York Region Activity-Based Model

Presentation to Travel Modelling Group (TMG)

May 4, 2022

Data and Forecasting Team, York Region

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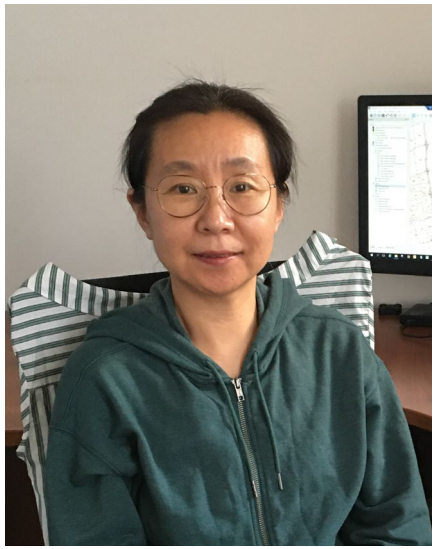

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Workshop purpose

York Region recently developed the state-of-the-practice Activity-Based Model (ABM). The model was successfully applied to the Official Plan, Transportation Master Plan and Development Charges Bylaw updates. **The main purpose of the workshop is to unveil the York ABM with the TMG and industry partners.**

Presentation outline

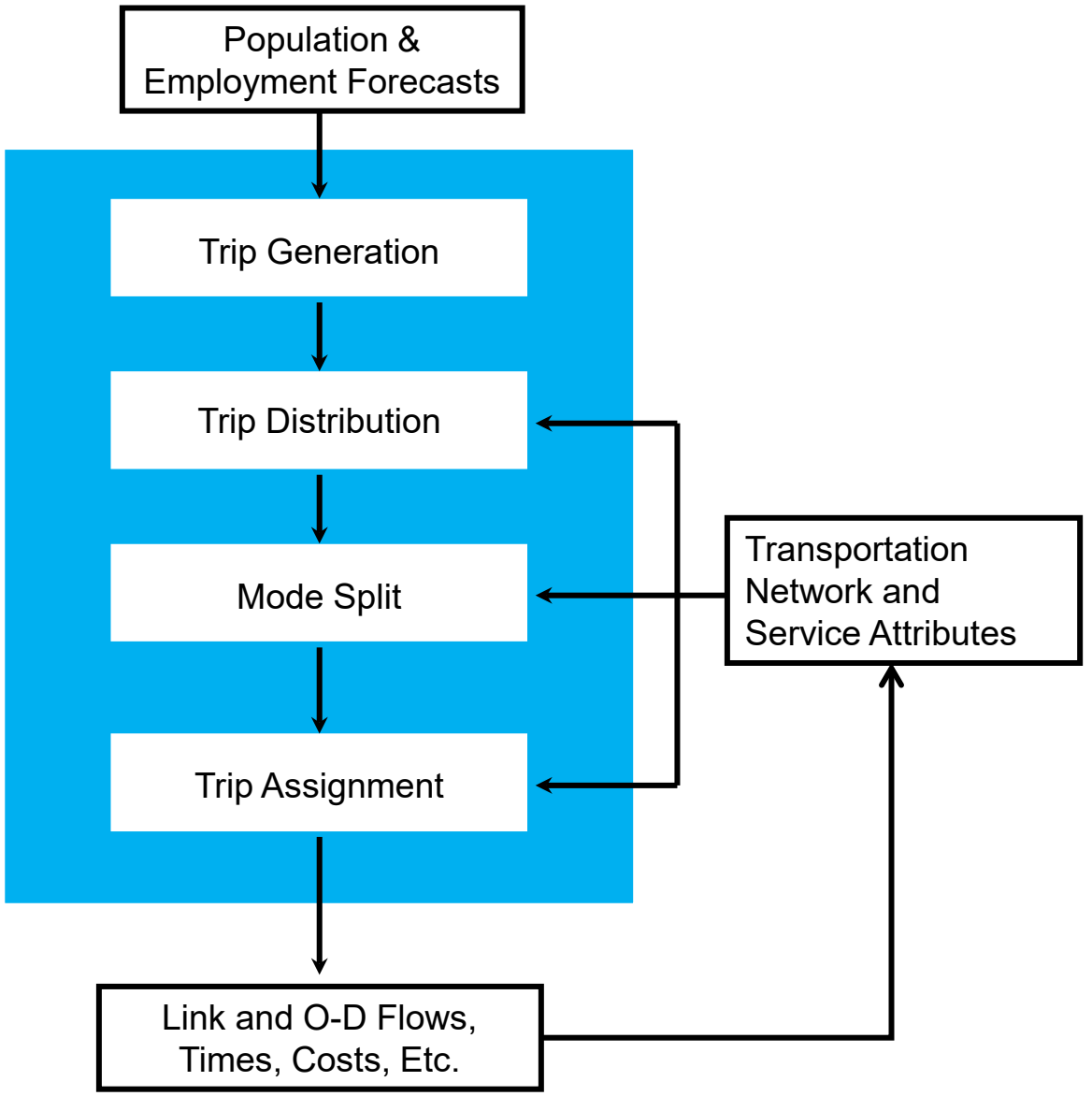
- Background
- York ABM: CT-RAMP2
- GHG Emission Calculator
- Model Application
- Next Steps
- Q&A / Discussion

BACKGROUND

MODEL UPDATE OBJECTIVES AND OVERVIEW

York model evolution

- Designed for long range and area-wide/corridor – level planning
- First Developed in 2003 using 2001 TTS
  - Traditional 4 stage travel demand model
  - AM Peak Model
  - Motorized Modes only
  - Greater Toronto and Hamilton Area
- Recalibrated in 2014 using 2006 TTS
- EMME Platform
- Transformed to ABM in 2021 using 2016 TTS



Model update motivation

1. Create a World Class Transit System

2. Develop a Road Network Fit for the Future

3. Integrate Active Transportation in Urban Areas

4. Maximize the Potential of Employment Areas

5. Make the Last Mile Work

York Region TMP big moves

- Maximize the potential of Regional Express Rail
- Complete Viva network / Extend the Yonge North Subway to Richmond Hill Centre
- Improve service and fare integration with partner transit systems
- Expand Park ‘N’ Ride facilities
- Expand HOV/transit network
- Utilize technology to improve efficiency of the road network (road pricing, autonomous vehicle, etc.)
- AT infrastructure to connect key corridors, Regional Centres and transit facilities
- Designate a Strategic Goods Movement Network
- Support transit-oriented development
- Improve mobility through technology and sharing economy
- Implement TDM Strategy
- Develop a Commuter Parking Management Strategy

The Design of the current model is limited to develop and assess the effectiveness of the TMP big moves

Overall objective of model update

To develop a comprehensive, robust and forward looking tool that would among others things:

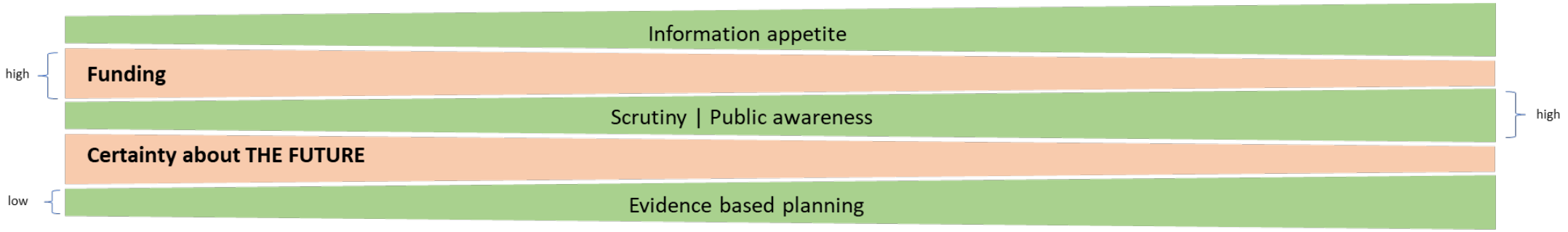
- Produce 24 hours travel demand patterns by TOD by all modes
- Be sensitive to the future land use, demographic and employment
- Be sensitive to the implementation of various planning and transportation policies or visions
- Be sensitive to changes in transportation facilities and services
- Produce quality information for project evaluation

York model update: a collaborative effort

CONTEXT

ACTIVITY-BASED MODEL

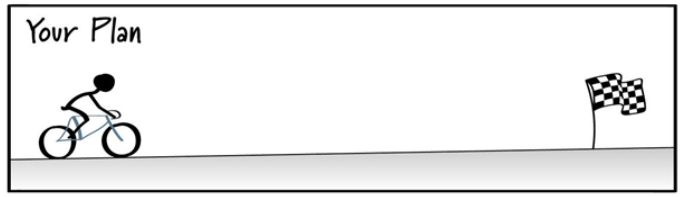
Planning revolution



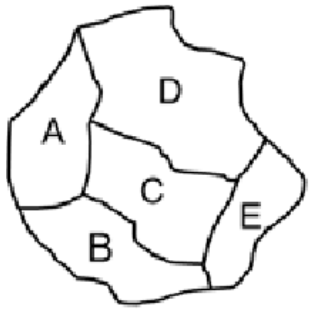
2003 YORK MODEL

CT-RAMP

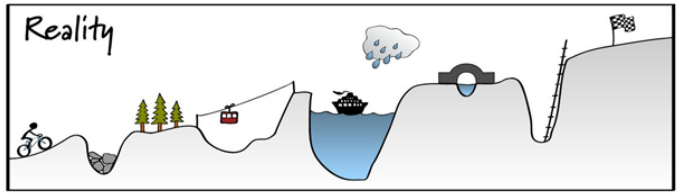
Evolution of analytical needs



Trip based models *sort off*
(Flaw of Averages)



	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	1
C	1	1	0	1	1
D	1	0	1	0	1
E	0	1	1	1	0



Activity based models
(The variability that makes us human)

Household records

householdID	size	region	vehicles	income
1001	3	Parry Sound	2	102118
1002	1	Parry Sound	0	68115
1003	2	Parry Sound	1	71032

… (for each household in the synthetic population)

Person records

householdID	personID	status	driver_lic	age	gender	home_loc	work_loc	sch_loc
1001	1	ft_service	Y	32	M	501	1803	NA
1001	2	pt_proftech	Y	34	F	501	2962	NA
1001	3	child	N	6	F	501	NA	503

… (for each person in synthetic population)

From long-term choice models

Generated using population synthesizer

Person activity-travel records

householdID	personID	tourID	activity	duration	origin	destination	purpose	mode	dep_time	travel_time
1001	1	1	home	8.23	501	1803	HW	a	8.23	.41
1001	1	1	work	9.10	1803	501	WH	a	17.74	.59
1001	1	1	home	6.26						

… (for each person and activity in synthetic population)

From person records for mandatory activities and activity location model for non-mandatory

Tour generation

Mode choice model(s)

Tour scheduler (or temporal allocation)

Pre-assignment

Vehicle trip matrices by user classes by period

Results aggregated for traffic assignment

ABMs – what they are and what they are not?

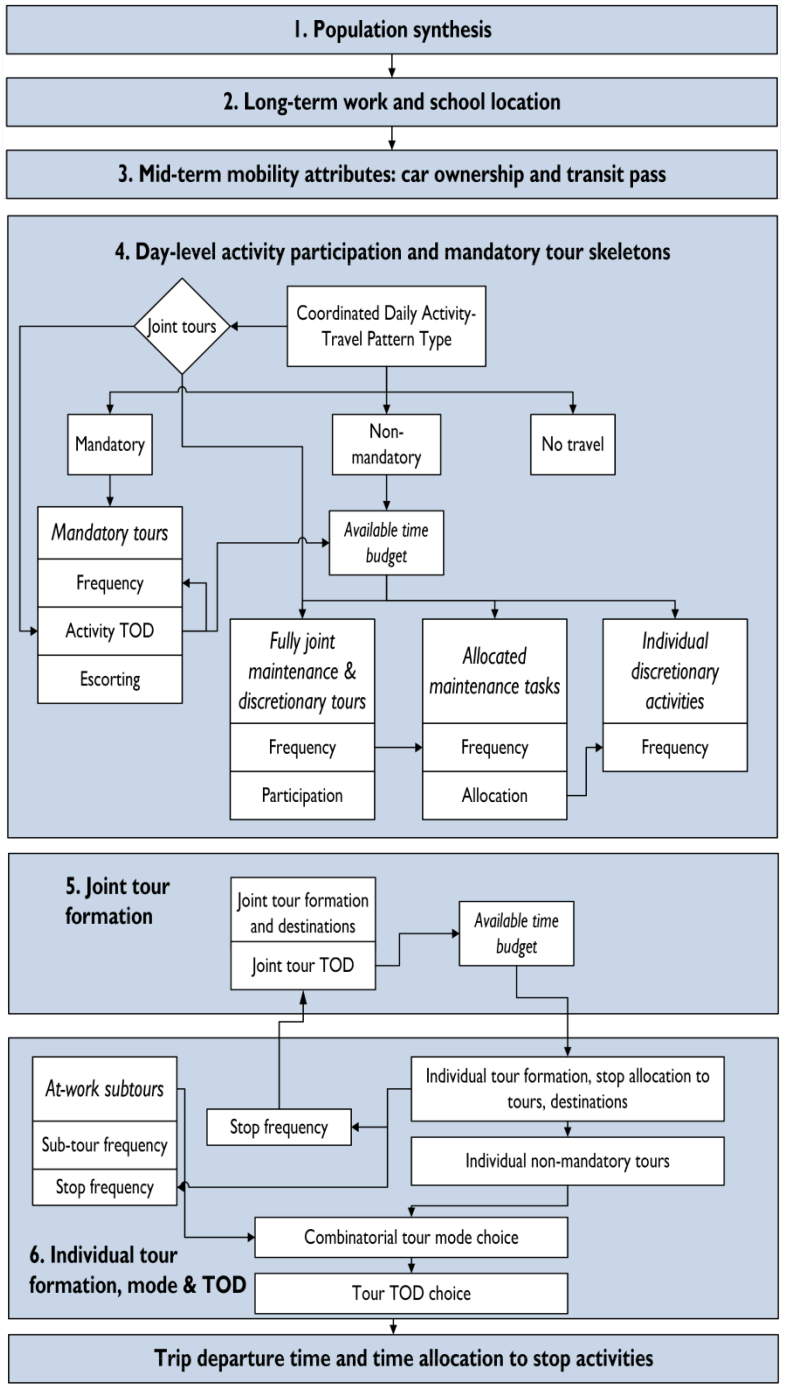
- They are not necessarily more accurate than trip or tour-based models
- They are not a simplified view of behavior, like the trip based model
- They are significantly more sensitive and aptly suited for forecasting
- They are consistent
  - Home → Markham GO → Union → Bay Street
  - Bay Street → Union → Markham GO → Home
- They recognize that decisions like auto ownership, auto availability, trip route choice etc. are not made by an individual independent of other household members
- They allow for amazing visualizations and insight

YORK ABM

COORDINATED TRAVEL-REGIONAL ACTIVITY MODELLING PLATFORM (CT-RAMP2)

York ABM structure (CT-RAMP2)

- Activity generation + tour formation instead of tour generation + stop insertion
- Combinatorial mode choice instead of two-stage tour/trip mode choice
- Improved temporal resolution and trip departure in continuous time instead of 30 min

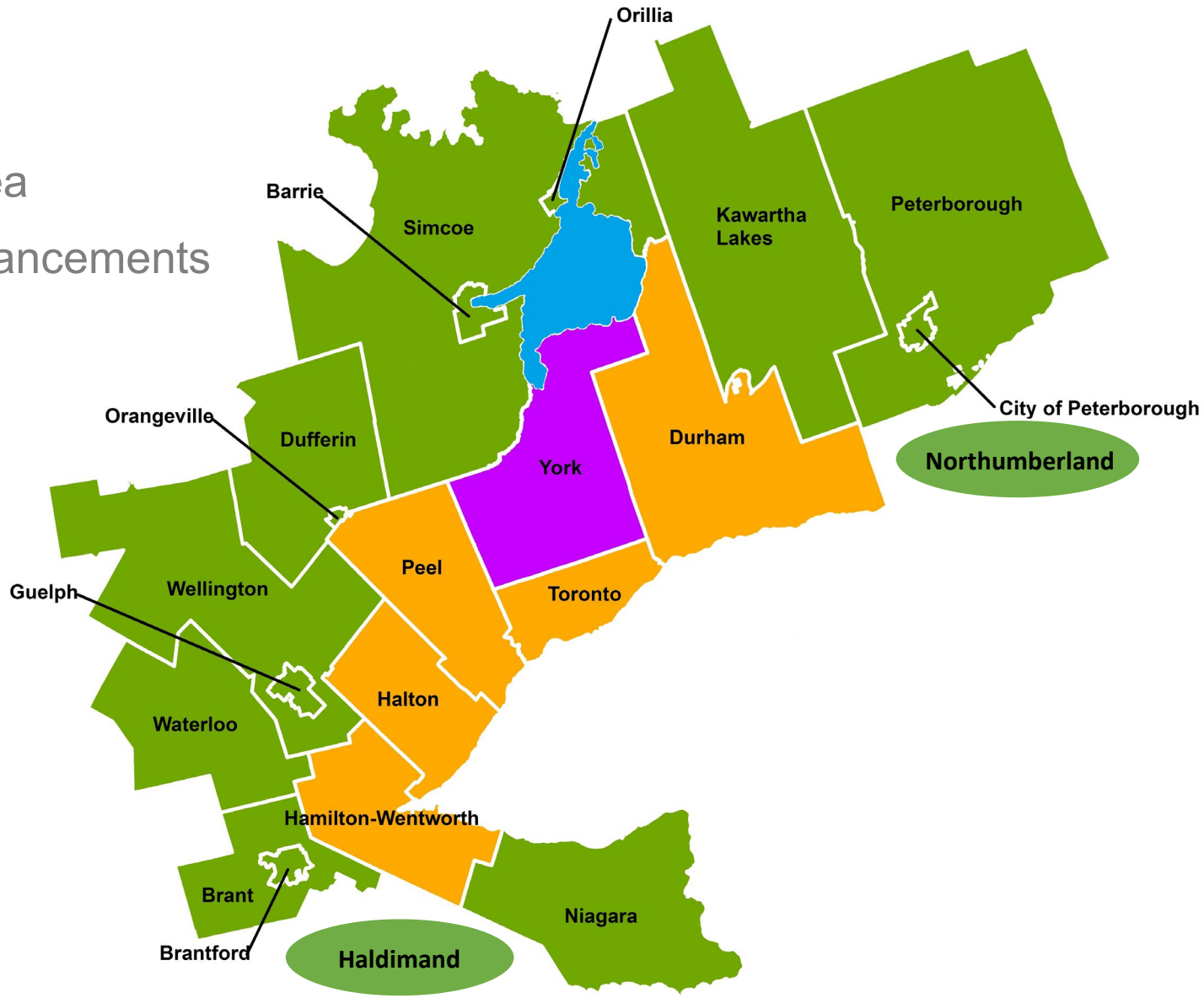


2016 INPUT DATA

NETWORK, LAND USE

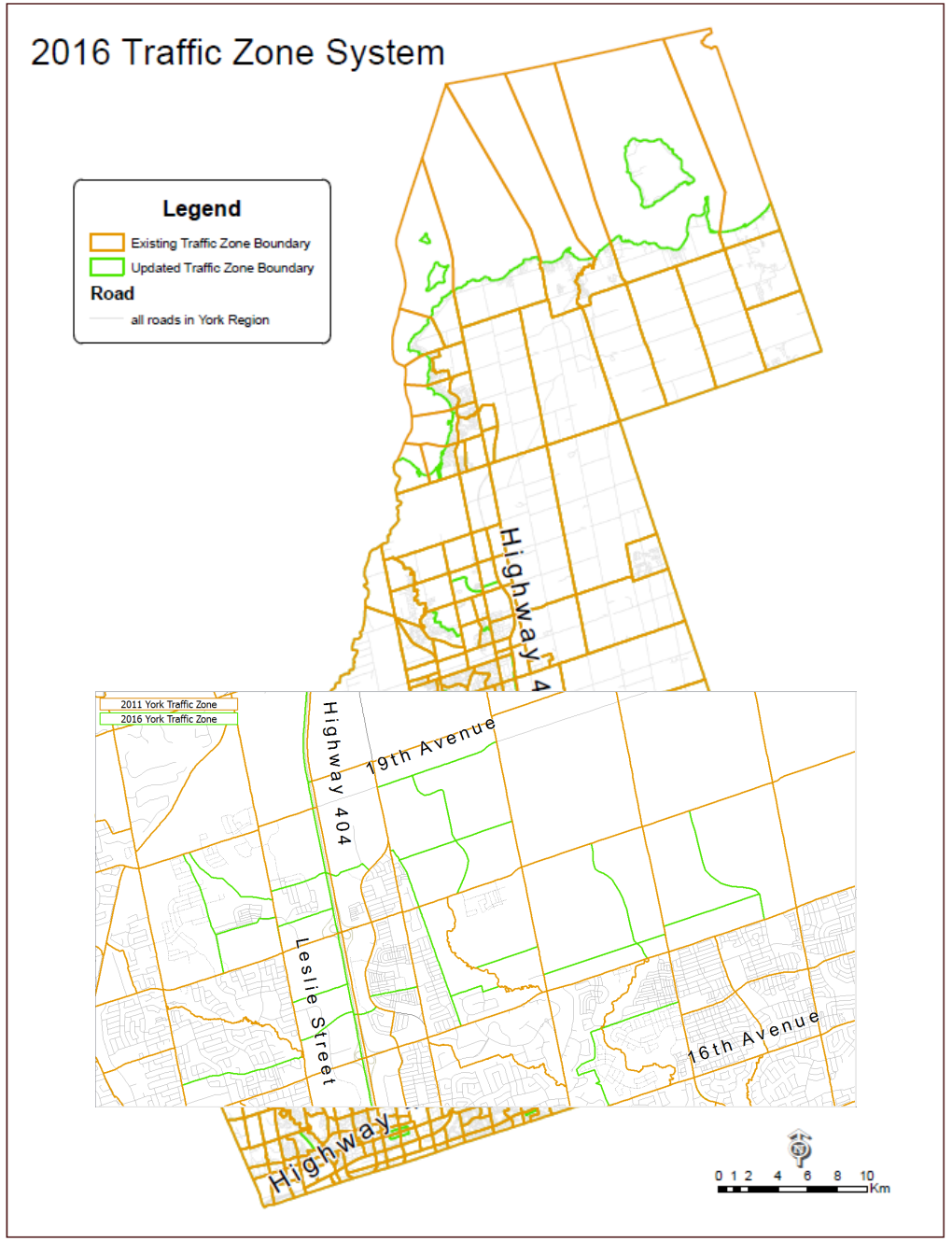
Network

- Covers Greater Golden Horseshoe Area
- Auto → GGHM v4.0 as a base + enhancements within the Region
  - TAZ System
  - Harmonized speeds and capacities
  - Adding road links
- Transit → GGHM v4.0 as a base + enhancements within the Region using GTFS
  - 5 time-of-day network
  - Improved transit time functions

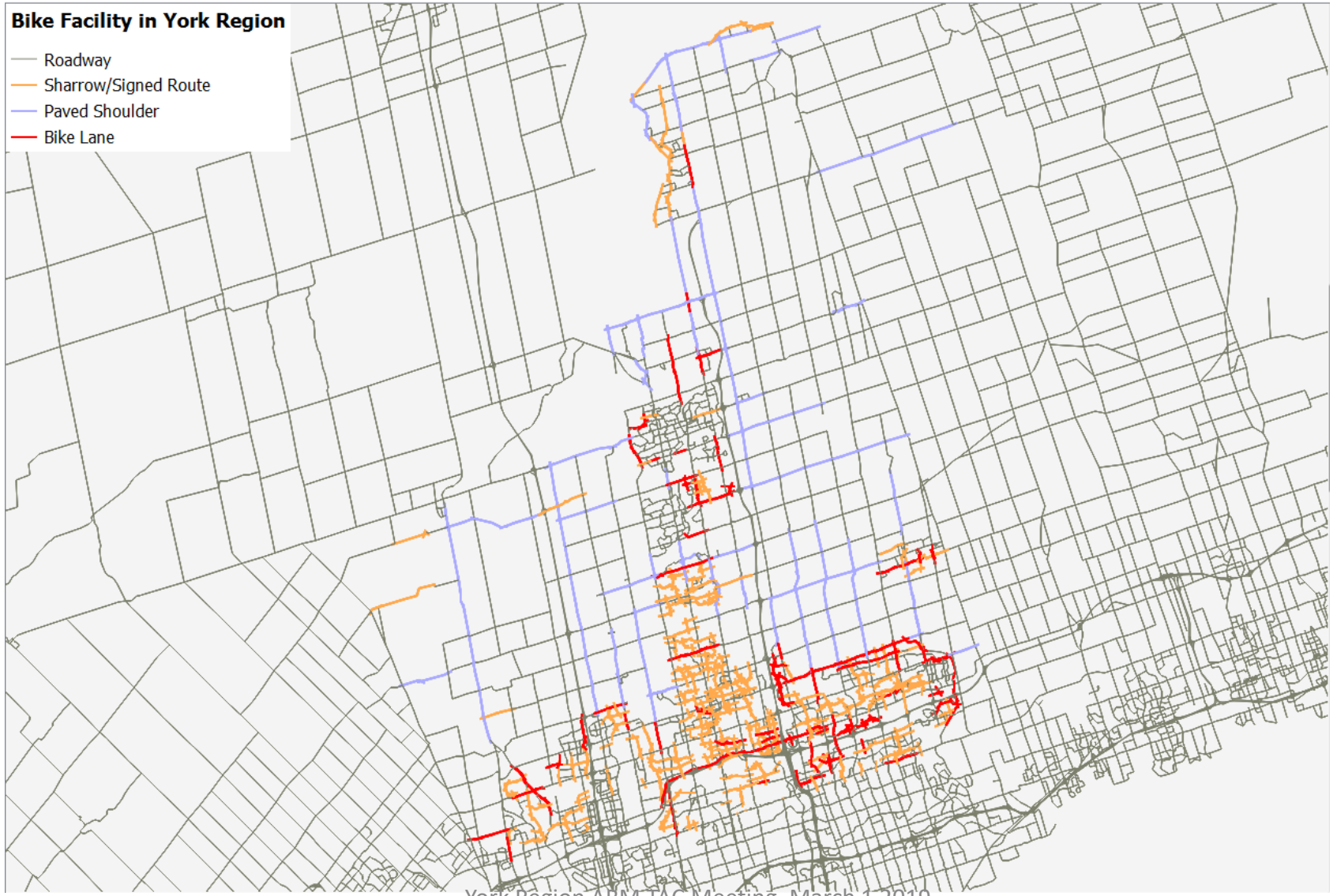


TAZ system

- Adopted GGHM v4.0 TAZ System
- Traffic zones in York Region were reviewed
  - Centres and Corridors
  - Planned development areas
  - Pop/Emp/Activity thresholds
- ~ 100 new traffic zones in York Region
- Total traffic zones = 3,240 including 611 in York Region



Network improvements – bike facility



Household and population

- Detailed population characteristics tabulated for TAZs and/or municipalities
- Sourced from StatsCanada for 2016 base year

Population attribute	Geography
Total households	TAZ
Total population Total residential population	TAZ
Household size	TAZ
Total number of workers	TAZ
Dwelling unit type	TAZ
Household income	TAZ
Population age	Municipality
Worker occupation (POR)	Municipality
Work from home (POW)	Municipality

Employment and school enrollment

- All employment data sourced from StatsCanada for 2016 base year
- School enrollment compiled for York Region from multiple sources; for rest of region from GGHM v4.0

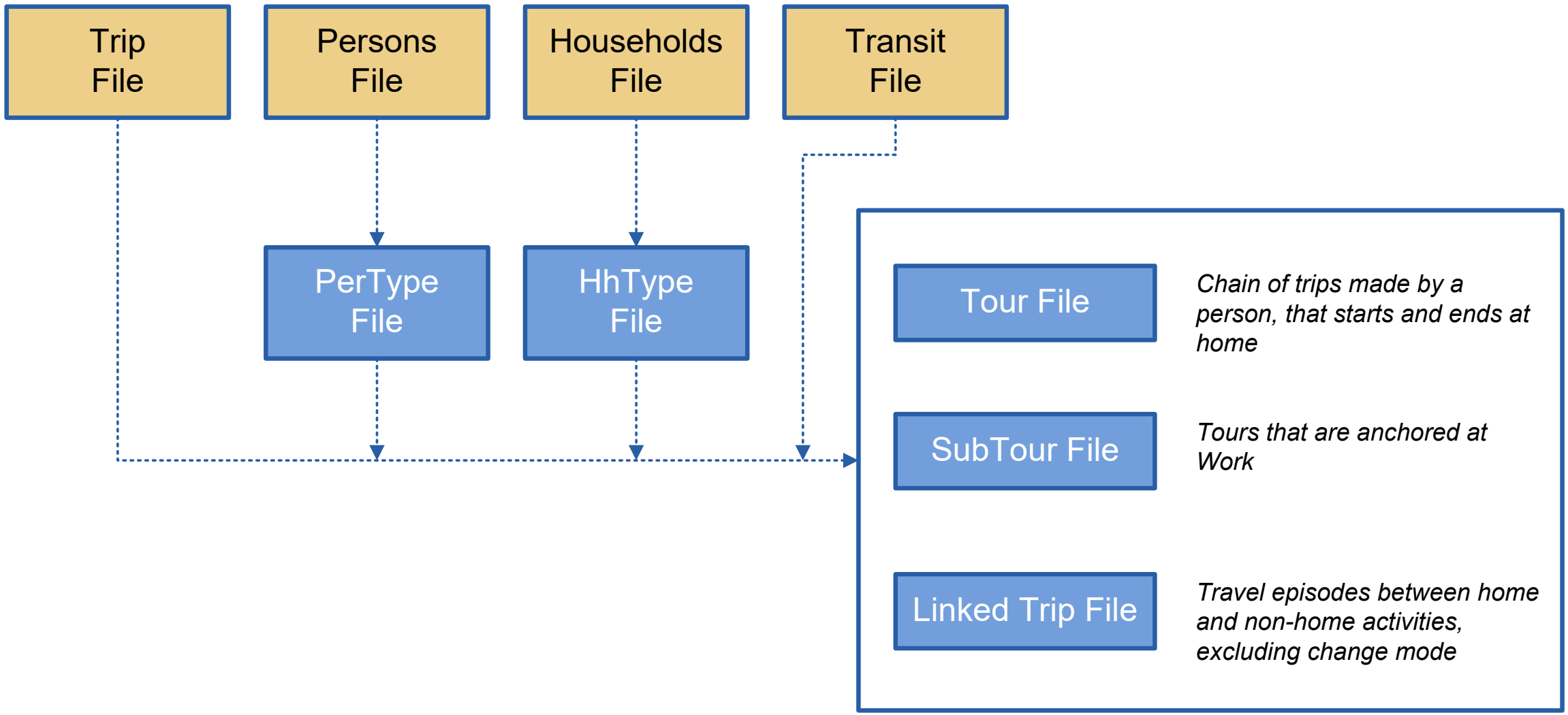
Population attribute	Geography
Workers by type of occupation (NOC) at POW	TAZ
Workers by type of industry (NAICS) at POW	TAZ
School enrollment by grade level (elementary, secondary, post-secondary)	TAZ

Built environment attributes

- job mix
- pop/hh/emp density
- percent of high transit area
- Bus stop density
- Road speed density
- bike infrastructure density
- parking cost
- etc.

2016 TTS DATA PROCESSING

TTS data processing framework



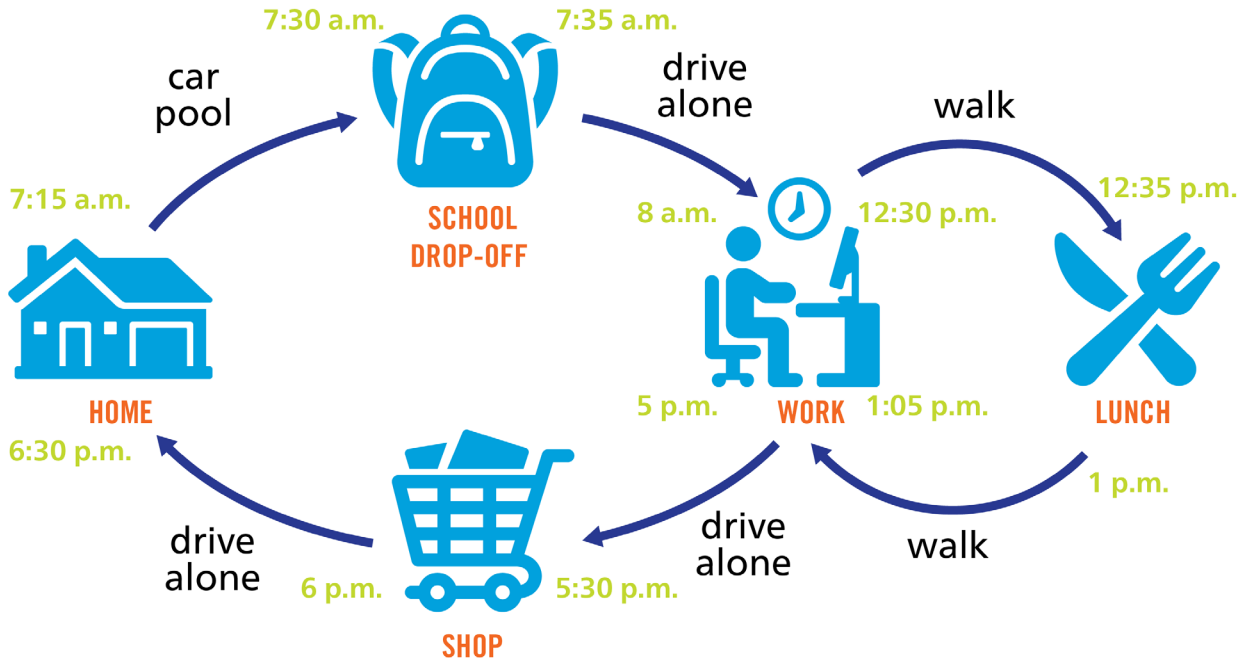
Survey data processing framework

- HHTYPE: Each record represents a household and includes household attributes useful for travel analysis (home location TAZ, income, household size, etc.).
- PERTYPE: Each record represents a person and includes person-level attributes useful for travel analysis (age, worker status, gender, etc.). Each person is assigned one of eight person types.

Person types	Age	Employment status	Student status
1=Full-time worker	[18, 100)	Full-time, Work at home full-time	--
2=Part-time worker	[18, 100)	Part-time, Work at home part-time	Part-time student, Not a student, Unknown
3=University student	[18, 100)	--	Full-time student
		Unknown, Not employed	Part-time student
4=Non-worker	[18, 65)	Not employed, Unknown	Not a student, Unknown
5=Retiree	[65, 100)	Not employed, Unknown	Not a student, Unknown
6=Driving-age student	[16,17]	--	Full-time student, Part-time student
7=Pre-driving age student	[5,15]	--	Full-time student, Part-time student
8=Pre-school children	[0,4]	--	--

Survey data processing framework

- LTRIPS: Each record is a linked trip, where “from place“ represents a trip origin and the “to place” a trip destination. Linked trip purpose is the purpose of the final trip in the set of unlinked trips.
- TOURS: Each record is a full tour, and includes information about each segment and leg of the tour delineated by tour destination and stops.
- SUBTOURS: Each record is a subtour (non-home-based), includes information about each segment and leg of the subtour delineated by tour destination and stops.



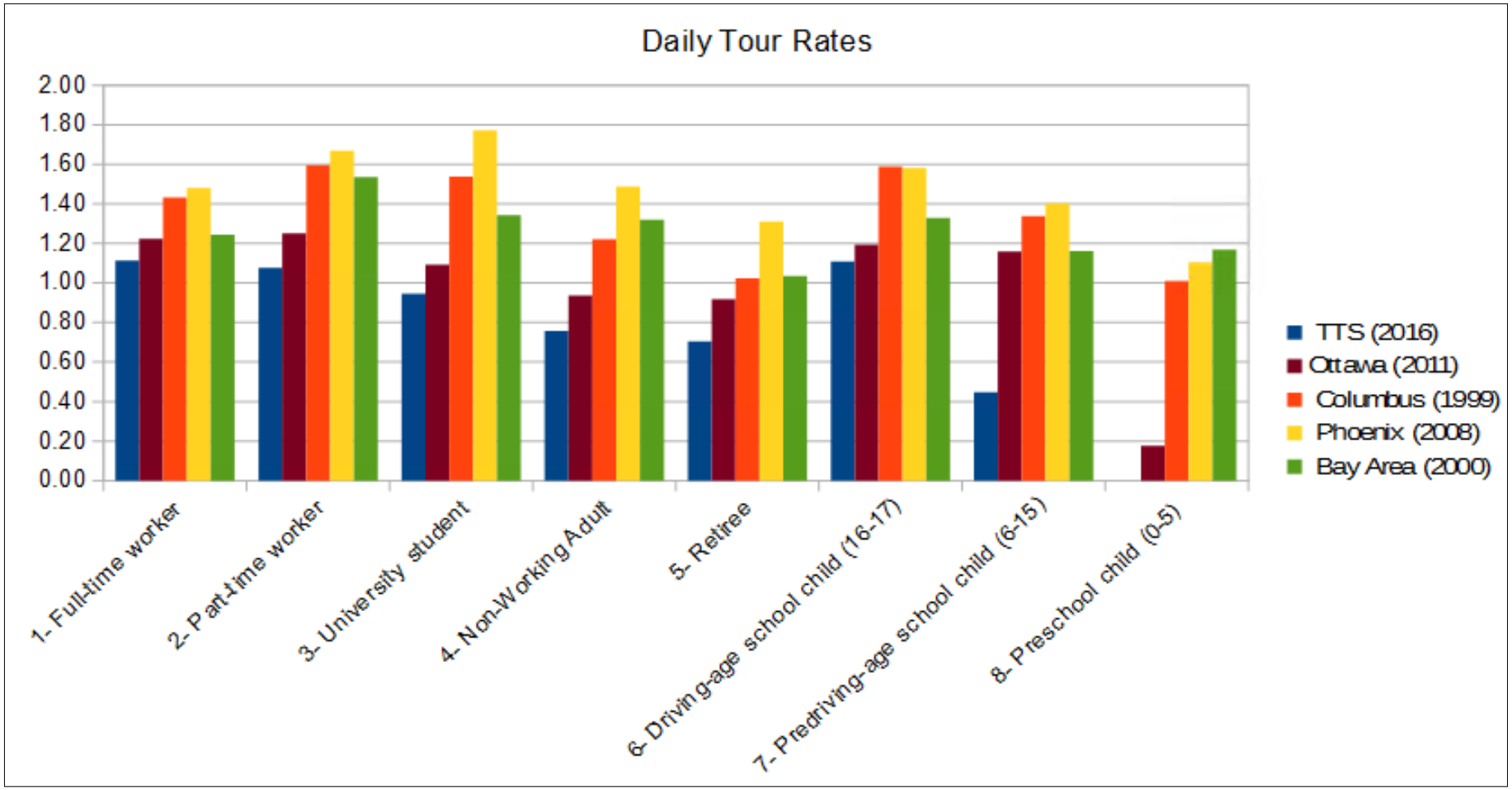
Trip data quality/completeness checks

	Number of Trips				
Destination purpose	Total	Known mode	Known timing	Known destination	All Known
Absolute number of trips in the survey (not expanded):					
0=Home	335,758	335,758	335,758	335,758	335,758
1=Work	164,329	164,329	164,329	164,328	164,328
2=University	21,398	21,398	21,398	21,398	21,398
3=School	26,161	26,161	26,161	26,161	26,161
4=Escort	49,818	49,818	49,818	49,814	49,814
5=Shopping	81,858	81,858	81,858	81,855	81,855
6=Other	118,743	118,743	118,743	118,728	118,728
Total	798,065	798,065	798,065	798,042	798,042
Row percent:					
0=Home		100.00%	100.00%	100.00%	100.00%
1=Work		100.00%	100.00%	100.00%	100.00%
2=University		100.00%	100.00%	100.00%	100.00%
3=School		100.00%	100.00%	100.00%	100.00%
4=Escort		100.00%	100.00%	99.99%	99.99%
5=Shopping		100.00%	100.00%	100.00%	100.00%
6=Other		100.00%	100.00%	99.99%	99.99%
Total		100.00%	100.00%	100.00%	100.00%

Tour data quality/completeness checks

	Number of Tours						
Destination purpose	Total	Known mode	Closed	Valid timing	Known primary destination	All Known	Symmetric mode
Absolute number of tours in the survey (not expanded):							
1=Work	146,271	146,271	142,142	140,879	146,270	139,659	122,710
2=University	15,361	15,361	14,918	14,354	15,361	14,071	11,554
3=School	25,749	25,749	25,405	23,459	25,749	23,202	20,735
4=Escort	29,159	29,159	28,698	23,693	29,155	23,521	9,769
5=Shopping	55,939	55,939	55,225	52,350	55,936	51,963	53,094
6=Other	66,380	66,380	63,430	61,675	66,368	61,117	59,196
Total	338,859	338,859	329,818	316,410	338,839	313,533	277,058
Row percent:							
1=Work		100.00%	97.18%	96.31%	100.00%	95.48%	83.89%
2=University		100.00%	97.12%	93.44%	100.00%	91.60%	75.22%
3=School		100.00%	98.66%	91.11%	100.00%	90.11%	80.53%
4=Escort		100.00%	98.42%	81.25%	99.99%	80.66%	33.50%
5=Shopping		100.00%	98.72%	93.58%	99.99%	92.89%	94.91%
6=Other		100.00%	95.56%	92.91%	99.98%	92.07%	89.18%
Total		100.00%	97.33%	93.38%	99.99%	92.53%	81.76%

Survey data – comparison to other Regions



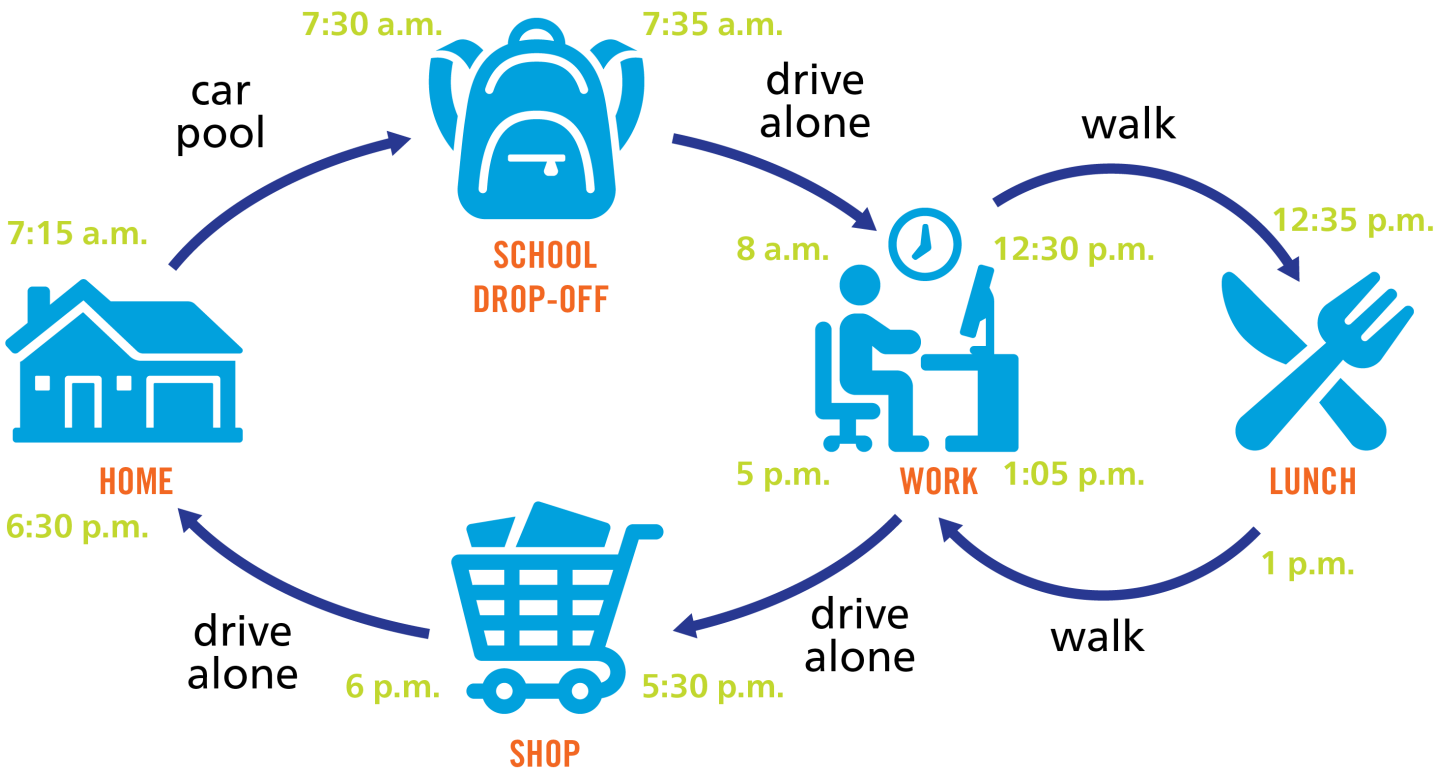
ABM SEGMENTATION

Person-type segmentation

Person Type	PERSON-TYPE	AGE	WORK STATUS	SCHOOL STATUS
1	Full-time worker	18+	Full-time	None
2	Part-time worker	18+	Part-time	None
3	Non-Worker	18 – 64	Unemployed	None
4	Retired	65+	Unemployed	None
5	College student	18+	Any	College +
6	Driving age student	16-17	Any	Pre-college
7	Pre-driving age student	6 – 16	None	Pre-college
8	Pre-school children	0-5	None	None

Activity-type segmentation

- Mandatory activities
  - Work
  - University
  - School
  - School escorting
- Non-mandatory activities
  - Escort
  - Shopping
  - Maintenance
  - Eating out
  - Visiting
  - Discretionary



Temporal resolution

1. AM Peak (6:00 AM to 8:59 AM)
2. Midday (9:00 AM to 2:59 PM)
3. PM Peak (3:00 PM to 6:59 PM)
4. Evening (7:00 PM to 11:59PM)
5. Night (12 AM to 5:59 AM)

Travel mode classification

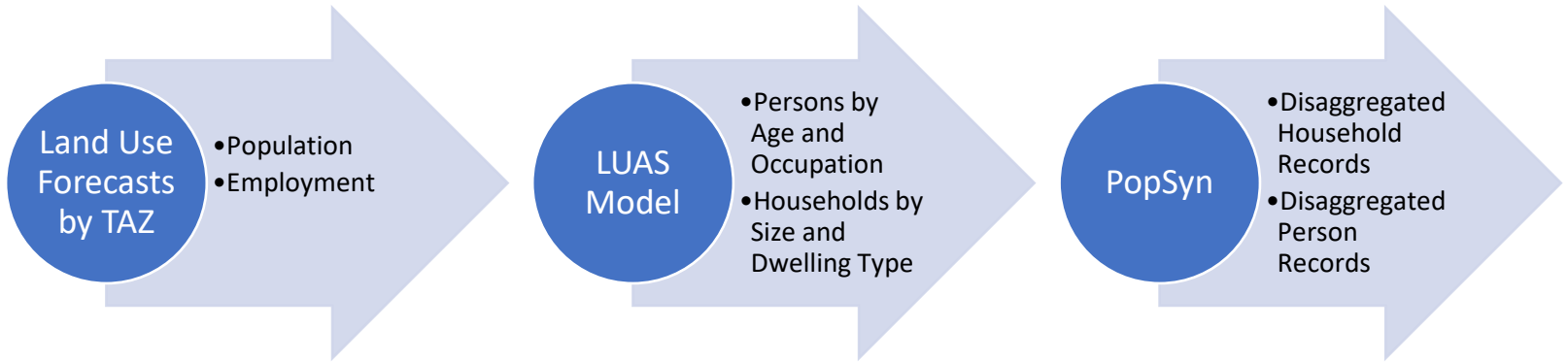
1. SOV
2. HOV2
3. HOV3+
4. Auto Passenger
5. Walk Transit (conventional and premium)
6. Kiss-and-Ride Transit (conventional and premium)
7. Park-and-Ride Transit (conventional and premium)
8. Walk
9. Bike
10. Taxi
11. School Bus

Employment classification

#	Two-digit NAICS code	Industry
1	11, 21	Agriculture, Mining
2	22, 23	Construction, Utility
3	31, 42	Manufacturing, Wholesale
4	44, 81	Retail, Other Services
5	51, 54-56	Information, Business Services
6	61, 62	Education & Health/Social Service
7	52, 53	Finance, Investment, Real Estate Services
8	71, 72	Arts, Entertainment, and Hospitality, Food Service
9	92	Public Administration

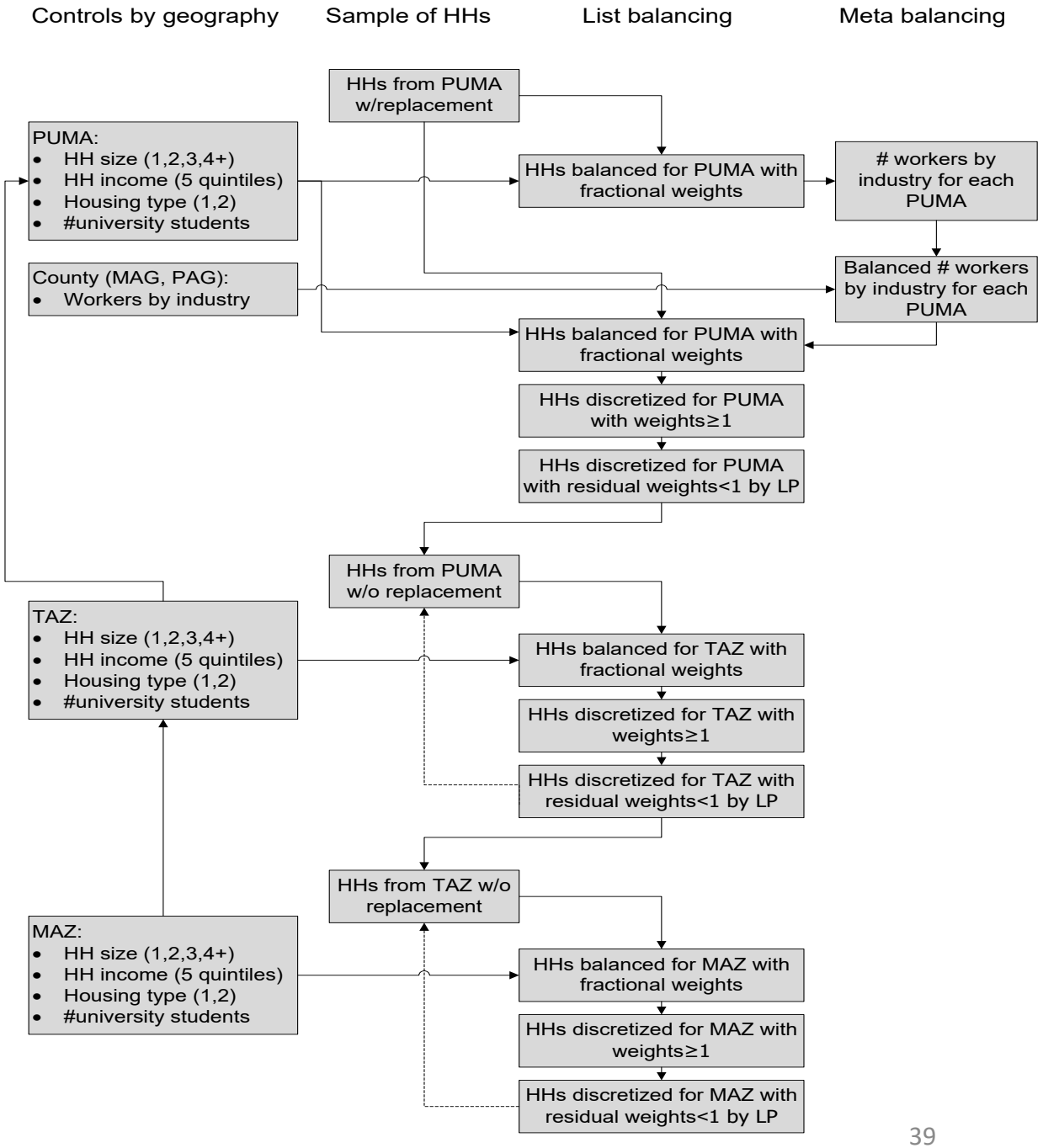
POPULATION SYNTHESIS

Population synthesis framework



Popsyn3 population synthesizer

- Creates a list of persons that “looks” like a 100% census of the regional population
- Flexible list balancing core procedure:
- Any household-level and person-level controls at different levels of geography
- Weights reflecting relative importance and reliability of control inputs
- Uniform household expansion weights as much as possible



Control totals by source

Control type	Geography Available	Categories control	Categories PUMF	Used Categories	Importance
Total Households	TAZ	continuous	continuous	continuous	1000000000
Total Population	TAZ	continuous	continuous	continuous	1000000
Age	Municipality	0-14, 15-24, 25-44, 45-64, 65+	0-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-64,65-74,75+	0-14, 15-24, 25-44, 45-64, 65+	1000
Income	TAZ	0-14,999 15,000-39,999 40,000-59,999 60,000-99,999 100,000-124,999 125,000+	continuous	0-39,999 40,000-59,999 60,000-99,999 100,000+	1000
Household Size	TAZ	1, 2, 3, 4+	continuous	1, 2, 3, 4+	1000
Work Status	Municipality	full time, part time	full time, part time	full time, part time	10000
Dwelling type	TAZ	single-detached house, semi-detached-house, apartment in building of 5 or fewer storeys, apartment in building of 5 or more storeys, apartment or flat in a duplex, row house, other single-attached house, movable dwelling	single-detached house, semi-detached house, row house, apartment or flat in a duplex, apartment in building of 5 or fewer storeys, apartment in building of 5 or more storeys, other single-attached house, movable dwelling	house apartment other	1000
Work Location	Municipality	worked at home, worked outside Canada, no fixed workplace, usual place of work-inside province, usual place of work-outside province	worked at home, no fixed address, worked outside Canada, worked in census subdivision, worked in different census subdivision, worked in a different census division, worked in a different province	work at home work away from home	1000

Regional household control validation

Control category	Target	PopSyn	Diff
tothh	3,400,255	3,400,255	-
hhsize1	838,010	837,681	(329)
hhsize2	1,040,735	1,040,635	(100)
hhsize3	576,515	576,551	36
hhsize4pl	944,995	945,388	393
hhinc0_39	808,900	805,178	(3,722)
hhinc100pl	1,244,915	1,255,304	10,389
hhinc40_59	508,865	506,442	(2,423)
hhinc60_99	837,575	833,331	(4,244)
house	2,193,660	2,193,632	(28)
apartment	1,197,095	1,197,107	12
other	9,500	9,516	16

Similar comparisons have been prepared for each municipality in the model area

Regional person control validation

Control category	Target	PopSyn	Diff
totpop	9,158,770	9,158,787	17
age0_14	1,519,525	1,518,995	(530)
age15_24	1,184,440	1,184,007	(433)
age25_44	2,444,205	2,442,412	(1,793)
age45_64	2,570,495	2,569,199	(1,296)
age65pl	1,440,105	1,397,320	(42,785)
fulltime	2,548,995	2,550,406	1,411
parttime	1,899,445	1,897,956	(1,489)
work_away_home	4,114,910	4,115,004	94
work_home	333,530	333,542	12

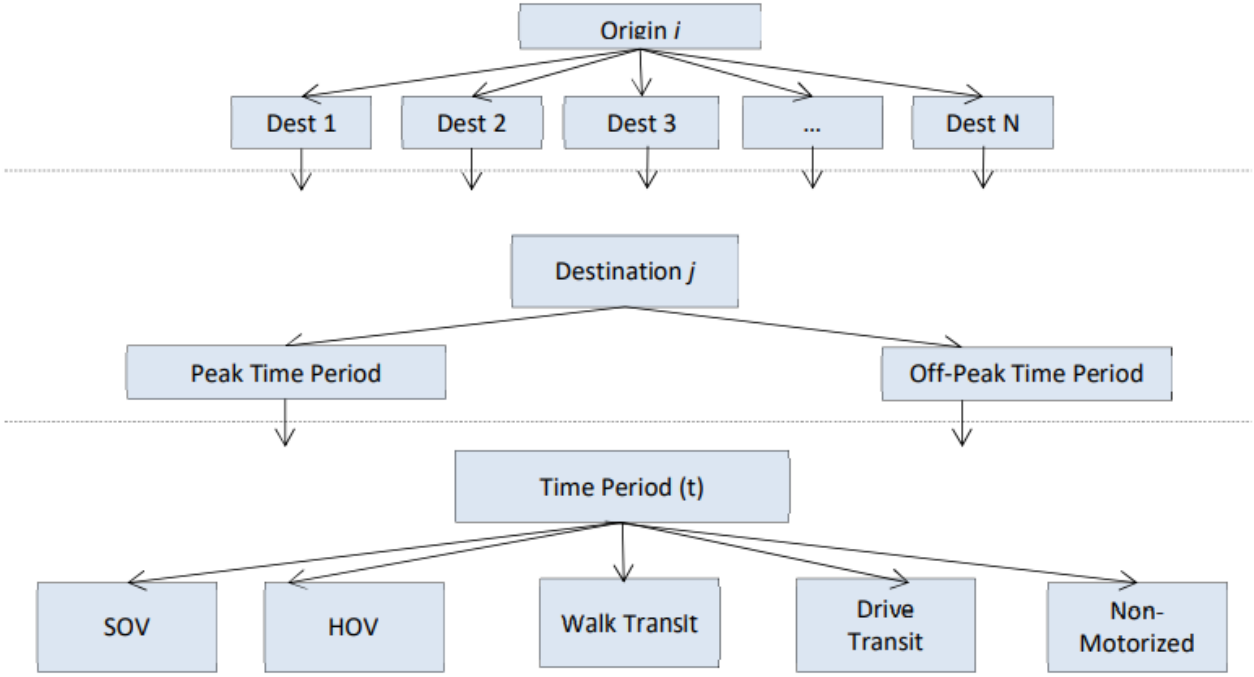
Similar comparisons have been prepared for each municipality in the model area

LONG TERM ACCESSIBILITIES

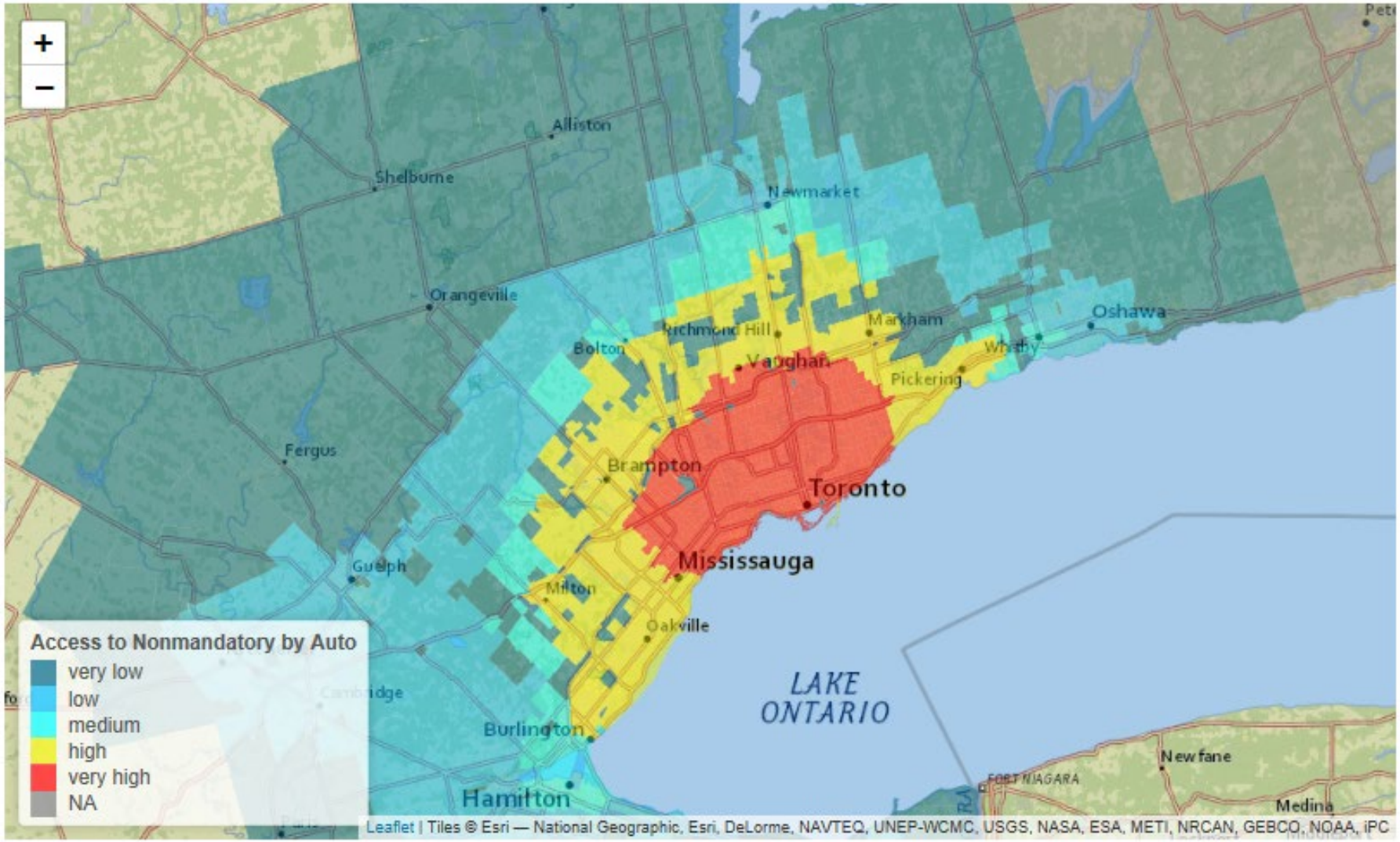
ACCESSIBILITY MANAGER

Accessibilities

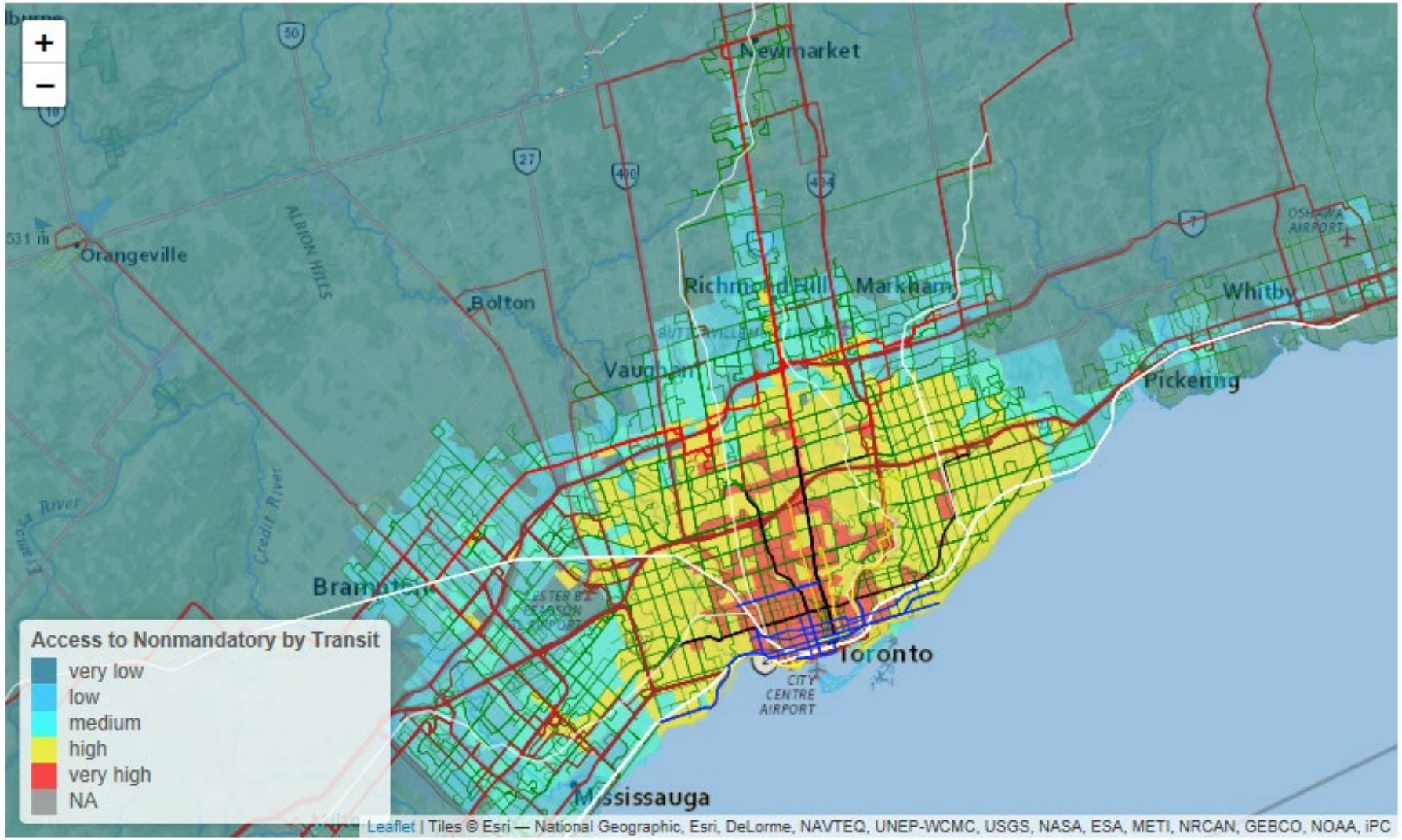
- Inform many long-term and mobility choice models
- Accessibility components:
  - Type of destination
  - Travel mode
  - Travel purpose
- York ABM accessibilities:
  - Non-mandatory activity by mode (3)
  - Work activity (industry category) (9)
  - Non-mandatory activity by auto sufficiency (3)
  - Non-mandatory activity for purpose (5) by auto sufficiency (3)



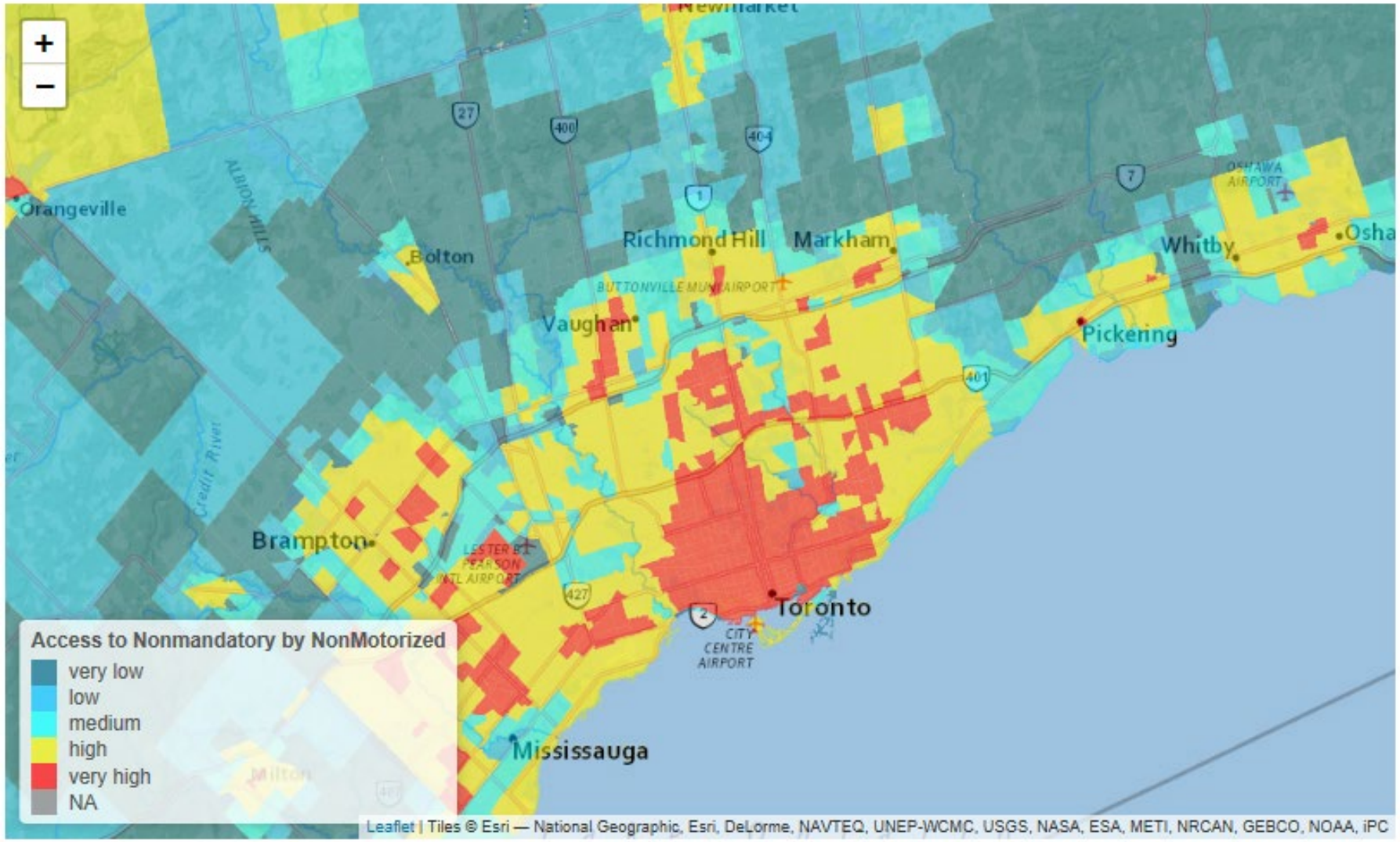
Auto accessibility



Transit accessibility



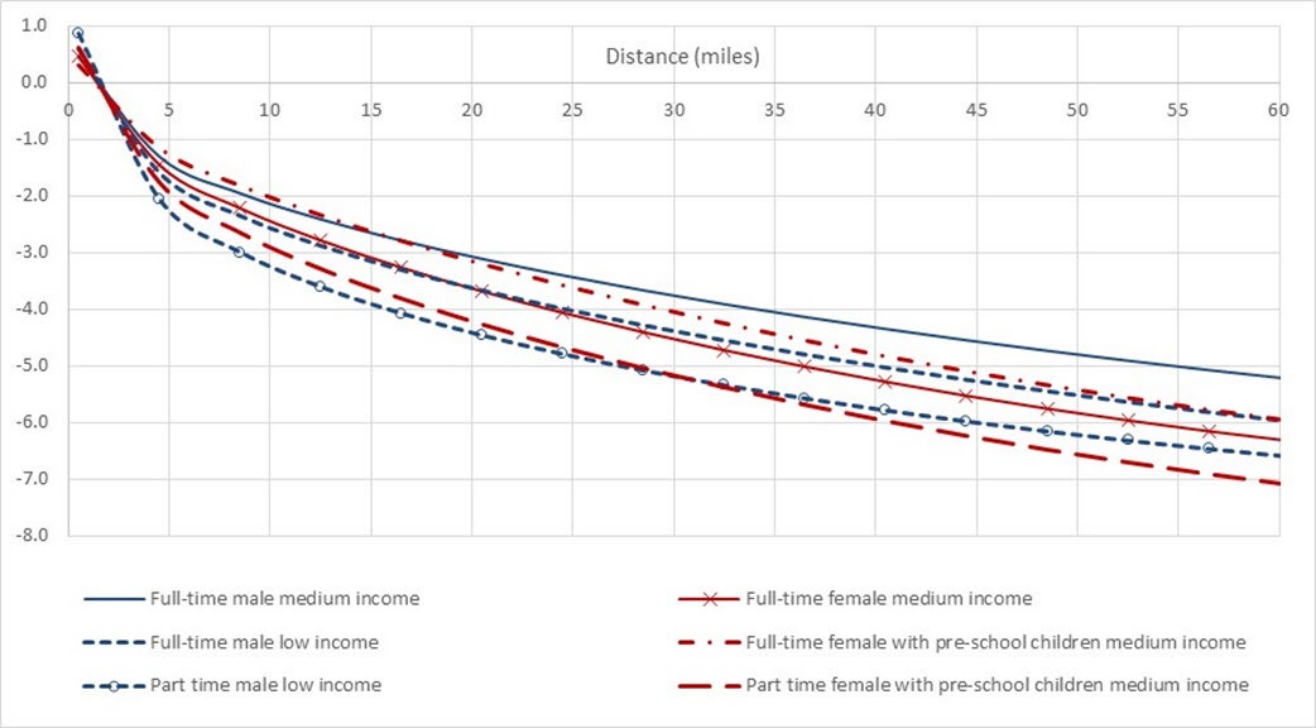
Walk accessibility



LONG-TERM CHOICE

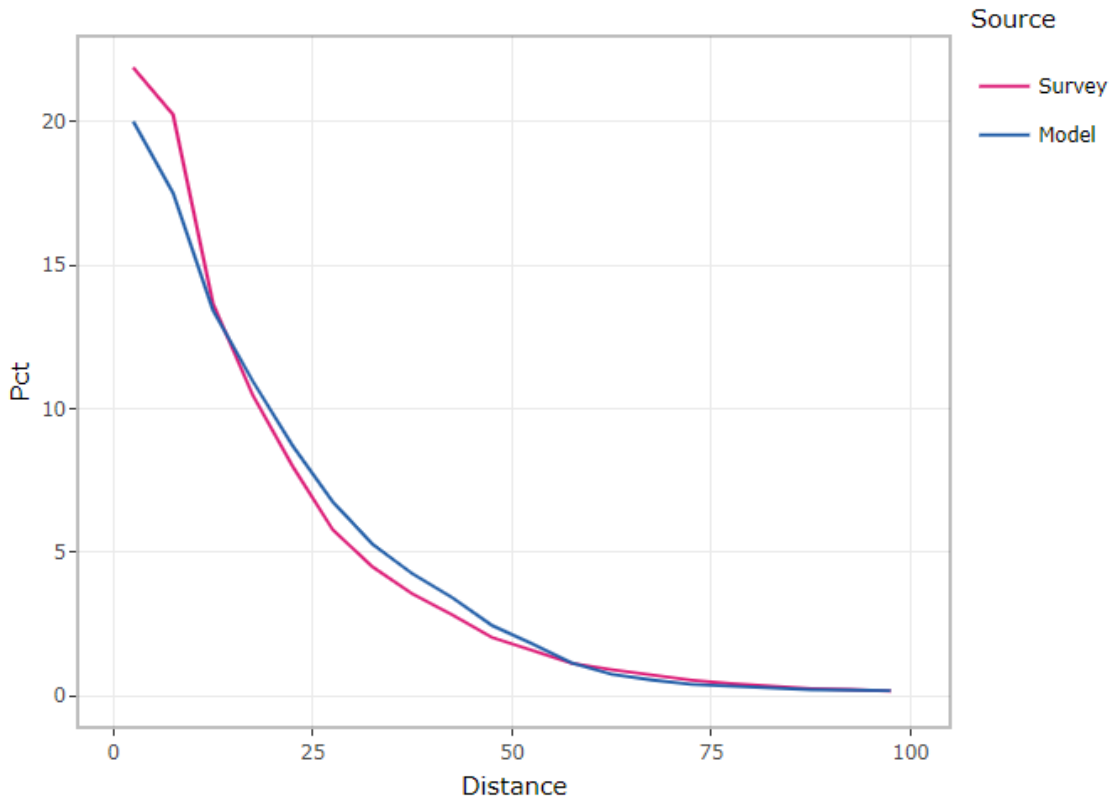
Long term choice

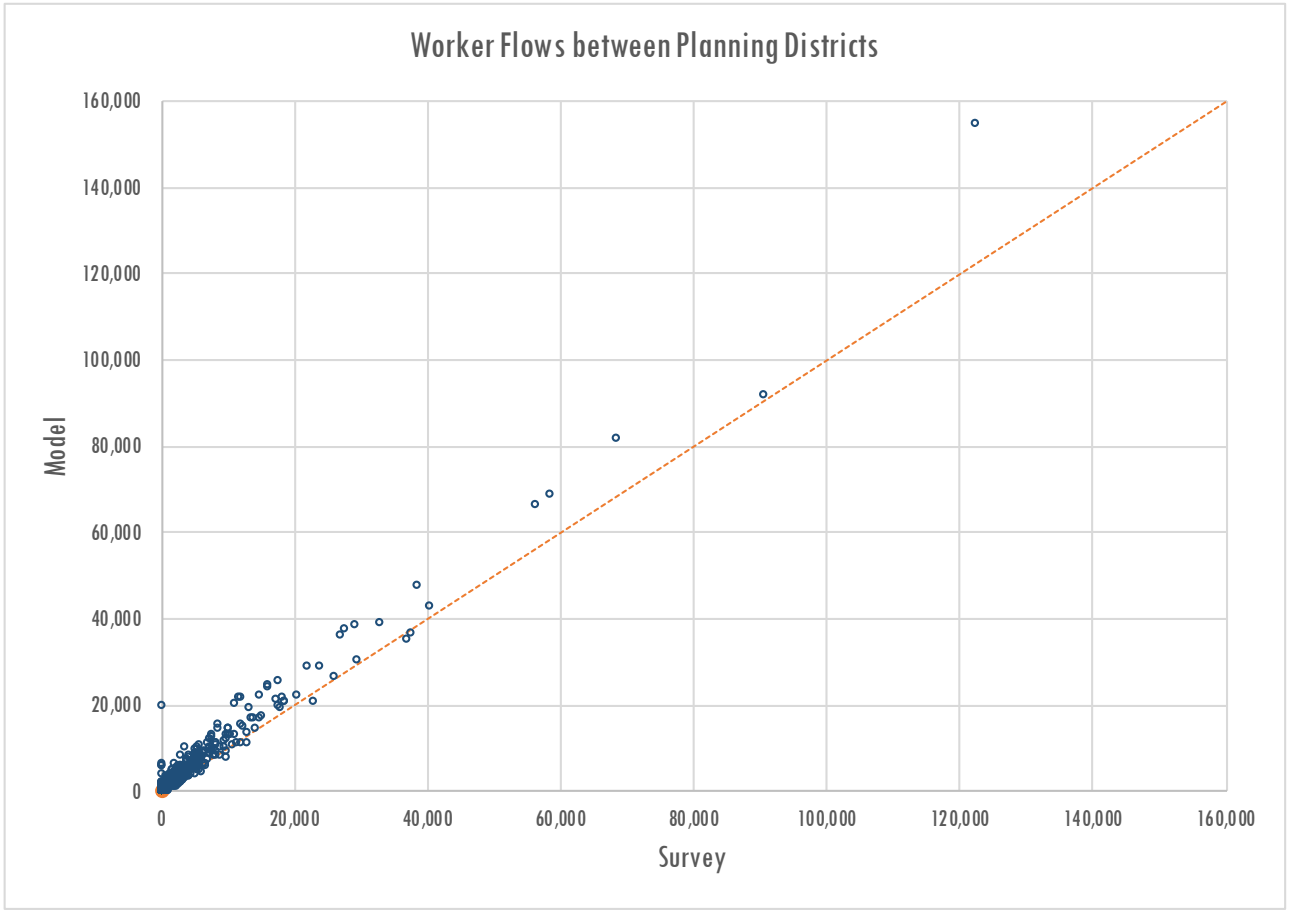
- Work arrangements
  - Weekly work duration on primary job
  - Primary workplace location type (fixed workplace, home, variable workplace)
  - Number of jobs
- Usual work/school location
- Work schedule flexibility



Usual work location

Source	WeightedLength
Survey	18.9
Model	20.5

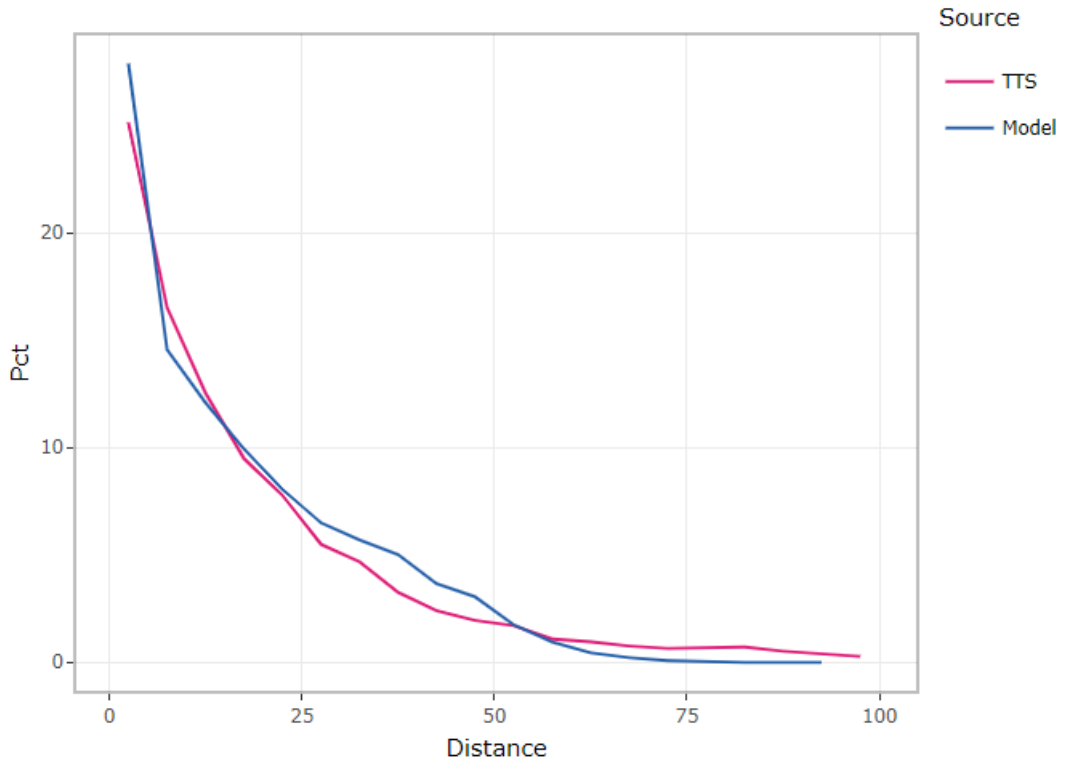




Usual school location

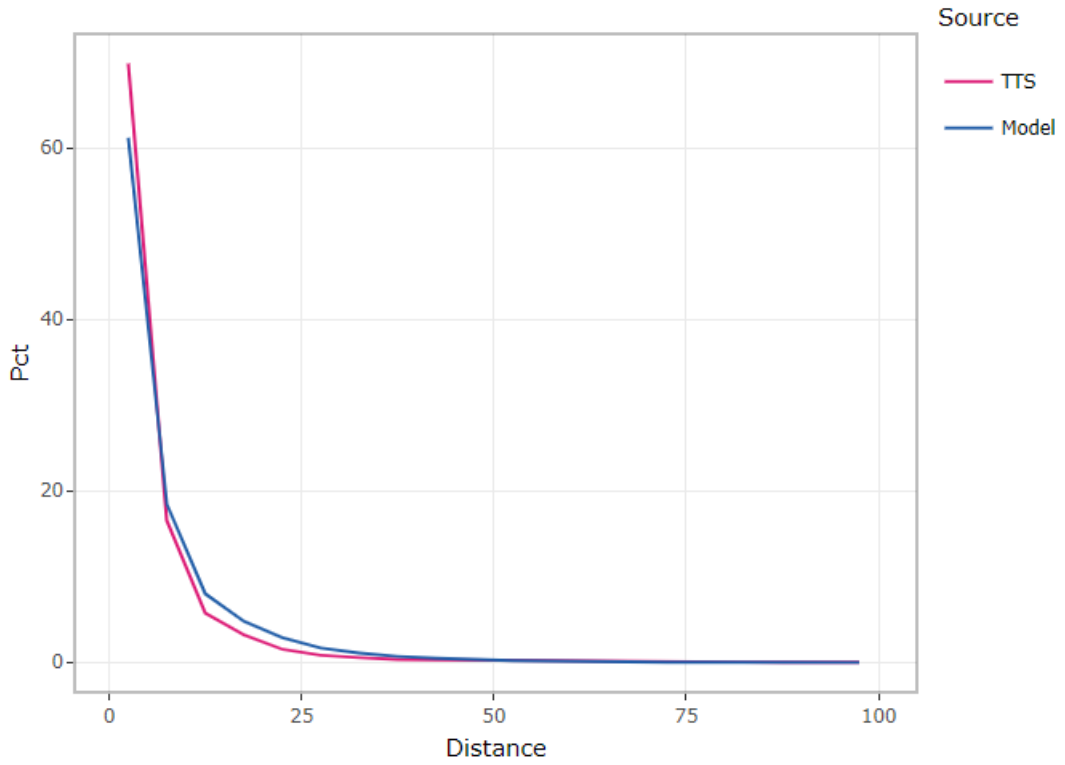
University

Source	WeightedLength
TTS	22.0
Model	17.5



Grade School

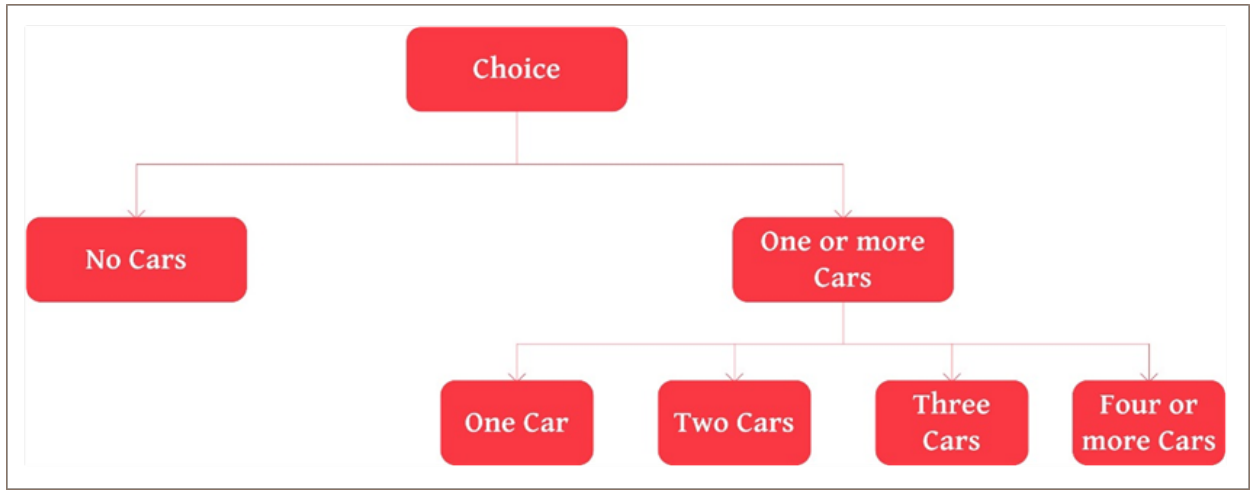
Source	WeightedLength
TTS	5.7
Model	6.9



MOBILITY ATTRIBUTES

Mobility choice

Predicts decisions of holding driver license and number of cars owned by each household



Driving license holding

Person Type	Survey	Model
1 Full-time worker	94%	94%
2 Part-time worker	85%	86%
3 College student	77%	77%
4 Non-working adult	75%	76%
5 Non-working senior	71%	72%
6 Driving-age child	42%	41%
Total	84%	83%

Auto ownership

	Vehicles per Household -- Survey				
Drivers	0	1	2	3	4P
0	97%	3%	0%	0%	0%
1	19%	75%	6%	1%	0%
2	3%	30%	58%	7%	2%
3	1%	13%	45%	34%	7%
4P	1%	5%	26%	34%	34%

	Vehicles per Household -- Model				
Drivers	0	1	2	3	4P
0	97%	3%	0%	0%	0%
1	22%	73%	5%	1%	0%
2	4%	31%	58%	6%	1%
3	2%	13%	45%	35%	5%
4P	1%	5%	26%	38%	30%

Auto ownership

	Vehicles per Household -- Survey			
Workers	0	1	2	3P
0	28%	53%	16%	3%
1	16%	51%	27%	6%
2	6%	26%	55%	14%
3P	3%	13%	35%	50%

	Vehicles per Household -- Model			
Workers	0	1	2	3P
0	32%	47%	17%	4%
1	15%	50%	28%	7%
2	5%	28%	51%	15%
3P	2%	17%	40%	41%

Auto ownership

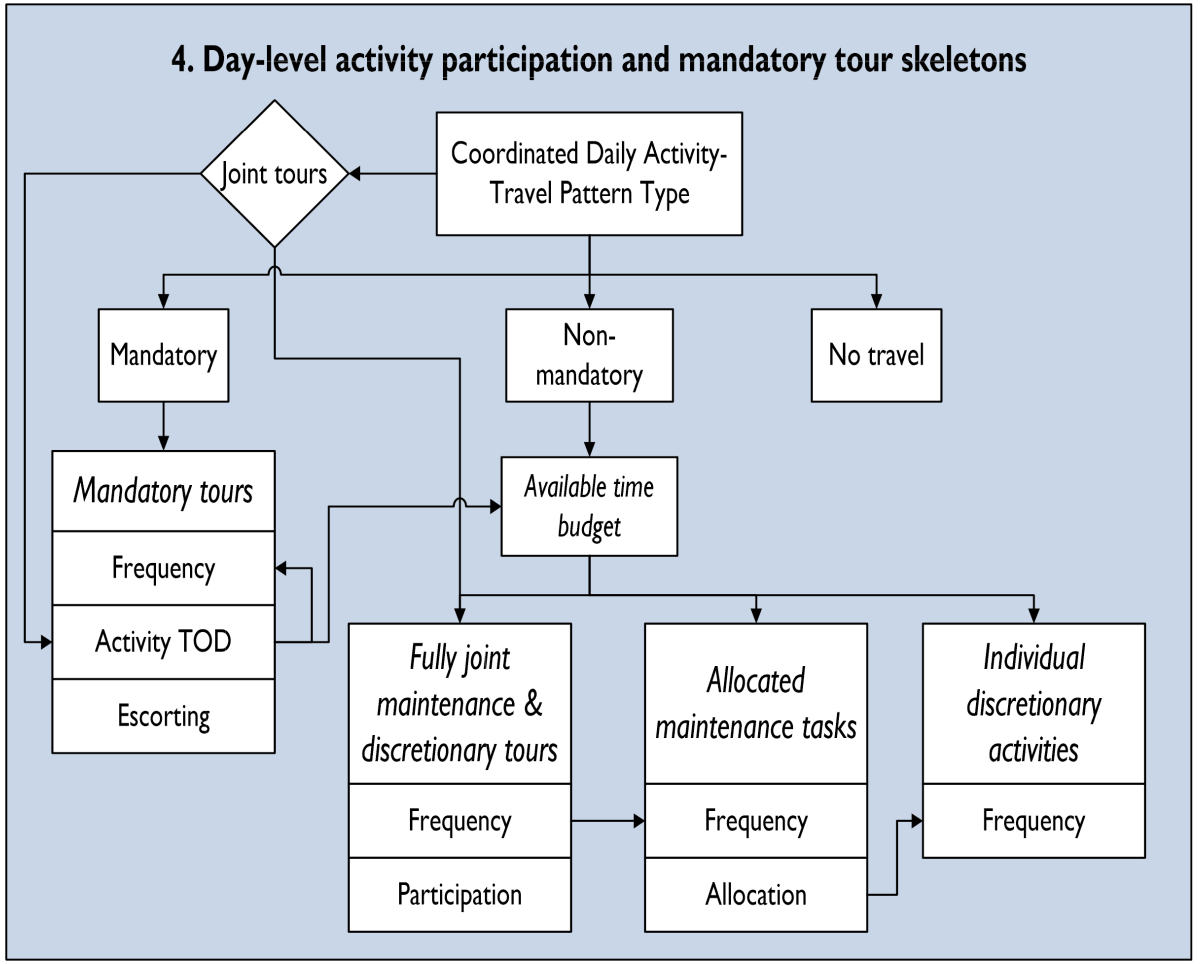
	Vehicles per Household -- Survey			
Population Density	0	1	2	3P
Lowest	6%	38%	30%	25%
Low	2%	20%	45%	34%
Med-Low	3%	24%	43%	30%
Med-High	5%	35%	43%	17%
High	14%	40%	35%	11%
Highest	42%	49%	8%	1%

	Vehicles per Household -- Model			
Population Density	0	1	2	3P
Lowest	13%	42%	30%	15%
Low	7%	31%	38%	24%
Med-Low	8%	32%	38%	22%
Med-High	12%	38%	36%	15%
High	15%	39%	34%	12%
Highest	35%	49%	14%	2%

MANDATORY TOUR SKELETONS

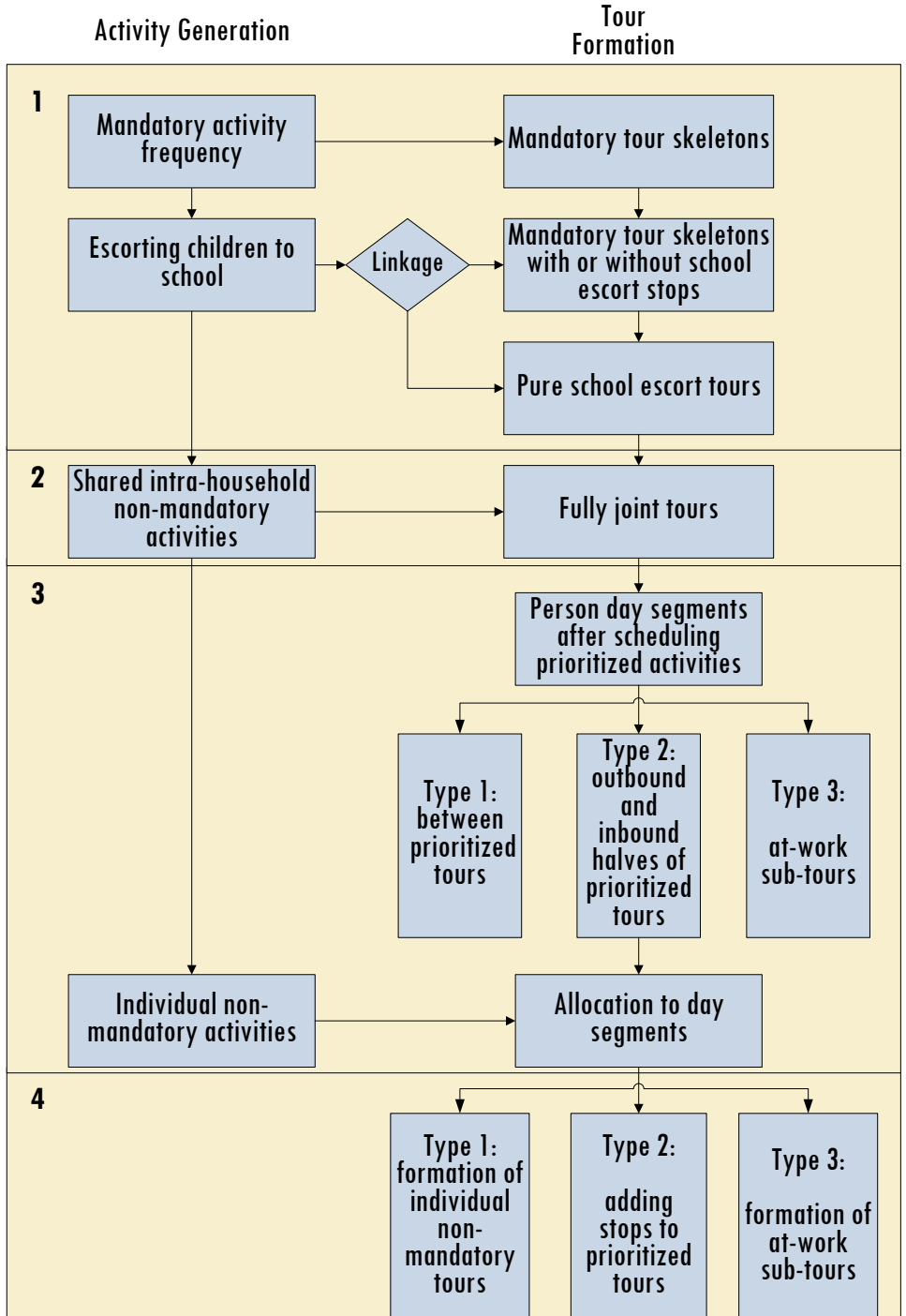
Activity episode generation

- Activity Day-Pattern
- Prioritized activity generation and sequencing
  - Work episodes
  - Business episodes
  - School episodes
  - Fully-joint activities
- Prioritized activity start and end time



Activity episode generation

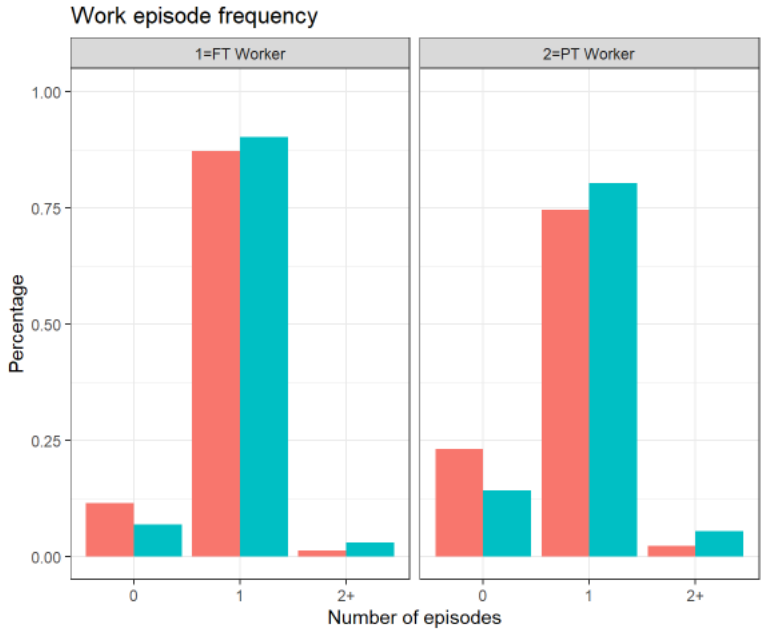
- Mandatory tour skeletons
- School escort arrangements
- Joint activities and tours
- Formation of day-segments
- Non-mandatory activity generation
- Adding stops to mandatory tours, and
- Formation of non-mandatory tours

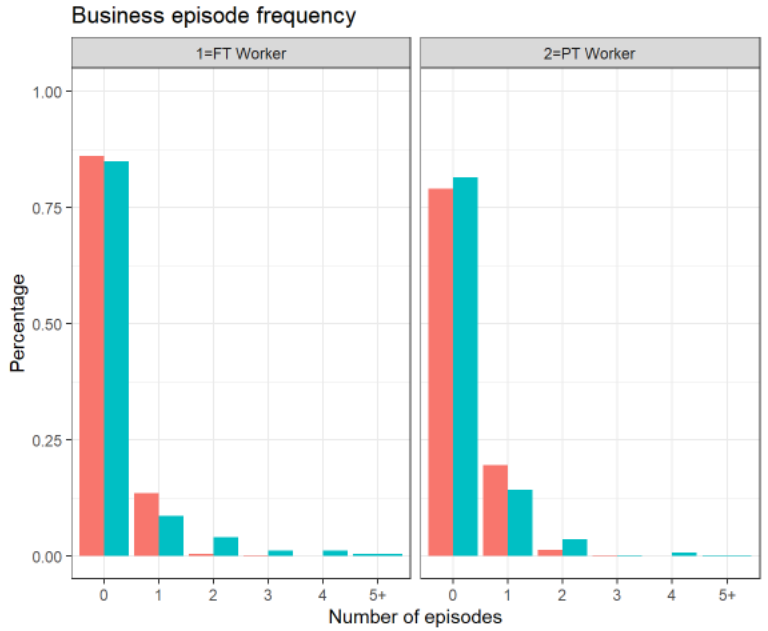


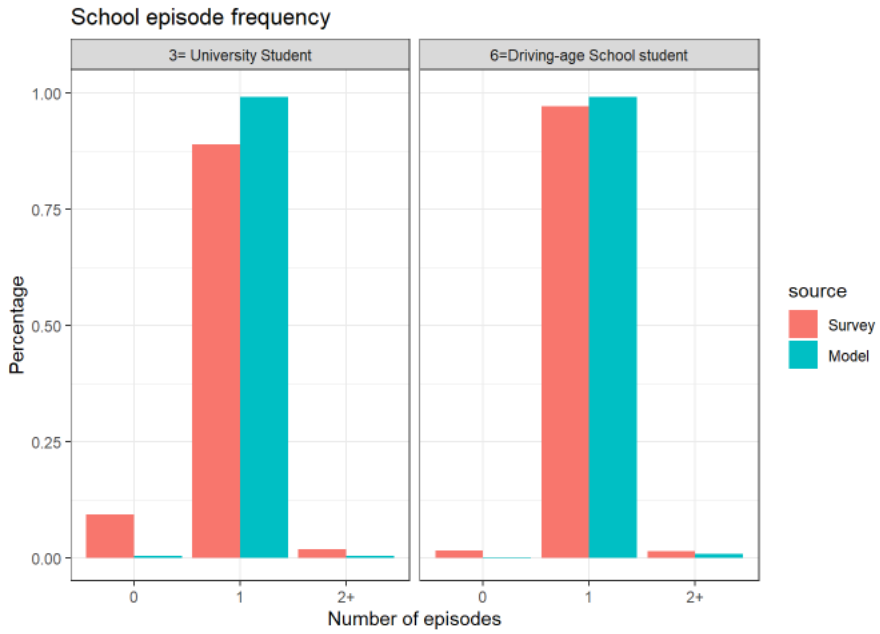
Coordinated daily activity pattern

	Survey			Model		
Person type	**Mandatory**	**Non Mandatory**	**Home**	**Mandatory**	**Non Mandatory**	**Home**
Full-time worker	82%	8%	10%	81%	8%	10%
Part-time worker	54%	24%	22%	55%	23%	22%
University student	71%	8%	21%	68%	8%	23%
Non-working adult[1]	0%	50%	50%	0%	49%	51%
Non-working senior	0%	53%	47%	0%	52%	48%
Driving age student	89%	3%	8%	88%	3%	8%
Pre-driving student[1]	85%	4%	11%	85%	4%	11%
Pre-school[1]	12%	2%	86%	13%	2%	85%

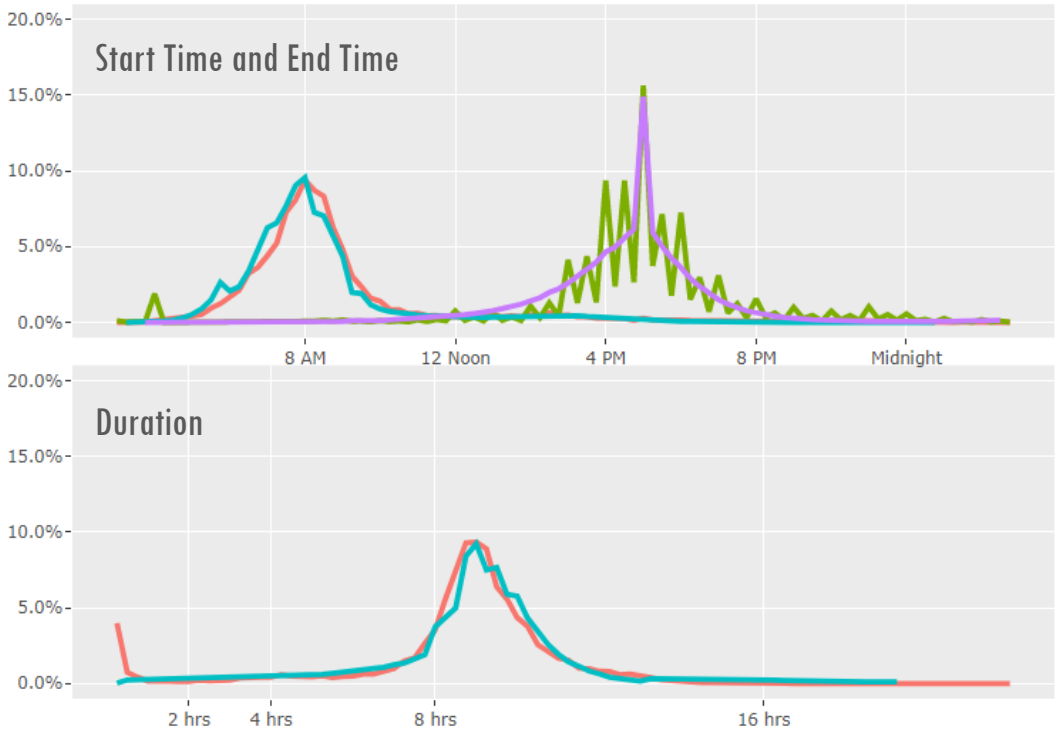
Mandatory activity episode frequency



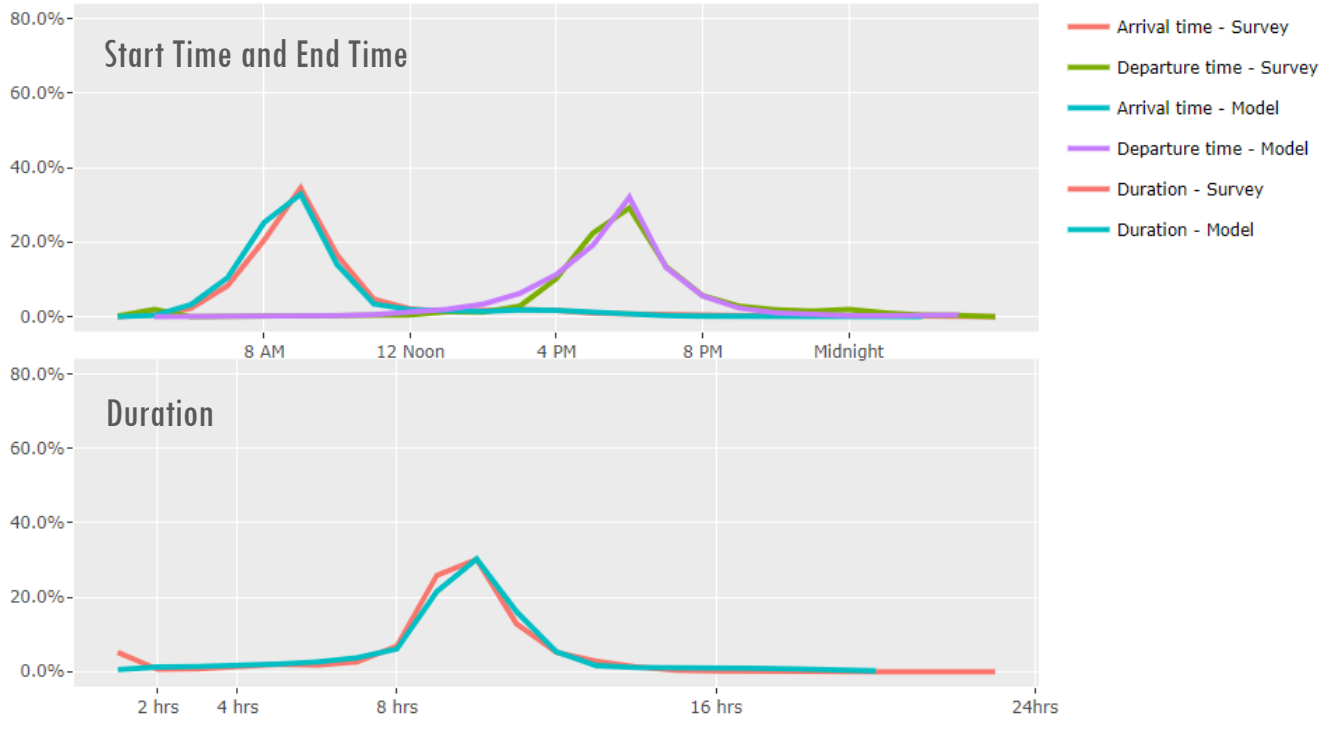




Mandatory activity schedule
Full-time workers

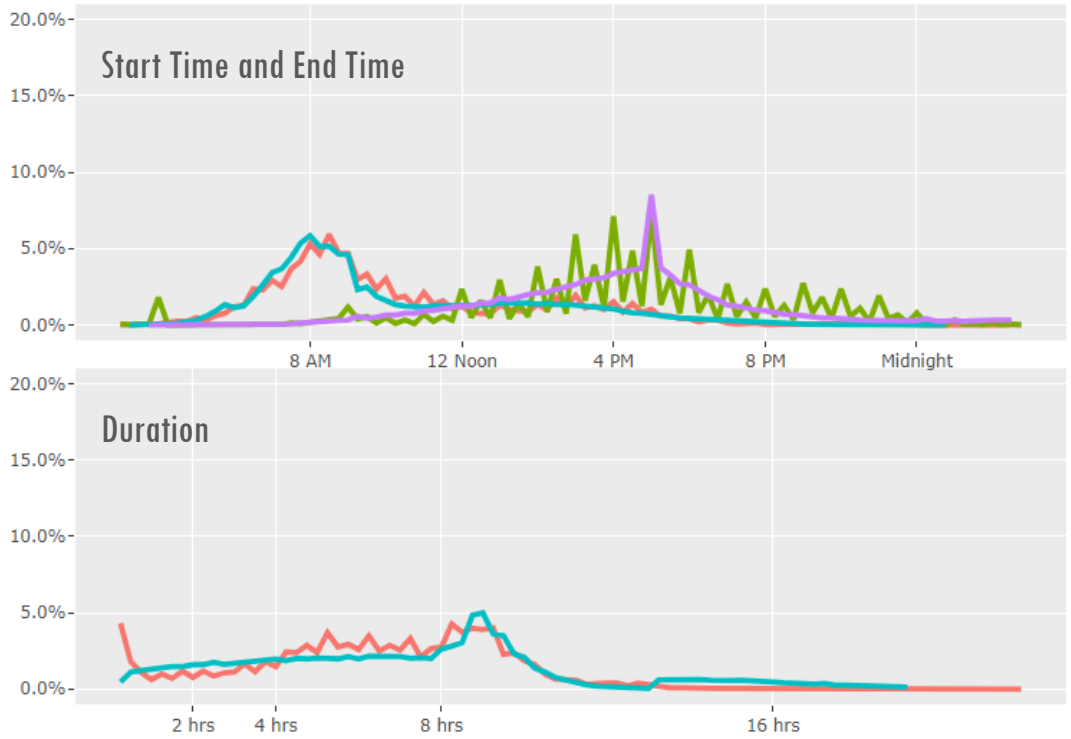


15-minute intervals

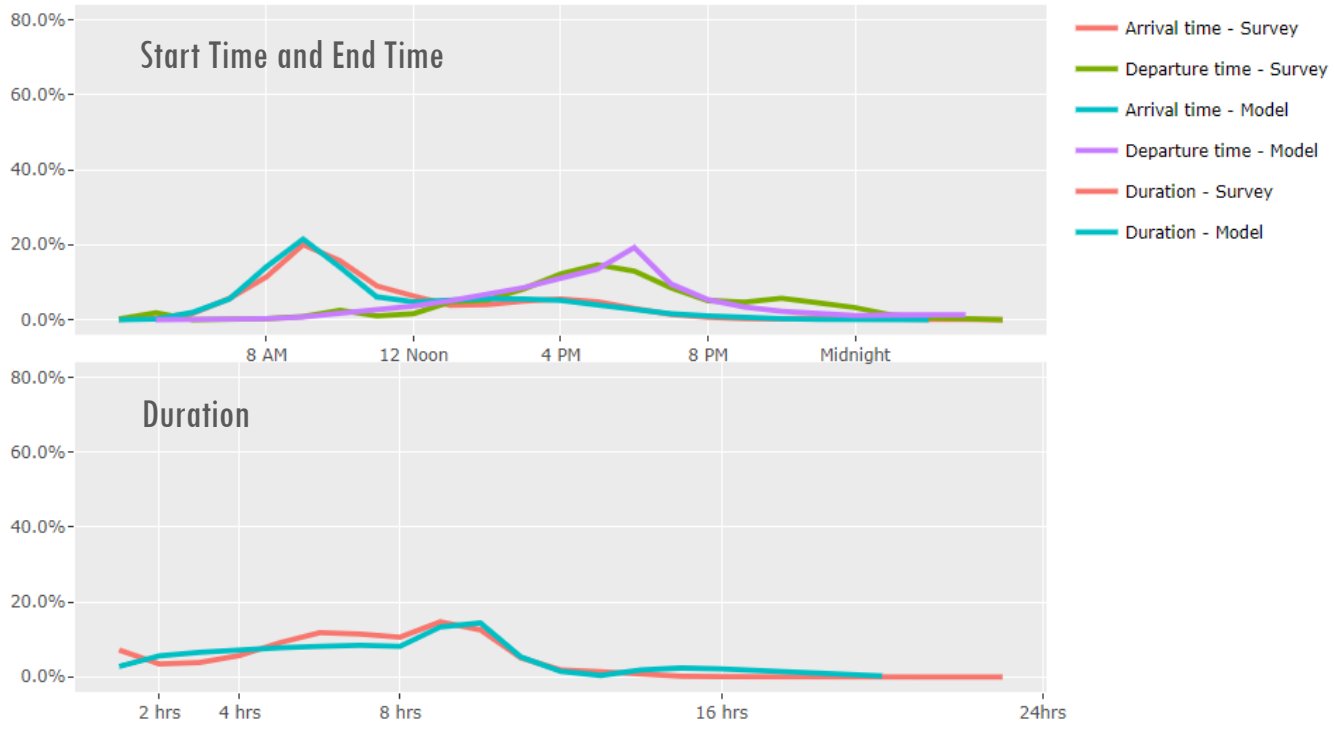


One-hour intervals

Mandatory activity schedule
Part-time workers

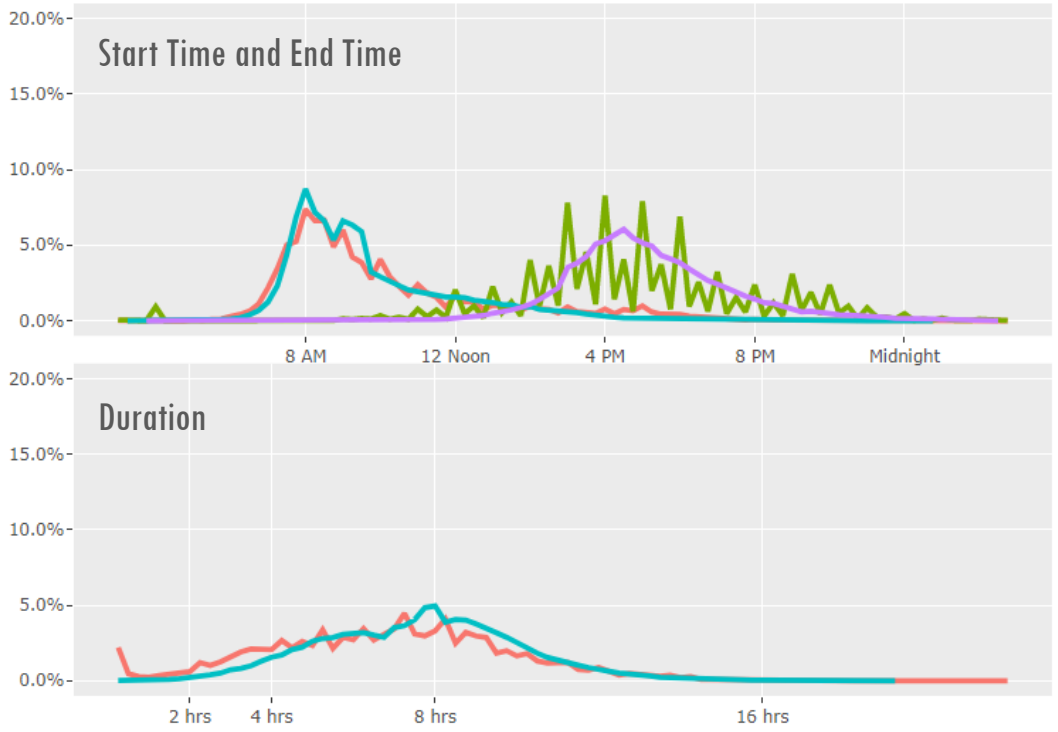


15-minute intervals

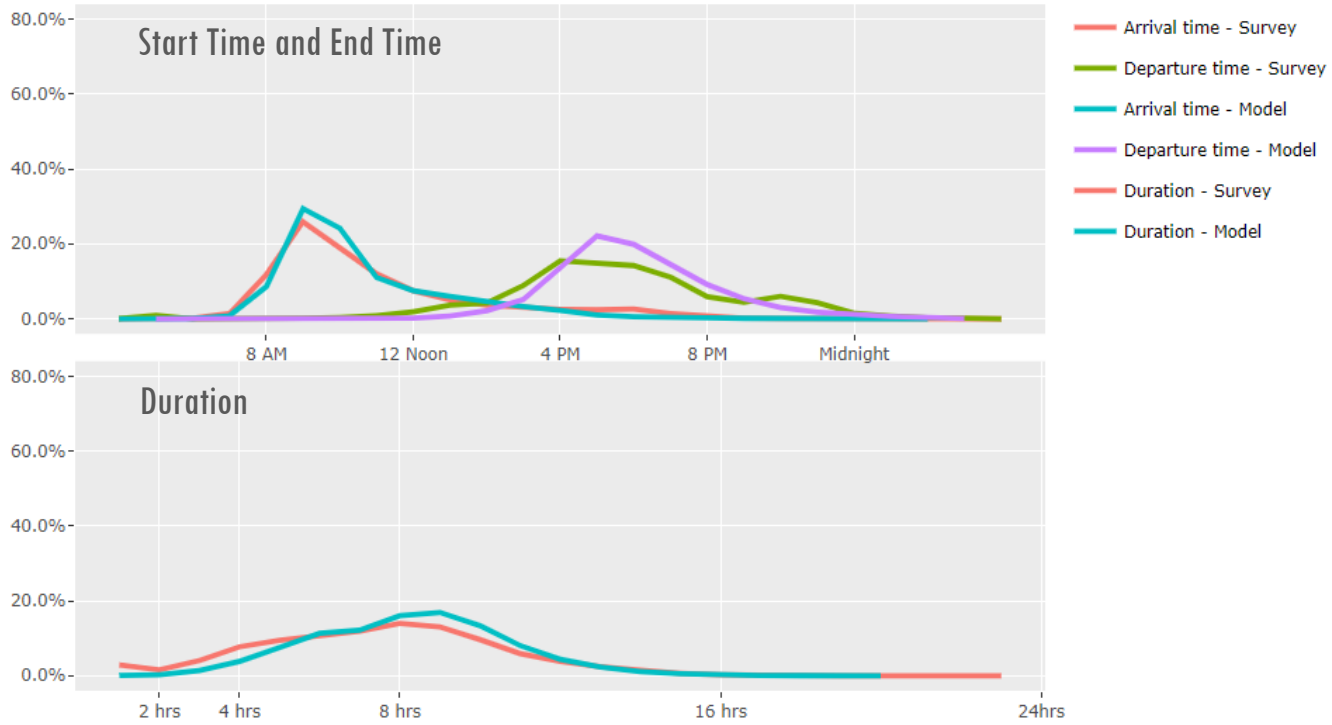


One-hour intervals

Mandatory activity schedule
College students

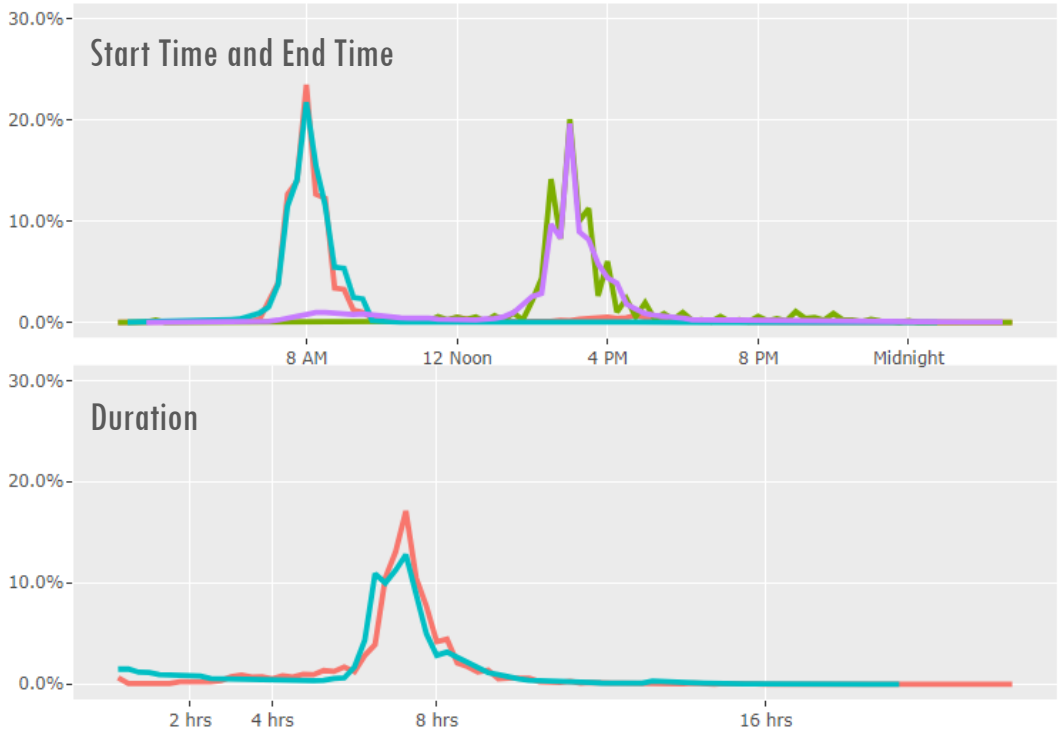


15-minute intervals

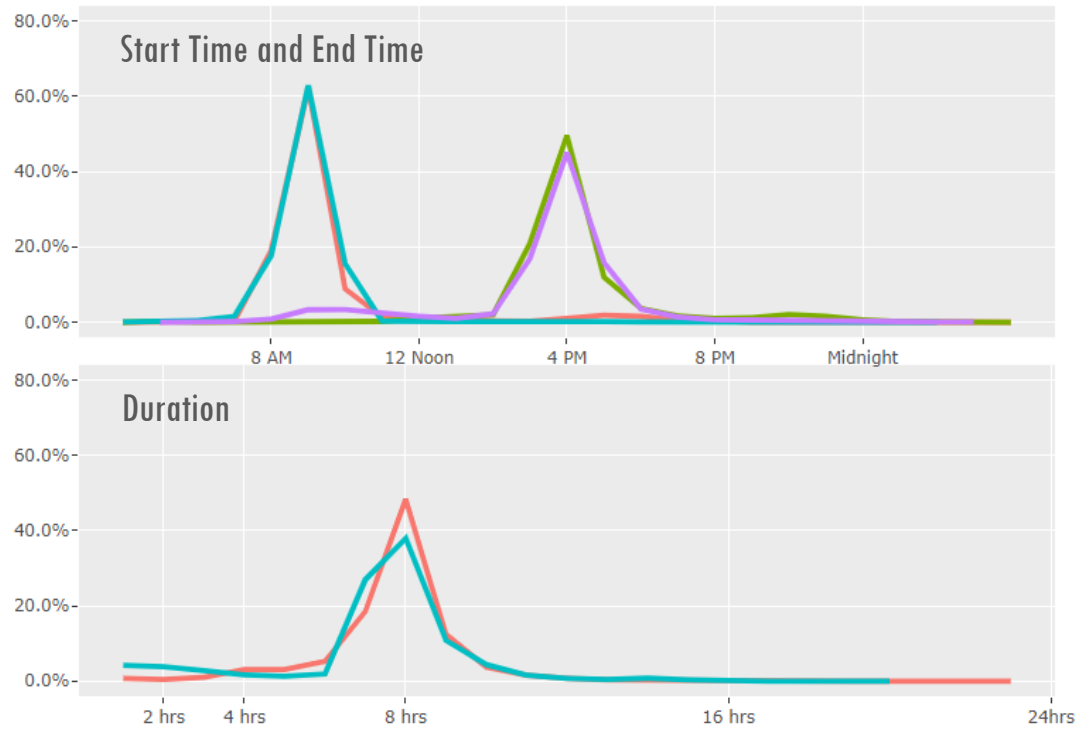


One-hour intervals

Mandatory activity schedule
Driving-age children

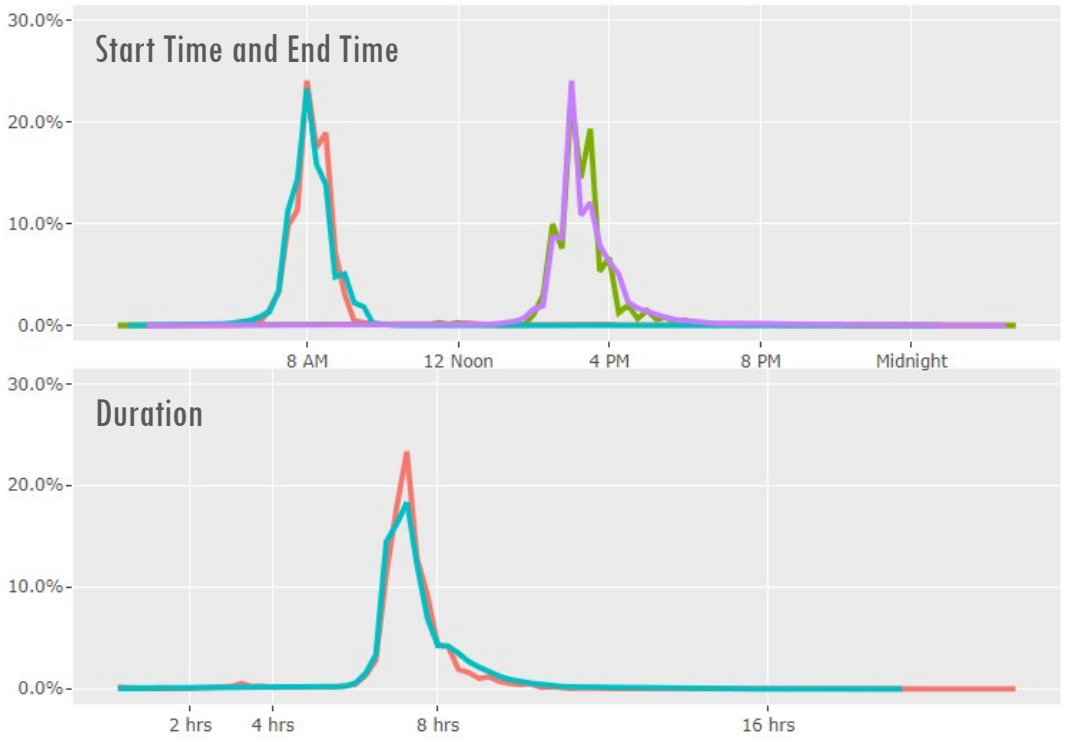


15-minute intervals

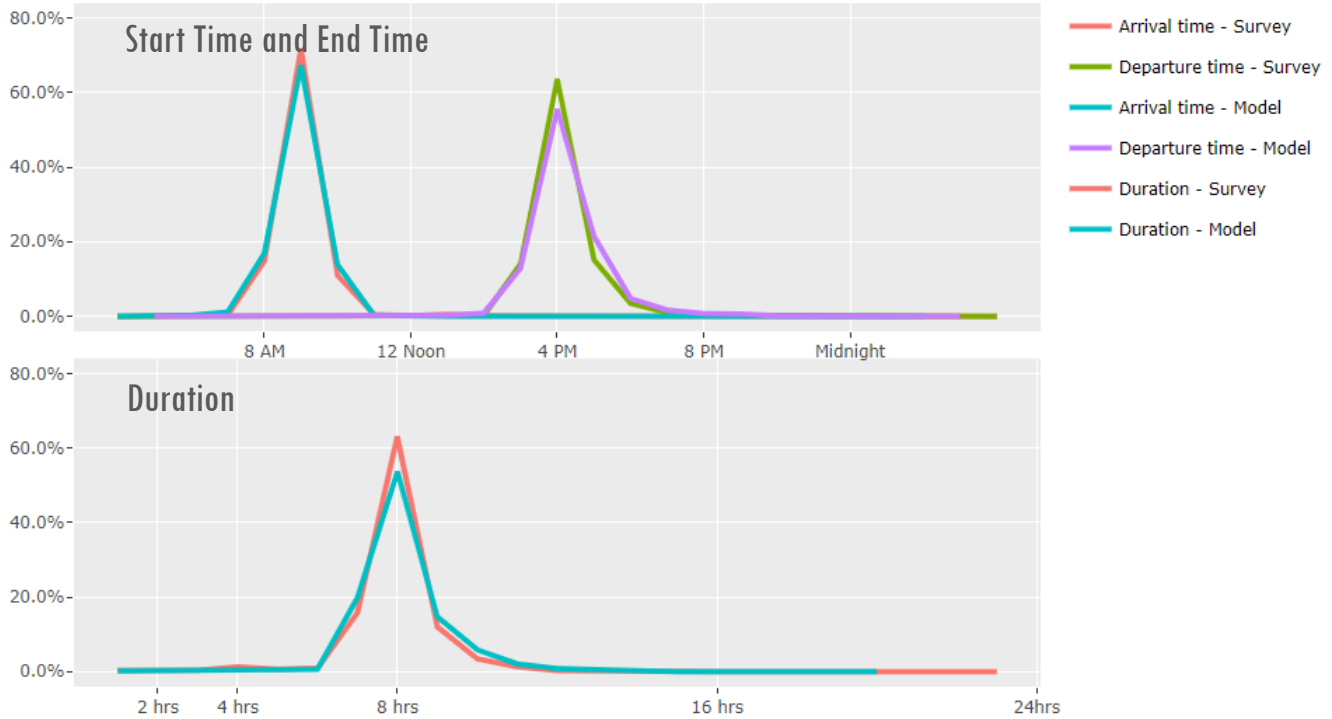


One-hour intervals

Mandatory activity schedule
Pre-driving-age children



15-minute intervals



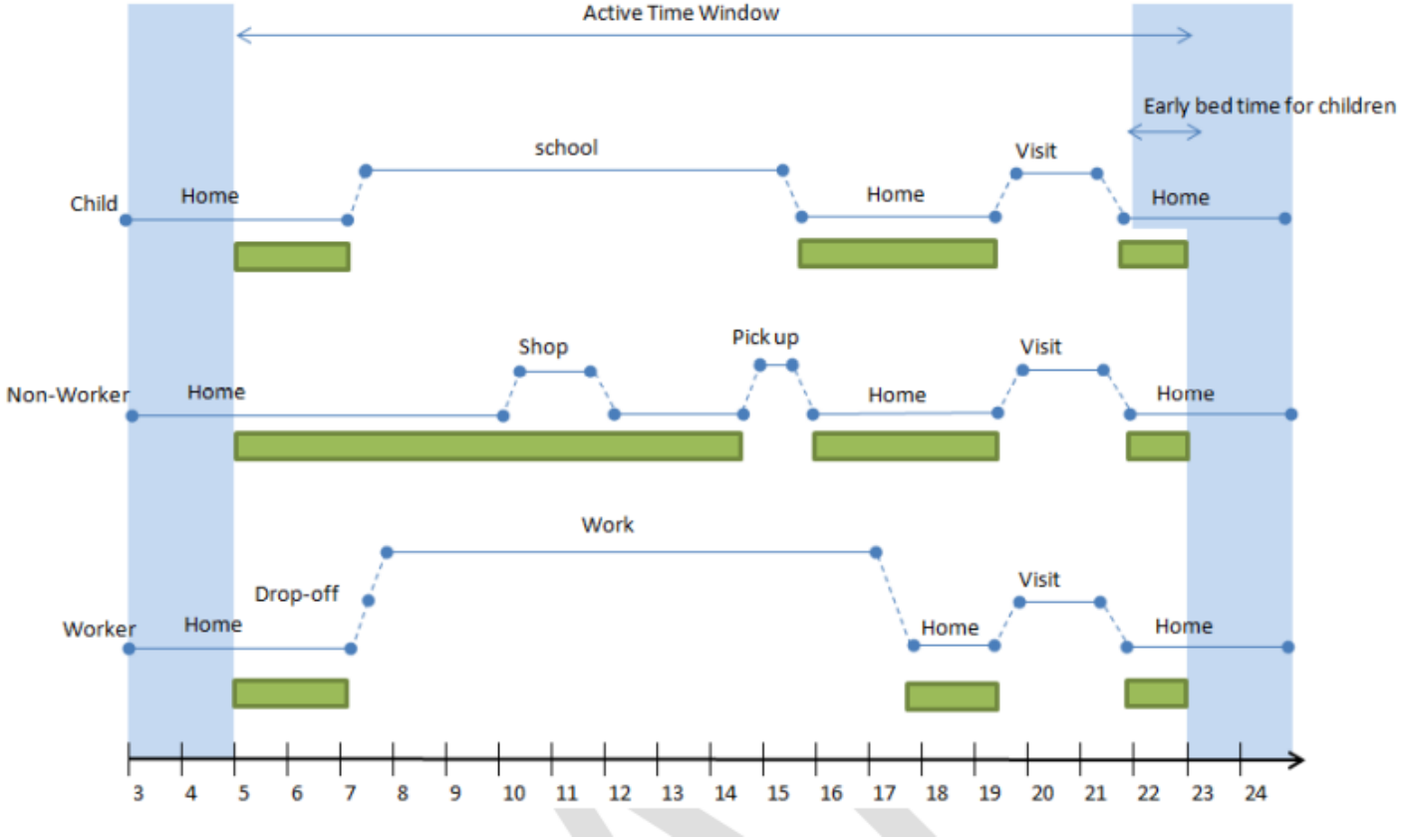
One-hour intervals

NON-MANDATORY ACTIVITIES

Non-mandatory activity

- Household maintenance activity
- Discretionary activity

Residual time windows



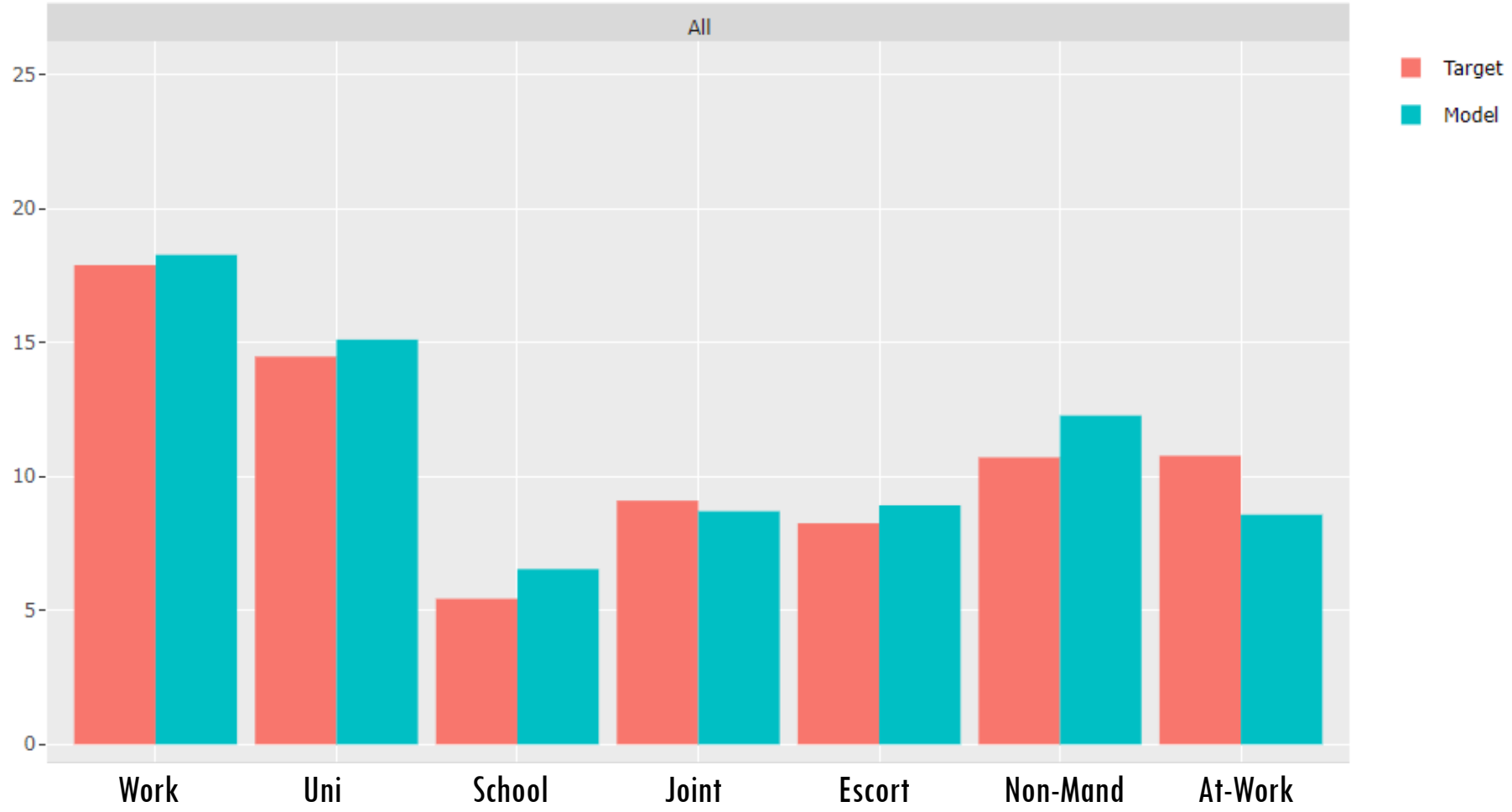
Activity episodes

	Activity Purpose	Survey	Survey w/ trip non-response adjustment	Model
W	Work	3,522,000	3,640,000	3,668,000
S	University	364,000	371,000	513,000
S, D	School & Day care	825,000	845,000	1,131,000
F	Facilitate Passenger / Escort	588,000	604,000 (person trips only reported for people > 11 years)	1,744,000 (person trips for all ages)
M	Market / Shopping	1,484,000	1,947,000	2,005,000
J, O	Other	2,171,000	2,815,000	3,298,000
9	Unknown	6,000	7,000	0
	Total	8,929,000	10,230,000	12,361,000

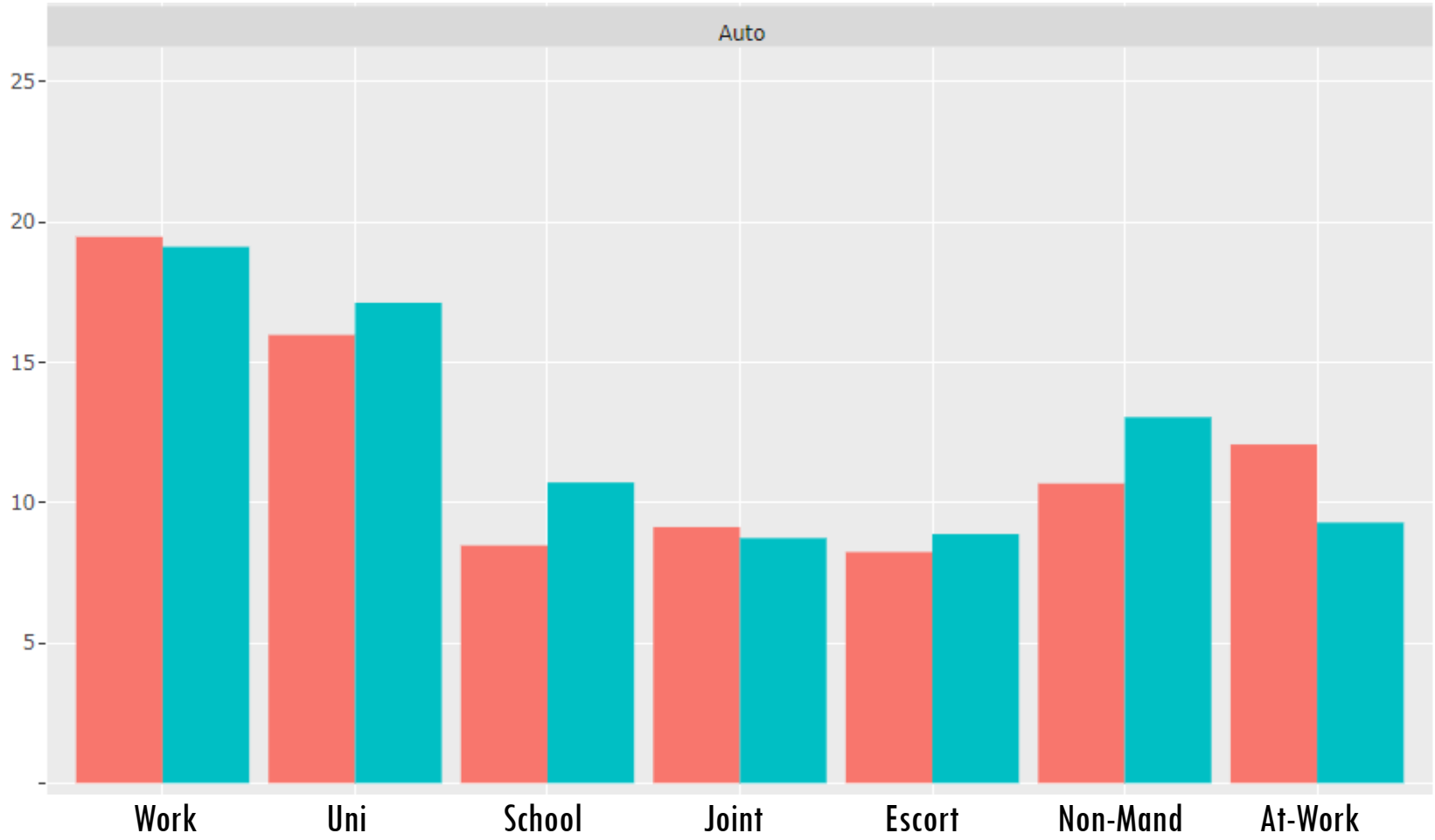
Trips by mode

	Trip mode	Survey	Survey w/ trip non-response adjustment	Model
D	Auto driver	9,366,000	10,691,000	13,378,000
P	Auto passenger	2,163,000	2,587,000	3,377,000
B	Transit	1,911,000	2,069,000	2,121,000
W	Walk	1,038,000	1,116,000	720,000
C	Bike	233,000	261,000	152,000
T	Taxi	56,000	69,000	54,000
S	School bus	351,000	353,000 (does not include persons <11 years)	823,000 (include all persons)
	Total	**15,118,000**	**17,147,000**	**20,625,000**

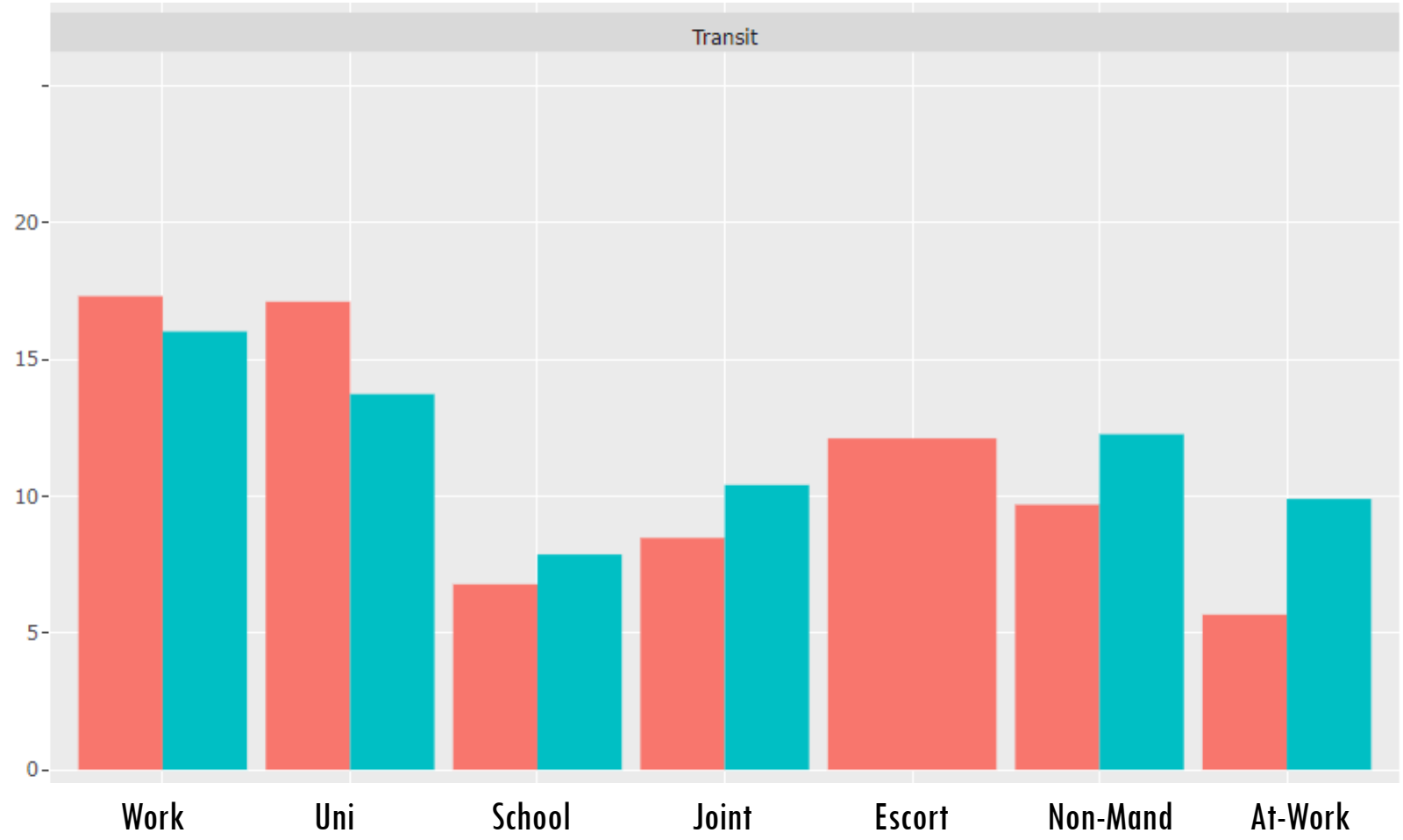
Trip length – all modes



Trip length – auto modes



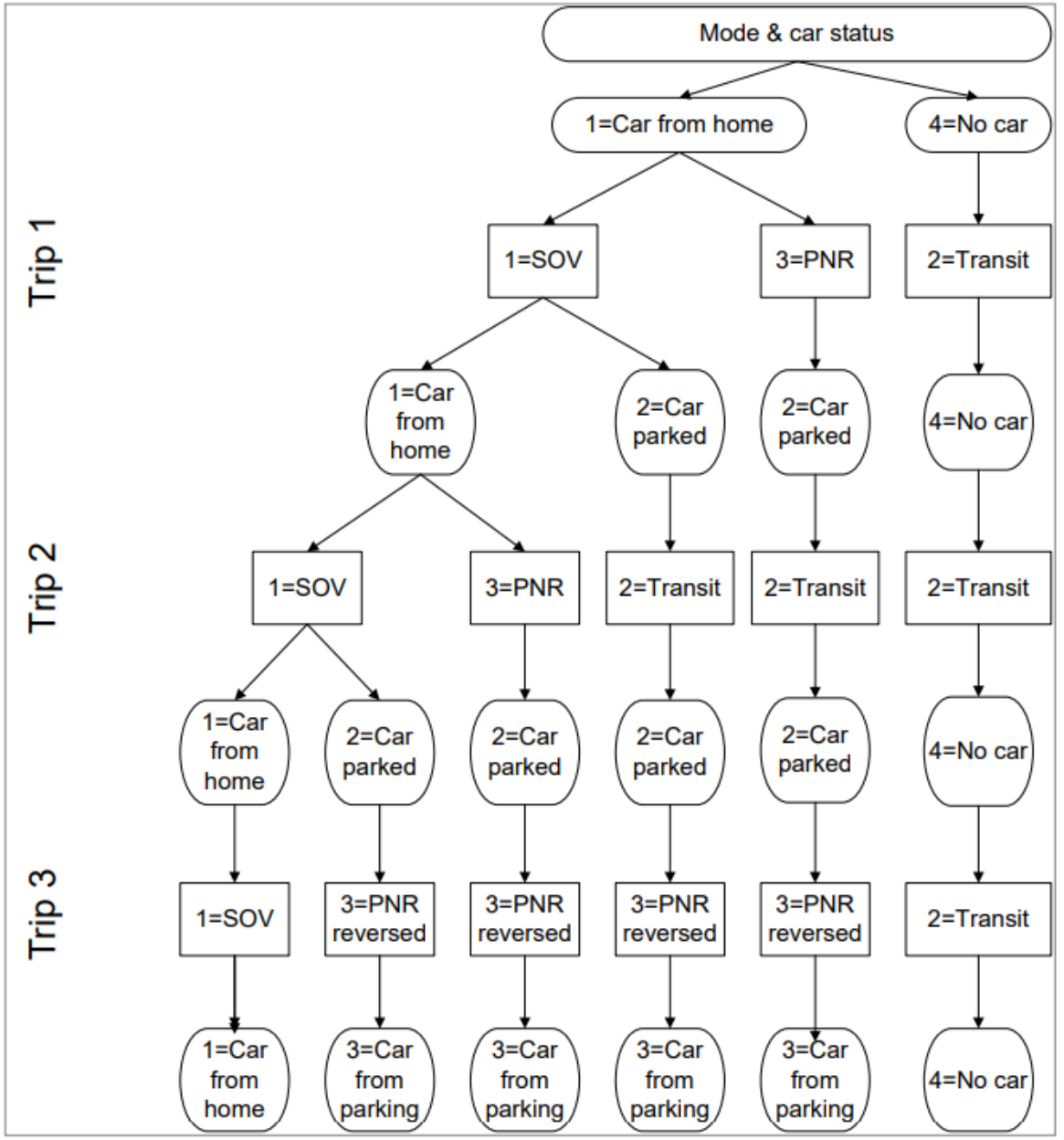
Trip length – transit modes



MODE CHOICE

Mode choice

- Tour-level and trip-level mode choices are integrated in a network combinatorial representation



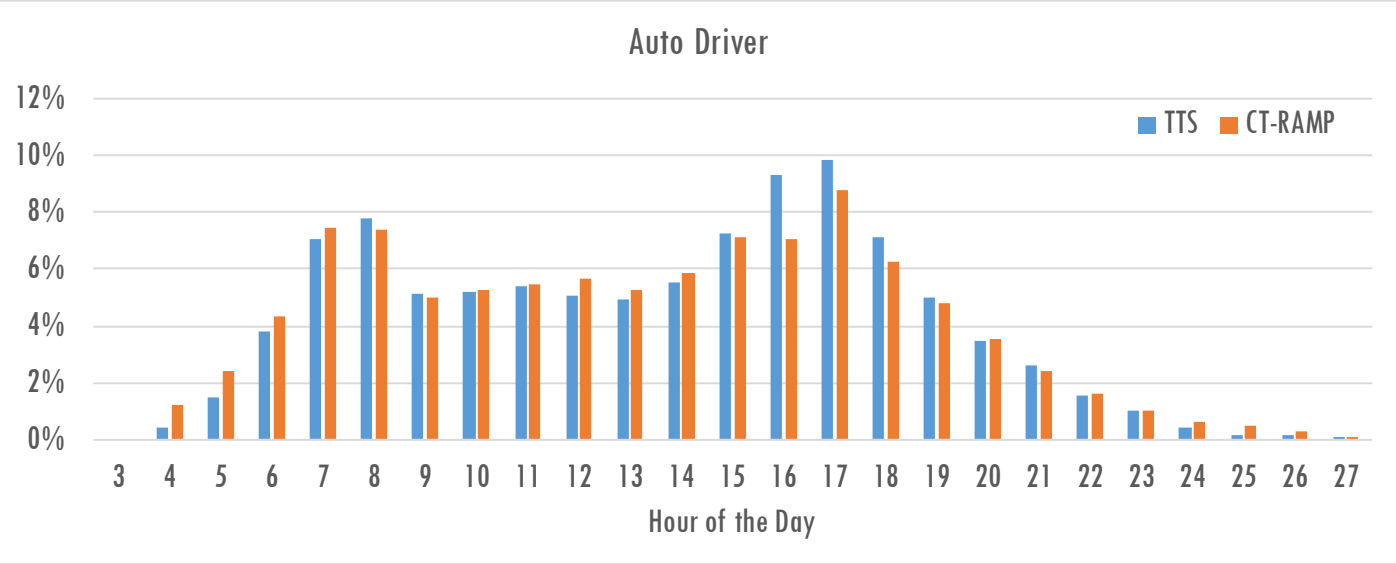
Trips on work tours

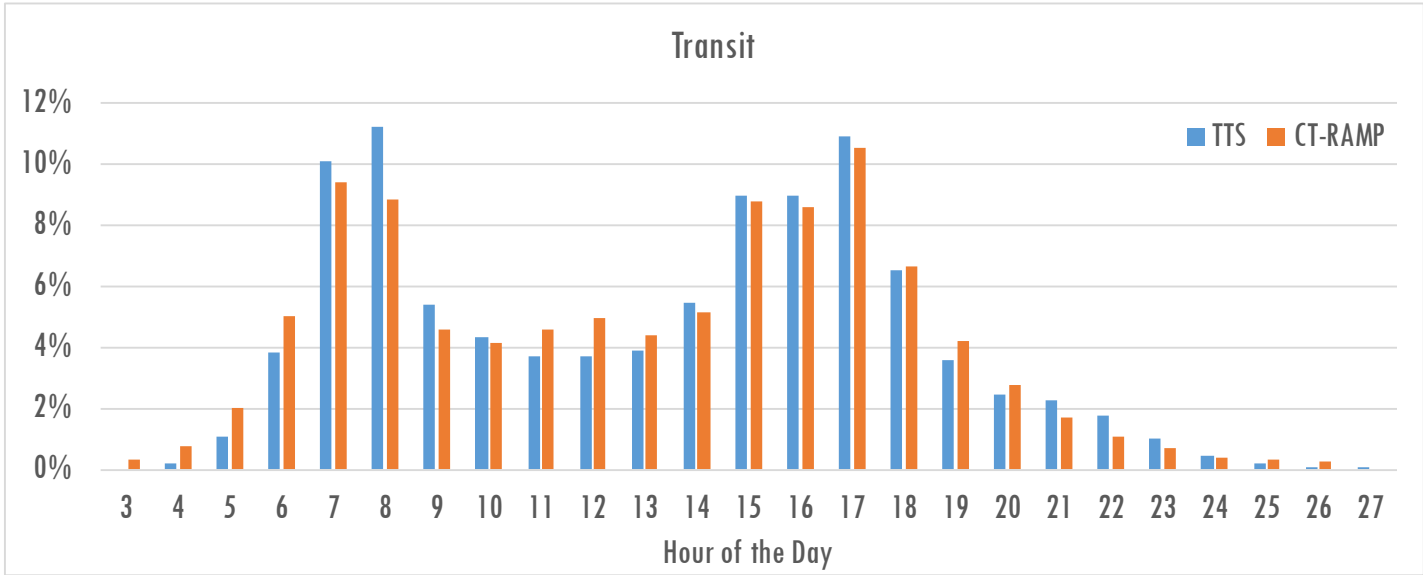
	Mode Share - Survey				Mode Share - Model			
Mode	Zero Cars	Cars < Wrks	Cars = Wrks	Cars > Wrks	Zero Cars	Cars < Wrks	Cars = Wrks	Cars > Wrks
Auto Driver	1%	57%	86%	92%	0%	68%	86%	93%
Auto Passenger	4%	12%	4%	3%	11%	10%	3%	3%
Conventional transit -- walk	61%	19%	5%	2%	64%	16%	9%	2%
Conventional transit -- pnr	0%	0%	0%	0%	0%	0%	0%	0%
Conventional transit -- knr	1%	1%	0%	0%	0%	0%	0%	0%
Premium transit -- walk	1%	2%	1%	1%	2%	1%	0%	0%
Premium transit -- pnr	0%	0%	1%	1%	0%	0%	0%	0%
Premium transit -- knr	0%	0%	0%	0%	0%	0%	0%	0%
Walk	21%	6%	2%	1%	15%	3%	1%	1%
Bike	8%	2%	1%	0%	4%	1%	0%	0%
Taxi	2%	1%	0%	0%	3%	0%	0%	0%
School bus	0%	0%	0%	0%	0%	0%	0%	0%

Trips on all tours

	Mode Share - Survey				Mode Share - Model			
Mode	Zero Cars	Cars < Wrks	Cars = Wrks	Cars > Wrks	Zero Cars	Cars < Wrks	Cars = Wrks	Cars > Wrks
Auto Driver	2%	54%	76%	78%	0%	66%	81%	84%
Auto Passenger	8%	15%	9%	14%	16%	14%	7%	12%
Conventional transit -- walk	57%	17%	6%	3%	60%	12%	8%	1%
Conventional transit -- pnr	0%	0%	0%	0%	0%	0%	0%	0%
Conventional transit -- knr	0%	1%	0%	0%	0%	0%	0%	0%
Premium transit -- walk	1%	1%	1%	0%	2%	1%	0%	0%
Premium transit -- pnr	0%	0%	0%	0%	0%	0%	0%	0%
Premium transit -- knr	0%	0%	0%	0%	0%	0%	0%	0%
Walk	21%	7%	4%	3%	14%	4%	2%	1%
Bike	7%	2%	1%	1%	3%	1%	0%	0%
Taxi	4%	1%	0%	0%	3%	0%	0%	0%
School bus	0%	1%	1%	1%	2%	2%	1%	1%

Trip diurnal distribution





Trip assignment

Trips by mode	Auto network	Transit network
Auto driver (SOV)	X	
HOV2	X	
HOV3+	X	
Truck (light, medium, heavy)	X	
Conventional Transit with KnR		X
Conventional Transit with PnR	X	X
Conventional Transit with walk access		X
Premium Transit with KnR		X
Premium Transit with PnR	X	X
Premium Transit with walk access		X

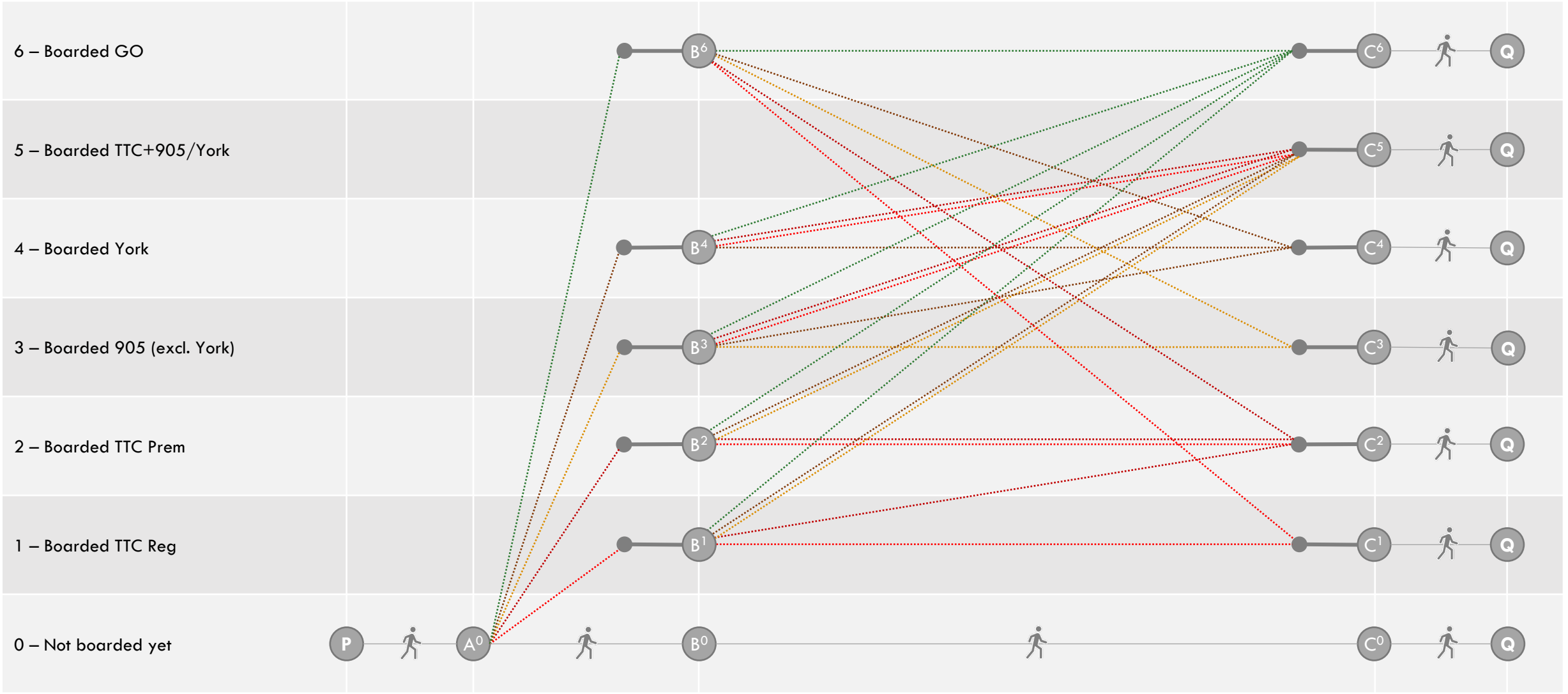
TRANSIT ASSIGNMENT

JOURNEY LEVEL TRANSIT ASSIGNMENT

Objectives

- Accurately model fares:
  - Transit routings
  - Good skims to feedback to demand model
  - Particular emphasis on GTHA / YRT / TTC fare system

York ABM – Transit journey levels



Legend

Transit Mode (Emme Code): TTC Reg (T, m, s) · TTC Prem (p) · 905 excl. York (b) · YRT/VIVA (Y, n) · GO (g, r)

York ABM journey levels in Modeller

3. Journey levels

Transition rules | Times and costs

	Description	Destinations reachable?	Next journey level T	Y	b	g	m	n	p	r	s	R
0	Not boarded yet	☑	1 - Boarded	4 - Boarded	3 - Boarded	6 - Boarded	1 - Boarded	4 - Boarded	2 - Boarded	6 - Boarded	1 - Boarded	6 - Boarded
1	Boarded TTC Reg	☑	1 - Boarded	5 - Boarded	5 - Boarded	6 - Boarded	1 - Boarded	5 - Boarded	2 - Boarded	6 - Boarded	1 - Boarded	6 - Boarded
2	Boarded TTC Prem	☑	2 - Boarded	5 - Boarded	5 - Boarded	6 - Boarded	2 - Boarded	5 - Boarded	2 - Boarded	6 - Boarded	2 - Boarded	6 - Boarded
3	Boarded GTHA/Other (	☑	5 - Boarded	4 - Boarded	3 - Boarded	6 - Boarded	5 - Boarded	4 - Boarded	5 - Boarded	6 - Boarded	5 - Boarded	6 - Boarded
4	Boarded YRT/VIVA	☑	5 - Boarded	4 - Boarded	4 - Boarded	6 - Boarded	5 - Boarded	4 - Boarded	5 - Boarded	6 - Boarded	5 - Boarded	6 - Boarded
5	Boarded TTC+York/GT	☑	5 - Boarded	5 - Boarded	5 - Boarded	6 - Boarded	5 - Boarded	5 - Boarded	5 - Boarded	6 - Boarded	5 - Boarded	6 - Boarded
6	Boarded GO	☑	1 - Boarded	4 - Boarded	3 - Boarded	6 - Boarded	1 - Boarded	4 - Boarded	2 - Boarded	6 - Boarded	1 - Boarded	6 - Boarded

Add a journey level

York ABM journey level fare structure

Level	Description	Attribute	
0	Not Boarded Yet	@bcost_lvl_0	• Full fares on all transit lines
1	Boarded TTC Reg	@bcost_lvl_1	• 0 fares on TTC regular, reduced TTC premium fares • Full fares outside Toronto
2	Boarded TTC Prem	@bcost_lvl_2	• 0 fares on all TTC routes, • Full fares outside Toronto
3	Boarded GTHA/Other (excl. York)	@bcost_lvl_3	• 0 fares on all GTHA routes (including York Region) • Full fares in Toronto • Reduced GO boarding fares
4	Boarded York	@bcost_lvl_4	• 0 fares on all GTHA routes (including York Region) • Full fares in Toronto * • Reduced GO boarding fares
5	Boarded TTC+GTHA/ Other/York	@bcost_lvl_5	• 0 fares on all GTHA routes (including York Region) and Toronto • Full GO fares
6	Boarded GO	@bcost_lvl_6	• 0 GO boarding fares • Discounted fare in GTHA Other (including York Region) • Full TTC fares

* Special fare rules apply between TTC and YRT.

VALIDATION

Trip origin-destination – conventional transit AM peak period

2016 TTS

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	363,262	388	8,006	6,130	227	276	7	49	378,345
2	**Durham**	3,088	7,292	97	-	-	-	-	-	10,477
3	**York**	26,469	198	10,213	519	44	38	52	26	37,559
4	**Peel**	17,787	55	638	28,949	1,308	1,228	-	110	50,075
5	**Halton**	940	-	-	419	2,538	746	-	-	4,643
6	**Hamilton**	529	-	32	167	571	15,359	-	-	16,658
12	**Barrie**	116	-	-	-	-	9	938	-	1,063
13	**Simcoe**	248	-	45	-	-	-	71	153	517
	Sum	412,439	7,933	19,031	36,184	4,688	17,656	1,068	338	499,337

York ABM (2016)

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	379,420	1,470	10,000	15,270	850	490	-	20	407,520
2	**Durham**	3,950	5,050	670	30	-	-	-	-	9,700
3	**York**	26,900	20	11,940	1,230	90	30	-	-	40,210
4	**Peel**	16,120	-	1,260	21,810	2,080	1,630	-	-	42,900
5	**Halton**	1,080	-	300	4,340	3,630	540	-	-	9,890
6	**Hamilton**	90	-	-	1,310	660	9,060	-	-	11,120
12	**Barrie**	-	-	-	-	-	-	1,320	10	1,330
13	**Simcoe**	70	-	-	-	-	-	30	-	100
	Sum	427,630	6,540	24,170	43,990	7,310	11,750	1,350	30	522,770

Trip origin-destination – auto driver AM peak period

2016 TTS

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	404,007	11,033	69,492	53,632	7,044	1,201	517	1,087	548,013
2	**Durham**	41,721	126,844	19,043	3,426	432	139	151	122	191,878
3	**York**	97,350	5,413	220,663	22,037	2,131	497	1,462	2,362	351,915
4	**Peel**	69,189	932	24,200	290,917	20,900	2,770	291	873	410,072
5	**Halton**	13,065	189	3,392	44,957	109,227	12,200	162	229	183,421
6	**Hamilton**	2,593	70	880	6,681	23,964	108,512	37	-	142,737
12	**Barrie**	1,352	9	3,672	668	135	8	32,466	7,769	46,079
13	**Simcoe**	4,390	243	11,593	3,925	229	-	14,174	46,605	81,159
	Sum	633,667	144,733	352,935	426,243	164,062	125,327	49,260	59,047	1,955,274

York ABM (2016)

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	434,030	9,880	73,370	57,760	5,490	280	90	310	581,210
2	**Durham**	32,720	145,120	15,630	1,050	40	-	-	160	194,720
3	**York**	106,150	6,830	214,490	14,790	400	-	360	2,800	345,820
4	**Peel**	91,230	80	18,310	307,660	31,030	1,010	40	700	450,060
5	**Halton**	9,600	-	430	39,410	101,460	16,180	-	-	167,080
6	**Hamilton**	550	-	-	1,890	25,930	116,060	-	10	144,440
12	**Barrie**	210	-	1,880	140	-	-	33,550	9,200	44,980
13	**Simcoe**	2,180	340	10,430	3,480	50	-	17,260	50,430	84,170
	Sum	676,670	162,250	334,540	426,180	164,400	133,530	51,300	63,610	2,012,480

Trip origin-destination – conventional transit PM peak period

2016 TTS

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	483,256	3,599	30,182	20,632	797	849	133	253	539,701
2	**Durham**	743	9,365	167	-	-	-	14	-	10,289
3	**York**	11,027	260	14,737	576	-	129	78	31	26,838
4	**Peel**	8,503	-	394	37,352	784	241	-	-	47,274
5	**Halton**	356	-	76	1,641	3,845	546	-	-	6,464
6	**Hamilton**	334	-	13	1,545	1,262	21,346	-	-	24,500
12	**Barrie**	117	-	-	-	-	-	1,307	53	1,477
13	**Simcoe**	75	-	14	13	-	-	-	291	393
	Sum	504,411	13,224	45,583	61,759	6,688	23,111	1,532	628	656,936

York ABM (2016)

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	493,080	3,460	30,330	19,060	1,180	560	20	90	547,780
2	**Durham**	2,930	6,050	440	130	-	-	-	-	9,550
3	**York**	12,940	270	12,420	2,780	530	210	20	10	29,180
4	**Peel**	25,800	240	3,650	30,280	6,020	5,040	-	10	71,040
5	**Halton**	2,010	10	530	5,480	4,360	540	-	-	12,930
6	**Hamilton**	1,540	-	130	3,270	850	10,880	-	-	16,670
12	**Barrie**	80	-	-	-	-	-	1,730	20	1,830
13	**Simcoe**	30	-	-	-	-	-	10	-	40
	Sum	538,410	10,030	47,500	61,000	12,940	17,230	1,780	130	689,020

Trip origin-destination – auto driver PM peak period

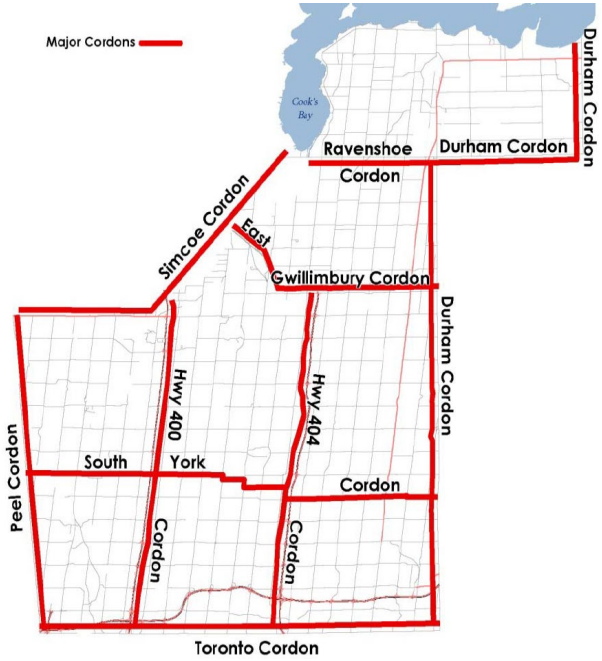
2016 TTS

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	618,840	48,836	120,141	82,284	15,632	4,075	2,255	6,462	898,525
2	**Durham**	15,773	210,299	7,746	1,618	445	268	103	480	236,732
3	**York**	95,526	21,908	337,500	29,115	4,286	1,389	4,581	14,551	508,856
4	**Peel**	67,550	4,332	27,482	398,693	53,256	8,094	1,502	5,518	566,427
5	**Halton**	9,134	420	2,223	30,034	181,958	30,340	129	487	254,725
6	**Hamilton**	2,270	275	699	2,877	18,024	185,423	56	159	209,783
12	**Barrie**	809	294	1,536	355	131	41	56,458	20,787	80,411
13	**Simcoe**	1,452	354	4,736	1,337	348	70	13,283	83,069	104,649
	Sum	811,354	286,718	502,063	546,313	274,080	229,700	78,367	131,513	2,860,108

York ABM (2016)

		Toronto	Durham	York	Peel	Halton	Hamilton	Barrie	Simcoe	Sum
		1	*2*	*3*	*4*	*5*	*6*	*12*	*13*	
1	**Toronto**	620,000	48,700	164,350	139,970	16,490	2,350	1,500	4,970	998,330
2	**Durham**	21,490	198,510	16,230	830	130	10	40	690	237,930
3	**York**	135,260	28,650	306,850	33,640	1,380	50	4,220	16,540	526,590
4	**Peel**	110,180	3,220	30,550	449,810	59,550	4,300	760	7,010	665,380
5	**Halton**	12,040	370	1,030	52,130	133,880	36,390	-	160	236,000
6	**Hamilton**	1,270	-	-	2,660	26,030	164,180	-	-	194,140
12	**Barrie**	590	40	1,070	170	20	-	49,110	24,050	75,050
13	**Simcoe**	1,930	390	6,710	2,100	60	-	15,330	71,200	97,720
	Sum	902,760	279,880	526,790	681,310	237,540	207,280	70,960	124,620	3,031,140

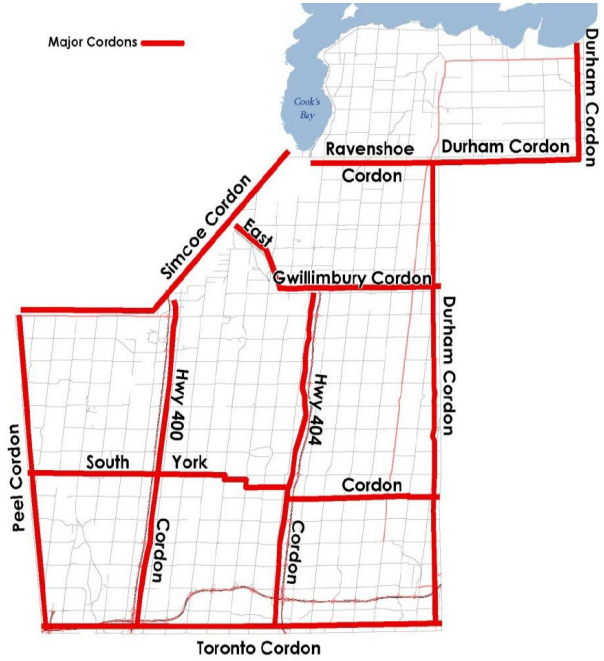
Screenline comparison



AM Peak Hour

Screenline	AM Peak Direction	Cordon Counts	ABM Model	Diff (%)
Screenline 1 (York-Simcoe Cordon)	SB	10,100	8,500	-16%
Screenline 2 (York-Durham Cordon)	WB	12,100	11,900	-2%
Screenline 3 (York-Peel Cordon)	EB	13,000	12,900	-1%
Screenline 4 (Steeles Ave)	SB	76,800	76,600	0%
Screenline 5 (South York)	SB	30,100	28,800	-4%
Screenline 6 (Highway 400 Cordon)	EB	26,000	25,200	-3%
Screenline 7 (Highway 404 Cordon)	WB	26,100	28,500	9%

Screenline comparison

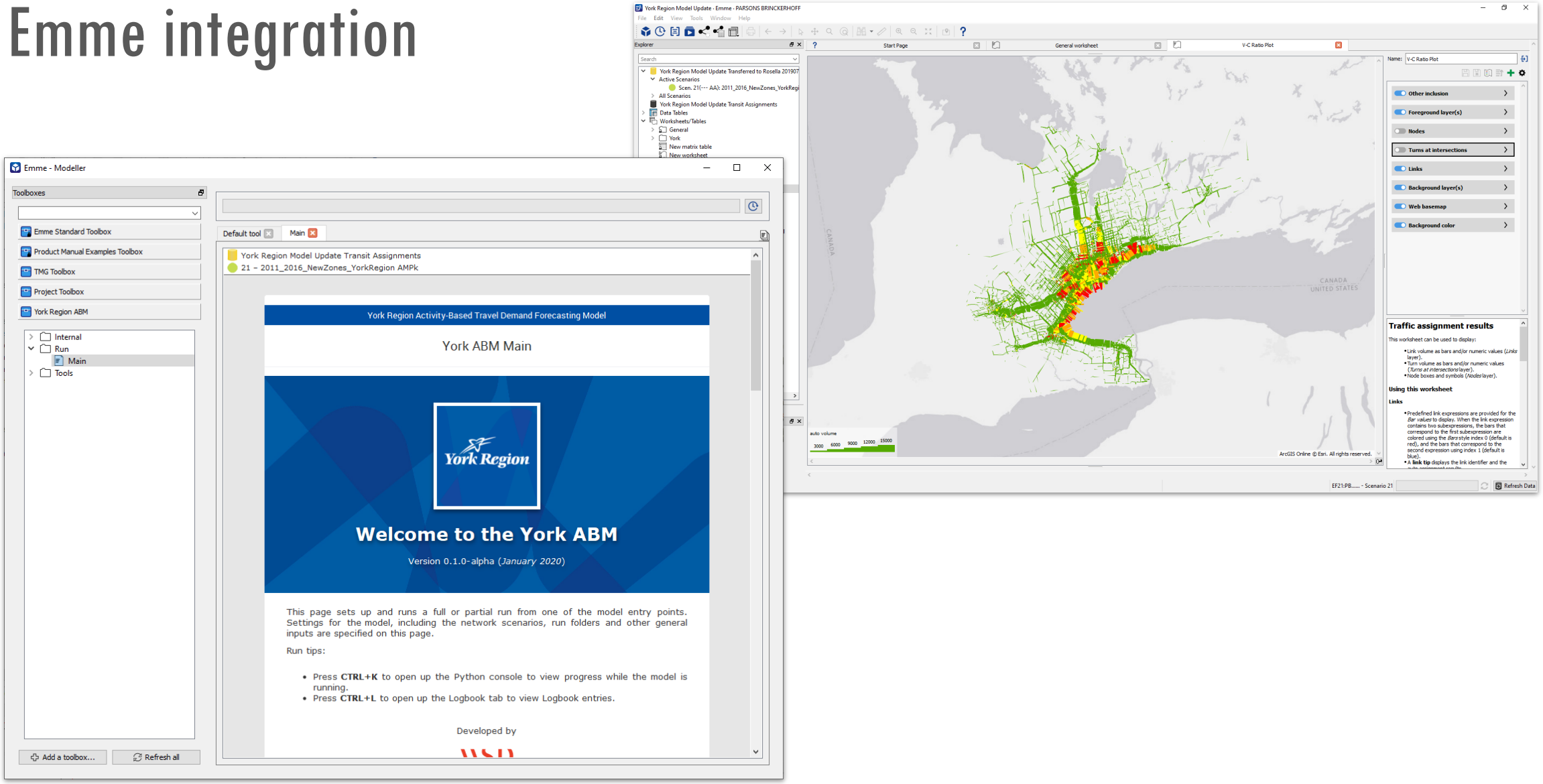


PM Peak Hour

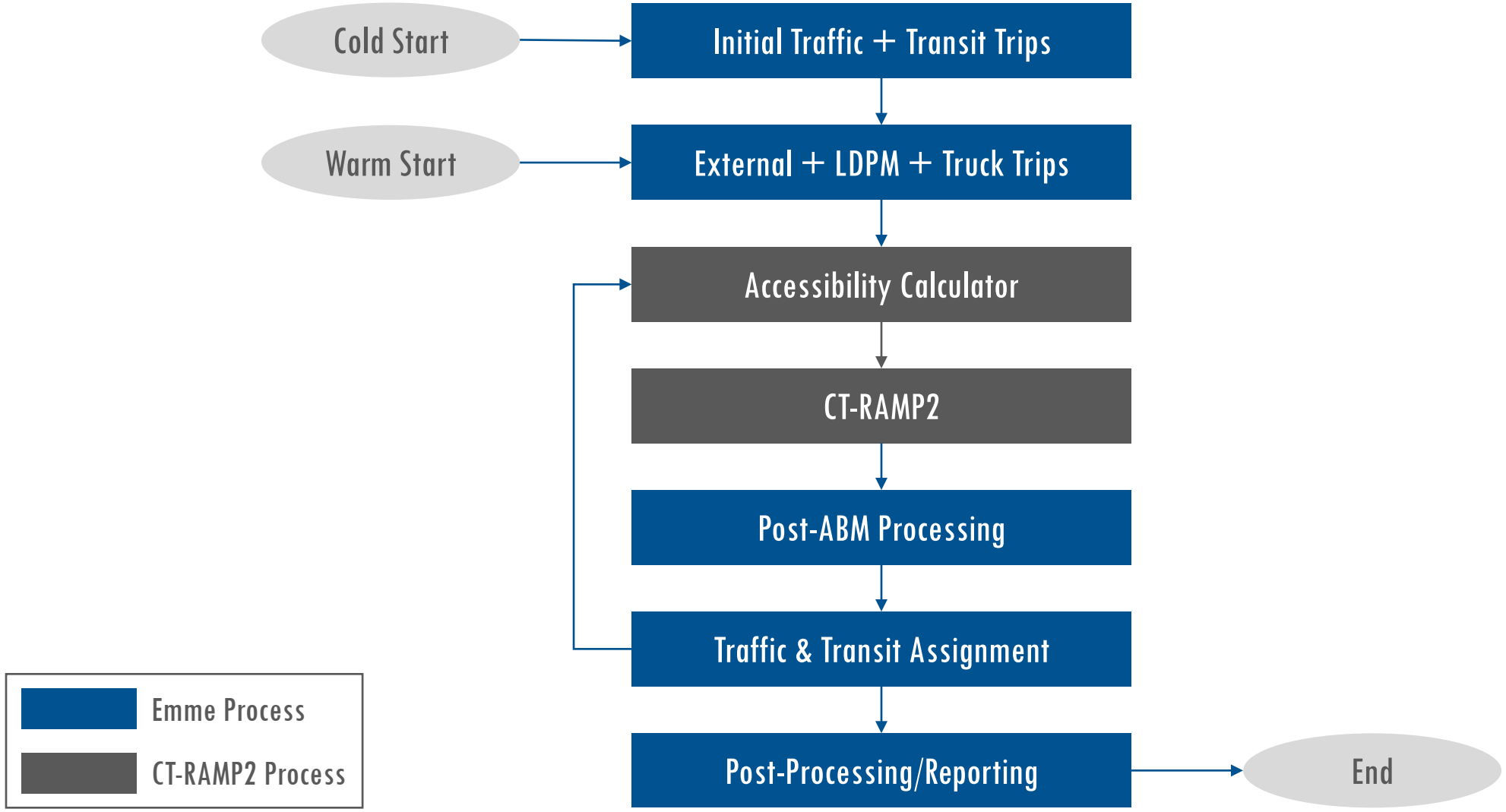
Screenline	PM Peak Direction	Cordon Counts	ABM Model	Diff (%)
Screenline 1 (York-Simcoe Cordon)	NB	9,100	10,300	13%
Screenline 2 (York-Durham Cordon)	EB	10,700	14,100	32%
Screenline 3 (York-Peel Cordon)	WB	17,200	18,500	8%
Screenline 4 (Steeles Ave)	NB	75,400	75,800	1%
Screenline 5 (South York)	NB	26,600	29,700	12%
Screenline 6 (Highway 400 Cordon)	WB	25,200	24,400	-3%
Screenline 7 (Highway 404 Cordon)	EB	29,100	32,500	12%

SYSTEM INTEGRATION

Emme integration



Overall program flow



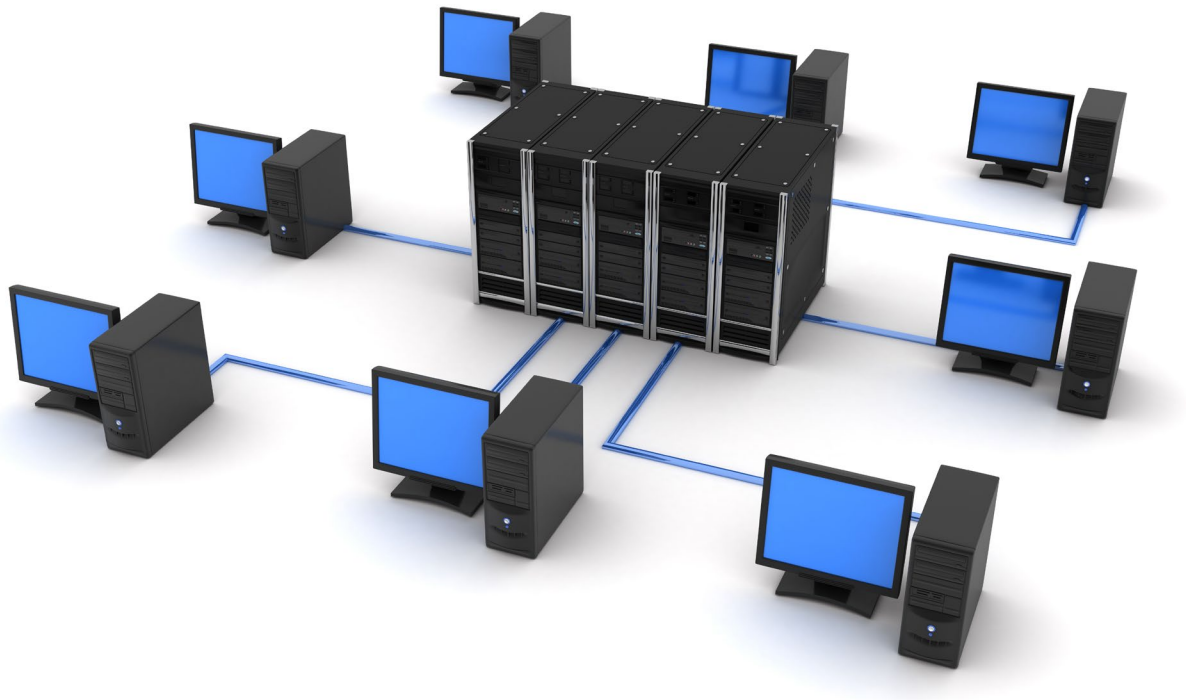
HARDWARE AND RUN TIME

Processing environment options

- Physical Server Processing
  - Non-expandable
  - Life cycle: 4-5 year
- Distributed Processing
  - Complex setup
  - Unstable
- Virtual Server Processing
  - Created a ykr-emme Virtual Machine (VM)
- Cloud Processing
  - Region has yet to use cloud processing
  - Physical licensing key for EMME not required

Virtual machine setup

- Virtual Server setup using VMware software
  - 32 core
  - 512gb Ram
  - Inter Xeon CPU ES-2640 V3 @ 2.6 GHz
- Consultant access is through Citrix
- York Region access through local account



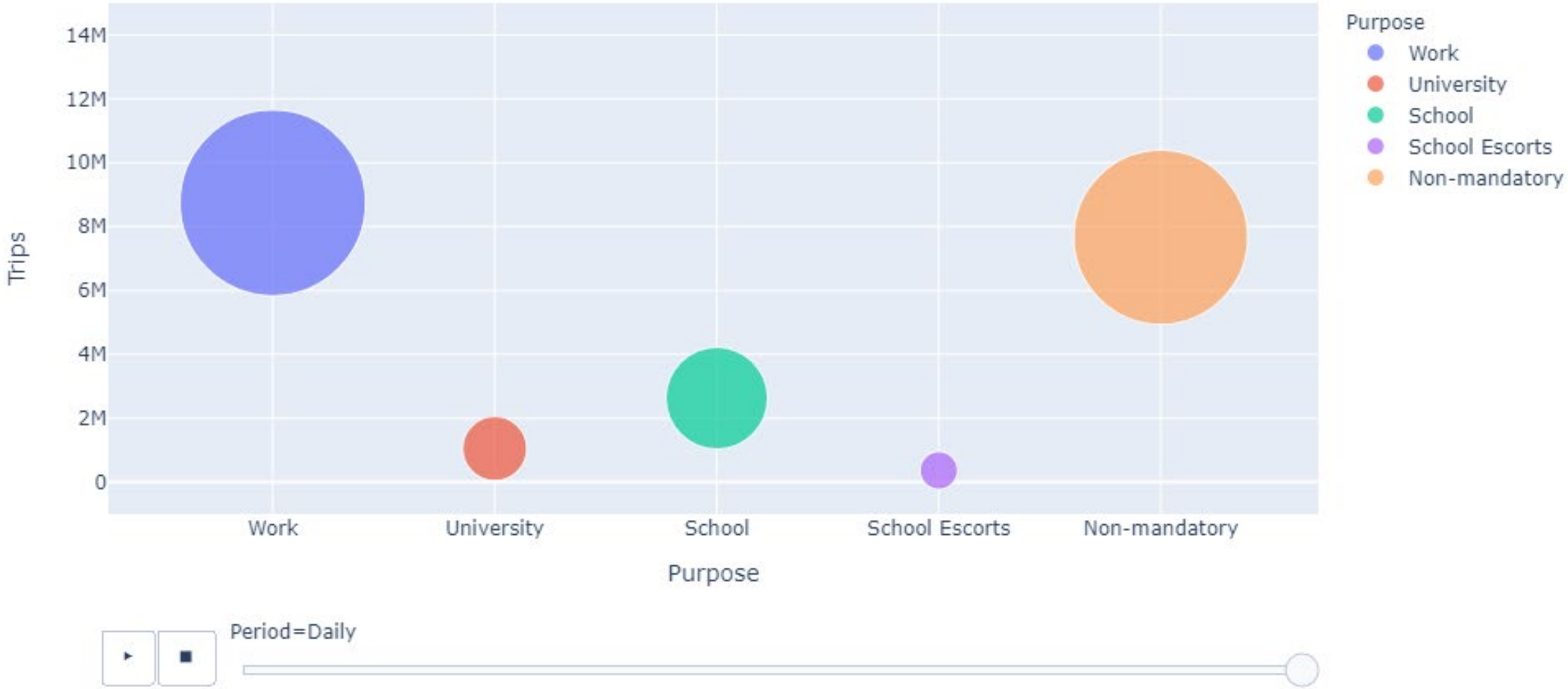
Run time

- Land Use Allocation System (LUAS)
  - 12 hours for new land use forecasts
- PopSyn
  - 12 hours for 2016 Land Use
  - 15 hours for 2051 Land Use
- ABM Model Run
  - 12 hours for 25% sample of 2016 data
  - 24 hours for 100% sample of 2016 data

VISUALIZATION

ABM data insight

Total GGHA Trips by Purpose

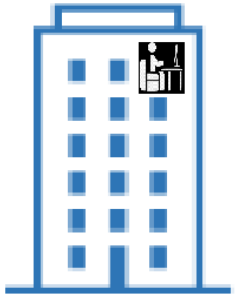


ABM data insight

Household 1 of 3 Persons:
Yearly Income $60,000, with 1 Car, 1 Driver's License & 1 Office Worker in York

Home (York)

School (York)



Office (York)

HOV 2 Trip:
(Persons 1 & 2)

SOV : (Person 1)

Time Period

Morning Peak

Mall (York)

SOV : (Person 1)

SOV : (Person 1)

Afternoon Peak

ABM data insight

Household 1 of 3 Persons:
Yearly Income $60,000, with 1 Car, 1 Driver's License & 1 Office Worker in York

Home (York)

School (York)

Walk Trip:
(Person 3)

Walk Trips:
(Persons 2 & 3)

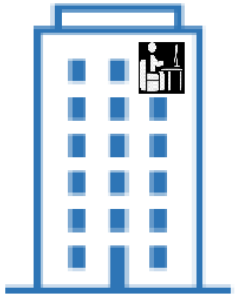
Time Period

Afternoon Peak

ABM data insight

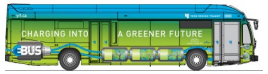
Household 2 of 3 Persons:
Yearly Income $100,000, with 1 Car, 1 Driver's License & 1 Office Worker in Downtown Toronto

Home (York)



Office (Downtown Toronto)

Conventional Transit Trip: (Person 1)

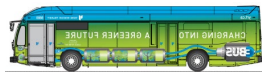


Premium Transit Trip: (Person 1)

Time Period

Morning Peak

Conventional Transit Trip: (Persons 1)



Premium Transit Trip: (Person 1)

Afternoon Peak

ABM data insight

Household 2 of 3 Persons:
Yearly Income $100,000, with 1 Car, 1 Driver's License & 1 Office Worker in Downtown Toronto

Home (York)

HOV2 Car Pool Trip:
(Person 2 & 3)

SOV Trip:
(Person 3)

School (York)

SOV Trip:
(Person 3)

HOV2 Car Pool Trip:
(Person 2 & 3)

Mall (York)

HOV3 Car Pool Trip:
(Person 1, 2 & 3)

HOV3 Car Pool Trip:
(Person 1, 2 & 3)

Time Period

Morning Peak

Afternoon Peak

Evening Peak

GHG EMISSION CALCULATOR

Standalone tool

- Apply to scenarios with traffic assignment results in the ABM
- Traffic related air pollutants calculation for CO2, CO, NH3, NOx, PM2.5, PM10, SO2, VOC

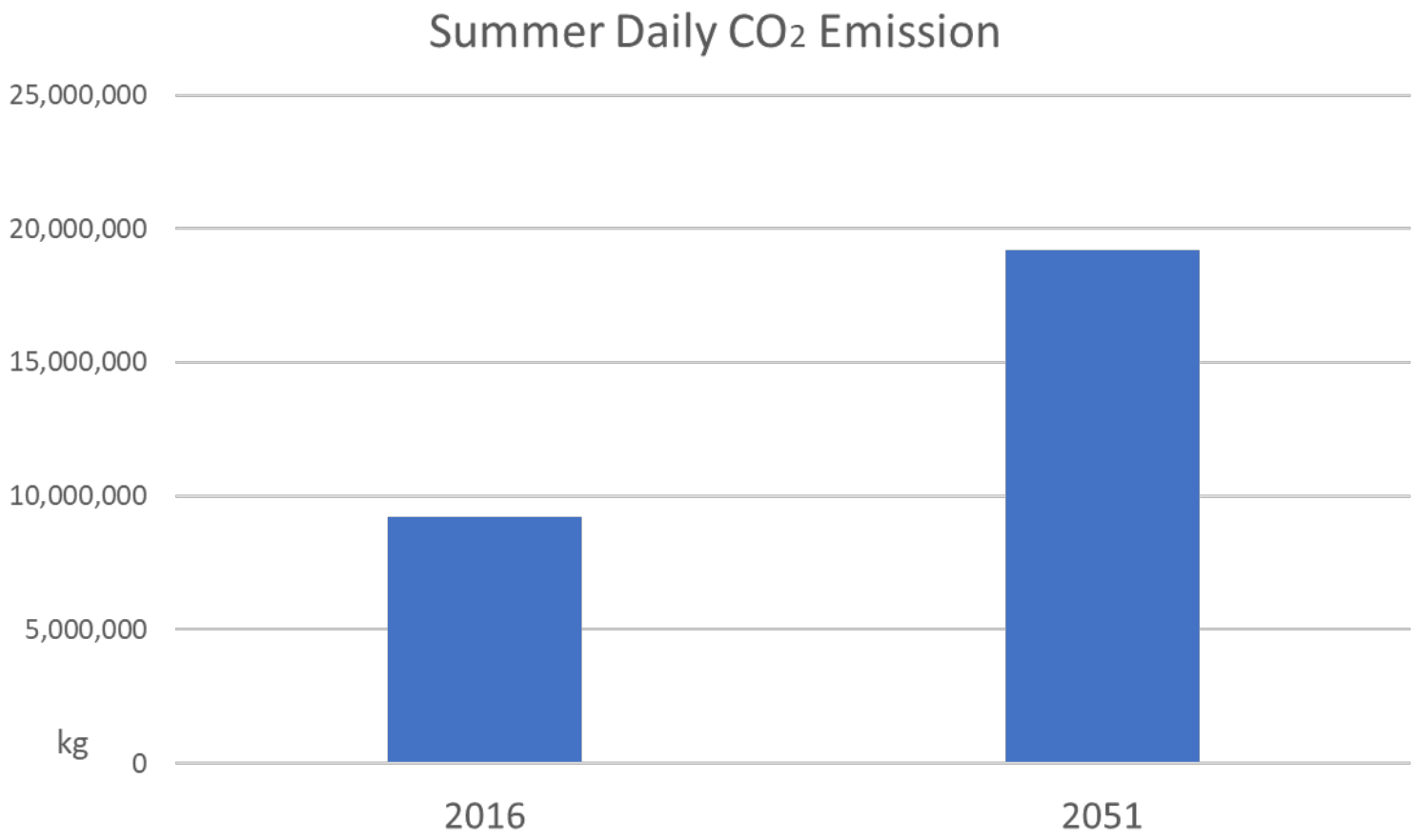
Emission factors

- Estimated by Motor Vehicle Emission Simulator (MOVES) based on vehicle population, travel activity and fuel supply
- Summer and winter rates
- Provided by road type and speed bin
- Vehicle Kilometer Traveled (VKT) from the ABM for different time period scenarios of daily travel activity

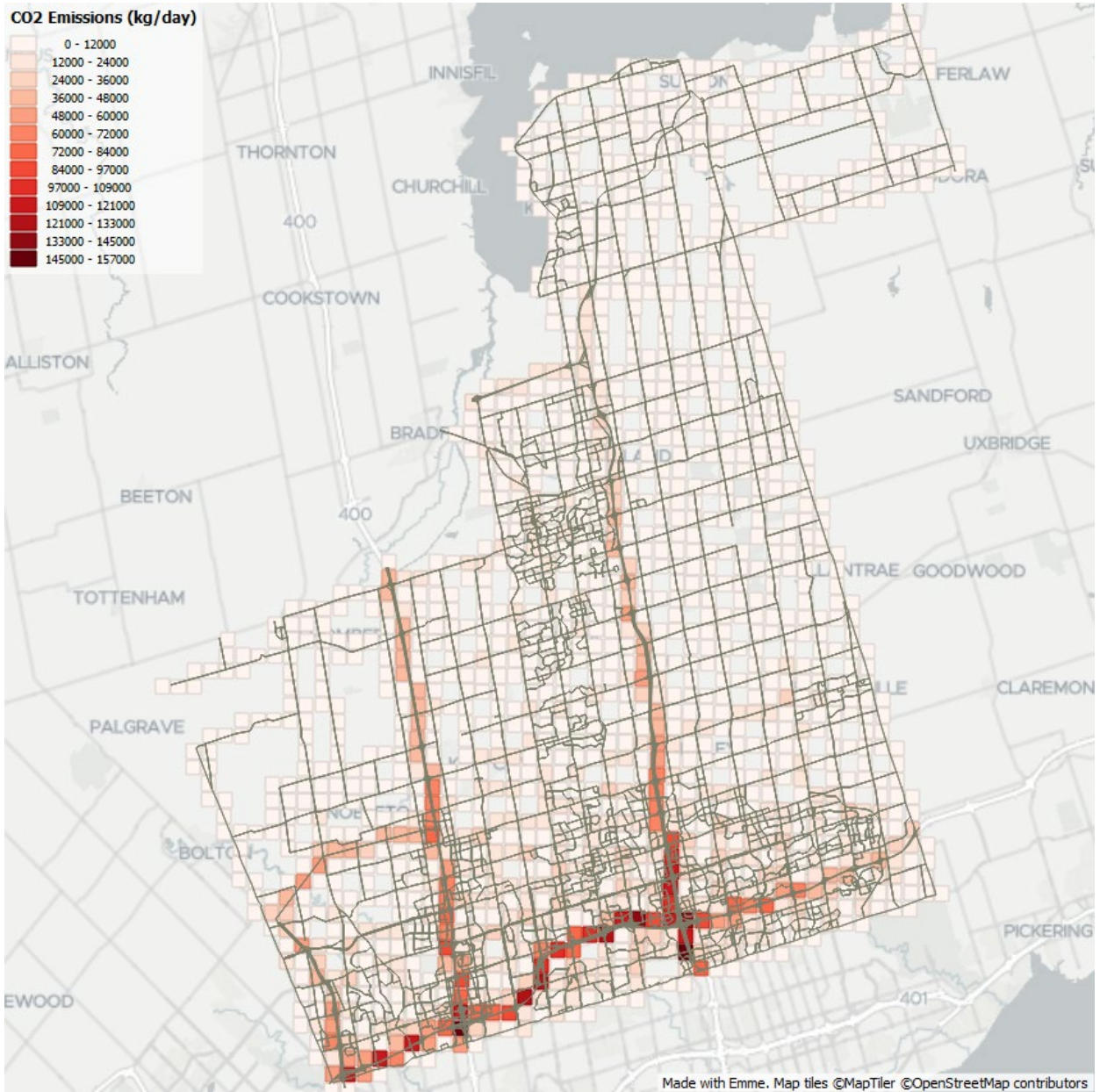
Summer daily emissions by local municipalities in 2051

Municipality	CO2 (kg/day)	CO (kg/day)	NOx (kg/day)	PM10 (kg/day)	NH3 (kg/day)	VOC (kg/day)	PM2.5 (kg/day)	SO2 (kg/day)
Georgina	323,000	862	238	37	16	13	7	2
East Gwillimbury	1,060,000	2,867	930	148	52	45	27	5
Newmarket	327,000	1,043	262	67	17	16	11	2
Aurora	351,000	1,095	307	72	17	18	12	2
Richmond Hill	1,650,000	5,189	1,573	343	83	87	54	9
Whitchurch-Stouffville	1,420,000	3,807	1,458	215	66	64	39	7
Markham	5,110,000	14,825	5,735	945	245	262	155	26
King	1,990,000	5,497	2,124	335	93	95	58	10
Vaughan	6,950,000	19,711	7,661	1,242	328	338	208	35
York	19,181,000	54,896	20,289	3,405	916	938	570	97

CO2 growth from 2016 to 2051 in York Region



Map of 2051 summer daily CO2 concentration



MODEL APPLICATION

TRANSPORTATION MASTER PLAN UPDATE

Tested scenarios

- Network Scenarios:
  - Base case
  - Transit improvements
  - Option 1
  - Option 2
  - Option 3
  - 2016 TMP Network
- Planning Scenarios:
  - Parking charges
  - Work from home (Teleworking) + e-shopping
  - Integrated transit fare
  - Higher AT travel
  - Peak spreading

WFH policy target

Industry sector	Telework capacity (1)	Teleworking or working remotely is not a possibility for any employees of the business or organization (2)	Total jobs, GTHA (3)	Workplace type is home, 2016 (4)	WFH scenario factor	WFH scenario target
Agriculture	5%	89%	32,885	11%	1.00	11%
Mining	25%	61%	5,910	11%	2.00	23%
Construction	12%	85%	141,580	10%	1.00	10%
Utility, Transportation	38%		198,380	10%	3.00	29%
Manufacturing	19%	62%	450,870	5%	3.00	15%
Wholesale	57%	45%	187,190	5%	3.00	15%
Retail	22%	88%	480,925	7%	2.00	14%
Other Services	32%	67%	174,970	7%	3.00	20%
Information, Professional, Business Service	70%	25%	674,995	14%	4.00	56%
Education	85%		313,400	4%	2.00	9%
Health, Social Services	30%	55%	428,730	4%	4.00	18%
Finance, Insurance	85%	23%	297,320	12%	4.00	48%
Real Estate	50%	55%	95,605	12%	3.00	36%
Arts, Entertainment	40%	61%	82,330	7%	4.00	30%
Hospitality, Food Service	7%	96%	282,760	2%	2.00	5%
Public Administration	32%	71%	183,660	8%	3.00	24%
Total	**43%**		**4,031,510**	**8%**	**3.21**	**25%**

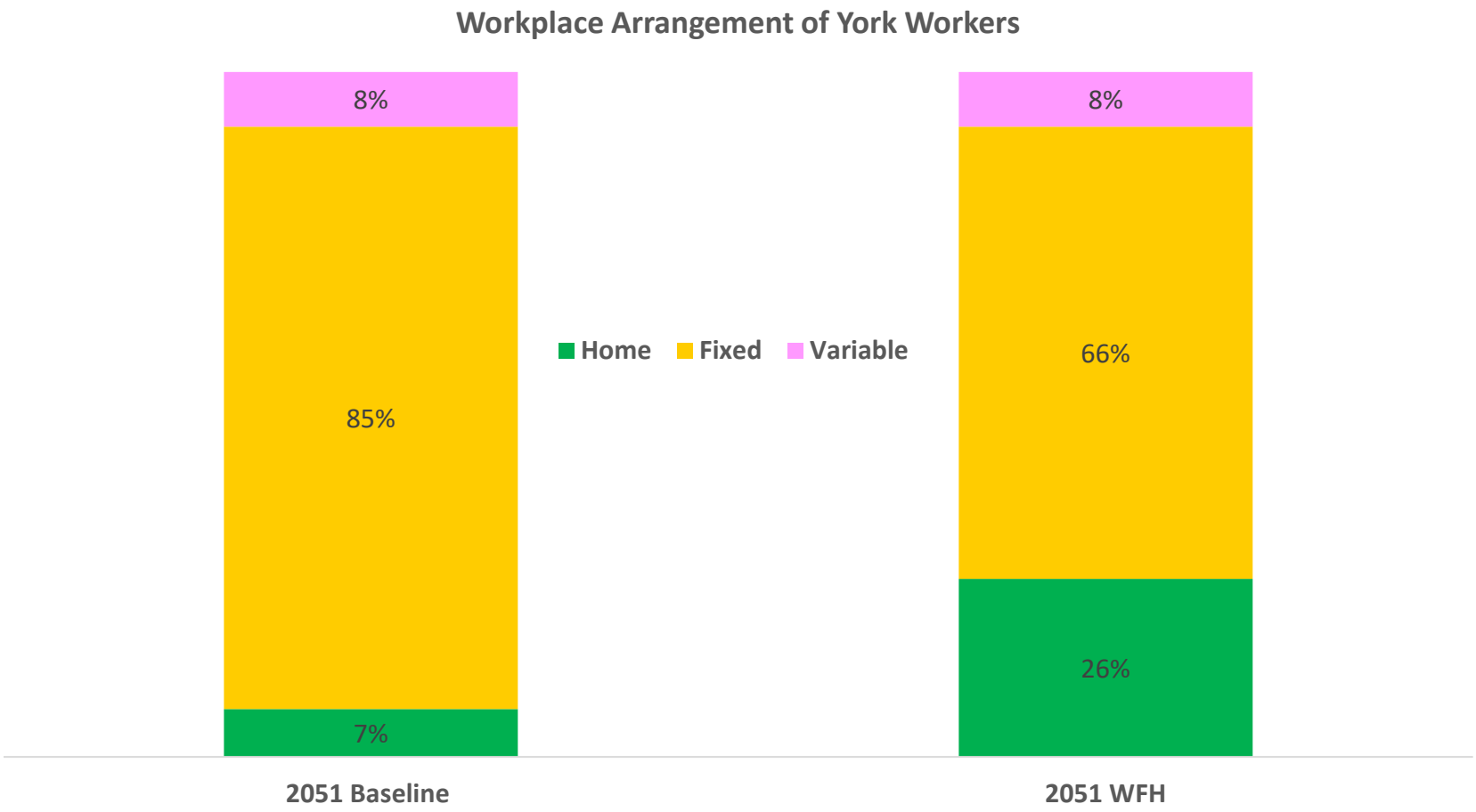
*(1) Statistics Canada, Labor Force Survey, 2019; and the Occupational Information Network, O*Net (https://www150.statcan.gc.ca/n1/pub/11-631-x/11-631-x2021001-eng.htm)*

(2) Statistics Canada, Percentage of workforce teleworking or working remotely, and percentage of workforce anticipated to continue primarily teleworking or working remotely after the pandemic, by business characteristics.

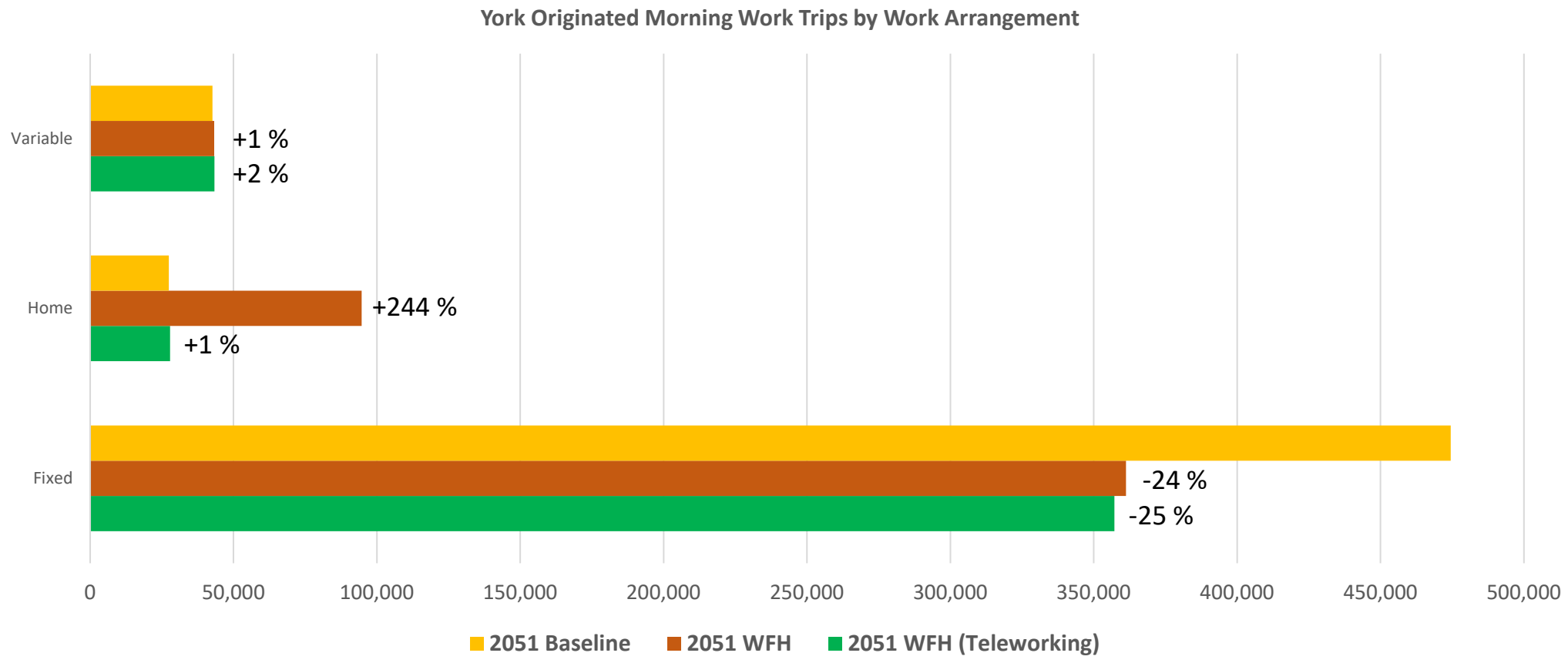
(3) York ABM 2016 SED

(4) York ABM 2016, Work Arrangements

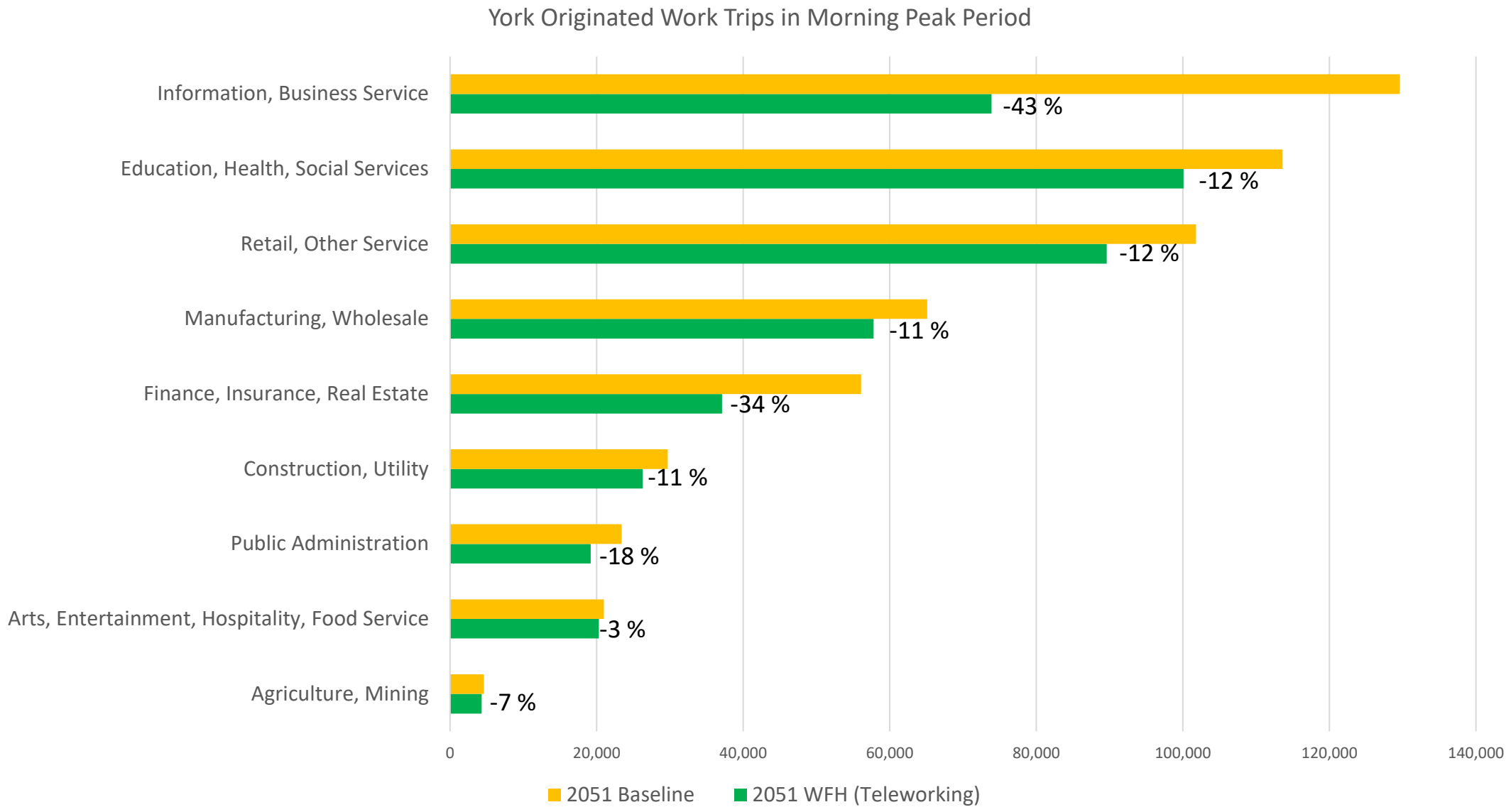
Impacts of WFH - workplace arrangement



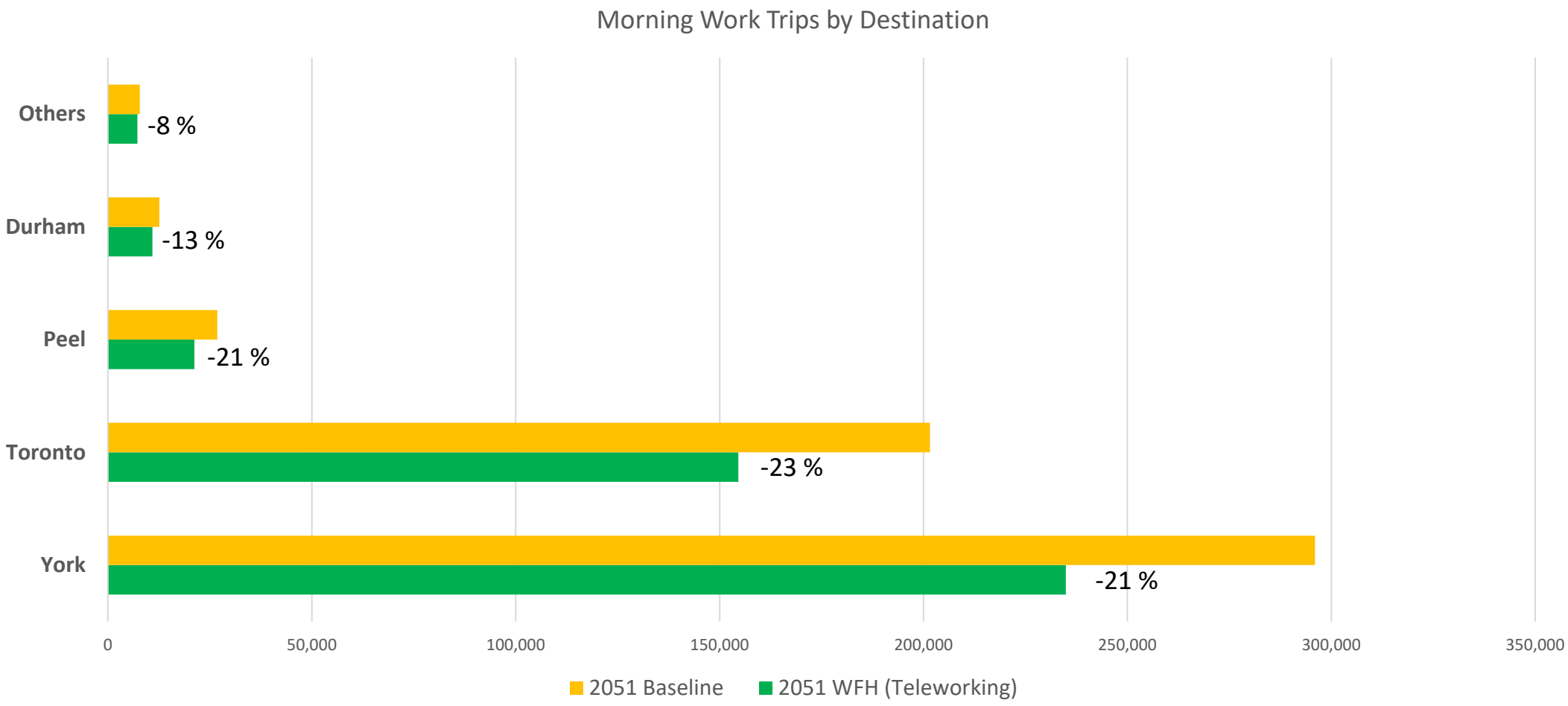
Impacts of WFH – work trips by work arrangement



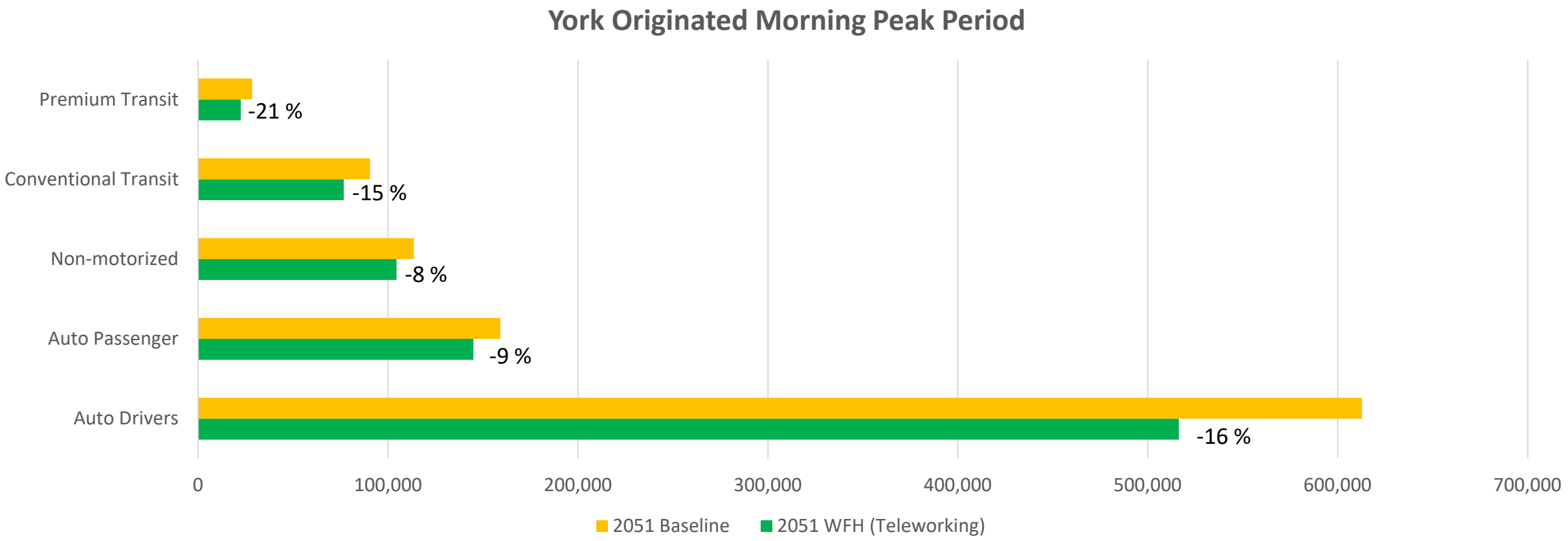
Impacts of WFH - work trips by job sector



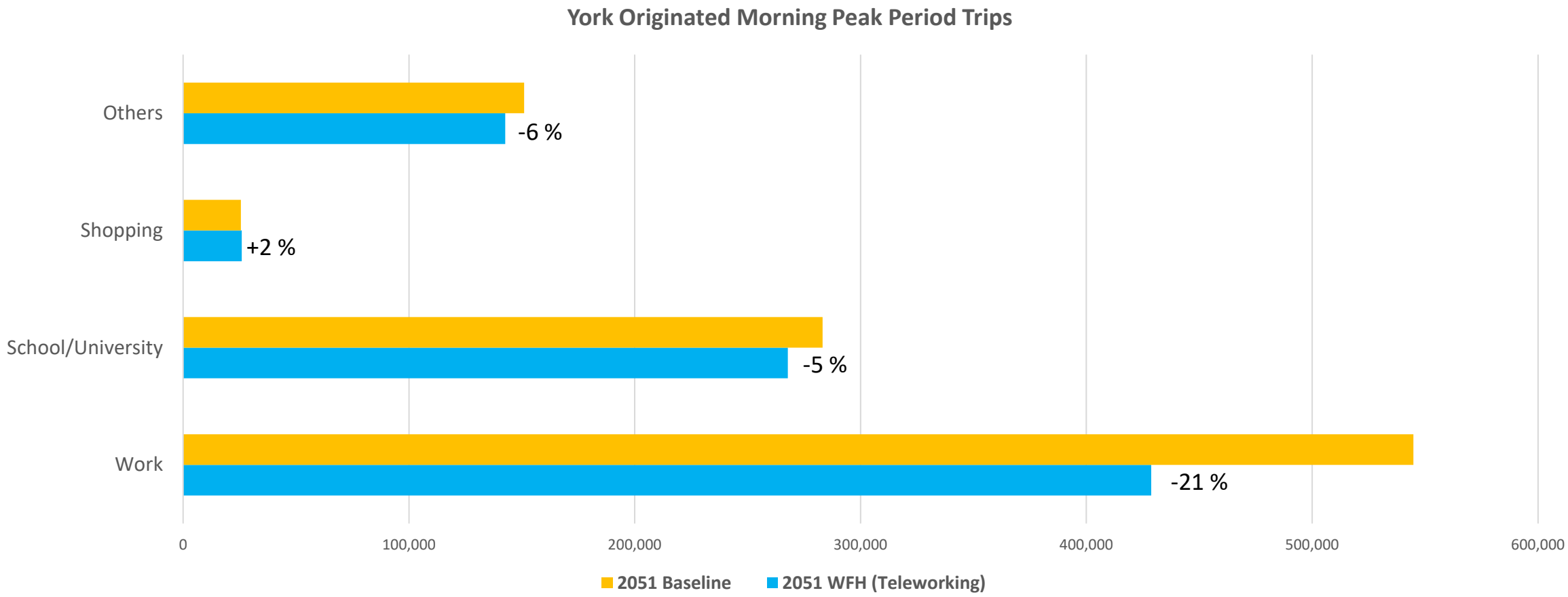
Impacts of WFH – work trips by destination



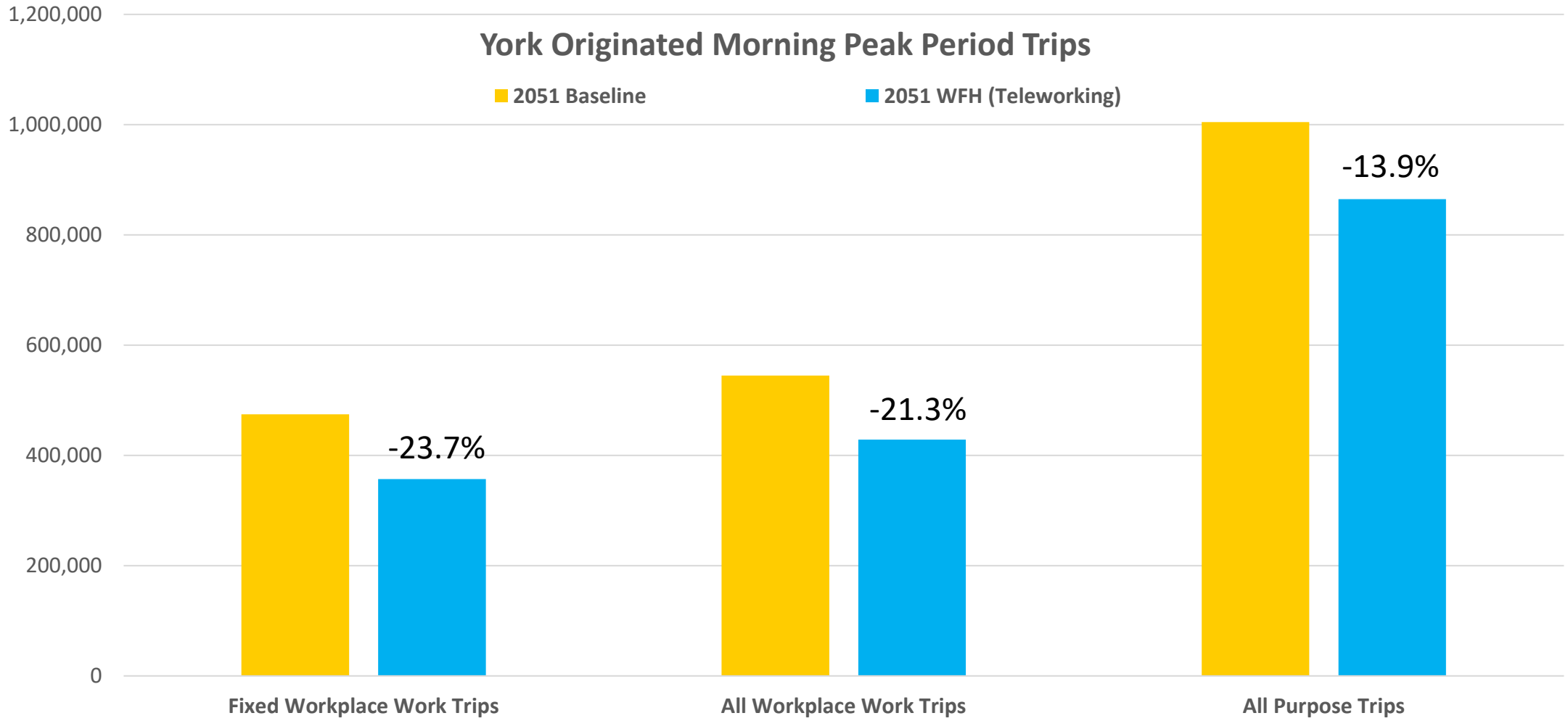
Impacts of WFH – trips by mode



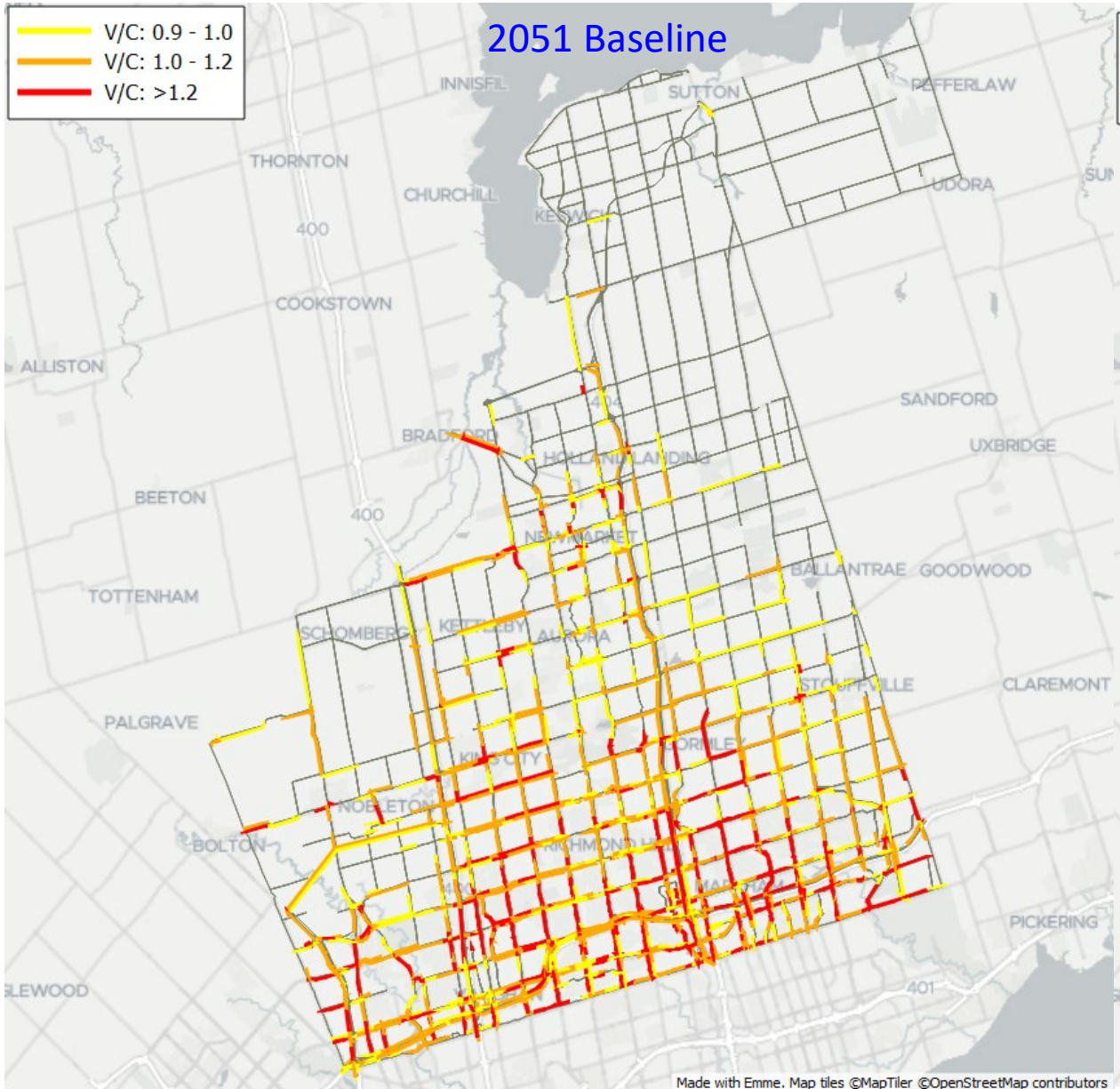
Impacts of WFH – trips by purpose

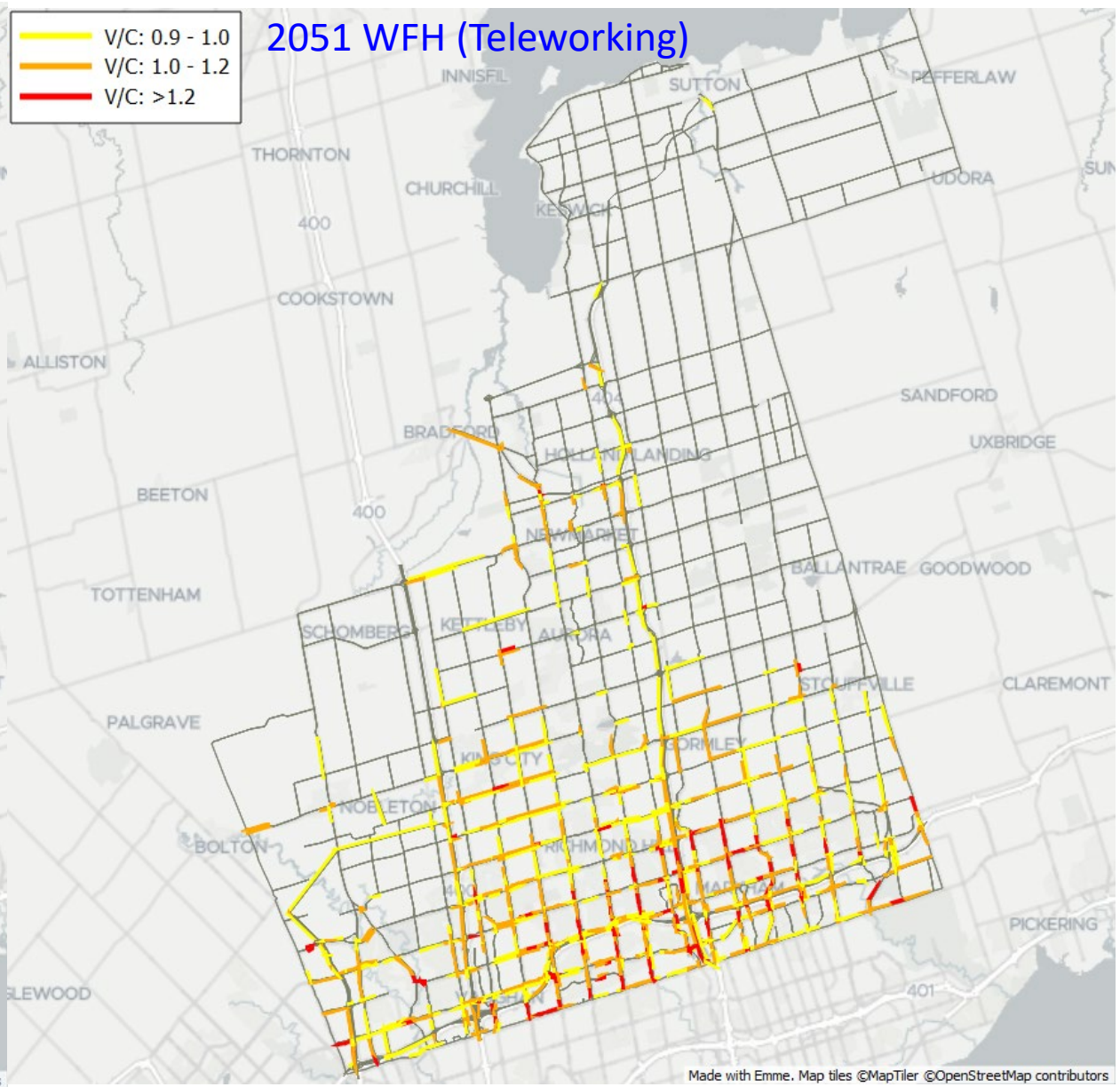


Impacts of WFH – overall travel



Impacts of WFH+e-shopping - Morning peak hour V/C





NEXT STEPS

To wrap up – motivation capabilities expanded

- Regional transportation plan
- Highway and transit infrastructure (capacity) investments
- TDM policies targeting tele-commuting
- Active transportation: bike use, bike share programs, transit first/last mile
- Transportation systems management to reduce congestion (TSM)
- Land use strategies such as TOD (Transit Oriented Development), MTSA (Major Transit Station Area), Centres and Corridors
- Pricing such as express lane, parking price, fuel price and auto operating cost
- Analysis of demographic changes and demographic evolution
- Future enhancements:
  - Ride-hailing (Uber/Lyft)
  - Connected and autonomous vehicles (CAV)
  - DTA model development (undergoing)
  - ABM-DTA integration

Lessons learned

- Run time is higher than the 4-stage model
- Forecasting capabilities increased beyond the traditional 4-stage model
- Learning curve for staff
- Programming skill is **must** for data analysis

QUESTIONS / DISCUSSION

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