Using Micro-Simulation in Evaluating Neighbourhood Infiltration Counter-Measures

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Abstract:

This paper reviews how micro-simulation modeling was applied to support a traffic infiltration study in the Thornhill Community in the Town of Markham, Ontario. The analysis was necessary to quantify impacts of proposed counter-measures on traffic flow patterns and traffic operations and involved modeling the entire area using the *Paramics* micro-simulation model.

To support the modeling efforts, extensive data collection was undertaken and included a plate trace survey to identify predominant infiltration routes within the community. The model was calibrated to existing conditions and used to evaluate impacts of proposed measures. The measures included turn restrictions, signalization and signal timing adjustments at key intersections in the community. Animation of traffic operations with those measures demonstrated their impacts in a way that the public could easily understand and identify with.

The public participation component involved participation of community leaders in the steering committee, thus ensuring their input in all key decisions. The community leaders subsequently held meetings with their respective associations to communicate study goals and findings before a final public meeting was held to formally present the study recommendations to the entire community. A strong public support to the recommended measures was recorded during the meeting.

Some of the measures have since been implemented and preliminary data confirms that they are generally effective in reducing infiltration rates through the community in accordance to model predictions. It was concluded that simple solutions such turn restrictions could be effective in controlling neighbourhood infiltration problems if they are well planned and evaluated by using innovative analysis methods such as micro-simulation.

INTRODUCTION

The Thornhill Community in the Town of Markham has a long history of traffic operations problems including infiltration. Residents have expressed concerns that traffic volumes on many streets in the community exceed what would reasonably be expected on similar roads, given the prevailing land use patterns and network characteristics in the community. Although past studies had identified and confirmed the problem, the Town had not implemented solutions because of lack of public support arising primarily because of the inability to convincingly evaluate and demonstrate impacts of proposed measures.

In response to continued concerns, the Town of Markham initiated a Traffic Infiltration Study in the Community to identify suitable traffic management strategies that could mitigate the traffic infiltration problems. The aim of the Study was to identify suitable traffic management strategies to control infiltration in the community. Some of the measures considered viable included turn restrictions, road closures, improvements to the surrounding arterial roads, intersection signalization and traffic calming.

It was generally recognized that the range of measures considered would result in varying impacts on traffic operations on the neighbourhood streets and the surrounding arterial roads. To overcome previous challenges, a quantitative assessment of those impacts was required to provide an objective evaluation of the proposed measures. That approach would in turn help identify suitable measures that would be acceptable to the area residents and stakeholders. The above requirement mandated the use of an innovative analysis approach capable of quantifying traffic operations in the network under various measures, and micro-simulation modeling was identified as the most appropriate approach.

The use of micro-simulation modeling is becoming increasingly popular as the preferred method for analyzing complex transportations systems. The capability of micro-simulation to model both the transportation network and the driver-vehicle units in detail provides the flexibility required to evaluate the performance of complex systems under a range of intervention scenarios. A micro-simulation model simulates the motion of individual vehicles in small time steps and follows each vehicle from the time it is generated to the point it exits the network. Both spatial and travel details of each vehicle including instantaneous speeds are recorded at every time step and aggregated for all vehicles to obtain the network performance parameters like volumes, densities, delays, number of stops and lane change manoeuvres.

Advanced micro-simulation models have been applied predominantly in research and analysis of complex transportation systems like performance of HOV lanes, deployment of ITS components, congested networks and freeway systems. However, with increasing demand for more realistic modeling, micro-simulation is finding greater application in urban network analysis and particularly in sub-area analysis where they can be used to bridge the gap between planning models on the one hand and the more detailed operational models on the other. Recent examples in which micro-simulation has been applied in sub-area analysis can be found in reference (*1*). In this Study, micro-simulation was applied to assess impacts of the proposed measures on route choice decisions and the resultant traffic operations at mid-block areas and intersections in terms of traffic volumes, intersection delays and level of service.

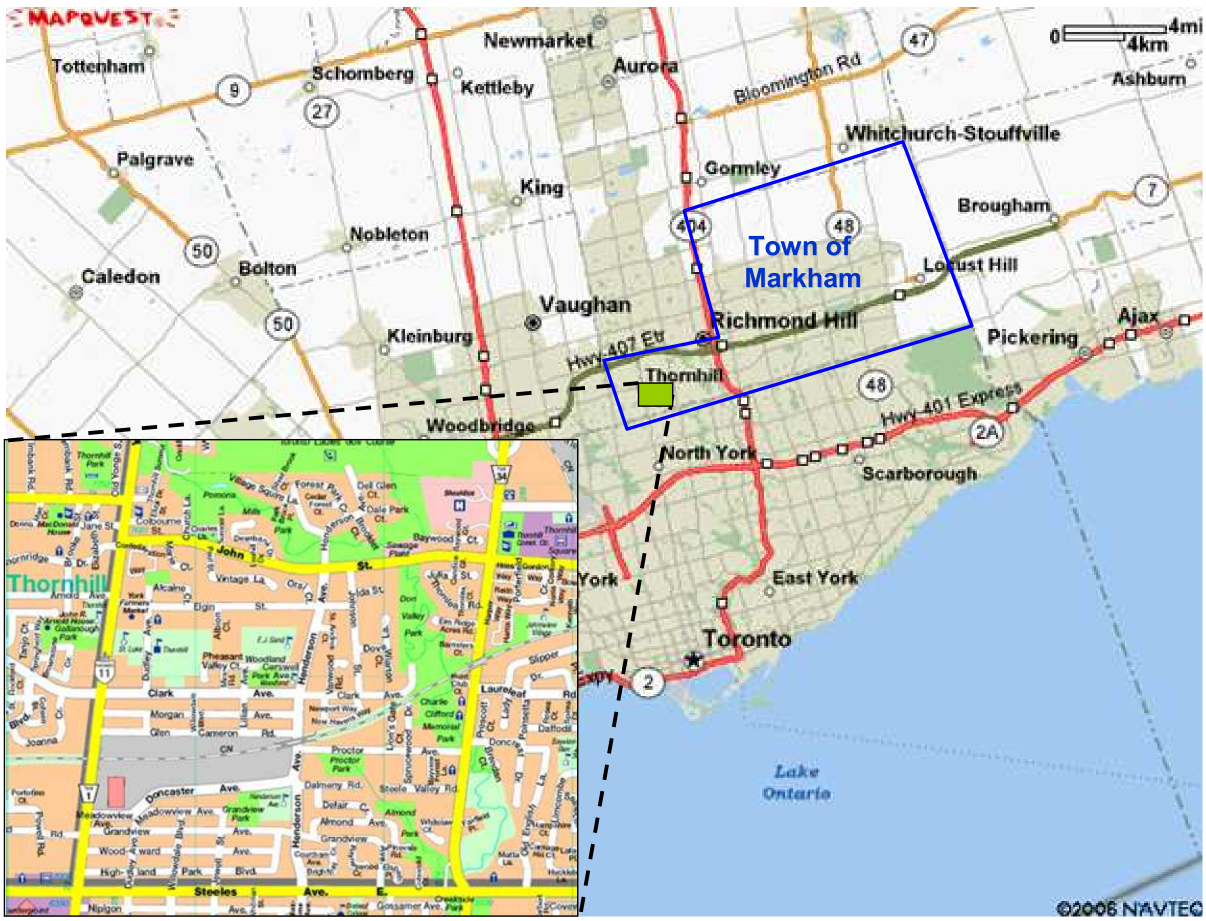
This paper reviews the technical analysis as well as the public consultation process implemented in the Study. In particular, it reviews application of micro-simulation modeling in the Study and discusses data collection, calibration and the obtained results. Moreover, the public consultation process is also presented and participation of community leaders in the Study Steering Committee and the conduct of the public meeting are discussed. Implementation of the recommended measures and the results of field studies conducted thereafter are also presented to provide a preliminary evaluation the effectiveness of the measures in addressing the infiltration problem. Conclusions and recommendations are provided at the end.

STUDY PLANNING

STUDY AREA

The Study Area was the Thornhill Community in the western section of the Town of Markham, just north of the City of Toronto. The area is approximately 2 km long and 2 km wide and is bounded by Yonge Street (RR1) to west, John Street to the north, Bayview Avenue (RR34) to the west and Steeles Avenue to the south, as shown in inset-map in **Figure 1.**

Figure 1: Map of Study Area



The community borders other jurisdictions including the Town of Vaughan to the west and the City of Toronto to the south. The City of Toronto owns the Steeles Avenue, which marks the southern boundary of the Study Area. Moreover, the Town of Markham is a constituent municipality in the Region of York and the north – south arterial roads to the west and east of the community, namely Yonge Street (RR1) and Bayview Avenue (RR34) belong to the Region of York. For that reason, a working group with representatives from the various jurisdictions was set up to participate in the study as described in the fifth section.

NEED FOR MICRO-SIMULATION

The aim of the Traffic Infiltration Study was to identify suitable traffic management strategies to control the infiltration problem in the community. Some of those measures could result in traffic diversion to other roads in the network and impact not only on the Town collector roads but also on the arterial roads under the jurisdiction of the City of Toronto and the Region of York. For that reason, an innovative analysis approach was required and micro-simulation was identified as the most suitable approach that could successfully facilitate traffic operations analysis under the range of alternative measures under consideration.

As noted in (*2*), the selection of the appropriate analytical tool is a key part of the study scope and plays a pivotal role achieving the Study objectives. Among the available models, the Paramics micro-simulation model was used in the study primarily because of its advanced capability in modeling route choice decisions and various network characteristics. The model incorporates route choice algorithms that facilitate traffic reassignment following changes in the network. It captures various network characteristics and provides a range of outputs that include travel speeds, delays, queues and level of service. Moreover, the model has advanced animation capabilities that are useful in identifying problem areas and for visual representation of analysis results.

DATA COLLECTION

Once the decision was made to undertake micro-simulation analysis, the necessary data required to support the analysis was identified and a data collection process commenced. The data was collected through field studies/observations and compilation from the existing inventories of the City of Toronto, the Region of York and the Town of Markham. The data included road geometric data, traffic demand data and intersection control information. Details of the data were as follows:

- Road geometric data including lane information, intersection layout, turning lanes and designated storage lengths and any channelization details. Additional details included presence of special lanes and posted speeds;

- Traffic data including volumes and speeds at mid-block areas and turning movement counts at intersections;

- Traffic controls at intersections including signalization or stop control information. At signalized intersections, the signal timings and coordination details were required. The control strategy such as all-way or two-way stop signs were also necessary at unsignalized intersections.

Most of the traffic data was provided by the various jurisdictions involved in the study: Town of Markham provided data on the collector and local roads, the City of Toronto and the Region of York supplied traffic data and signal operation information for the arterials roads.

Because of the modeling requirements, additional data collection was necessary to supplement the available inventory information. Field studies were undertaken in February 2005 to confirm the network geometric features and to collect additional traffic data including turning movement counts (TMCs) at signalized intersections and Automatic Traffic Recorder (ATR) counts at various street sections. Moreover, a plate trace survey was also undertaken to confirm the infiltration concerns and to identify route choice decisions within the Study Area. The TMC data represented traffic operations during the morning peak period (8 - 9 am) and afternoon peak period (5 - 6 pm).

The data was reviewed to confirm its quality and consistency. Some data reduction or balancing was necessary to ensure consistency of traffic volumes at intersections and mid-block areas as well as at consecutive intersections. A summary of the characteristics of the main roads in the study area is provided in **Table 1**.

Table 1: Characteristics of Study Area Streets

Road	Class	Section Lanes	Directional Peak Hour Volume	Posted Speed [km/h]	Comments/ Feature
Yonge Street	Arterial	5 to 7	2400 to 2850	50	HOV, TWLT lanes, signal coordination
Bayview Ave	Arterial	4 or 5	1700 to 2100	60	TWLT lanes, signal coordination
Steeles Ave	Arterial	4 or 5	1700 to 1900	60	TWLT lanes, signals under SCOOT system
Doncaster Ave	Collector	4	400 to 450	40	
Willowdale Ave	Collector	4	400 to 950	50	
John Street	Collector	2	450 to 800	40	On street parking
Henderson Ave	Collector	2	550 to 750	40	Speed humps
Proctor Avenue	Collector	2	350 to 400	40	
Clark Avenue	Collector	2 to 4	550 to 1050	40	
Glen Cameron Rd	Collector	2	250 to 350	40	
Elgin Street	Collector	2	250 to 350	40	

TWLT: Two way left turn lanes
HOV: High Occupancy Vehicle Lanes

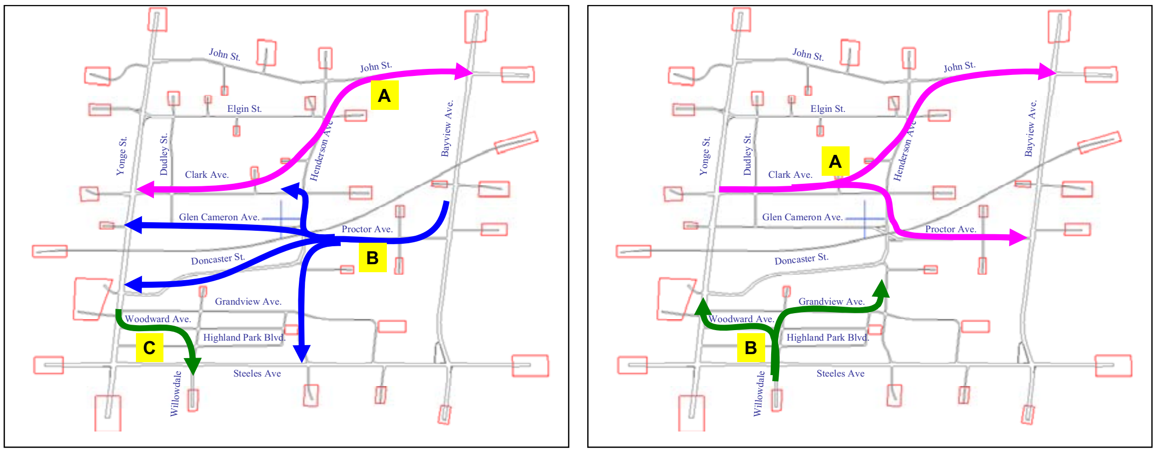
INFILTRATION PATTERNS AND POTENTIAL COUNTER-MEASURES

INFILTRATION PATTERNS

Infiltration patterns were established from previous studies conducted by Town staff as well as the plate trace survey conducted in February 2005. The plate trace survey recorded the number of vehicles entering and exiting the community at 14 locations on the arterial roads and other streets. In accordance with the industry practice, the matched plates related only to vehicles seen entering and exiting the community within a five minute interval. Traffic entering the community but did not exit within that interval was assumed to represent residents who live in the community or are engaged in legitimate business such as working or going to school.

The plate trace survey confirmed that traffic infiltration occurred on the neighbourhood streets and helped identify the most significant routes across the community. At the 14 locations studied, infiltration rates ranged from 50% to 75% and 45% to 80% during the AM and PM peak periods respectively (**Table 2**). Overall, approximately 65% of the traffic entering the Study Area during the peak periods was found to be cut through traffic. The predominant infiltration patterns during the morning and afternoon peak period are shown in **Figure 2**:

Figure 2: Existing Infiltration Patterns in the Study Area



a. AM Patterns　　　　b. PM Patterns

A description of the pattern is as follows:

- *Pattern A (AM)*: Eastbound traffic on Clark Avenue proceeding to Henderson and to John Street. A significant number of vehicles use the same route but in the eastbound direction;

- *Pattern B (AM)*: From southbound Bayview Avenue through Proctor Avenue to Glen Cameron Road, Doncaster Avenue, and Henderson Avenue. Previous studies indicate that over 75% of the westbound traffic at the Bayview/Proctor intersection is cut through traffic;

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- *Pattern C (AM)*: Southbound traffic on Yonge Street making left turn onto Grandview Avenue, Woodward Avenue and Highland Park Boulevard onto southbound Willowdale Road to proceed south to Toronto;
- *Pattern A (PM)*: Eastbound traffic on Clark Avenue proceeding to Henderson Avenue and to John Street. Some of the traffic proceed east on Proctor Avenue. A significant number of vehicles use the same route but in the eastbound direction;

- *Pattern B (PM)*: Northbound traffic on Willowdale Avenue turning left onto Grandview Avenue, Woodward Avenue and Highland Park Boulevard and then right to proceed north on Yonge Street. A smaller proportion of vehicles on Willowdale proceed east onto Grandview and then north onto Henderson Avenue.

POTENTIAL COUNTER-MEASURES

Identification of potential counter-measures was undertaken with an underlying goal of reducing traffic volumes on key infiltration routes while keeping through traffic on the arterial roadways. The considered measures included turn restrictions, road closures, improvements to the surrounding arterial roads, intersection signalization and traffic calming. The measures were screened on the basis of a number factors including their potential benefits and impacts, ease of implementation, constructions costs, planning duration, approval requirements and resident support. These considerations led to the selection of measures that involved a combination of turn restrictions and signal timing modifications. **Table 2** lists the recommended measures and shows how they related to the previously identified infiltration patterns.

Table 2: Potential Counter-Measures for Key Infiltration Routes

Time	Pattern Details	Entering Volume [vph]	Infiltra-tion Rate	Potential Counter-Measure	Target Action / Implications
AM	*Pattern A*: EB traffic on Clark Ave	320	75%	Advance green phase on the westbound approach at Yonge/Clark	To encourage EB traffic to remain on arterial road
AM	*Pattern A*: WB traffic on John St.	580	45%	No special measure recommended	
AM	*Pattern B*: From SB Bayview Ave.	400	77%	SB right turn restriction at Bayview/Proctor during the AM peak	May require changes in signal head to include a right turn arrow
AM	*Pattern C*: SB traffic on Yonge St.	240	60%	SB left turn restrictions on each roads during the morning peak	Only signage is required at each intersection
PM	*Pattern A*: EB traffic on Clark Ave.	350	68%	Advance green phase on the westbound approach at Yonge/Clark	To encourage EB traffic to remain on arterial road
PM	*Pattern B*: NB traffic on Willowdale Ave	250	58%	WB right turn restrictions on each road and signal timing changes at Steeles/ Willowdale	Signal timing changes to accommodate increased NB LT volumes at Steeles/ Willowdale

In addition to the measures in **Table 2**, signalization of the Proctor/Henderson intersection was also recommended. Implementation of the above measures required only installation of turn prohibition signs at the affected intersections and signal timing adjustments. Micro-simulation analysis was undertaken to assess impacts of the measures on traffic operations at intersections and to quantify volume changes on the streets within the community

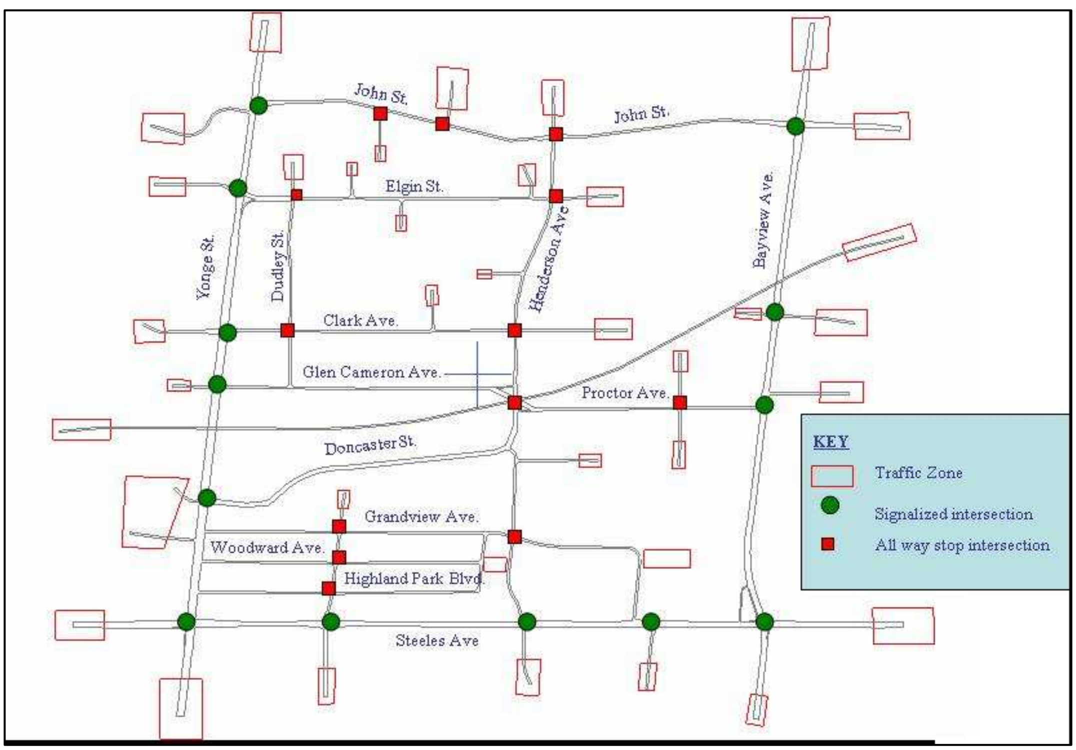
MICRO-SIMULATION MODELING

PARAMICS MODEL

Operations analysis was conducted using the Paramics micro-simulation model. The Paramics model is a state of the art micro-simulation tool with advanced traffic flow algorithms that facilitate analysis of complex transportation systems. Detailed information on the Paramics model and how it has been applied in recent studies can be found in references (*1, 3 & 4*). 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 with the proposed counter-measures.

The road network within the Study Area was modeled 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 but left out a number of minor streets that were not considered significant to the analysis. The Paramics model uses a link and node structure to define the roadway network and traffic zones to control vehicular movements through the network.

Figure 3: The Modelled Network



The network was coded with more than 500 links and 240 nodes representing individual road sections and intersections or areas where there were changes in the physical characteristics of roadways such as alignment and pavement width respectively. A total of 38 zones were used in the study including two for the railway line. The zones represent areas of traffic generation or points at which they exit the network. The zones were located in such a way as to provide realistic travel patterns in the network and to correspond with various neighbourhoods, or entry and exit at the network periphery, where vehicular trips are expected to begin and end.

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 zone. 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.

In total, 26 intersections were coded in the model including 13 signalized intersections on the arterials roads and 13 all way stop controlled intersections on the collector roads. The intersections on Yonge Street and Bayview Avenue north of Steeles Avenue operated under signal coordination. On the other hand, signal operations on Steeles Avenue are controlled by the centralized SCOOT system in the City of Toronto. Because of the high traffic volumes during the peak periods, the intersections of Yonge/Steeles and Bayview /Steeles effectively operate under fixed timing strategies. The other intersections operate under vehicle-actuated strategies controlled by the SCOOT system. Coding of traffic signals on the arterial roads was done to represent the average operational conditions in the field.

The Paramics model has advanced animation capabilities that make the analysis results easy to understand and present. The range of outputs provided includes traffic volumes on road sections and intersection, travel speeds, link and intersections delays and level of service. The level of service at signalized and unsignalized intersections was determined on the basis of average vehicle delays in accordance with the Highway Capacity Manual criteria.

CALIBRATION

Calibration is necessary to ensure that the model is able to replicate actual traffic operations in the modeled network. Previous studies (*1, 5, and 6*) have shown that an area model of this nature is adequately calibrated when the modeled and observed traffic volumes and speeds match to acceptable tolerances. In this study, the process involved selecting suitable model parameters and appropriate traffic assignment methods and estimating representative origin and destination matrices that provided the best match between model results and observed data. It also involved comparing modeled and observed link volumes and turning movement volumes at intersections. The model parameters that were adjusted included driver reaction time, target headways and the assignment parameters.

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. The cost is specified for each link with the equation:

$$Cost = a * T + b * D + c * P$$

The parameters T, D and P represent time, distance and toll costs and a, b and c are the corresponding coefficients in minutes, minutes per km and minutes per monetary cost respectively. The Study applied a dynamic assignment technique in which the links costs were updated every five minutes.

A review of the model results indicated that observed and modeled volumes matched to acceptable tolerances generally used in similar modelling tasks. It was therefore concluded that the model adequately reflected the base conditions and could be used with a high degree of confidence to model the required scenarios in the Study Area.

TRAFFIC OPERATIONS 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 five 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 five simulation runs.

Analysis of existing conditions provided results that corresponded to observed field conditions. Traffic operations at most intersections were generally satisfactory, however, a number of intersections were found to be operating at low levels of service with long delays and queues. Areas of particular concern included the Henderson/Clark and Henderson/Elgin intersections which experienced substantial delays. The simulation provided valuable insight that explained the poor operations at those locations. The animation showed that queues were extending form the Henderson/Proctor intersection and hindering vehicles on Clark Ave. and Elgin St. from joining Henderson Ave., thereby resulting in long delays.

Most of the arterial intersections were operating satisfactorily with average delays of less than 20 seconds. However, delays of up to up to 45 seconds with substantial queues were experienced at the Yonge/Steeles and Steeles/Bayview intersections. Observations in the field generally corroborated those findings. An example of existing traffic operations is illustrated in the screen shot image shown in **Figure 4**.

Figure 4: Screen Image of Paramics Analysis Showing Traffic Operations at the Yonge/ Steeles Quadrant

Following the analysis of base network operations, the model was modified to include the recommended measures. Simulation runs were subsequently undertaken to evaluate impacts of those measures on traffic operations in the network. As previously noted, five simulation runs were done for each scenario and the results averaged to obtain final results. The resultant traffic operations and link volume changes were then assessed and summarized as shown in **Table 3** and **Table 4**.

The analysis confirmed that the measures would result in reduced traffic volumes on key infiltration routes while keeping through traffic on the arterial roads. For example, the model predicted that traffic volumes on Proctor Avenue and Glen Cameron Road (AM Pattern B) and the Grandview/Woodward /Highland Park corridor (AM Pattern C) would reduce by various proportions ranging from 30% to 70% during the AM peak period (**Table 3**). At the same time traffic volumes on Yonge Street, Bayview Avenue and John Street would generally increase.

Imposing a right turn restriction on the southbound approach at the Bayview/Proctor intersection will result in significant volume reduction on Proctor Avenue. Most of the diverted traffic will proceed south on Bayview Avenue and turn right on Steeles Avenue, although a small proportion will prefer to follow westbound John Street and then southbound Henderson Avenue to continue to their intended destinations. As a result, traffic volume would increase on southbound Bayview Avenue between Proctor Avenue and Steeles Avenue, and on westbound John Street between Bayview Avenue and Henderson Avenue. The volume reduction on Proctor Avenue would cause a corresponding reduction on Glen Cameron Avenue.

Table 3: Volume Changes on Street Sections during AM and PM Peak Period

Street Name	Section	AM Volume [vph]			PM Volumes [vph]		
		Base	After	Change	Base	After	Change
Yonge St.	Steeles to Highland Park	3698	4141	12%	4697	4629	-1%
Yonge St.	Clark to Elgin	3335	3535	6%	3972	3952	-1%
Bayview Ave.	Steeles to Proctor	2465	2844	15%	3046	2906	-5%
Bayview Ave.	Laureleaf to John	3020	3104	3%	3503	3353	-4%
Steeles Ave.	Yonge to Willowdale	2579	2855	11%	3082	3186	3%
Steeles Ave.	Henderson to Bayview	3055	3448	13%	3395	3320	-2%
John St.	Yonge to Henderson	701	842	20%	705	702	0%
John St.	Henderson to Bayview	1267	1634	29%	1260	1257	0%
Henderson Ave.	Steeles to Grandview	525	580	11%	459	506	10%
Henderson Ave.	Grandview to Doncaster	800	812	2%	604	780	29%
Henderson Ave.	Glen Cameron to Clark	651	1023	57%	935	1019	9%
Henderson Ave.	Elgin to John	719	1015	41%	705	744	6%
Willowdale Ave.	Steeles to Highland Park	543	473	-13%	534	485	-9%
Glen Cameron	Dudley to Henderson	590	365	-38%	376	331	-12%
Proctor Ave.	Henderson to Bayview	706	447	-37%	676	681	1%
Clark Ave.	Dudley to Henderson	398	503	26%	616	555	-10%
Elgin St.	Dudley to Henderson	617	776	26%	413	461	12%
Doncaster Ave.	Yonge to Henderson	549	431	-21%	458	398	-13%
Highland Park	Yonge to Willowdale	173	123	-29%	226	146	-35%
Woodward Ave.	Yonge to Willowdale	166	70	-58%	59	42	-29%
Grandview Ave.	Yonge to Willowdale	216	59	-73%	83	25	-70%
Grandview Ave.	High. Park to Henderson	307	312	2%	298	369	24%

The model predicted that similar results would be obtained by implementing southbound left turn prohibitions on Yonge Street at the Grandview Avenue, Woodward Avenue and Highland Park Boulevard intersections. Traffic volumes on the sections of these roads between Yonge Street and Willowdale Avenue would reduce and traffic unable to turn left at those intersections would proceed south on Yonge Street resulting in a volume increase in the southbound direction between Grandview and Steeles Avenues.

Similarly, traffic volumes on Willowdale Avenue and the Grandview/Woodward /Highland Park corridor (PM Pattern B) would generally reduce during the PM peak period. Introduction of right turn restrictions at on Grandview Avenue, Woodward Avenue and Highland Park Boulevard at their intersections with Yonge Street will effectively block movement out of the quadrant to Yonge Street and cause the northbound traffic to remain on Steeles Avenue and Yonge Street. The result will be an increase in the northbound left turn volume at Steeles/Willowdale intersection and a corresponding decrease in volume on Willowdale Avenue between Steeles Avenue and Grandview Avenue. Those benefits notwithstanding, the analysis also showed that traffic volumes would increase on certain community roads, especially Henderson Avenue and Elgin Street.

Impacts on delays and level of service at the intersections (**Table 4**) are expected to be generally modest. Traffic volumes on most intersections would increase because those intersections are all located on either the arterial roads or on Henderson Avenue that are expected to experience increased traffic volumes. Despite those volume increases, changes in delays and hence level of service were predicted to be insignificant in most cases except at the Henderson/Clark and Henderson/Elgin intersections which would improve because of the generally improved operations at the Proctor / Henderson intersection.

Table 4: Modelled Volume Changes on Streets during AM Peak Period

Intersection	AM - Base		AM - After		PM - Base		PM - After	
	Vol [vph]	Delay [s]	Vol [vph]	Delay [s]	Vol [vph]	Delay [s]	Vol [vph]	Delay [s]
Yonge/Steeles	6313	41.1	6875	42.1	7709	43.1	7588	43.4
Yonge/Doncaster	4085	14.3	4307	17.3	5185	29.8	4944	31.4
Yonge/Glen Cameroon	3877	24.8	4033	22.3	4458	17.2	4261	23.3
Yonge/Clark	4374	33.3	4797	36.3	5284	26.1	5152	37.6
Yonge/Elgin	3888	23.3	3817	22.6	4143	11.8	3883	12.0
Yonge/John	3396	16.6	3531	16.4	4110	12.7	4026	12.8
John/Henderson	1439	19.6	1881	23.0	1309	11.2	1484	13.2
Elgin/Henderson	1005	40.9	1477	35.2	940	10.6	1145	9.8
Clark/Henderson	872	86.5	1380	25.0	1079	46.0	1330	17.4
Proctor/Henderson	1256	28.8	1404	10.9	1323	21.0	1663	11.4
Doncaster/Henderson	869	5.7	1070	15.8	962	6.1	1205	6.9
Henderson/Grandview	728	4.7	905	6.7	634	8.1	850	3.4
Steeles/Willowdale	3548	21.9	3824	20.0	4062	29.2	4090	30.0
Steeles/Henderson	3522	17.5	3888	19.5	3734	15.0	3730	14.9
Steeles/Conacher	3133	3.7	3527	6.2	3475	3.7	3415	4.1
Steeles/Bayview	5632	41.9	5877	38.8	6262	35.6	6163	37.6
Bayview/Proctor	3399	18.3	3147	18.0	3481	24.0	3428	25.0
Bayview/Laureleaf	3478	18.0	3301	17.5	3712	9.5	3616	9.2
Bayview/John	4887	32.1	4835	31.0	4735	25.8	4717	26.9

These results underscore the benefits of micro-simulation in assessing and quantifying impacts of the recommended measures on traffic operations in the entire network. The approach facilitated tracing routing changes between the various origin and destination zones and the resultant impacts on link volumes and traffic operations at intersections. The ability of the approach to quantify those impacts in a fast and retraceable manner played a crucial role in winning stakeholder support for the Study recommendations.

PUBLIC PARTICIPATION

Given the long history of traffic infiltration problems in the community, it was recognized that public participation would play a pivotal role in progressing with the project from the study phase to implementation stage. Although past studies had identified and confirmed the infiltration problem, it had not been possible to proceed with any recommendations to implementation because of lack of sufficient public support. The lack of support was attributed primarily to the inability of past studies to convincingly evaluate and demonstrate impacts of proposed measures. To overcome those obstacles, the study followed a community participation process that ensured involvement of a broad range of stakeholders, in addition to the strong technical analysis already discussed.

BROAD BASED WORKING GROUP

The public participation component involved engaging residents and other stakeholders at various stages of the planning process to ensure that a wide variety of opinions and interests were accommodated. As already indicated, a broad-based working group was necessary because of the location of the Study Area and the ownership of the arterial roads surrounding the community. The working group was composed of the Ward Councillor, community representatives and Staff from the Town as well as from the Town of Vaughan, The Region of York and the City of Toronto.

In particular, the Ratepayer Presidents were included in the steering committee as a first step, thus ensuring their input in all key decisions. The Ratepayer Presidents subsequently held meetings with their respective associations to communicate study goals and findings, thereby effectively achieving a buy-in of the members before a final public meeting for the entire community.

PUBLIC MEETING

A public meeting was held in May 2005 to formally present the study recommendations to the entire community. Members of the public were invited through mail-outs and advertisements in the community newspapers. The meeting was attended by more than 60 residents from all parts of community. The meeting was used to inform the public of the recommended measures and how they would impact traffic operations on the neighbourhood collector streets. A formal presentation was made during which the simulation animation of traffic operations in the area was shown.

The meeting participants were satisfied with the level of analysis undertaken, and particularly the simulation and its ability to assess volume impacts on the community streets. Noting that volume increase was predicted on some streets, the meeting stressed the need for residents to focus on the overall benefits to community instead of focusing on impacts on individual streets. A strong public support to the recommended measures was recorded during the meeting.

IMPLEMENTATION OF MEASURES

APPROVALS

Following the public meeting, approvals were obtained from the Town of Markham Council and the York Regional Council to implement the measures. It was decided that the implementation would be done in two phases; the first phase would involve installation of the turn restriction signs followed by a monitoring period to allow changes in traffic flow patterns to stabilize. The second phase would involve signal timing adjustments and signalization of the Henderson/Proctor intersection. The monitoring period following the first phase was necessary to evaluate changes in traffic flow patterns and confirm the need for and the extent of the signal timing adjustments to be undertaken in phase two.

IMPLEMENTATION

Approvals were received in fall 2005 and the turn restriction signs installed on Yonge Street and Bayview Avenue, in November 2005. The Region was responsible for the sign installations since both Yonge Street and Bayview Avenue are under their jurisdiction. The signs were installed to be in effect from 6 am to 10 am in the morning and from 4 pm to 6 pm in the afternoon. The responsible detachment of the York Regional Police was informed about the new installations and asked to provide increased enforcement to ensure adequate compliance levels were achieved.

AFTER STUDIES

Following implementation of the measures, traffic volume counts were undertaken to provide a preliminary evaluation of their impacts on traffic flow and infiltration patterns. The counts were undertaken one to two weeks after installation of the signs and it was apparent that the conditions traffic conditions had not fully stabilized. As such, the compliance levels to the turn restrictions were still relatively low and ranged from 50% to 75%. An overview of the volume changes on various streets during the AM peak period is provided in **Table 5**.

As expected, traffic volumes reduced on the key infiltration routes including Proctor Avenue, Glen Cameron Road, and the Grandview/Highland Park/Woodward area in accordance with the model predictions. Moreover, volume increases were also observed on John Street (Henderson to Bayview), Bayview Avenue (Steeles to Proctor) and on Clark Avenue in accordance with the model results. Specific turning volumes at a number of intersections also changed as expected: traffic volumes increased on the southbound right turn movements at the Bayview/John and the Steeles/Bayview intersections and at the southbound left turn movement at the Yonge/Steeles intersection. Overall, the rate of infiltration along the predominant routes decreased from the s 45% to 80% before the measures to 40% to 60% after implementation of the measures.

The above results notwithstanding, variations between model predictions and field data were also noted. A notable difference occurred on Yonge Street between Steeles and Highland Park where traffic volumes decreased instead of increasing as predicted by the model. These variations were attributed to a number of factors, the most significant of which was the difference between the modelled and studied systems. In contrast to the model analysis that assumed implementation of the full range of measures including signal timing adjustments, the "after" studies were undertaken after only partial implementation of the measures. With signal timing adjustments, additional changes in flow patterns can be expected. Moreover, whereas the 100% compliance was assumed in the model, the data indicated low compliance ranging from 50 to 75%. A better match between the model results and the field data will be expected with time when enforcement takes effect and compliance increases to more acceptable levels.

Table 5: Observed Before and After Traffic Volumes during AM peak period

Street Name	Section	Model Results [vph]			Actual Counts* [vph]		
		Base	After	Change	Before	After	Change
Yonge St.	Steeles to Highland Park	3698	4141	12%	3673	3435	-6%
Yonge St.	Clark to Elgin	3335	3535	6%	3705	3022	-18%
Bayview Ave.	Steeles to Proctor	2465	2844	15%	2720	3022	11%
Bayview Ave.	Laureleaf to John	3020	3104	3%	3330	3199	-4%
Steeles Ave.	Yonge to Willowdale	2579	2855	11%	2568	2303	-10%
Steeles Ave.	Henderson to Bayview	3055	3448	13%	3483	3713	7%
John St.	Yonge to Henderson	701	842	20%	772	652	-16%
John St.	Henderson to Bayview	1267	1634	29%	1506	1664	10%
Henderson Ave.	Steeles to Grandview	525	580	11%	556	672	21%
Henderson Ave.	Grandview to Doncaster	800	812	2%	883	813	-8%
Willowdale Ave.	Steeles to Highland Park	543	473	-13%	536	396	-26%
Glen Cameron	Dudley to Henderson	590	365	-38%	350	267	-24%
Proctor Ave.	Henderson to Bayview	706	447	-37%	696	452	-35%
Clark Ave.	Dudley to Henderson	398	503	26%	337	436	29%
Doncaster Ave.	Yonge to Henderson	549	431	-21%	641	386	-40%
Highland Park	Yonge to Willowdale	173	123	-29%	155	74	-52%
Woodward Ave.	Yonge to Willowdale	166	70	-58%	122	80	-34%
Grandview Ave.	Yonge to Willowdale	216	59	-73%	132	104	-21%

*Before counts were undertaken in February 2005, after counts were undertaken in December 2005

The preliminary data generally confirmed that the measures functioned as intended and resulted in reduced volumes on key infiltration routes in accordance to the model predictions. These results underscore the advantages of using micro-simulation in the analysis. However, further analysis of volume changes will be necessary when traffic flow patterns become more stable after the full range of measures are implemented and compliance levels to the turn prohibition signs reach acceptable levels.

CONCLUSIONS

This paper has outlined the technical analysis and the public consultation process for a Neighbourhood Infiltration Study in the Thornhill Community in the Town of Markham. The technical analysis involved micro-simulation modelling that was necessary to quantify impacts of the proposed counter-measures. The measures included turn restriction signs, signalization and signal timing adjustments.

The analysis confirmed that the proposed measures would result in positive benefits to the community by reducing traffic volumes on key infiltration routes. Those gains notwithstanding, traffic volumes on some streets would inevitably increase. The public consultation process provided residents with an opportunity to participate in the study through their representatives and at the public meeting where a strong support for the recommended measures was noted. Preliminary traffic data following implementation of the turn restriction signs confirmed reduced infiltration rates through the community in general agreement to the model predictions. However, further monitoring and analysis will be required to confirm the long term travel pattern changes after the full range of measures are implemented.

It was concluded that simple solutions such turn prohibitions could be effective in controlling neighbourhood infiltration problems if well planned and evaluated. Moreover, the use of innovative technical analysis methods with the ability to clearly demonstrate study findings could be instrumental to the success of such neighbourhood studies.

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