JCCTRP

Joint Clean Climate Transport Research Partnership

Partenariat de recherche conjoint sur le climat et les transports

- *JCCTRP Webinar: Modeling Low-Carbon Urban Transportation in Toronto*
- *Webinaire JCCTRP : Modélisation du transport urban à faible émission de carbone à Toronto*

Development of the TRANUS Land-use and Transportation Integrated (LUTI) Model to Evaluate the Feasibility of California-style Regional Climate Plan Targets for the Greater Toronto Metropolitan Region

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Special Thanks to Tomás de la Barra

ESG UQÀM

UNIVERSITY OF TORONTO | Engineering

JCCTRP Webinar, 11 February 2021

Website: www.jcctrp.org

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Outline of Presentation

- **Introduction**
- **Research Question**
  - What changes to the transportation system of the Toronto metropolitan region would be necessary to reduce greenhouse gas (GHG) emissions per vehicle mile traveled below a targeted level, as is currently required in California?
- **Background on California metropolitan regional climate policy**
- **Background on Toronto regional climate policy**
- **Overview of the TRANUS model**
  - Land-use model components
  - Transport model components
- **Modeling Challenges**
  - Calibration challenge
  - Application of the model for GHG emission modeling
- **Conclusion and Next Steps**

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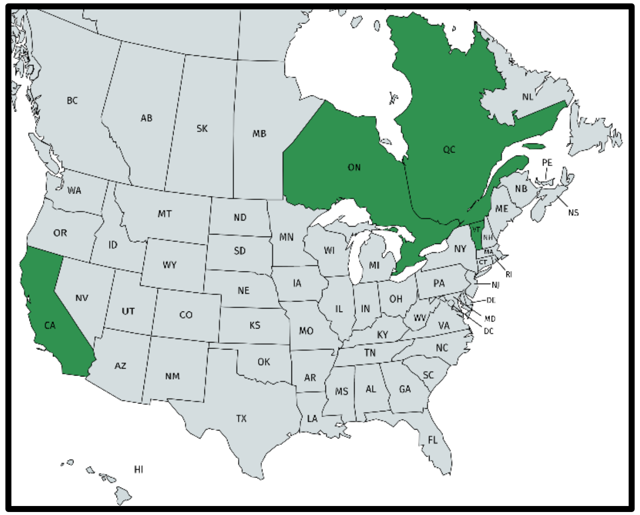
- **Goal**
  - To identify technical, economic and political factors shaping the potential for environmentally effective, economically efficient, and politically viable low-carbon transport and climate mitigation policy. The JCCTRP is addressing this goal by bringing together modeling and policy researchers in various jurisdictions into engagement with decision-makers.



- **Partner organizations**
  - Leading universities, private research institutions, businesses and non-profit organizations
  - **Quebec**, **California**, **Ontario** and **Vermont**
  - Includes jurisdictions of the WCI, RGGI and TCI
- **Funding**
  - Recipient of a Partnership Development Grant from the Canadian Social Sciences and Humanities Research Council (SSHRC)

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Working Groups

1) **Carbon Pricing and Policy Sequencing**
   - Modeling Policy Sequencing: carbon pricing, ZEV Mandates, LCFS, VES
   - Ontario and Quebec
   - Economic Advantages of Linking State/Provincial Carbon Markets
2) **Urban Transit**
   - California Sustainable Communities and Climate Protection Act
   - Model Regional Plan Climate Targets for California in Toronto using TRANUS transport and land-use change model
3) **Transport-Energy Nexus**
   - Modeling the impact of electric vehicle penetration on energy demand in Quebec using UVermont transport-energy model
4) **Low-Carbon Fuel Standard (LCFS)**
   - LCFS comparison of California, Canada, BC, including modeling differences
5) **Comparative Policy**
   - Investigating role of modeling urban transport through comparison of Montreal, Toronto and Los Angeles

Policy Issues

Regional Transport Planning in California (before climate policy)

- **Metropolitan Planning Organizations (MPOs)**
  - Since 1962, large US metropolitan areas must create an MPO to facilitate a "continuing, comprehensive, and cooperative" transportation planning process in order to obtain federal transportation funds
- **Regional Transportation Plans (RTPs)**
  - MPOs fulfill its mandate by creating regional transportation plans (RTPs) every five years which define transportation investments over the next twenty years
- **Important Role for Transport System Modeling**
  - Bulk of day-to-day operations of MPOs involves assessing the impact of planned investments for the RTP using transportation forecasting models

Giuliano G, Kim S-O and Mallet Z (2020) *Regional Planning and Climate Change Mitigation in California*, Joint Clean Climate Transport Research Partnership (JCCTRP), Montreal.

California Sustainable Communities and Climate Protection Act (2008)

- **Requires that MPOs adopt "Regional Plan Climate Targets"**
  - Expressed as a percent change in per capita passenger vehicle GHG emissions relative to 2005
  - In practice, these focus on reductions in vehicle miles traveled (VMT)
    - 18 MPOs currently plan for a 9.6% reduction by 2020 relative to 2005 levels of per capita passenger vehicle GHG emissions on average and an 18% reduction by 2035
- **Also requires that a Sustainable Communities Strategy (SCS) be incorporated into the RTP**
  - A land use element that accommodates forecasted population growth
  - A transportation network to meet all regional needs
  - Transportation forecasting models have become critical to the demonstration of RTP compliance with federal and state air pollution and GHG reduction requirements.
  - CARB determines SCS compliance

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Metropolitan Region	Sacramento	San Diego	San Francisco	Los Angeles
MPO	Sacramento Area Council of Governments (SACOG)	San Diego Association of Governments (SANDAG)	San Francisco Bay Area Metropolitan Transportation Commission (MTC)	Southern California Association of Governments (SCAG)
Regional Population (Approx, 2010)	2,323,000	3,095,000	7,375,000	18,075,000
Regional Land Area	6,193 sq. mi.	4,230 sq. mi.	7,000 sq. mi.	38,000 sq. mi.
No of Counties in Region	6	1	9	6
No. of Cities in Region	22	7	101	191
Size of RTP-SCS (latest)	2016 MTP-SCS ($35 billion)	San Diego Forward 2050 ($204 billion)	Plan Bay Area 2040 ($303 billion)	2016 RTP-SCS ($556.5 billion)
CARB Approved GHG Emission Reduction Target	2020 : 7% 2035 : 19%	2020 : 15% 2035 : 19%	2020 : 10% 2035 : 19%	2020 : 8% 2035 : 19%

Four Largest MPOs in California and their Regional Climate Plan Targets

Giuliano G, Kim S-O and Mallet Z (2020) *Regional Planning and Climate Change Mitigation in California*, Joint Clean Climate Transport Research Partnership (JCCTRP), Montreal.

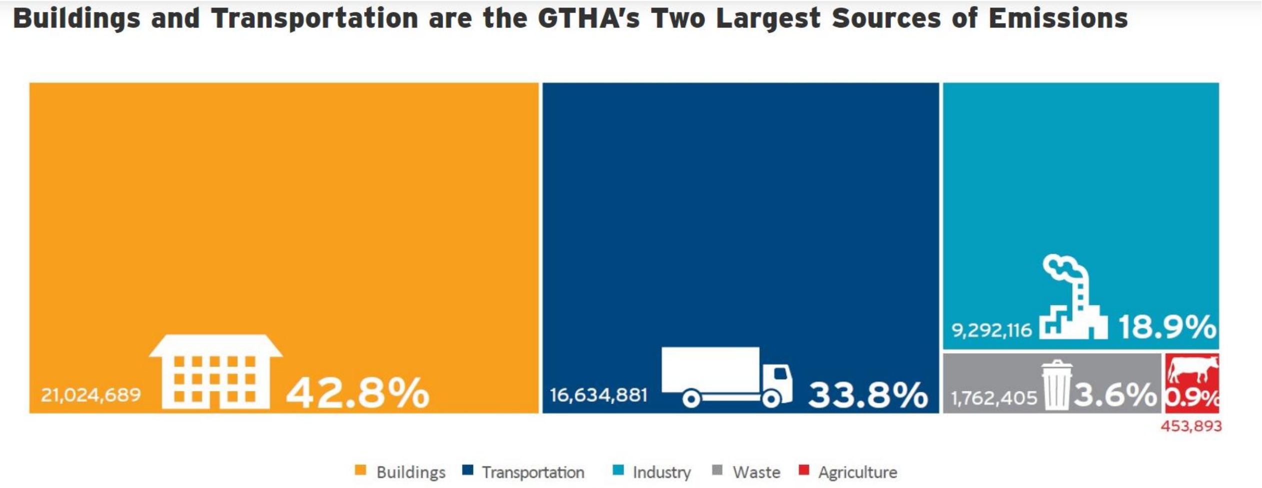
Ontario Climate Policy

- **A Made-in-Ontario Environment Plan**
  - Presented in November 2018
  - Relaxed 2030 target
    - 21% reduction the province's GHG emissions relative to 1990 by 2030
    - Significant rolling back of relative to the previous government target, which was a 37% reduction by 2030 relative to a 1990 baseline
  - Repealed cap-and-trade and replaced with regulatory framework for industrial emitters
  - No links to modelling or other substantiation to support the claimed reductions

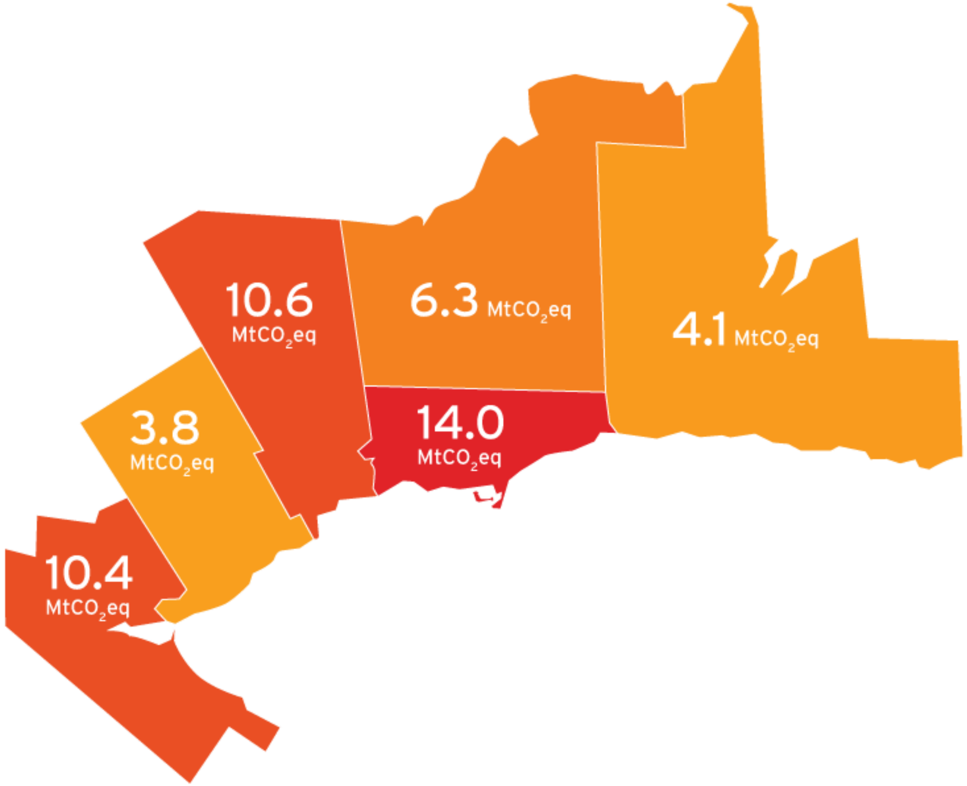
https://marksw.blog.yorku.ca/2018/12/03/the-ontario-climate-change-plan-an-assessment/

Toronto Metropolitan Region Climate Policy

- **Greater Toronto and Hamilton Area**
  - 49.2 MtCO2e in 2017
  - 41% of Ontario's carbon emissions
  - Emissions fell 3.3% between 2015-2016, then remained flat between 2016-2017



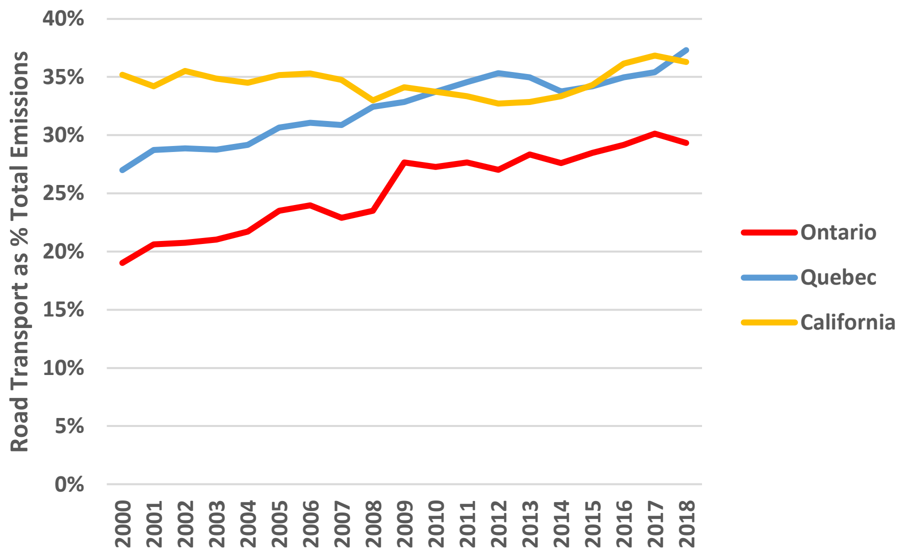
Carbon emissions by sector in 2017, in tonnes of carbon dioxide equivalents



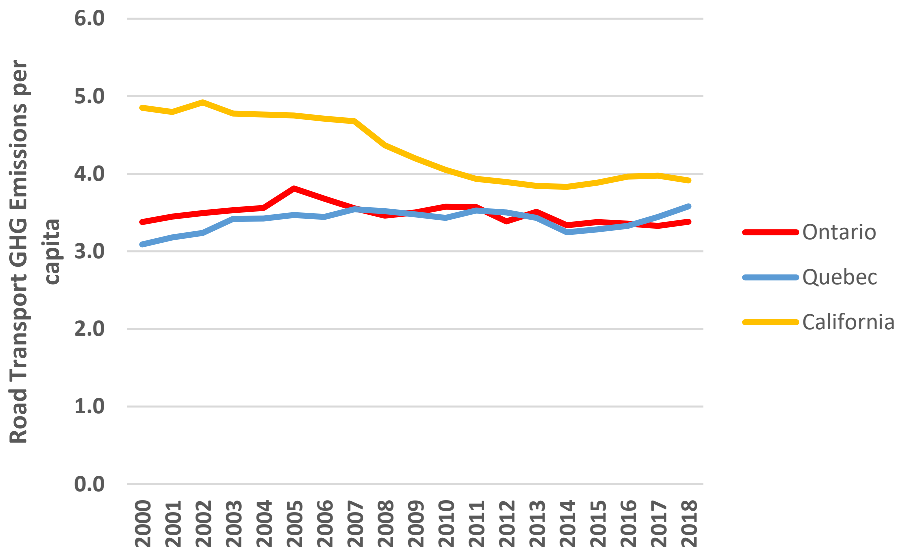
https://taf.ca/gtha-carbon-emissions/

Comparing Transportation Emissions in California, Ontario and Quebec

Road Transport as % Total GHG Emissions



Road Transport GHG Emissions per Capita



Background on TRANUS Model

Study Area

- Transportation Aspects
  - Road transportation account for 29.3% of the GHG area emissions produced in Ontario 13% Transit ridership (TTS 2016)
  - 86% of households own private vehicles (TTS 2016)
  - On average, each household has 2.6 persons and makes 5.3 trips/day (TTS 2016)
  - 0.74 daily worker trips / worker (TTS 2016)

Study Area

- Characteristics
  - 65% of residential land is zoned for single-family residential. (TTS 2016)
  - The GGH has a large central city (Toronto), representing about 37.2% of the total population
  - Residential land use account for 13.2% of the GHG area emissions produced in Ontario
  - High transit ridership in North America and relatively high population density (12 transit agencies and 1 inter regional transit system)

Path to LUTI Modeling (USA case)

Federal-Aid Highway Act of 1962

- Goal: Accessibility
- Result: Traffic Growth & Residential land and firms dislocation -> Environmental degradation, Social equity

3C Planning progress

- Goal: Continuing, Comprehensive, Cooperative planning process
- Result: Continuing independent development plans.

LUTI Modeling

Addressing:

- Interdependence
- Multi-objective modeling
- Dynamic
- Comprehensive goal based boundaries
- Supply / Demand / Pricing models all together

Similar Approaches

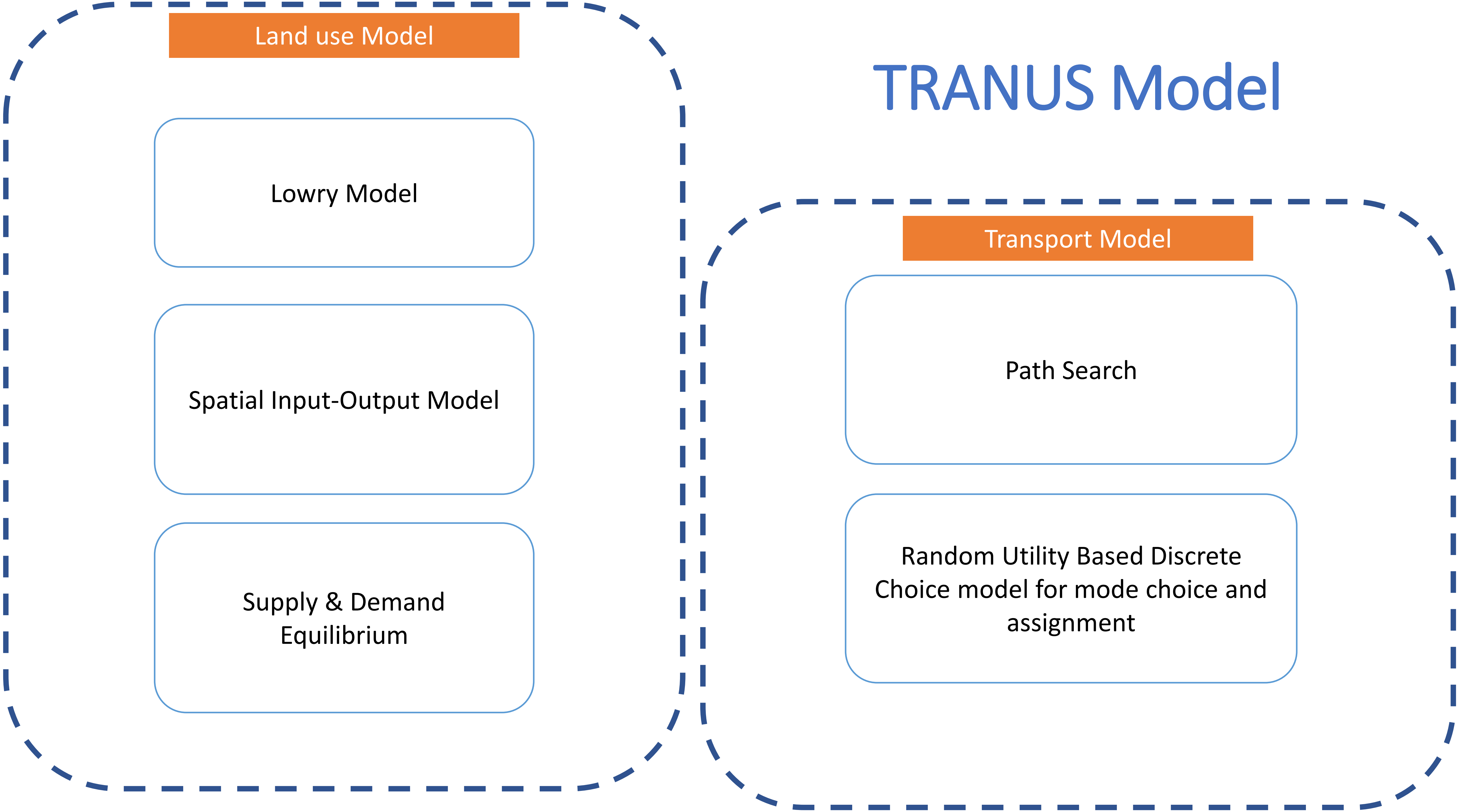
- Most work centered in Europe
  - Ruhrgebiet model in Germany
  - Tyndall Centre model in UK
  - LUMAS in Netherlands

- New Zealand's Wellington Integrated Land Use-Transport-Environment Model (WILUTE)

- ABAG in San Francisco uses UrbanSim

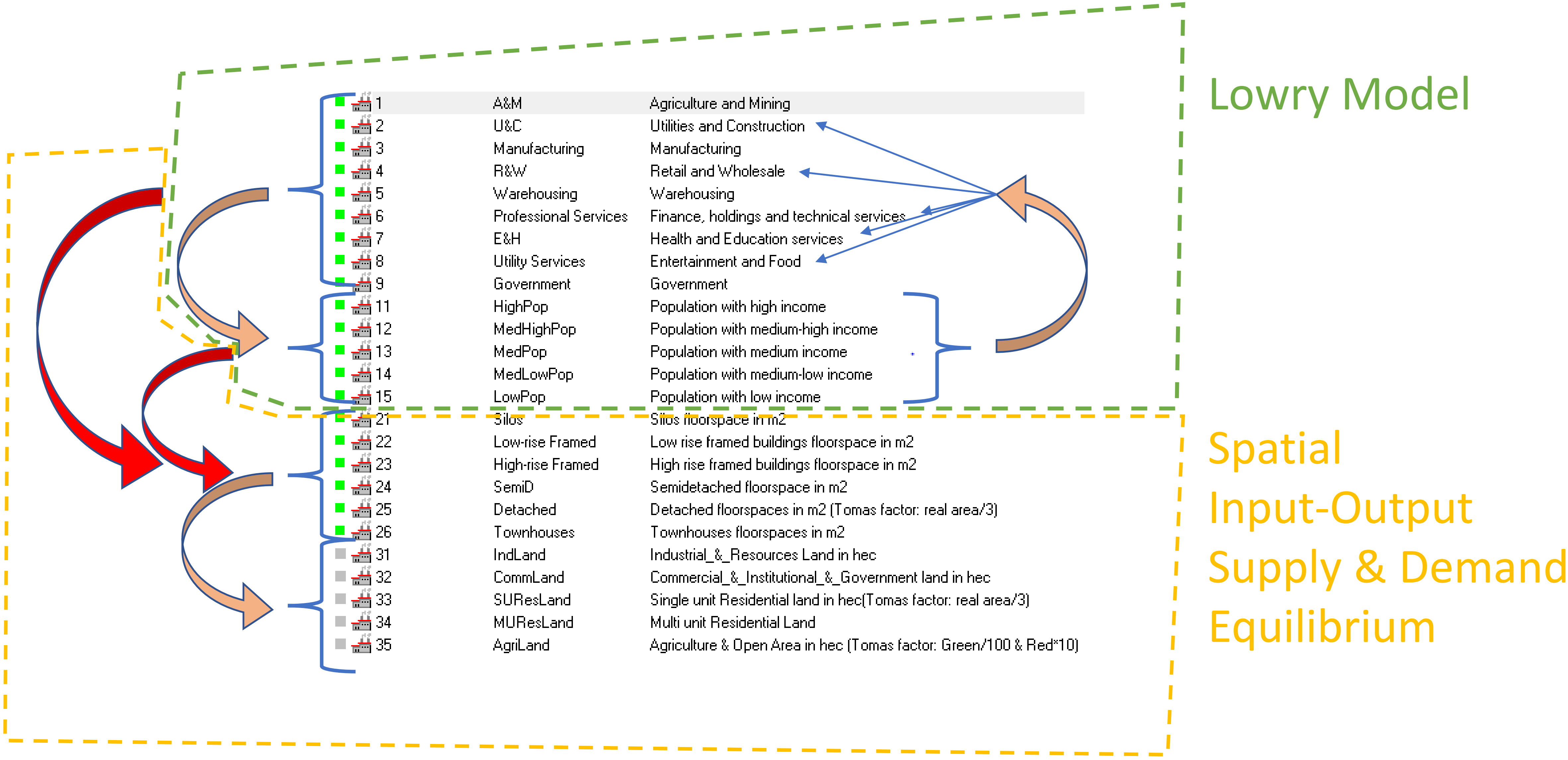
- Sacramento, Southern California, and San Diego Metropolitan Planning Organizations have versions of a PECAS model

Toronto’s TRANUS Model


TRANUS Model
Land use Model
Lowry Model
Spatial Input-Output Model
Supply & Demand Equilibrium
Transport Model
Path Search
Random Utility Based Discrete Choice model for mode choice and assignment

Land Use Sectors

Arrow ≡ Consumes



Lowry Model

Attractor Factor

Elasticity

Disutility of product of sector n demanded by zone i located in zone j

$$\Pr_{ij}^{n} = \frac{(A_j^n)^{\alpha^n} \cdot \exp\left(-\beta^n \widetilde{U}_{ij}^n\right)}{\sum_j (A_j^n)^{\alpha^n} \cdot \exp\left(-\beta^n \widetilde{U}_{ij}^n\right)}$$

P(production of sector n demanded by zone i and located in zone j)

Two elements make the disutility function: price and transport disutility. The price scale weights the price element within the disutility function.

A logit scale parameter sets the degree of scaling of utilities in the logit model. Must be a value from zero to one (recommended value = 1).

The attractor factor is an exponent applied to the attractor function of the sector in the distribution logit model (default=1).

Elasticity is the distribution parameter that multiplies the disutility function of the logit or powit model. Non-transportable sectors are defined by setting a value of zero to the distribution parameter. This also applies to fully exogenous sectors, whose production is not consumed in the study area.

Price Factor

$$U_{ij}^{n} = \lambda^{n}\left(p_j^n + h_j^n\right) + t_{ij}^n, \qquad (15)$$

$$\widetilde{U}_{ij}^{n} = \frac{U_{ij}^n}{\left(\min_j U_{ij}^n\right)^{\theta^n}} \qquad (16)$$

Logit Scaling

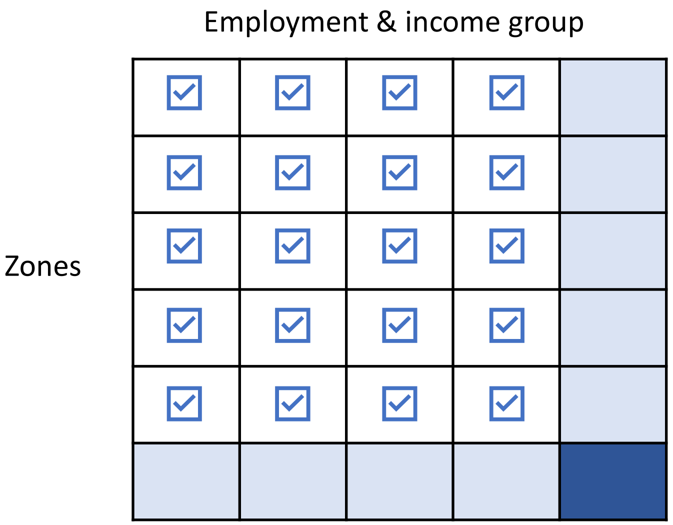
Lowry Model in Simple Words

- External sectors consumes population (Example: agriculture employment opportunities attract a family of three in that zone)
- Population induce internal sectors (Example: household members need health care which induce internal health employments)
- Internal sectors consume population (Health care employments will attract new population)
- …

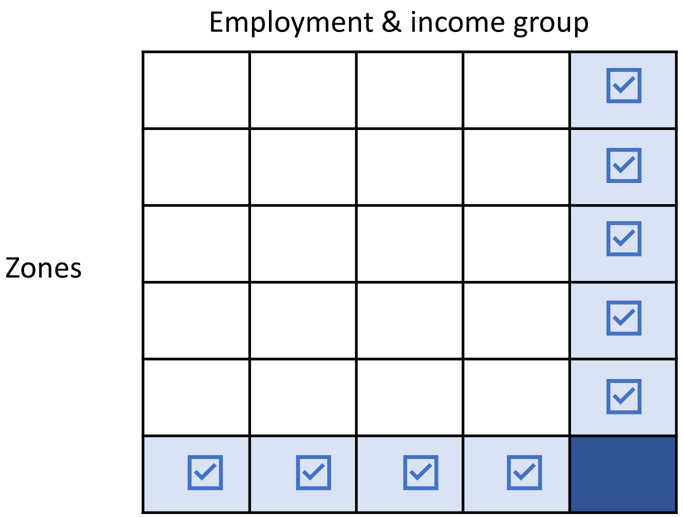
Toronto’s Lowry Model

- Info Canada 2011 (to know employment distributions in the region)
- Validation with Stats Canada’s 2011 Census for aggregate data

Info Canada



Stats Canada



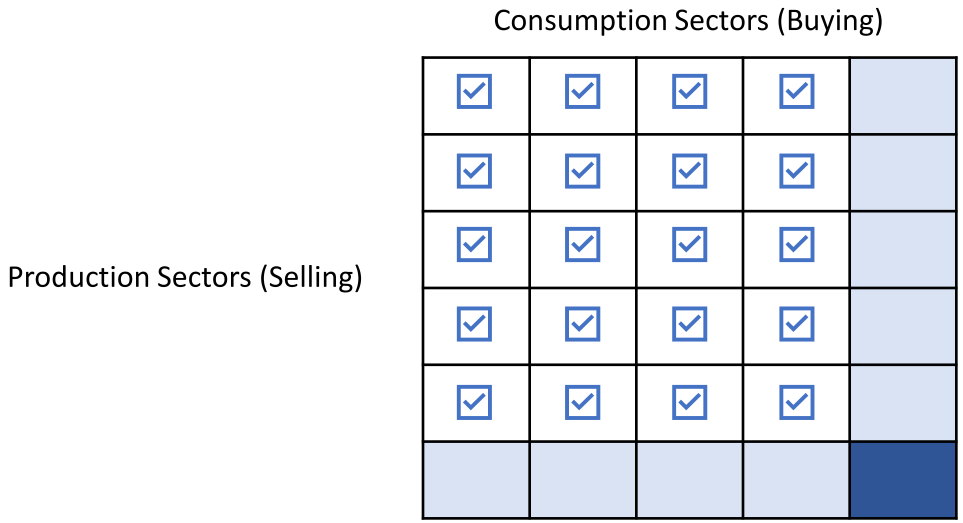
Land Sectors

- Same procedure applies to land sectors with the following constraint:
- Min production = Production = Max production
- All the flexibility go to land price
- Data Source: TREB 2011

The Input-Output Model

- Lowry gives us a balance inside each zone for economy sectors and population sectors

- How about the equilibrium the sectors across zones? how the interactions between sectors are simulated?



- Stats Canada’s 2011 Census

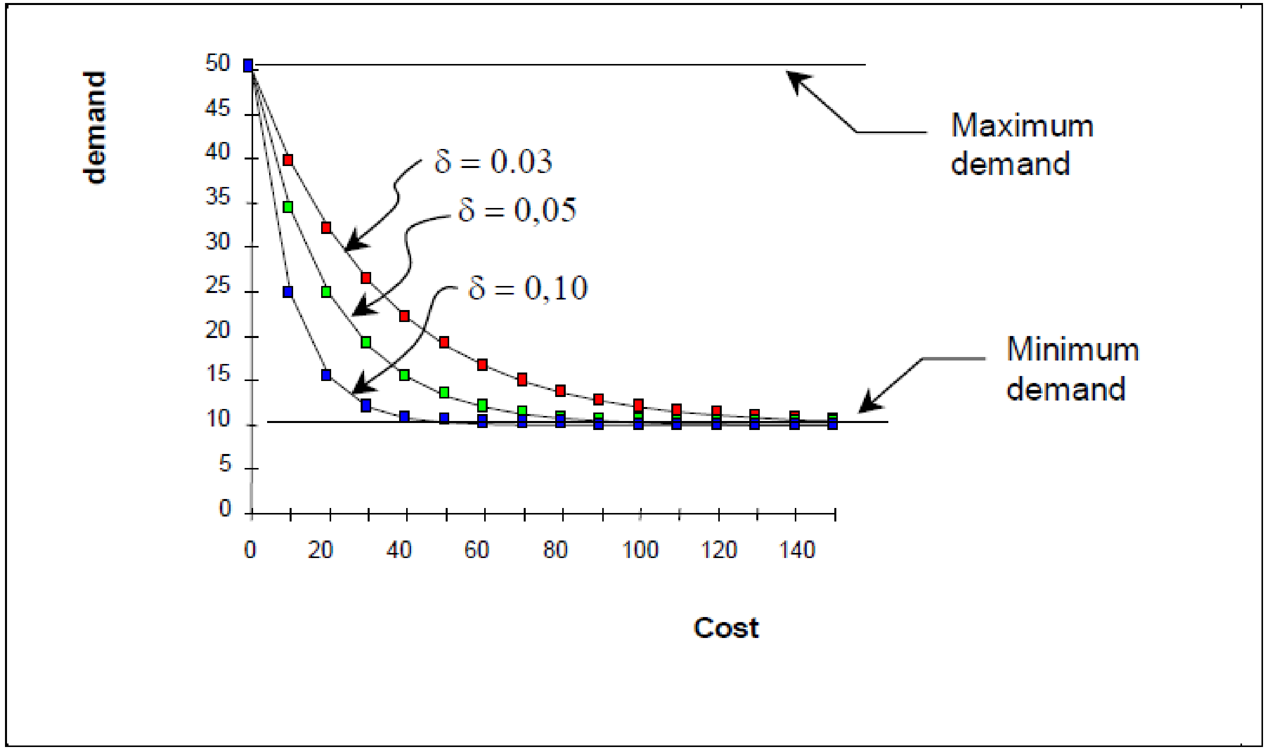
The challenge of Input-Output model

- Input-Output is an aggregate urban economics model which gives total input and outputs by sectors for the GGH.

- However, the Input-Output model does not produce transport flows, so TRANUS divides it into separate production and consumption equilibriums for each zone.

Supply & Demand Equilibrium

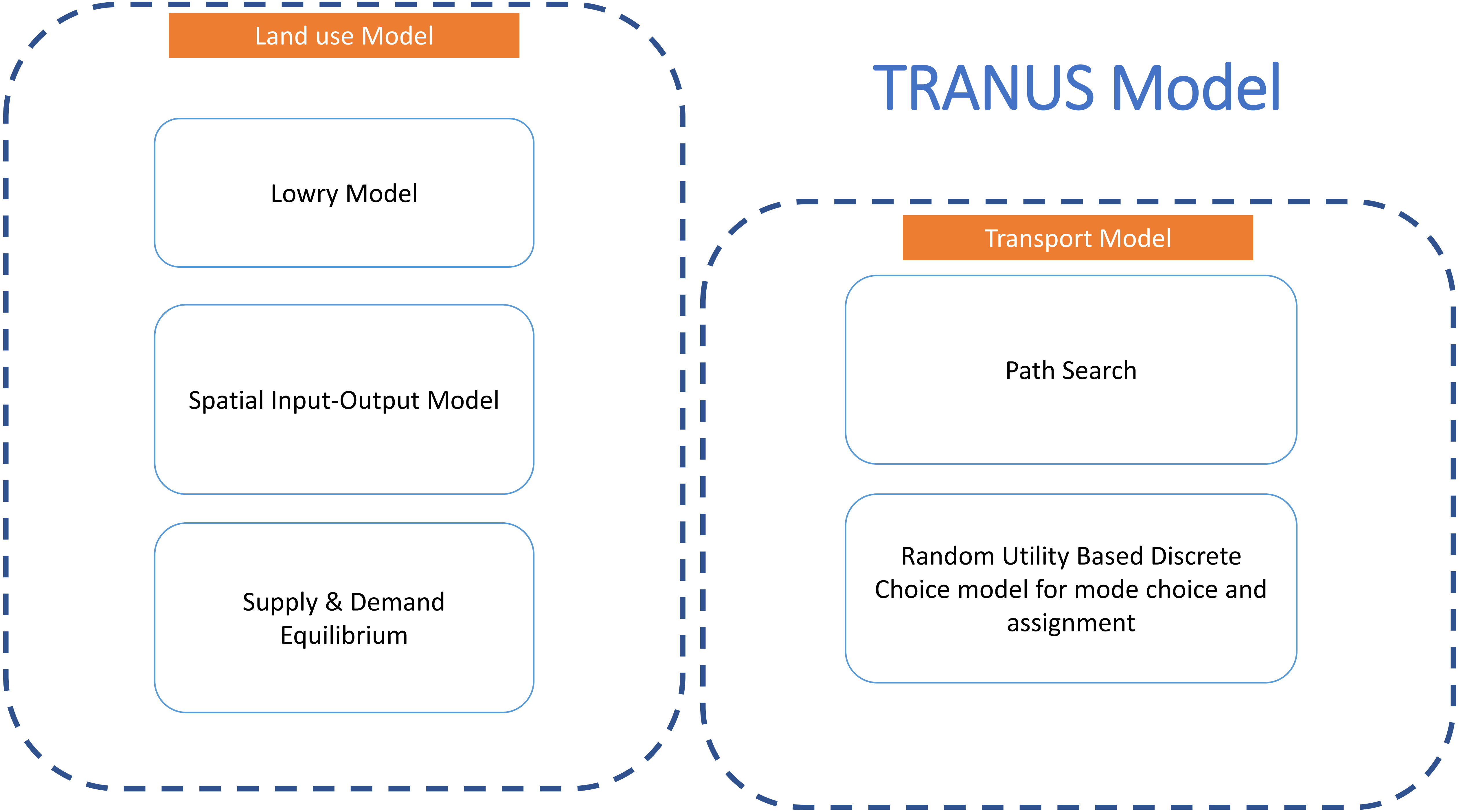
$$a_i^{mn} = \min^{mn} + \left(\max^{mn} - \min^{mn}\right) \cdot \exp\left(-\delta^{mn} U_i^n\right),$$



Land Use Calibration

- Equilibrium between consumption and production between each zone.

- Pairwise equilibrium among 105 zones * 30 interactions


TRANUS Model
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Activities to transportation demand

Endogenous sectors in land use model	Transport categories in transport model
High income population	work based trips income 1
Medium-high income population	work based trips income 2
Medium income population	work based trips income 3
Medium-low income population	work based trips income 4
Low income population	work based trips income 5

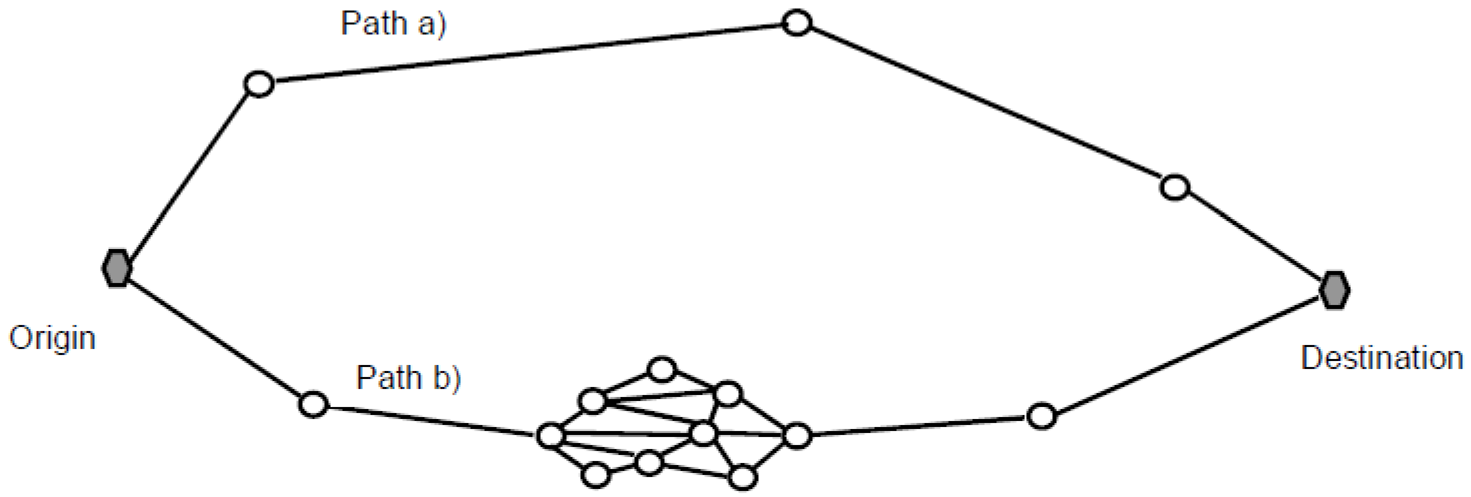
Endogenous sectors in land use model	Transport categories in transport model
Utilities and Construction	Trips to Services
Retail and Wholesale	
Finance, holdings and technical services	
Health and Education services	Trips to Health or Education Centers
Entertainment and Food and Shopping	Trips for entertainment and shopping

Path building

$$c_{ijp}^{ks} = \sum_{m=1}^{z} RT_m^s + RD_m^s + TR_{m-1,m}^s ,$$

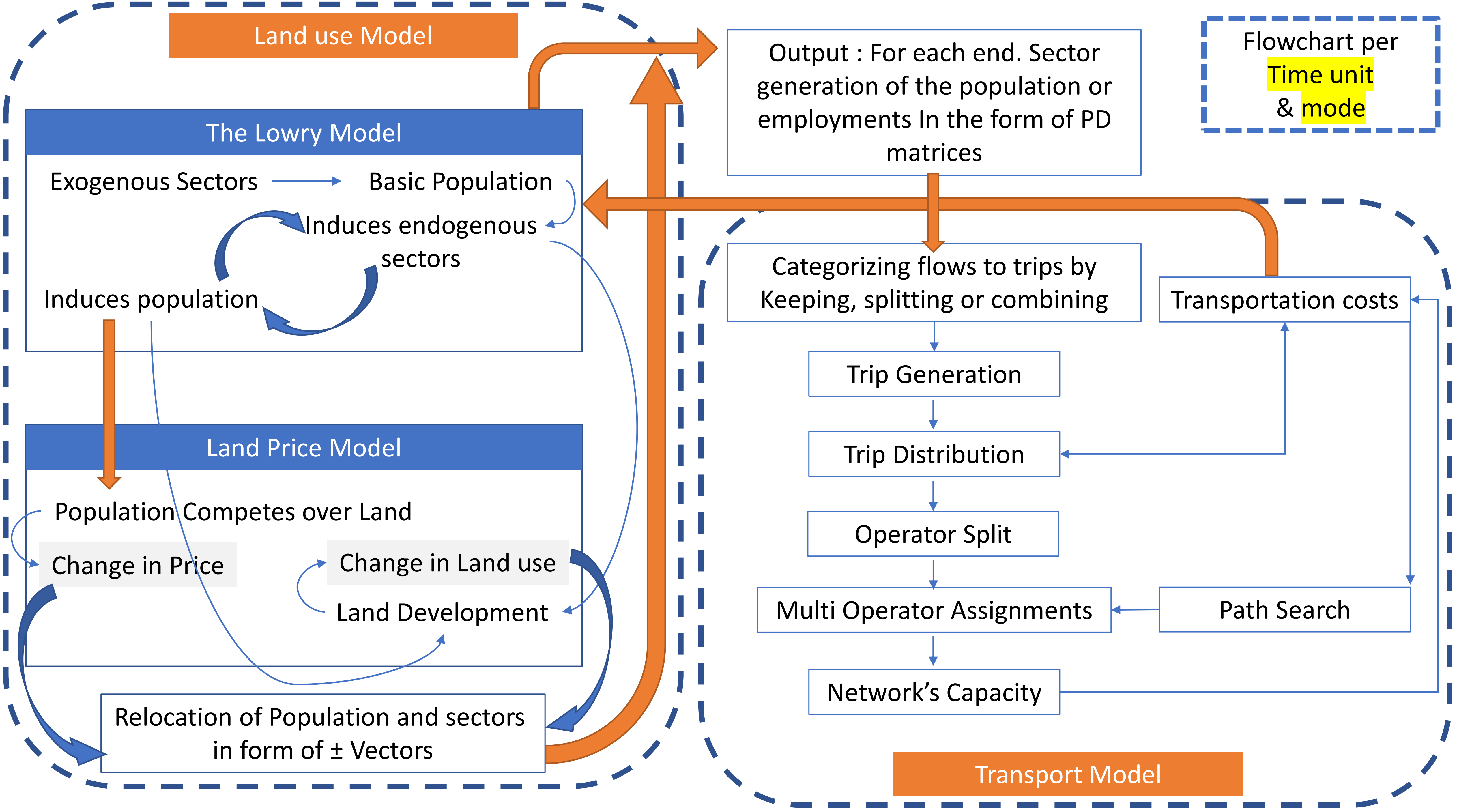
- K-shortest path
- Overlapping factor

$$P_{ijp}^{ks} = \frac{\exp\left(-\gamma^s \tilde{c}_{ijp}^{ks}\right)}{\sum_p \exp\left(-\gamma^s \tilde{c}_{ijp}^{ks}\right)} ,$$

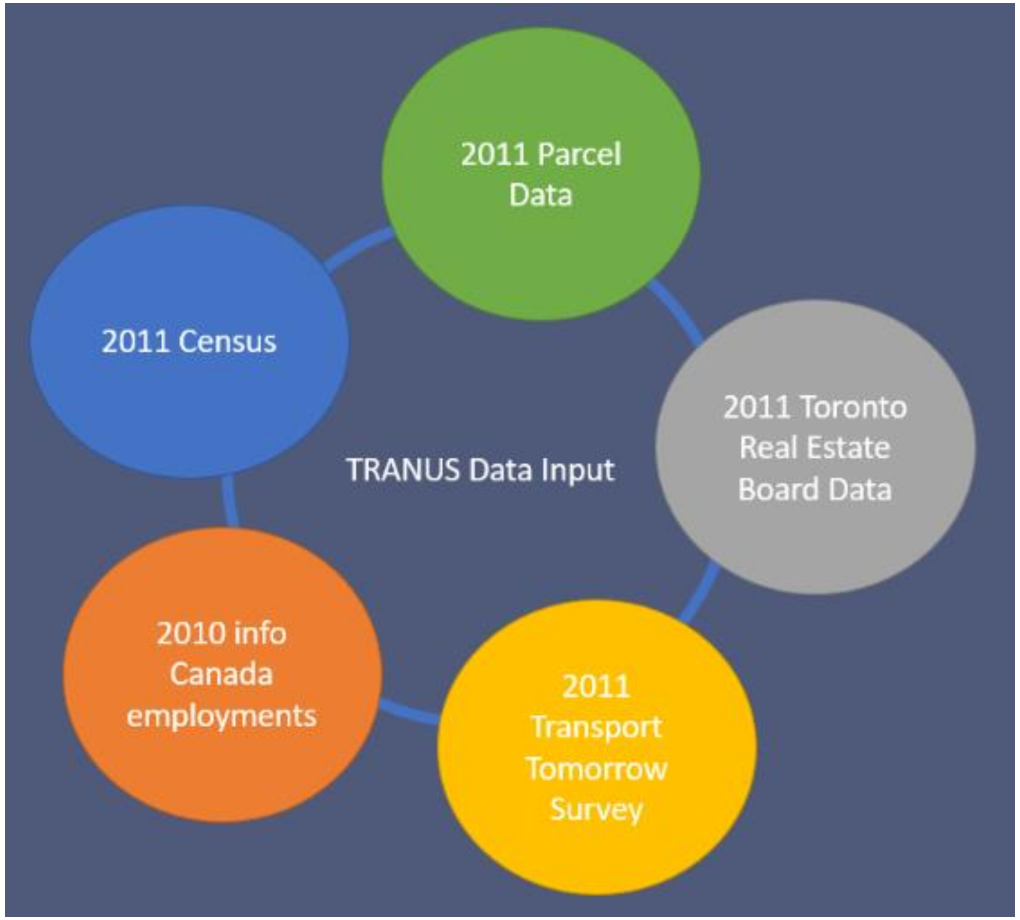


Preparing Transport Characteristics

- Defining modes
- Defining operators
- Defining Transfers and transport costs and Tariffs
- Defining Link types and right of way


Land use Model
The Lowry Model
Exogenous Sectors
Basic Population
Induces endogenous sectors
Induces population
Land Price Model
Population Competes over Land
Change in Price
Change in Land use
Land Development
Relocation of Population and sectors in form of ± Vectors
Output : For each end. Sector generation of the population or employments In the form of PD matrices
Flowchart per Time unit & mode
Categorizing flows to trips by Keeping, splitting or combining
Transportation costs
Trip Generation
Trip Distribution
Operator Split
Multi Operator Assignments
Path Search
Network's Capacity
Transport Model

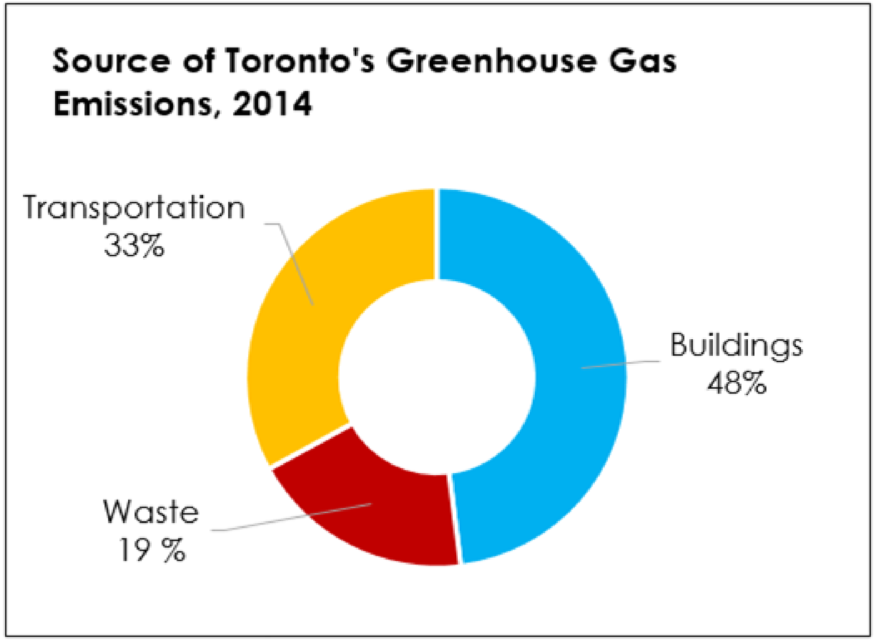
Calibration & Validation



TRANUS Model Preliminary Findings

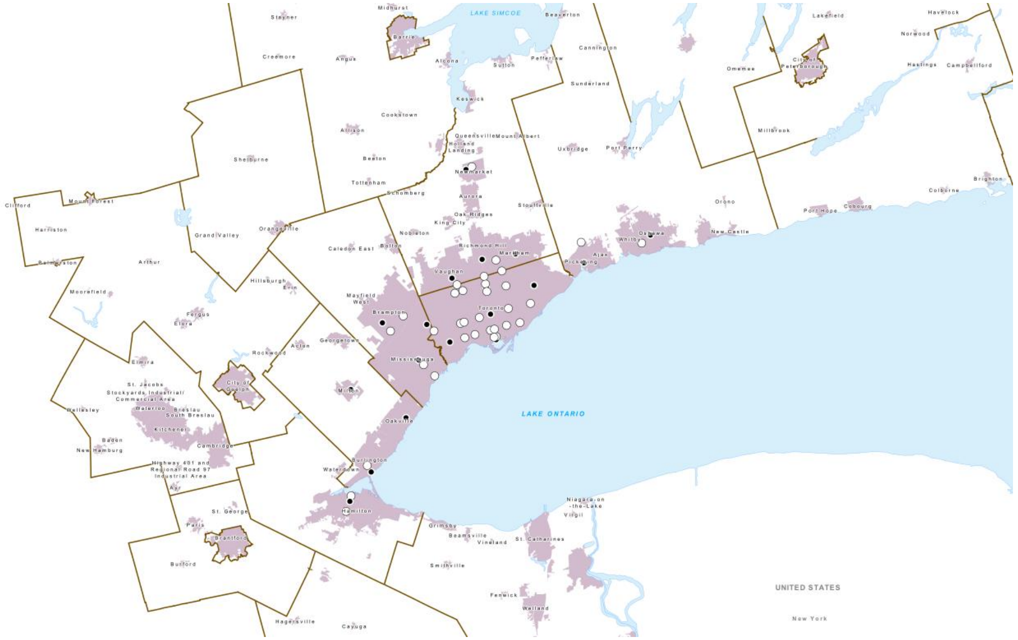
TRANUS Outputs & GHG Emissions

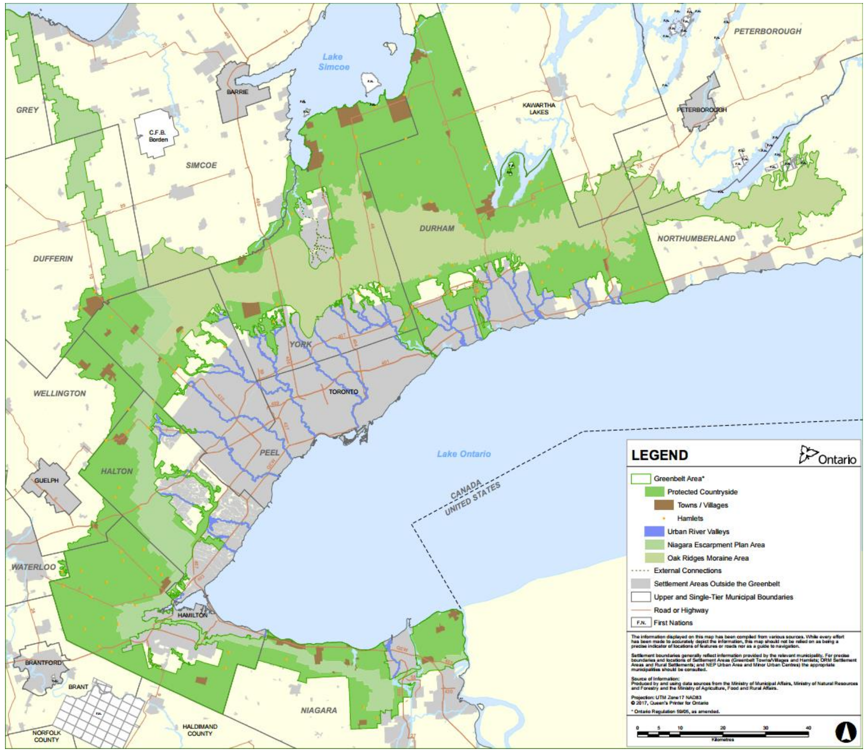
- Traditional transportation demand output is traffic volumes on roads, which are fed into an emissions model (MOVES, MOBILE, etc.)
- What about building emissions?
- Integrated models help us better include the full range of GHG impacts from transportation and land use policy



Future Scenarios

- California style regional climate plan target
- Autonomous Vehicle mode (~16% more 1 hour+ commutes in an Austin, TX study)
- Eglinton Crosstown LRT / Yonge North extension / Relief Line
- Active mode dominated downtown
- Urban form changes around Metrolinx mobility hubs & Green Belt





Conclusions

- Our goal has been to fill a gap in the Toronto region by developing a strategic model to assess regional climate plan targets for transportation and land use.
- The model will be transferred the new TRANUS 3 interface, which makes it simple for policy analysts to explore outputs and build maps.
- We are currently in the calibration stage for 2011 Census data.
- Overall, there is sufficient technical capacity in the Toronto metropolitan region to develop a LUTI model similar to that used in the regional climate policy process in California

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