An Integrated Transport - Economics Model for Ontario

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Paper prepared for presentation

at the Travel Demand Modeling: Applications for Transportation Investment and Economic Development Session

of the 2017 Annual Conference of the
Transportation Association of Canada
at
St.Johns, NL

ABSTRACT

Background

Travel demand forecasting models are an essential tool for planning and policy analyses and evaluations. In Ontario, several planning agencies have developed urban transportation models, either using the traditional four-stage trip-based modelling approach or the more advanced types (for example, activity-based models). The Ministry of Transportation of Ontario (MTO) has several forecasting tools to aid in planning and policy analyses, including the one for the mega-region of Greater Golden Horseshoe (GGH). Outside of this area, there was no single forecasting tool for passenger and freight that is consistent and integrated. To fill this gap, MTO undertook a best practice review of practice on multimodal, integrated modelling framework at the provincial scale and embarked on a project to develop such a tool.

Study Details

The purpose of this paper will be to present the scope and overview of the project that developed Ontario's Provincial Passenger and Freight Model (PPFM). This model has five key components, a) macroeconomic model that is spatially disaggregated, b) person travel model dealing with "urban trips", c) person travel model that covers "intercity" or long-distance travel by residents and visitors, d) freight model that deals with commodity flows by mode, i.e., road, rail, marine, and intermodal, and e) a common-element that deals with the "supply-side", i.e., the network.

All these model components are inter-related. The macroeconomic model provides the key "drivers" for the transportation demand components which interact with the supply-side component. The complete forecasting system provides the framework to come up with forecasts and outputs that can be analysed to evaluate impacts of infrastructure or investment options/scenarios and/or policies. The paper will conclude with an illustration of potential applications.

Background

Ministry of Transportation, Ontario (MTO) has several transportation demand forecasting and analysis tools to support planning, policy analysis and decision making. The key ones include the urban model for the region of Greater Golden Horseshoe (GGH), i.e., the GGH Model (GGHM), a commercial vehicle forecasting for the provincial highway road network, i.e., Provincial Commercial Vehicle Model (PCVM) and a data sharing/dissemination system called *iCorridor*. Development of such tools requires collection of travel and transportation data from primary sources and secondary sources. MTO, along with municipal partners, undertakes household travel surveys in the GGH (Transportation for Tomorrow Survey, TTS) and Ottawa Metropolitan Area, as well as road-side Commercial Vehicle Survey (CVS) that covers the whole province.

While these tools have been used for various applications, there are some gaps that have been identified, e.g., lack of a consistent tool for urban areas outside the two major metropolitan regions as well as lack of integration between passenger and freight demand modelling, linked with economic modelling. In an effort to address these gaps, MTO undertook a best practice review of provincial/ statewide modelling in passenger/freight demand and integration between land use, transport, and economics. This led to the identification and development of the scope and design for a first-generation province-wide model for Ontario. This paper provides an overview of this model, its structure and components along with potential applications.

Existing Tools

The GGHM was the first multimodal urban model developed and operationalised in 2008 by the Ministry to support its highway corridor planning studies and environmental assessments in the GGH as well as the development of the first regional transportation plan for the Greater Toronto and Hamilton Area by its agency, Metrolinx. It was a conventional four-stage urban model, but had several new features that were first of a kind among planning agencies in the region, such as:

- Modelling travel demand in the a.m. and p.m. peak periods,
- Consisted of a commercial-vehicle component that forecast movement of the passenger autos and trucks on the road network in those time periods, and
- Included non-motorised modes.

Since the first operational version in 2008, it underwent a series of improvements until a major revamp to the model in recent years to migrate toward the next generation version (V4), which put parts of model into an activity-based modelling framework. Besides that, it also added other features like modelling all-day demand, accounting for transit capacity and crowding, and more explicit treatment of carpooling.

Outside the GGH, MTO had several ad hoc tools such as a simplified sketch model to forecast daily traffic volumes on the highway road network that is owned and operated by MTO, or sub-area models for specific corridors or regions built using road-side origin-destination surveys. The other major tool was a forecasting system that was built from the Commercial Vehicle Survey (CVS) – also a roadside survey of trucks – which collected and compiled very detailed information on truck configuration, commodity carried, axle weights, and routes taken.

Best Practice Review

As a first step to filling the gap, i.e., lack of a consistent and integrated approach to forecasting and analysis for the province, MTO undertook a review of best practices in three topic areas, i.e., multi-modal passenger demand forecasting, multimodal freight forecasting, and integrated land use – economic – transport modelling, at the large regional scale, i.e., provincial/statewide or national. That review considered various models that are in use among various planning agencies in North America, the lessons learnt, the level of effort spent in developing such models, etc., relative to the functionalities and applications, against the priorities and needs of MTO.

One of the key findings of that review was that while the modelling approach and methods varied significantly between passenger demand and freight demand modelling, there are several common components, such as the network analysis model and macroeconomic model, that are shared between the two. In terms of integrating land use, economic and transportation modelling, it was recognized that an agile approach of building model components incrementally would be more appropriate than embarking on a fully integrated complex model. This led to the development of a model scope that kick started the integrated, multi-modal passenger and freight forecasting model for Ontario.

System Framework

Figure 1 shows the overall system framework of the model. At the top are the common components such as the demographic, employment and economic activity input data generated by the spatial disaggregation model. The other key common component shown in the middle is the supply-side / network analysis model. The demand side of the model covers both person travel – by residents in the province as well as visitors to the province – and freight flow by commodity and mode.

The resident person travel model is separated by geography into Southern and Northern Ontario, respecting the diverse nature of urban/rural landscape in Ontario. The model will simulate the interaction between economy and transport demand, both in passenger and freight arising from the needs of persons on businesses. At the bottom of the figure is the key outputs from the model system that provides for post-processing, evaluations and visualization.

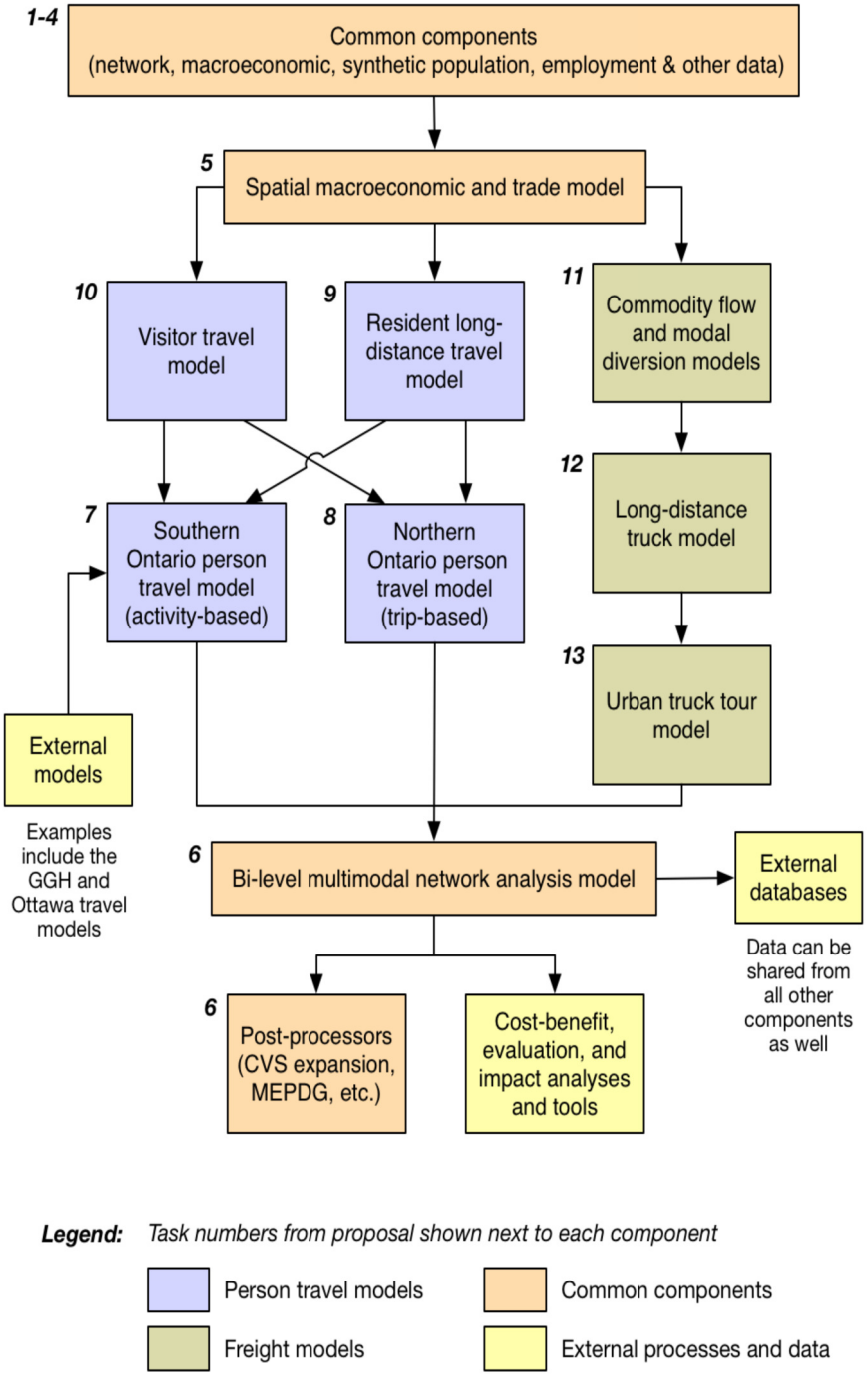

Figure 1 : Model Framework

Model Components

Spatial Macroeconomic Model: this model uses current and past data from various sources, such as Statistics Canada's Census (2011 National Household Survey) and the National Economics Accounts, that gives a detailed profile of households, persons, industry and the economy in current conditions. The model projects the future trends in production, employment and activity by detailed industry at the national, provincial and sub-provincial (Census Sub-Division) level for Ontario. It does this by taking into account the future trends in Ontario's major trading partners, i.e., rest of Canada, the United States and other nations.

It provides the detailed breakdown of demographics by different segments, e.g., age, gender, occupation status and type, and employment by major industry. In terms of economic activity, it provides the GDP by major industry from source-use table. The industry groupings have been adopted using the first 2-digit NAICS [1], with further breakdown in some sectors that are important in Ontario, for example mining or manufacturing.

All these data at the CSD level within Ontario, at the province/CMA level for rest of Canada and similar data at the state level in the United States form the key input data / drivers for the prediction and forecasting of transportation demand.

Resident Person Travel Model(s): this component deals with the trips made by persons residing in the Province on a regular day-to-day basis; trips that may be classified as "urban" trips undertaken to support daily activity patterns of persons. The GGHM already does this for the GGH area using a hybrid activity-based / trip-based approach. One of the design features of the provincial model, based on the outcome of the best practice review, is to adopt the activity-based (AB) modelling approach using the microsimulation framework for this component.

Thus, the resident travel model is built using the microsimulation framework for all areas of the Province, while using an AB approach for the more-densely populated southern region and a tip-based approach for the northern regions. The latest version of the GGHM already uses AB framework for pre- mode choice steps of demand modelling, and this is extended to the rest of Southern Ontario. Since the GGHM simulates all the trips by GGH residents that are within the GGH (intra-regional trips), the provincial model does not recreate these trips but retains them to be combined with external and long-distance person trips before trip assignment to the provincial network.

1 North American Industry Classification System (2017), Statistics Canada

Long-distance Person Travel Model(s): this component consists of simulating trips that are made by residents in Ontario and visitors to Ontario that are long-distance or intercity trips by nature. The definition of what constitutes such trips in Ontario's Provincial Model is somewhat different from the traditional intercity models. Instead of using a threshold of distance, say greater than 50 miles or 80 km, to classify if the trip is intercity, it uses the concept of including trips that are not routinely made within the region where the person lives and works/attends school, etc. With this definition, a person's daily commute trips regardless of the distance would not be considered long-distance, whereas a trip to a cottage on a weekend in the summer even if it is only 50km away, would be considered a long-distance trip. This definition is consistent with the Statistics Canada's TSRC (Travel Survey of Residents of Canada) which forms a key source of data to build the long-distance trip model.

The structure of the resident long-distance person travel model is similar to the urban model, dealing with tour generation, destination and mode choice, by households and persons, except the trip assignment is not considered for air and bus modes. The only major difference is in terms of the way the model treats the "average" day for which the rips are simulated. In the case of urban model, e.g., GGHM, the trips are reckoned for the average weekday in the Fall season. In the case of long-distance trips, given that there can be significant differences in trip characteristics and patterns between summer, winter and fall seasons, the model does account for these variations. With that, the model will be generating annual long-distance trips by season or the month-of-the-year.

Commodity Flow & Long-distance CV Model: this model takes advantage of a variety of commodity flow data by mode that MTO already had, for example the CVS and Statstics Canada's TCOD (Trucking Commodity Origin Destination Data), supplemented by those gathered from Transport Canada. The main objective is to augment the commodity flows by non-truck modes in the base year in order to make it comprehensive and link it closely with the spatially and sectorally disaggregated macroeconomic model. In particular, employment and outputs by industry at the CSD level is mapped with the commodity flow data by geography and further disaggregated to finer geography of traffic zones using microdata from primary and secondary sources.

This process creates the functionality that freight flows can be sensitive to changes in land use, for example new firms or cluster of firms in a zone or the changes at the macro CSD level, as provided by the macroeconomic forecast. Modelling the choice of mode of shipping freight is far more complex than person travel model. Therefore, this model uses a simpler rule-based modal diversion approach that utilizes a few simple measures like distance (total and dryage), commodity type, and size to alter the modal share of rail / truck / marine flows due to infrastructure changes. This method has been adapted from the version first developed in a study by Transports Quebec.

Once the modal commodity flows are determined, the next component deals with transferring the commodity flows into vehicle flows in the network. While marine and air modes are not critical in the network analysis model, truck movement on the road network and to a lesser extent the rail cars flows are the focus of this model. Long-distance truck flows model is also a great enhancement to MTO's existing PCVM that "assigned" the CVS trips by vehicle type and commodities to the road network. The major enhancement is that it enables accounting for the truck movement in the entire major road network, not just the provincial highway system, as opposed to the current PCVM. Additionally, it now links the vehicle type to commodity carried in terms of tonnage and value to the macroeconomic model making the whole model system interacting with each components.

Urban Truck Touring Model: The last component in the freight model is the representation of the pick-up / drop-off type of truck movements on the road network within urban areas. This model implements a variation of the microsimulation based truck touring model that developed in Calgary[2] by Hunt and Stefan (2007). The model starts with the tour generation based on the establishment surveys conducted in the GGH, following the commodity flows by truck tonnage and type. Nest step in the model determines the tour start time followed by stop patterns, i.e., next stop and stop duration until the tour loop is closed. GPS tracking data from third party that MTO acquired for various applications is used to calibrate the model to replicate urban truck travel patterns observed from passive data. The output from this model is a set of vehicular demand matrices by vehicle type and trip start time that can be combined with passenger vehicle demand matrices from person travel model for trip assignment.

Network Analysis Model: The last component is the network model which combines demand matrices from various steps for trip assignment in order to obtain link-level traffic volume by class and by time period, which can provide system performance and other impact analysis. One of the limitations of the static user-equilibrium assignment methods, especially in large area networks is the absence of temporal aspect of travel demand as individual vehicles pass through different areas with varying levels of congestion at different periods in a day, as long-distance trips and local trips have to share the fixed road capacity. Dynamic traffic assignment (DTA) is a viable alternative to static assignment to adequately address this requirement. However, DTA for large area models pose a challenge in terms of computational overhead to an integrated model that already complex.

A pragmatic alternative using a planning-level DTA or a mesoscopic simulation approach offered in dynamic assignment / simulation models is adopted for this model, coupled with measures to reduce the number of vehicle classes and time periods to be considered in the trip assignment process. Note that this only applies to traffic

2 Hunt, J.D., Stefan, K.J., 2007. Tour based microsimulation of urban commercial movements. Transportation Research Part B: Methodological, 41(9), pp. 981-1013.

assignment of autos and trucks, while public transit trips in urban areas will not be assigned within the provincial model. For major metropolitan areas such as the GGH and Ottawa, the provincial model will depend on urban models for these areas to carry out transit trip assignments, and migrating the transit flows as well as "skims" (travel time, costs, utility, logsum, etc) data from those models.

System Architecture

In terms of software for model implementation, the provincial model follows the same platform choice, i.e., Emme software platform with API using Python programming language, as the principal design architecture, supplemented by other tools for GIS mapping and visualization of model outputs. However, the final detailed system architecture and implementation has not been reached as at the time of writing this.

A preliminary flow diagram in Figure 2 shows the model components and the interaction between them. The main objective of the model system in forecasting future demand is to achieve an equilibrium between the supply and demand, for a given macroeconomic forecast and infrastructure/policy scenario.

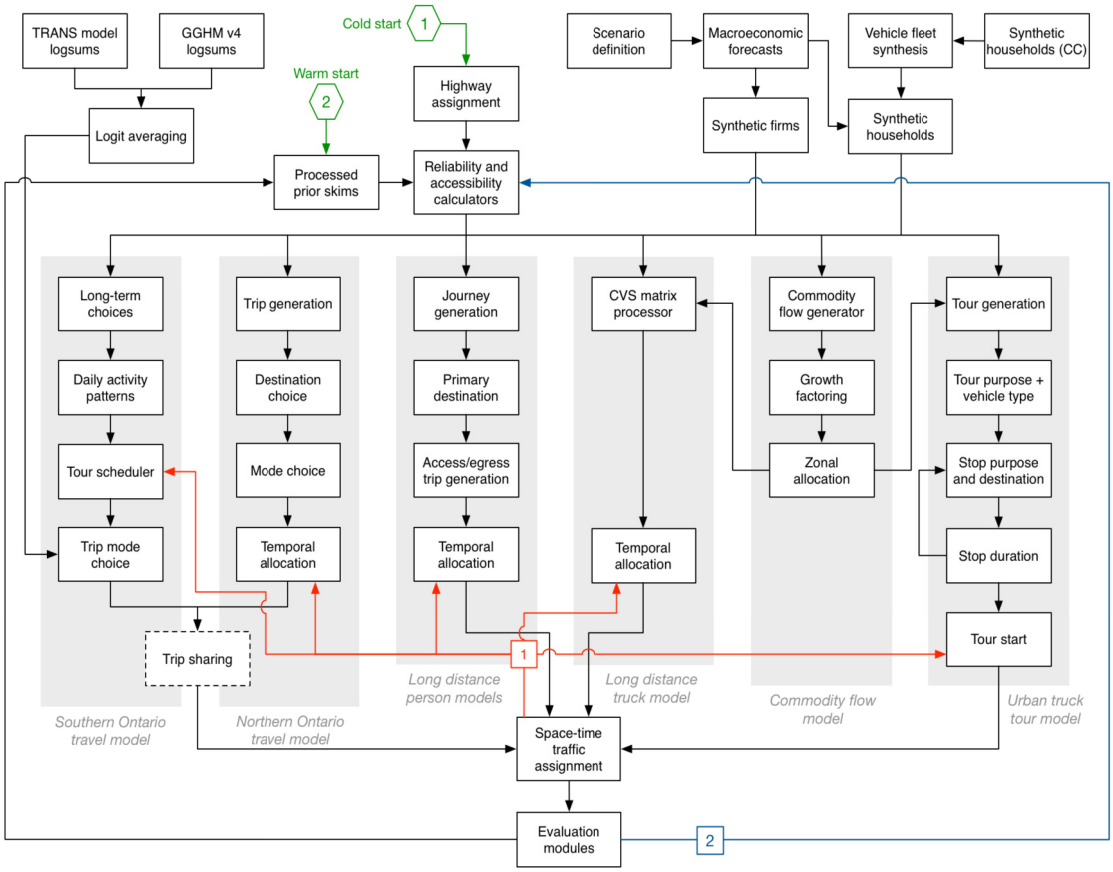

Figure 2: Flow Diagram of the Model System

Potential applications

As mentioned in the beginning, the provincial model has been developed with the aim of providing a consistent forecasting and analysis tool for all areas of the province. Once operational, it will provide inputs into MTO's major infrastructure planning studies such as planning and design for corridor improvements, highway capacity expansion, interchange improvements, high speed rail on existing or new corridors, etc.

At the policy studies/analysis, it can support system-wide evaluation of policy options impact analysis such as energy and emission impacts, fuel price and carbon pricing impacts, etc.

Besides these, a new area of application the provincial model will open up is in the area of collaborative planning with MTO's partners. For example, at the municipal level, many smaller community planning agencies in Ontario that do not have the tools or resources to develop tools, can benefit from the provincial model by sharing data at the sub-area level to quickly develop their own analytical tools. This will help them with the evidence base to aid in effective planning and decision-making.

Summary and Conclusion

Ontario's multi-modal integrated passenger and freight forecasting model is one of the first models that covers such a large area with diverse and disparate characteristics in demographics, density, and transport options. It will aid in the better understanding of the impacts of policy and investment options or scenarios on all modes across the provincial system. With a single consistent framework across all modes, it will support more robust cost-benefit evaluation of various investment options. Finally, it will help MTO's partners especially municipal planning agencies, to use better and more evidence base in support of local transportation planning and decision-making that conforms with the provincial goals and objectives.