DURHAM HIGHWAY 2 TRANSIT PRIORITY MEASURES

Class Environmental Assessment and Design
(Macroscopic and Microscopic Modelling)

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Abstract

In recent years, macroscopic and microscopic simulation modelling have become widely used among transportation engineers and planners, and accepted as a means to assess and evaluate existing and future traffic conditions or determine the feasibility of proposed infrastructure. Hybrid modelling, however, is not as commonly used, where macroscopic models are used in conjunction with microscopic models to determine the feasibility of transit infrastructure.

This paper presents the hybrid modelling process by incorporating the dynamic user equilibrium technique obtained from EMME/3 macroscopic models and the microscopic simulation results using VISSIM. The objective of the study was to examine potential roadway modifications to facilitate priority transit service along Durham Regional Highway 2 (Highway 2) in Ajax and Pickering. The study is seen as the first step towards a planned bus rapid transit service (BRT) connecting Durham Region to rapid transit in the City of Toronto. The alternatives examined include curbside bus-only lanes, High-Occupancy Vehicle (HOV) lanes, mixed traffic lanes, median transit way and the do-nothing alternative. The study required building a regional road network model that mainly encompassed arterials and collectors in the City of Pickering and the Town of Ajax, including approximately 10 km long Highway 2 where the BRT is planned to run.

To conduct the BRT feasibility study, an extensive data collection was undertaken including traffic volumes at key intersections and also 24-hour traffic volumes, speeds, and travel times along Highway 2. The data collected were crucial in the modelling process, that ensuring that VISSIM model accurately replicated the existing traffic conditions at key intersections.

The study focused on analysing the PM peak period only rather than the AM Peak and Weekend peak periods, as it was determined to be the critical period. The study horizon years were 2016, which coincides with the opening year for the "Quick Win" and 2021, five years later, to assess the performance of the transit priority measures design concepts. The study results concluded that the preferred design of widening Highway 2 for Quick Win initial BRT service is having the buses running along a dedicated curb side lane. The calibration and validation process was effective and served as a crucial tool in arriving at the preferred BRT design concept.

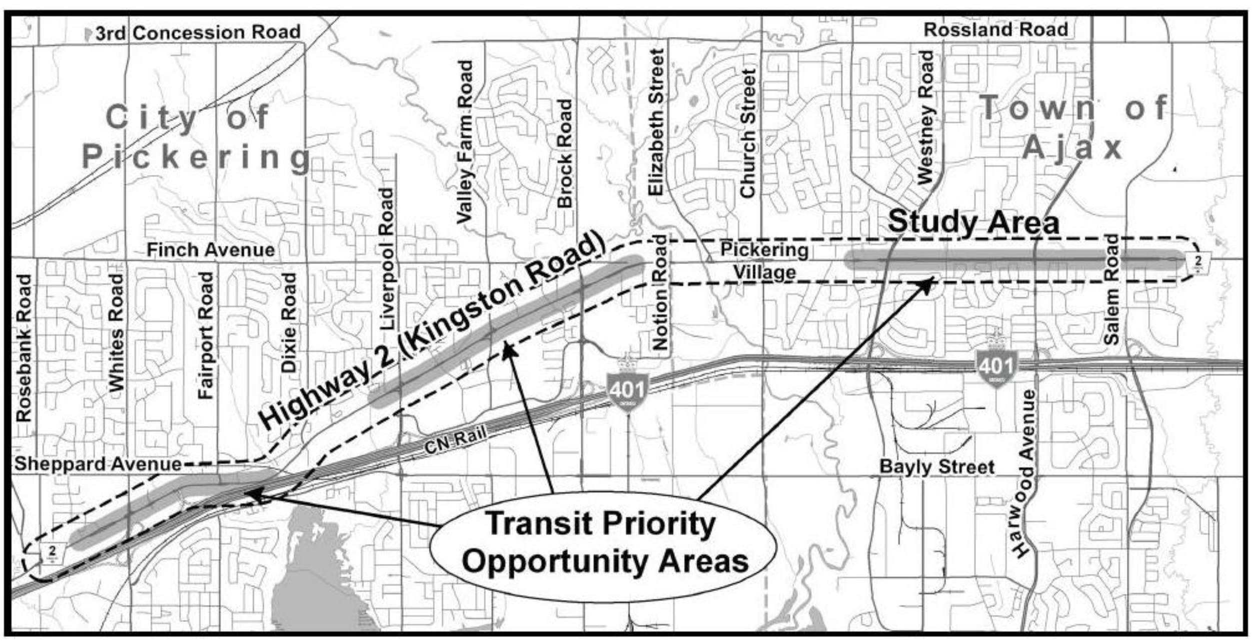
AECOM was the consulting firm retained by the Region of Durham to undertake the study, where the author contributed to this study.

1. Introduction

Durham Regional Highway 2 (Kingston Road in the Town of Ajax and the City of Pickering) is The Regional Municipality of Durham's (Durham Region) primary transit corridor. It connects the urban areas of Durham Region's lakeshore municipalities. In recognition of this key role, the Province of Ontario has committed funding to implement Stage one of a Bus Rapid Transit (BRT) service on Highway 2. A key component of the BRT service is construction of road works to provide priority for transit (buses). In 2011, the Region initiated a Schedule 'C' Municipal Class Environmental Assessment (EA) to study alternative priority measures. The study investigated potential roadway modifications and widening of Highway 2 corridor to facilitate priority transit service along Highway 2 in the Town of Ajax and the City of Pickering.

The study examined three priority areas along Highway 2, in the vicinities of Whites Road to Fairport Road, Liverpool Road to Brock Road, and Westney Road to Salem Road (see Figure 1). The study corridor is approximately 10 km stretching from the Town of Ajax in the east to the City of Pickering in the west. The road widening alternatives examined included curbside bus-only lanes, High-Occupancy Vehicle (HOV) lanes, mixed traffic lanes, median transit way and the do-nothing alternative.

Figure 1: Map of Highway 2 Study Corridor



2. Study Approach

The study approach consisted of five stages which helped examine the existing network traffic operational conditions. The first stage was to determining the study areas for macroscopic modeling using EMME and for microscopic modeling using VISSIM. The second stage was to undertake data collection. Third stage was modelling and calibration and the fourth stage was to forecast traffic volumes at different horizon years along major corridors that were gathered from EMME model and used in VISSIM model. The fifth and final step was to cross-compare results obtained from each alternative to arrive at the preferred design.

2.1 Study Area

The objective of the study is to examine the performance of each BRT scenario along Highway 2, and also to assess potential vehicular infiltration to the local roads. An EMME subarea model for Ajax and Pickering was created large enough to include the farthest potentially impacted municipal roads on the north and south of both municipalities, to forecast traffic volumes as well as determine the level of traffic infiltration for each scenario. For the VISSIM model, separate scaled down study areas were used for each municipality, Ajax and Pickering, as the purpose of the assessment was to examine the traffic operations along the corridor within the vicinity of Highway 2.

As shown in Figure 2, the EMME subarea model limits covered most of the urban area in both municipalities, and the scaled down study area used in VISSIM assessment.

Figure 2: Subarea and VISSIM models Study Area Limits

2.2 Traffic Data Collection

The data collected as part of the study included turning movement counts (TMC) at key signalized and unsignalized intersections, Automatic Traffic Recorder (ATR) counts along major corridors, and speed within the study area. TMC's and ATR counts were undertaken on the same day in each municipality. This process was followed to ensure consistency in traffic volumes at each intersection, and for ease of balancing volumes. In addition, extensive historical traffic volumes were obtained from the Region of Durham to complement the data collected. A thorough field survey was also performed to collect posted speed limits and confirm lane configurations including turning lanes and channelization at intersections, plus locations of on-street parking. Finally, a Region of Durham Synchro model was used to obtain signal timings at intersections within the study area.

2.3 Modelling and Calibration

2.3.1. Macroscopic Modelling (Using EMME Software)

In order to forecast travel demands along the corridors, a sub-area model was built from Durham Region's EMME model where the network and zone system were kept from the original model for consistency with the forecasts that the Region would produce for various planning studies. Since the purpose of the study was to assess potential traffic infiltration, the zone system and road network were refined to enable the infiltration assessment through local roads as a result of different Highway 2 widening alternatives by adding additional network links to represent the minor roads and major access points that were not part in the Durham Regional Model. Furthermore, capacity and volume-delay functions were refined in the EMME sub-area model to better reflect the delays that drivers experience and their effects in their route choice. Synchro turning delay estimates were used as the turn delay penalties in the EMME model.

After completion of the initial calibration work to an acceptable level of detail, a demand adjustment process was undertaken to modify the base matrix for the sub-area model to match the observed turning volumes for the PM peak hour (worst case scenario used for the VISSIM modelling). The demand adjustment process is the final step in the modelling process that makes adjustments for local trips that are not represented as well in macro models (i.e linked trips or mid trip stops). The process adjusts the matrix to include intrazonal trips that are not typically included in the assignment runs in macro models; and it captures the influence of midblock entrances which can add or remove trips from the network.

Figures 3, 4 and 5 illustrate the correlation between simulated and observed link volumes on the entire sub area network, on Highway 2 itself, and for the Highway 2 turning volumes.

Figure 3 – 2010 Observed vs Simulated Link Volumes

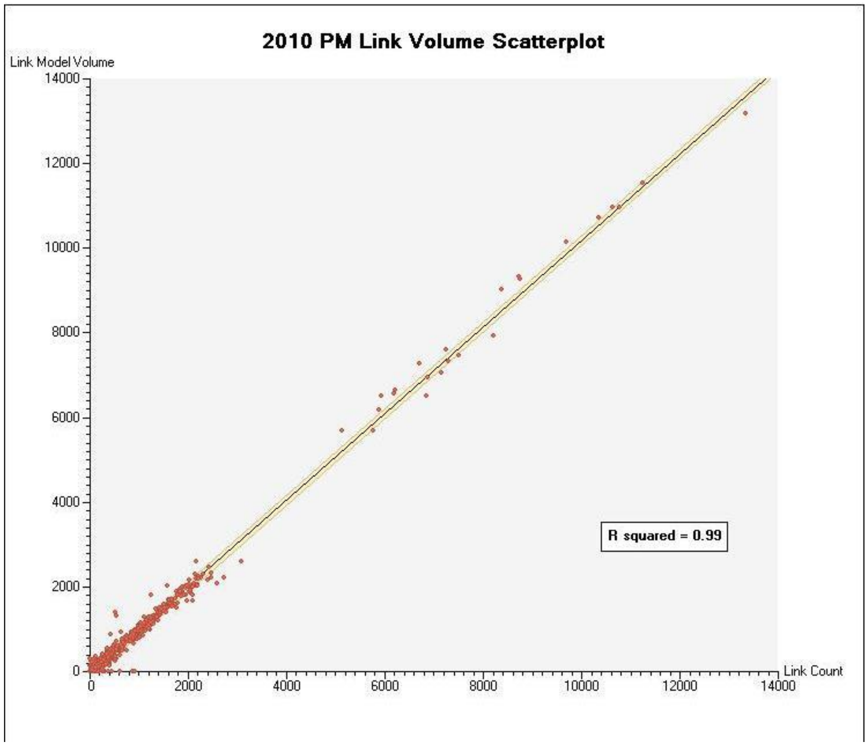


Figure 4 – Highway 2 Simulated vs Observed Volumes

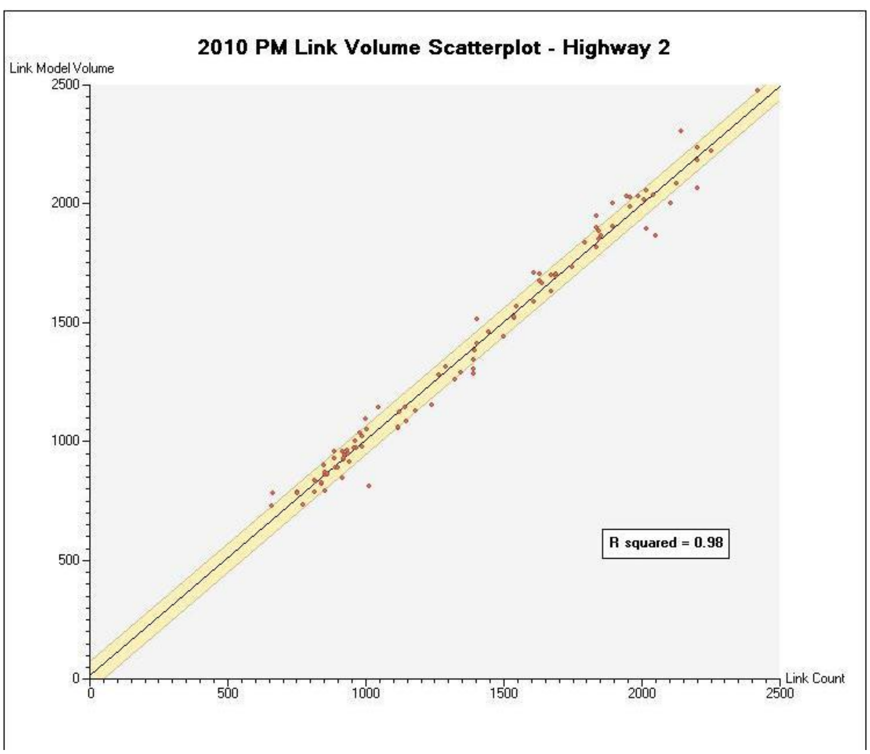
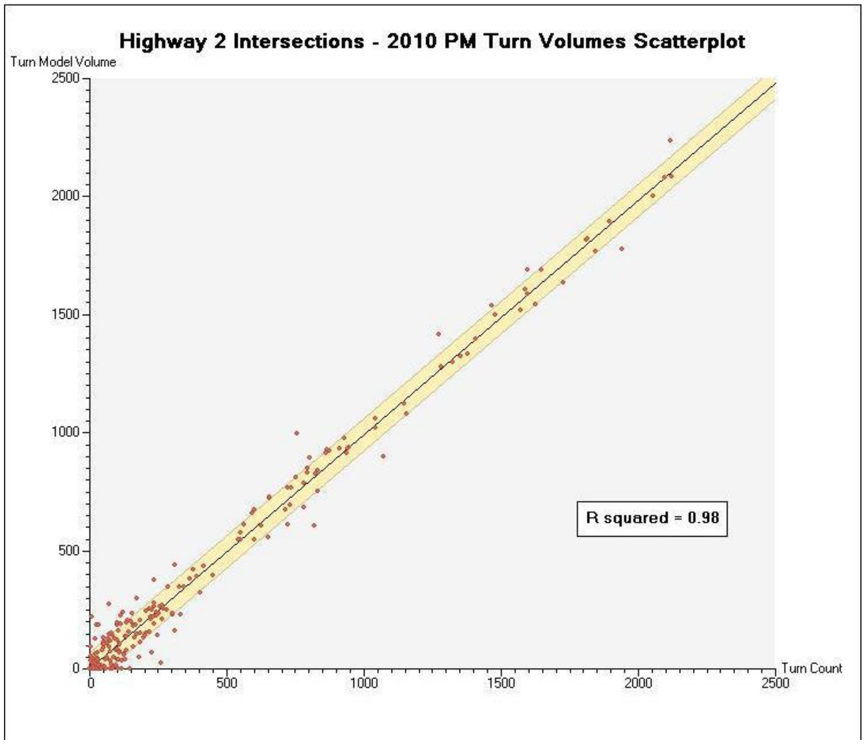


Figure 5 – Highway 2 Simulated vs Observed Turning Volumes



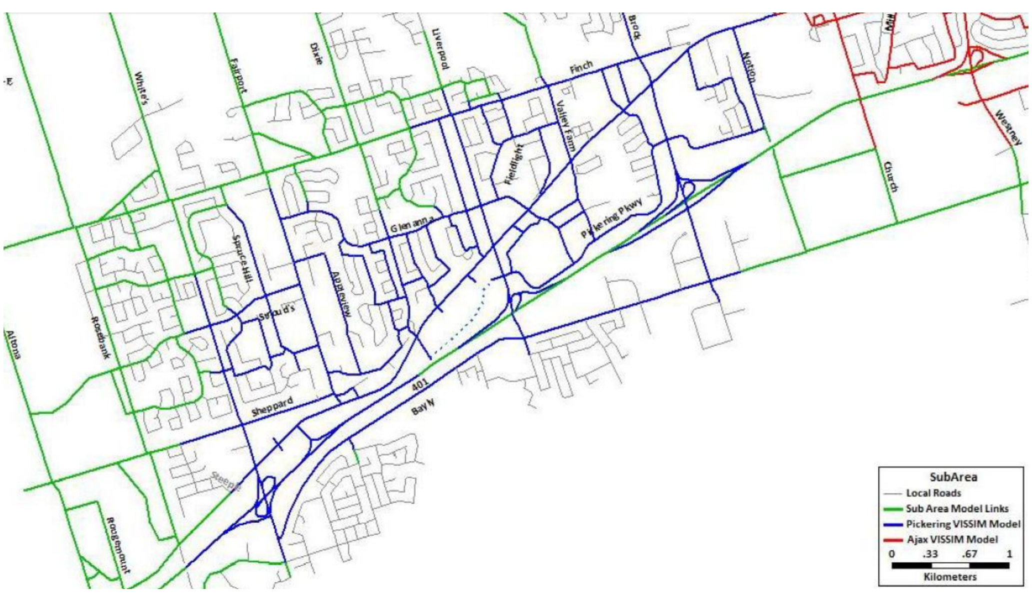
2.3.2. Microscopic Modelling (Using VISSIM)

Separate VISSIM models were developed for the Ajax and Pickering study areas to improve the micro simulation run times given the size of the respective networks. The Ajax model, as illustrated in Figure 6, includes the area bounded by Elizabeth Street to east of Salem Road and from Delaney Drive / Magill to Highway 401 / Station Street, in the south. The Ajax VISSIM model includes 11,653 links and 33 traffic signals. The Highway 401 interchanges were simulated in the model, but Highway 401 itself was not included in order to reduce calibration effort, as it was included in the EMME models for each alternative and any changes in travel patterns obtained from the macroscopic models were then included in VISSIM models.

Figure 6 – Ajax VISSIM Model Limits

The Pickering model, as illustrated in Figure 7, includes the area bounded by west of Whites Road to East of Notion Road and from Finch Avenue / Glenanna Avenue to Bayly Street. The model includes 11,293 links and 44 traffic signals. Similar to the Ajax model, the Highway 401 interchanges are simulated in the model but Highway 401 itself was not included in order to reduce calibration effort.

Figure 7 – Pickering VISSIM Model Limits



The VISSIM Model Calibration was undertaken at two levels; the first level compared the intersection turn volumes with observed results, and then the corridor travel times were compared to travel times from the Durham Region travel time survey data for the Highway 2 corridor.

Intersection turn volume calibration was undertaken using the average of at least 4 simulation runs with different random seeds that control the generation of unique vehicles into the network. Since each vehicle / driver exhibits different driver behaviours (based on a standard distribution curve), the use of random seeds and the averaging of results will provide an average travel time that is comparable to a series of travel time runs that would be used to collect observed data.

The calibration results were assessed using the GEH statistic, as calculated below.

$$GEH = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$

The calibration targets were achieved and in some cases exceeded the FHWA micro-simulation best practices for both Ajax and Pickering. Table 1 summarizes the VISSIM model calibration results for the Ajax model. Based on a summary of all major intersections, 94% of the turn volumes met the GEH target of 5, indicating a high level of calibration with observed volumes. On Highway 2 and Salem Road individually, these results are 97% and 100% respectively. Harwood Avenue intersections achieved 95% of turns within the calibration target and Westney Road fell little short with only 78% of turn volumes within GEH 5, although 22% were within GEH of 10.

Table 1: VISSIM Link Calibration Results – Ajax

Row Title	% of Turn Volumes GEH <5	% of Turn Volumes 5< GEH <10	% of Turn Volumes GEH >10
All Major Intersections	94%	7%	0%
Highway 2	97%	3%	0%
Westney Road	78%	22%	0%
Harwood Avenue	95%	5%	0%
Salem Road	100%	0%	0%

For the Pickering model, as summarized in Table 2, 92% of all major intersection turning movements met the GEH calibration target of 5 or better and Highway 2 and Whites Road individually also achieved 91% of turn movements achieving this target. Liverpool Road and Brock Road achieved the GEH target on 85% of the turning movements, while Bayly Street fell slightly short with 83% of turning volumes meeting the GEH target of 5 or better.

Table 2: VISSIM Link Calibration Results – Pickering

Row Title	% of Turn Volumes GEH <5	% of Turn Volumes 5< GEH <10	% of Turn Volumes GEH >10
All Major Intersections	92%	7%	1%
Highway 2	91%	8%	1%*
Whites Road	91%	9%	0%
Liverpool Road	85%	15%	0%
Brock Road	85%	12%	3%*
Bayly Street	83%	13%	4%*
Finch Avenue	100%	0%	0%

*Notes: * Represents one movement that did not meet GEH >10 calibration target*

Tables 3 and 4 summarize the corridor travel time comparisons compared to the travel time survey results that were available from past studies for the Highway 2 corridor in Ajax and Pickering respectively. The target for calibration purposes is to have the simulated travel times within 15% of observed values. Where they do not match within 15% of the observed average travel time, the variance should be within the standard deviation of the observed travel times from the survey – as these travel times were collected two years earlier (2008) and the collection was undertaken using a series of floating car runs and there can be a wide variation between individual observations that can influence the calculated average travel time.

Table 3: VISSIM Travel Time Calibration Results – Ajax

Row Title	Simulated 2010 PM Peak (sec)	Observed 2008 PM Peak (sec)	Standard Deviation of Observed Travel Times (sec)	Difference (sec)	Sim / Obs
Highway 2 – EB	408	411	159	-3 (00:03)	1.01
Highway 2 – WB	426	386	138	+40 (00:40)	1.10
Westney Road - NB	446	325	155	+121 (02:01)	1.37
Westney Road - SB	348	194	79	+154 (02:34)	1.79
Harwood Avenue - NB	198	177	65	+21 (00:21)	1.12
Harwood Avenue - SB	194	181	56	+13 (00:13)	1.07
Salem Road – NB	157	152	57	+5 (00:05)	1.03
Salem Road - SB	160	166	64	-6 (00:06)	0.96

In Ajax, Highway 2 eastbound and westbound results compared well with the observed travel times from the survey in 2008, with simulated travel times coming within 10% of observed times.. Harwood Avenue and Salem Road are also well calibrated in terms of travel times, with simulated travel times between 3% and 12% of observed and the difference well within the standard deviation of the observed values. Westney Road northbound does not achieve the 15% or better variation in simulated travel times but the difference does fall within the standard deviation of the observed values in the travel time survey. This suggests that there is wide variation in the times from the observed runs and the simulated results may still be representative of existing conditions. In the southbound direction, the simulated / observed ratio is worse than the target of 15% and the difference is greater than the standard deviation in the survey run results. This may be related to the operation of Westney Road in the vicinity of the GO train station entrance, where the extreme peaking during the period when a train arrives is difficult to simulate in detail. This difference, however, should not materially impact the assessment of Highway 2 corridor performance.

Table 4: VISSIM Travel Time Calibration Results – Pickering

Row Title	Simulated 2010 PM Peak (sec)	Observed 2008 PM Peak (sec)	Standard Deviation of Observed Travel Times (sec)	Difference (sec)	Sim / Obs
Highway 2 – EB*	271	344	86	-73 (01:13)	0.79
Highway 2 – WB**	328	380	96	-52 (00:52)	0.86
Whites Road - NB	508	294	63	+214 (03:34)	1.73
Whites Road - SB	397	374	77	+23 (0:23)	1.06
Liverpool Road - NB	225	209	47	+16 (00:16)	1.08
Liverpool Road - SB	210	248	79	+38 (00:38)	0.85
Brock Road – NB***	262	427	144	-165 (02:45)	0.61
Brock Road – SB***	267	313	68	-46 (00:46)	0.85

*Notes: * Whites Road to Valley Farm Road – observed values influenced by construction on Brock Road North*
*** Brock Road to Boyers Entrance*
**** Under construction in 2008.2009 north of Highway 2*

In Pickering, Highway 2 eastbound and westbound are relatively well calibrated compared to the observed travel times from the survey in 2009 with simulated travel times within 10% of observed for the westbound direction, although the eastbound direction does not meet the 15% target. In both directions, the difference in travel time is within the standard deviation of the travel time runs used to calculate the average of the observed values. Travel times on Whites Road southbound, Liverpool Road, and Brock Road southbound are also within the calibration target of 15% and on each of these segments the difference in travel times is within the standard deviation of the observed run results.

Whites Road northbound and Brock Road northbound both fall outside of the two calibration targets. For Brock Road northbound, it is recognized this segment of road was under construction during 2008/2009 when the survey was completed, and hence the VISSIM model is unable to simulate the delays experienced (hence the lower travel times in the simulation results). For Whites Road northbound, the difference in the simulation results should not materially impact the assessment of Highway 2 performance within the EA study area.

3. Assessment of Highway 2 Widening Alternatives

Transit operation assessments for each widening alternative were undertaken using the calibrated VISSIM base model for the future horizon years. The future traffic models for each widening alternative corresponding to 2016 and 2021 were extracted from the EMME Regional model where the network reflected the proposed roadway improvements in the surrounding road network.

The revised turning volumes and demands were input into the VISSIM model to obtain detailed operational statistics for each of the various BRT alternatives, including transit travel time, auto travel time, and intersection delays. For the purpose of simulating bus traffic, it was assumed that the Highway 2 BRT service would initially run on 7.5 minute headway during the peak periods, resulting in 8 buses per hour in both in the AM and PM peaks. The bus will essentially replace the Route 94 GO Bus service running along Highway 2, and will include stops at all major intersections within the EA study area. An initial assumed 30 second dwell time was utilized in the VISSIM model at each stop to allow for passenger loading / unloading. This may be revised as Durham Region Transit finalizes the actual service plan, ridership forecasts, and Transit Priority strategy that will be used for the Highway 2 BRT service. The same assumptions were used for the simulation of each design alternative so that the transit and auto travel time results would be comparable and would be based on how well the buses and autos performed for each design treatment as opposed to any differences in operational policies applied.

This process was repeated for the 2021 horizon year to examine future operations approximately 5 years after implementation of the Quick Win initial transit road works improvement.

3.1 Comparison of Transit Delay

The assessment of transit delays compares the transit travel time for each scenario compared with the free flow travel time (including dwell time at stops) that a transit vehicle should incur if there is no conflict with other vehicles or other sources of delay that impedes their operation. Within Transit Priority Opportunity Area 1, the HOV/BRT and Curb BRT scenarios both result in no delays to transit vehicles in 2016 and 2021 in the EB PM Peak travel direction as shown in Tables 5 and 6. The Median BRT scenario results in a modest 0.2 min average delay per bus in 2016, increasing to 0.5 min per bus by 2021. The Mixed Traffic widening scenario results in a 0.5 min average delay per bus in both horizon years. In the off peak (WB direction) the alternatives essentially rank the same, although the transit delays are slightly higher for the Curb BRT and HOV/BRT scenarios and are increased to 0.9 min / bus for the Median BRT scenario.

Table 5: Transit Delays – Transit Priority Opportunity Area 1 – Pickering

2016 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	5.9	5.9	5.9	5.9
Transit Travel Time EB (min)	6.4	5.9	5.9	6.1
Delay (min)	**0.5**	**0.0**	**0.0**	**0.2**
Free Flow Time WB (min)	5.9	5.9	5.9	5.9
Transit Travel Time WB (min)	6.3	6.2	6.2	6.8
Delay (min)	**0.4**	**0.3**	**0.3**	**0.9**

Table 6: Transit Delays – Transit Priority Opportunity Area 1 – Pickering

2021 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	5.9	5.9	5.9	5.9
Transit Travel Time EB (min)	6.4	5.9	5.9	6.4
Delay (min)	**0.5**	**0.0**	**0.0**	**0.5**
Free Flow Time WB (min)	5.9	5.9	5.9	5.9
Transit Travel Time WB (min)	6.0	6.1	5.9	6.8
Delay (min)	**0.1**	**0.2**	**0.0**	**0.9**

As shown in Tables 7 and 8, for Transit Priority Opportunity Area 2, between Brock Road and Notion Road in Pickering, the HOV/BRT and Curb BRT scenarios both result in modest delays to transit vehicles (3.3 min) in 2016 and 2021 in the EB PM Peak travel direction. The Median

BRT scenario results in a 5.0 min average delay per bus in 2016, reducing slightly to 4.7 min per bus by 2021. The Mixed Traffic widening scenario results in a 3.4 min average delay per bus in 2016, increasing to 3.8 min per bus by 2021. In the off peak (WB direction) the alternatives essentially rank the same, although the transit delays are slightly reduced compared to the peak direction.

Table 7: Transit Delays – Transit Priority Opportunity Area 2 – Pickering

2016 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	7.0	7.0	7.0	7.0
Transit Travel Time EB (min)	10.4	10.3	10.3	12.0
Delay (min)	**3.4**	**3.3**	**3.3**	**5.0**
Free Flow Time WB (min)	7.0	7.0	7.0	7.0
Transit Travel Time WB (min)	8.9	10.0	9.8	10.6
Delay (min)	**1.9**	**3.0**	**2.8**	**3.6**

Table 8: Transit Delays – Transit Priority Opportunity Area 2 – Pickering

2021 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	7.0	7.0	7.0	7.0
Transit Travel Time EB (min)	10.8	10.3	10.3	11.7
Delay (min)	**3.8**	**3.3**	**3.3**	**4.7**
Free Flow Time WB (min)	7.0	7.0	7.0	7.0
Transit Travel Time WB (min)	13.5	9.6	10.0	10.5
Delay (min)	**6.5**	**2.6**	**3.0**	**3.5**

As shown in Tables 9 and 10, within Transit Priority Opportunity Area 3 in Ajax, the Curb BRT scenario provides a slightly better performance than the HOV and Median BRT scenarios in terms of transit delays, and all of the dedicated BRT facilities perform much better than the mixed traffic widening scenario, which results in average transit delays of 4.3 minutes per bus in 2016 and 5.2 minutes per bus in 2021 in the EB PM peak travel direction.

By 2021, as summarized in Table 10, the HOV BRT alternative performs slightly better than the Curb BRT although the benefits of the Median BRT alternative are beginning to result in the lower transit delays in this segment in both directions of travel

Table 9: Transit Delays – Transit Priority Opportunity Area 3 – Ajax

2016 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	12.3	12.3	12.3	12.3
Transit Travel Time EB (min)	16.6	12.9	12.8	12.9
Delay (min)	**4.3**	**0.6**	**0.5**	**0.6**
Free Flow Time WB (min)	12.3	12.3	12.3	12.3
Transit Travel Time WB (min)	13.4	13.7	13.7	13.7
Delay (min)	**1.1**	**1.4**	**1.4**	**1.4**

Table 10: Transit Delays – Transit Priority Opportunity Area 3 – Ajax

2021 PM Peak	Mixed Traffic	HOV / BRT Lanes	Curb BRT Lane	Median BRT
Free Flow Time EB (min)	12.3	12.3	12.3	12.3
Transit Travel Time EB (min)	17.5	12.6	12.8	11.4
Delay (min)	**5.2**	**0.3**	**0.5**	**-0.9**
Free Flow Time WB (min)	12.3	12.3	12.3	12.3
Transit Travel Time WB (min)	20.8	14.1	14.1	12.7
Delay (min)	**8.5**	**1.8**	**1.8**	**0.4**

4. Conclusions

The hybrid use of a macroscopic and microscopic simulation approach on a large scale road network demonstrated that the methodology is feasible as long as the model is well calibrated. It should be noted that running numerous simulation runs, more than 5 runs, is necessary step to ensure the validity of model calibration. In this study, 8 runs were performed and proved to provide consistent output results.

Additionally, using a hybrid approach, given the availability of the functioning Region wide EMME model, saved significant computational effort compared to using Dynamic Traffic Assignment (DTA) approach found in VISSIM for such a large area. Adjusting the existing EMME network to a finer grain within the study area was relatively straightforward and was shown to provide reasonable results. Focusing the VISSIM modelling on the Ajax and Pickering Highway 2 corridor areas allowed more time and effort to be spent on data collection instead of model creation.

From an overall transportation perspective, the Curb BRT design alternative provides the best performance in each of the 3 Transit Priority Opportunity Areas. From a transit travel time and transit delay perspective, the Curb BRT performs similar to the HOV/BRT design alternative and both of these tend to perform better than the Median BRT alternative when construction is limited to only the Transit Priority Opportunity Areas (i.e. as discontinuous BRT segments, rather than a system). The Curb BRT design alternative is expected to reduce overall bus delays on Highway 2 by approximately 15% compared to base conditions in the Ajax area and by almost 5% in the Pickering area. This is critical in terms of attracting new ridership, maintaining the reliability of service, and encouraging the shift in this corridor from an auto oriented environment to one that provides more balance between the various modes of travel (including pedestrians and cyclists).

Additionally, the Curb BRT alternative also balances the impact to auto traffic on the Highway 2 corridor and, with the exception of the widening for mixed traffic alternative which generally performs the best in this regard. The Curb BRT alternative tends to perform better than the HOV and Median BRT design treatments, particularly as congestion grows to the 2021 horizon. By 2021, the Median BRT option would increase auto delays in the Ajax area by approximately 32% compared to base conditions, while the Curb BRT alternative only results in an approximately 24% increase in auto delays. This highlights the need to implement other broader network improvements to draw the longer distance traffic away from the Highway 2 corridor, prior to moving to the ultimate long term vision of a median LRT system through the study area.

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