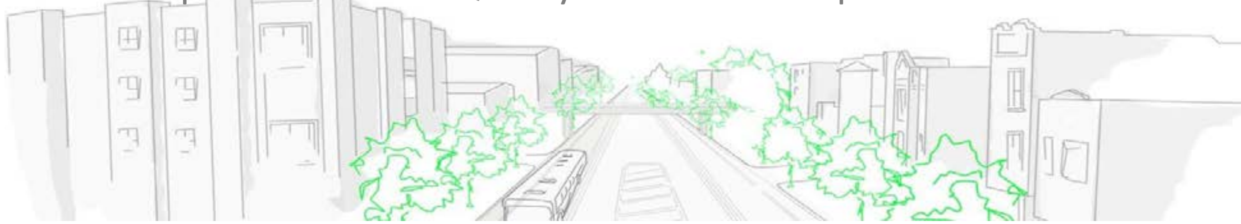
TRAQ

The Transportation & Air Quality Research Group



Implications of Automated Vehicles on Urban Sustainability

Marianne Hatzopoulou

iCity-CATTS Symposium

June 28, 2018

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

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Automated vehicles and sustainability

How green are self-driving cars?

James Phillips
Monday, July 27, 2015 - 1:30am

Environmental impacts of self-driving cars are evolving as automakers and tech firms get the vehicles closer to market.

Could self-driving cars stall sustainable transportation?

Jocelyn Timperley
Wednesday, July 6, 2016 - 12:45am

How will self-driving cars interact with public transit?

Sensemaking / What will autonomous vehicles mean for sustainability?

Driverless vehicles are poised to remake transportation, the urban landscape and employment. What else might their mainstreaming bring?

BY JACOB PARK / 27 FEB 2017

WILL SELF-DRIVING CARS REDUCE EMISSIONS?

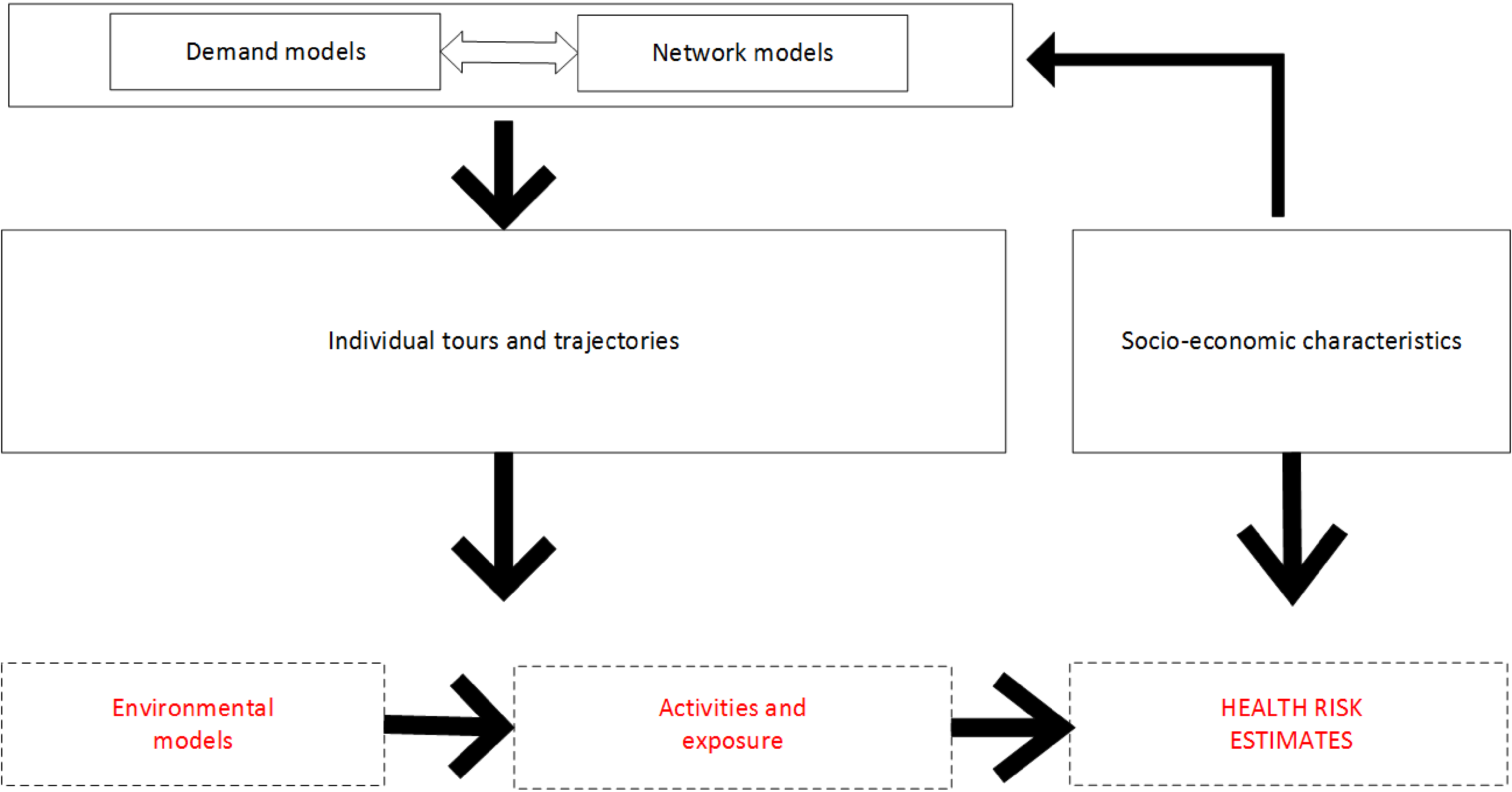
Posted on April 18, 2018 by Katrina Kazda

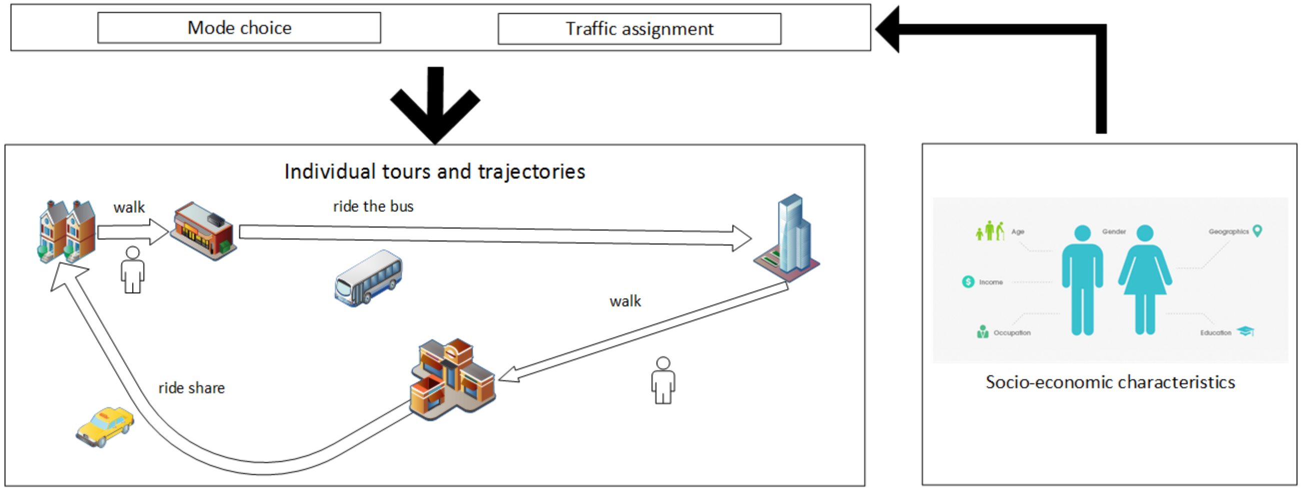
Like 3 Tweet Pinterest Email

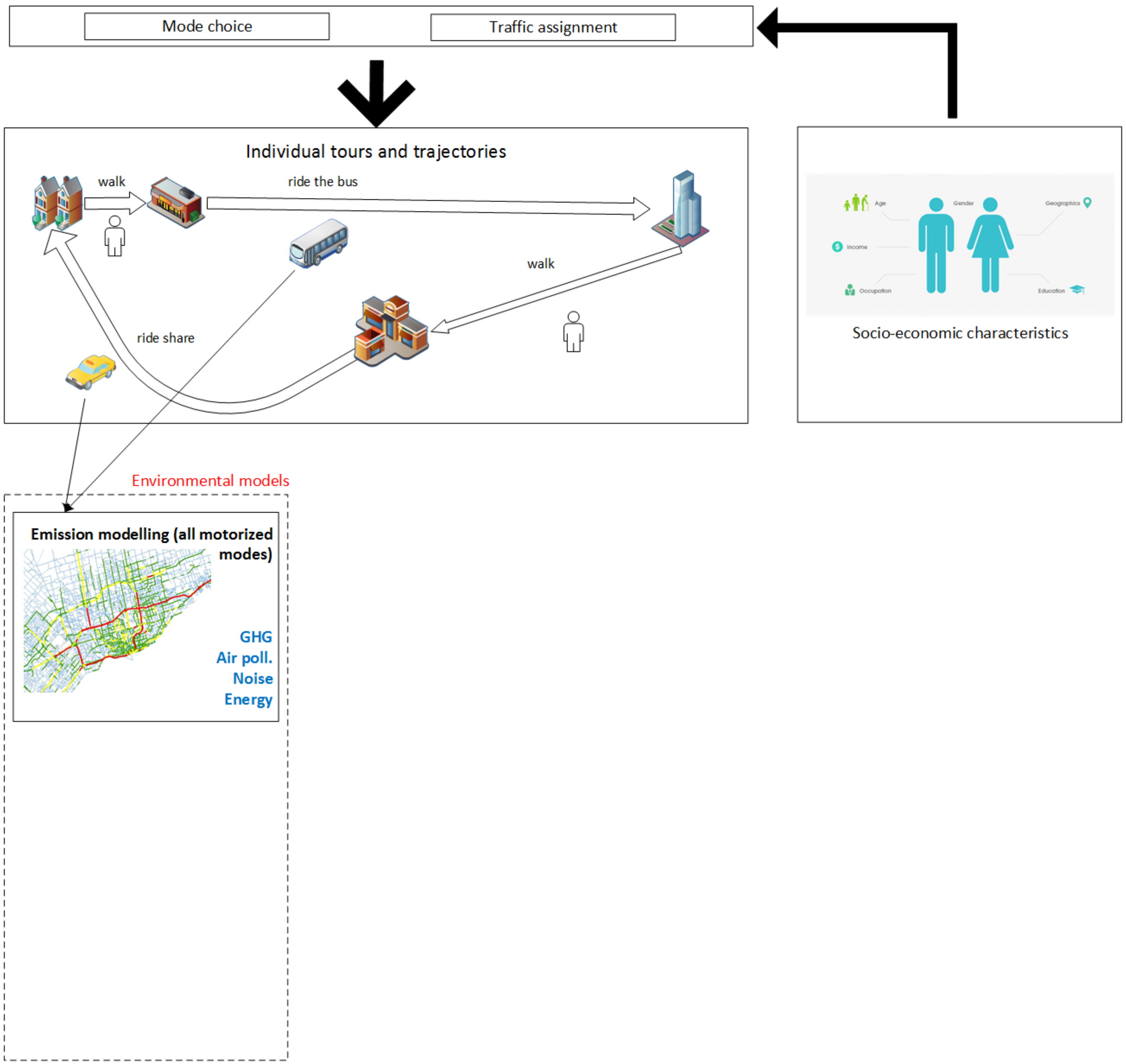
Audi's Aicon Concept autonomous, all-electric car has no steering wheel or pedals with a range of close to 500 miles per charge. Photo: Audi

OUR PROPOSAL

Anticipating the impacts of transformative transportation technologies on greenhouse gases, air pollution, and health


Demand models
Network models
Individual tours and trajectories
Socio-economic characteristics
Environmental models
Activities and exposure
HEALTH RISK ESTIMATES


Mode choice
Traffic assignment
Individual tours and trajectories
walk
ride the bus
walk
ride share
Age
Gender
Geographics
Income
Occupation
Education
Socio-economic characteristics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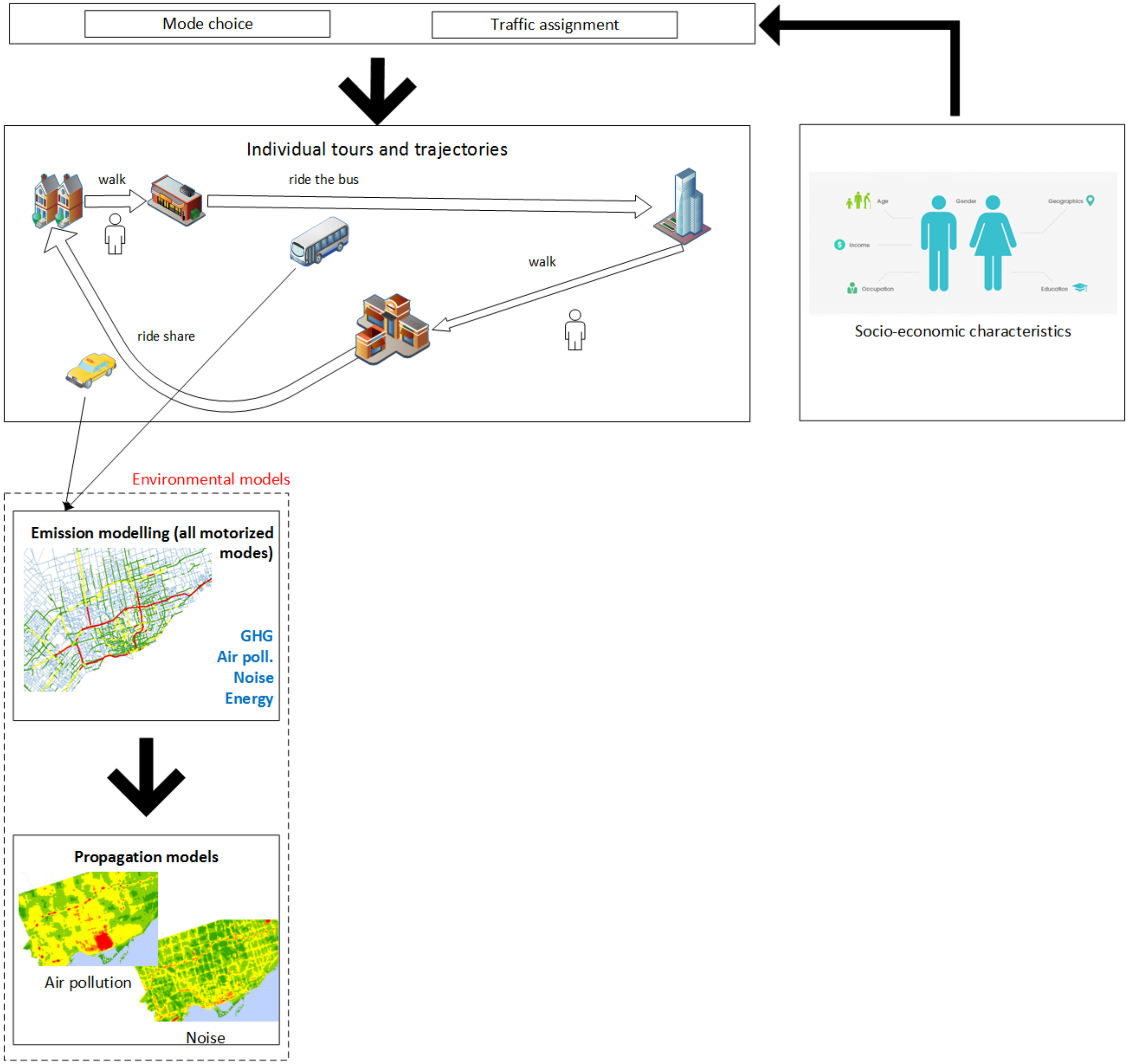
Environmental models
Emission modelling (all motorized modes)
GHG
Air poll.
Noise
Energy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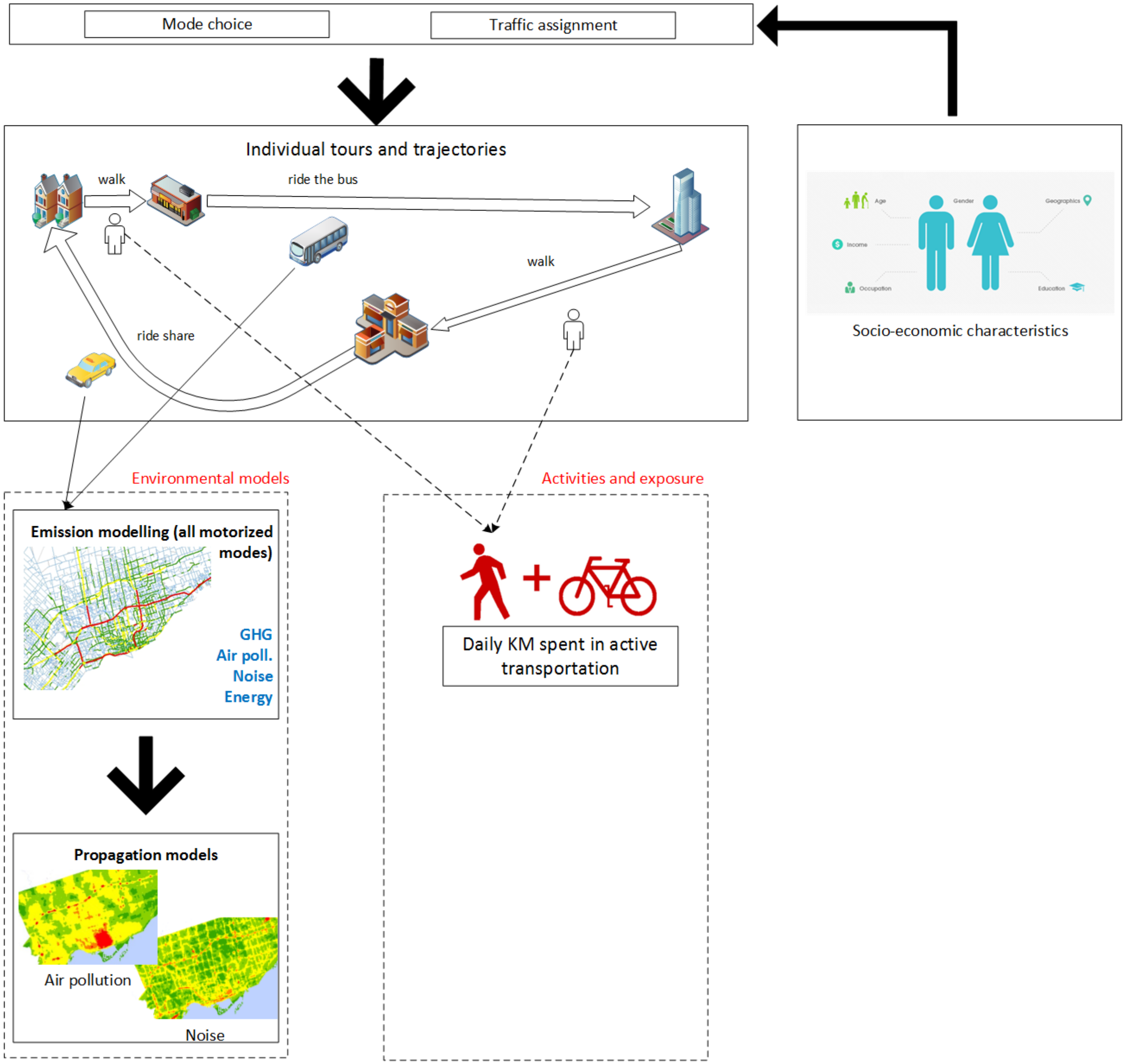
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Activities and exposure
Daily KM spent in active transportation

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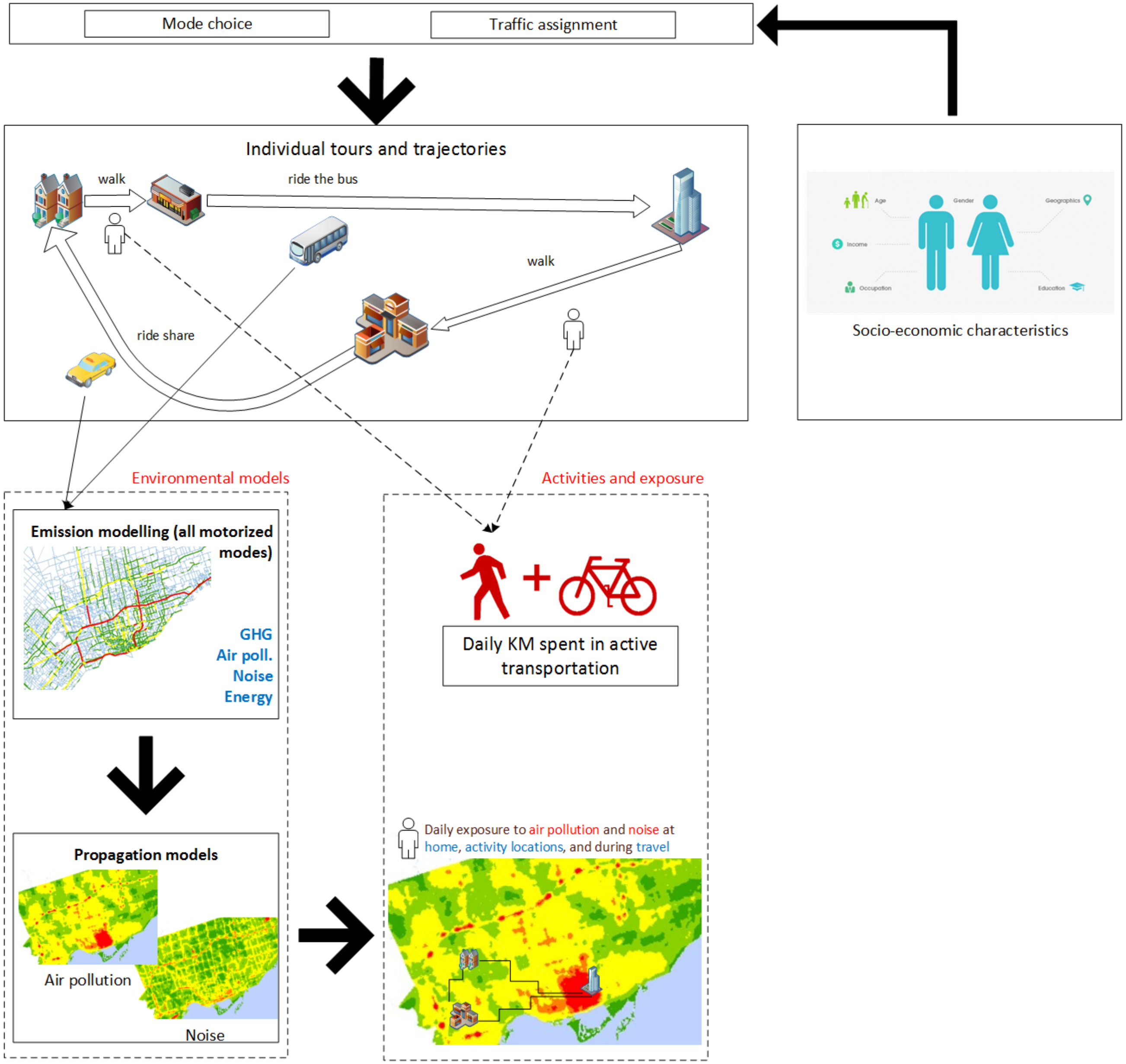

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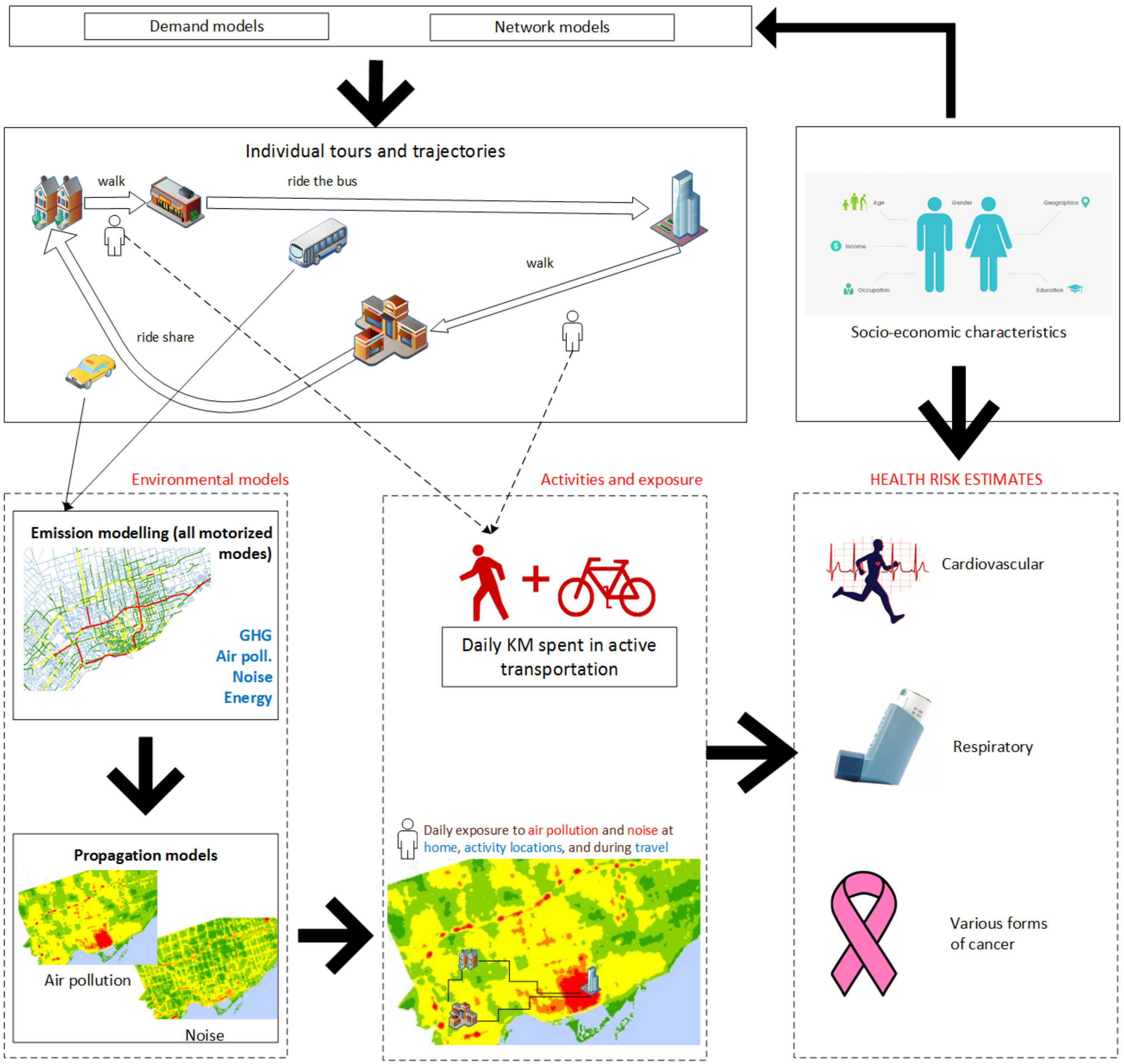
Daily KM spent in active transportation
Daily exposure to air pollution and noise at home, activity locations, and during travel

UTTRI



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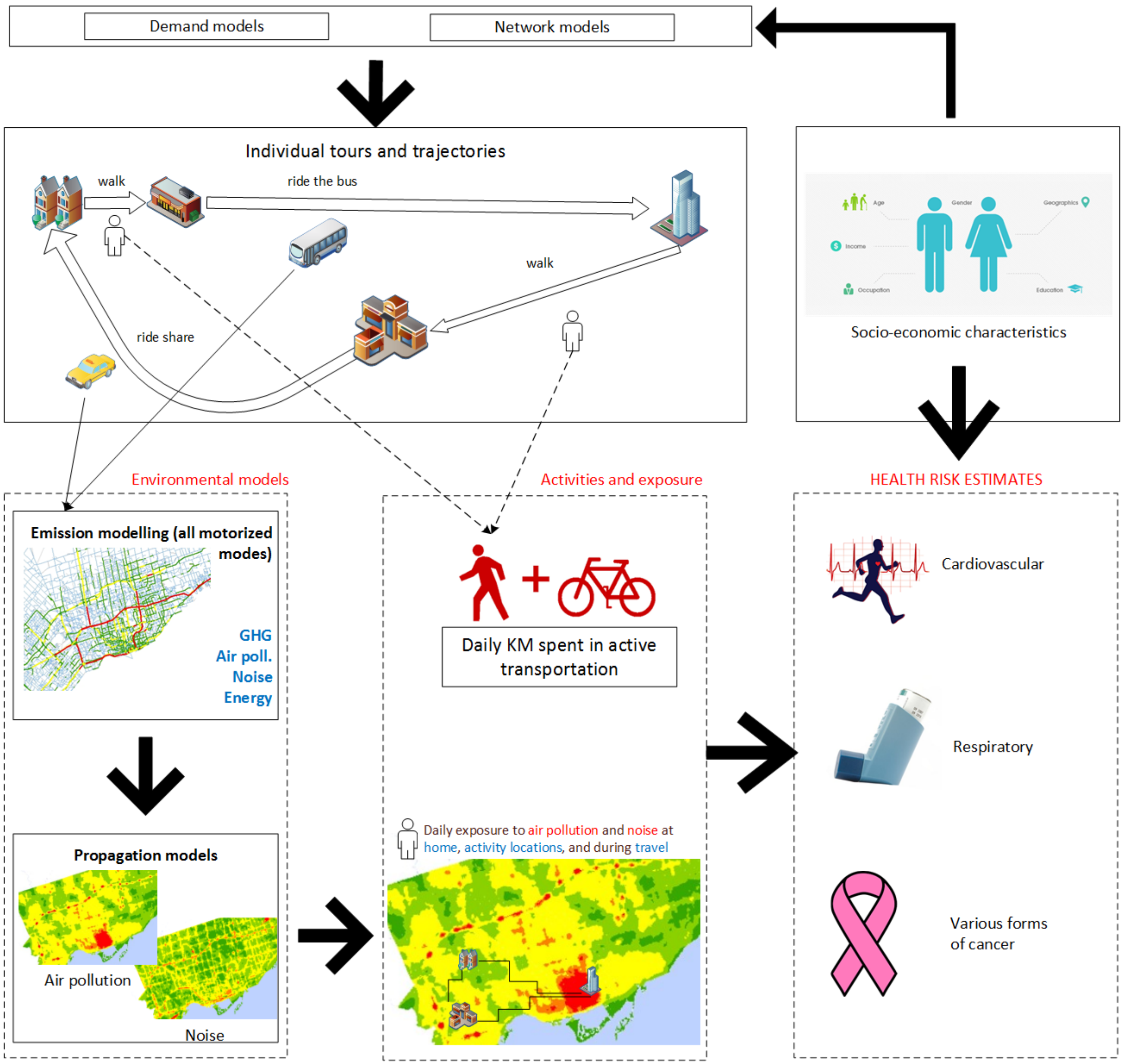
Daily KM spent in active transportation
Cardiovascular
Respiratory
Various forms of cancer
Propagation models
Air pollution
Noise
Daily exposure to air pollution and noise at home, activity locations, and during travel



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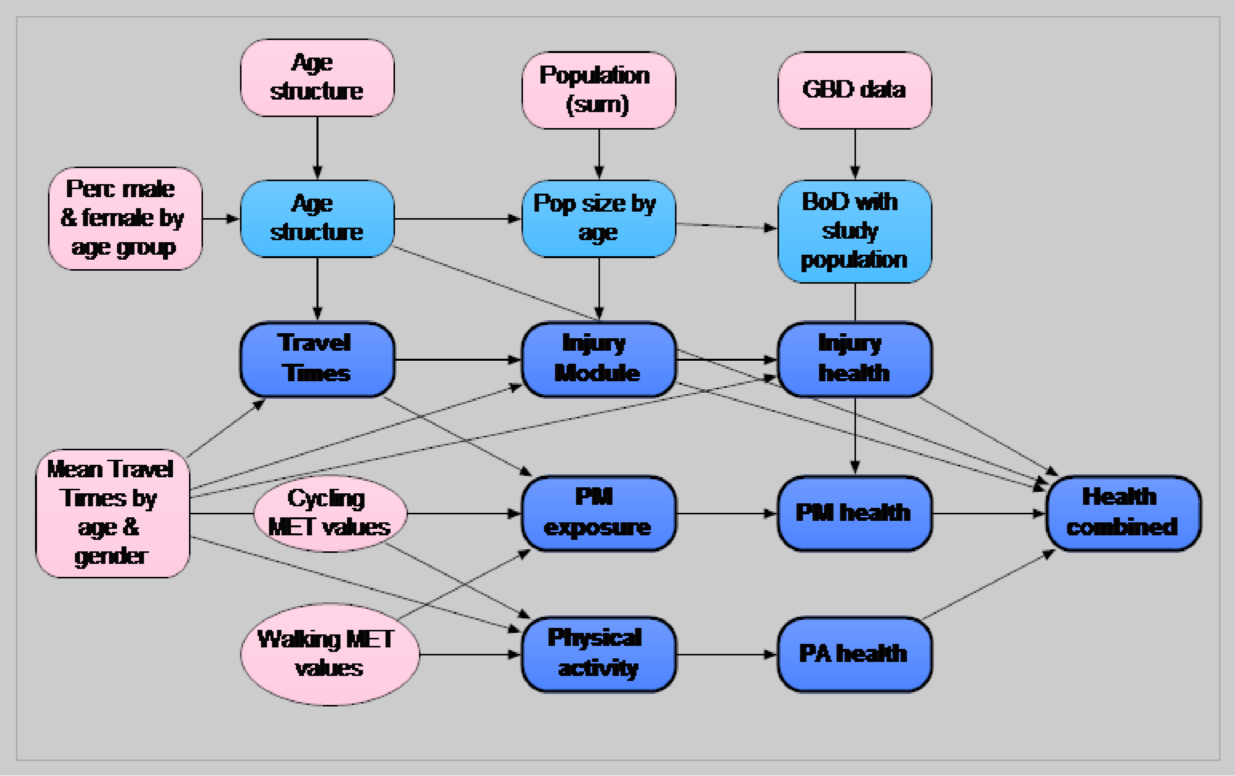
Integrated Transport and Health Impact Modelling Tool (ITHIM)



http://www.cedar.iph.cam.ac.uk/research/modelling/ithim/

Contents lists available at ScienceDirect

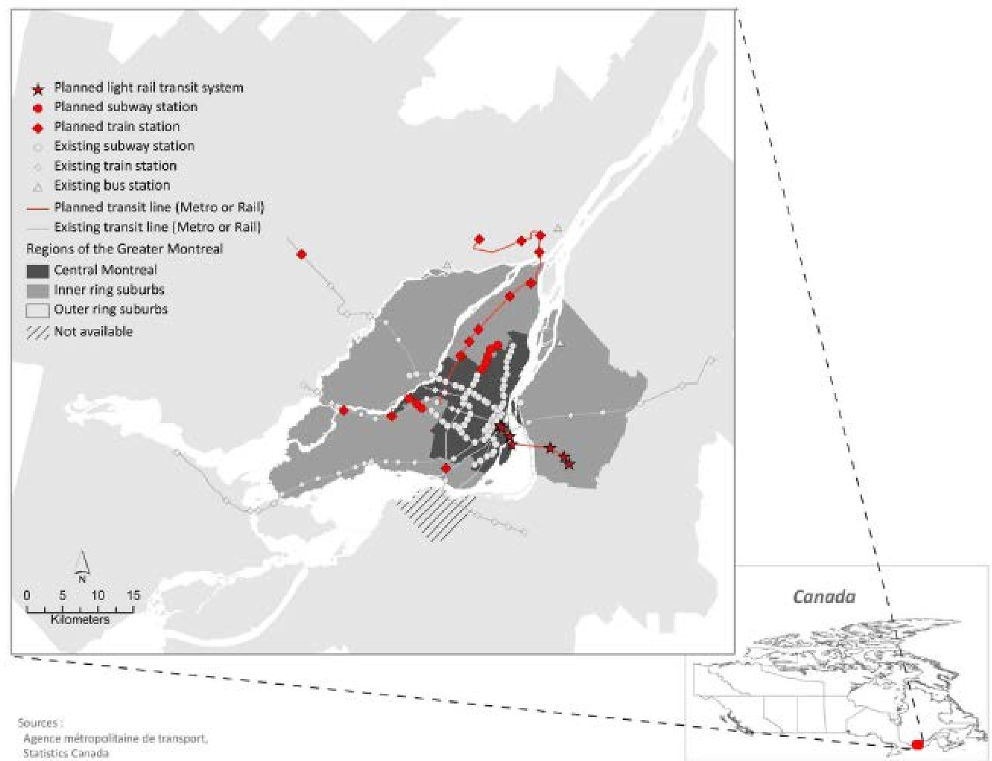
Environmental Research

journal homepage: www.elsevier.com/locate/envres

ELSEVIER

Estimating the health benefits of planned public transit investments in Montreal

Louis-François Tétreault[a,b], Naveen Eluru[c], Marianne Hatzopoulou[d], Patrick Morency[b,e], Celine Plante[b], Catherine Morency[f], Frederic Reynaud[g], Maryam Shekarrizfard[d], Yasmin Shamsunnahar[c], Ahmadreza Faghih Imani[g], Louis Drouin[b,e], Anne Pelletier[b], Sophie Goudreau[b], Francois Tessier[b], Lise Gauvin[e], Audrey Smargiassi[a,h,*]



Health impacts were computed in terms of Disability Adjusted Life Years (DALY)

Table 3
Burden (in DALYs) linked to transportation patterns between BAU and PT for regions of the greater Montreal in 2031[a].

		Central Montreal	Inner suburbs	Outer suburbs	Greater Montreal
Population		1051,327	1716,288	1388,276	4155,891
Burden (DALYs)					
	Road Injuries	35.5	20.7	7.3	63.4
	Air pollution	0.5	1.2	0.2	1.5
Gain					
	Active transportation	6.1	20.3	12.8	39.2

Predicted gain of **39.2 DALYs**
in 2031 Transit Scenario
compared to 2031 BAU
➔ 2.5 DALYs per 100,000 individuals
➔ very small effect

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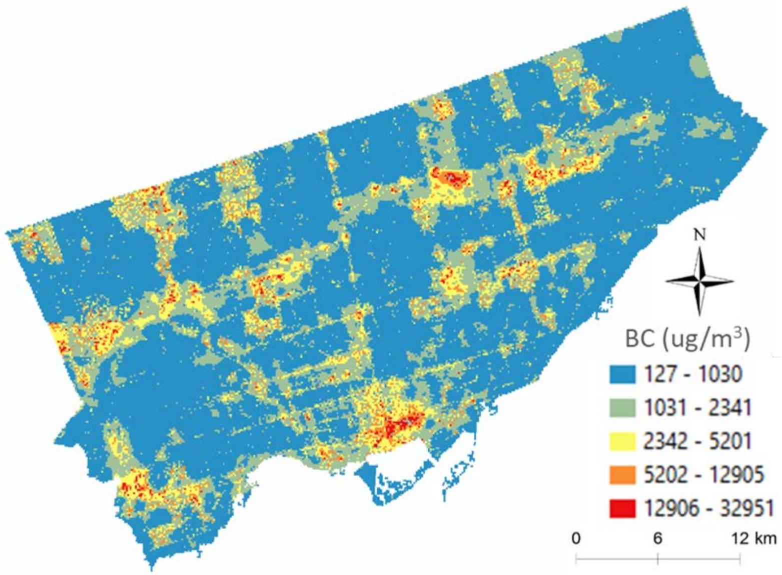
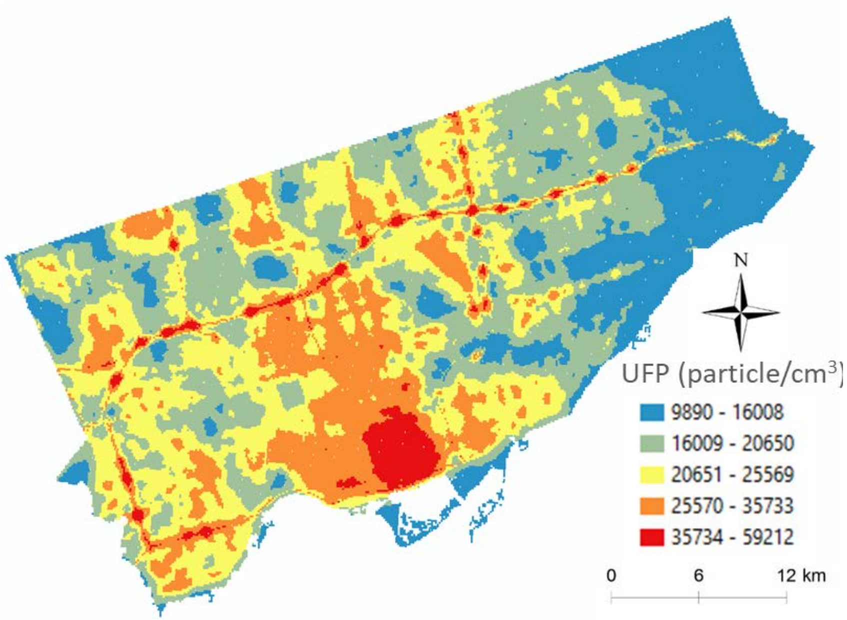
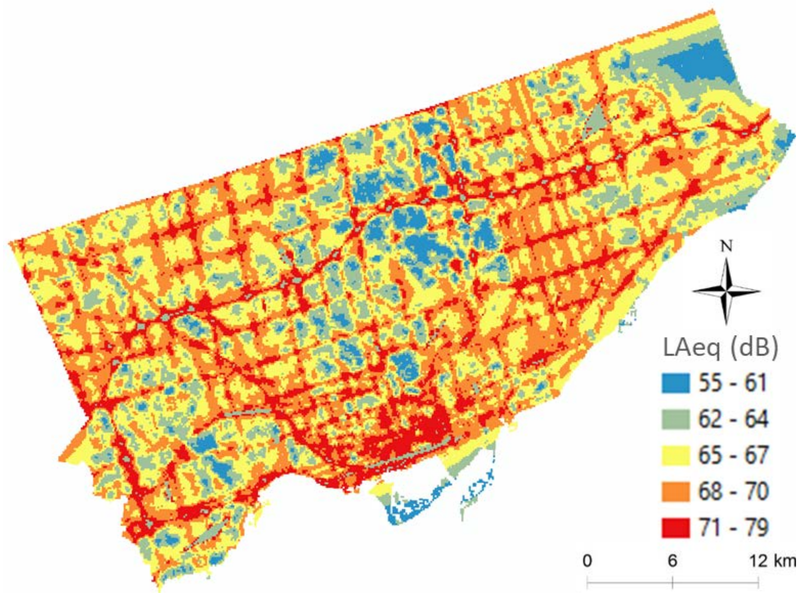
Developing air pollution maps using sensors







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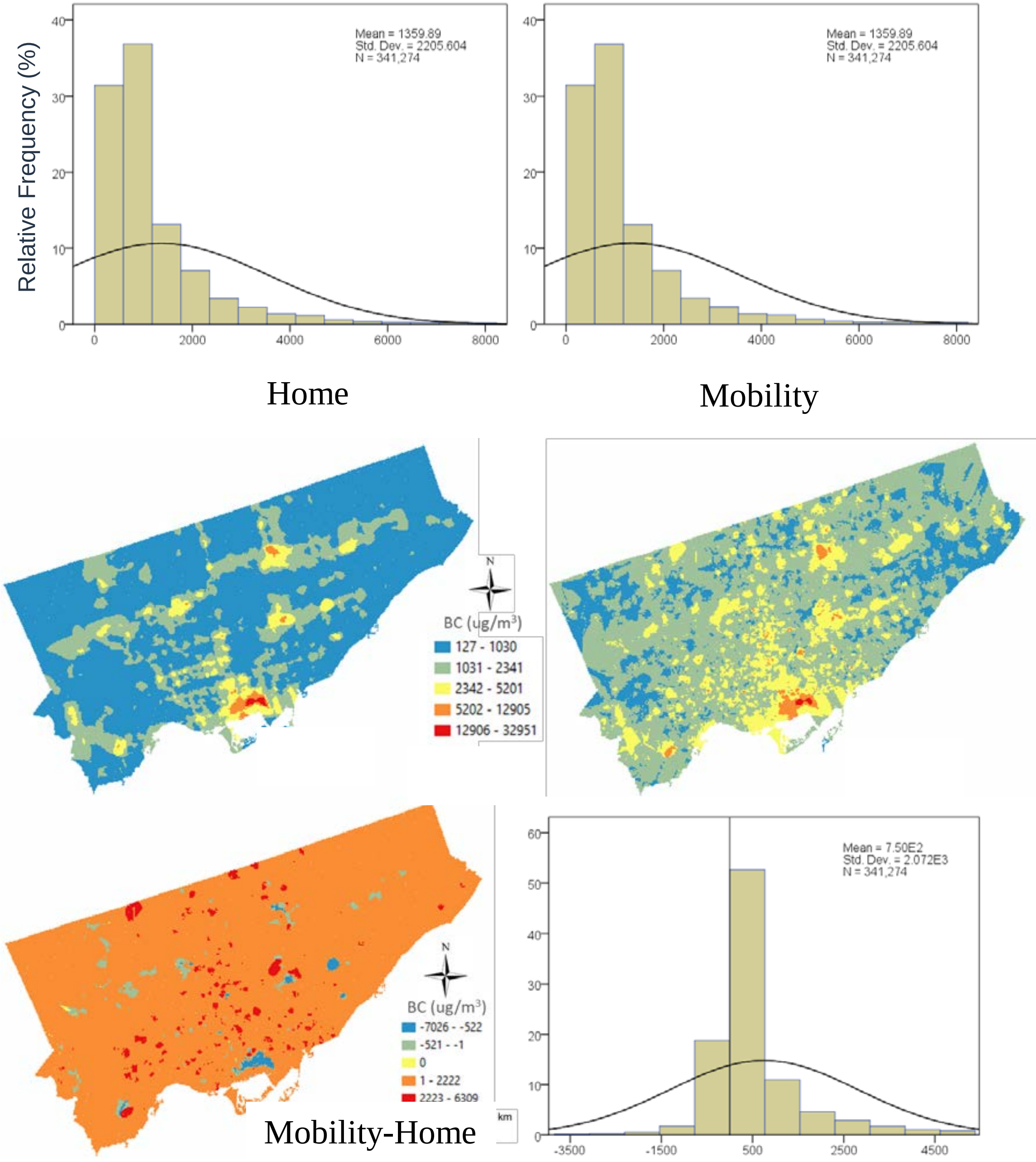
Maps expressing daily exposure of individuals



Outcomes of models explaining daily exposure

- Transit pass has + and significant effect
- Driver has – and significant effect
- Transit users generally have highest exposures followed by pedestrians/cyclists
- Important injustice in generation of air pollution and exposure

OUR ACHIEVEMENTS TO DATE

Automated, electric, or both?

Anticipating the impacts of transformative transportation technologies on energy consumption and greenhouse gas emissions in the GTHA

GTHA: Two tales

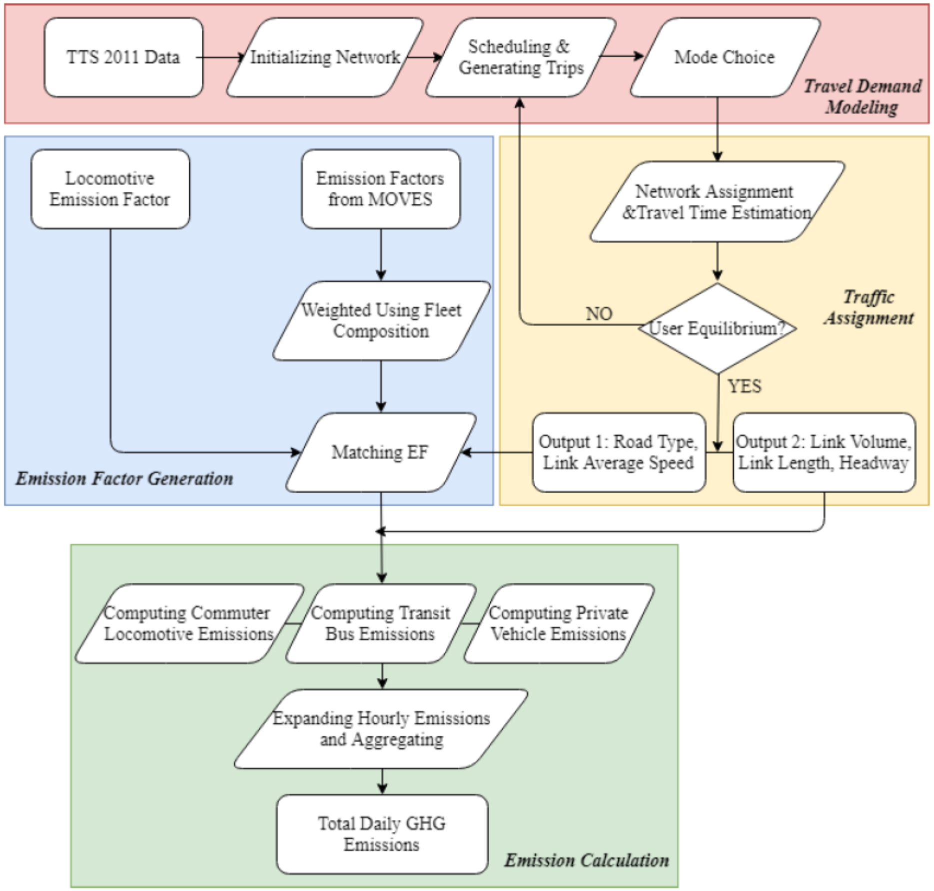
- Regional effects of automation and electrification

- Local effects of automation and electrification

GTHA: Two tales

- Regional effects of automation and electrification
- Local effects of automation and electrification

Extending the GTAModel



Scenarios for Automated Vehicles (AVs)

- ❖ Adoption
  - ❖ Households were assigned AVs if :
    1. Household income >80,000 CAD
    2. Daily commute distance > 20km
    3. Have at least one child
    4. Have at least one private vehicle

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Impacts on road capacity

Effects on Driving

Changes in:

- Acceleration/ deceleration behaviour
- Longitudinal following behaviour (headways)
- Lateral behaviour and gap acceptance thresholds

Automated Vehicles

Expected Benefits

- Increased road capacity
- Improved fuel efficiency, traffic flow, & safety
- Reduction in traffic congestion and GHG emissions

However…

- Initially, it is expected that AVs may degrade road capacity due to conservative driving characteristics
- Positive effects may not be noticed until >50% penetration and with intermediate to aggressive driving characteristics

Road capacity effect

$$Capacity_{New} = \frac{Capacity_{Initial}}{[AV_{ratio} * (1 - efficiency_{AV}) + (1 - AV_{ratio})]}$$

What if AVs were electric?

- Ontario electricity generation mix obtained from the Independent Electricity System Operator (IESO)

- Four electricity generation scenarios:

  1. Current Ontario mix:
     61% nuclear, 23.7% hydro, 8.4% gas/oil,
     6.2% wind, 0.3% biofuel, 0.3% solar

  2. All fossil mix: 100% natural gas

  3. Only dispatchable source mix: 73% hydro, 26% gas/oil, and 1% biofuel

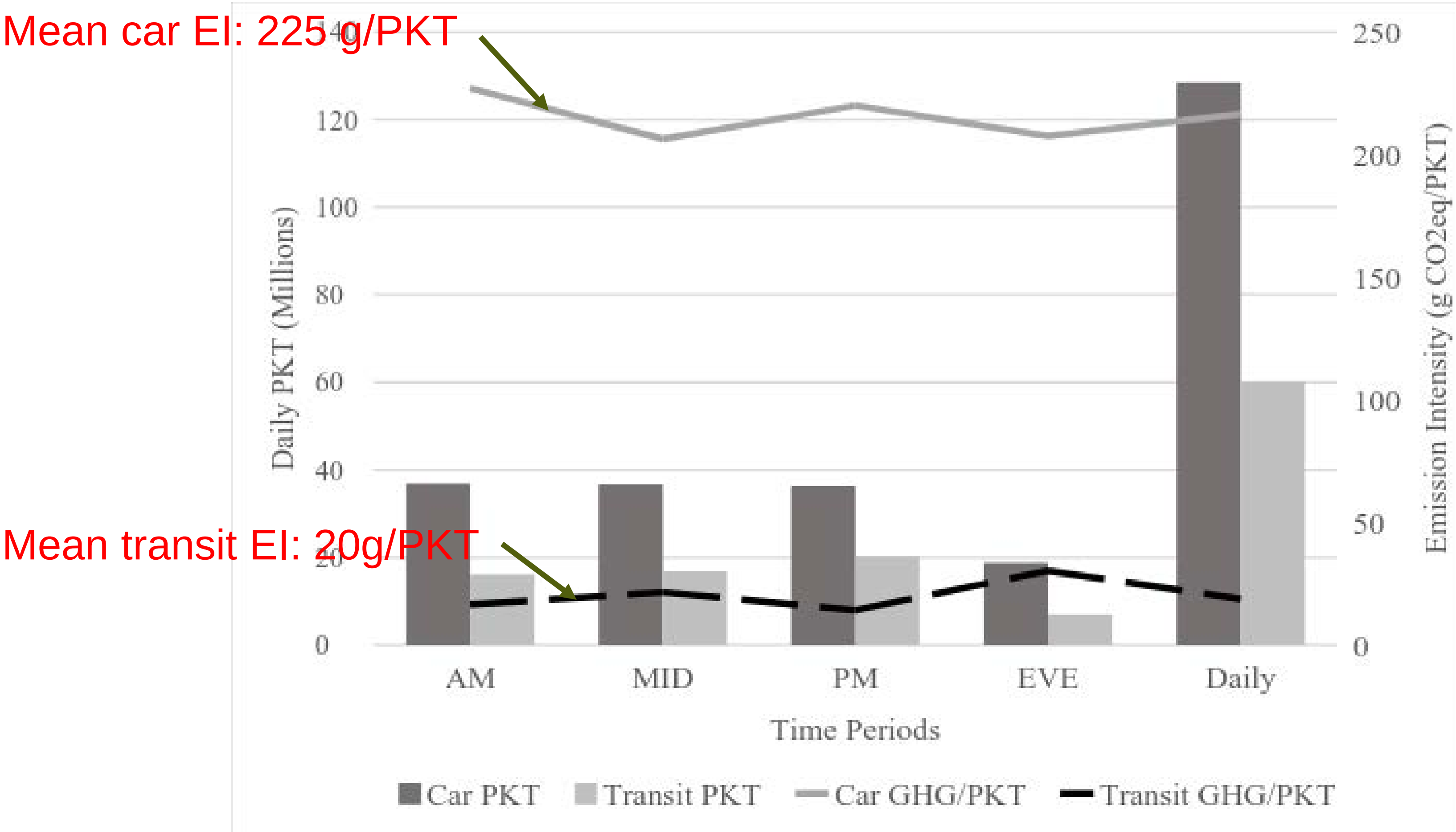
  4. Solar and wind mix: 95.3% wind and 4.7% solar

Automated and Electric Vehicle Scenarios

Scenarios	AV savings in road capacity	Conventional vehicles	Automated Vehicles
A0 (Base Case)	1	Gasoline Fueled	None
A1	50%	Gasoline Fueled	Gasoline Fueled
A2.1		Gasoline Fueled	Electric; Electricity Mix1
A2.2		Gasoline Fueled	Electric; Electricity Mix2
A2.3		Gasoline Fueled	Electric; Electricity Mix3
A2.4		Gasoline Fueled	Electric; Electricity Mix4
B1	10%	Gasoline	Gasoline Fueled
B2.1		Gasoline Fueled	Electric; Electricity Mix1
B2.2		Gasoline Fueled	Electric; Electricity Mix2
B2.3		Gasoline Fueled	Electric; Electricity Mix3
B2.4		Gasoline Fueled	Electric; Electricity Mix4

Base Case Results

- Daily operating GHG emissions for passenger transportation in the GTHA were estimated at 29,000t CO_2eq
- 96% are from private vehicles
- 4% from public transit (buses and locomotives)
- AM peak (3 hours) and PM peak (4 hours) emissions are 59% of the total daily operating emissions
- Daily lifecycle emissions in the GTHA are estimated to be 36,200t



- Assuming each private vehicle carries 1.15 passengers
- While sharing 4% of the total GHG emissions, public transit serves up to 32% of daily total PKT

TABLE 2 Lifecycle GHG Emissions for All Scenarios

Scenarios	Efficiency	Fuel Options	Lifecycle Emissions (tonne)	VKT (millions)	Emission Intensity (g CO_2eq/PKT)
A0 (Base Case)	1	Gasoline	36,200	112	282
A1	0.5	Gasoline	37,000	118	273
A2.1		Electric AV Mix1	33,900	118	250
A2.2		Electric AV Mix2	37,200	118	275
A2.3		Electric AV Mix3	34,600	118	255
A2.4		Electric AV Mix4	33,600	118	248
B1	0.9	Gasoline	36,800	116	276
B2.1		Electric AV Mix1	33,700	116	253
B2.2		Electric AV Mix2	36,900	116	277
B2.3		Electric AV Mix3	34,400	116	258
B2.4		Electric AV Mix4	33,500	116	251

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The additional electricity needed to support new EVs is supplied by renewable sources

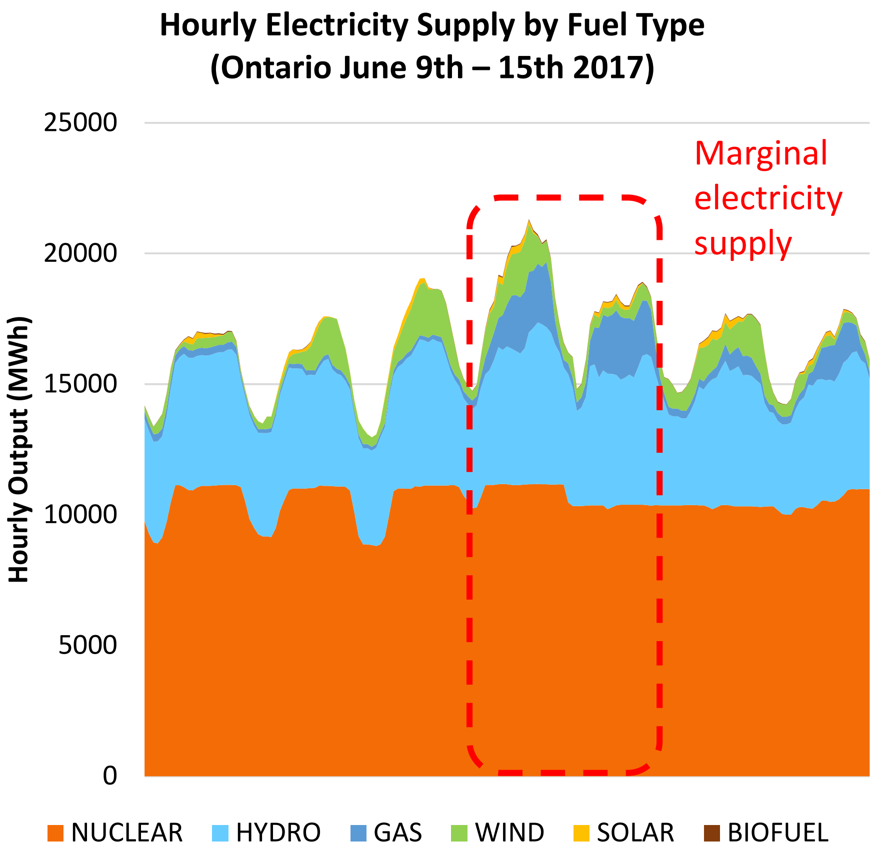
The additional electricity needed to support new EVs is supplied by Natural Gas

BUT EV CHARGING PATTERNS CAN AFFECT GHG EMISSIONS

Introducing Marginal Emission Factors (MEF) for electricity production

Marginal Emissions of Electricity Generation

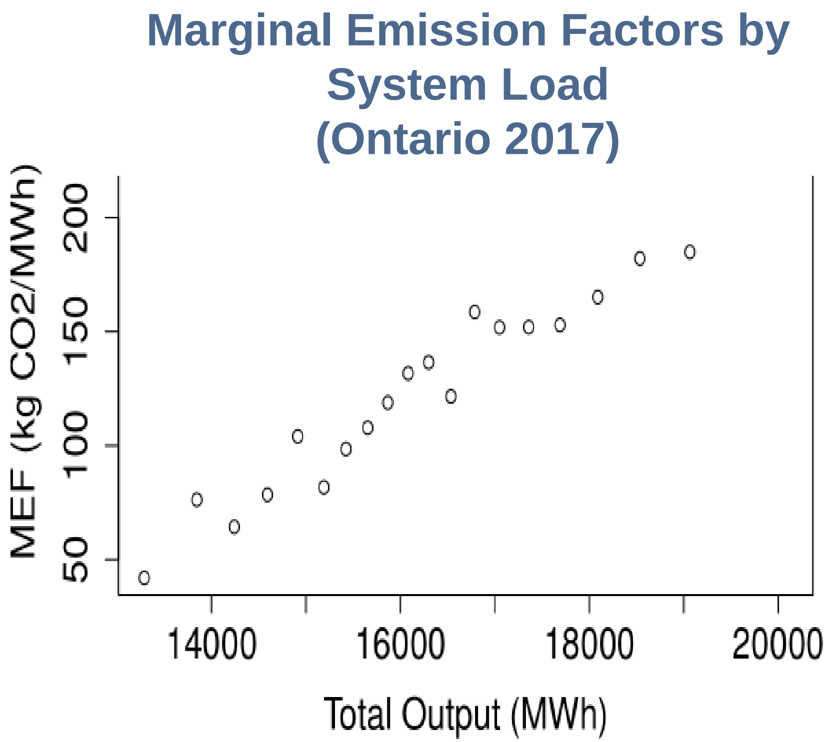
- To estimate GHG emissions due to EV charging:
  - Traditional approach: using average emission factors (**AEFs**)
  - New approach: using marginal emission factors (**MEFs**) that reflect the marginal electricity supply

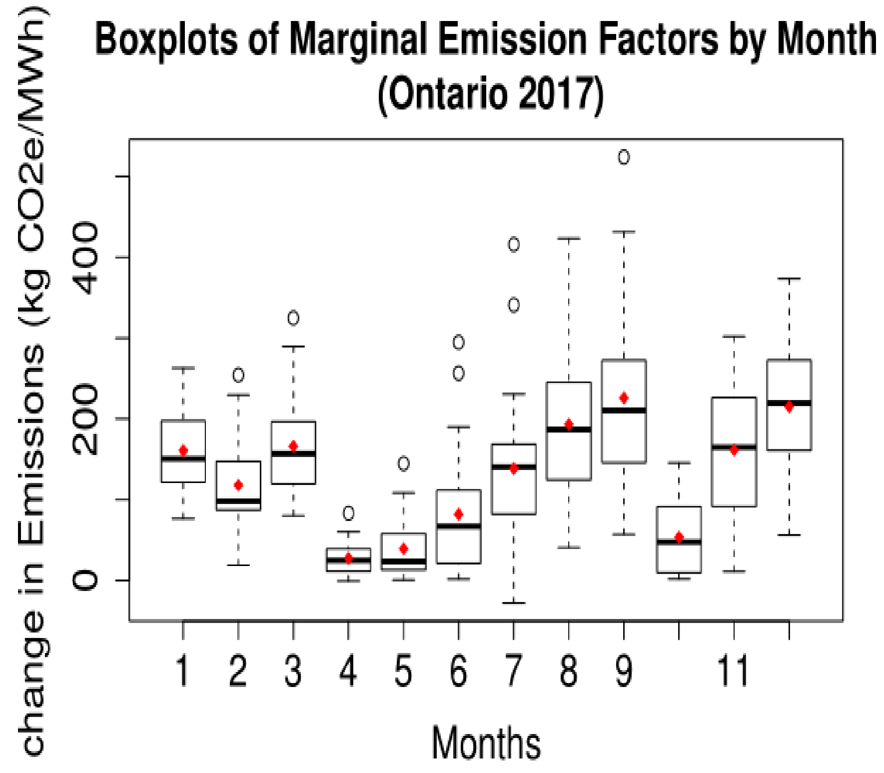


Marginal Emission Factors by system load and month

MEF

$$\Delta E = \beta_0 + \underbrace{(\beta_{0*} + \beta_{1*}G + \beta_{2*}\Delta G)}_{\text{MEF}} D_{Month} D_{\Delta G} \Delta G$$





Four charging scenarios

S1: Home Charging

- Charge once arrived home

S2: Work & Shopping Place Charging

- Charge at work place or shopping mall only

S3: Night Charging

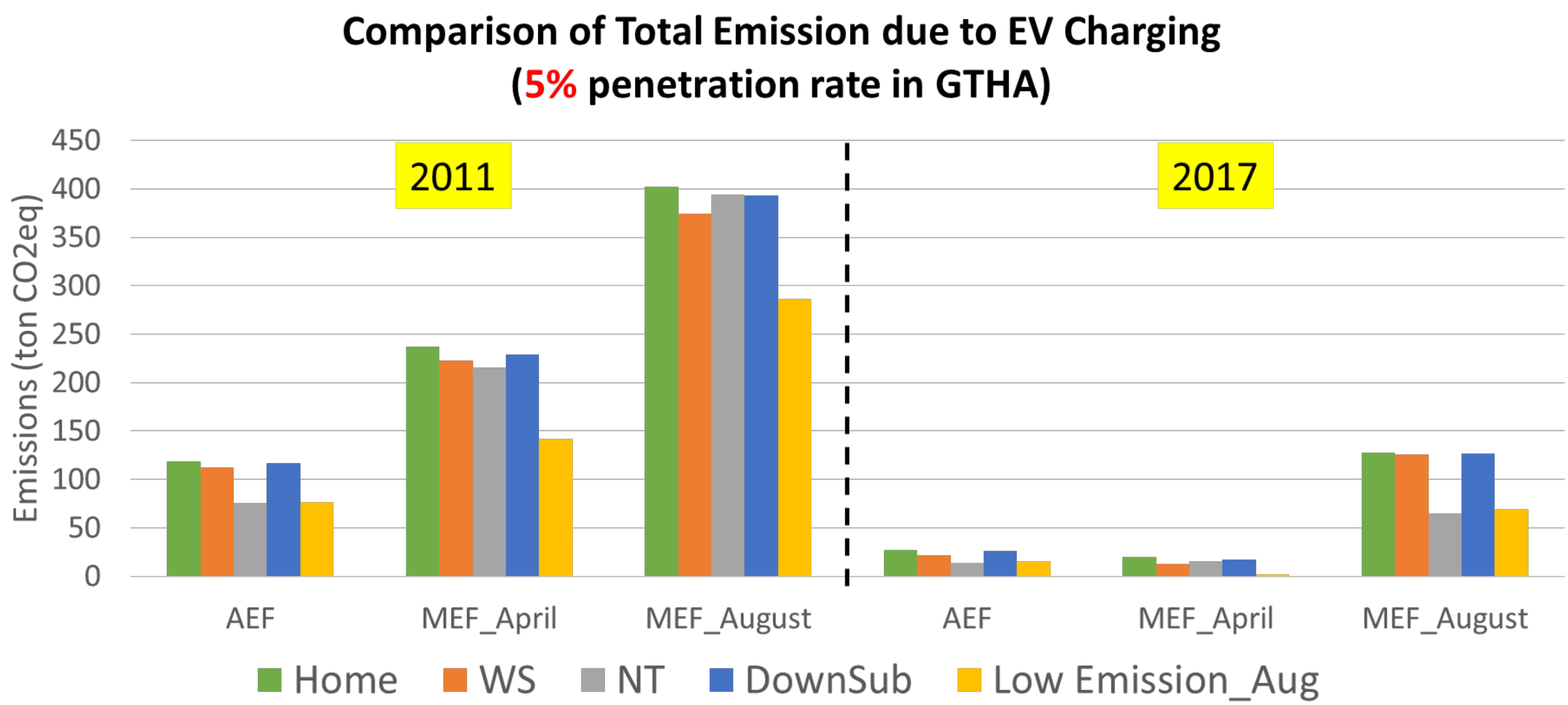
- Charge at 12am or later

S4: Downtown Vs. Suburb Charging

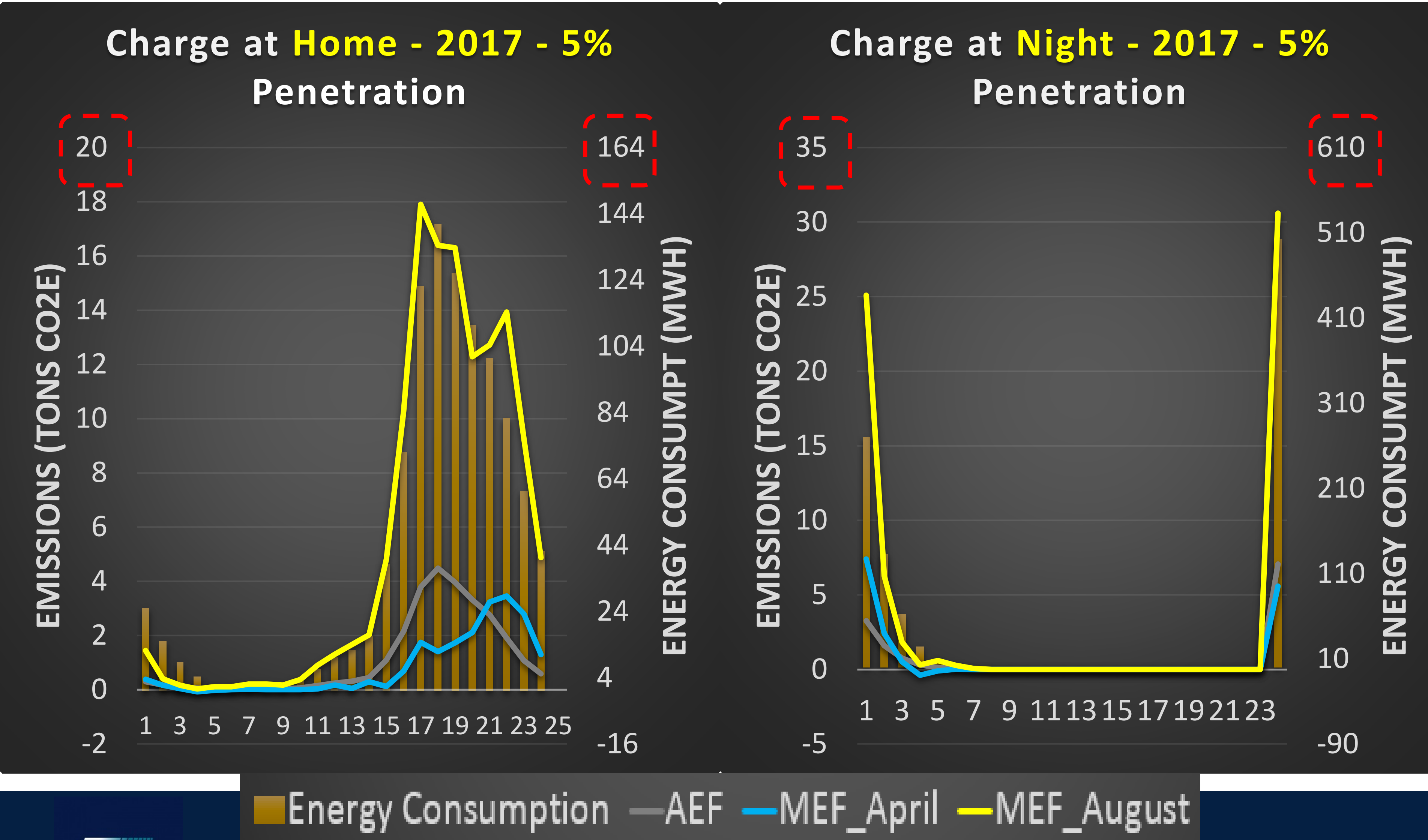
- Live in downtown charge at work place; Live in suburb charge at home

S5: Low Emission Charging

- Charge order based on the magnitude of hourly MEFs


Comparison of Total Emission due to EV Charging
(5% penetration rate in GTHA)
Emissions (ton CO2eq)
450
400
350
300
250
200
150
100
50
0
2011
2017
AEF
MEF_April
MEF_August
AEF
MEF_April
MEF_August
Home
WS
NT
DownSub
Low Emission_Aug

Hourly Emissions of EV Charging in GTHA



GTHA: Two tales

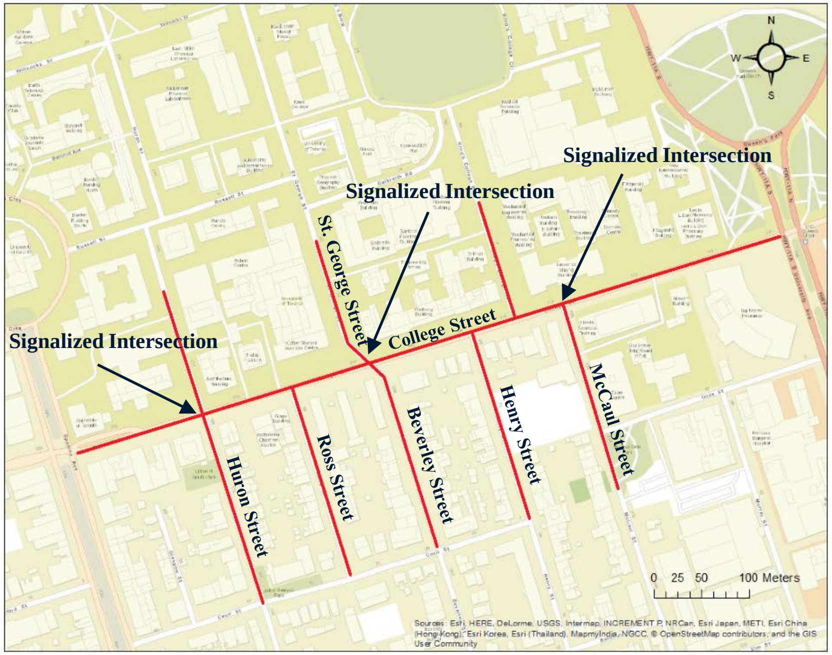
- Regional effects of automation and electrification

- Local effects of automation and electrification

Traffic Microsimulation

Gardiner Expressway

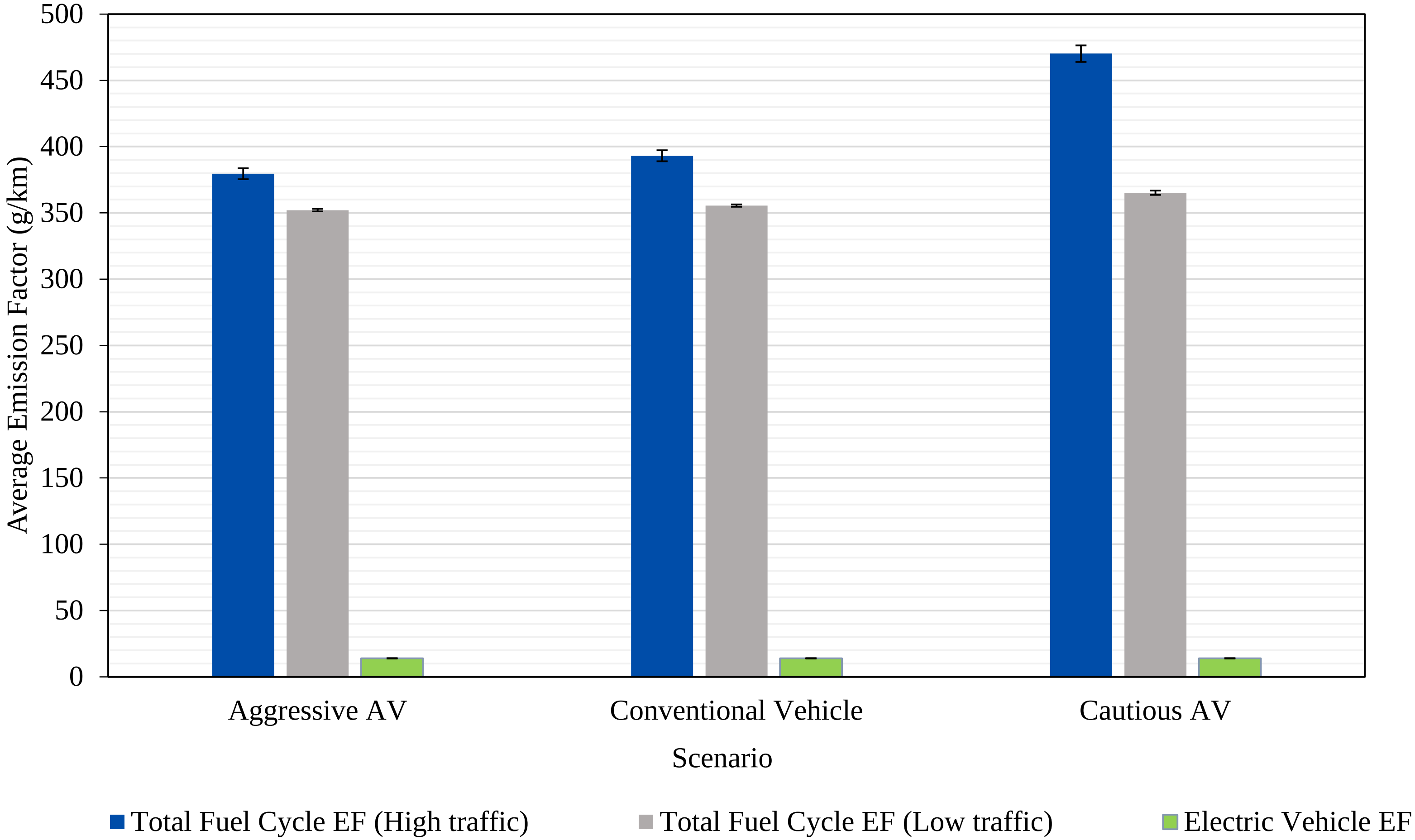
- Uninterrupted flow
- On/off-ramps
- Merging/diverging
- Lane drops



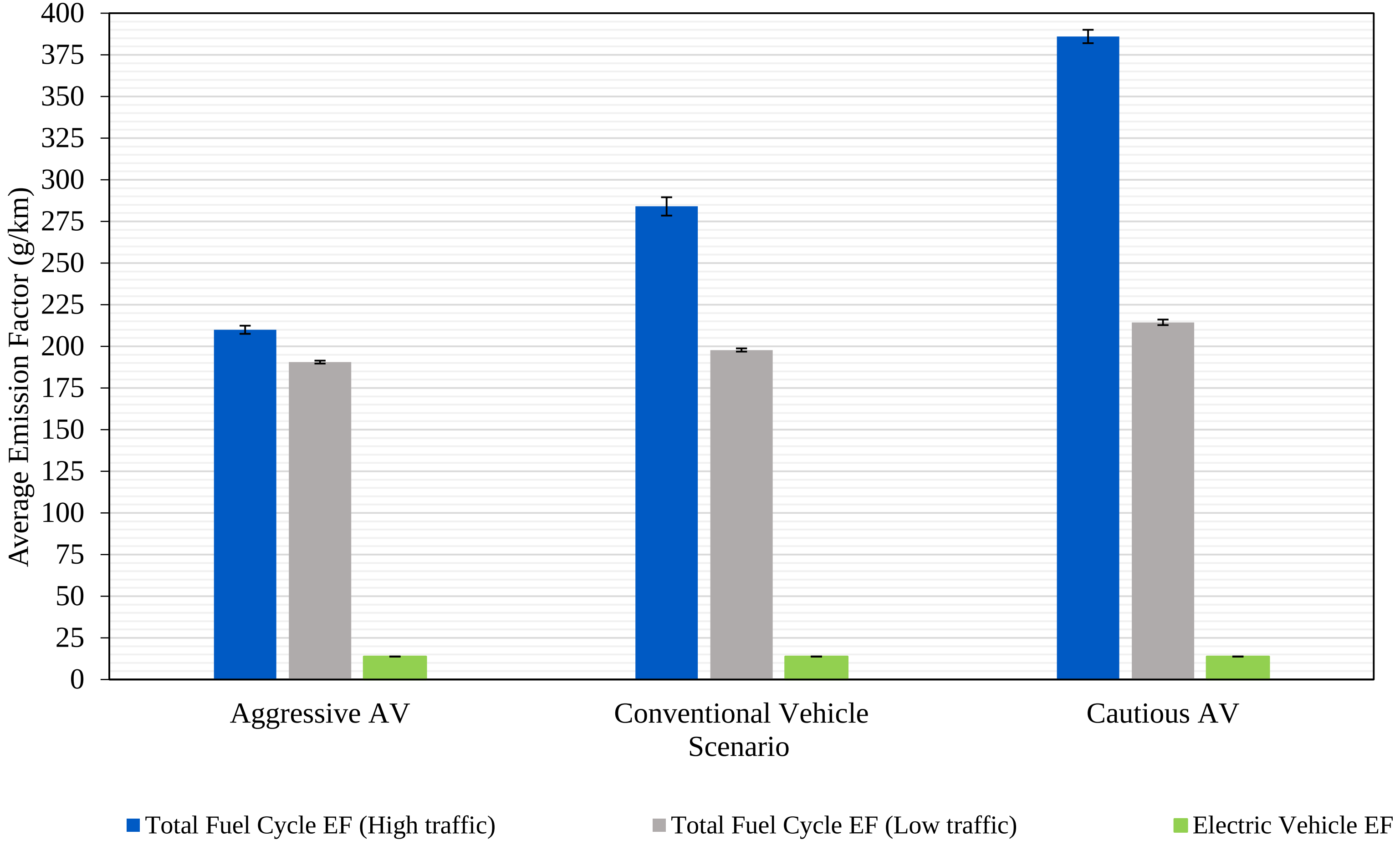
College Street

- Interrupted flow
- Signalized intersections
- Turning movements

College Street

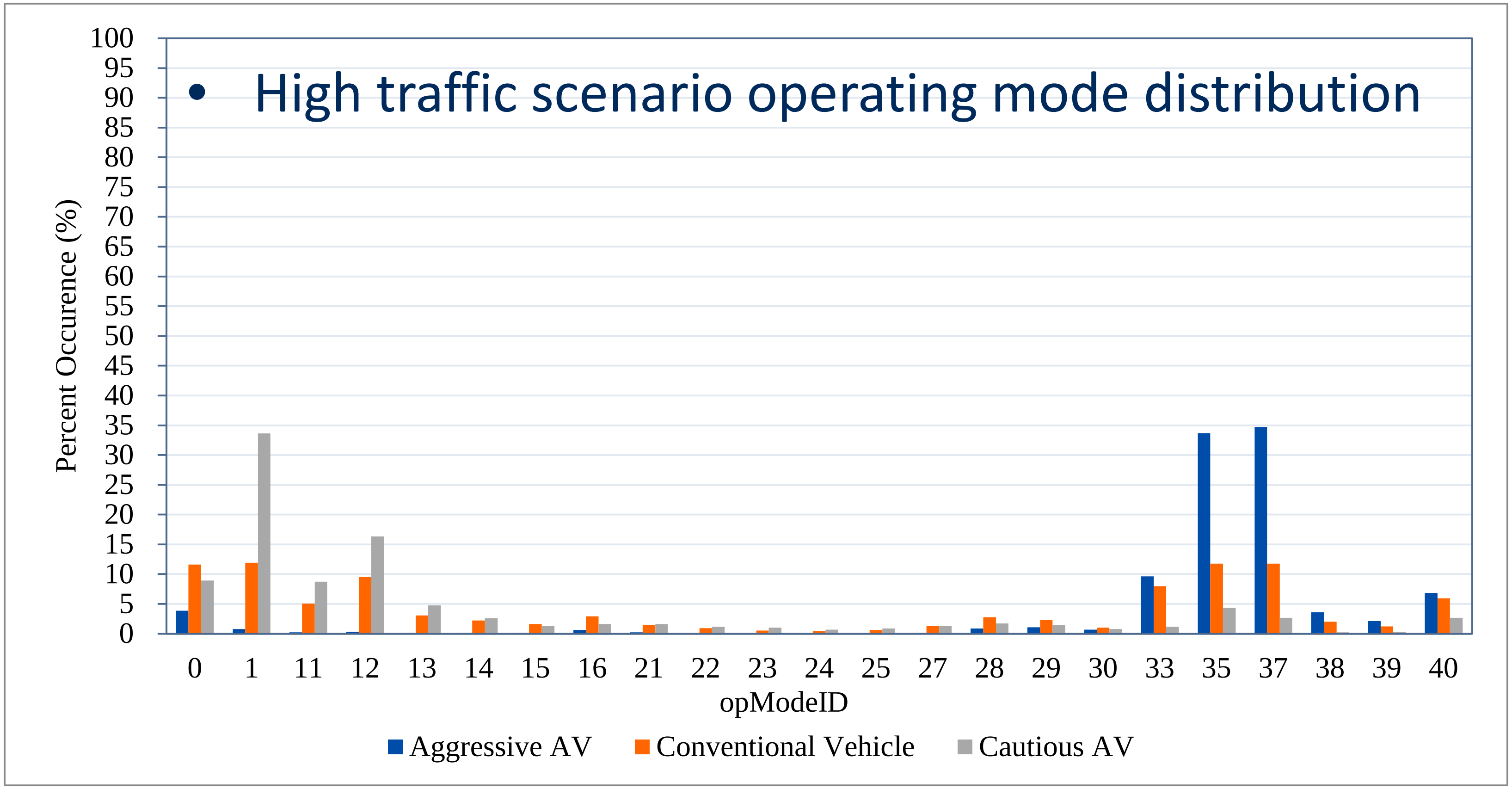


Gardiner Expressway



Gardiner Expressway

- High traffic scenario operating mode distribution



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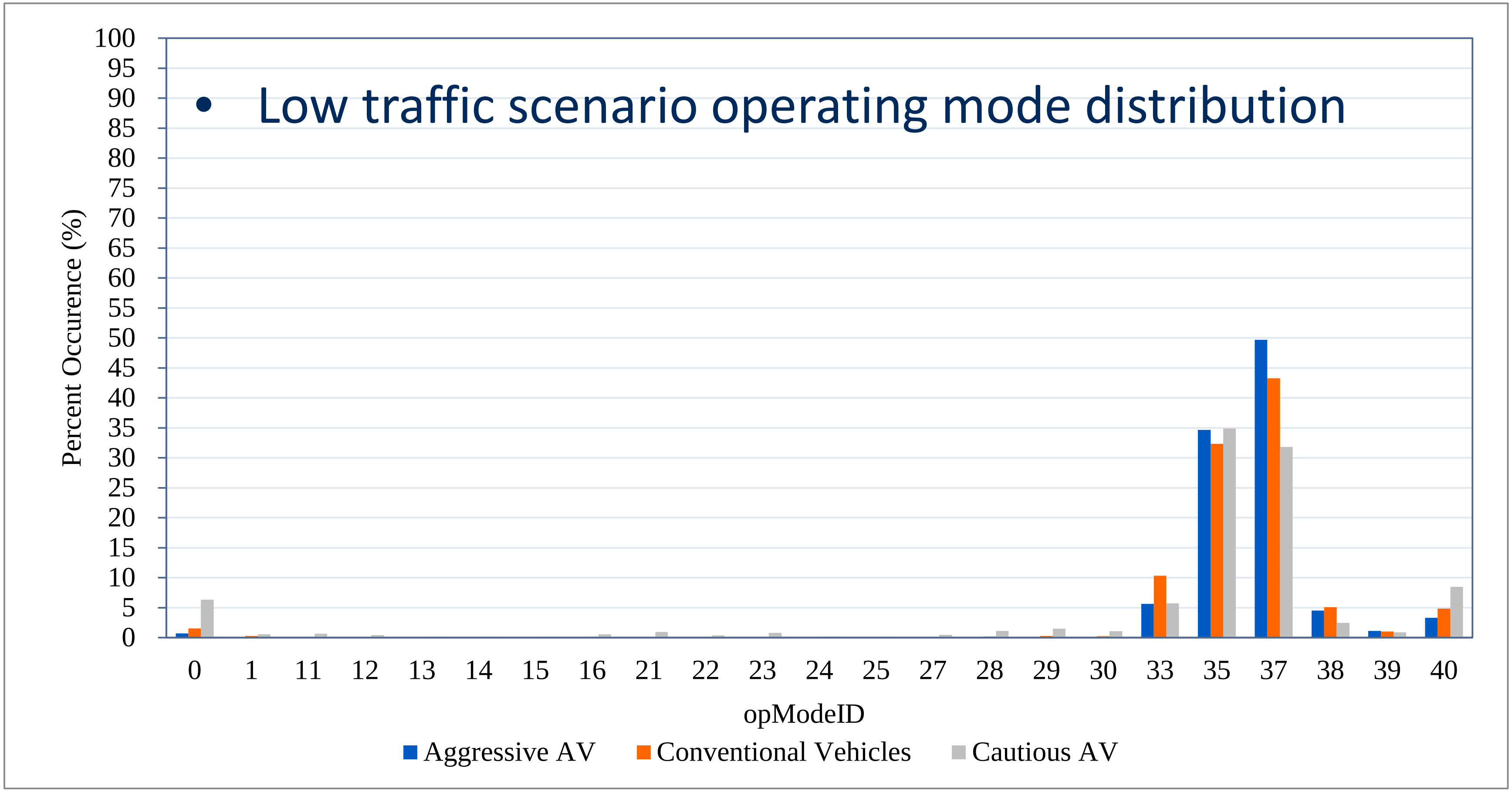
Scenario Analysis: Gardiner Expressway



Conclusion

- Automation can bring about positive benefits in terms of GHG emissions but only if the effect of "smoother" drive cycles is not offset by additional demand

- Electrification will bring the highest benefit in terms of GHG with or without automation

- Health effects are uncertain and the reason why we need tools that can represent these relationships!