Assessing Future Network Requirements using Micro-Simulation Modelling

By
Timothy Oketch, P. Eng. and James Garland, P. Eng.,

This paper reviews network modelling of the southern area of the City of Oshawa using the Paramics micro-simulation model. The objective of the study was to identify future network improvements at the operational level for the area in response to continued traffic growth and strategic changes in the roadway network. The Study involved building a mid-sized network covering an area approximately 4 km long and 2 km wide with mainly arterial and collector roads and over 40 signalized intersections. The model was calibrated to existing conditions by estimating suitable origin-destination matrices and comparing observed and modelled traffic volumes at screen-line, link and intersection levels.

Future traffic demands were assessed for the 2012 and 2021 horizon years based on the projected land use and employment data using the Region of Durham's EMME/2 Demand forecasting model. Planned residential, commercial and institutional developments within the downtown area were specifically assessed and included in the analysis. The resultant traffic demands were then adjusted to correct for differences in zonal arrangements in the demand forecasting and the Paramics models. Final demands were then applied to the existing network to identify future bottlenecks and problem areas, and to formulate potential solutions.

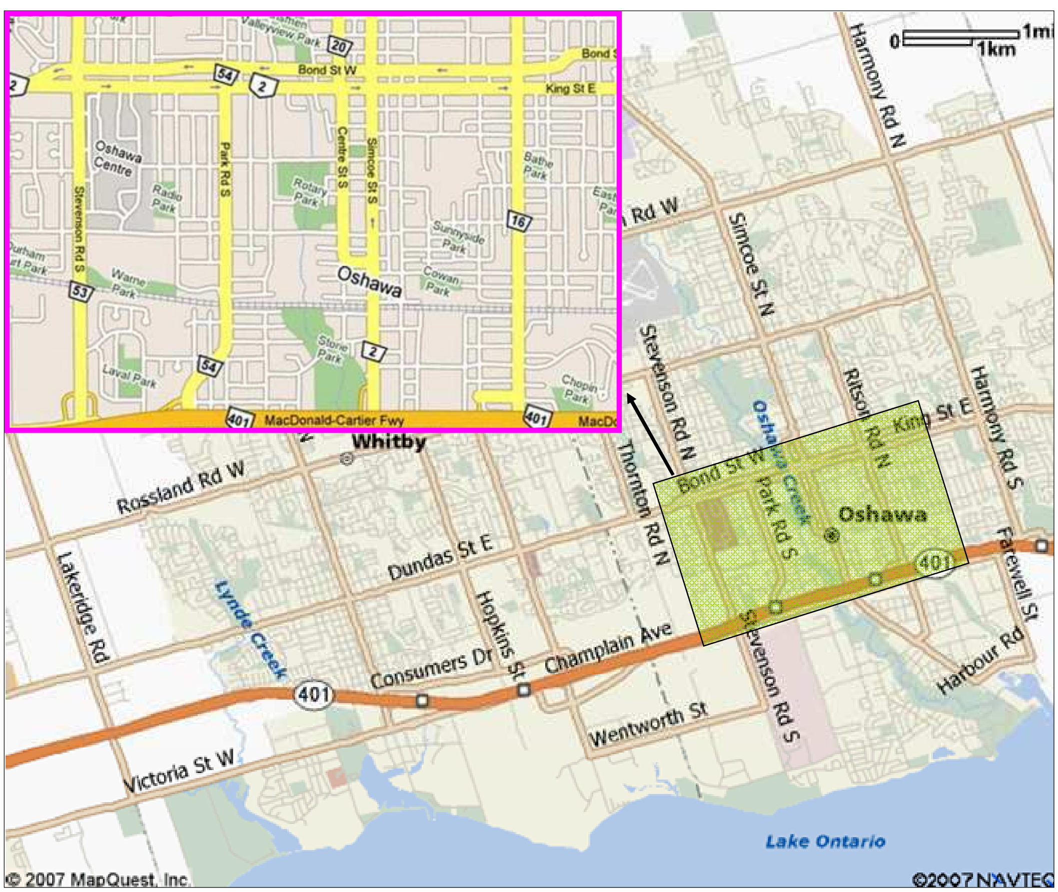
The analysis made it possible to identify suitable network improvements that included a combination of roadway widening, intersection improvements and construction of two new links in the downtown area. Based on the results of the modelling, the Region of Durham and the City of Oshawa are now undertaking Class Environmental Assessment Studies to widen and connect Gibb Street to Olive Avenue and to provide a new link between John Street and Eulalie Avenue. The paper underscores the advantages of using micro-simulation in identifying problems and formulating solutions at a network level.

1. INTRODUCTION

This Study was undertaken to examine the required network improvements to support future traffic demands in the southern section of the City of Oshawa. Traffic volumes in the southern section of the City of Oshawa have continued to grow as the population and economic activities increase. This growth is characterized by emerging traffic congestion and higher collision experience on the arterial roads as well as collector and local streets that are owned by the Region of Durham and the City of Oshawa respectively. Unless improvements are made, these problems are expected to get worse in the future.

The Region of Durham and the City of Oshawa have undertaken various studies in the past that have identified a future capacity deficiency in the east-west direction in the area and included improvements to the road network at the planning level. However, with continued growth and developments in the downtown area over the years and coupled with strategic network changes in the surrounding area, there was need to reconfirm the capacity deficiency and to identify suitable network improvements that would support future traffic demands in the area both from a planning and an operational level. The Study Area shown in **Figure 1** below is approximately 4 km long and 2 km wide and extends from Stevenson Road in the west to Wilson Road in the east and from just north of Highway 401 in the south to Bond Street in the north.

Figure 1: Map of City of Oshawa showing the Study Area

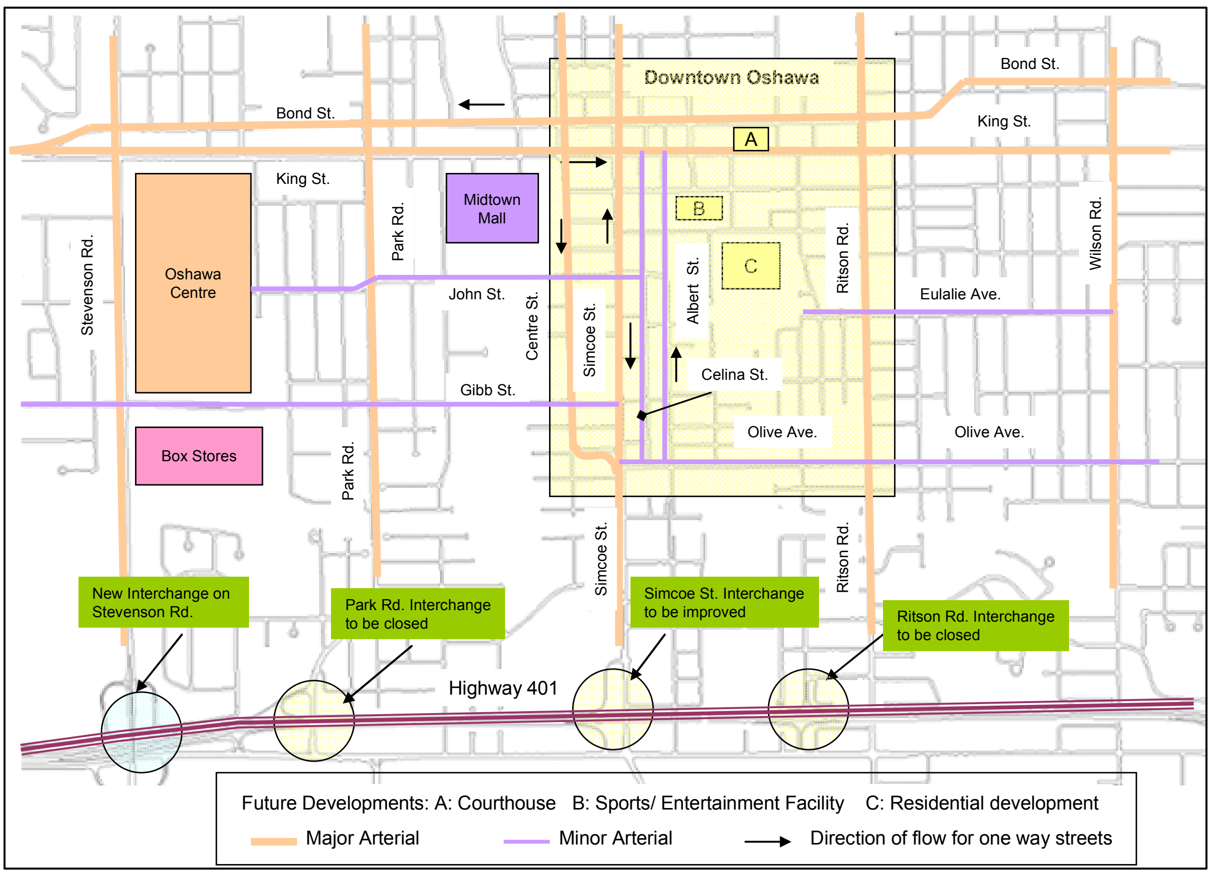


2. STUDY APPROACH

2.1 Background

The objective of this Study was to examine the network improvements that are required to address existing operational problems in the south-east downtown Oshawa and to accommodate future traffic demands in the general Study Area. As can be seen in **Figure 2** below, there is a discontinuity between Gibb Street and Olive Avenue, and the east-west traffic along the two streets has to merge with the north-south traffic in order to proceed from one road to the other. This has led to operational problems characterized with long queues and delays at a number of intersections in the area. Moreover, the problem is exacerbated by the discontinuity between John Street and Eulalie Avenue. With planned developments in the downtown area, there is need to provide better connection for east west traffic and to provide extra capacity.

Figure 2: Road Network and Major Developments in Study Area



As shown in **Figure 2**, a number of major traffic generators are present in the study area and include the Oshawa Center and the Midtown Mall located to the west of the downtown area. In addition, new developments are planned in the downtown area and include a major residential development, a Sports and Entertainment Facility that is currently under construction and a new Court House. From the south, traffic from Highway 401 follow the arterial roads to the downtown area. Future improvements to Highway 401 including widening from 6 to 10 lanes and the planned changes to interchanges will result in higher traffic volumes to the Study Area. These developments are expected to generate additional traffic in the area and put extra pressure on the existing roadways especially in the east-west direction.

The road network in the Study Area is composed of a grid of north-south and east-west streets that include major and minor arterials as well as collector and local roads. Some of those streets have one way operations and parking is permitted along various sections thereby reducing available capacity. The major arterial roads including Bond Street, King Street, Stevenson Road, Park Road, Centre Street, Ritson Road and Wilson Road have a posted speed limit of 50 km/h with the remaining roads generally posted at 40 to 50km/h. As shown in **Table 1**, typical traffic volumes range from 1,500 to 3,600 vehicles per hour (vph) for the four lane roads and from 400 to 1,700 vph for the two lane ones during the peak hours. The PM peak hour has higher traffic volumes.

Table 1: Study Area Roadway Characteristics

Road	Operation	Peak Hour Volume*		Lanes /Direction
		AM	PM	
Bond Street	One way WB, parking	2,600	3,000	4 lanes WB
King Street	One way EB, parking	2,600	3,600	4 lanes EB
Centre Street	One Way SB	1,800	2,400	3 lanes SB
Simcoe Street	One Way NB, parking	2,400	2,400	4 lanes NB
Stevenson Road	Two way	1,500	2,700	2 lanes NB/2 lanes SB
Park Road	Two way	1,700	2,200	2 lanes NB/2 lanes SB
Ritson Road	Two way	1,500	2,300	2 lanes NB/2 lanes SB
Wilson Road	Two Way	1,300	1,700	1 lane EB/ 1 lane WB
John Street	Two way	500	700	1 lane EB/ 1 lane WB
Gibb Street	Two way	800	1,600	1 lane EB/ 1 lane WB
Olive Avenue	Two way	900	1,000	1 lane EB/1 lane WB
Eulalie Avenue	Two way	100	200	1 lane EB/1 lane WB
Celina Street	One Way SB, parking	400	500	2 lane SB
Albert Street	One Way NB, parking	400	500	2 lane NB

*Highest total volumes observed along each roadway within the Study Area. Directional split ranged from 0.5 to 0.7 for two way streets

2.2 Study Methodology

In order to assess future network improvements at an operational level, it was necessary to use micro-simulation modelling. The Paramics micro-simulation model was used in this Study. The Paramics model is a state of the art micro-simulation model with advanced traffic flow algorithms that facilitate analysis of complex transportation systems. It was applied in this Study mainly because of its capability to analyze the entire road network as one unit and to assess route choice changes following network modifications.

The Study involved building a model covering the arterial roads and other roadways considered important for the study objectives. Details of the model are discussed in **Section 3**.

Future traffic demands were assessed for the 2012 and 2021 horizon years based on the projected land use and employment data using the Region of Durham's EMME/2 Demand forecasting model. Planned residential, commercial and institutional developments within the downtown area were specifically assessed and included in the analysis. The resultant traffic demands were then adjusted to correct for differences in zonal arrangements in the demand forecasting and the Paramics models. Final demands were then applied to the existing network to identify future bottlenecks and problem areas, and to formulate potential solutions.

2.3 Traffic Data

Data for the study included turning movement counts (TMCs) at signalized intersections, traffic signal timings, Automatic Traffic Recorder (ATR) counts, as well the information from previous studies completed in the Study area. Most of the TMCs were undertaken in 2005. A field survey was also undertaken to confirm roadway characteristics including posted speeds, lane configurations and turning lane details and channelization at intersections and location of on-street parking. Signal timing information was obtained from the Region. Additional traffic count information was obtained from the City of Oshawa.

2.4 Future Traffic Demands

In order to forecast future travel demands for the Study Area, a two step approach was used. A strategic forecasting model, developed and maintained by the Region of Durham, was used to derive Region wide volume forecasts for the p.m. peak hour in consideration of the regional transportation network, including major roadways in the downtown Oshawa and in consideration of planned Region wide infrastructure improvements. The p.m. peak hour was selected because it represents the highest traffic loading in the network.

The results of the strategic level forecasting were then used as input to a sub-area operational model created the Paramics environment. The sub-area model focused on the more detailed road network in the Study Area and provided the ability to review and analyze operational characteristics of the area.

As stated previously, the Regional Strategic (EMME/2) model was used to derive system wide volume forecasts in consideration of horizon year travel demands and transportation infrastructure. The strategic model contains coded road and transit network infrastructure for both existing facilities and planned long-range improvements and is based on the Regional traffic zone system (approximately 500 zones in Durham), and includes network and zones west of Durham Region.

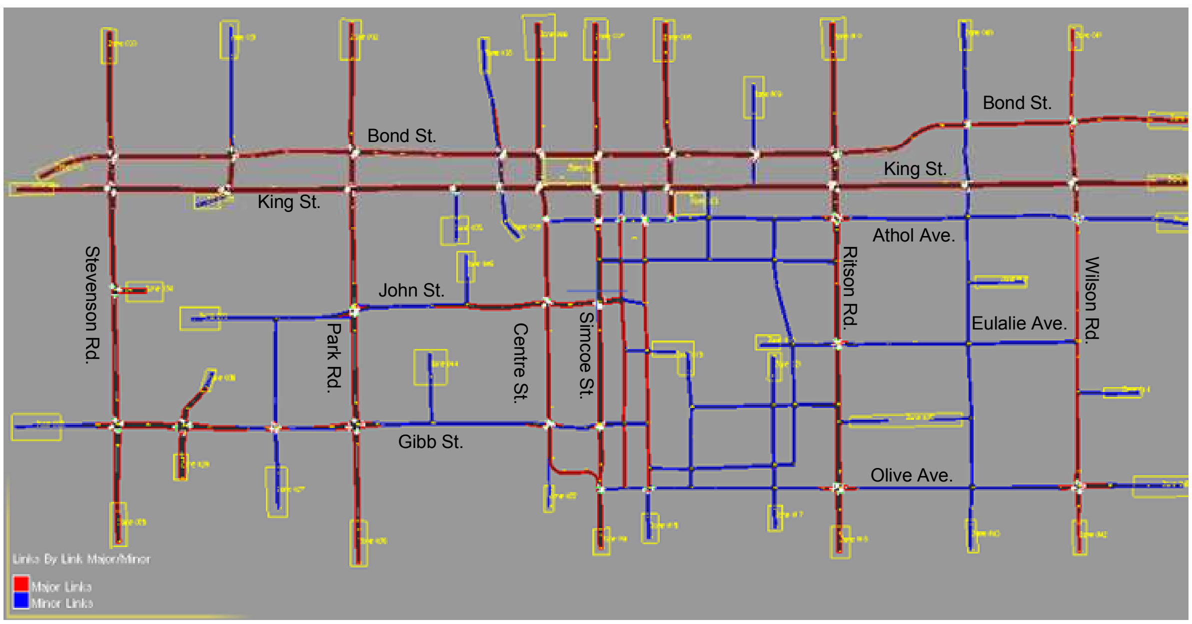
Forecasts from the EMME/2 model were used to derive screenline forecasts (by road link crossing the screenline) for existing, future planned and future alternative networks. Assessment of trips for the specific developments planned in the downtown area was done separately and included in the model.

3. MODEL DEVELOPMENT AND CALIBRATION

3.1 Model Description

The road network within the Study Area was modelled as shown in **Figure 3** to reflect the existing traffic conditions during the morning (AM) and afternoon (PM) peak periods. The model included most of the streets within the Study Area as listed in **Table 1** but left out a number on minor streets that were not considered significant to the analysis. Inputs to the model include traffic data, road geometry and traffic signal timings at intersections. Traffic volume information is specified in a matrix format consisting of traffic demand between an origin and destination point. Calibration is then undertaken to ensure that the specified traffic demands result in traffic volumes that match observed volumes both at the mid-block and at intersection locations.

Figure 3: The Modelled Road Network



The network was modeled with close to 700 links and 300 nodes representing road sections and intersections or points where there were geometric changes in the roadways. There were 42 signalized intersections included in the model. A total of 45 zones and gateways were used to represent traffic origin and destination points with total traffic demands of approximately 20,000 vehicles during the PM peak hour. At any point in the simulation there were between 2,000 and 3,000 vehicles in the network.

3.2 Model Calibration and Validation

The calibration effort was iterative and involved selecting suitable model parameters and assignment methods that provided the best match between modelled and observed traffic volumes. Previous studies have shown that a sub-area model of this nature is adequately calibrated when the modelled and observed traffic volumes match to acceptable tolerances.

The estimation process involved defining an initial matrix and changing it iteratively until the modelled network flows matched the observed data to specified tolerances. The existing AM and PM trip matrices were estimated on that basis and used in the simulation.

The Paramics model supports various assignment techniques including all or nothing assignment, stochastic assignment and dynamic assignment techniques. The assignment is done on the basis of an overall travel impedance expressed as a cost function consisting of distance, travel time and out of pocket costs. For this Study, a stochastic assignment with perturbation in route costs was applied. In other words route selection varies to reflect a range of driver preferences.

Comparison of modelled and observed traffic volumes was undertaken for various road sections and intersections within the Study Area. Comparisons were undertaken at the screen line, link and intersection levels. At the intersection level both total intersection volumes and individual turning movements were compared. In total, 27 comparisons were undertaken at the screen line level, 200 at the link level, 42 for total intersection volumes and 326 for individual turning movements for each analysis period. **Table 1** shows comparison of the modelled and observed volumes at various screenlines across the network.

Table 2: Comparison of Modelled and Observed Screenline Volumes

Gibb-Olive Screenlines	Dir	AM			PM		
		Obs	Mod	% Dif	Obs	Mod	% Dif
East-West Screenlines							
H1 - North of Bond	NB	3439	4213	22%	6429	5812	-10%
	SB	5402	5141	-5%	4926	4776	-3%
	Total:	8,841	9,354	6%	11,355	10,588	-7%
H2 - Between King and John	NB	3462	4057	17%	5387	5060	-6%
	SB	3668	3755	2%	4351	4032	-7%
	Total:	7,130	7,812	10%	9,738	9,091	-7%
H3 - South of Gibb/Olive	NB	4220	4533	7%	5670	5524	-3%
	SB	3105	3506	13%	4786	4466	-7%
	Total:	7,325	8,039	10%	10,456	9,990	-4%
North-South Screenlines							
V1 - West of Stevenson	EB	1627	1798	11%	2060	1987	-4%
	WB	1006	1155	15%	1749	1631	-7%
	Total:	2,633	2,954	12%	3,809	3,618	-5%
V2 - Between Grenfell and Park	EB	1706	2094	23%	3036	3134	3%
	WB	1997	2068	4%	2477	2123	-14%
	Total:	3,703	4,162	12%	5,513	5,257	-5%
V3 - Between Park and Centre	EB	1511	2033	35%	2585	2487	-4%
	WB	1830	1988	9%	1983	2115	7%
	Total:	3,341	4,021	20%	4,568	4,602	1%
V4 - Between Mary and Division	EB	1339	1635	22%	2336	2062	-12%
	WB	2234	2257	1%	1709	1974	16%
	Total:	3,573	3,892	9%	4,045	4,036	0%

Gibb-Olive Screenlines	Dir	AM			PM		
		Obs	Mod	% Dif	Obs	Mod	% Dif
V5 - Between Ritson and Central Park	EB	884	1090	23%	2311	1660	-28%
	WB	2189	2392	9%	1623	1769	9%
	Total:	3,073	3,482	13%	3,934	3,429	-13%
V6 - East of Wilson	EB	839	1028	23%	1789	1706	-5%
	WB	2006	2306	15%	1413	1494	6%
	Total:	2,845	3,334	17%	3,202	3,200	0%

A review of the model results showed that the model outputs were comparable to observed volumes. As shown in **Table 1**, the differences between observed data and model results were generally less than 25% and 10% (with few exceptions) for the AM and PM peak hour respectively. Similar results were for the other comparisons. Those comparisons indicated that observed and modelled volumes matched to acceptable tolerances generally used in similar modelling tasks.

Animation of traffic operations was also examined and found to be consistent with the typical traffic operations in the Study Area. It was therefore concluded that the model adequately reflected the base year conditions and could be used with a high degree of confidence to model future scenarios in the Study Area.

3.3 Existing Conditions Analysis

Detailed analysis of traffic operations was undertaken at all major intersections within the Study Area. The analysis involved summarizing delays and level of service from the simulation outputs at each intersection. Since each simulation run represents only one condition that could occur in the network on any typical day, a complete analysis consisted of six computer runs with different random seed numbers to generate a spectrum of possible traffic scenarios in the network. Final results for each analysis period were averaged from the simulation runs.

The results of the analysis indicated satisfactory traffic operations at virtually all intersections with level of service (LOS) A or B during both AM and PM peak periods. The corresponding delays generally range from 5 to 20 seconds with the majority of the intersections having an average delay in the range of 10 to 16 seconds. Traffic operations at individual approaches are similar with LOS A or B and average delays of up to 20 seconds. The only exceptions to the above occurred at the Centre/Gibb and the Simcoe/Olive intersections where some approaches operate at LOS C or worse, reflecting deteriorating conditions at the south-east downtown area. A screen capture of the simulation animation and LOS outputs for that area is shown in **Figure 4**.

Figure 4: Screenshot of Simulation Animation and Outputs for Existing PM Peak Hour

4. FUTURE NETWORK CONDITIONS

Traffic operations analysis was undertaken with the Paramics model for the future horizon years. The traffic demands and matrices for use in the model were developed from the results of the strategic analysis as described in **Section 3**. The analysis was conducted for the 2012 and 2021 horizon years taking onto consideration expected improvements in the road network within the City and in Durham Region that would affect traffic flow patterns in the Study Area. All the analysis represents traffic operations during the PM peak hour which had higher traffic demands than the AM peak period.

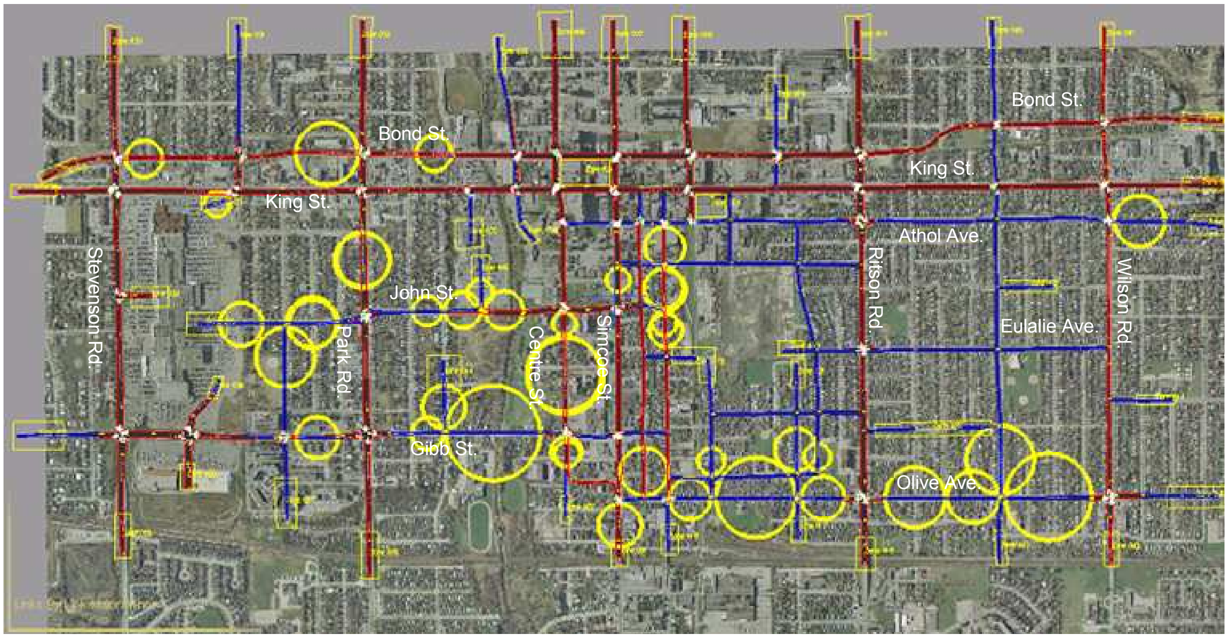
The 2012 traffic demands represent conditions with improvements in the surrounding network and provide an overall growth of about 5-10% in the total traffic volumes in comparison to the existing conditions. The 2021 conditions will result in traffic demands higher than the existing demands by 20 to 30%.

4.1 Base Conditions

During the 2021 horizon year, traffic operation with the existing network (*do-nothing scenario*) is expected to deteriorate with several links and intersections experiencing substantial congestion as shown in **Figure 5**. The figure shows a snapshot of the simulation process under the 2021 base scenario during the PM peak hour. The circles in the figure indicate roadway sections that will experience long queues and delays.

Congestion will predominantly occur on east west roadways including Gibb Street, Olive Avenue and John Street thereby confirming future east-west capacity deficiency. Problems will also be experienced on Centre Street and Simcoe Street. Extensive queuing will occur and extend backwards thereby creating gridlock conditions at several key intersections on those streets. Those intersections will fail and operate at LOS F or E. Network improvements will therefore be required to ensure acceptable traffic operations.

Figure 5: Congestion in Study Area under Future PM Base Scenario



4.2 Improvements Considered

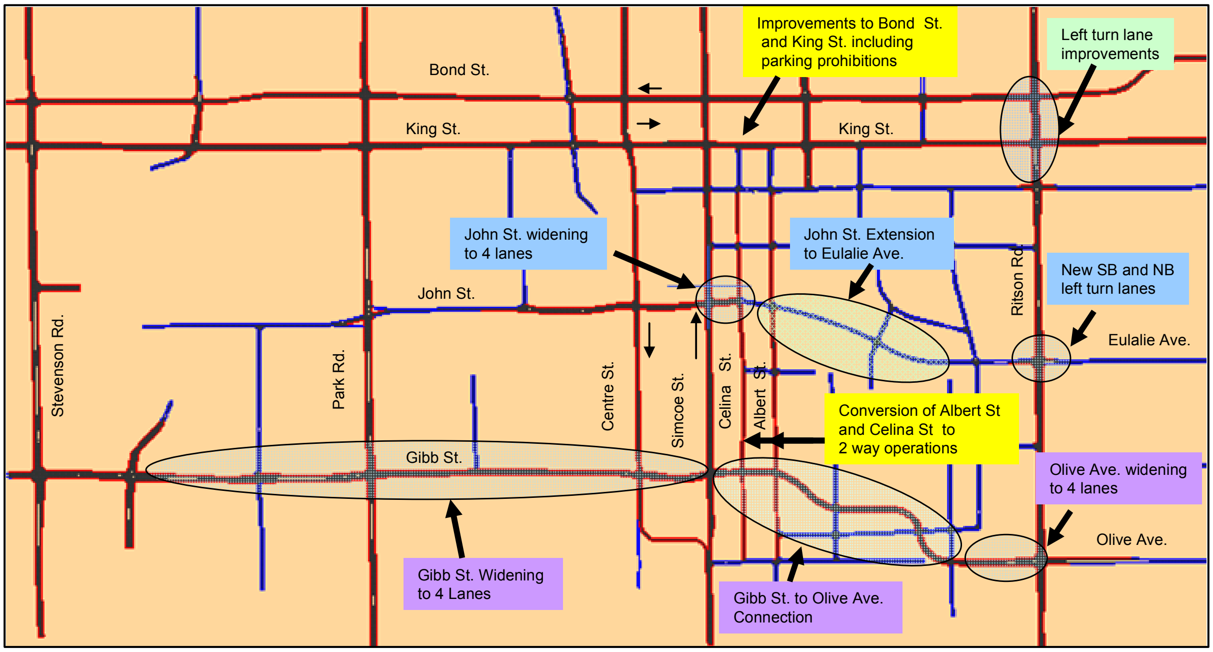
The model was used to identify a number of general Transportation System Management (TSM) improvements that will be required to accommodate the future traffic demands. The improvements include provision of left turn lanes at the Ritson/Eulalie intersection and modifications at Ritson/Bond and Ritson/King intersections to accommodate increased left turn traffic volumes in both northbound and southbound directions. The analysis showed that those general improvements will be required by 2012.

In addition to the above TSM measures, specific alternative network improvements were investigated to confirm their effectiveness in addressing future traffic problems. The improvements included:

- *Alternative 1*: Improvements of Bond Street and King Street and conversion of Albert Street and Celina Street from one way to two way street operations;
- *Alternative 2:* Extension of John Street to Eulalie Avenue including widening of John Street to four lanes between Simcoe Street and Albert Street and provision of SB and NB left turn lanes at the Eulalie Ritson intersection;
- *Alternative 3:* Improvements on Gibb Street and Olive Avenue including widening to four lanes and provision of a connection between Gibb Street and Olive Avenue; and
- *Alternative 4:* Combination of John Street Extension (Alt 2) and Gibb Street and Olive Avenue improvements (Alt 3).

Those improvements are illustrated in **Figure 6.**

Figure 6: Network Improvements Considered



An initial review of the alternatives showed that for Alternative 1, the required improvements on Bond Street and King Street would have far reaching impacts in the downtown area and would not be supported politically. Moreover, it was found that conversion of Albert Street and Celina Street from one way to two way street operations would result in severe operational problems at most intersections and lead to gridlock conditions. Consequently, Alternative 1 was not considered further in detailed analysis. Detailed analysis was undertaken with the remaining alternatives for the 2012 and 2021 horizon years. The results are summarized in **Table 3**.

Traffic operations will generally be satisfactory during the 2012 horizon year under Alternative 3 (Improvements to and connection of Gibb Street to Olive Avenue) and Alternative 4 (Combined Alternative). However, with Alt. 2 (John Street Extension) some intersections such as Centre/Gibb will operate at LOS D with individual approaches failing. These results indicate that with the Gibb Street to Olive Avenue connection, traffic operations in the network will be adequate even without the John Street extension. However, the John Street extension alone will not eliminate all the congestion in the network.

In the 2021 horizon year, both Gibb-Olive connection and John Street extension to Eulalie Avenue will be required to resolve all the network operations problems. Although the LOS appears acceptable at most intersections (B to D) with either alternative alone, the processed demand was much less (70.3% and 83.4%) indicating that substantial levels of congestion will still be present in the network under Alt 2 and Alt 3. Congestion at any point in the network may cause reduced volumes at certain downstream intersections, thereby resulting in arbitrarily better levels of service than would otherwise be the case. In comparison, the processed demand for Alt 4 will be 97.3% which indicates negligible congestion levels and demonstrates that both Gibb-

Olive connection and John Street Extension will be required to provide satisfactory operations in the network in that year.

Table 3: Comparison of Improvement Alternatives

		Base: Do Nothing		Alt 2: John St. Extension		Alt 3: Gibb to Olive Connection		Alt 4: Both Alt 2 and Alt. 3	
	Existing	2012	2021	2012	2021	2012	2021	2012	2021
Intersection	**Level of Service**								
Centre/Gibb	C	D	E	D	D	B	B	C	C
Simcoe/Olive	B	C	D	C	D	C	C	C	C
Ritson/Olive	B	B	C	B	C	C	C	B	C
Ritson/Eulalie	B	D	F	B	B	B	B	B	B
Centre/John	A	C	F	A	C	A	C	A	C
Simcoe/John	B	B	C	B	B	B	C	B	C
Simcoe/Gibb	A	B	C	B	B	B	C	C	A
Parameter	**Simulation Performance**								
Average Delay [s]	8.7	11.4	24.7	10.2	10.6	9.6	10.4	9.1	10.6
Average Speed [kph]	27.8	26.9	21.2	27.6	27.4	27.5	26.9	27.9	27.1
Demand Processed [%]	99.2	95.5	***86.6***	96.8	***70.3***	98.2	***83.4***	99.1	97.3

4.3 Benefits of Micro-Simulation

These results underscore the benefits of micro-simulation in network analysis covering a broad area instead of focusing on one localized area or corridor. The simulation was particularly useful in undertaking a capacity constrained traffic assignment following network improvements that included construction of new links and road widening. It made it possible to identify the Transportation System Management measures including intersection enhancements that would be required to support the more comprehensive network improvements.

Further benefits of micro-simulation in the Study included animation capabilities and graphical user interface that allowed on-screen display of traffic operations. This was very important to the validation process and demonstrated the trustworthiness of the simulation results. In addition, it facilitated assessment and screening of a variety of alternative improvements relatively quickly without the need to conduct detailed analysis of the simulation outputs. The final results were also available in various formats that were easy to understand and to communicate even to non-technical audiences.

5. CONCLUSIONS AND RECOMMENDATIONS

This Study used micro-simulation modelling to assess future network requirements for the southeast downtown area of the City of Oshawa. The results show that a number of improvements will be necessary to ensure satisfactory traffic operations in the future horizon years. Those improvements include widening of Gibb Street from two to four lanes and connecting Gibb Street to Olive Avenue, and extension of John Street to Eulalie Avenue. Other general improvements will also be required.

It was found that the Gibb Street to Olive Avenue Connection and associated improvements will be required by 2012 and that in addition, the John Street Extension to Eulalie Avenue will also be required in 2021 to accommodate future traffic demands.

The Study therefore recommended implementation of the above improvements and as a result, the Region of Durham and the City of Oshawa have initiated Class Environment Assessment Studies for improvement to and connection of Gibb Street and Olive Avenue, and for extension of John Street to Eulalie Avenue respectively. It is expected that those improvements will be in place by the year 2012.

The Study demonstrates the importance of network analysis covering a broad area instead of focusing on one localized area or corridor in identifying future deficiencies and formulating appropriate solutions to address them. Micro-simulation modelling plays a pivotal role in that process.

AUTHORS

Timothy Oketch, Ph.D., P.Eng., Project Manager –Transportation, Totten Sims Hubicki (**TSH**) Associates, 300 Water Street, Whitby, Ontario, L1N 9J2, Tel: 905-668-9363, Fax: 905-668-0221, Email: TOketch@tsh.ca, http://www.tsh.ca

Timothy is a professional engineer with over 15 years experience in transportation engineering and planning, specializing in traffic engineering. Timothy works as a project manager with Totten Sims Hubicki Associates (**TSH)** in Whitby, Ontario where his duties include project management and micro-simulation modelling.

EDUCATION
Ph.D.: Transportation Engineering, Karlsruhe University, Germany, 2001
Previous graduate and undergraduate education in Technical University, Delft, The Netherlands and University of Nairobi, Kenya

PROFESSIONAL ASSOCIATIONS
Registered as Professional Engineer (PEO) in Ontario
Member Institute of Transportation Engineers

WORK EXPERIENCE
Since 2003: Totten Sims Hubicki Associates Limited,: Project Manager.
Previous Employers: Ontario Ministry of Transportation and City of Toronto

James H. Garland, P. Eng., Project Manager, Region of Durham Works Department, 605 Rossland Road East, Whitby, Ontario L1N 0B7, Telephone: 905-668-4113, X3439 Fax: 905-668-2051 Email: james.garland@region.durham.on.ca

James is a professional engineer with over 20 years experience in transportation design. James works as a project manager for the Regional Municipality of Durham Works Department in Whitby, Ontario where his duties include project management of Class EA studies and road design projects.

EDUCATION
B. A. Sc (Civil Engineering), Queens University at Kingston, Canada.

PROFESSIONAL ASSOCIATIONS
Registered as Professional Engineer (PEO) in Ontario and a member of the Institute of Transportation Engineers and the Canadian Society for Civil Engineering.

WORK EXPERIENCE
James has worked for the Region of Durham since 2005. Previously he worked for a Canadian consulting engineering firm.