Modeling of Streetcar and Bus TSP in Toronto using Aimsun Microsimulation Software

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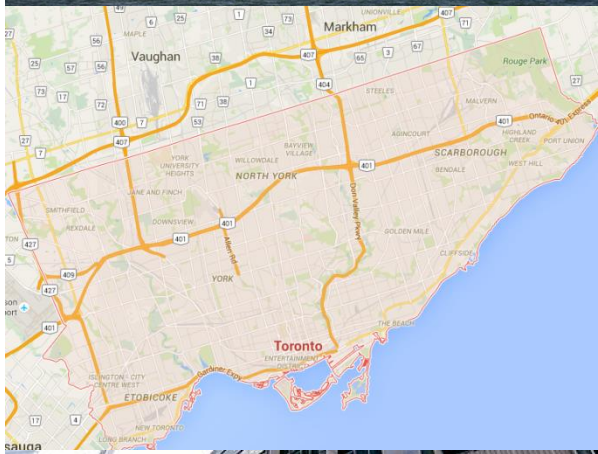
Outline

- Introduction
- Pilot Corridors
- Signals and TSP Algorithms
- API development for Aimsun
- Model Development in Aimsun
- Application within Aimsun

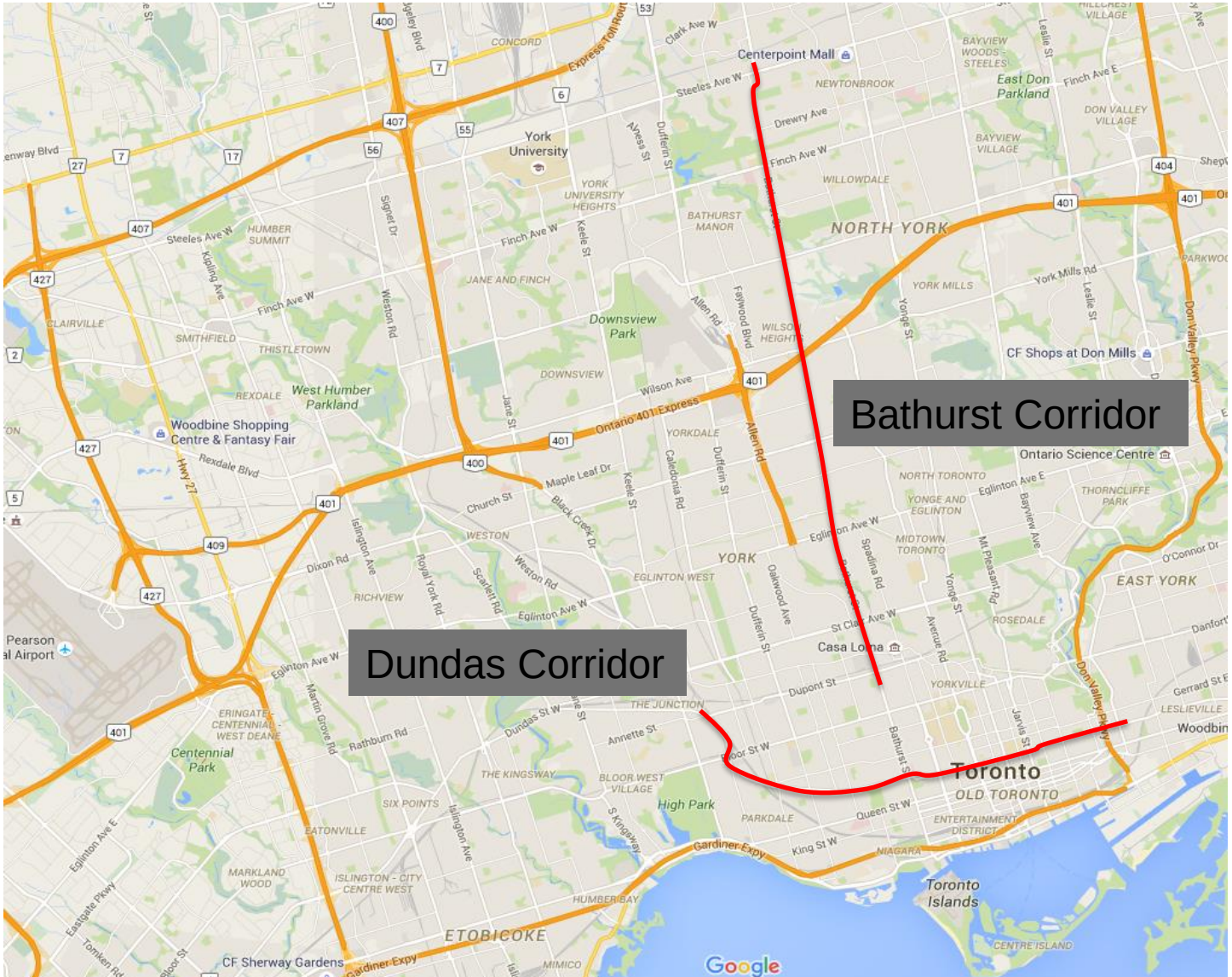
Introduction

The City of Toronto

- Approximately 2.8 million people
- Toronto Transit Commission (TTC) operates transit services – subways, LRTs, streetcars, buses, Wheel-Trans
- Annual TTC ridership of over 500 million trips on all transit modes
- 143 bus routes, 11 streetcar routes, 3 subway lines, 1 LRT

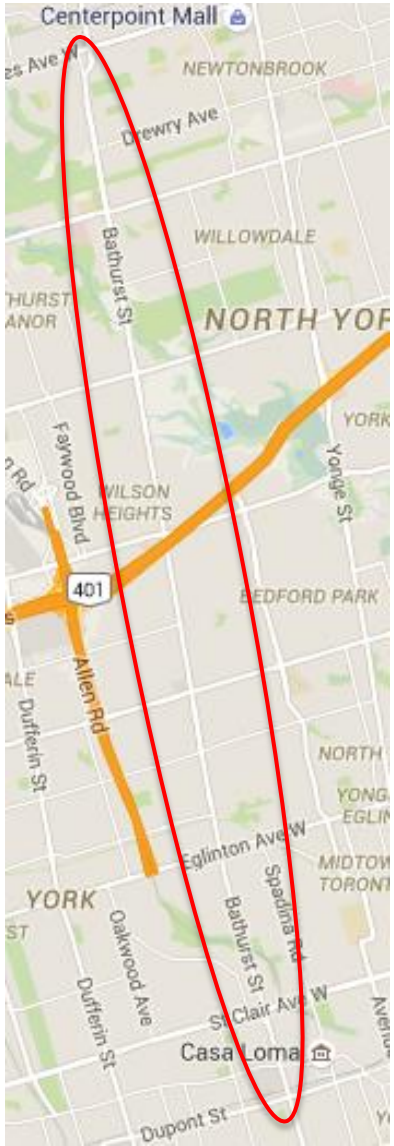


Pilot Corridors



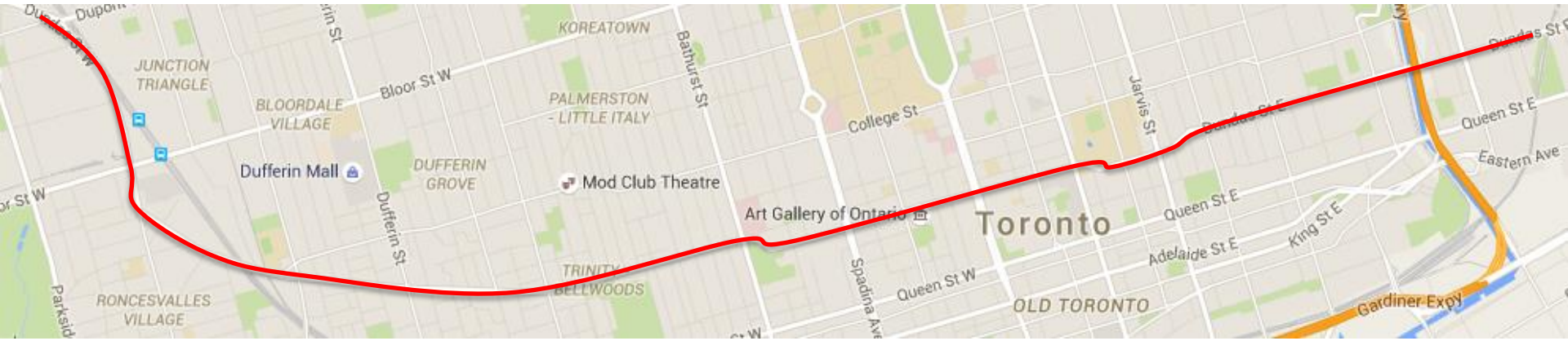
Pilot Corridors

- Bathurst Street
  - Bus operations
  - 48 signals
  - 15 kilometer long N/S corridor
  - Several heavy pedestrian/car intersections
  - Team Lead - HDR



Pilot Corridors

- Dundas Street W
  - Streetcar operations
  - 37 signals
  - 10 kilometer long E/W corridor
  - Several heavy pedestrian/car intersections
  - Team Lead - IBI Group



Interval-Based Timing

LOCATION	Spadina Ave & Dundas St W	DISTRICT	Toronto & East York
MODE/COMMENT	FXT with 2-wire Polara APS and Transit PE 55 & 5B	COMPUTER SYSTEM	MTSS
PX	277	CONTROLLER/CABINET TYPE	Novax 30 cct / M
PREPARED/CHECKED BY	JM	CONFLICT FLASH	Red & Red
PREP.DATE	April 27, 2015	DESIGN WALK SPEED	1.0 m/s (FDW based on full crossing at 1.2 m/s)

STREET	Spadina Ave					Transit		Dundas St W						Transit		North-South Arrow					REMARKS
COMPUTER INT.	1	2	3	4	5			6	7	8	9	10	11			12	13	14	15		
ASPECT	NSG	>	>	NSY	ALLR			EWG	>	>	>	EWY	ALLR			NSG	>	>	>		
	NSTG	>	>	NSTY	NSTR			NSTR	>	>	>	>	>			NSTG	>	>	>	No Calls	Pedestrian Minimums: NSWK = 7 sec; NSFD = 13 sec
	NSWK	>	NSFD	NSDW	>			EWWK	>	>	EWFD	EWDW	>			NSWK	>	>	>		EWWK = 7 sec; EWFD = 25 sec
	APS							APS								APS					Fully protected NBLA and SBLA callable 24 hours by stopbar loop.
																NBLA	>	NBLY	NBLR		NS transit turn-out phase provided through timing preemption.
																NBG	>	>	>	NBLA Call	
																NSTR	>	>	>		Fixed APS on during WALK periods only when no arrows are displayed
																NSWK	>	>	>		
																East Side Only					
																SBLA	>	SBLY	SBLR		
																SBG	>	>	>	SBLA Call	
																NSTR	>	>	>		
																NSWK	>	>	>		
																West Side Only					
																NSLA	>	NSYA	ALLR		
																NSTR	>	>	>	NSLA Call	
																NSDW	>	>	>		
						ALLR	>	NSTB Called						ALLR	>	NSTB Called					
						NSTB	NSTR							NSTB	NSTR						
						DTWK	>							DTWK	>						

CONTROLLER INT.			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	SCHEDULES
IMP. DATE	CL	C/S																				
April 27, 2015	90	C1S1	2	17	13	4	3	0	0	2	2	3	25	4	3	0	0	3	3	3	3	All Other Times
								7	6							7	6					
	90	C2S1	2	16	13	4	3	0	0	2	2	4	25	4	3	0	0	3	3	3	3	06:30 - 09:30, Mon-Fri
								7	6							7	6					
	90	C3S1	2	17	13	4	3	0	0	2	2	3	25	4	3	0	0	3	3	3	3	15:30 - 18:30, Mon-Fri
								7	6							7	6					

NOTES: Two decision points for NS transit turn-out phase, however only provided once-per-cycle

28/04/2015

Phase-Based Timing

Page 1 – Basic

LOCATION:	Bathurst St & Ava Rd
MODE/COMMENT:	SA2-VMG with WRM, TSP & Jewish FXT Operation
PX:	505
PREPARED/CHECKED BY:	CL/SL
PREPARATION DATE:	April 25, 2014
IMPLEMENTATION DATE:	April 28, 2014
DISTRICT:	Toronto & East York
COMPUTER SYSTEM:	TransSuite
CONTROLLER/CABINET TYPE:	Peek ATC 1000 / TS2 T1
CONFLICT FLASH:	Red & Red
DESIGN WALK SPEED:	1.0 m/s (FDW based on full crossing at 1.2 m/s)
CHANNEL/DROP:	4019/21

NEMA Phase		OFF All Other Times	AM 06:45-09:30 M-F	PM 15:45-18:15 M-T, 15:45-16:20 Fri	J. SABB-AM See High Holiday Schedule	J. SABB-PM 16:20-18:15, Fri & see High Holiday Schedule	J. SABB-OFF 18:15-23:59 Fri, 06:00-22:20 Sat & see High Holiday Schedule	Phase Mode (Fixed/Demanded or Callable)	Remarks
	Local Plan	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6		
	Split Table	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6		
1 NOT USED	WLK FDW MIN MAX1 AMB ALR SPLIT								Pedestrian Minimums: NSWK = 7 secs; NSFD = 11 secs EWWK = 7 secs; EWFD = 13 secs EB phase is callable by vehicle or pedestrian actuation. If a vehicle call is received, the minimum EBG is 7 seconds. If ongoing vehicle demand exists on the stopbar loop, the EBG is capable of providing vehicle extensions up to the maximum green split. If a pedestrian call is received, the pedestrian minimums will be served. The EWWK & EWFD are only displayed on the pedestrian signal heads if a pedestrian call is received. Extension time is based on vehicle demand. Unused extension time is given to the NSG.
2 Bathurst St NBSA	WLK 7 FDW 11 MIN 18 MAX1 59 AMB 4 ALR 2 SPLIT 64	64	64	64	64	64	64	Fixed POZ activated by Request Loop (max extension of 30 secs in Green/Walk)	The signal constantly cycles through main street FDW to improve response to side street vehicle and pedestrian
3 NOT USED	WLK FDW MIN MAX1 AMB ALR SPLIT								NSFD reverts to NSWK if there is no side street vehicle demand at the end of the NSFD. Side Street passage = 3 sec TSP disabled - TSP activation pending new firmware testing & field validation See back for TSP Instructions. System plan 4, 5 & 6 provide for FXT operation during Jewish Sabbaths and High holidays. Walk and FDW are displayed for side street during FXT operation. See attached paper for the updated High Holiday Schedule.
4 Ava Rd.	WLK 7 FDW 13 MIN 7 MAX1 20 AMB 3 ALR 2 SPLIT 26	26	26	26	26	26	26	Callable by Stopbar loop and/or Pushbutton; Extendable by Stop bar loop	BLI on during FXT operation
5 NOT USED	WLK FDW MIN MAX1 AMB ALR SPLIT								
6 Bathurst St SBSA	WLK 7 FDW 11 MIN 18 MAX1 59 AMB 4 ALR 2 SPLIT 64	64	64	64	64	64	64	Fixed POZ activated by Request Loop (max extension of 30 secs in Green/Walk)	
7 NOT USED	WLK FDW MIN MAX1 AMB ALR SPLIT								
8 NOT USED	WLK 7 FDW 13 MIN 7 MAX1 20 AMB 3 ALR 2 SPLIT 26	26	26	26	26	26	26		
	CL OF	90 27	90 59	90 79	90 59	90 79	90 27		

NOTE: Ava Rd. is one-way Eastbound.
Jewish High Holidays schedule 2014 updated on Feb 28, 2014 and implemented on Mar 21, 2014
Picked up system control on April 29, 2014

Page 2 – TSP

LOC: Bathurst St & Ava Rd
MODE: SA2-VMG with WRM, TSP & Jewish FXT Operation
PX: 505 PREPARATION DATE (TIMING CARD): April 25, 2014

OFFSET CORRECTION PARAMETERS

2.3.4 O.C. Extend / Reduce (Max. time added & subtracted in sec.)

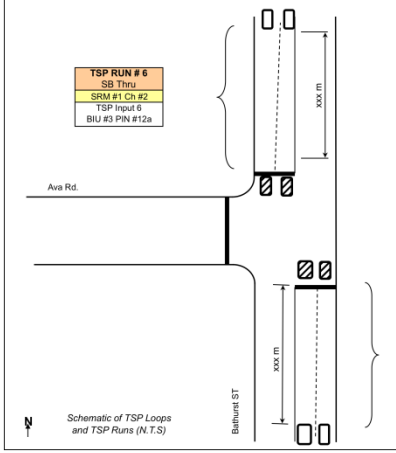
		→ 1	→ 2	→ 3	→ 4	→ 5	→ 6	→ 7	→ 8	From page 1 [Cycle]	From page 1 [Slop]	2.3.2.x O.C. Thres.
OFF & J. SABB-OFF												Pattern 1
Split 1,6	Ext.	--	34	--	--	--	34	--	--	90	41	23 s [25 %]
	Rdc.	--	40	--	1	--	40	--	1			
AM & J. SABB-AM												Pattern 2
Split 2,4	Ext.	--	34	--	--	--	34	--	--	90	41	23 s [25 %]
	Rdc.	--	40	--	1	--	40	--	1			
PM & J. SABB-PM												Pattern 3
Split 3,5	Ext.	--	34	--	--	--	34	--	--	90	41	23 s [25 %]
	Rdc.	--	40	--	1	--	40	--	1			

T.S.P. PARAMETERS

PREPARED: CL/SL

	TSP RUN # 2 NB Thru	TSP RUN # 6 SB Thru
2.8.2 Transit Run Parameters		
ATC Green Extend Mode (Equivalent TTC Algorithm)	Mode 2 A	Mode 2 A
2.8.3 Transit Action Plan 1 (Used for all Patterns)		
Run Enable (X = Yes)	X	X
Run Config = 1 | Recovery = 2 (O.C. with delay)		
2.8.4 Transit Run Configuration 1		
Delay / Extend / Fail	-- / -- / 235	-- / -- / 235
CALLS (and Extends)	→ 2/6	→ 2/6
Skips	--	--
Reduces (Truncates)	→ 4/8	→ 4/8

2.8.6 TSP Split Tables: 1, 2, 3, 4, 5 & 6	→ 1	→ 2	→ 3	→ 4	→ 5	→ 6	→ 7	→ 8
GRN EXT (SDW Extension)	--	--	--	--	--	--	--	--
GRN RDC (Reduction)	--	--	--	-1	--	--	--	-1
WLK EXT (Walk Extension)	--	30	--	--	--	30	--	--



Notes:

ATC Mode	0	2	3	4
TTC Algor'm	B-2	A	C	D
Extensions	SDW	Walk	W/SDW	W/SDW

TSP SUMMARY
Maximum Green Extensions:
NSG: 30 s Green/WLK
EBG Truncation to ped minimum

Toronto's TSP Operations

- Active Priority Control Strategy
  - Priority given to transit vehicle following detection
  - Detection via transit loops
- Unconditional Priority Requests
  - First Sequenced, First Serve
- Generally PEEK ATC-1000 controllers
  - Other NEMA controllers for special cases

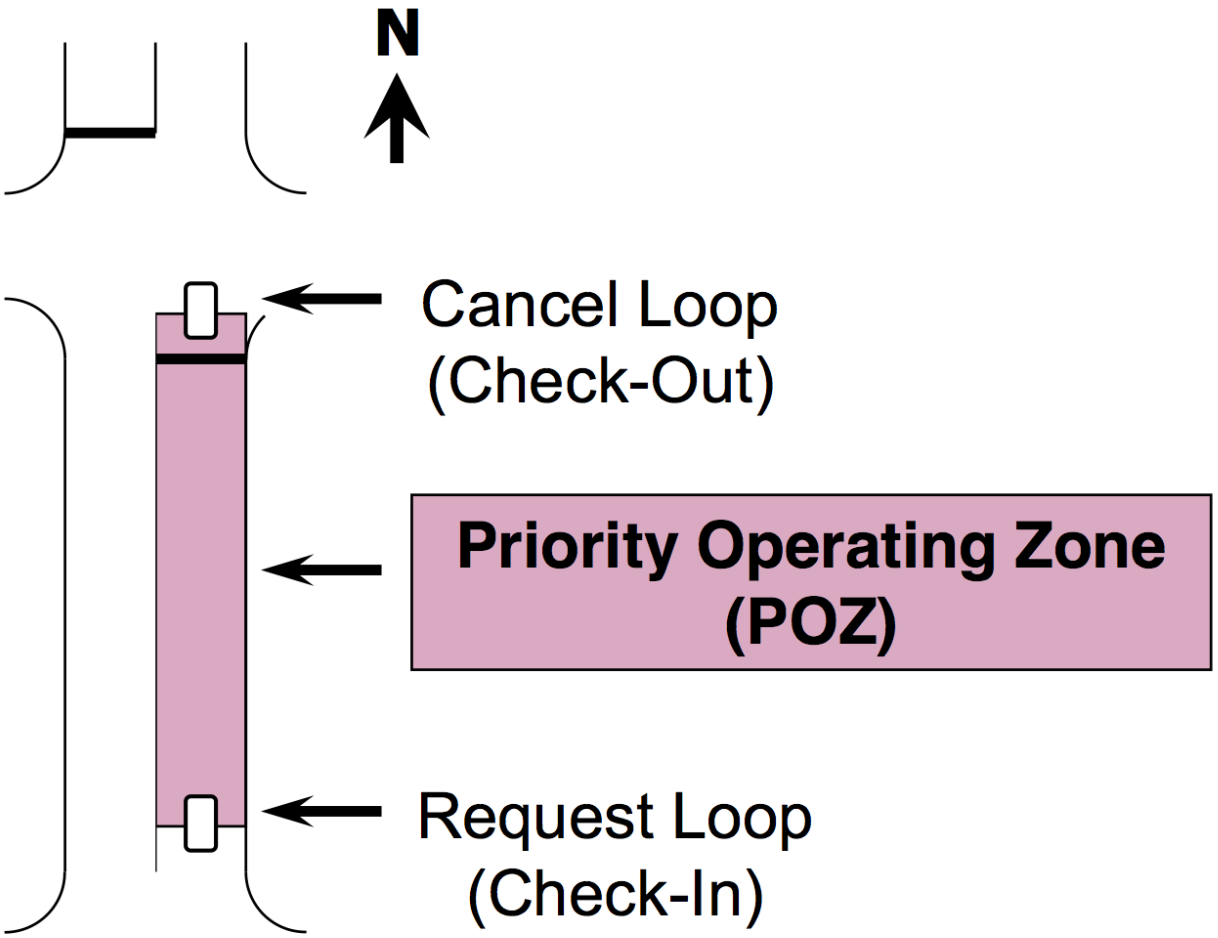
Overview of TSP Features

- Existing TSP Features
  - Green Extension
  - All Direction Transit Priority
  - Phase Truncation (i.e. Early Green)
  - Call/Extend Special Transit Phases
  - Multiple TSP Opportunities per cycle
  - Shifting and skipping phases
- Recovery after TSP
  - Offset Correction
  - Adverse effect on signal coordination

Extension Algorithms

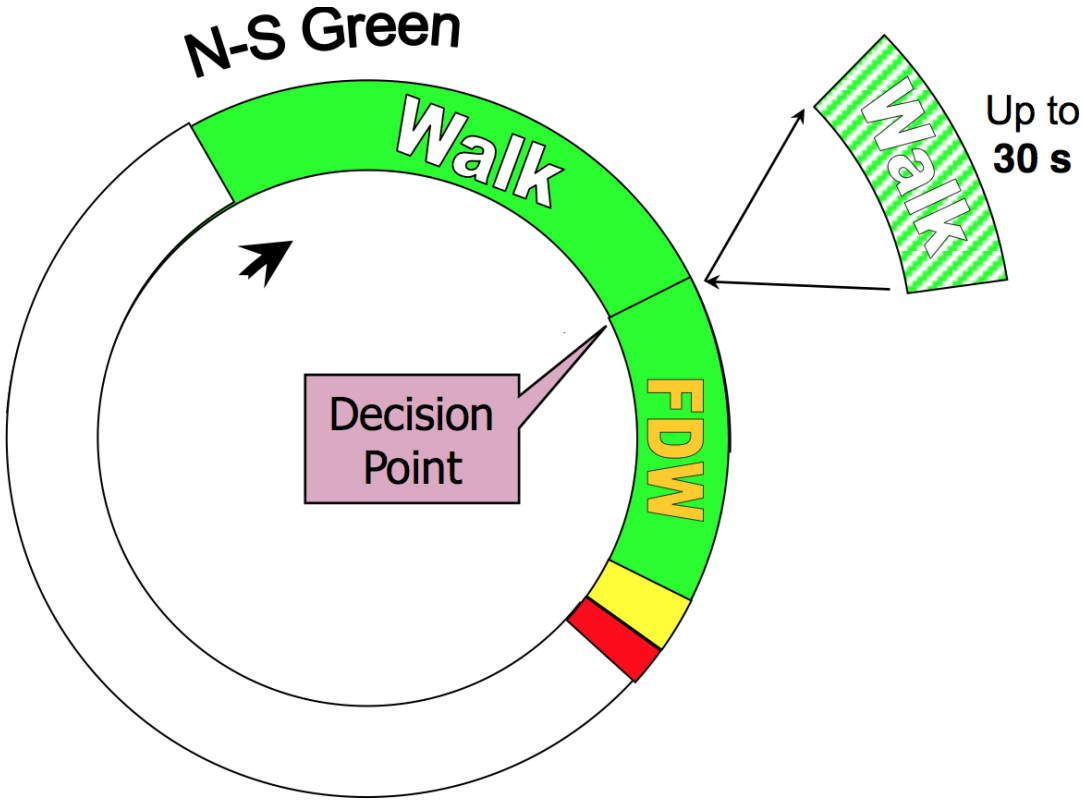
- Current green extension algorithms (included in pilot projects)
  - Algorithm “A”: Green/Walk extension
  - Algorithm “B”: Green/SDW extension
- Enhanced Algorithms
  - Algorithm “C” included as part of pilot
  - Algorithm “D” not included

Green Extension



Algorithm A

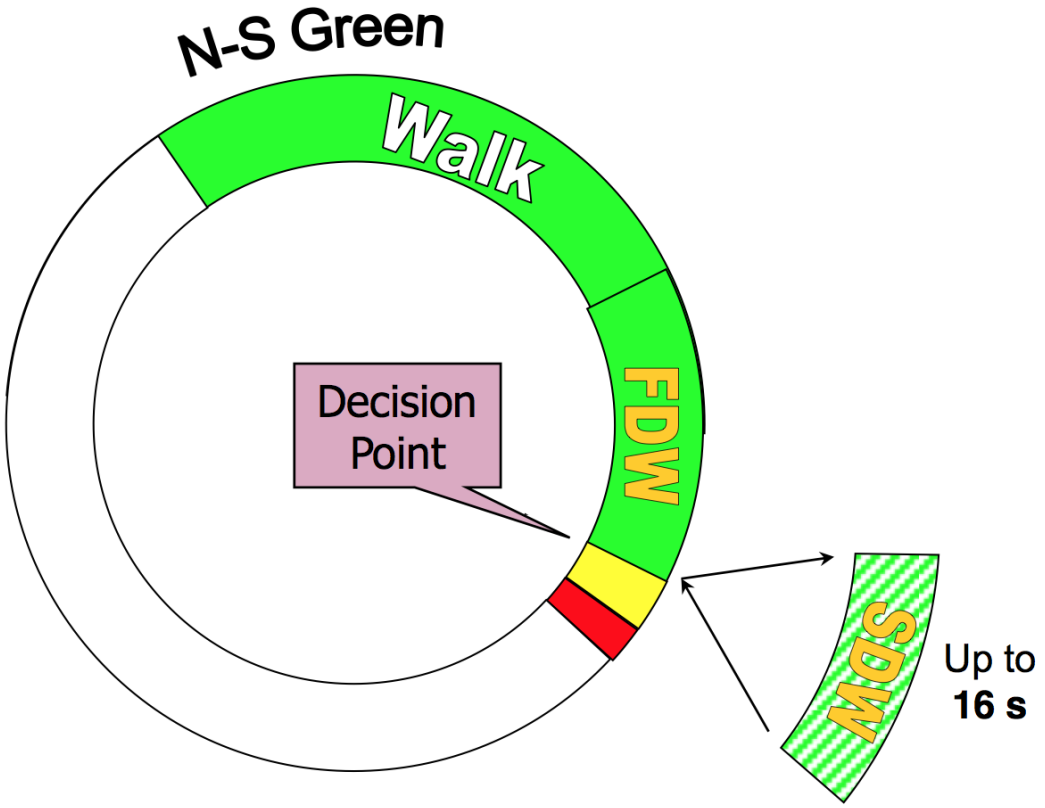
- Advantages
  - Few Failed Extensions (30 s max.)
  - More pedestrian friendly
- Disadvantages
  - Less Efficient signal operation (with longer FDW, City provides full clearance in FDW)
  - Not practical everywhere



Algorithm B

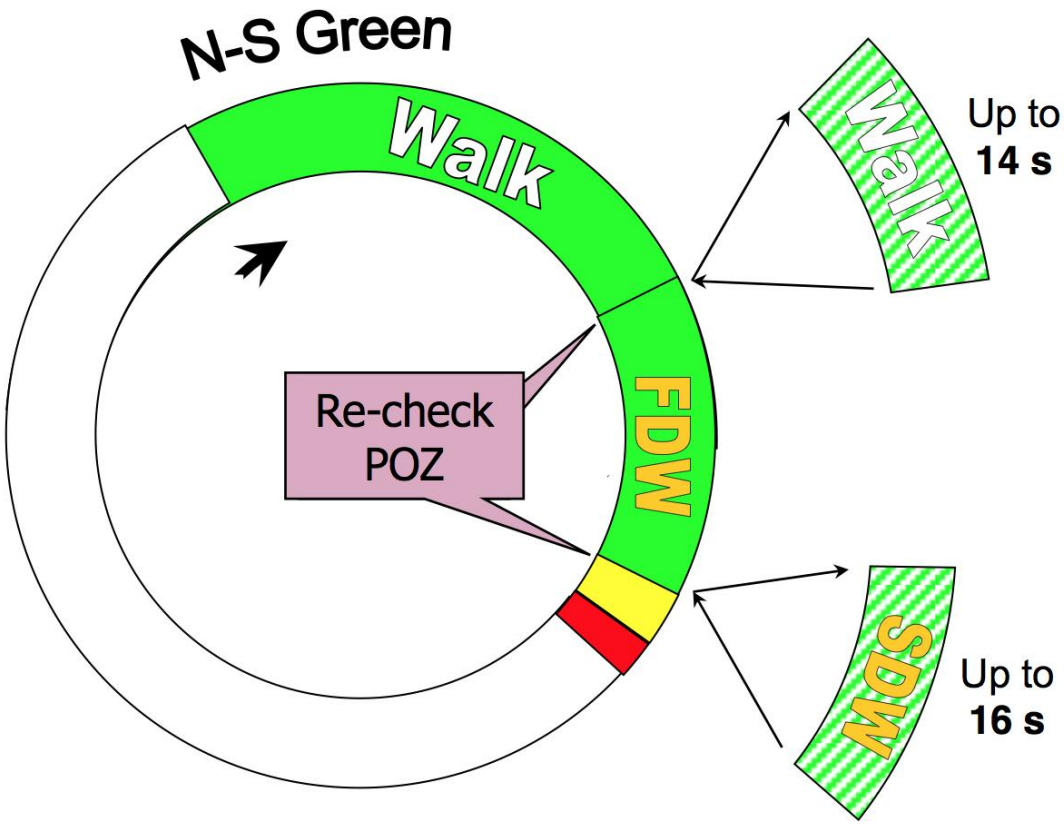
- Advantages
  - Efficient Signal operation
  - Practical with closely spaced signals
- Disadvantages
  - More Failed extensions

    (16 s max.)
  - Less pedestrian friendly



Algorithm C

- Advantages
  - Fewer Failed extensions
  - Improved efficiency (w.r.t. “A”)
  - More pedestrian friendly than “B”
- Disadvantages
  - Less efficient than “B”
  - Not practical everywhere

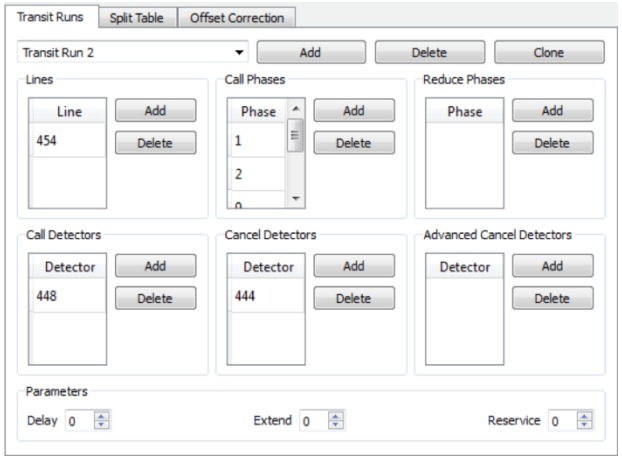


Modeling challenges

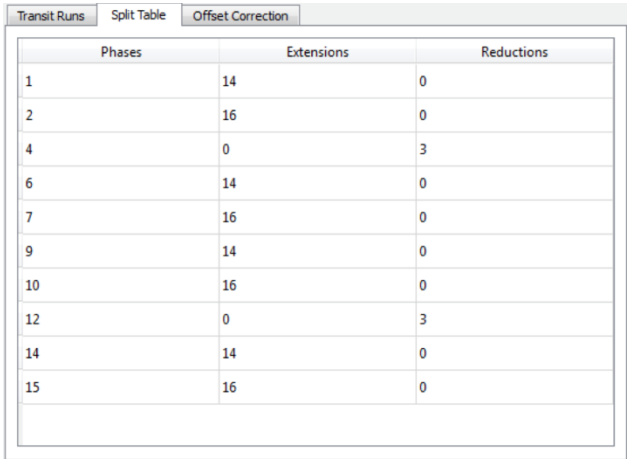
- Emulate the operation of the real signal controller
  - Basic operation
    - FXT, SAP, SA2
  - TSP operation
    - Algorithm A, Algorithm B, Algorithm C
- Emulate the operation of the real detectors
- Model the rules of road around the streetcar

Modeling the signal controllers

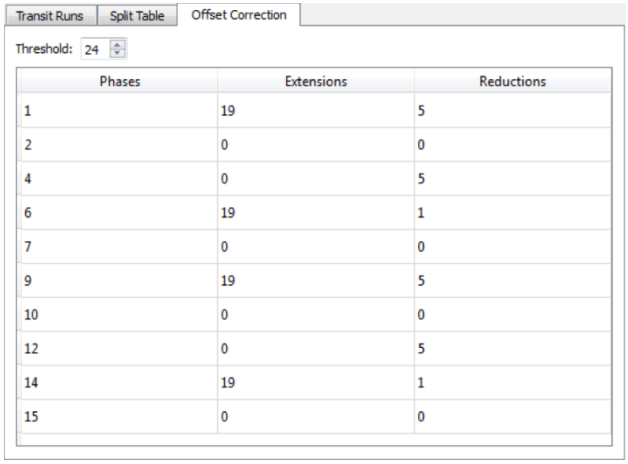
- Standard NEMA controller for basic operation
- Customized API to handle changes with TSP calls
- Customized UI to input TSP parameters



Transit Run Attributes



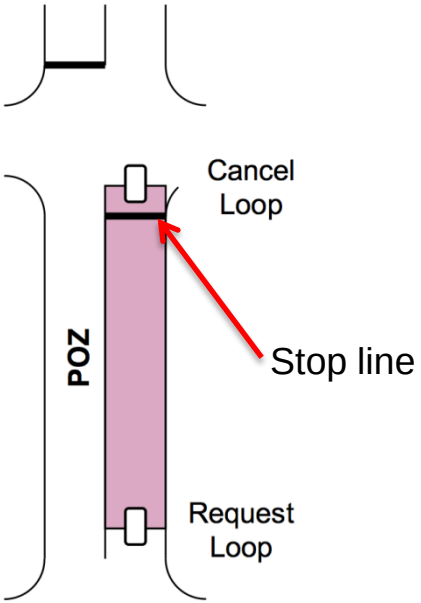
Phase Split Attributes



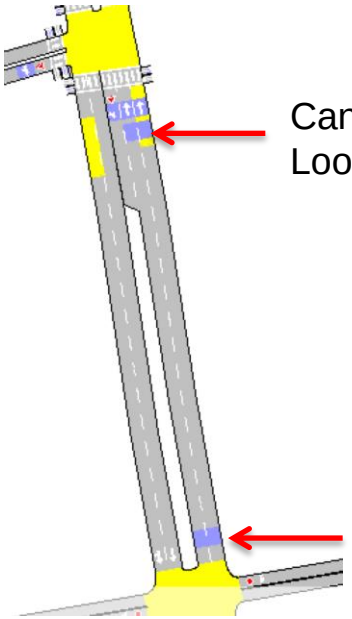
Phase Offset Correction Attributes

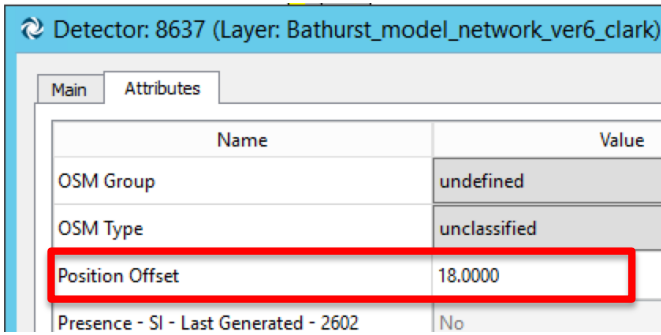
Modeling the detectors

- Real World Placement



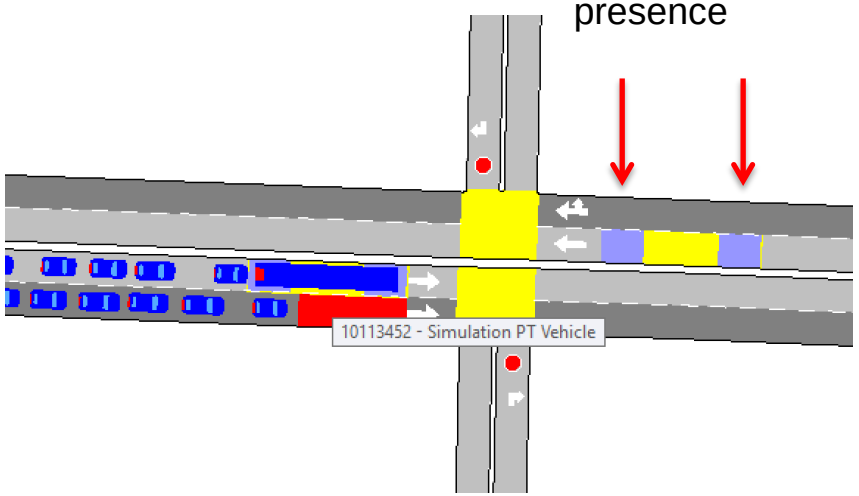
- Model Placement
  - Offset needed to place detector beyond the stop line





Modeling the rules of road

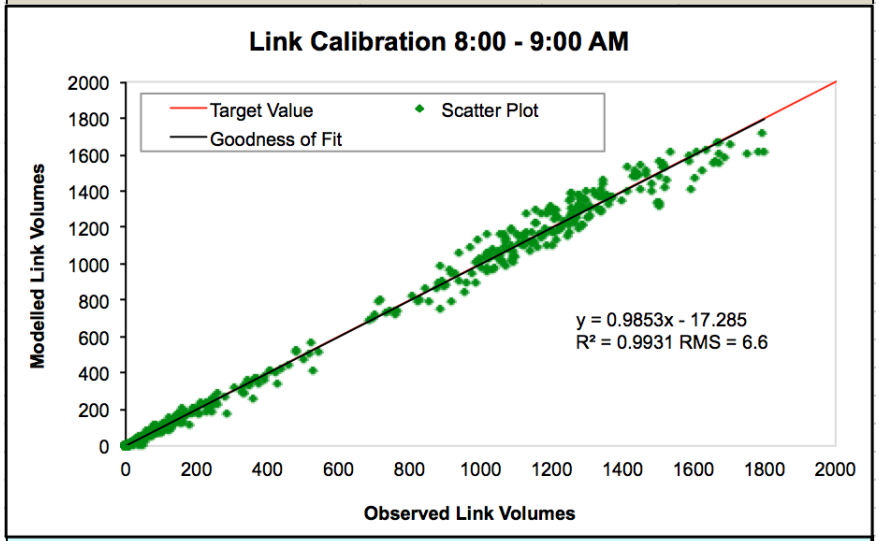
- Private vehicles cannot overtake when the doors of the streetcar are open



Model Calibration

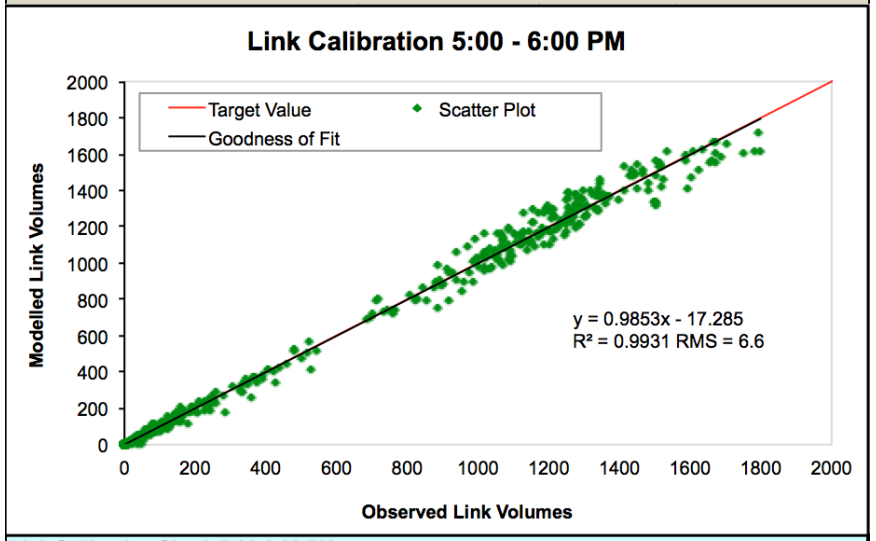
- Modeled Section Flows - Bathurst

Link Counts



Link Calibration Check 8:00-9:00 AM			
Peak Direction	**Modelled**	**Target**	**Check**
Percentage of Links with GEH <= 5	100%	85%	OK
Percentage of Links with GEH <= 10	100%	95%	OK
Percentage of Links with GEH > 10	0%	5%	OK
RMSE	8%	30%	OK
Sum of All Link Flows within 5% of sum of	100%	95%	OK
Corridor Screenline Volumes Within 15%	100%	100%	OK

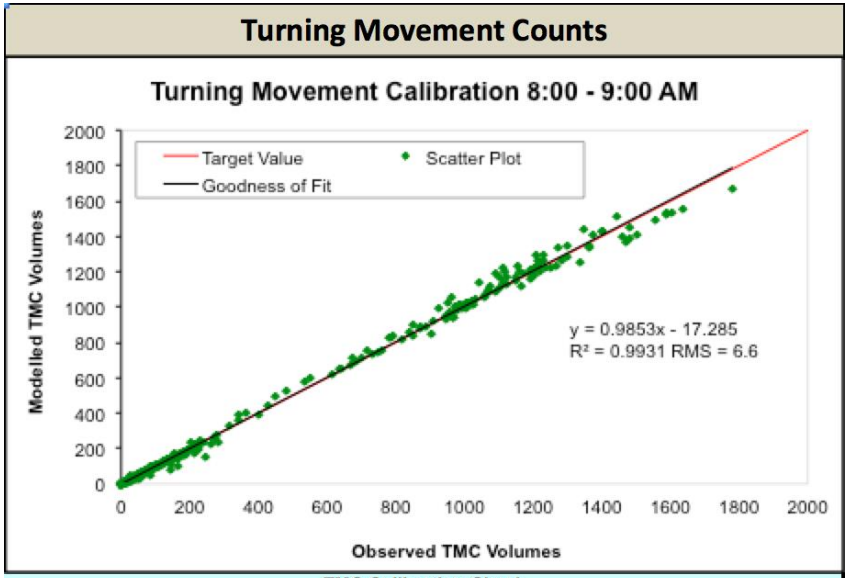
Link Counts



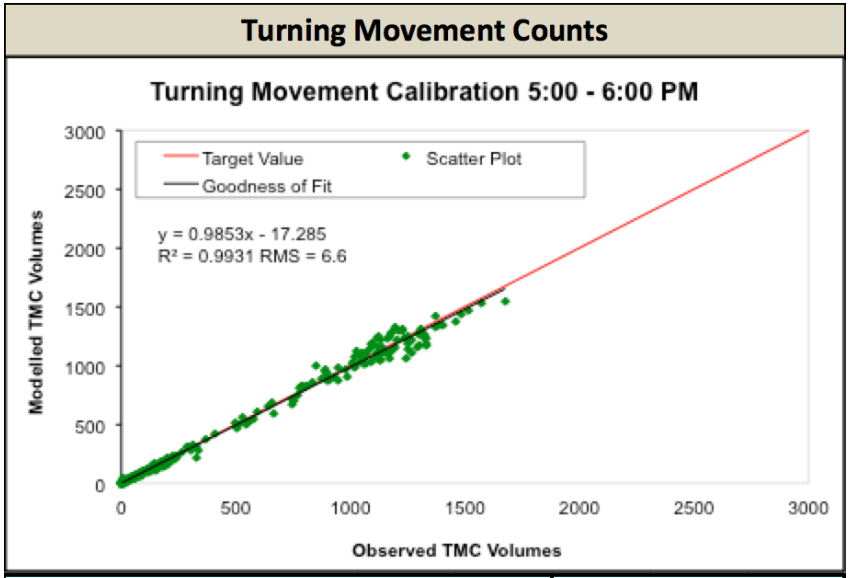
Link Calibration Check 5:00-6:00 PM			
Peak Direction	**Modelled**	**Target**	**Check**
Percentage of Links with GEH <= 5	100%	85%	OK
Percentage of Links with GEH <= 10	100%	95%	OK
Percentage of Links with GEH > 10	0%	5%	OK
RMSE	8%	30%	OK
Sum of All Link Flows within 5% of sum of	100%	95%	OK
Corridor Screenline Volumes Within 15%	100%	100%	OK

Model Calibration

- Modeled Turn Flows - Bathurst



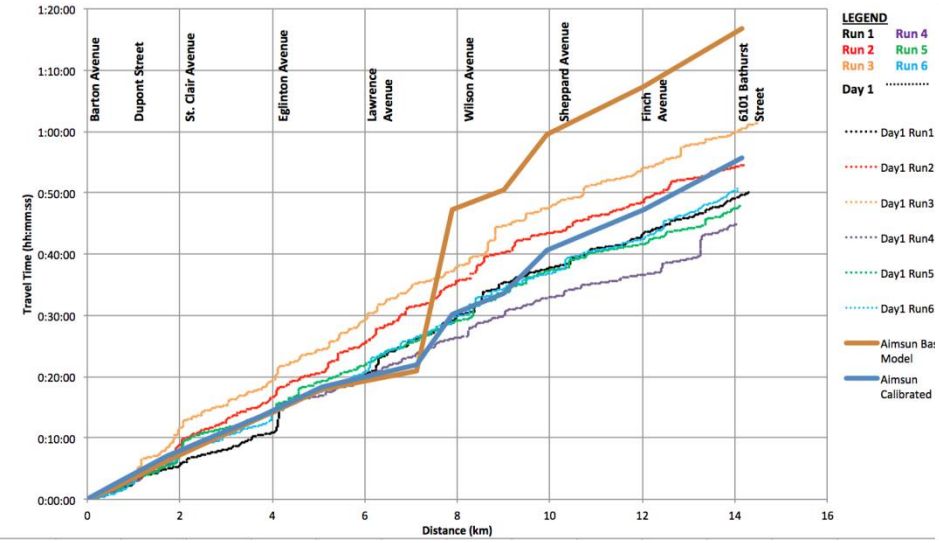
TMC Calibration Check			
Peak Direction	**Modelled**	**Target**	**Check**
Percentage of Links with GEH <= 5	99%	85%	OK
Percentage of Links with GEH <= 10	100%	95%	OK
Percentage of Links with GEH > 10	0%	5%	OK
RMSE	8%	30%	OK



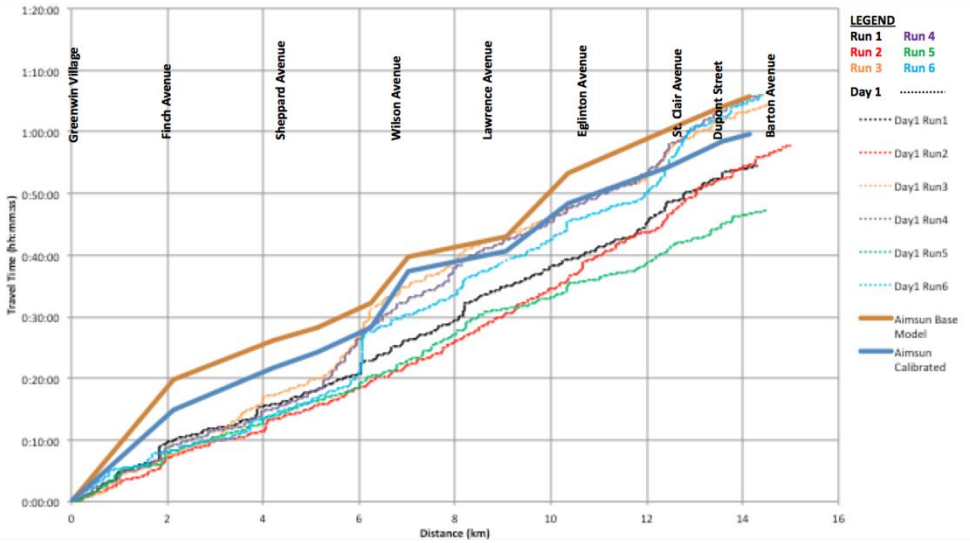
TMC Calibration Check			
Peak Direction	**Modelled**	**Target**	**Check**
Percentage of Links with GEH <= 5	99%	85%	OK
Percentage of Links with GEH <= 10	100%	95%	OK
Percentage of Links with GEH > 10	0%	5%	OK
RMSE	7%	30%	OK

Model Calibration

- Modeled Transit Travel Times- Bathurst AM



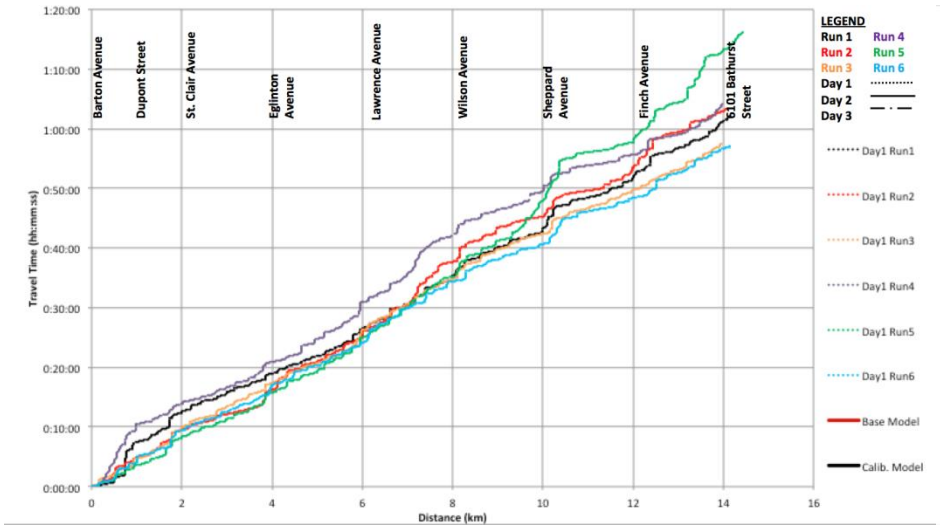
Northbound



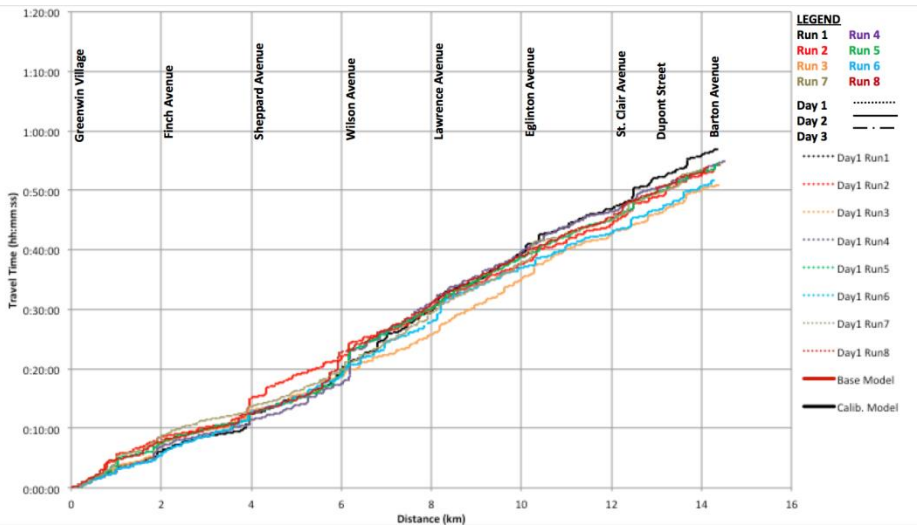
Southbound

Model Calibration

- Modeled Transit Travel Times- Bathurst PM

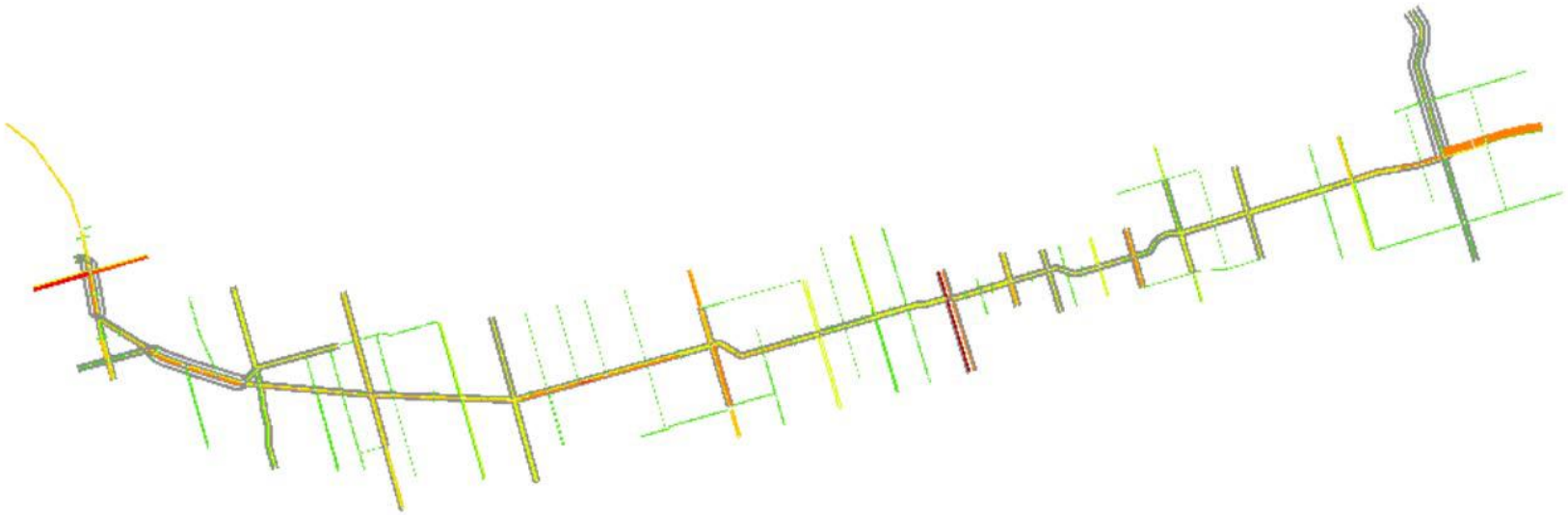


Northbound



Southbound

Simulation Video



Questions

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