

USING MICRO-SIMULATION TOOLS TO IMPROVE TRANSPORTATION DECISIONS

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ABSTRACT

Decision-makers are continually challenged to do more with less and to efficiently allocate scarce resources. Unfortunately, many of the tools used to assess the relative benefits of alternative strategies were developed over two decades ago, and they often do not provide the levels of precision required to perform accurate evaluations. In the past, this level of precision was not as important given that financial resources were more readily available to “build” our way out of the problem. In the future, it will be necessary to demonstrate that our solutions are operationally feasible while avoiding major infrastructure upgrades and their associated environmental /social impacts and costs.

Recent development of micro-simulation tools such as INTEGRATION have helped to add a new level of sophistication and precision to transportation decisions. These tools allow individual vehicle simulation in network conditions. They also allow the simulation and analysis of the interaction of sources/sinks with upstream and downstream signals. They permit much more sophisticated analysis than tools applied to individual intersections or traditional transportation planning and traffic network models. Further, tools such as INTEGRATION, allow the visual representation of conditions under time-varying traffic demands and alternative solutions that may range from operationally-based to structural improvements. Visual feedback from models is a very powerful feature in demonstrating the feasibility of solutions to decision-makers.

This paper illustrates the benefits of using such simulation tools in case studies in London and Toronto Ontario. In each of these cases, the decision-makers were faced with the selection of the best approach to address complex operational problems. The traditional analysis tools did not lend themselves to adequately determine the impacts of alternative solutions. By using INTEGRATION, and studying the operational issues in more detail, the feasibility of the proposed solution was demonstrated.

NEED FOR BETTER TOOLS

In the past, transportation decisions were made from a strictly supply-side perspective. Provincial, regional and municipal decisions were focussed on accommodating the fast-growing economy. Financing this growth was seen as important and resources were more readily available to “build” the infrastructure required. Given that Level-of-Service-based decisions were made for traffic conditions far removed from capacity, precision in estimating the ultimate feasibility of operating without a substantial capacity improvement was not as important.

Municipal resources allocated to improving the transportation system have reduced in recent years. Demands for improvements to the systems and use of the system are at the same time increasing. As a result, decision-makers are continually challenged to do more with less and to efficiently allocate scarce resources. This pattern has allowed congestion levels to reach unprecedented levels. Yet, decisions for growth must continue to be made to help ensure that the local economies are not stifled.

To achieve growth without improving these municipal and provincial systems at the same rate and not allowing congestion levels to reach unacceptable conditions requires increased efficiency. This requires more and more that decisions be made in near capacity situations. For example, should a development be granted access and allowed to proceed in a situation where the existing traffic conditions are quite onerous? If there is a potential solution, how is it evaluated adequately and fairly?

Unfortunately, many of the tools used to assess the relative benefits of alternative strategies were developed over two decades ago, and they do not provide the levels of precision required to perform accurate evaluations. These tools are often based on heuristics and practices that provide for greater margins of error. Now, all too frequently, decisions call for a further increment in the level of congestion. Traditional tools, which tend not to be particularly well-suited for applications to conditions near capacity, often indicate that the proposed project should not be allowed to proceed. However, this result is often more a function of the limitations of the decision-making tool, rather than the feasibility of the solution. To gain a greater appreciation of the feasibility of proposed alternatives, evaluation tools with greater precision are required.

TRADITIONAL TOOLS

Many different techniques have been developed and used to assist transportation engineers to evaluate alternatives. Most of these tools are now micro-computer based software. These software tools allow some degree of “what-if” testing. The downside of these processes is that they rely on macroscopic, top-down, aggregate functions to predict individual microscopic behaviour. In essence, they predict the average conditions and provide static results that require the analyst to review the results in printed form. Some of the more commonly used tools in this category include:

- ❑ Transportation Planning Models – EMME/2, System II, T-Model/2
- ❑ Canadian Capacity Guide - CCG/Calc2
- ❑ HCS/HCM Cinema
- ❑ PASSER
- ❑ CONTRAM
- ❑ Transyt 7F- Release 8

MICRO-SIMULATION TOOLS

Micro-simulation tools have been developed, in-part, to respond to the need for a greater level of precision in transportation planning and traffic engineering. Recently developed micro-simulation tools, such as INTEGRATION have helped to add a new level of sophistication and precision to transportation decisions. These tools allow individual vehicle simulation in combined highway and arterial networks. They also allow the simulation and analysis of the interaction of sources/sinks with upstream and downstream signals. They therefore provide much more sophisticated analysis than tools applied to individual intersections or traditional transportation planning and traffic network models. Further, tools such as INTEGRATION, allow the visual representation of conditions under time-varying traffic demands and alternative solutions that may range from operationally-based to structural improvements. The visual component of the model is a very powerful feature in demonstrating the feasibility of solutions to decision-makers.

Indeed, the response to the need for these types of tools has been quite large. There are very many products now readily available. The following section provides a cursory review of the content of the most common micro-simulation tools.

Review of Micro-simulation Models¹

The results tabulated in this section are taken from a research project conducted by the University of Leeds in which they reviewed 33 simulation models. Developers of micro-simulation tools were surveyed in 1996 and 1997. This research project was intended to document, in detail, the various supported functions, objects and phenomena modelled, indicators provided and other properties for each of the models.

This review was extremely comprehensive. Table 1 contains a listing of some of the more popular models evaluated in this review and the agency that has developed the model, along with the country of origin.

¹ Eric Bernauer, Laurent Breheret, Staffan Algers, Marco Boero, Carlo Di Taranto, Mark Dougherty, Ken Fox and Jean-François Gabard, Institute for Transport Studies, University of Leeds, 1997

TABLE 1: COMMON MICRO-SIMULATION MODELS AND FEATURES

			Functions																		Phenomena																
Model	Organization	Country	Co-ordinated traffic signals	Adaptive traffic signals	Priority to public transport vehicles	Ramp metering	Motorway flow control	Incident management	Zone access control	Variable message signs	Regional traffic information	Static route guidance	Dynamic route guidance	Parking guidance	Public transport information	Automatic debiting and toll plazas	Congestion pricing	Adaptive cruise control	Automated highway system	Autonomous vehicles	Support for pedestrians and cyclists	Probe vehicles	Vehicle detectors	Weather conditions	Search for a parking space	Parked vehicles	Elaborate engine model	Commercial vehicles	Bicycles / motorcycles	Pedestrians	Incidents	Public transports	Traffic calming measures	Queue spill back	Weaving	Roundabouts	
CORSIM	FHWA	USA	X	X	X	X	X	X																	X	X	X		X	X	X		X	X	X		
CONTRAM	TRRL/Systematica	UK	X	X	X	X					X															X		X			X		X		X		
FLEXSYT II	MOT	Netherlands	X	X	X	X	X	X	X							X						X	X				X	X	X	X	X	X	X	X	X	X	
FREEVU	Univ. of Waterloo	Canada																					X	X			X						X	X			
FRESIM	FHWA	USA					X	X	X															X				X			X	X		X	X		
INTEGRATION	Queen's Univ.	Canada	X	X	X	X	X	X		X	X	X	X		X	X	X						X	X				X			X	X	X	X	X	X	X
MITSIM	MIT	USA	X	X		X	X	X		X	X	X				X							X	X	X	X	X	X		X		X	X	X	X	X	X
MIXIC	TNO	Netherlands					X											X	X	X				X		X						X		X			
SIGSIM	Univ. of Newcastle	UK	X	X	X	X	X	X							X			X		X			X	X		X		X	X		X	X		X	X		
THOREAU	MITRE	USA	X	X		X				X	X	X											X	X	X	X			X	X		X	X	X	X	X	X
TRAF-NETSIM	FHWA	USA	X	X	X		X																X		X	X	X		X	X	X		X	X			
VISSIM	PTV/GMBH	Germany	X	X	X	X	X								X								X	X	X		X	X	X		X	X	X	X	X	X	X

The entries in Table 1 indicate that this research and product development is a world-wide activity. Of particular interest to Canadians, is the development of two products, FREEVU, at the University of Waterloo, and INTEGRATION, developed at Queen's University. Bernauer et al. also surveyed 23 other model developers who came from France, Spain, Germany, Australia and Finland.

Table 1 describes the functions supported by each model. The measures used range from demand side effects, such as congestion pricing and support for pedestrians and bicycles, to detailed traffic measures like vehicle detectors, probe vehicles, and adaptive traffic signals. INTEGRATION provides for many of the measures studied, including co-ordinated traffic signals, adaptive traffic signals, priority to public transport vehicles, ramp metering, motorway flow control, static and dynamic route guidance, public transport information, automatic debiting and toll plazas, congestion pricing, probe vehicles and vehicle detectors.

Table 1 illustrates that INTEGRATION compares well to other models providing for commercial vehicles, pedestrians, incidents, public transport, traffic calming, queue spill back, weaving and roundabouts.

INTEGRATION also is capable of providing a number of generalized and vehicle-specific performance measures including travel time, delay, travel speed, vehicle emissions and fuel consumption.

INTEGRATION

The INTEGRATION model was conceived in the mid-1980's. INTEGRATION is a commercial product that continues to incorporate enhancements, which improve it and respond to demands from the engineering community. Among the most recent enhancements are fully Windows '95 compatible platform and an improved Graphical User Interface (GUI).

The INTEGRATION model² is a microscopic routing-oriented simulation model of integrated freeway and surface street networks. Individual vehicle movements are traced through the network as they interact with traffic control devices, such as traffic signals, and with other vehicles.

The software permits the modelling of probe vehicles, which report key characteristics of their current travel experience, including trip start time, origin, destination, unique vehicle identification number, current location, time to traverse the previous link, and time of probe report.

The primary objective of the software is to provide a single model that can represent many isolated functions used in other traffic simulation and assignment models. To achieve this objective, INTEGRATION makes use of the same logic to represent both freeway and signalized links.

Useful technical features

INTEGRATION is computationally able to handle very large networks. The model can process up to 10,000 nodes and 10,000 links with up to 150,000 vehicles on the system at any one time. This is comparable to many regional transportation planning models.

The model incorporates several features including:

- ❑ Individual Vehicle Simulation
- ❑ Freeway and arterial street networks
- ❑ Car following and lane change logic
- ❑ Signalized and unsignalized intersections
- ❑ Real time graphics animation
- ❑ Measures-of-Effectiveness such as travel time, delay, stops, fuel consumption and emissions.

The model allows the user to vary control parameters associated with traffic control, route guidance, traffic assignment, impacts of variable message signs, etc. Typically, models are validated and calibrated against

² M. Van Aerde, "INTEGRATION RELEASE 2: User's Guide-Volumes I and II", M. Van Aerde and Associates, Ltd. and the Transportation Systems Research Group, Queen's University, Kingston, Canada, December, 1995.

field data.

As illustrated in Figure 1, INTEGRATION provides on-screen animation while simulating. The Graphical User Interface continuously reflects the current network status. Various parameters can be visualised by clicking on objects and zooming capabilities assist in helping users to view the operations of various parts of the network under study.

Data management is achieved through text input and output files. Output statistics on network conditions, and individual vehicles are very extensive.

Limitations on the model are primarily that the individual driver characteristics cannot be altered and that it does not reflect the impact of external influences.

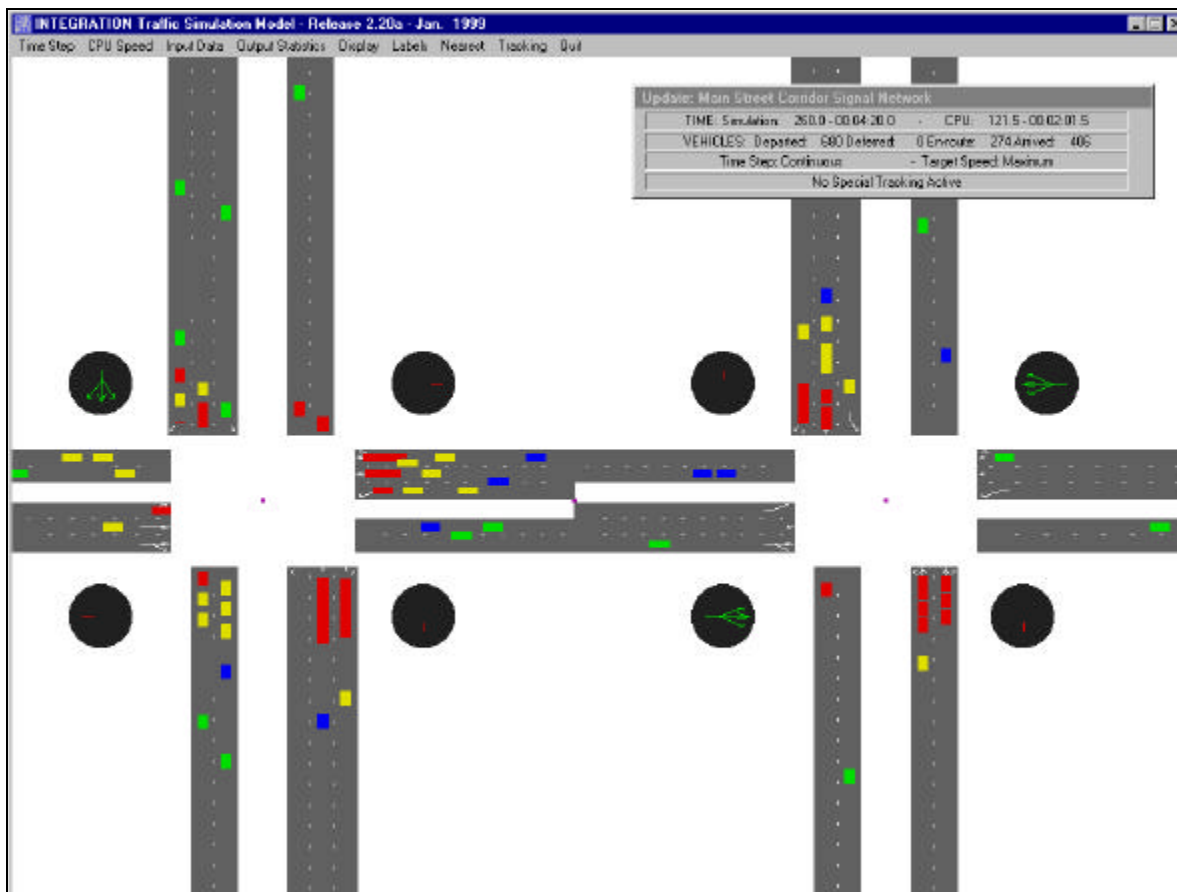


FIGURE 1: EXAMPLE OF ON-SCREEN ANIMATION PROVIDED BY INTEGRATION

CASE STUDY 1: BOLER ROAD (LONDON ONTARIO)

Context

The Proposed Riverbend Community is located in the western part of London Ontario adjacent to the Byron area. (Figure 2) The development is proposed to contain over 16,000 residents. The Transportation Master Plan calls for the extension of Oxford Street to service the development to the ultimate level (Figure 3). Construction of this facility was planned for 5-7 years into the future but, as annual budgets are revised from year to year, actual construction could be much further away. Therefore, it was considered important to maintain the flexibility to proceed with some portion of the Riverbend Community development prior to the implementation of the Oxford Street extension.

The Boler Road bridge currently carries over 20,000 vehicles per day on its two-lane cross-section. The intersection to the south (Commissioners Road/Boler Road) was considered to be operating at capacity during the AM and PM peak hours. For any development to proceed prior to the extension of Oxford Street, operational improvements to this intersection were required.

Problem Statement

As illustrated in Figure 3, the roadway network in the immediate vicinity of the Boler Road bridge contains two existing signals. One is located at the Boler Road and Commissioner's Road intersection, and one at the Boler Road and Riverside Drive intersection. Hall's Mills Road currently functions as one-way southbound.

The following operational issues exist:

- ❑ Operational reviews found that the existing intersection at Boler Road and Commissioners Road was approaching capacity. The main operational problem was caused by a peak hour demand of in excess of 400 eastbound left-turns on a single lane approach during the AM peak period.
- ❑ Queue spillback from the eastbound approach to Boler Road on Commissioners Road was observed to be quite extensive and frequently blocked Hall's Mills during the AM peak period.

It had been determined that the following improvements to the Boler Road and Commissioners Road intersection were required before the initial phase of the Riverbend Community could be developed:

- ❑ Address the existing operational constraints.
- ❑ Accommodate future external traffic growth.
- ❑ Accommodate traffic from the initial phase of the proposed Riverbend Development (500 new residential units).

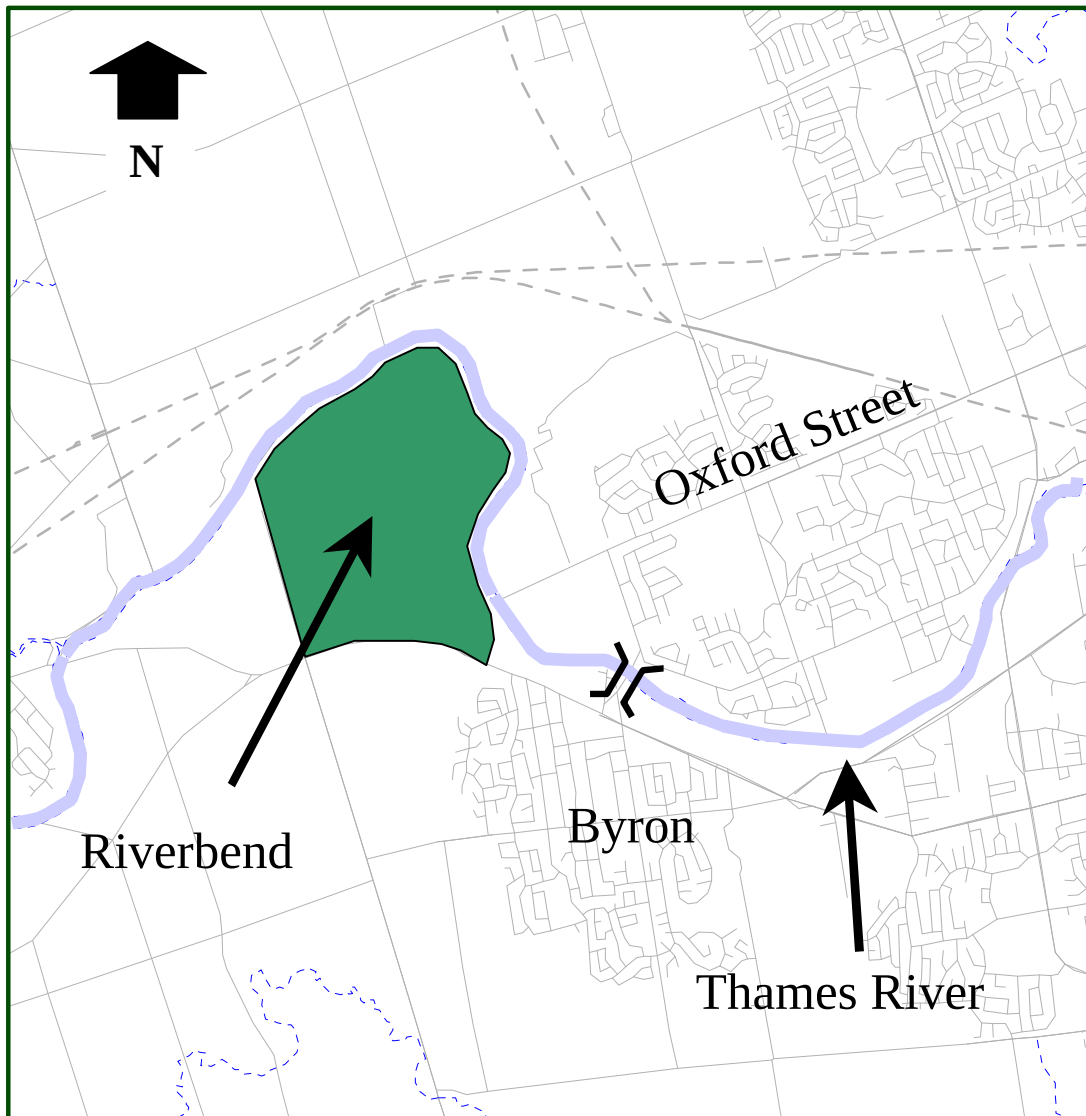


FIGURE 2: RIVERBEND DEVELOPMENT

Possible Interim Solution

Initial investigations using conventional traffic operational tools indicated that the existing operational problems at the intersection could be eliminated with the conversion of Hall's Mills Road to two way operation and the signalization of both ends of this link on Boler Road and Commissioners Road. This solution would double the capacity of the eastbound left turn movement (from eastbound Commissioners Road to northbound Boler Road) thereby accommodating even further growth in traffic from development in Riverbend and external areas west of the City.

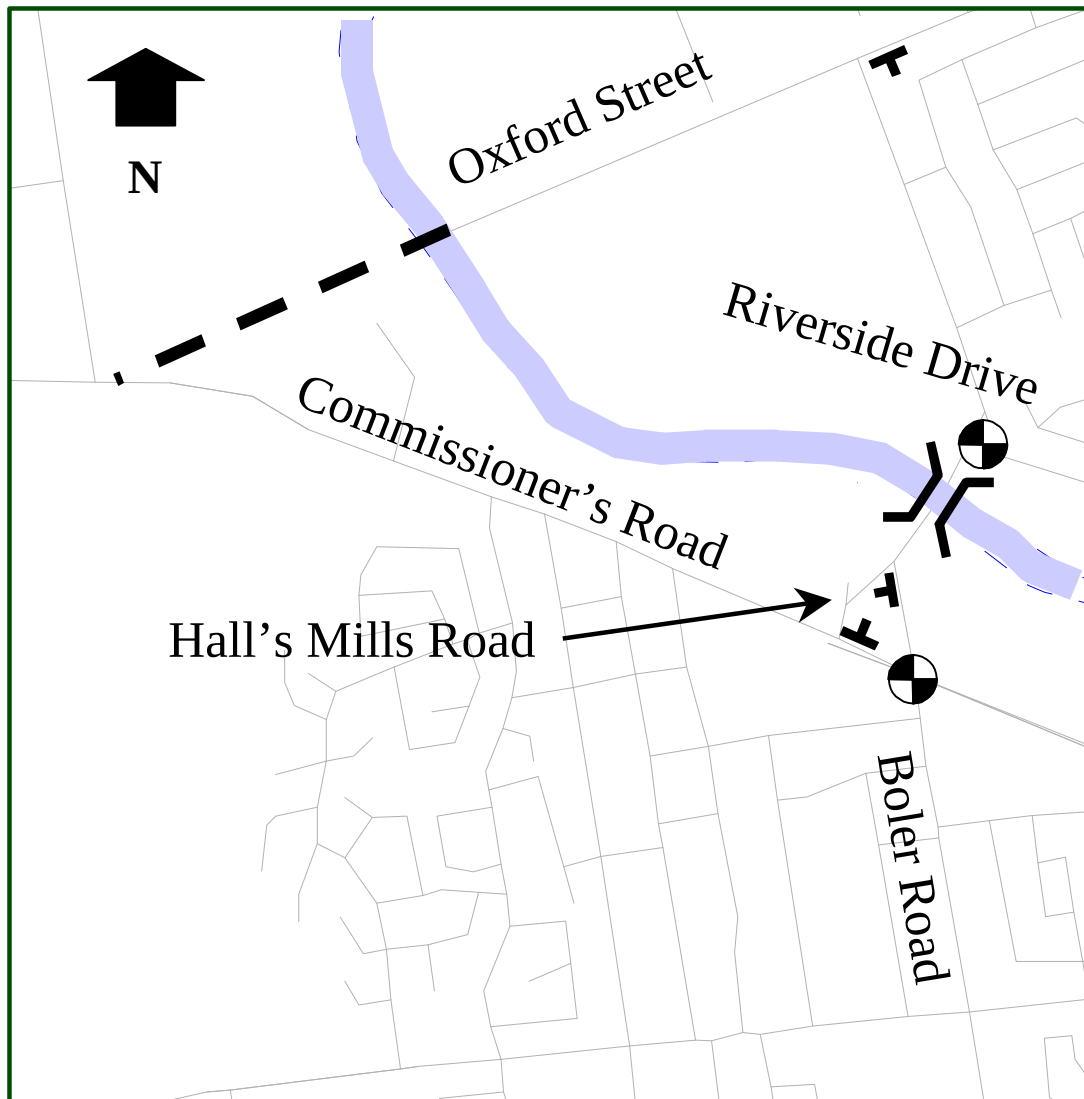
However, City officials were concerned that the proposed solution would push the bridge beyond its capacity and the closely spaced signals would cause grid-lock to occur. Conventional traffic engineering tools, were unable to consider the dynamic interaction of the various intersections, and required manual mathematical calculations to describe peak queuing conditions. They were therefore unable to address these concerns and clearly demonstrate feasibility to decision-makers and the public.

Simulation Testing

Accordingly, the INTEGRATION model was used to simulate the AM and PM peak hour conditions under both existing and future conditions with and without the improvement in place. The simulation results for these conditions are shown in Tables 2 and 3 below.

TABLE 2: AM PEAK HOUR SIMULATION

Measure of Effectiveness	Existing Demand on Existing Network	2006 Background Demand on Existing Network	2006 Background + 500 Unit Demand on Proposed Network
Average Travel Time (sec)	119.04	218.52	111.00
Average Travel Distance (km)	0.70	0.69	0.66
Average Travel Speed	21.17	11.37	21.41
Average Number of Stops	1.38	1.42	1.52
Fuel Consumption (litres)	0.18	0.20	0.18
Hydrocarbon emissions (grams)	4.56	4.18	4.38
Carbon Monoxide emissions (grams)	30.16	24.90	29.85
Nitrous Oxide emissions (grams)	1.31	1.12	1.32



⬤ Traffic Signal

⊥ Stop Sign

FIGURE 3: ROADWAY NETWORK

TABLE 3: PM PEAK HOUR SIMULATION

Measure of Effectiveness	Existing Demand on Existing Network	2006 Background Demand on Existing Network	2006 Background + 500 Unit Demand on Proposed Network
Average Travel Time (sec)	144.17	236.74	140.37
Average Travel Distance (km)	0.67	0.67	0.65
Average Travel Speed	16.73	10.17	16.57
Average Number of Stops	1.61	1.78	1.83
Fuel Consumption (litres)	0.20	0.25	0.20
Hydrocarbon emissions (grams)	4.96	5.70	5.25
Carbon Monoxide emissions (grams)	30.65	30.18	32.23
Nitrous Oxide emissions (grams)	1.28	1.12	1.25

The first step was to simulate the existing network operation in order to determine that the model was capable of adequately reflecting current operational problems at the intersection and along the adjacent road network. It was determined by all concerned that the existing conditions were adequately reflected by the model. The visual capabilities of the model made the communication of these results much easier.

The next step was to simulate future conditions assuming no development in Riverbend but continued growth in background traffic generated by areas west of the City. Tables 2 and 3 show how the measures-of-effectiveness deteriorate indicating that the need for an interim solution would occur whether the initial phase of the Riverbend development was to proceed or not.

In order to predict the operations under future traffic demands, the final step was to simulate the operational changes including the additional traffic demands generated by background traffic growth and the addition of 500 residential units in the initial phase of the Riverbend development. Tables 2 and 3 show that the additional traffic combined with the operational improvement would ensure that conditions would be similar to that which occur today. The results indicated that the existing network would operate more efficiently accommodating higher traffic demands with very modest capital improvements and permit some initial development to occur.

Other less sophisticated models such as TRANSYT 7F could provide similar MOE comparisons. However, the dynamic nature of the INTEGRATION model enabled the results to be shown visually as well and assisted greatly in communicating the results. The model indicated the maximum extent of queuing that would occur and demonstrated the operational feasibility of the proposed solution.

CONCLUSION

The above example demonstrated that the model was capable of replicating existing operational conditions and proving the operational feasibility of a solution that would push the limits of the road network and the bridge to their ultimate capacities. The visual aspect of the model was instrumental in communicating the results to decision-makers and the public in subsequent meetings.

As a result, an interim solution is available should development proceed prior to construction of the ultimate road network improvement which involves the Oxford Street extension.

CASE STUDY 2: AUTOMATED INCIDENT DETECTION ON HIGHWAY 401 IN TORONTO, ONTARIO

Similar to the first case study presented, the second case study illustrates the benefit of using a traffic simulation model to develop and test prototype traffic management strategies prior to implementing or evaluating these strategies in the field. In this case study, the objective is to enhance existing incident detection capabilities. Currently, most jurisdictions perform incident detection using one or more of the following three methods:

- ❑ Rely on commuters, emergency services, and/or media, to inform the traffic management centre (TMC) of an incident,
- ❑ Obtain complete visual coverage of the roadway, typically via closed circuit television, and rely on operators in the TMC to scan the camera views and identify incidents, or
- ❑ Rely on an automatic incident detection (AID) algorithm to process induction loop detector data and alert the operator when an incident is detected.

Most AID algorithms currently in use, such as the McMaster algorithm³, the California Algorithms⁴, and the Minnesota algorithm⁵, rely solely on spot traffic data, such as spot speed, volume, and/or occupancy, that can be obtained from in-road induction loop detectors. However, the recent introduction of electronic toll collection systems and automatic vehicle identification (AVI) systems that use dedicated short range communication between a transponder in the vehicle, and an antenna mounted over the roadway, permit the acquisition of individual vehicle travel times. The ability to obtain individual vehicle travel times in real-time provides an opportunity to develop a new family of AID algorithms that rely on travel time data rather than loop detector data to detect incidents. However, it is not possible to know what the performance

³ Hall F.L., Shi Y. and Atala G., 1993, "On-line Testing of the McMaster Incident Detection Algorithm Under Recurrent Congestion," *Transportation Research Record 1394*, pp. 1-7.

⁴ J. Arceneaux, J. Smith, A. Dunnett, and H. Payne, 1989, "Calibration of Incident Detection Algorithms for Operational Use," *Proceedings of 'Engineering Foundation Conference'*, Santa Barbara, California.

⁵ Stephanedes Y.J. and Chassiakos, 1993, "Application of Filtering Techniques for Incident Detection," *Journal of Transportation Engineering*, Vol. 119, No. 1, January/February, pp. 13-26.

characteristics of these new AID algorithms will be, without first developing prototype algorithms and testing them.

Field travel time data were not available at the time of this study. However, in order to perform an initial examination of the potential of AID via travel time data, travel time data were generated through the use of the INTEGRATION traffic simulation model.

In this study, two candidate AID algorithms were evaluated. The first, called *historical*, relies on historical travel time data (say from the previous day, or previous week). Current vehicle travel times are compared to statistical confidence limits, developed on the basis of the historical data. If the current travel time exceed the limits, an incident is declared. The second algorithm, called *Adaptive*, compares current travel times to confidence limits that are developed on the basis of the preceding 15 minutes of reported travel times. No data from previous days are used for this algorithm.

Description of study network

The study area is composed of eight interchanges along a 12-km freeway section on Highway 401 in Toronto, Canada. This facility experiences an average daily traffic flow of approximately 340,000 vehicles, making it one of the most heavily travelled freeways in North America. The section utilized in this study extends from Bathurst Street in the east to Dixon Road in the west, as illustrated in Figure 4. This 12-km freeway section includes an express facility and a parallel collector facility, each of which typically consists of three or more lanes in each direction. The express and collector facilities are connected at some locations by transfer lanes.

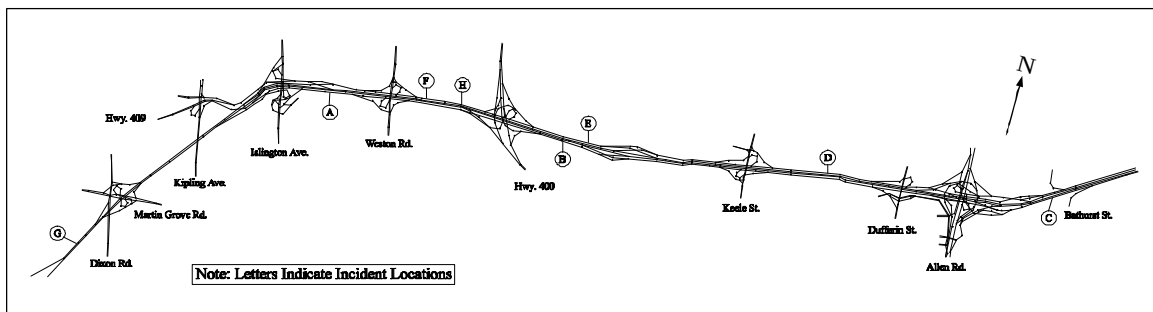


FIGURE 4: STUDY NETWORK

This roadway section was selected for this study for several reasons. First, the section experiences severe recurring congestion at several locations during both the AM and PM peaks, permitting the testing of AID during both uncongested and congested conditions. Second, the network had already been used in a previous study in which the model had been calibrated against field data.

The coded network is composed of 478 nodes, 30 origin-destination zones, and 597 links. The O-D demand had been constructed to replicate the build up of the AM peak from 5:00 AM to 11:00 AM. A total of 200,139 vehicle trips were simulated during this 6-hour time period.

It was assumed that AVI antenna were located at all on and off-ramps, (i.e. at the location of the origin and destination zones), such that travel time data from all trips could be considered. It was assumed that no mainline readers existed. This configuration of readers was deliberately chosen, as it most closely represents the configuration typically used for electronic toll roadways, such as Highway 407 in Toronto, where the tag readers are placed at all access and egress points, in order to facilitate billing. It is expected that the location and spacing of the AVI antennae will have a significant impact on AID performance.

Two separate scenarios were simulated. The first represented the base case, in which no incidents were modelled. This scenario was used to represent historical conditions. The second scenario used the same network and O-D demand characteristics, but included the modelling of 8 incidents. As illustrated in Table 4, these incidents occurred at different locations on the network, at different times, and had different durations and severities. The location of these incidents is also illustrated in Figure 3.

TABLE 4: INCIDENT DESCRIPTIONS

Incident	Time (AM hr)		Lanes Blocked	Total Lanes	Location ¹
	Start	Stop			
A	5:30	5:50	2	4	EBC
B	7:30	7:50	1	5	EBC
C	5:45	5:46	2	3	EBE
D	5:45	6:05	1	3	WBE
E	6:00	6:01	1	4	WBC
F	8:15	8:16	1	3	WBE
G	8:30	8:50	2	5	WBS
H	8:00	8:01	2	4	WBC

¹ EBC = Eastbound Collector; EBE = Eastbound Express
WBC = Westbound Collector; WBE = Westbound Express
WBS = Westbound Single

Results

Table 5 provides the aggregate performance characteristics of the historical and adaptive AID methods. There are three primary measures used to characterise the performance of AID algorithms, namely detection rate (DR), false alarm rate (FAR), and mean time to detect. In this study, only the DR and FAR are used to compare performance. Table 5 also provides performance measures for the McMaster AID algorithm, a leading conventional AID algorithm that is based on spot loop detector measures. These results were obtained by coding the McMaster algorithm on the basis of descriptions of the algorithm provided in the literature, and applying this algorithm to the detector data obtained from the simulation model. It must be noted that this coded version of the McMaster algorithm may differ from the commercial version of the

algorithm. A detailed description of the application of this algorithm to this network is available elsewhere⁶.

The results in Table 5 indicate that the detection rates for the travel time based algorithms are considerably higher than the detection rate of the McMaster algorithm. However, the off-line FARs for the travel time based AID algorithms are more than two orders of magnitude higher than the off-line FAR for the McMaster algorithm. The on-line FARs are similar for all three AID algorithms.

TABLE 5: AGGREGATE COMPARISON OF AID ALGORITHM PERFORMANCE CHARACTERISTICS

Parameter		Travel Time Based		Loop Detector Based
		Historical	Adaptive	McMaster ¹
Number of incidents	A	8	8	75
Incidents detected	B	6	5	28
Detection rate ($B/A \times 100\%$)	C	75%	62.5%	37.3%
Correct alarms	D	1,174	484	28
False alarms	E	25,686	4,068	473
Number of tests	F	197,040	197,055	2,235,600 ²
Off-line FAR ($E/F \times 100\%$)	G	13.0%	2.1%	0.0212%
On-line FAR ($E/(D+E) \times 100\%$)	H	95.6%	89.4%	94.4%

¹ Data obtained from reference 3

² $10 \text{ runs} \times 6 \text{ hours/run} \times 60 \text{ minutes/hour} \times 3 \text{ tests/minute} \times 207 \text{ detectors} = 2,235,600$

Evaluation of Use of Simulation:

This study required that an extensive set of data be available on which to test travel time based AID algorithms. Since field data were not available, an alternate source of these data was required. The use of a traffic simulation model enabled the data to be generated. In addition to providing a mechanism for generating the data, the use of a simulation model also provided the benefit of complete control over many of the important study parameters, such as the number, location, duration, and severity of incidents and the location of AVI antennae. The use of the simulation data provides an opportunity to conduct preliminary evaluations of candidate AVI algorithms, within a controlled environment. It would be expected that the results of these evaluations would lead to modifications and enhancements to the candidate algorithms, and that final performance characteristics would be evaluated using field data.

⁶ H. Rakha, B. Hellinga, and M. Van Aerde, 1996 "Testbed for Evaluating Automatic Incident Detection Algorithms", Final Report submitted to the Advanced Traffic Management Section of the Ontario Ministry of Transportation

MORE EXPERIENCE

INTEGRATION has been applied internationally to model many freeway systems, including;

- ❑ I-4, Orlando, Florida, USA
- ❑ Sun Yat-Sen National Freeway, Taiwan
- ❑ A10 Ring Road, Amsterdam, Netherlands
- ❑ Santa Monica Freeway, Santa-Monica California, USA
- ❑ I-696, Detroit, Michigan, USA
- ❑ Highway 401, Toronto, Ontario, Canada

INTEGRATION has also recently begun to be used in more Canadian urban applications. Municipal agencies in British Columbia and Ontario have used the tool to help evaluate unique solutions to difficult operational problems.

POTENTIAL USES

The above examples represent some possible uses for the software in aiding decision-makers. Other potential uses include:

- ❑ Signal system co-ordination design
- ❑ Sub-area assignment model
- ❑ Operational assessment of access and driveway locations
- ❑ Conversion of one-way systems to two-way operation
- ❑ Future impact of not implementing required road improvements

IMPLICATIONS AND DIRECTION

In the future, it will be necessary to demonstrate that our solutions are operationally feasible while avoiding major infrastructure upgrades and their associated environmental /social impacts and cost. Models such as INTEGRATION can help develop solutions that will enable us to maximize the efficiency of our road networks and thereby minimize congestion or the need for high cost and environmentally insensitive solutions. As demonstrated by the first case study, simulation models can also assist in communicating the results to decision-makers and the public - something that is not done very well by most traditional models.

The second case study illustrates how the model can be used to assist in determining the benefits of advanced traffic management control, in this case improved incident detection methodologies. The tool can be instrumental in the initial evaluation of prototype algorithms and systems.

Greater use and enhancement of these more sophisticated models will be necessary as the transportation profession faces the challenge to do more with less and develop more sensitive solutions to transportation issues.