

RAPID Travel Demand Modeling Frameworks for Smaller Municipalities

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ABSTRACT

As growth pressures in the future increase, coupled with limited financial means, there will be an increasing need to optimize infrastructure to address questions surrounding mobility, congestion management, and sustainability. These questions are challenging enough when addressed individually, but in tandem they present a complex interconnected transportation puzzle. A puzzle that needs an intelligent assessment and evaluation tool.

Some medium and many large urban areas have a number of comprehensive and complex tools with varying capabilities for deciphering this puzzle. These tools take the form of travel demand models developed in proprietary packages like EMME, VISUM, TransCAD.

However, most smaller and some medium municipalities face significant hurdles to developing such tools due to small budgets, limited staff and technical knowledge, and a general lack of understanding on how these tools work. To overcome these limitations, staff mostly relies on traffic studies and sometimes on large urban area models from surrounding municipalities. These urban models are generally not sensitive to travel patterns in these municipalities, resulting in significant generalizations and poor performance.

A new paradigm shift in transportation analysis and thinking is warranted by the medium and smaller municipalities who do not possess such tools. This shift should be focused towards developing a common travel demand modeling framework (CTDMF) that can be shared across these municipalities. The CTDMF will greatly improve cost effectiveness by allowing knowledge transfer of model parameters and procedures, wherever possible. It will also act as a knowledge databank that the municipalities can tap into in order to improve their tools and gain a better understanding of travel behavior in their municipalities. The cornerstone of such a CTDMF should be i.e. A Rigorous tool for **A**ssessment, **P**rioritization, **I**mplementation, and **D**ecision-making. Three recent success stories of such a RAPID tool have been described to illustrate its wider potential.

INTRODUCTION

Over the last couple of decades, especially in the large urban areas, there has been a policy shift aided by public support that the “build your way out of traffic congestion” philosophy is not viable from an environmental or economic standpoint. It is now well recognized that a plethora of initiatives, both infrastructural and policy based, are needed to manage this congestion, thereby improving mobility and sustainability within the system in a cost effective manner. The interaction between initiatives, and their resulting composite effect on mitigating and managing congestion, mandates the application of intelligent tools to evaluate and measure successes and failures. In the field of transportation planning, these tools routinely take the form of travel demand models.

Rising to the challenge in the past 15 years, significant advances in travel demand modelling in Canada, and specifically Ontario, have been made in the four-stage trip-based and state-of-the-art activity based models. While earlier comprehensiveⁱⁱ four-stage models were limited to a handful of large citiesⁱⁱⁱ, the efforts of policy makers, practitioners, and academicians alike has facilitated the development and application of such models to other large urban areas^{iv}. This increasing application of comprehensive models has been greatly aided by the transferability and use of a number of common modelling elements^v (CME) and frameworks across urban areas, thereby, improving efficiencies, reducing costs, and imparting confidence in the abilities of the models.

While much has been accomplished in the larger urban areas, the smaller municipalities^{vi} have not benefitted by the significant advances in travel demand modelling. They have largely operated in isolation, making decisions based on local traffic studies, expert judgement, and in some cases adjacent large urban area models that exhibit very limited sensitivity, if any at all to issues in the small urban area in question. This is further compounded by the limited resources, personnel and otherwise, available for an arduous undertaking such as developing and maintaining a travel demand model.

The issues and constraints facing the smaller municipalities are to a great extent similar to those in the larger urban areas. However, they differ in the scale of the problems, the number of possible solutions, and limited financial resources. These limited financial resources present an even greater challenge because staff has to allocate the few resources efficiently without the aid of an intelligent tool, such as a travel demand model- a tool that can analyze potential solutions and also inform the municipality of additional options.

This paper presents a potential philosophy for developing and sharing CMEs across these smaller municipalities and a subsequent Common Travel Demand Modelling Framework (CTDMF) that can be ported, adapted, applied, and maintained in a cost effective manner while epitomizing the virtues of being RAPID - A **R**apid tool for **A**ssessment, **P**rioritization, **I**mplementation, and **D**ecision-making. Three case studies are presented to showcase some initial successes of such a philosophy. In the long run, it is hoped that the Ministry of Transportation (MTO) or other provincial agencies formalize this or a similar philosophy, to ensure compatibility with any province-wide

modelling efforts underway. In Ontario, this effort is being led by the Systems Analysis and Forecasting Office (SAFO), MTO.

COMMON MODELLING ELEMENTS (CME)

The CMEs can be thought of as the building blocks of the modelling framework. Traditionally, a CME would be supply and/or demand-side elements such as networks, zone structures, and socioeconomic data, to name a few, which can be shared between different model types (passenger, freight etc.) for the same geography.

In this context however, CMEs are the attribute definition of those elements and in some cases the philosophy behind their development. The formalization of the CMEs is expected to significantly improve quality control and provide a roadmap for developing the pieces of the CTDMF. It will also allow the assertion of parameters between pre-existing large urban models, but more importantly from other municipalities that have already implemented and validated a travel demand model using the CTDMF philosophy.

Network Coding Conventions

Establishing the appropriate level of network representation for each smaller municipality is a unique exercise and thus cannot be generalized. However, the attributes of the network and their definitions can be generalized in order to facilitate transfer of parameters. Once transferred, the parameters can be calibrated to improve model performance. The table below is one such example of generalizing attribute definitions.

Table 1: Potential Link and Node Attribute Definitions

Link Attribute	Definitions	Node Attribute	Definitions
Volume-Delay Functions	Categorized by road type.	Superzones	Group of zones that represent larger sub-area of interest.
Road Type	Integer identifier for road classification; preferably matching approach adopted for large regional models in the vicinity to achieve conformity	Internal Zone Centroids	Sequential, starting from 1 with centroids within a superzone clustered.
Capacity	Result of road type, speed, and area type.	External Zone Centroids	Sequential, and ranging between 900 to 999.
Speeds	Result of road type and area type – local	Regular nodes	Sequential, starting from 1000 with nodes within a

	conditions and data to over write any general definitions.		superzone clustered.
Counts	Separate attributes for different peak hours, AADTs.		
Area Type	Categorize by urban, sub-urban, and rural.		

Traffic Analysis Zone (TAZ) Structure

Similar to the network, the TAZ structure will be unique to the municipality in question. But some common ground can be built around the philosophy of developing TAZs. At a minimum the TAZs should be built around the Census Dissemination Areas (DA) as this is the smallest standard geographical area for which population and employment data, especially Place of Residence-Place of Work data categorized by the North American Industrial Classification System (NAICS) ^{vii}. The granularity of the TAZs can be increased for avoiding bisecting zones with roads, if required, but in subsets of the CDA, which will allow disaggregating the data relatively easily using any standard geographic information system software.

Population and Employment Data

Population and employment input data is the backbone for all types of travel demand models. To ensure compatibility with the TAZ structure it is recommended that population and employment data at the DA level be used for developing this important input dataset. Municipal level population information, which is most likely available at a geography such as a census tract or some other larger agglomeration, can be used to fill gaps and/or act as a control total. DA level employment data on the other hand is not designed to capture establishments with very few jobs, due to privacy reasons. Thus, employment numbers will have to be supplemented with data gathered from local business associations. This hybrid approach is extremely useful for developing credible population and employment datasets, especially in municipalities that do not have a strong culture of maintaining disaggregated forms of data.

COMMON TRAVEL DEMAND MODELLING FRAMEWORK (CTDMF)

The lack of technical resources to devote to the development and maintenance of complex decision-aiding tools such as travel demand models, along with the pressing need to efficiently assign the limited financial resources lays the theoretical underpinnings for the need of a CTDMF - a CTDMF, which does not necessarily promise the most theoretically advanced modelling platform, but rather a practical one. One that is modular and flexible to implement and update considering the differing

needs of the municipalities; multi-scaled to be able to represent geographical, temporal, and behavioral levels of resolution most appropriate to it; and facilitate interoperability with surrounding large urban area models, if any, including the Province-wide models, planned by SAFO. In other words the CTDMF must follow the agile development techniques being embraced in model design^{viii}.

This might seem a tall order to begin with, but with careful consideration such a framework can be developed and implemented. Three critical factors that will need to be explicitly addressed to help achieve such a CTDMF are listed below:

Software

There are currently two primary software products used for developing and implementing macro travel demand models in the Province of Ontario. First, EMME, which is developed by INRO and is used primarily for the more advanced travel demand models; limited to the Greater Golden Horseshoe (GGH) and Ottawa area models. Second, TransCAD, developed by Caliper Corporation and used by municipalities outside the above aforementioned urban areas, except for the Region of Waterloo and Niagara Region that are within the GGH. Recognizing the wide spread use of both the software platforms, the CTDMF should be implementable in both software environments.

User Operability

Enhancing user experience with the CTDMF by implementing a Graphical User Interface (GUI) to run the model, generate reports, and display results. The GUI is necessary to limit application times and to reduce the likelihood of errors in the process. Due to the GUI's simplicity users do not require as much experience to perform basic modelling tasks, allowing more time to interpret the results.

Technical Approach

Time Periods: A truly flexible CTDMF must allow for the implementation of the a.m. and/or p.m. time periods, as per the requirements of the municipality. This can be accomplished by establishing trip linkages at the 24-hour level, then "slicing" the a.m. or p.m. time periods via peak period and peak hour factors.

Trip Purpose: At a bare minimum, six trip purposes to be included; Home-based Work (HBW), Home-based School (HBS), Home-based Other (HBO); Non-home based (NHB), External-Internal (EI), Internal-External (IE), External-External (EE). This will ensure compatibility with the Transportation Tomorrow Survey (TTS)^{ix} and facilitating the use of the survey for model development.

Trip Generation: To allow the modelling of different time periods, the trip generation sub-model must include trip rates for a.m. and p.m. time period, by trip purpose.

Trip Distribution: Gravity and destination-choice model paradigms for the HBW, HBS, HBO, and NHB trip purposes. Of the two, the destination-choice models are preferred as they provide more variables to control trip distribution and trip length frequency distribution (TLFD).

Mode Choice: The CTDMF is a tool for smaller to medium municipalities where auto is the predominant mode of transportation with some active transportation. Mode choice needs to be modelled explicitly either as a global factor or a zone-to-zone rate, by trip purpose. The option of implementing asserted mode choice parameters for implementing a traditional mode-choice model for municipalities with transit service must be included.

Trip Assignment: Single class standard and/or path-based assignment^x.

CASE STUDIES

The three critical factors noted before were used as a blueprint for developing a CTDMF design that was applied across three municipalities, with a fourth one in progress^{xi}. Notable in their application was the efficiency gained in designing, calibrating, validating, and applying the models using the CTDMF, as compared to the traditional approach of developing a model from the ground-up. The flow chart shows the CTDMF design and the feedback loops that strive to achieve convergence. Some salient features that are not highlighted in the design process are:

- HBW – Tour type model at the daily level using Place of Residence-Place of Work linkage.
- HBS – Tour type model at the daily level using Place of Residence-Place of School linkage.
- HBO and NHB – Time period specific trip model.

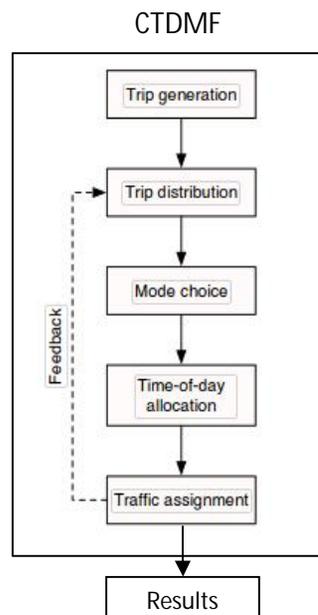


Table 2. CTDMF Design

Criterion	Simcoe County Modelling System	Northumberland County Model	Quinte West Model	Norfolk County Modelling System
Common Modelling Elements (CMEs)				
Zone Geography	Subdivisions of 2001 TTS zones	CDA	CDA	To be implemented
Population / Employment	County	CDA	CDA	To be implemented
Software	TransCAD	EMME/4	EMME/4	TransCAD
User Operability	GUI	GUI	Macros	GUI
Geography				
Focus Geography	County	County	City	County
Forecasted Population	700,00+	125,000	60,000	80,000
Internal Zones	350	250	75	100
Technical Specifications				
Time-period	PM	PM	AM	To be implemented
Trip Purposes*	Tour-based : HBW, HBS Trip-based: HBO, NHB, E-I, I-E, E-E			
Trip-distribution*	Gravity Model / Destination-choice	Gravity Model / Destination-choice	Gravity Model	To be implemented
Mode-choice	Policy-based at the zone level			
Trip-assignment	Standard Multiple Successive Average	Path-based	Standard	To be implemented

*HBW-Professional, General Office, Sales and Service, Manufacturing
HBS-Elementary, Secondary, Post Secondary
HBO-24 cross classification segments used in trip generation. Segments aggregated for trip distribution and a user defined distance variable for calibrating. E.g. User can input 25km as a maximum distance for calibrating trip lengths (HBO and NHB).

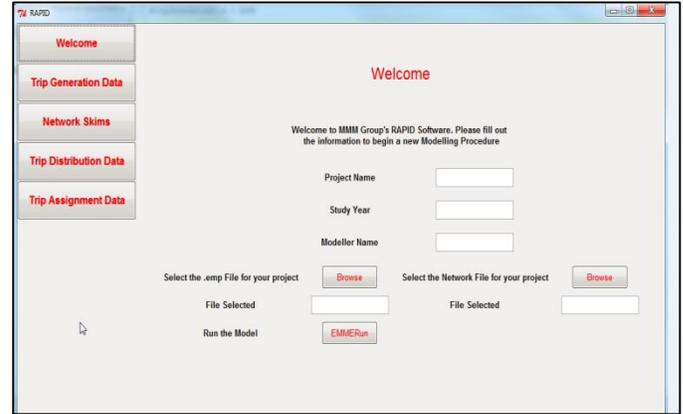
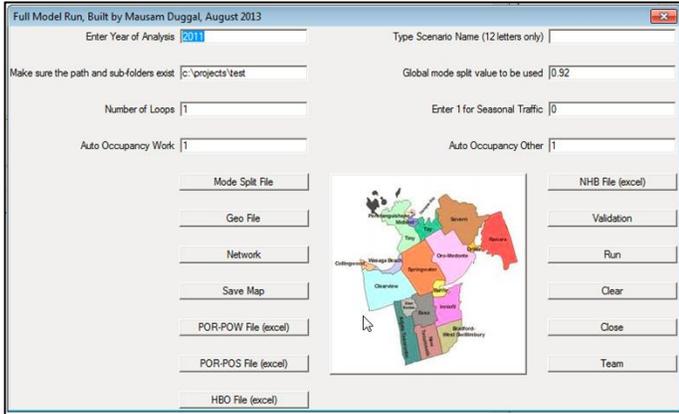
User operability is another key issue of the CTDMF. This is especially important because as a client transportation planning analyst, the focus should be on the applicability and processing of results from the model. Valuable time and resources should not be spent on ensuring model process consistency, deciphering the macro programming syntax, guaranteeing repeatability of the results, and/or confirming that the internal workings of the model are error free.

A user friendly and comprehensive GUI of the CTDMF were developed in the TransCAD and EMME/4 software platforms.

CTDMF User Operability

TransCAD GUI

EMME/4 GUI



An important aspect of the CTDMF and the corresponding CME philosophy is the ability to quickly transfer and recalibrate parameters for each specific municipality. Of the three models listed, the Simcoe County Travel Demand Modelling System served as the primary source for transferability as it was estimated and calibrated using the 2011 Transportation Tomorrow Survey. Table 3 shows the transferable elements and the adjustments made across the models.

Table 3. Transferability of Elements and Sub-Models

Transferable Elements	Source Model	Transferred Model	Adjustments
Trip Generation Rates	Simcoe County Modelling System	Northumberland County, Norfolk County, Qunite West	Base trip rates to reflect local special generators and characteristics using ITE Trip Generation Manual, NCHRP 735.
Trip Distribution Parameters	Simcoe County Modelling System	Northumberland County, Norfolk County, Qunite West	Distance parameter adjusted using screenline count data.
VDFs	Simcoe County Modelling System and Quinte West	Northumberland County, Norfolk County	Alpha/beta parameter adjustments to validate to screenline count data.

In addition to the advantages documented above, an interesting application of such a CTDMF and CME approach is the potential to start stitching together a mega-region travel demand modelling system at a fraction of the cost. Particularly, models built using the CTDMF could be used to improve the external trip information used in the GGHM and other large regional models by providing a logical, consistent, and extendable modelling platform. This will avoid the significant generalization that is currently adopted to develop external trips, resulting in poor boundary condition traffic patterns.

CONCLUSION

The initial efforts made in the development of Common Modelling Element (CME) and the accompanying Common Travel Demand Modelling Framework (CTDMF) has proved to be very encouraging. Resources that would traditionally be spent on collecting surveys, model design, and the processing of CMEs, to build a model, are now formalized and can be easily implemented or ported across models. Although effort will still be required by analysts to tailor the model to be specific to the geography in question, it has significantly improved the process of building some of the most fundamental elements of model design, and in other cases, presented a blue print for doing so.

The CME and the CTDMF documented in this paper are generally tailored for municipalities that do not currently have such a tool. But the CME and the accompanying CTDMF are mutually exclusive, thereby allowing the analyst to implement one without the other. This is especially useful for municipalities that currently have a model, but also have an urgent need to update and/or upgrade it using a modelling philosophy that is more cutting-edge, while not forgoing the practicality in doing so^{xii}. While updating pre-existing and time-period specific models to a recently collected Origin-Destination survey is a big undertaking, a bigger challenge is to expand these models to other time periods in the day. The challenges are due to the significant time and effort required to maintain two different models, as well as the behavioral inconsistency between the model themselves i.e. a person choosing the auto mode for the morning work commute could choose transit in the evening due to increasing congestion in the network.

The CTDMF with its 24-hour tour-based approach takes care of both the aforementioned challenges. It provides a theoretical and practical foundation that could be very useful as awareness about the need to develop complex decision-aiding tools in transportation planning grows beyond the traditional GGH and Greater Ottawa Regions.

Mausam Duggal, is a Senior Transportation Planner with over 10 years of experience in the field of travel demand modelling and forecasting. He graduated from the Georgia Institute of Technology, Atlanta, GA, with a Masters in Transportation Planning and GIS, and has been estimating, calibrating, validating, and applying travel demand macro and mesoscopic models in North America and the Middle East. He currently works in the Systems Analysis Group (SAG) of Parsons Brinckerhoff.

Christopher Tam, is a Senior Project Engineer at MMM with over five years of experience in the transportation planning and modelling. Chris is currently engaged as project coordinator for the Northumberland County Transportation Master Plan and the Norfolk County Transportation Master Plan, both of which utilize the RAPID travel demand modelling framework. The results of this framework are being used to provide current and future travel demands, resulting in new road rationalization schemes to streamline the County road networks.

Nemanja Radakovic, is a transportation designer in MMM Group Limited's Transportation Planning department. He graduated with distinction from the University of Waterloo with a B. A. Sc. degree in Civil Engineering. His main area of interest is travel demand modelling and microsimulation. He has been, and continues to be, involved in projects in this area.

Trajce Nikolov, is a Civil Engineer with a focus on Transportation Modelling and Planning. He studied his undergraduate degree at the University of Toronto (2015 expected) where he is also currently beginning his Masters studies. Trajce has had two years of experience working with and validating Travel Demand Models and has also worked on creating numerous attachments (i.e. Performance measures, Greenhouse gas models) for Toronto's GTAModel V4. He currently works with the Travel Modelling Group (TMG) on the SmartTrack modelling efforts.

ⁱ Mausam Duggal built and spear-headed this effort while at MMM Group where he led the travel demand modelling group at MMM's Thornhill office for 10 years.

ⁱⁱ Comprehensive four stage models in this context are referred to as those that do not use policy-based or observed mode splits to estimate trip demand by modes.

ⁱⁱⁱ City of Toronto and City of Ottawa.

^{iv} York Region, Durham Region, Region of Waterloo have comprehensive four-stage models

^v To the knowledge of the primary author, the CME concept was first introduced in the Province-wide Multimodal and Freight Modelling Jurisdictional Reviews completed for MTO by Parsons Brinckerhoff and MMM Group in 2013. In the context of this paper, CMEs represent network coding rules, volume-delay-functions, data sources such as the Transportation Tomorrow Survey, trip purpose behavior, amongst others that have been ported and calibrated to local conditions in a number of models in the Greater Golden Horseshoe Area. One key source for such CMEs and modelling frameworks has been the GTA family of models built by Prof. Eric Miller at the University of Toronto.

^{vi} Loosely defined based on population < 150,000, with the exception of Simcoe County that has a population of over 250,000

^{vii} Statistics Canada

^{viii} *Are Your Models Agile, or Fragile?*, The Third Conference on Innovations In Travel Modeling, 2009. Rick Donnelly, Parsons Brinckerhoff.

^{ix} Detail reports on the TTS and access can be gained from the University of Toronto's Data Management Group. The TTS is a very good resource within Southern Ontario, however, it can be substituted or supplemented with area specific Origin-Destination surveys.

^x Two authors of this paper, Mausam Duggal and Nemanja Radakovic, carried out extensive comparisons of the application of the standard vs path-based assignments in smaller municipalities using the City of Lethbridge's model. The results from the tests were promising enough to transfer the City's a.m. and p.m. peak hour assignments to path-based, thereby greatly improving model assignment performance.

^{xi} Norfolk County, Ontario

^{xii} City of London, Kingston, Windsor.