM, when the simulation briefly recovers to the uncongested regime, before becoming congested again. These rapid transitions are not evident in the field data.

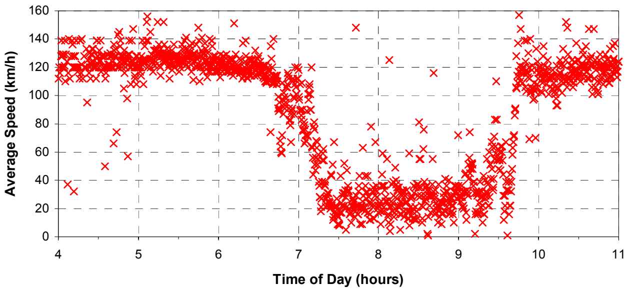

Fig. 11: Temporal variation in observed 20-second speeds for the centre lane at detector station 6

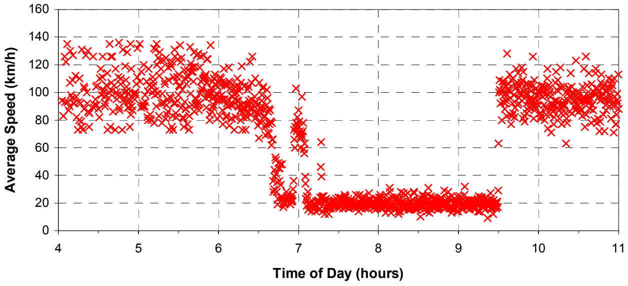

Fig. 12: Temporal variation in simulated 20-second speeds for the centre lane at detector station 6

B. Comparison of Average Speed and Standard Deviation of Speed

In an effort to quantify the amount of variability in station average speed in both the simulated and observed data, the 20-second data were sorted into occupancy bins of 5%. The mean and standard deviation of all of the observations in each bin were computed for both the simulated and field data. On the basis of these results, which are illustrated in Fig. 13, two observations can be made:

1. The simulated and observed average speeds are similar and reveal a non-linear speed-occupancy relationship. The largest discrepancy between the simulated and observed data occurs between 5 - 15% occupancy, where simulated speeds underestimate the observed data by approximately 10 km/h. This underestimation is consistent with the underestimation illustrated in Fig. 7, since occupancy between 5 - 15% represent uncongested flows between 750 vph/lane and 2200 vph/lane (the volume range over which simulated speeds underestimated the input speed-flow relationship).
2. The variation in speed, as measured by the standard deviation, is also indicated in Fig. 13. The variation of simulation results follows a similar trend as depicted by the field data, however, this variation is consistently less than the variation in the observed data. This underestimation tends to increase with increasing occupancy.

These results are also consistent with early observations made on the basis of Fig. 11 and 12.

It should be noted, however, that the standard deviations illustrated in Fig. 13 are computed on the basis of the raw 20-second data, and can be significantly influenced by erroneous detector data, particularly at high occupancies, where there tends to be fewer number of observations.

To illustrate, consider Fig. 14, in which the 20-second speed data is plotted as a function of occupancy for the centre lane at detector station 6. It is clear that a number of these 20-second observations are highly erroneous (e.g. speed = 150 km/h at an occupancy = 83%) and bias the computed standard deviation.

While errors in the observed data tend to increase the computed standard deviation, the general conclusion that there is less variation of speed in the simulation results than in the field data, is still true.

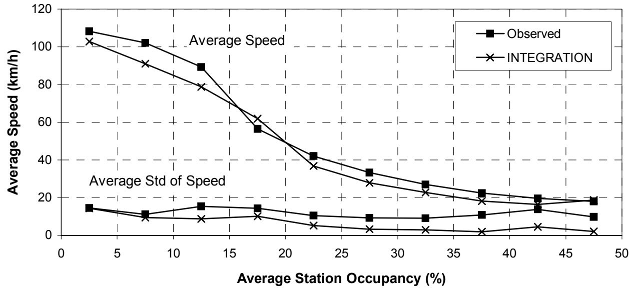

Fig. 13: Observed and simulated average speed and average standard deviation of speed as a function of occupancy.

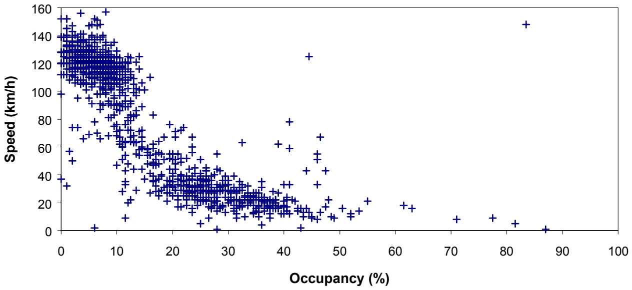

Fig. 14: Observed 20-second speed data as a function of occupancy for the centre lane at detector station 6

C. Flow as a Function of Occupancy

Many incident detection algorithms rely on flow and occupancy data to decide whether or not an incident has occurred. One algorithm in particular, the McMaster algorithm (Gall and Hall, 1989; Hall *et al*., 1993), overlays the flow-occupancy relationship with a template, in which

6 regimes are defined. The regime in which a particular data observation is located is compared to the regime of the upstream and downstream station, to decide if an incident has occurred or if recurring congestion is being observed. The parameters of this template (slope of LUD line, V_{crit}, O_{init}, O_{crit}) must be calibrated for each lane at each detector station.

Fig. 15 illustrates the McMaster template on the observed 20-second volume-occupancy data for the centre lane at detector station 6. The parameter values associated with this template were those used by the COMPASS system for this station during the time of this study.

Fig. 16 illustrates the same McMaster template overlaid on the simulated 20-second volume-occupancy data for the centre lane at detector station 6.

It is evident from Fig. 15 and 16 that the simulated data exhibit less variability than the field data. However, the shape of the fundamental volume-occupancy relationship is quite similar.

On the basis of these comparisons, it can be stated that the simulated data exhibit similar trends as the field data, but do not exhibit as much variability as the field data. Furthermore, unlike the field data, the simulated data do not contain what would appear to be field measurement errors.

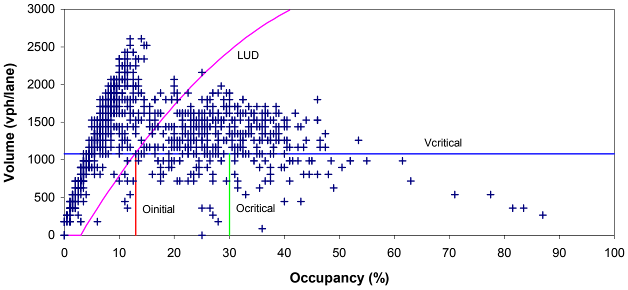

Fig. 15: Observed 20-second flow-occupancy data for the centre lane at detector station 6

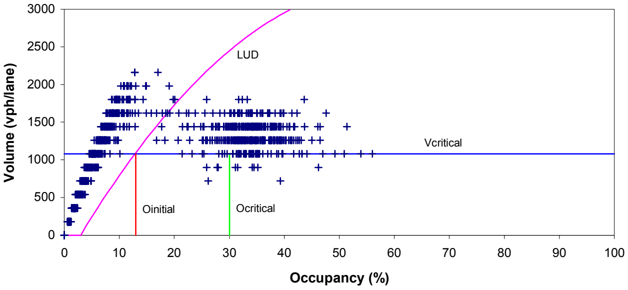

Fig. 16: Simulated 20-second flow-occupancy data for the centre lane at detector station 6

VI. SAMPLE SYNTHETIC TEST-BED DATA

The objective of this paper is to assess the potential of using simulation data for the purposes of testing AID. Previous sections of this paper have examined the characteristics of both field and simulated data. In this section, an incident is modelled, and the microscopic simulation results are briefly examined.

The same network and demand characteristics were utilised as in the verification analysis, however, an incident was modelled to block the shoulder lane 45 metres upstream of detector station 6 from 6:30 AM to 6:40 AM. Fig. 17, 18, and 19 depict the resulting temporal variation in 20-second occupancy at stations 5 and 6 for the median, centre, and shoulder lanes respectively.

Examination of the data for the median and centre lanes provides no indication that an incident has occurred. However, data for the shoulder lane are more informative. At 6:30 AM, the occupancy in the shoulder lane of station 6 decreases from approximately 11% to approximately 6%, while the occupancy of the upstream station (station 5) remains at approximately 11%. Just as the incident clears, the occupancy at both stations 5 and 6 increases rapidly in all lanes. It is hypothesised that this is caused in part by the incident queue discharging and this higher density platoon conflicting with merging traffic. The resulting queue causes congestion at detector station 6 that grows and recedes with fluctuations in arrival rates, such that the tail of the queue moves upstream and then downstream of detector station 5. This is evident from the cyclic fluctuations in occupancy between 12 and 30%.

While the above discussion has served to illustrate the characteristics of the simulated data when an incident is modelled, no direct microscopic comparison has been made with comparable field data.

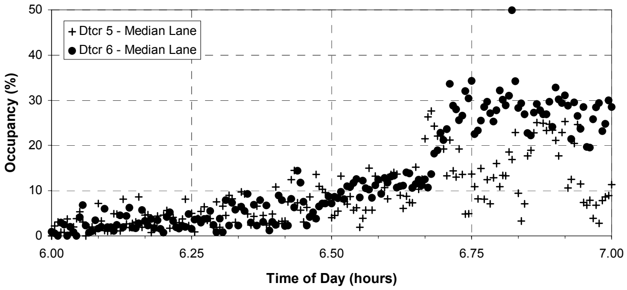

Fig. 17: Simulated 20-second occupancy data for the median lane in the presence of an incident.

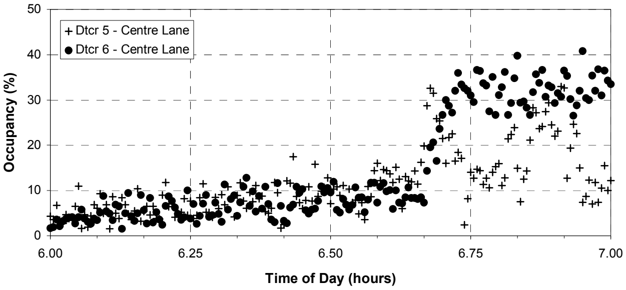

Fig. 18: Simulated 20-second occupancy data for the centre lane in the presence of an incident.

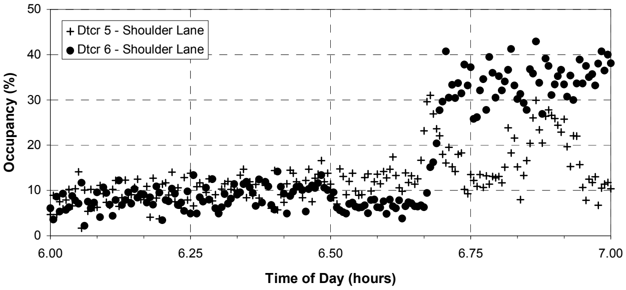

Fig. 19: Simulated 20-second occupancy data for the shoulder lane in the presence of an incident.

VII. CONCLUSIONS

This paper has examined the data produced by the INTEGRATION simulation model and compared these data to field data at both the macroscopic and microscopic levels. On the basis of these comparisons, a number of conclusions can be made.

1. At the macroscopic level, the synthetic data reflected similar temporal and spatial speed variation trends as exhibited by the field data for the study freeway section.
2. The synthetic data exhibited less variation in speed and occupancy than was exhibited by the field data, particularly under heavy congestion conditions.
3. The variation in speed exhibited by the field data is biased by the presence of erroneous data, particularly under conditions of heavy congestion.
4. The synthetic speed data, when represented as a function of flow, indicated that estimated speeds produced by INTEGRATION were underestimated when compared to the speed-flow relationship specified as input to the model. This underestimation was made more severe with the introduction of random variation in speed.
5. The synthetic data generated by the INTEGRATION simulation model are sufficiently similar in character to the field data as to be useful for the evaluation of AID algorithms.

On the basis of these conclusions, the following recommendations are made:

1. That a number of actual incidents be modelled using INTEGRATION, and a microscopic comparison be made between the observed field data and the simulation results.
2. That the INTEGRATION model be used to create an initial suite of test-bed scenarios which, in combination with field data, could be used to objectively evaluate different AID algorithms or different versions of the same algorithm.
3. That field data be compiled, in conjunction with synthetic data, to form complementary second test-bed for the objective evaluation of AID algorithms.
4. That a number of currently used AID algorithms be evaluated using the test-bed of field and synthetic data. This evaluation would serve not only to evaluate the AID algorithms, but also to establish the degree of correlation between the performance of the algorithms on the field data and on the synthetic data.
5. That, if the high correlation between the performance of AID algorithms on the synthetic data and field data is sufficiently strong, this test-bed be made available to researchers and practitioners to facilitate the evaluation of AID algorithms on a common test-bed platform.
6. That the manner in which speed variation is introduced within the INTEGRATION model be examined in more detail and that appropriate field data be obtained from which more appropriate microscopic relationships can developed.

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