Large-Scale Application of MILATRAS: Case Study of the Toronto Transit Network
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This paper documents the efforts to operationalize the conceptual framework of MILATRAS (MIcrosimulation Learning-based Approach to TRansit Assignment) and its component models of departure time and path choices (Wahba and Shalaby, 2009a and 2009b). The methodology is applied to a large-scale real-world application, namely the multi-modal transit network of Toronto which is operated by the Toronto Transit Commission (TTC).

The TTC transit service, in 2001, operated over 500 branches with more than 10,000 stops in the AM peak period (6-9AM). A mesoscopic model was developed to represent the dynamics of the transit service at the network level with a detailed representation of branch/vehicle-level operations. The developed mesoscopic model represents the movement of each transit vehicle between stops while it microscopically represents individual passenger alighting and boarding activities at each stop, including the interactions among passenger agents and between passenger agents and the transit network. The supply model acknowledges loading priorities at stops and represents congestion through fail-to-board handling.

The demand for the TTC transit service for the modelling period is about 320,000 passengers including trips with four categories for trip purpose: home-based work trips (HBW, 67%), home-based school trips (HBS, 27%), home-based other trips (HBO, 4%), and non-home-based trips (NHB, 2%).

A learning-based departure time and path choice model was adopted using the concept of mental models for the modelling of the transit assignment problem as a Markovian Decision Process (MDP). The generalized cost, GC, is assumed to be a function of the parameters \(\bar{\beta}\), fixed-cost components \(\bar{Y}\), and variable-cost components \(\bar{X}\). These variables components largely depend on passengers’ travel choices and the transportation network performance. For a state \(s\) and an action \(a\), the \(GC(s,a)\) is defined as:

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\begin{align*}
\hat{GC}(S,a) = & \text{fixed immediate cost } \sum \beta_i Y_i \\
+ & \text{expected immediate cost (i.e. variable component) } \sum \beta_j \bar{X}_j \\
+ & \text{expected future return } \left[ \gamma \cdot \min_{a' \in A(S')} \{GC(S',a')\} \right]
\end{align*}
\]

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The goodness of the calibrated values is assessed on the basis of the comparison of the entropy of the predicted values to that of the observed values. The estimation procedure employs Genetic Algorithms (GAs); a Parallel Genetic Algorithm engine called *GenoTrans*, developed at the University of Toronto, was used for the parameter calibration process. Recently, GA-based parameter estimation procedures have been adapted in the transportation field (e.g. Parveen et al., 2007).

The estimated parameters suggest that passengers perceive a minute spent in a rail transit system (e.g. subway) less than a minute spent in a surface road service (e.g. bus or streetcar), \( \beta_{inv\,RT}^{0.8} < \beta_{inv\,SUR}^{1.0} \). The waiting time disutility is higher than the in-vehicle time disutility, \( \beta_{waiting\,RT}^{1.4} > \beta_{waiting\,RT}^{0.8}, \beta_{waiting\,SUR}^{5.0} > \beta_{waiting\,inv\,SUR}^{1.0} \). The travel time components related to rail transit systems are perceived to have less disutility in comparison to travel time components associated with surface transit service, e.g. \( \beta_{waiting\,RT}^{1.4} < \beta_{waiting\,SUR}^{5.0} \); this is in line with our expectation and common findings of transit assignment procedures. The fare weight is estimated as 8.5, and it has a unit of minute per $. This translates to a money value of time as $7/hour (12c/minute), which is close to the minimum wage in Ontario for the year 2001 ($6.85/hour).

The surveyed choices are compared with the modelled departure time and path choices for validation purposes. About 99% of the surveyed departure time choices were replicated by passenger agents with similar origin, destination, access mode and egress mode attributes. The first route choice was matched for 79% of observed choices, while the predictability of the exact sequence of route transfers was about 60%. The first boarding stop choice was reproduced for about 75% of the surveyed origin stop choices and 75% of the exact sequence of transfer point choices were correctly predicted by the off-stop/on-stop choice mechanism.

Indicators of passengers’ *learning* include over-crowding which was observed to decline as the number of iterations increased – this was due to passengers’ *adaptation* to experienced congestion levels and capacity constraints. The learning and adaptation is also clear from tracing the individual level behaviour (e.g. en-route replanning and day-to-day trip choices) and the network-level statistics over iterations.

The model outputs details on individual passenger-agents’ trip choices, accumulated experiences stored in the mental model, departure time frequency distributions, dynamic transit-OD matrices for the modelling period, run-level performance indicators, and tracking of travellers’ behaviour during the trip and over time. This raw data can be aggregated using various factors to generate useful network-level and demand-level outputs and findings.

The assignment process converges to a steady state where passengers continue to make the same choices over iterations and such trip decisions are reinforced as they minimize the generalized travel cost compared to other available options. This steady state was reached without the availability of perfect knowledge by all passengers and without assuming equilibrium *apriori*.

This application deals explicitly with trip timing and path selection, and the mechanism through which passengers adjust these decisions in response to experienced congestion, control measures, and supplied information (if any). Furthermore, it represents a coherent behavioural integrated framework, where aggregate travel patterns can be properly extracted from individual choices.
It is worth investigating the similarities and differences between the outputs of equilibrium and non-equilibrium based models for the transit assignment. The integration of dynamic transit assignment models (such as MILATRAS) and activity-based urban planning models is needed as transit assignment is a key component of land use and transportation models. Eventually, MILATRAS is envisioned to be used in designing transit networks and services.

REFERENCES

