Final Report

Saint John Transportation Strategic Plan

Travel Demand Forecasting Model Development

Prepared for City of Saint John
by IBI Group

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1 Introduction

The Saint John Model is a travel demand forecasting model developed as part of Phase 2 of MoveSJ, the City of Saint John's Transportation Strategic Plan. A travel demand forecasting model is a tool used in transportation planning to estimate traffic demand based on where people live, work, shop and go to school. A model can be used to assess city-wide transportation question such as the impacts of population and employment growth, the impacts of changing travel behaviour and use of alternative modes, the impacts of new transit services, the impacts of building new roads or widening existing roads, and the impacts of closures or reduced lanes.

As the City of Saint John continues to grow over the next 25 years, in line with PlanSJ and City's Neighbourhood Plans, the Saint John Model will assist the City in managing growth by identifying potential transportation capacity issues, testing alternative solutions to address those issues, and developing a preferred transportation system to serve future travel needs in Saint John.

The Saint John Model is customized to the City of Saint John. It was developed using observed travel characteristics of residents of Saint John and surrounding areas collected in the 2015 household travel survey conducted in Phase 1 of MoveSJ and traffic count data provided by the City and the Ministry of Transportation and Infrastructure.

This report describes the development of the Saint John Model as a state-of-practice forecasting tool that is sensitive to socio-demographic changes, transportation policy, and new infrastructure.

2 Model Structure

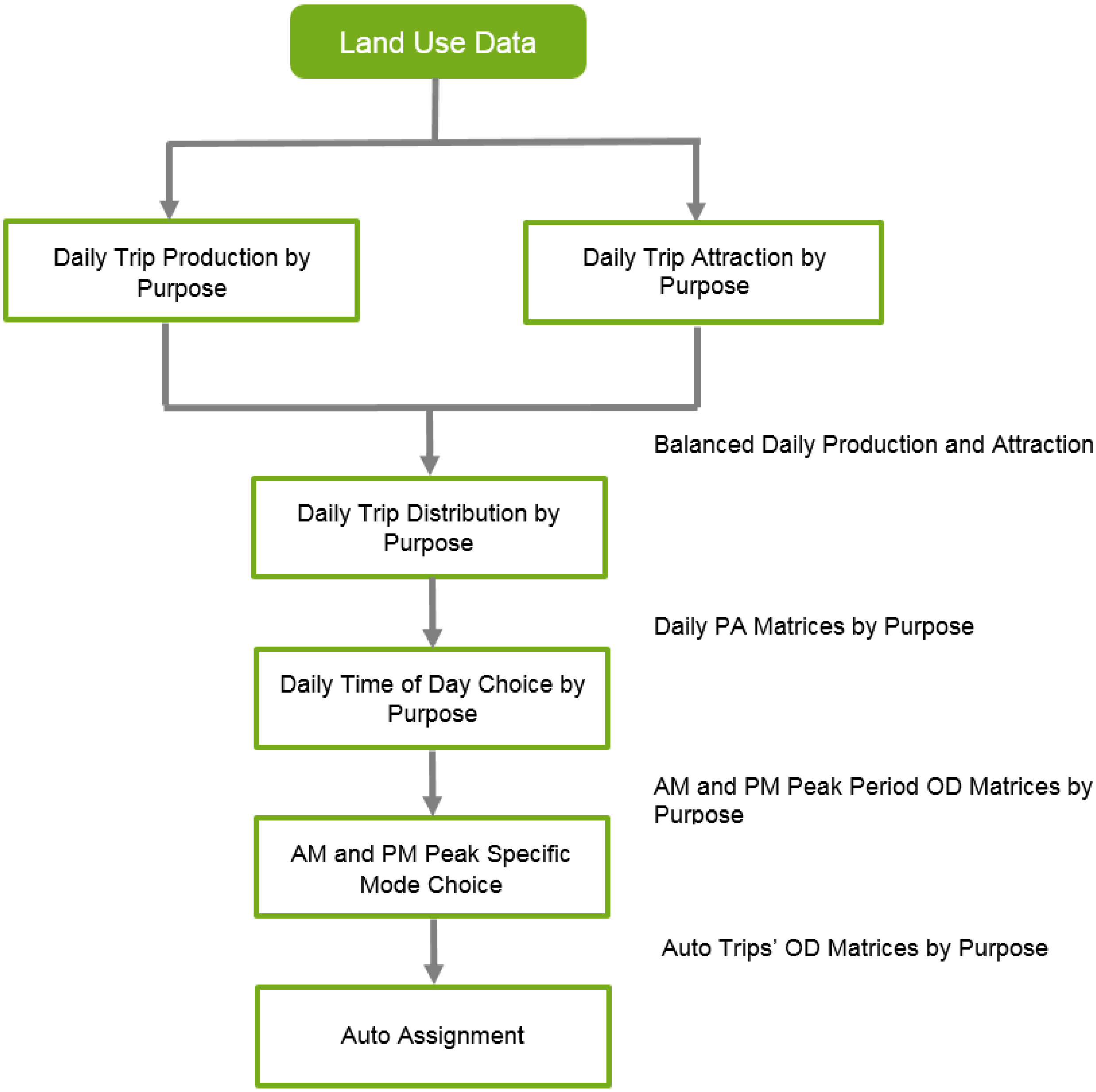
2.1 Architecture

The travel demand model developed follows the four-stage model structure common to most urban transportation forecasting models:

- trip generation – the trip productions and attractions from and to each zone;
- trip distribution – the pairing of trip origins and trip destinations;
- mode choice – the mode(s) used to travel from origin to destination; and
- trip assignment – the routes used from trip origin to trip destination.

The model architecture is illustrated in Exhibit 2.1.

Exhibit 2.1: Model Architecture



2.2 Road Network

The existing road network was built from GIS road network data from the City of Saint John. The network was updated and cleaned for directionality, lanes and road classification. Eight road classifications were used, ranging from Freeways to Rural, as shown in Exhibit 2.2 with the associated network attributes for each class.

Exhibit 2.2: Road Classification

Classification Type	Class	Capacity Per Lane (vphpl)	Free Flow Speed (km/h)
Freeway	1	1,800	60-70
Freeway Ramp	2	1,400	30
Provincial Highway	3	1,200	60
Major Arterial	4	900	50
Minor Arterial	5	700	50
Collector	6	650	30
Local Street	7	500	30
Rural	8	900	40

Lane capacities of links are defined in terms of vehicles per hour per lane (vphpl), and speeds of links are defined in terms of kilometre per hour (km/h).

The existing road network and a complete map showing each road classification are provided Exhibit 2.3 and Exhibit 2.4, respectively.

Exhibit 2.3: Existing Road Network

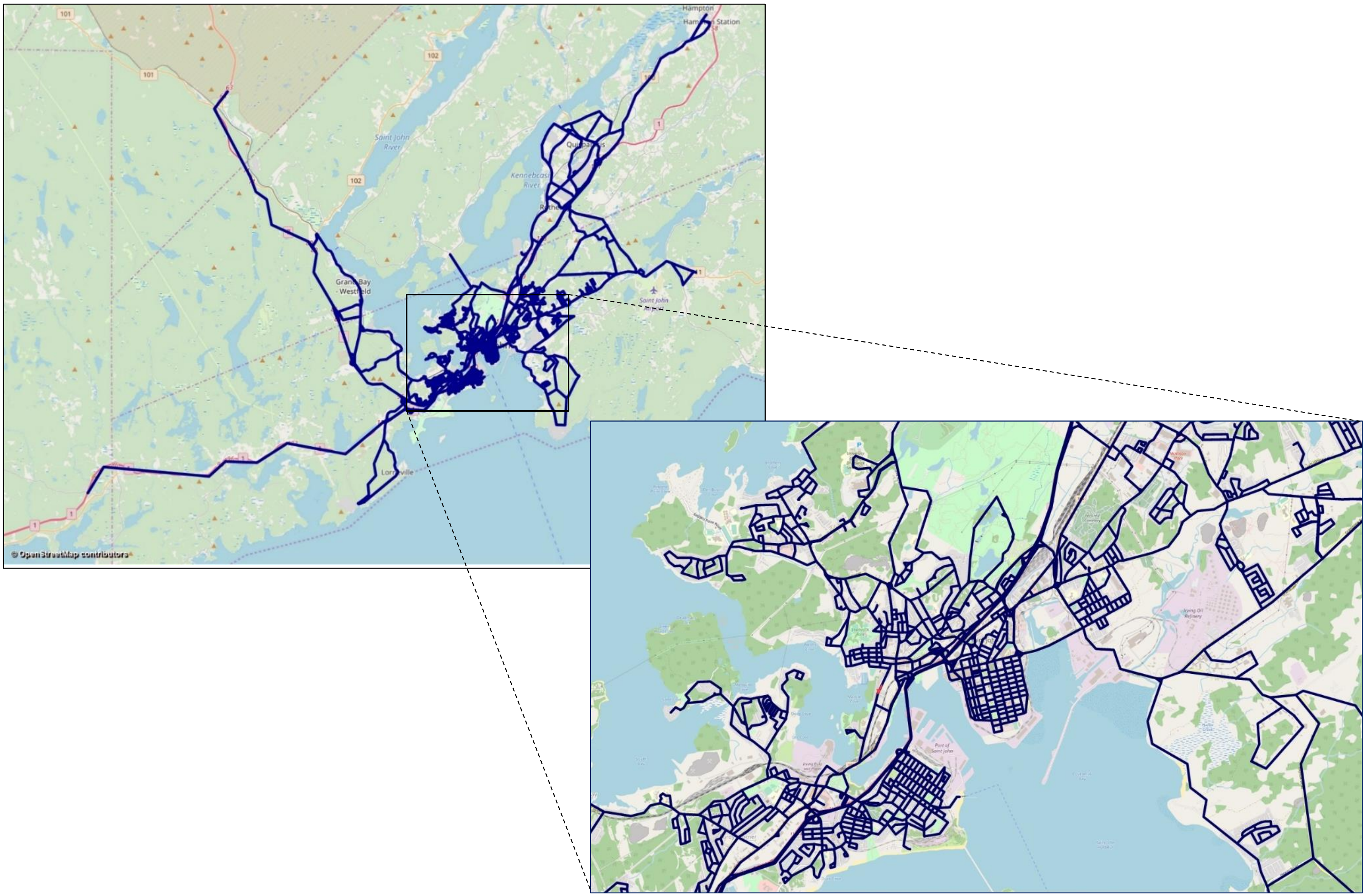
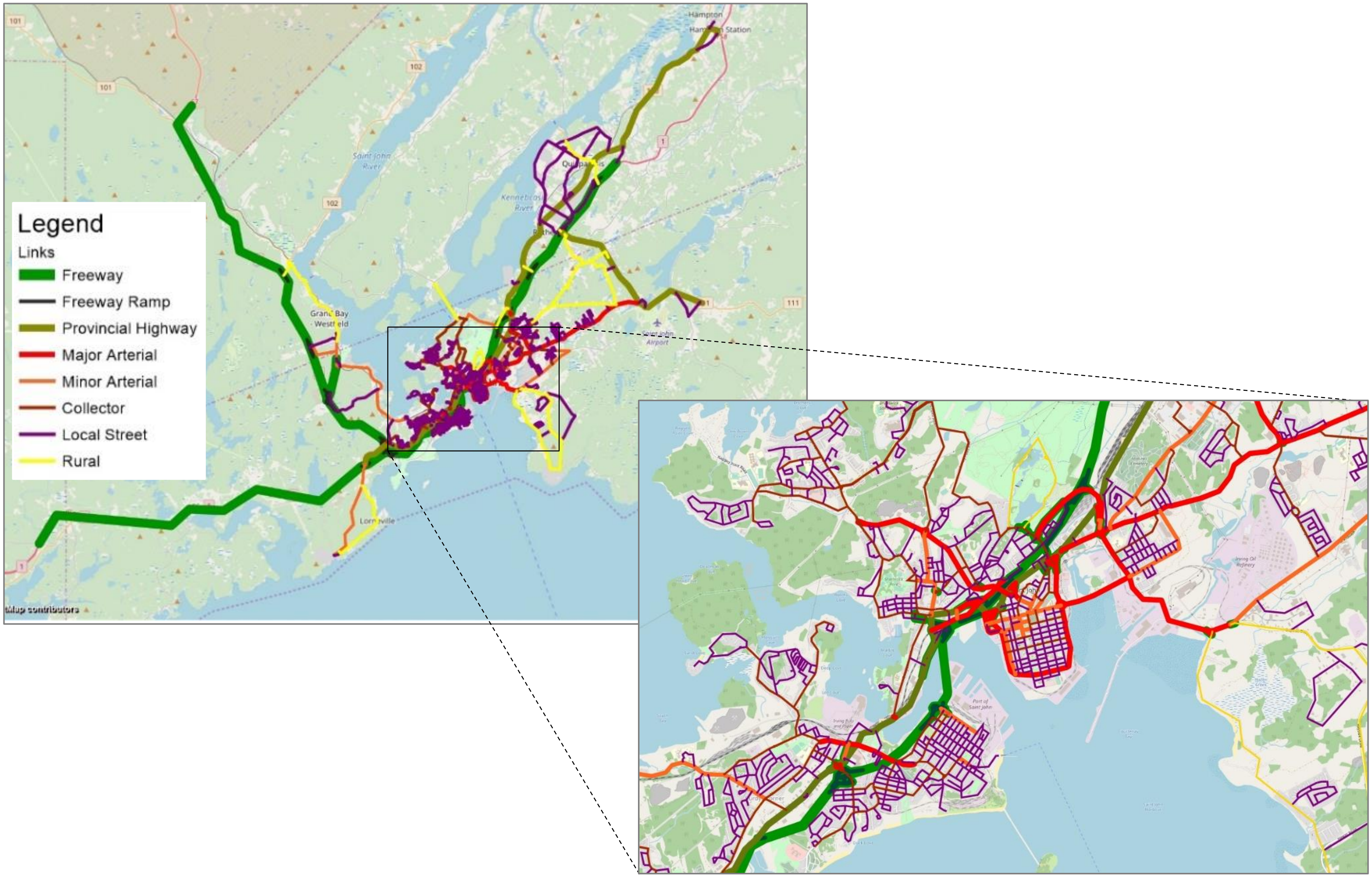


Exhibit 2.4: Road Classifications



2.3 Zone System

A traffic zone system was developed for the Saint John census metropolitan area. The zones within the City of Saint John were based on census dissemination areas (these are to a higher level of disaggregation than the traffic zones originally developed in MoveSJ Phase 1). Four large dissemination areas were further disaggregated based on the geographical distribution of population and employment centres within those zones.

In total, there are 165 traffic analysis zones (TAZ) within the network as shown in Exhibit 2.5, including 137 zones within the City and 28 zones external to the City but inside the study area. There are also 2 external zones to the study area that represent external trips to and from the study area.

2.4 Superzone System

To assist in aggregating model results for analysis, a superzone system was developed that included an aggregation of contiguous zones with similar population and employment levels. In this system, the 165 traffic zones within the study area were aggregated into 12 superzones. The map of the superzones is shown in Exhibit 2.6.

Exhibit 2.5: Traffic Analysis Zone (TAZ) System

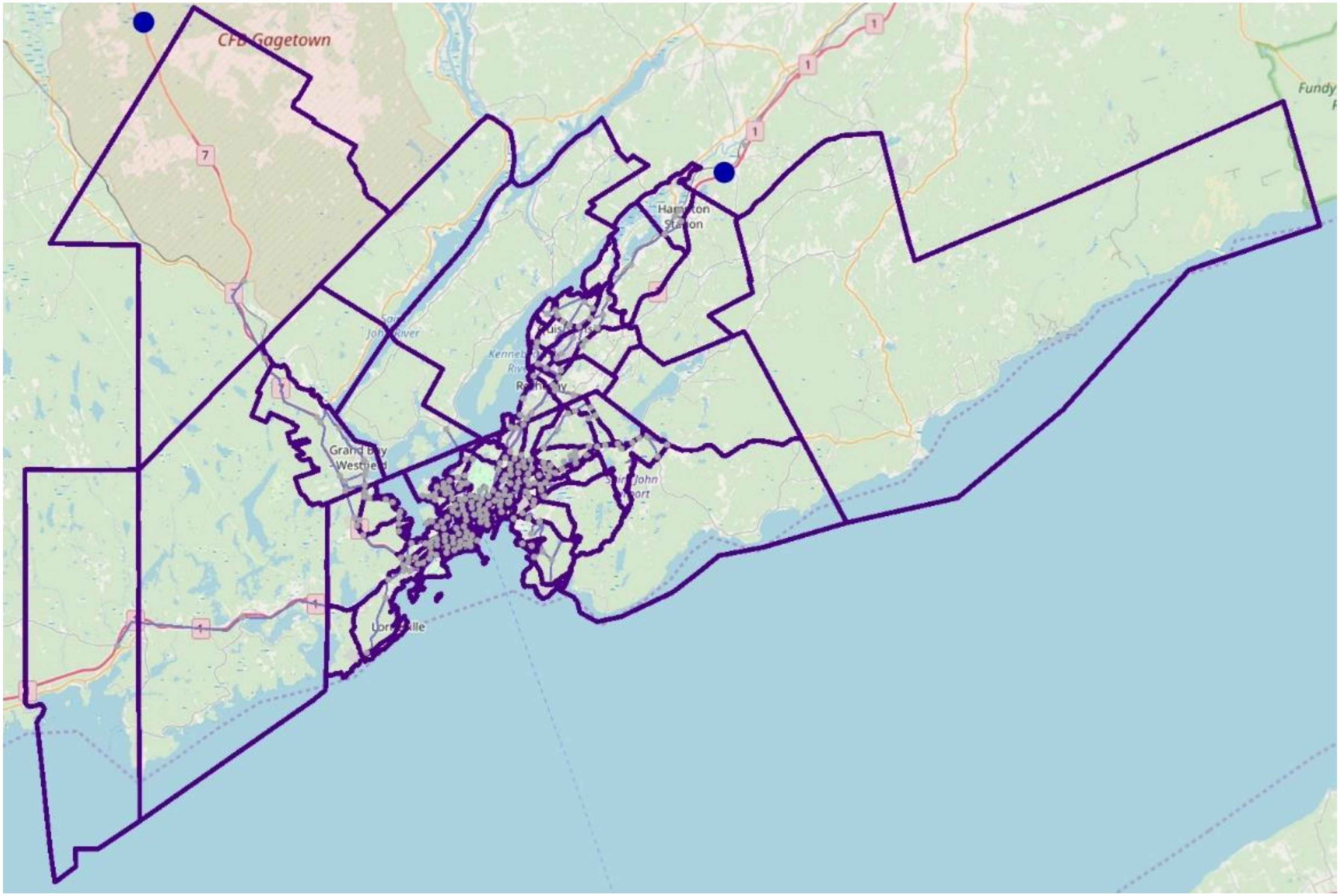
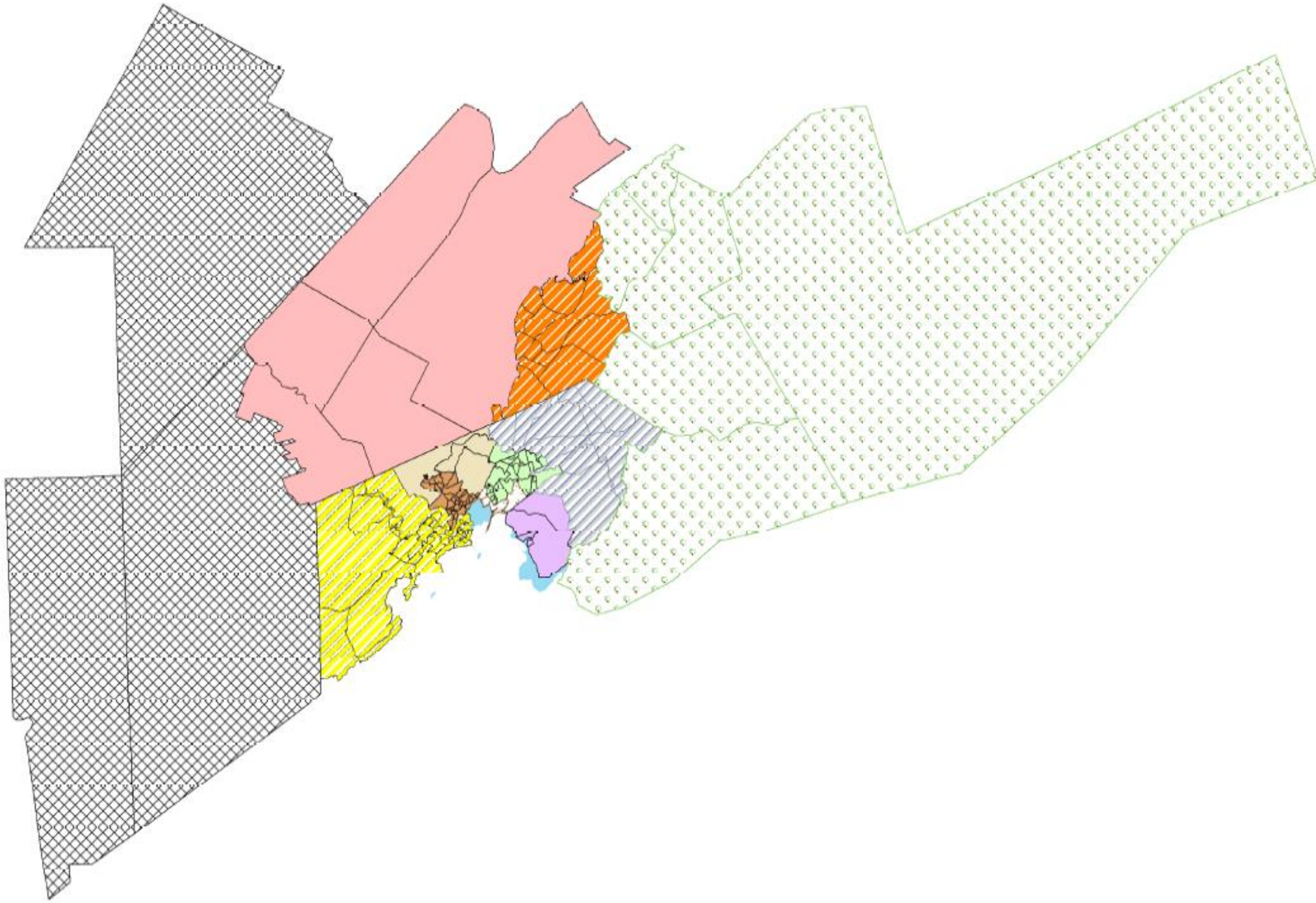


Exhibit 2.6: Superzone System Map



2.5 Model Input Data

2.5.1 Model Estimation Dataset

The travel behaviour data for the model estimation was collected in the 2015 household travel survey undertaken in Phase 1 of MoveSJ. This survey collected travel information from 5% of the households within the City of Saint John and 2.5% in the surrounding suburbs. This data was expanded using 2011 and 2016 census information such that the survey data used for the model represents 2016 population.

The survey data has limited socioeconomic attributes such as occupation type of the respondents. To better model the trip type such as a work or school-related trip, the population in each zone was categorized by age group based on the age distribution of the Census Tract. This better represents the types of trips produced from each zone – for example, school trips and work trips are typically generated by a different age group than.

The attraction of trips to a zone is highly correlated to the amount and type of employment within the zone. Each traffic zone was categorized as either predominantly retail or predominantly non-retail employment based on a review of aerial imagery of the land uses within each zone.

2.5.2 Model Application Dataset

To apply the model, the 2016 Census population and employment data at the traffic zone level, as provided by the City of Saint John, was used for the base year. To apply the model for future years, the projected population and employment totals by traffic zone will be used.

The same approach was taken to prepare the model application dataset as in the model estimation dataset – that is, the distribution of the population within each age group and distribution of employment type (retail versus non-retail) were determined.

3 Travel Demand Model Development

3.1 Trip Generation

Trip generation is the first step in developing a travel demand model. This step includes modelling daily productions and attractions from each zone within the study area. For home-based trips, productions are the home end of a trip and attractions are the non-home end of a trip. In the case of non-home-based trips, the terminology used is origins and destinations instead of productions and attractions. Productions and attractions matrices were converted into origin and destination matrices later in the model process.

Trip production and attraction rates were estimated applying regression on the expanded survey data for four trip purposes:

- home-based work (HBW),
- home-based school (HBS),
- home-based other (HBO), and
- non-home-based (NHB).

The modelled production and attraction rates represent one-directional trip rates. Trip generation rates were estimated at the individual level as a function of zonal attributes such as population and employment. The applied variables and their corresponding estimated coefficients are summarized in Exhibit 3.1 and Exhibit 3.2 for trip production and attraction, respectively.

Exhibit 3.1: Trip Production Estimation Results

	Population				Employment		
Trip Purpose	Age >= 20	Age < 25	Age >= 25	Total Population	Retail	Non-retail	Total Employment
Home-based Work	0.39	-	-	-	-	-	-
Home-based School	-	0.16	-	-	-	-	-
Home-based Other	-	-	-	0.71	-	-	-
Non-home-based	-	-	-	0.11	2.34	0.6	-

Exhibit 3.2: Trip Attraction Estimation Results

Trip Purpose	Population	Employment		
	Total Population	Retail	Non-retail	Total Employment
Home-based Work	-	-	-	0.55
Home-based Other	0.36	1.71	-	-
Non-home-based	0.08	1.91	0.06	-

For home-based school trips the base year observed attraction levels are applied. These attraction rates will be scaled up for the future applications of the model, assuming that school trip demand is directly proportional to population growth.

3.2 Trip Distribution

The next stage after trip generation was distribution of the produced trips within the study area based on the estimated zonal attractions. This stage determines the number of daily trips between each pair of zones. Summing up either the produced number of trips from each zone or attracted number of trips to each zone in the study area is representative of the total number of trips. However, these two numbers may not match based on the estimated trip generation coefficients. Therefore, the total number of attractions were balanced to the total number of productions for all four trip purposes (e.g., HBO, HBS, HBO, and NHB), as it was expected that population data (of which production is a function) is more accurate than the employment data (of which attraction is a function).

Trip distribution was done using a Fratar model for all four purposes. In a Fratar model, the base year observed trip distribution is scaled based on the modelled productions and attractions. To resolve the issue of the limited survey sample, which cannot possibly include all trips to and from all traffic zones, a “seed matrix” was synthesized based on observed trip distribution matrices. In the seed matrix, trips were synthesized wherever trips are expected but either not observed or have a low rate.

3.3 Time of Day

Up to this point of the model, trips were generated and distributed in a daily production and attraction level. At this stage, production and attraction matrices were converted into origin and destination matrices for the AM and PM peak periods. For this purpose, time of day static factors were applied to each bound of home-based tours and each NHB trip. These factors were extracted from the expanded survey data based on the percentage of observed trips during the peak period to the total number of trips of the same purpose. Time of day probabilities for AM and PM peak periods are shown in Exhibit 3.3.

Exhibit 3.3: Time of Day Factors

Trip Type ID	Trip Type Description	Time Period		
		AM Peak	PM Peak	Other
1	HBW - Home to Work	61.8%	5.3%	32.9%
2	HBW - Work to Home	1.8%	64.7%	33.6%
5	HBS - Home to School	91.4%	3.0%	5.6%
6	HBS - School to Home	0.0%	25.0%	75.0%
7	HBO - Home to Other	27.3%	23.2%	49.5%
8	HBO - Other to Home	7.4%	29.7%	62.9%
9	NHB	15.9%	25.8%	58.3%

3.4 Mode Choice

The next step was to estimate the mode split. As travel modes in Saint John are predominantly by private automobile (auto), a static factor was applied for modelling this choice. The probability of choosing auto for travelling between each two super zones was calculated based on the expanded survey data in the peak period and was then disaggregated to the zonal level. The calculated probabilities were multiplied in the AM and PM peak period origin-destination matrices to calculate the number of auto trips between each origin-destination pair.

3.5 Auto Trip Assignment

The last step of the Model involved assigning auto trips to the network. For this purpose, first AM and PM peak period auto trips were converted to AM and PM peak hour trips using peak hour factors calculated from the expanded survey data, as shown in Exhibit 3.4. Conversion of peak periods to peak hour is to model the “peak” or most congested situation of the transportation network. Moreover, lane capacity of the transportation network is reported on a per hour basis. The assignment of peak hour auto trips to the network was done using VISUM, a software platform for traffic analyses and travel demand forecasts.

Exhibit 3.4: AM and PM Peak Hour Factors

Time period	AM (7:30-8:30)	PM (16:30-17:30)
Peak Hour Factor	0.476	0.400

3.5.1 Volume-Delay Functions

The Model uses VISUM’s equilibrium assignment procedure which is based on Wardrop’s first principle. Based on this principle, every traveller chooses his route in a manner that travel time on all alternative routes between each origin-destination pair is equal and shifting between the routes does not change the travellers' travel time. Using an incremental assignment as the beginning point, the equilibrium is gained in multiple iterations.

Volume-Delay Functions (VDFs) are used to estimate the time it takes for a vehicle to travel the length of the link given a specified capacity, link volume, and free-flow speed. VDFs defined in this model take the industry-standard Bureau of Public Roads (BPR) functional form. The BPR function relates link travel times as a function of the volume-to-capacity ratio as show in equation 1 and 2.

$$t_i = t_{0i}\left[1 + asat_i^b\right] \qquad (1)$$

$$sat_i = \frac{q_i}{C.q_{imax}} \qquad (2)$$

Where:

t_{0i} = free-flow travel time on link *"i"*

q_i= flow on link *"i"*

q_{imax} = capacity of link *"i"*

a = constant, equal to 1

b = constant, equal to 2

C = constant, equal to 1

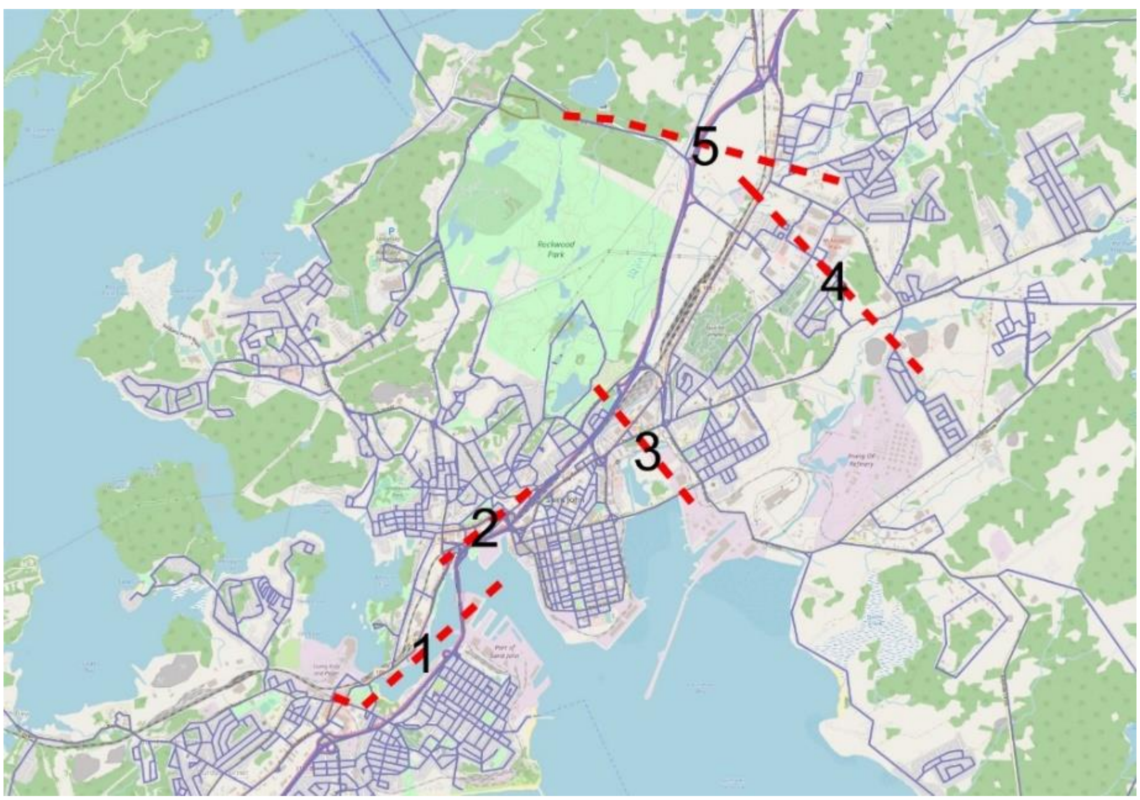
4 Model Calibration and Validation

4.1 Screenline Analysis

A screenline is an imaginary line on a map composed of one or more straight line segments. Screenline analysis is a method to validate the results of a traffic assignment by comparing the results of the model run with observed traffic count data. In this work, five screenlines and eight key locations were used to validate the Model's assignment results against on available traffic count data.

The screenline locations are shown in Exhibit 4.1 (where the red dashed line represents a screenline). There is no strict standard or threshold for matching the modelled volumes to traffic counts in practice; however, the ratio of modelled and observed volumes provides an indication of the "reasonableness" of the match.

Exhibit 4.1: Screenlines Used for Model Validation



4.2 Base Model Adjustments

The results of the initial model run is compared to the traffic counts at the screenlines. The initial base model is then calibrated to better fit the traffic counts. The incremental adjustments used to calibrate the model are reviewed below:

- Base Run 1 – Decreasing the speed on freeways and increasing the speed on local links to match the count volumes on the links, as the model over-assigns demand to the highways.
- Base Run 2 – Increasing the production rates for all zones by 10% to better match the observed total volumes crossing the screenlines.
- Base Run 3 – Increasing the attraction of the downtown superzone and the superzone containing oil refinery site for home-based work trips to better match the observed commute demand to those superzones.

4.3 Origin-Destination Matrix Estimation

The last step in calibrating the Model to better match the observed traffic counts was to estimate the origin-destination matrix. An origin-destination matrix estimation (ODME) involves updating the model-generated origin-destination assignment matrix to a new matrix that is consistent with observed traffic counts.

The upper and lower bound adjustment was capped at 10% and increased incrementally. With allowance for a 20% and 30% ODME for AM and PM peak hours, the model results appears to significantly improve and reflect actual traffic counts. An ODME “adjustment matrix” was developed based on the estimated origin-destination matrix. For this purpose, the differences between the model-generated and ODME estimated origin-destination matrices were found at the 12 by 12 superzone level and was disaggregated to the traffic zone level by weighting the zones within each two superzones based on the number of trips between them. The adjustment is implied on the modelled origin-destination matrix and the assignment is re-run on the adjusted matrix. In this manner, the modelled origin-destination matrix is incrementally adjusted taking advantage of the previous steps of the model assignment.

The modelled AM traffic volumes are shown in Exhibit 4.2 and the resulting volume-to-capacity (v/c) ratio on the road network is presented in Exhibit 4.3. The screenline analysis and spot validation results are shown in Exhibit 4.4 to Exhibit 4.7 for AM and PM peak hours.

Exhibit 4.2: Modelled AM Volumes

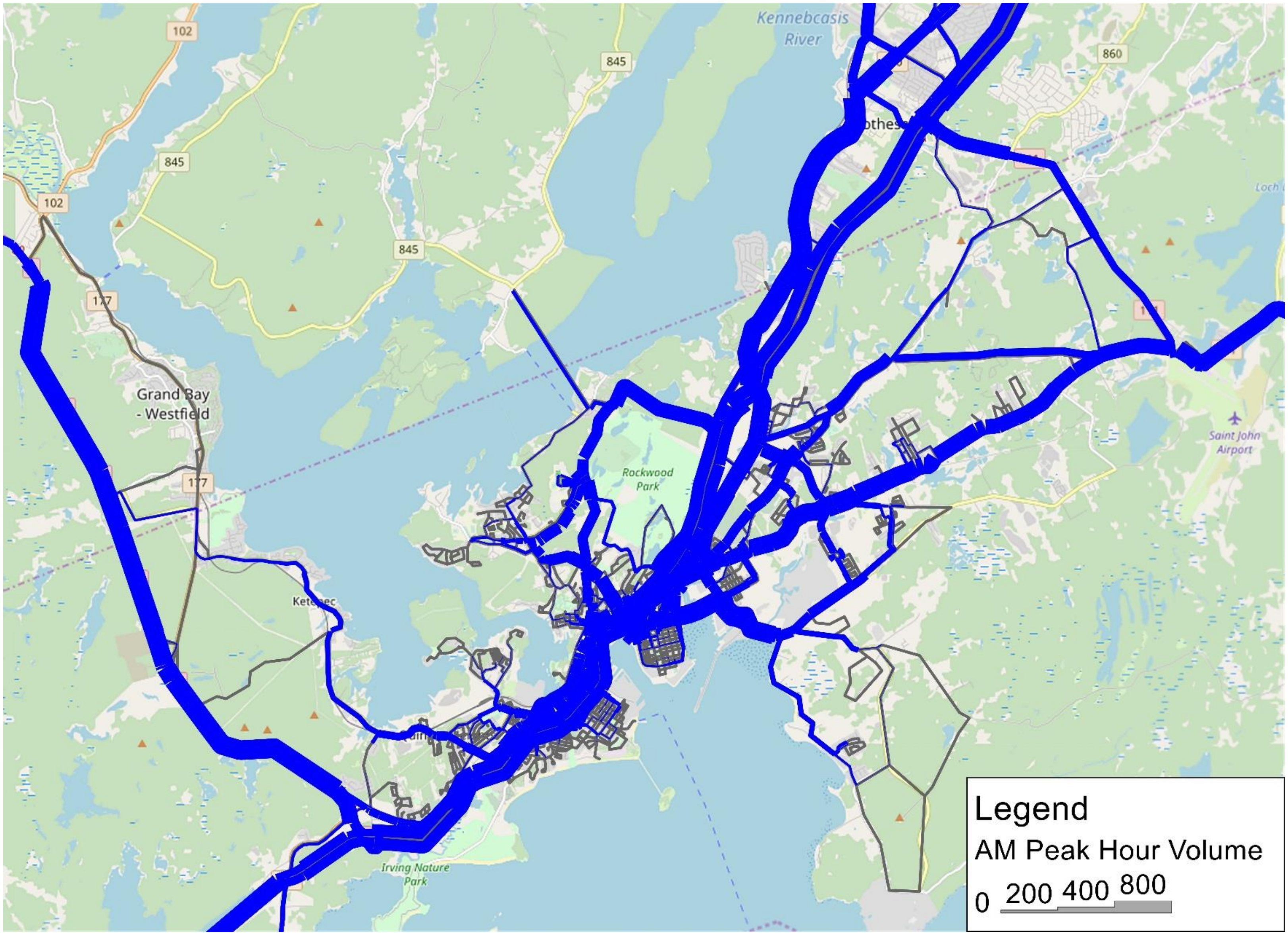


Exhibit 4.3: Volume Capacity (V/C) Ratio

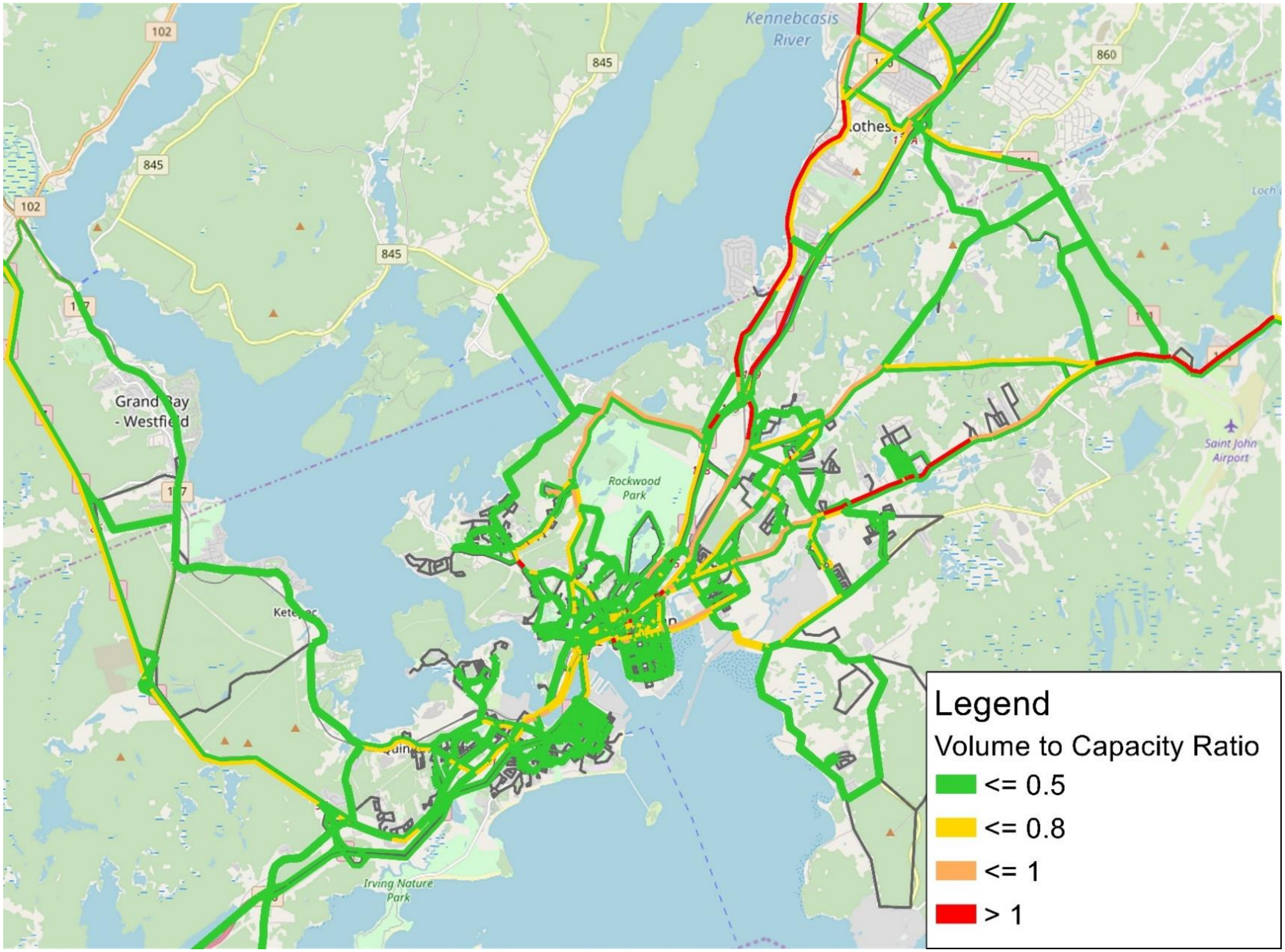


Exhibit 4.4: Screenline Analysis for AM Peak Hour

			Count			Model			Model/Count	
ID	Roadway	Location	SB / EB	NB / WB	Total	SB / EB	NB / WB	Total	SB / EB	NB / WB
1	Harbour Bridge	East of Market Place I/C	1,550	1,110	**2,660**	1,992	1,162	**3,154**	1.29	1.05
	Reversing Falls Bridge	East of Lancaster Ave	1,018	440	**1,458**	897	597	**1,494**	0.88	1.36
	Screenline Total		**2,568**	**1,550**	**4,118**	**2,889**	**1,759**	**4,648**	1.12	1.13
2	Hilyard Street	East of Chesley Drive	356	249	**605**	448	318	**767**	1.26	1.28
	Main Street	East of Metcalf Street	462	852	**1,314**	496	419	**914**	1.07	0.49
	Somerset Street	North of Paradise Row	528	608	**1,136**	482	705	**1,187**	0.91	1.16
	Screenline Total		**1,346**	**1,709**	**3,055**	**1,426**	**1,442**	**2,868**	1.06	0.84
3	Seely Street	West of Route 1 Ramps	182	845	**1,027**	186	932	**1,118**	1.02	1.10
	Route 1	East of Gilbert Street I/C	920	1,637	**2,557**	886	1,699	**2,585**	0.96	1.04
	Rothesay Avenue	West of Russell Street	257	535	**792**	244	617	**861**	0.95	1.15
	Thorne Avenue	East of Rothesay Ave	250	456	**706**	496	759	**1,255**	1.98	1.66
	Courtenay Bay Causeway	West of Bayside Drive	610	937	**1,547**	523	758	**1,281**	0.86	0.81
	Screenline Total		**2,219**	**4,410**	**6,629**	**2,335**	**4,765**	**7,100**	1.05	1.08
4	Rothesay Avenue	East of Retail Drive	440	845	**1,285**	306	1,046	**1,352**	0.70	1.24
	Westmorland Road	West of Consumers Dr	293	376	**669**	187	552	**738**	0.64	1.47
	Loch Lomond Road	West of McAllister Drive	320	875	**1,195**	388	869	**1,257**	1.21	0.99
	Champlain Drive	South of Loch Lomond Rd	324	312	**636**	396	166	**562**	1.22	0.53
	Screenline Total		**1,377**	**2,408**	**3,785**	**1,277**	**2,632**	**3,908**	0.93	1.09
5	Foster Thurston Road	Foster Thurston Road	146	738	**884**	288	621	**909**	1.97	0.84
	Route 1	Route 1	470	2,720	**3,190**	780	2,623	**3,403**	1.66	0.96
	Rothesay Avenue	Rothesay Avenue	456	1,134	**1,590**	347	1,074	**1,421**	0.76	0.95
	Golden Grove Road	Golden Grove Road	290	264	**554**	120	401	**521**	0.41	1.52
	Screenline Total		**1,362**	**4,856**	**6,218**	**1,535**	**4,718**	**6,254**	1.13	0.97
	Overall Total		**8,872**	**14,933**	**23,805**	**9,462**	**15,316**	**24,778**	1.07	1.03

Exhibit 4.5 Screenline Analysis for PM Peak Hour

			Count			Model			Model/Count	
ID	Roadway	Location	SB / EB	NB / WB	Total	SB / EB	NB / WB	Total	SB / EB	NB / WB
1	Harbour Bridge	East of Market Place I/C	1,330	1,920	**3,250**	1,525	2,253	**3,778**	1.15	1.17
	Reversing Falls Bridge	East of Lancaster Avenue	600	808	**1,408**	668	920	**1,588**	1.11	1.14
	Screenline Total		**1,930**	**2,728**	**4,658**	**2,193**	**3,174**	**5,366**	1.14	1.16
2	Hilyard Street	East of Chesley Drive	480	290	**770**	407	532	**940**	0.85	1.84
	Main Street	East of Metcalf Street	527	827	**1,354**	480	730	**1,210**	0.91	0.88
	Somerset Street	North of Paradise Row	747	511	**1,258**	516	829	**1,345**	0.69	1.62
	Screenline Total		**1,754**	**1,628**	**3,382**	**1,403**	**2,092**	**3,495**	0.80	1.28
3	Seely Street	West of Route 1 Ramps	435	405	**840**	271	464	**735**	0.62	1.14
	Route 1	East of Gilbert Street I/C	2,277	973	**3,250**	2,389	1,048	**3,436**	1.05	1.08
	Rothesay Avenue	West of Russell Street	608	507	**1,115**	657	310	**966**	1.08	0.61
	Thorne Avenue	East of Rothesay Avenue	645	377	**1,022**	892	640	**1,531**	1.38	1.70
	Courtenay Bay Causeway	West of Bayside Drive	946	706	**1,652**	732	686	**1,417**	0.77	0.97
	Screenline Total		**4,911**	**2,968**	**7,879**	**4,940**	**3,146**	**8,086**	1.01	1.06
4	Rothesay Avenue	East of Retail Drive	927	598	**1,525**	841	508	**1,349**	0.91	0.85
	Westmorland Road	West of Consumers Drive	799	686	**1,485**	459	318	**777**	0.57	0.46
	Loch Lomond Road	West of McAllister Drive	1,004	486	**1,490**	796	638	**1,434**	0.79	1.31
	Champlain Drive	South of Loch Lomond Road	302	385	**687**	248	375	**623**	0.82	0.97
	Screenline Total		**3,032**	**2,155**	**5,187**	**2,344**	**1,839**	**4,184**	0.77	0.85
5	Foster Thurston Road	Foster Thurston Road	550	175	**725**	655	209	**864**	1.19	1.19
	Route 1	Route 1	2,320	630	**2,950**	2,717	1,183	**3,901**	1.17	1.88
	Rothesay Avenue	Rothesay Avenue	1,136	790	**1,926**	845	594	**1,439**	0.74	0.75
	Golden Grove Road	Golden Grove Road	218	567	**785**	394	261	**655**	1.81	0.46
	Screenline Total		**4,224**	**2,162**	**6,386**	**4,611**	**2,248**	**6,859**	1.09	1.04
	Overall Total		**15,851**	**11,641**	**27,492**	**15,491**	**12,499**	**27,990**	0.98	1.07

Exhibit 4.6: Spot Validation for AM Peak Hour

		Count			Model			Model/Count	
Roadway	Location	SB / EB	NB / WB	Total	SB / EB	NB / WB	Total	SB / EB	NB / WB
Bay Street	East of Station Road	109	98	**207**	91	70	**162**	0.84	0.72
NB Route 7	South of Route 177	879	414	**1,293**	1,103	498	**1,601**	1.25	1.20
NB Route 1	East of Route 7	1,220	730	**1,950**	1,316	787	**2,103**	1.08	1.08
Manawagonish Road	West of Fairville Boulevard	501	228	**729**	535	202	**737**	1.07	0.89
Crown Street	North of Union Street	1,034	580	**1,614**	740	289	**1,029**	0.72	0.50
Bayside Drive	South of Loch Lomond Road	659	417	**1,076**	462	245	**707**	0.70	0.59
Bayside Drive	West of Red Head Road	734	544	**1,278**	561	591	**1,152**	0.76	1.09
NB Route 1	East of Route 100	300	3,100	**3,400**	584	2,753	**3,338**	1.95	0.89
Overall Total		**5,436**	**6,111**	**11,547**	**5,393**	**5,436**	**10,829**	0.99	0.89

Exhibit 4.7: Spot Validation for PM Peak Hour

		Count			Model			Model/Count	
Count Location	Location	SB / EB	NB / WB	Total	SB / EB	NB / WB	Total	SB / EB	NB / WB
Bay Street	East of Station Road	199	199	**398**	95	172	**267**	0.48	0.86
NB Route 7	South of Route 177	409	809	**1,218**	616	1247	**1,863**	1.51	1.54
NB Route 1	East of Route 7	905	959	**1,864**	1,000	1,397	**2,397**	1.10	1.46
Manawagonish Road	West of Fairville Boulevard	344	571	**915**	379	436	**816**	1.10	0.76
Crown Street	North of Union Street	636	1,139	**1,775**	449	737	**1,186**	0.71	0.65
Bayside Drive	South of Loch Lomond Road	467	708	**1,175**	288	546	**834**	0.62	0.77
Bayside Drive	West of Red Head Road	537	647	**1,184**	605	694	**1,300**	1.13	1.07
NB Route 1	East of Route 100	2,780	730	**3,510**	2,902	1,171	**4,073**	1.04	1.60
Overall Total		**6,277**	**5,762**	**12,039**	**6,336**	**6,400**	**12,736**	1.01	1.11

5 Summary

This report summarizes the development of the Saint John Travel Demand Model undertaken as part of MoveSJ, the City of Saint John's Transportation Strategic Plan. The model was developed primarily as a tool for the final phase of MoveSJ to forecast and assess future travel demand and develop a comprehensive transportation system improvement plan for the City of Saint John.

Beyond MoveSJ, the model is a tool that can assist the City in its day-to-day transportation planning and growth management needs. For example, the model can be used to identify needs for new infrastructure or transit services, assess the transportation impacts of new land development growth, and develop solutions to accommodate changing travel behaviours and modal shifts.