

Estimating Urban Commercial Vehicle Movements in the Greater Toronto- Hamilton Area

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Executive Summary

In order to assist Metrolinx in its mandate to better understand commercial vehicle movements in the Greater Toronto-Hamilton Area (GTHA), MITL has undertaken a project to generate estimated origin-destination (O-D) matrices of commercial vehicle movements for light, medium and heavy commercial vehicles. Results are reported based on a 2252 zonal system which covers the GTHA and is well-suited to representing urban commercial vehicles movements.

There are three main types of urban commercial vehicle movements being estimated: tour-based, fleet allocator and internal-external. Tour-based movements are those associated with a commercial vehicle leaving an establishment and carrying out a series of stops to deliver/pick up goods or provide services. Tours can be carried out by light, medium or heavy vehicles and can involve stops for non-business purposes. Generally, a tour terminates when the vehicle returns to the business establishment where the tour originally commenced.

In this work, a microsimulation framework has been applied to model tour-based movements. The tour generation piece of this framework has been driven by the firm level InfoCanada data set which contains information on approximately 185,000 establishments located in the GTHA. This data set is very rich for understanding what types of businesses are located where and how large they are. Observed tour generation behavior from the Peel Commercial Vehicle Survey has been instrumental in complementing the insight provided by the InfoCanada data. The other component of the microsimulation relates to actual simulation of tours. This is done one tour at a time and considers all aspects such as the origins and destinations of trips within tours with respect to precise time and location. Information from the Peel Survey in terms of stop durations during tours and in terms of overall tour characteristics has been useful in developing models to actually trace out the tours. The tour simulation framework has been imported from the work of Hunt and Stefan (2007) in Calgary. To some degree, pre-calibrated models from Calgary have been directly used in this project in combination with custom-calibrated models based on the Peel Data. The bulk of the effort in this project has been directed toward an accurate implementation of the tour-based component.

Fleet-allocator movements are involved with systematically covering a territory within an urban area and are associated with functions such as mail delivery, courier services, garbage and recycling pick up and so on. Trip results for this component have been developed through a trip generation phase followed by a trip distribution phase. For the former, a survey-based regression model that was developed for Edmonton has been imported to the GTHA and used to impute light, medium and heavy vehicle total fleet-allocator trips for each of the 2252 zones in the study area. A spatial interaction model with inferred statistical parameters has then been used to distribute these trips to likely prospective destinations. In this manner, O-D matrices for these types of movements have been put in place.

The final category of commercial vehicle movements relates to movements where a maximum of one of the origins or destinations for a trip is within the GTHA study area. Generally, we refer to these as

internal-external movements but they include trips that start in the GTHA and terminate elsewhere, trips which start elsewhere and terminate within the GTHA and trips which start and finish elsewhere but pass through the GTHA in the process. This component of the work has largely been an empirical exercise (as opposed to a modelling exercise) and is based solely on the 2006 MTO Commercial Vehicle Survey. The survey provides information on heavy and medium vehicles but not for light vehicles. Therefore, we do not report on the internal-external movements of light commercial vehicles in this research.

In total, 72 O-D matrices were produced that relate to tour-based commercial movements (24 hours by light, medium and heavy vehicles). There are three matrices that relate to fleet allocator movements and there are three smaller matrices that capture internal-external movements. A useful summary matrix is provided below which illustrates how GTHA commercial vehicle movements are divided by vehicle type and movement type:

Summary of Estimated Daily GTHA Commercial Vehicle Trips

Trip Type	Heavy Vehicle	Medium Vehicle	Light Vehicle	Total
Tour Based	199,381	323,547	842,820	1,365,748
Fleet Allocator	37,589	271,700	235,490	544,779
Internal-External	51,379	14,517	-	65,896
Total	288,349	609,764	1,078,310	1,976,423

The results suggest that 69.1% of the trips are tour-based, 27.6% are fleet-allocator based and 3.3% are internal-external. Note that this latter percentage would rise if information were available on the internal-external movements of light vehicles. For heavy vehicles, the internal-external movements represent 17.8% and for medium vehicles it is only 2.3%.

Summary of Estimated Daily GTHA Vehicle Kilometres Travelled

Trip Type	Heavy Vehicle	Medium Vehicle	Light Vehicle	Total
Tour Based	3,249,380	5,892,670	15,564,506	24,706,556
Fleet Allocator	292,960	2,398,484	2,124,767	4,816,211
Internal-External	2,952,876	719,481	-	3,672,357
Total	6,495,216	9,010,635	17,689,273	33,195,124

In terms of the aggregate kilometers travelled in association with these trips, the table immediately above summarizes the results under the same categorizations. It is interesting to note, for example, that for heavy vehicles the VKT percentage is much higher for internal-external trips than it is in terms of trip counts. While these results are estimates, they nevertheless underscore that a very large number of commercial movements are occurring within the GTHA on an intra-urban basis every day.

Overall, the framework is fairly ambitious and speculative and bearing this reality in mind, a concluding section reports on some of the potential sources of error. One of the main messages is that efforts should be redoubled to collect an extensive array of data and survey results on urban commercial

vehicle movements within the GTHA. This will lead to the most accurate possible estimates and new modelling efforts to help explain the collected behavior. Sources such as the InfoCanada dataset could prove very useful in guiding some of these future data collection efforts.

Introduction

Traffic analysis is a fundamental component of urban planning. However, urban transport and land-use modelling has traditionally focused on passenger vehicle movements across transport networks. Research in recent years has revealed that the omission of Commercial Vehicles (CVs) from these models can compromise their predictive abilities (see: Waddell et al., 2002; Holguin-Veras and Patil, 2007; Kanaroglou and Buliung, 2008). Stefan et al., (2005) report that “an estimated 10% to 15% of urban vehicle trips are made for commercial purposes.” They further note that CVs, particularly “large” CVs, have a significantly greater impact on traffic congestion, pollutant emissions, and road wear, per vehicle, when compared with personal vehicles. For instance, medium and large sized CVs emit 30 to 100 times more particulate matter (PM) than personal passenger vehicles (Kanaroglou et al., 2000). Given the economic importance of the GTHA, its impact on the environment and its high rate of population growth, accurate and comprehensive traffic and land-use models are a necessity.

There is actually little precedent for the modelling of intra-urban commercial vehicle trips in the literature. One exception is the work of Hunt & Stefan (2007), who present a tour-based microsimulation of urban commercial vehicle movements (UCVM) for the city of Calgary, Alberta. Following Hunt and Stefan, we will concern ourselves with commercial vehicle flows of three distinct types: 1) tour-based; 2) fleet allocator; and 3) internal/external. In order to measure tour-based flows, a microsimulation framework is employed, where UCVMs are conceptualized as tours emanating from

particular business establishments. The reason for the emphasis on tours is that a very large percentage of UCVM are composed of a coordinated series of stops to service a variety of clients. After this series of stops, which would typically span several hours, the tour terminates at the place of origin which is typically the home establishment.

While the vast majority of this project's effort has been invested in the accurate representation of these tour-based movements, we need to consider the other two types of movements also. Fleet-allocator movements are being modelled with traditional trip generation and trip distribution methods. Here, Fleet-allocators are CVs which are dispatched to cover and service territories on an ongoing basis. Examples include: road maintenance vehicles, mail delivery or garbage trucks.

The final category of UCVM relates to internal-external trips. There are three sub-categories of trips to consider here: external-external are truck trips that pass completely through the GTHA and are considered as not stopping within the GTHA; internal-external are trips that originate within the GTHA and terminate at some location outside the GTHA; external-internal trips are those which originate at some location outside the GTHA and terminate within the GTHA. Work on these three sub-categories of trips is based purely on the 2006 MTO Commercial Vehicle Survey. A model per se is not constructed with the MTO data.

Some final overview notes about the process are worth mentioning. While it is true that a set of data products related to UCVM for light, medium and heavy vehicles is being developed, it is also true that a framework to permit scenario testing for UCVM is being developed also. The framework, building on the work of Hunt and Stefan, could theoretically accommodate external changes and forecast their impacts on UCVM. For example, if certain sectors of the economy are hard hit by a recessionary environment, the tool being developed for the GTHA could provide some assessment of impacts on UCVM. In addition, this framework could be transferred relatively easily to other metropolitan areas to assist in answering similar types of questions.

The main departure from the work of Hunt and Stefan is the use of commercially available firm-level data sets such as those that are available from InfoCanada or InfoUSA. Typically, these data sets are used for direct marketing purposes but we are suggesting that there is application also in the context of developing estimates of UCVM. The precise process of how to go about utilizing these data sets is outlined below.

One final note about the nature of this work is that there are no estimates of the flow of commodities or inferences about whether a truck is full or empty at a given point in time. The purpose of this work is to estimate trip-making behavior by commercial vehicles of the three basic types. This latter consideration is a key aspect in determining how the road network is getting used and the levels of congestion that ensue. While it is true that fully-loaded trucks probably cause more congestion and more road damage than empty trucks, these aspects are beyond the scope of the current analysis.



Literature Background

Traditionally, CV modelling has focused on freight transport, usually at a regional or ‘inter-city’ level (Kanakoglou and Buliung, 2008). While these models are useful for predicting the flow of medium and large sized trucks in and out of urban areas, their use for modelling CV movements within urban areas is limited. While regional goods transport often involves truck, rail, sea and air modes, CV traffic in urban areas is composed almost entirely of road based vehicles (Ogden, 1992). Furthermore, data from the Cities of Calgary and Edmonton, in Alberta suggests that more than 60% of CV movements in both cities are made by four-tire vehicles such as cars, vans, pick-ups and SUVs (Stefan et al., 2005-1). These findings underscore serious limitations of relying on conventional methods to address urban CV movements.

Modelling urban CV travel can be conceptualized as comprising two stages (see: Kanakoglou and Buliung, 2008). First, the estimation of CV flows between discrete origins and destinations within the study area. Second, the assignment of CV flows to the urban road network. In some cases, CV flows from the first stage are modelled as tours which begin and end at a commercial establishment (see: Figliozzi, 2007; Hunt and Stefan, 2007). Various methodologies exist to model CV flows in the first stage, and these range from aggregate matrix expansion techniques, to state-of-the-art microsimulation.

One common set of techniques used in the first stage of modelling are referred to as Origin-Destination (OD) matrix expansion, where OD matrices based on traffic counts or surveys are scaled for future years (see: Kawakami et al., 1992; Ortuzar and Willumsen, 1994; Holguin-Veras and Patil, 2007). OD expansion techniques have been criticized for being policy insensitive, as well as for failing to capture 'small' commercial vehicles, such as those used for services and deliveries.

Another commonly used set of CV modelling techniques adapt the trip generation and distribution stages of the four-stage modelling process in order to generate OD matrices of CV flows. See McNally (2002) for more on four-stage models, which are commonly used to predict passenger travel demand. Some early efforts to model urban CV travel using the four-stage approach include Ruitter (1992), and Schlappi et al. (1993). As reported by Marker and Goulias (1998): "These models have several characteristics in common. They attempt to follow the methodology used in the four-step process, also known as the Urban Transportation Planning System, typically using employment or area, in some form, to predict truck trip generation rates at the traffic analysis zone level. The models perform trip distribution by means of a gravity model using travel time for impedance." This general modelling framework is most notably presented in the 'Quick Response Freight Manual' (QRFM), put forth by the U.S. Department of Transportation in 1996. Many efforts to model CV movement in urban areas over the last decade have made use of the four-step methodology (see for example: List et al., 2002) as well as information from the QRFM.

Two notable, though less popular methods of modelling urban CV patterns are supply-chain modelling, and spatially disaggregate Input-Output (IO) modelling. Supply-chain models attempt to account for the main actors and elements involved in given supply-chains, such as suppliers, shippers, consumers, and goods themselves. Hunt and Stefan (2007) note that: "this approach is useful for examining a limited range of industries (say, in an area dominated by one type of company or economic sector), but would require substantial data to produce a comprehensive model for a typically diverse North American urban area." For more on supply-chain modelling, see: Boerkamps et al., 2000; Wisetjindawat et al., 2005. IO modelling, on the other hand, makes use of an estimated technical coefficient matrix that summarizes the relationship and linkages between the different sectors of an economy. In such an approach, traffic analysis zones are treated as regions with markets that interact with other markets to deliver or acquire goods and services. Consequently, ideas and concepts related to multiregional IO modelling have been employed in the past to model trade flows between traffic analysis zones. Despite its conceptual profoundness, a major drawback of the IO approach is the need for detailed data that are usually lacking. For more on spatially disaggregate IO modelling, see Hunt and Abraham (2003).

Some efforts to model urban CV patterns using an agent-based (also known as microsimulation) framework have been made recently. In this approach, trips are modelled at a disaggregate level that often utilizes the business establishment as the unit of analysis. Accordingly, commercial trips are generated per establishment as opposed to per zone, as is the case with the four-stage model. Hunt and Stefan (2007) present a model where the majority of CV movements are microsimulated, while CVs making external or internal movements, as well as "fleet-allocator" movements, are modelled using aggregate methods. Wisetjindawat and Sano (2003), microsimulate firms in order to model urban CV flows. Here, commodity generation and distribution are modelled at the firm level, and then translated

into CV trips; traffic assignment was not addressed by the model. Another notable effort for microsimulating CVs is presented by Gliebe et al. (2007). The latter study utilizes 'traveling workers' as the agents of the model.

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Overview of Key Data Components

3.1 The Study Area and Zonal System

The study area, referred to as the Greater Toronto and Hamilton Area (GTHA) throughout this report, is composed of the Hamilton, Halton, Peel, Toronto, York, and Durham Census Divisions (see Exhibit 1). The study area is further divided into Traffic Analysis Zones for analysis. In particular, the GTHA is covered by 2,252 zones (see Exhibit 2). The final zonal system utilized is an extract of the Greater Golden Horseshoe Zonal System which was developed for another project. This system includes areas beyond the GTHA such as Kitchener-Waterloo and the Niagara Peninsula. This current extract of 2,252 zones includes the vast majority of the zones in the GGHM system and the zones themselves are very well suited to the analysis of UCMV. Zonal systems based on census geography such as dissemination areas, for example, would lead to a zonal system of over 8,000 zones and an over-representation of residential zones. The chosen system gives a lot more relative weight to industrial areas that would be particularly associated with UCMV.

Exhibit 1: Municipal Breakdown of GTHA Study Area

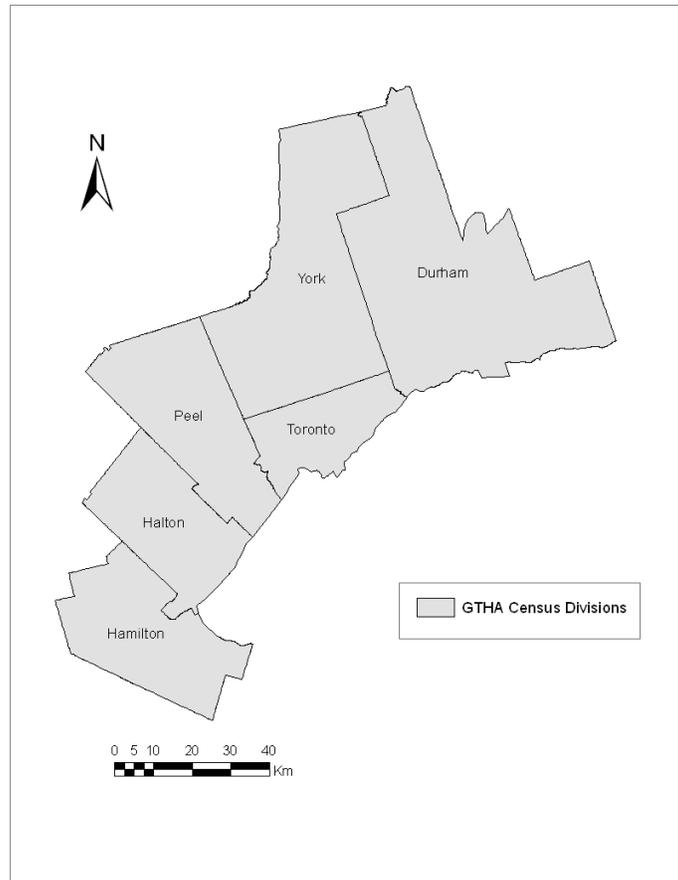
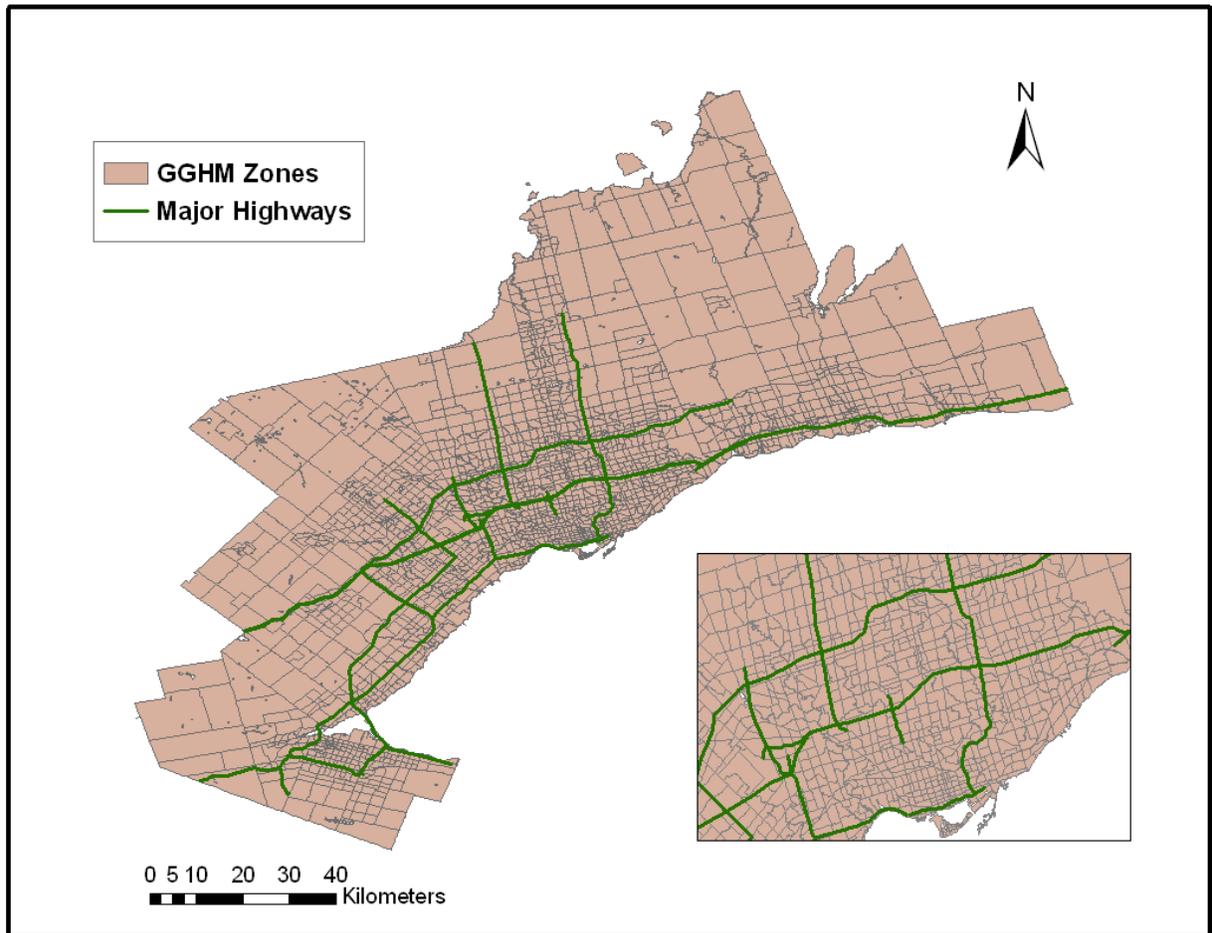


Exhibit 2: Zonal System Used for Study



3.2 InfoCanada Data

The InfoCanada firm dataset consists of 185,790 records of establishments in the GTHA, a nearly exhaustive list of firms in the area. Some key attributes included in the dataset are: Address, Number of Employees, and six-digit SIC Code. Exhibit 3 provides an example of selected records and fields from the InfoCanada dataset. Here, the fields 'SIC' and 'SIC Description' indicate the type of firm in question. Note the wide variety of establishment types: from 'Churches' and 'Banquet Rooms' to 'Automobile Renting' and 'Foods-Carry Out'. The diversity is certainly much larger than shown here. Note that some of the records are not represented as having sales. This field serves as one useful screening mechanism for those records which we would not expect to generate UCVM.

Exhibit 3: Selected InfoCanada Firm Records

ID	CITY	Employees	Sales Volume	SIC	SIC Description
14	BOLTON	1-4	LESS THAN \$500,000	871301	SURVEYORS-LAND
15	ACTON	5-9	\$500,000-\$1 MILLION	753812	TRUCK-REPAIRING & SERVICE
16	BRAMPTON	1-4		581223	BANQUET ROOMS
17	BURLINGTON	10-19	\$1-2.5 MILLION	799935	HALLS & AUDITORIUMS
18	MISSISSAUGA	20-49	\$5-10 MILLION	751401	AUTOMOBILE RENTING
285	ROCHES POINT	1-4		866107	CHURCHES
286	ROCHES POINT	1-4	\$500,000-\$1 MILLION	871201	BUILDING DESIGNERS
287	SUTTON WEST	5-9	LESS THAN \$500,000	581206	FOODS-CARRY OUT
288	SUTTON WEST	1-4	LESS THAN \$500,000	562105	BOUTIQUE ITEMS-RETAIL

Considering that the InfoCanada file is intended primarily for marketing purposes, it is not surprising that there are no fields that are directly related to UCVM. There is no information on number of CVs per firm, number of CV drivers per firm, or number of deliveries to/from the firm. The InfoCanada data set does provide a powerful linkage mechanism via SIC code. Unfortunately, the PEEL survey data (discussed in the next section) does not contain a great deal of differentiation at the SIC code level.

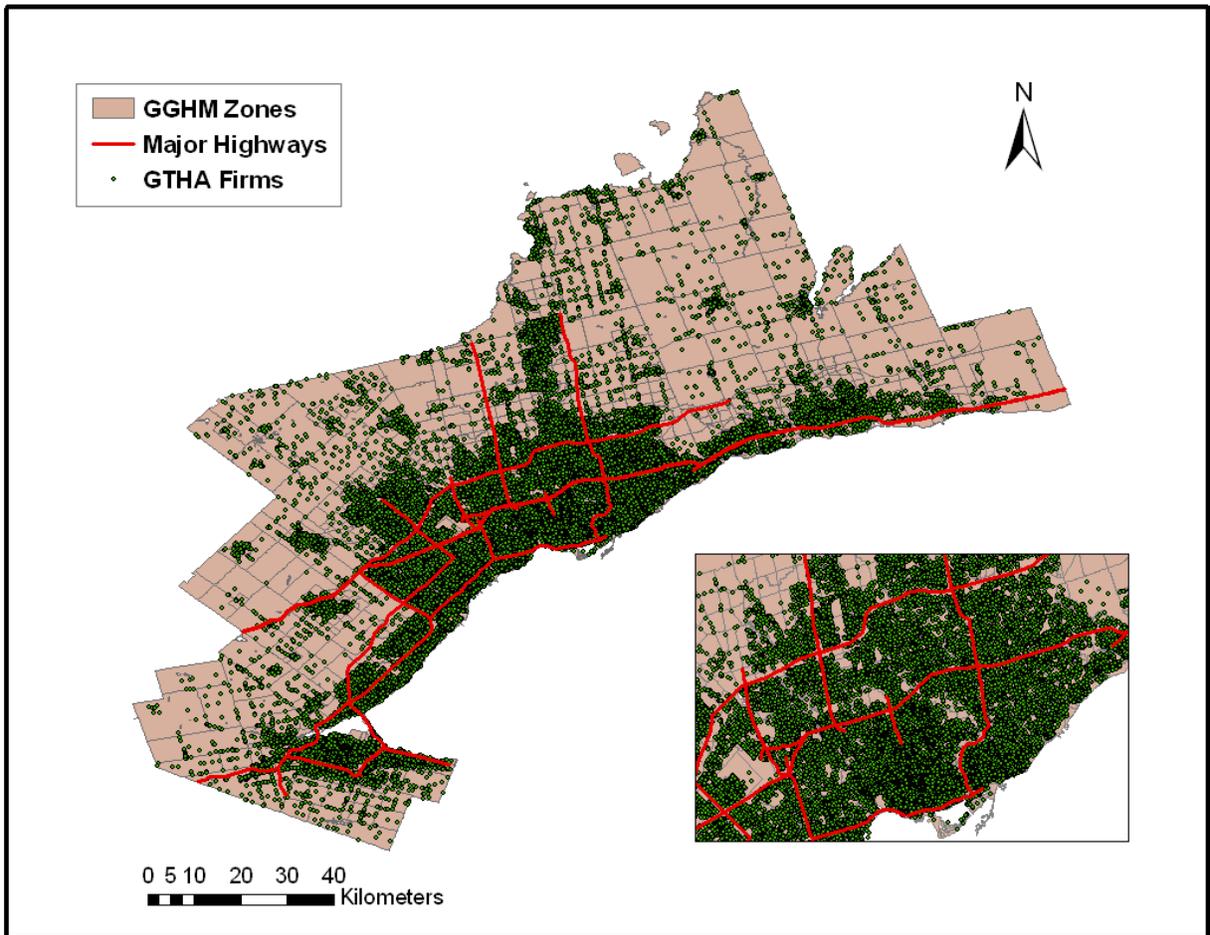
The InfoCanada dataset did not arrive geocoded. After the data were cleaned and organized, each firm record was geocoded with longitude and latitude. The majority of firms were geocoded by street address (94%), while the remaining 6% were geocoded in a less accurate way, by postal code or forward sortation area (FSA). Exhibit 4 shows the geocoded firms in the GTHA study area. Note that while the majority of firms are located in urban areas and are well serviced by major highways. Firms are more thinly spread throughout peripheral rural areas of the study area although still in fairly large numbers.

The main attributes from the InfoCanada dataset used to predict CV tours were: number of employees and SIC code. In the case of number of employees, a range of values was provided per firm in the dataset (see Exhibit 3). In order to derive an integer value for this field, the midpoint of the provided range was used as an approximation. For instance, for the range of '1 to 4' employees, we set the number of employees to 2, while for the range '20 to 49', we assigned 35 employees. This approximation was followed throughout the database.

Another field was added to the dataset which classified each firm based on its SIC code. The classification scheme assigned firms to the following categories: those which are likely to produce no tours, those which are likely to produce "fleet allocator" type tours, those which are likely to produce

many tours, and those which are likely to produce a low amount of tours. Firms from the dataset which were classified as producing no tours accounted for 105,258 of the 185,790 total firms, or approximately 57% of the firm population. The creation of this categorical field is one way that the detailed 6-digit SIC code was used to help estimate the number of tours emanating from each firm. This process was followed for the over 3000 distinct SIC codes captured in the database.

Exhibit 4: Geocoded InfoCanada Firm Data



For the purposes of UCVM, there were some problematic records present in the InfoCanada data. Head office issues were apparent where the SIC code of the associated industry did not seem consistent with the apparent administrative role of the head office. For example, mining functions in downtown Toronto were apparent as well as potential attribution of outlying employees to that head office location. Such a location is unlikely to generate the types of CV movements typically associated with mining. Certain CVs, such as taxies, may not begin or end their tours at a business establishment, making them difficult to account for. Also, it is likely that government CVs are not fully accounted for in the dataset although it is anticipated that a large percentage of these movements are captured under the fleet allocator category. For the most part, we did not undertake the task of attempting to revise the InfoCanada data since this would be an extremely time-consuming process. Instead the decision

was made to utilize the InfoCanada data in its basic form under the assumption that, in aggregate, many of the problems would cancel out. Certainly though, this would be a matter to consider for future research.

3.3 The Peel Data Survey

The Peel Survey and resulting data is the result of a 2006/07 survey of 597 firms in the Peel region (see Roorda et al, 2007a and 2007b). Exhibit 5 provides an example of selected firm records from the survey, including some of the attributes collected for each firm. One limitation of the data is the broad industry classifications that are used, most likely for reasons of confidentiality. This issue reduces the potential for linkages to other more sectorally-specific firm data (such as InfoCanada).

Exhibit 5: Selected Firm Records and Fields from Peel Survey

ID	Employees	Industry	Square Feet	Yearly Shipments	Shipment Value Within Peel	x1	y1
209	50 to 99	Construction	348,482	15,000+	10,000,000	-79.4726	43.7293
288	100+	Manufacturing	5,200	5,000 to 9,999	500,000	-79.7358	43.6946
314	1 to 4	Manufacturing	800	500 to 999	100,000	-79.6411	43.5665
320	5 to 9	Manufacturing	5,200	100 to 499	60,000	-79.6252	43.7155
326	10 to 49	Manufacturing	2,700	100 to 499	100,000	-79.6975	43.6899

For 80 of the 597 surveyed firms, detailed tour data was also collected. The result was data on 93 unique tours provided by 93 unique drivers. Collectively, the tours include 751 stops with x-y coordinate attributes, with an average of 8 stops per tour. Exhibit 6 provides an example of selected stop data, where each tour is composed of 2 or more stops. In Exhibit 6, two tours are shown, the first having Tour ID 3, and the second having Tour ID 21. There are six stops on Tour ID 3, while Tour ID 21 is composed of three stops. Also note that the type of commodity being picked up or dropped off at various stops on these two tours is described by the Pickup or Drop-off Commodity Type ID.

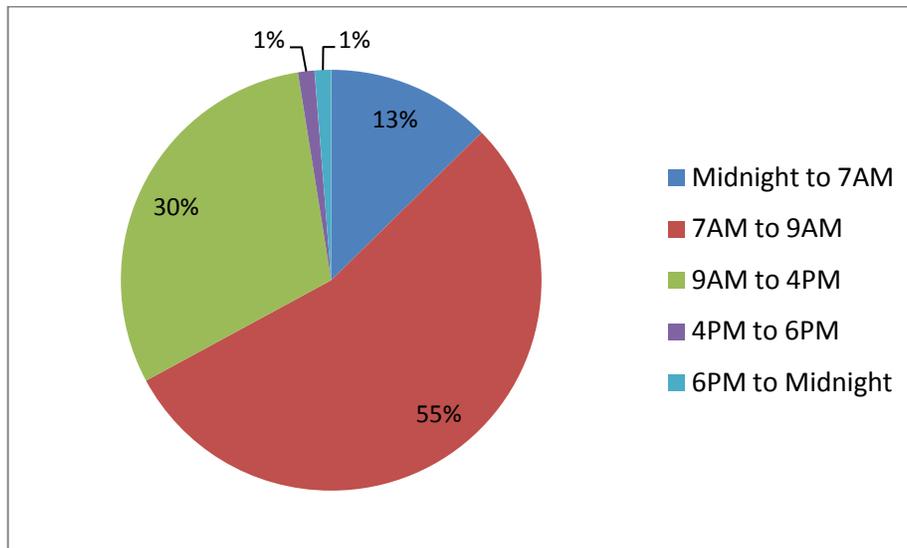
Exhibit 6: Example of Selected Tour Data from Peel Survey

Tour ID	Arrival Time	Departure Time	Pickup Commodity Type ID	Drop off Goods	Drop off Commodity Type ID	x1	y1
3	8:30 AM	9:05 AM		TRUE	5	-79.8934	44.2883
3	10:25 AM	10:45 AM	4	FALSE		-79.6077	43.6912

3	11:25 AM	11:35 AM		TRUE	4	-79.7425	43.6932
3	11:55 AM	12:20 PM	5	FALSE		-79.6913	43.7449
3	12:40 PM	1:10 PM	4	TRUE	5	-79.6077	43.6912
3	1:40 PM	2:00 PM		TRUE	4	-79.617	43.6934
21	7:30 AM	12:00 PM	15	TRUE	3	-79.3808	43.6499
21	12:15 PM	1:00 PM	14	FALSE		-79.4068	43.6363
21	1:45 PM	2:20 PM	14	FALSE		-79.6438	43.5882

Exhibit 7 shows the breakdown of tours by their departure times. The majority of tours from the Peel Survey depart their establishments in the morning, between 7:00 and 9:00 AM, while very few late afternoon departures are observed. Although it is obscured in Exhibit 7 by the broad time category of 9:00 AM to 4:00 PM, there are also relatively few observed departures after 12 noon. These temporal results somewhat contradict other studies, such as Hunt et al (2006), and are most likely due to the relatively small number of tours available from the Peel Survey.

Exhibit 7: Tour Depart Time Distribution



An important tour characteristic is the duration of stops made on the tour. In some cases, a tour’s timeline is composed almost entirely of stops. Exhibits 8 and 9 show distributions of stop times from the Peel Survey tours. These distributions were used as constraints in tour modelling (see Section 4.1). From Exhibit 8, we see that tour stop times are more likely to be shorter than longer, with the largest number of stops falling into the 1 to 5 minutes category. The pattern in Exhibit 8 is more reflective of goods tours than service tours since the former define the vast majority in the Peel Survey. In Exhibit 9, the

proportion of goods stops in each duration category is compared with the proportion of service stops in the same categories. Here it is clear that while longer stop durations are less likely for goods stops, service stops have an almost equal probability of long duration and short duration stops, with a relatively lower probability of medium length stops.

Exhibit 8: All Stops by Stop Duration

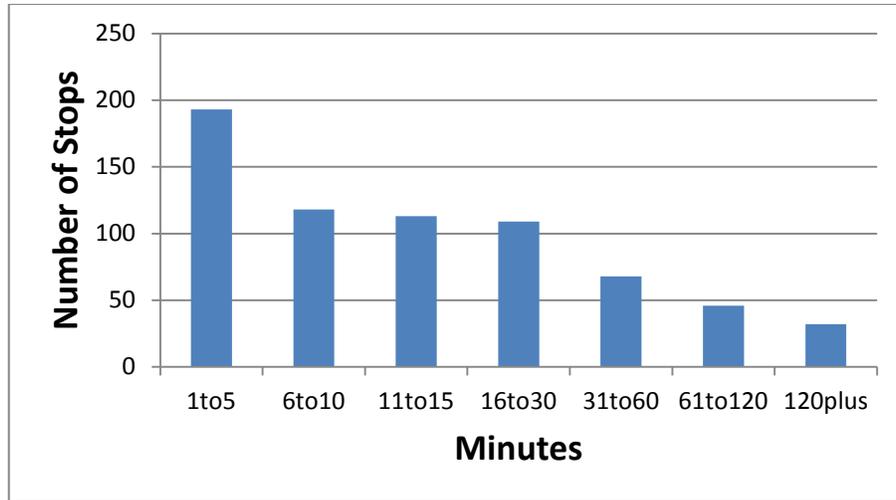
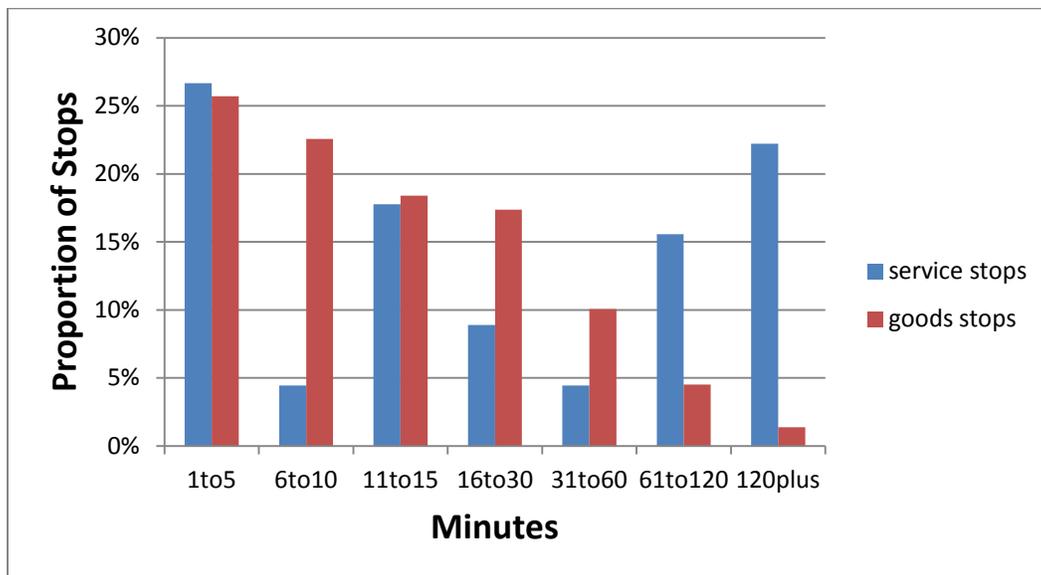


Exhibit 9: Proportion of Goods and Service Stops by Stop Duration



Other relevant tour aspects include the total distance of tours, as well as the distance per leg/trip of tours (the distance between stops of a given tour). Average tour distances, and tour leg distances from the Peel Survey tours are shown in Exhibit 10, by industry. The distribution of tour leg distances was taken into account during the tour modelling phase of this work (see Section 4.1).

Exhibit 10: Tour and Trip Distances by Industry

Industry Type	Average Tour Distance (km)	Average Tour Leg Distance (km)	Count of Firms
Industrial	119.3	17.5	20
Retail	81.6	16.2	7
Service	91.0	20.7	5
Transportation	125.3	14.2	12
Wholesale	149.5	22.0	7
Unclassified	160.7	16.9	12

Exhibit 11 shows the average number of tour legs per industry, and the average tour length per industry, for the Peel Survey tours. These distributions were used as guidelines rather than as constraints during the tour modelling exercise.

Exhibit 11: Average Tour Legs and Tour Lengths by Industry

Industry Type	Average Number of Legs	Average Tour Duration (Minutes)
Industrial	6.2	537
Retail	7.8	346
Service	5	343
Transportation	9	686
Wholesale	9.8	821
Unclassified	10.8	349



Implementation of Modelling Framework

The modelling framework that was implemented involved three distinct commercial vehicle trip types: tour-based, fleet-allocator and internal-external trips; as is consistent with the framework developed by Hunt and Stefan (2007). Most of the time and effort in this undertaking was dedicated to the microsimulation framework which underlies the tour-based movements and which makes up the majority of UCVM. The internal-external component is more of an empirical exercise than a modelling effort and the fleet allocator movements utilize a simple regression model that was developed elsewhere. The purpose of this section is to work through the processes that were followed and to demonstrate the results that were obtained.

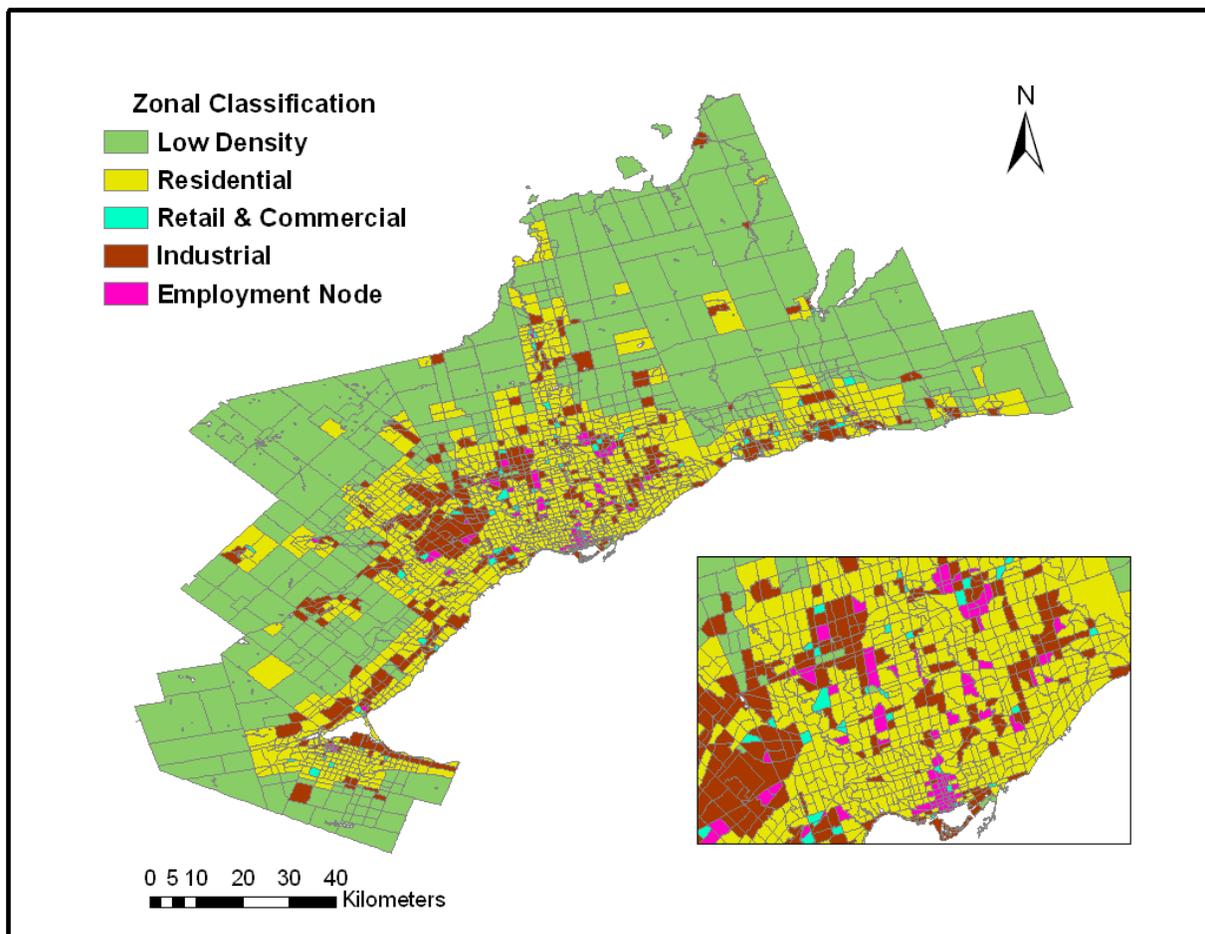
In brief, the main data used in the microsimulation modelling framework were the InfoCanada firm dataset, as well as the Peel firm dataset, and the Peel tour dataset (see previous section). Distributions of number of daily tours per employee per industry type were obtained from the Peel firm dataset, and these were generalized through Monte-Carlo methods to the InfoCanada firm set in order to estimate the gross number of CV tours emanating from each firm. The characteristics of these tours (such as CV type, number of stops, length of tour legs, and destination of stops) were estimated using specific models from Hunt and Stefan (2007). In some cases, parameters for these models were estimated using the Peel tour data.

4.1 Estimation of Tour-Based Trips

The tour-based microsimulation that was implemented relied heavily on the InfoCanada firm level data set. The underlying thought driving the use of these data is the possibility that firm-level data can be an excellent starting point for estimating the movements of commercial vehicles. The firms, after all, are the actual behavioural units that drive the vehicle movements of interest. The Peel Survey is another important component in that it contains some actual observed commercial vehicle movements linked to firms.

While the InfoCanada data are firm-based, there are key elements of the modelling framework which are zone-based. In particular, a basic land use classification, with rules taken from Hunt and Stefan (2007), forms a key determinant of model behavior. The results of the classification for the GTHA are shown in Exhibit 13. The pattern displayed there is quite useful for interpreting many of the results to follow.

Exhibit 12: Zonal classification for the GTHA



4.1.1 Tour Generation

The process followed for tour generation exploited the Peel Survey and also the InfoCanada data. For each firm in the Peel Survey, the number of CVs departing the establishment was recorded. This attribute was interpreted as the number of tours generated by each firm on a typical day. This attribute was captured for each firm, divided by its number of employees and aggregated by five major industry types to yield a distribution by industry. Exhibit 13 shows the distribution of ‘tours per employee’ by industry type. Each column in this table sums to 100 and thus defines a probability distribution that can be sampled from during a simulation. This distribution is used to estimate the raw number of tours emanating from businesses in the GTHA.

Exhibit 13: Tour Originations per Employee by Industry

Tours Per Employee	Industrial	Unclassified	Retail	Service	Transportation	Wholesale
0	21%	33%	31%	32%	24%	15%
0 to 0.05	5%	33%	6%	7%	2%	6%
0.05 to 0.1	10%	17%	5%	2%	6%	3%
0.1 to 0.2	10%	17%	11%	13%	2%	10%
0.2 to 0.3	10%	0%	3%	5%	4%	10%
0.3 to 0.4	9%	0%	4%	6%	6%	7%
0.4 to 0.5	7%	0%	6%	7%	6%	7%
0.5 to 1	15%	0%	13%	12%	18%	23%
1 to 2	12%	0%	11%	7%	8%	14%
2 to 3	0%	0%	2%	2%	10%	3%
3 to 5	0%	0%	2%	5%	4%	1%
5 to 10	0%	0%	2%	1%	6%	0%
10 to 50	0%	0%	3%	1%	2%	1%

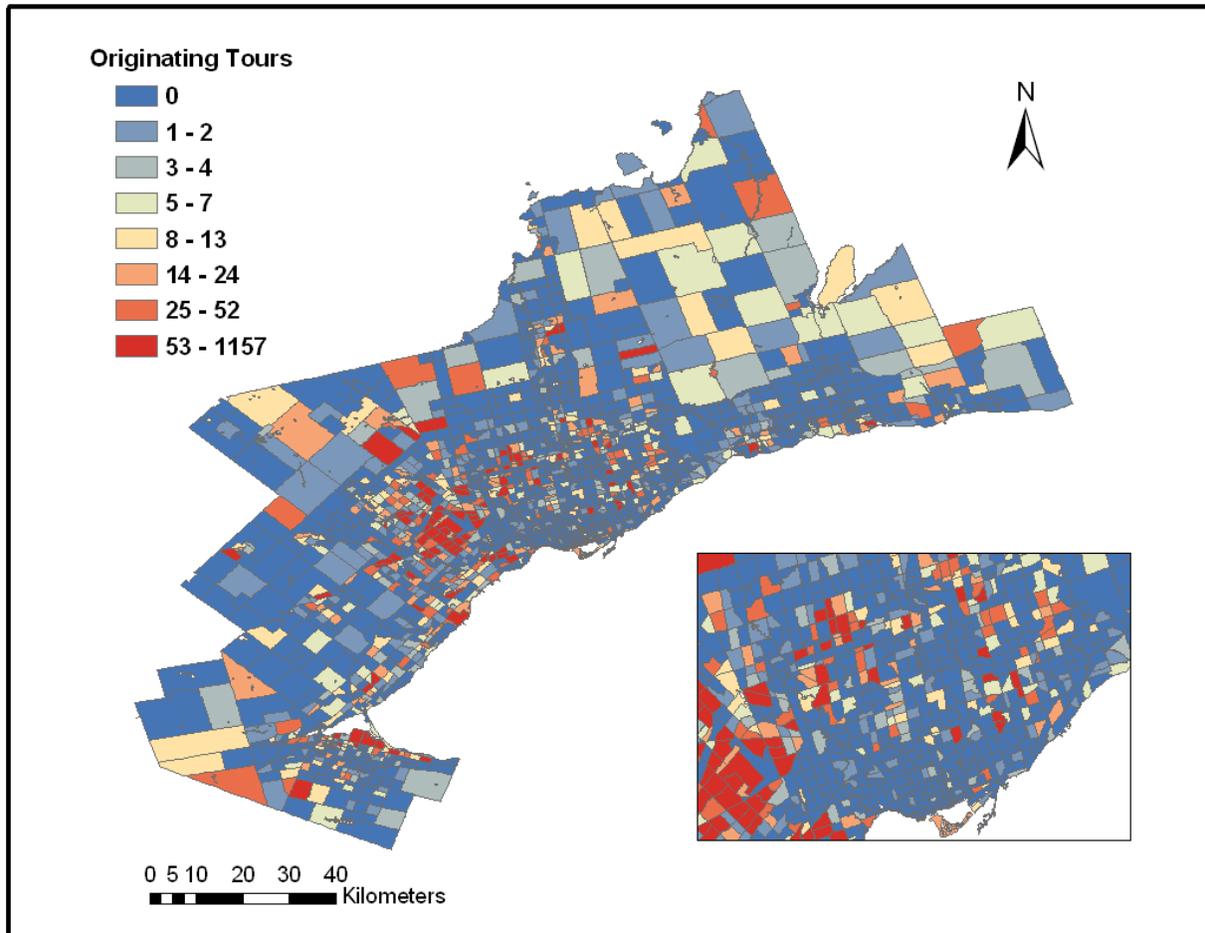
As mentioned earlier, the 6-digit SIC attribute from the InfoCanada firm dataset was used to classify each firm in terms of whether it was likely to produce: no tours, many tours, or few tours. In addition, a determination was made as to whether the establishment should be associated with fleet allocator movement instead.

A set of Monte Carlo simulations was run in order to estimate tours per firm for those establishments in the InfoCanada dataset. For a given firm, those producing no tours or fleet allocator trips were assigned zero tours. The remaining establishments were subject to a random draw from the ‘tours per employee’ distribution of their corresponding industry as seen in Exhibit 13. Some assigned value of tours per employee was obtained and then multiplied by the number of employees in the firm to estimate the total generated tours per day. For firms producing “many tours” or “a low amount of tours”, the ‘tours per employee’ distribution was modified to reflect a likely conditional distribution of tours per employee.

One of the reasons that it is difficult to refer to this analysis as truly “establishment-based” is that the level of SIC detail in the InfoCanada data is far greater than the segmented behavioural data that are available from the Peel survey. While the firms in the InfoCanada dataset were endowed with 6-digit

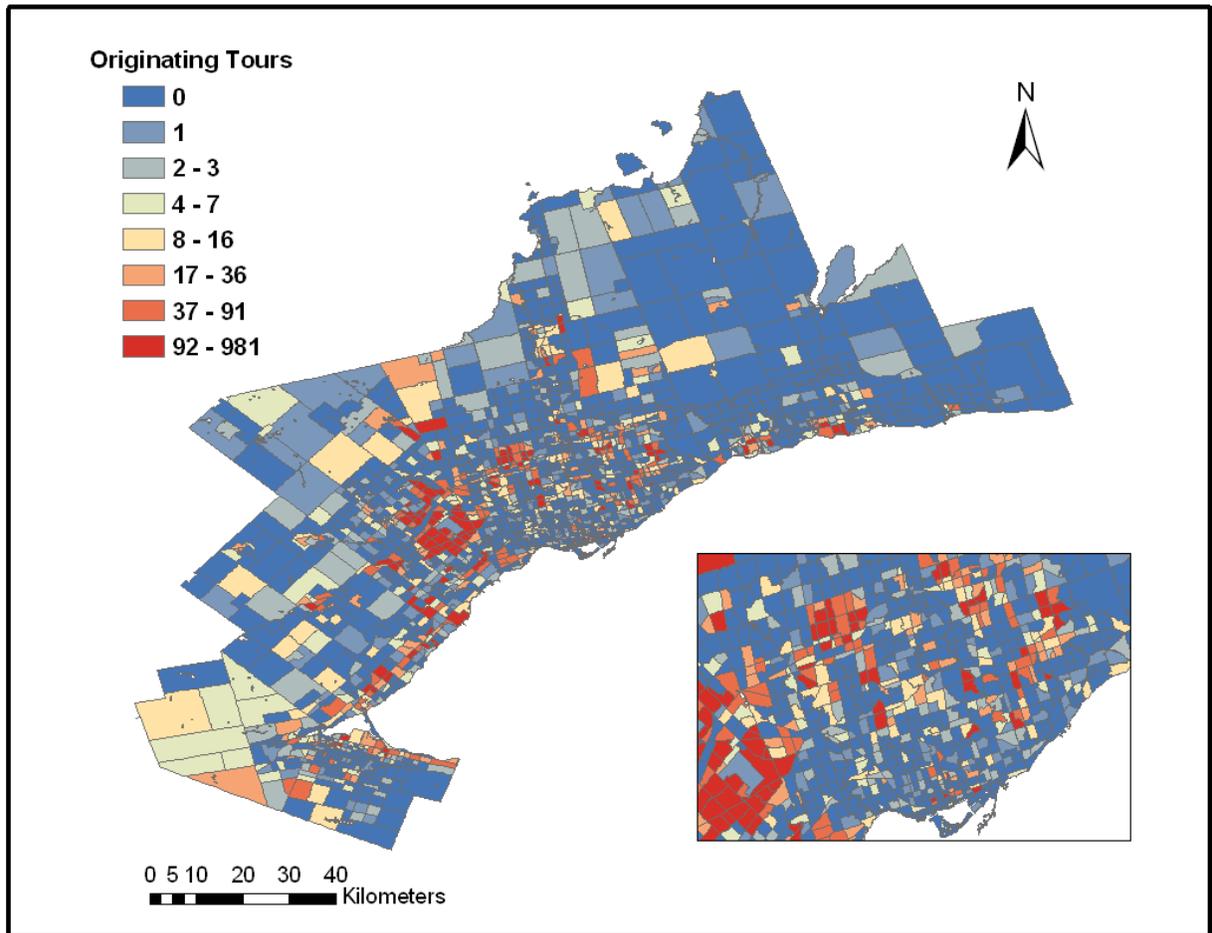
SIC, the firms from the Peel Survey (which were used to generate the ‘tours per employee’ distribution) reflected a broad industrial classification only. This means that a specific type of service firm from the InfoCanada dataset was treated during Monte Carlo simulations with a distribution of “tours per employee” reflective of a generic service firm. This error was mitigated somewhat by the screening process that was used on the InfoCanada data and which developed a prior classification of firms by broad tendency to produce tours.

Exhibit 14: Daily Tour Originations for Heavy Vehicles



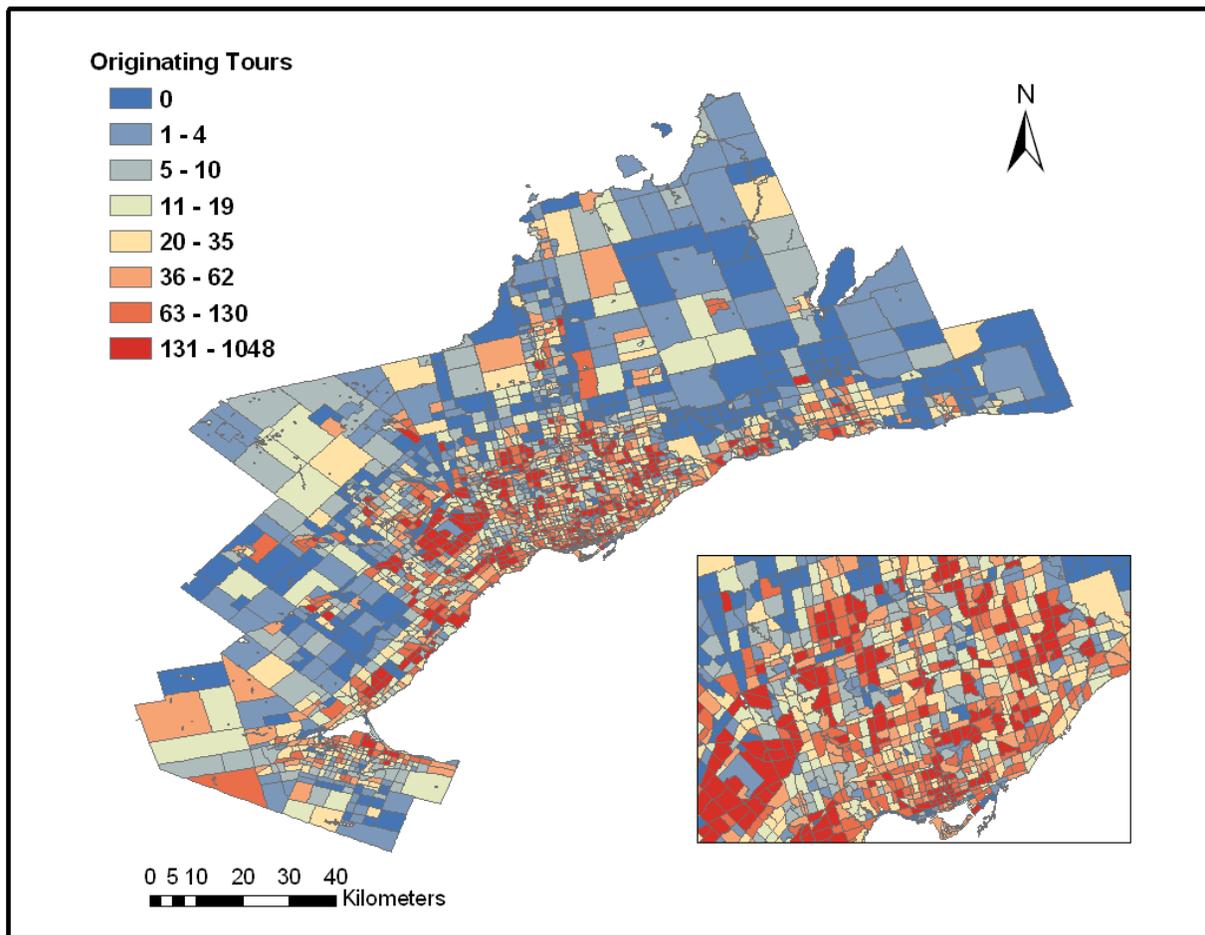
Exhibits 14, 15, and 16 show the results of the tour generation process on a zonal basis for heavy, medium, and light commercial vehicles, respectively. Of the three patterns, the one for heavy vehicles is most concentrated in certain key areas of the GTHA. Overall, heavy tour origins are most concentrated in Peel Region and in areas with good proximity to major highways. The industrialized area of Hamilton over to Stoney Creek is another spot of relative strength.

Exhibit 15: Daily Tour Originations for Medium Vehicles



As it turns out, the pattern for medium vehicles, seen in Exhibit 15, is a blend of the heavy and light patterns. While concentrations in Peel Region and Etobicoke are evident, the whole pattern is a bit less concentrated than is the case with heavy vehicles. The pattern is consistent with the fact that medium vehicles are more flexible in an intra-urban context than heavy vehicles and are better suited to many intra-urban applications.

Exhibit 16: Daily Tour Originations for Light Vehicles



The pattern for light commercial vehicles is the most dispersed of all, which makes sense in that many different types of firms will own such a vehicle and because these types of vehicles are very mobile. It is worth noting though that the areas which generate a lot of heavy vehicle tours are often doing the same for light vehicles.

Exhibit 17 shows the estimated per employee tour generation rates by industry. Note that the transportation industry has by far the highest rate, followed by wholesale. These results were derived from an iterative trial and error process with the overall micro-simulation, including tour simulation. Taking into account a variety of quantitative targets, these overall tour generation rates seemed to be associated with the most acceptable aggregate results. Further details are discussed below. In aggregate, the figures below are associated with an estimated 182,149 tours generated for the GTHA as a whole.

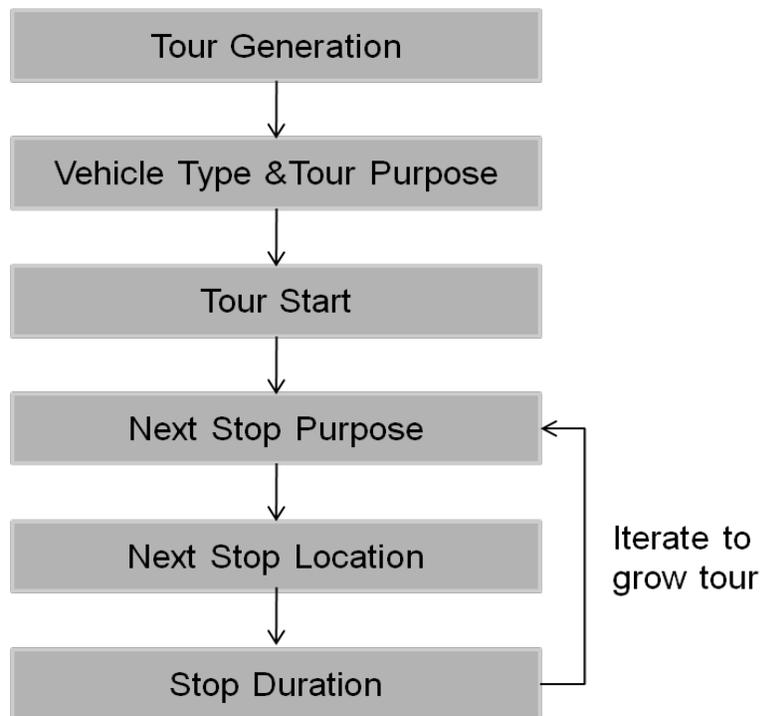
Exhibit 17: Estimated Tour Generation Rates Per Employee by Sector

Industrial	Wholesale	Retail	Services	Transportation
0.06019	0.13843	0.03458	0.04242	0.33181

4.1.2 Tour Simulation

In Exhibit 18, a schematic is shown which captures the essence of the tour-based framework. The tour generation phase has been described in the prior section and was based on a separate simulation and use of InfoCanada data. These firm level results from tour generation were aggregated into a matrix of estimated tour originations associated with the GGHM zones in the GTHA and the five broad firm types (industrial, wholesale, retail, services and transportation). As such, this matrix was of dimension 2,252 by 5.

Exhibit 18: Overall tour-based framework (source: Hunt and Stefan (2007))



A piece of the “tour start” process actually precedes the “vehicle type and tour purpose” process. In particular, there are a set of logit models by the five broad establishment types that seek to assign tour originations to a particular day part. The day parts of interest are midnight to 7AM, 7AM to 9AM, 9AM to 4PM, 4PM to 6PM and 6PM to midnight. These models were implemented with the same set of parameters and variables that Hunt and Stefan (2007) use in Calgary with the exception of some shifting of the model’s alternative-specific constants as was deemed necessary. Adjustments of this nature will be discussed later in this section. The models were heavily dependent on zonal land use dummy variables and measures of accessibility to employment. Because the GTHA has a different distribution of land uses than Calgary, the model adapted to the particular realities of the GTHA and adjusted forecasts

accordingly. For example, the GTHA is noted to be more industrialized than Calgary with more heavy manufacturing. The results for the GTHA, relative to Calgary, reflect this reality in terms of vehicle movements. The particular details of this sub-model can be found in Hunt and Stefan (2007).

With completion of this day part sub-model, and the utilization of another Monte Carlo process, each tour generated in the prior section was allocated to a day part. The ultimate result of this process was a 2,252 zone by 25 column matrix of tour origination totals. This matrix contained 5 blocks of 5 columns where each block related to establishment type and the columns within each block related to the five day parts.

Exhibit 19: Distribution of Tour Originations by Day Part and Industry

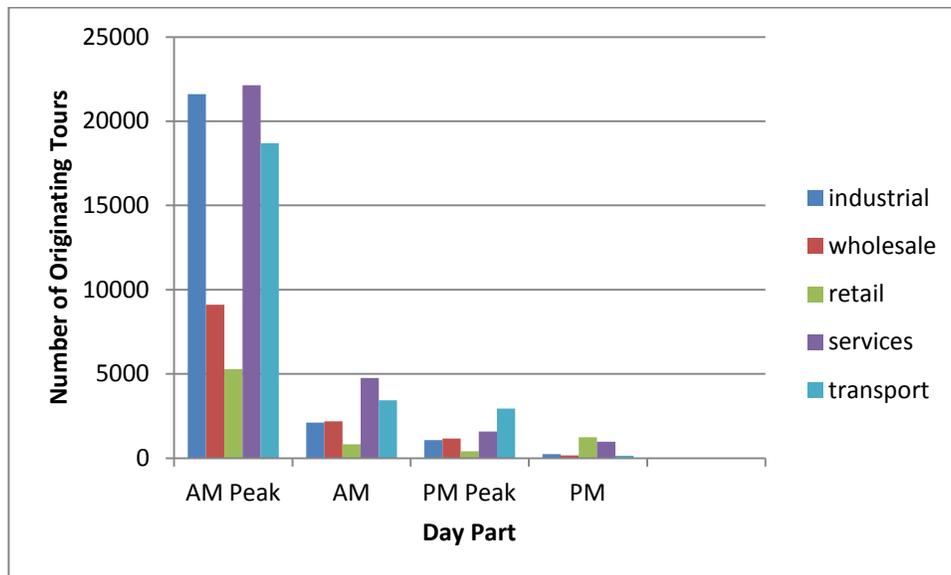


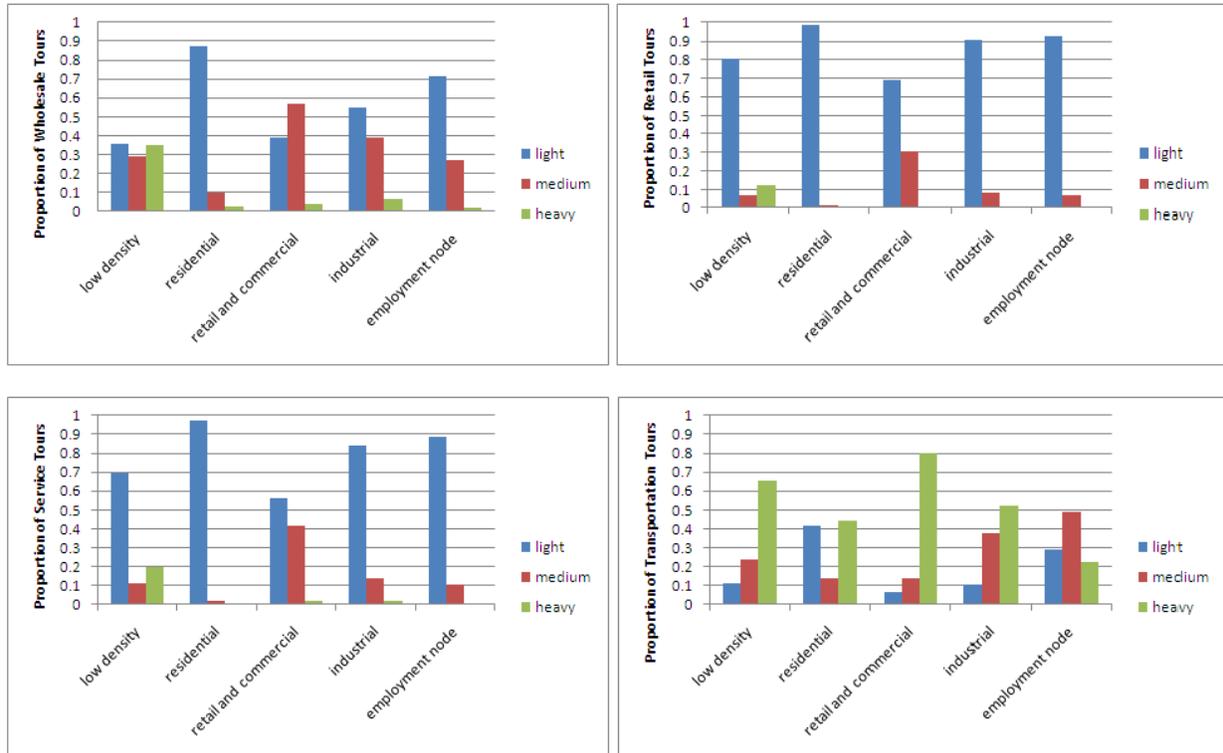
Exhibit 19 above illustrates how these 25 dimensions break down in terms of tour origination totals. Not surprisingly, the vast majority of tours are shown as commencing during the AM Peak and also during the daytime prior to PM Peak. Also, shown are some interesting sectoral patterns by time of day.

Vehicle type and tour purpose:

Having established the number of tours by establishment type and the broad time of day during which they would be originating, further characteristics of the tours needed to be defined. To this end, a nine alternative multinomial logit framework was adapted from the Calgary model where the alternatives were defined by the combinations of light, medium and heavy vehicles and goods, service or “other” tour purpose. As with the day parts model, there were five different models: one for each establishment type. The specification of this set of models is involved and can be seen in Hunt and Stefan (2007). Largely, the specifications rest on land use categorical variables and some associated interactions. However, it is interesting to study some of the outcomes of this model type. Exhibit 20 demonstrates a series of outcomes by land use type and establishment type. The focus is on the likelihood that a light, medium or heavy vehicle would be utilized for a given tour. These results were

obtained by considering the nine probabilities that the model estimates for each zone and then aggregating across the vehicle type dimension. To obtain a result for a given land use, the probabilities are averaged across all the zones that fall into the given land use.

Exhibit 20: Vehicle Type Probabilities by Land Use for Wholesale, Retail, Service and Transportation Establishments

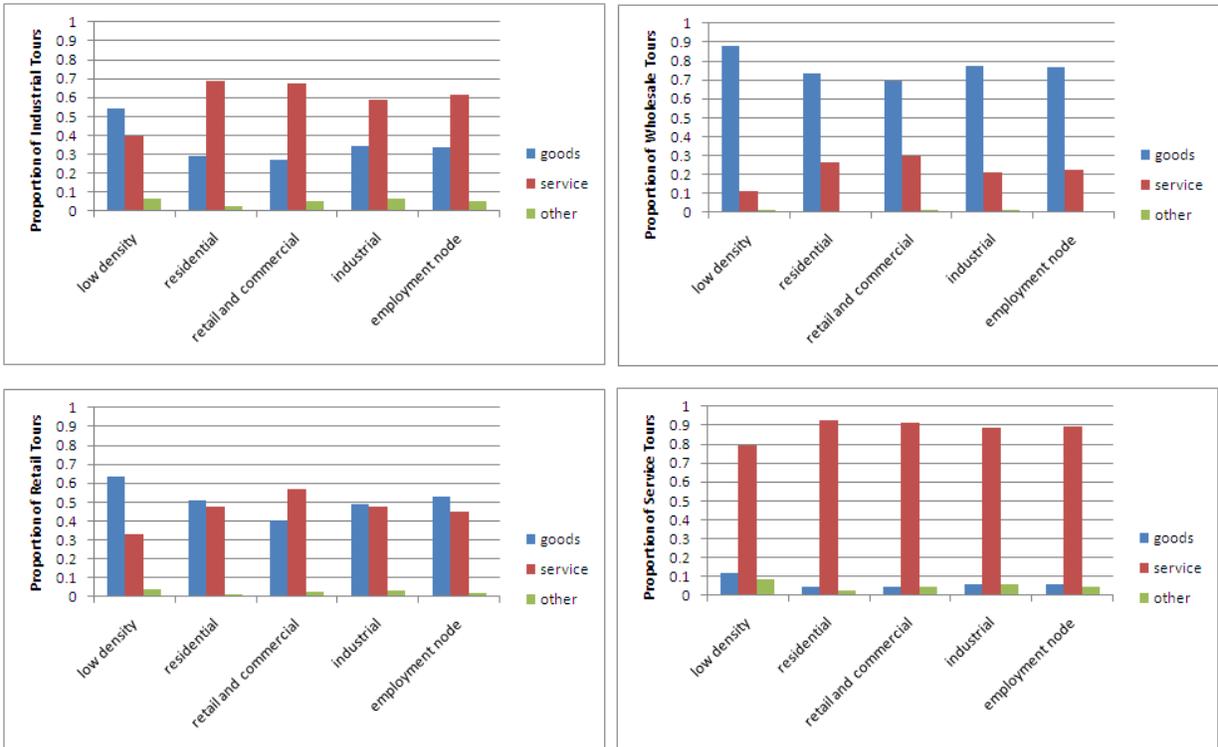


From Exhibit 20, observe that the likelihood of light vehicle usage is always highest for firms located in residential zones and typically lowest for firms located in low density zones. Heavy vehicle usage is more prevalent for industrial and wholesale establishments than it is for retail and services establishments. This outcome is not surprising. Selection of vehicle type is radically different for transportation establishments relative to all other establishment types. It is only for transport establishments that heavy vehicle usage predominates at all. Keep in mind that these results represent propensities that prevail given that a tour is originated. The degree to which these propensities are put into effect depends on that particular combination of establishment type and land use which apply for each firm.

Exhibit 21 provides the other perspective where the probabilities described previously are aggregated across the tour purpose instead of vehicle type, with the possibilities being: goods, services, and other. Some of the results are: that services firms have a low likelihood to originate goods tours, that wholesale firms have the highest overall likelihood to generate goods tours, and that land use effects are less well defined with respect to tour purpose than they are with respect to vehicle type. No chart

for transportation firms is displayed in Exhibit 21 because tour purpose is ambiguous for firms which provide the service of moving goods.

Exhibit 21: Tour type probabilities by land use for Industrial, Wholesale, Retail and Service Establishments



Tour start-time:

With the tour type and the vehicle type of the tour now identified, it was necessary to determine an exact departure time for the tour. Recall that the day part of this departure had been established but not the precise time of departure. This latter objective was accomplished with the use of a Monte Carlo process. No data were available to clearly show how tour departures were distributed across a given day part. While the Peel Survey did provide hints, the sample sizes were simply not large enough to determine tour departure times. Moreover, there appeared to be inadequate representation for certain day parts such as PM peak, for example.

To solve the problem, a trial and error process was adopted where the goal was to divide day parts into their hourly components so that a summation of all the hourly components for a day part would total 1.0. As a check, an hourly plot of all the simulated tour departures was derived where the intent was to avoid abrupt discontinuities at the boundaries between day parts. Ultimately, some ad hoc set of proportions for each day part was derived which appeared to provide reasonable temporal results. In terms of the actual implementation of the Monte Carlo process, for each tour a random number was generated which associated a tour with a specific hour within the day part and then an interpolation

process was used to determine the specific minute of departure within that hour. Clearly, the larger the probability associated with a day part hour, the more likely that a tour would depart within that hour.

Next stop purpose:

At this stage, all “one-time” elements of a tour are established. The “multiple-time” aspects relate to the purpose and destinations associated with a tour and how these elements evolve constantly as a tour progresses one trip at a time. The original Hunt and Stefan framework was associated with no less than thirteen different tour segments each linked to distinct tour behavior characteristics as calibrated on observed survey information. The segments are displayed in Exhibit 22 where it can be seen, for example, that the framework permits a services establishment to have a goods tour and a retail establishment to have a services tour. Note that none of the tour segments are specifically related to medium or heavy vehicles separately; the two vehicle types are always lumped together.

Exhibit 22: Thirteen Segments of Tour Types (source: Hunt and Stefan (2007))

Segment #	Segment Description
1	Service Tours by Services Establishments Using Light Vehicles
2	Service Tours by Services Establishments Using Medium or Heavy Vehicles
3	Goods Tours by Services Establishments with any vehicle type
4	Service Tours by Retail Establishments using any vehicle type
5	Goods Tours by Retail Establishments using any vehicle type
6	Service Tours by Industrial Establishments using light vehicles
7	Service Tours by Industrial Establishments using medium or heavy vehicles
8	Goods Tours by Industrial Establishments using any vehicle type
9	Service Tours by Wholesale Establishments using any vehicle type
10	Goods Tours by Wholesale Establishments using light vehicles
11	Goods Tours by Wholesale Establishments using medium or heavy vehicles
12	Business Tours by Transport Establishments using any vehicle type
13	Other Tours by any Establishments using any vehicle type

As any given trip originates within a tour, an important task is to determine the purpose of that trip. The three purposes considered within the Hunt and Stefan framework are related to the nature of the stop at the end of a given trip and are: a business stop, an “other” stop and a “return to establishment” stop. In the typical tour, all three stop types will be represented but this is not always the case. Hunt and Stefan have provided detailed specifications for implementing thirteen calibrated next stop purpose models (one for each segment) but, as it turned out, reasonable results for this particular set of calibrated results could not be obtained in the GTHA context. Given that several of their temporal variables are measured in minutes, several of the temporal parameters appear to give implausible results when implemented. It is possible that Hunt and Stefan’s tabular representation of calibrated results has not faithfully represented the true nature of their models.

Given the difficulty of implementing the next stop purpose models from Hunt and Stefan, the decision was made to calibrate some replacement models based on observed tour behavior from the Peel Survey. On the one hand, this route offered advantages since it captured behavior from the actual

GTHA study area but, on the down side, there was not a large amount of behavior with which to work. A series of models was built on the approximately 750 tour legs from the Peel Survey. For a small subset of the segments, there was enough information to generate some statistically significant results but for most of the thirteen segments, there was not nearly enough observed behavior.

Exhibit 23: Sample Specifications of Next Stop Purpose Models

	beta	t-stat	beta	t-stat	beta	t-stat
CONST (1)	4.255	7.7198	7.331	3.1891	5.239	5.6379
CONST (2)	2.262	3.7214	5.221	2.2397	3.562	3.5883
# previous biz stops (1)	-0.182	-2.8577	-0.374	-2.2125	-0.502	-3.2724
# previous biz stops (2)	-0.228	-2.7124	-0.324	-1.8427	-0.47	-2.4191
# previous other stops (1)	-0.356	-3.4179	0	0	-0.356	-3.0107
cumulative minutes in tour so far (1)	-0.004	-4.0107	-0.009	-2.8306	-0.002	-1.3766
cumulative minutes in tour so far (2)	-0.003	-2.3964	-0.007	-1.987	-0.003	-1.4819
rho-squared		0.374		0.397		0.407
rho-squared with constant		0.121		0.167		0.175

Exhibit 23 shows selected results from the multinomial logit calibrations and the types of variables that were employed. Key variables included the number of previous business stops that had occurred on a given tour, the number of previous stops for “other” purposes and also the cumulative minutes associated with the current duration of the tour. Note that this cumulative time variable would include travel times as well as stop times. The alternatives for these models are: 1) a business stop, 2) an “other” stop and 3) a return to establishment stop. Here, a business stop refers to either a goods or services stop. The three models displayed above cover goods tours in general, goods tours by retail firms with any vehicle type and goods tours by industrial firms with any vehicle type. Overall, the three models above have provided some significant results and reasonable fits, as indicated by the rho-squared statistics.

In the specifications of Exhibit 23, all variables are specific to the first two alternatives and in reference to the third alternative. In all cases, the alternative-specific constants are larger for the business stop alternative than “other” stop and both are larger than zero. On the first leg of a tour, all other variables are zero and hence the predicted probabilities can be derived with the constants alone. For the first model, this is associated with a business stop probability of 0.87, an “other” stop probability of 0.12 and a return to establishment probability of 0.01. As a tour progresses, the results are such that the probability for return to establishment increases. All results are consistent in reducing the utilities for business or other stops as the number of prior stops pile up and as more elapsed time passes. One result with respect to goods tours is that retail firms produce tours that appear more sensitive with respect to tour duration while industrial firms produce tours that are more sensitive to the count of prior stops.

To actually fill in parameter results across thirteen different segments, a variety of assumptions and approximations were required. Various subsets of the 750 tour legs were used to carry out calibrations. Some calibrations focused on vehicle type while others focused on establishment type and type of tour.

In the end, a patchwork of these models was used to fill in the parameter tables for each of the segments. While this approach was not ideal, and while the Peel Survey provided much more to work with on the goods side than the services side, the final set of results seemed to perform in a stable manner within the microsimulation framework. As mentioned, there was little alternative since the next purpose stop models of Hunt and Stefan could not be properly implemented.

Next stop location:

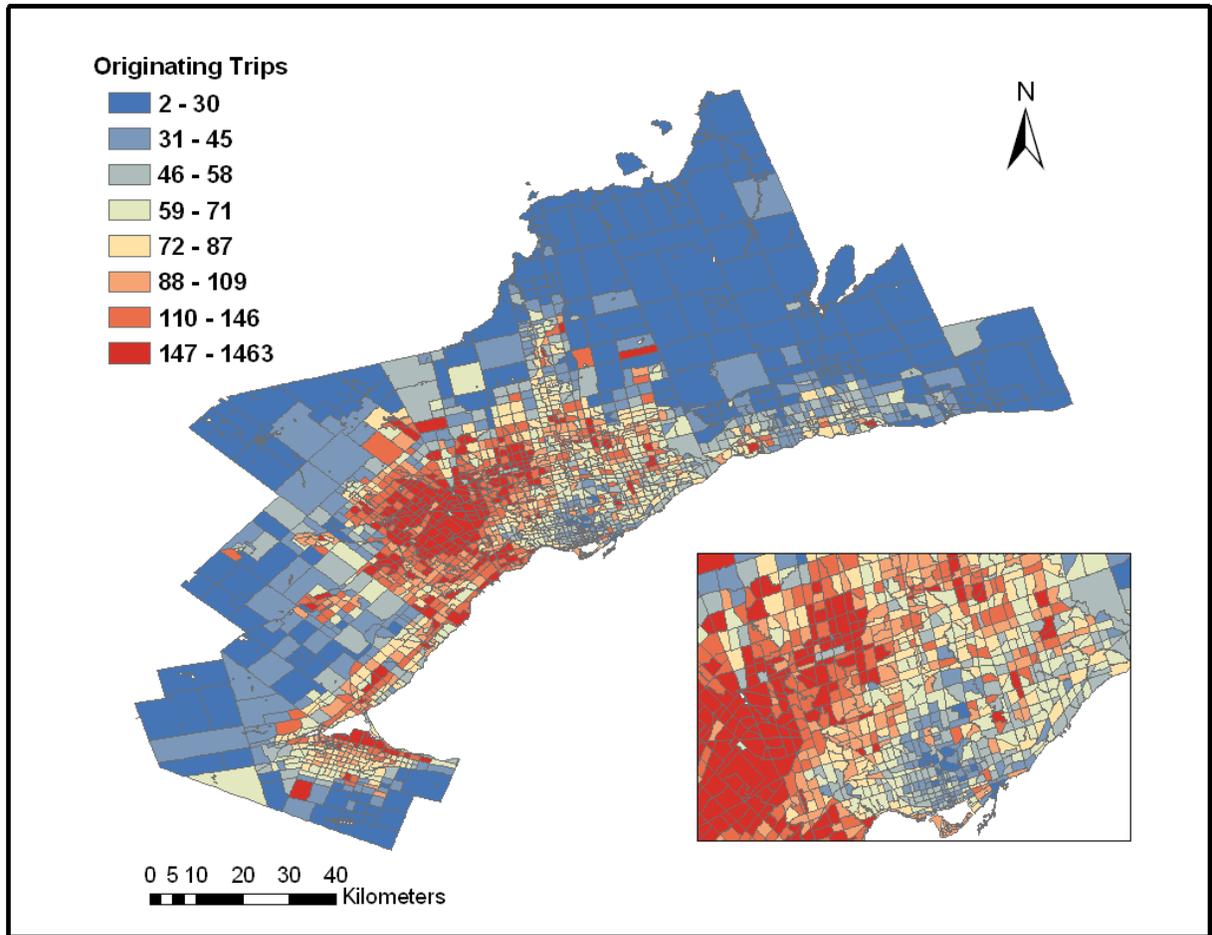
With respect to “next stop location”, more success was achieved in transferring the parameters obtained in Calgary and getting reasonable results in the GTHA. The details of the models for the thirteen different segments can be found in Hunt and Stefan (2007). There was a pair of parameter changes that were made to their results for application to the GTHA. In particular, parameters relating to measures of population and employment accessibility were reduced across the board and parameters relating to the “size” of prospective destinations, in terms of population and employment, were increased across the board. Repeated runs of the microsimulation suggested that these changes produced more intuitively correct results in the GTHA context.

With the implementation of the “next stop location” model, the overall framework was in place. For a given tour, the “next stop purpose” model adjusted the likelihood of choosing particular types of stops while the next stop location model determined where these stops would take place if the stop was for business or “other” purposes. Upon completion of a given tour, the microsimulation would move on to the next one and so on until all generated tours in all zones had been simulated. Overall, the microsimulation was run a number of times with adjustments being made along the way to steer the overall results towards target aggregates. For example, attention was paid to the ratio of light, medium and heavy trips and to the distribution of trips across the thirteen segments of the Hunt and Stefan framework. Also, it was important to produce reasonable temporal patterns for trips. From the point of view that many tours in the simulation lasted for several hours, it was actually not easy to achieve appropriate concentrations of trips in periods leading up to the PM peak for example. Many of the trips that are occurring at 4pm, for example, are parts of tours that had originated many hours earlier.

Results of the Tour-based microsimulation:

The primary result of interest for the tour-based microsimulation was a set of Origin Destination (OD) matrices describing modelled flows of light, medium, and heavy CVs between the 2,252 zones. One O-D matrix was produced for each hour leading to a total of 72 tour-based O-D matrices. To represent the tours in these O-D matrices, it was necessary to decompose the tours into their constituent trips. For each trip within a tour, the time and zone of departure was taken into account along with the zone of the destination. The appropriate hourly O-D matrix was chosen on the basis of the time of trip departure and was not related at all to the time of arrival. Of course, both the origin and the destination of the trip needed to be represented in the same hourly matrix. In this manner, every trip within every tour was assigned to one O-D matrix.

Exhibit 24: Daily Trip Originations from Heavy CV Tours



Exhibits 24, 25, and 26 show the number of daily tour-related trips originating in GTHA zones for heavy, medium, and light commercial vehicles, respectively. These maps are to be contrasted with Exhibits 14, 15, and 16, which show tour originations. Trip originations in this context reflect the originations of particular legs within tours after a given stop is complete and the next leg starts. The contrast with Exhibits 14-16 shows that tour-based trips will tend to originate in more places than the tours themselves. It makes sense that the stops on tours would likely cover a wider range of locational possibilities than the sites of tour beginnings. Nevertheless, fairly strong distance decay effects are evident where it can be seen that the trip origination patterns are somewhat anchored to the tour origination patterns. Again, the trip origination pattern for light vehicles is quite dispersed relative to that of heavy vehicles.

Exhibit 25: Daily Trip Originations from Medium CV Tours

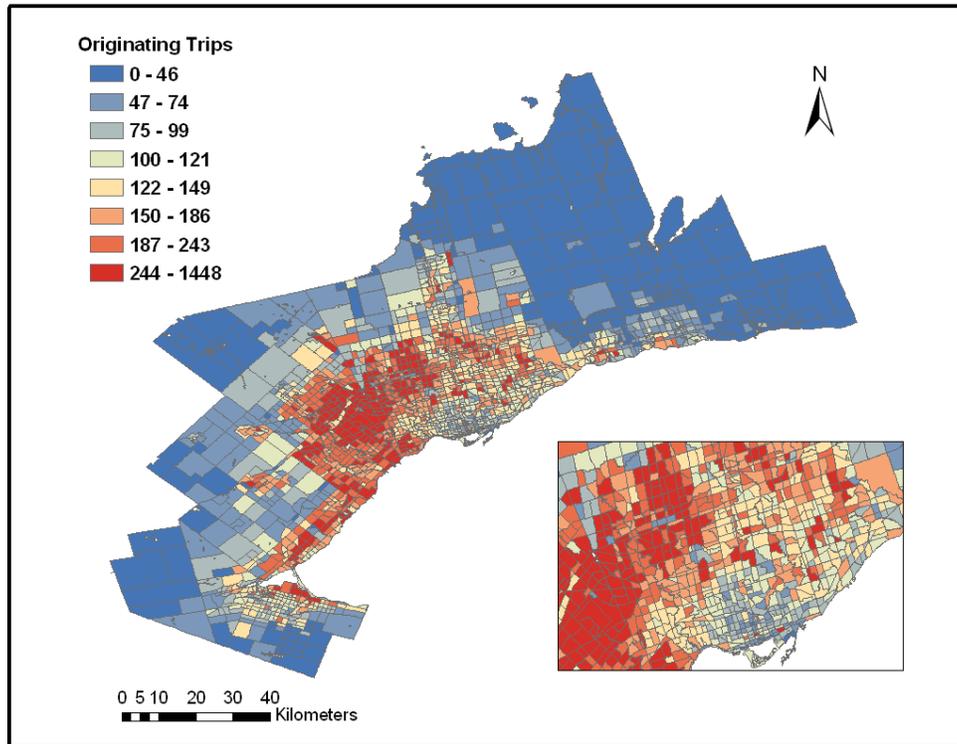


Exhibit 26: Daily Trip Originations from Light CV Tours

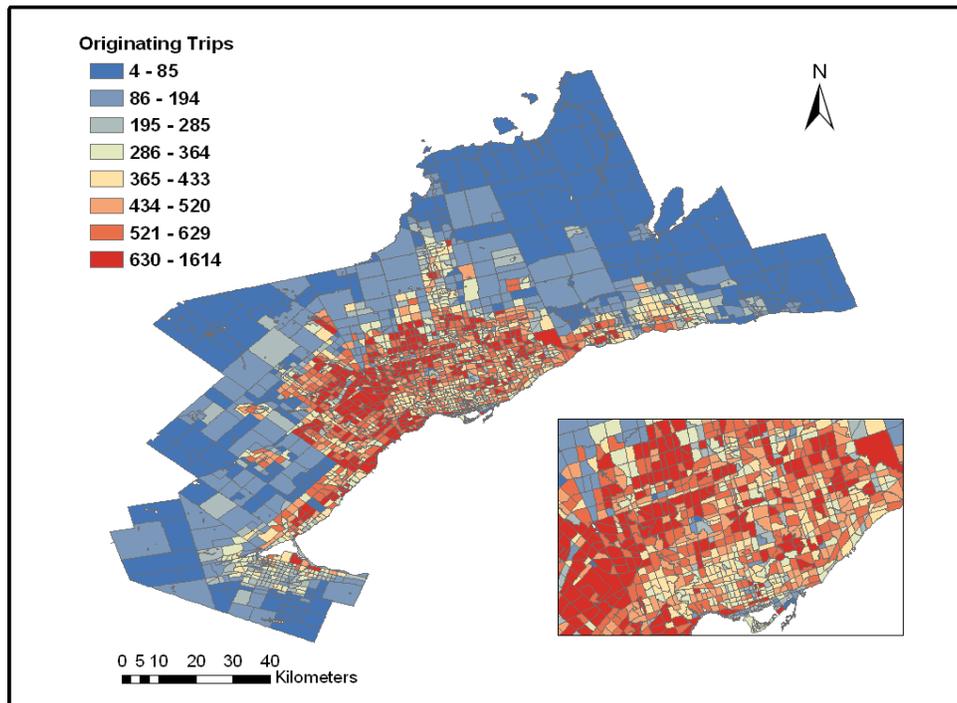
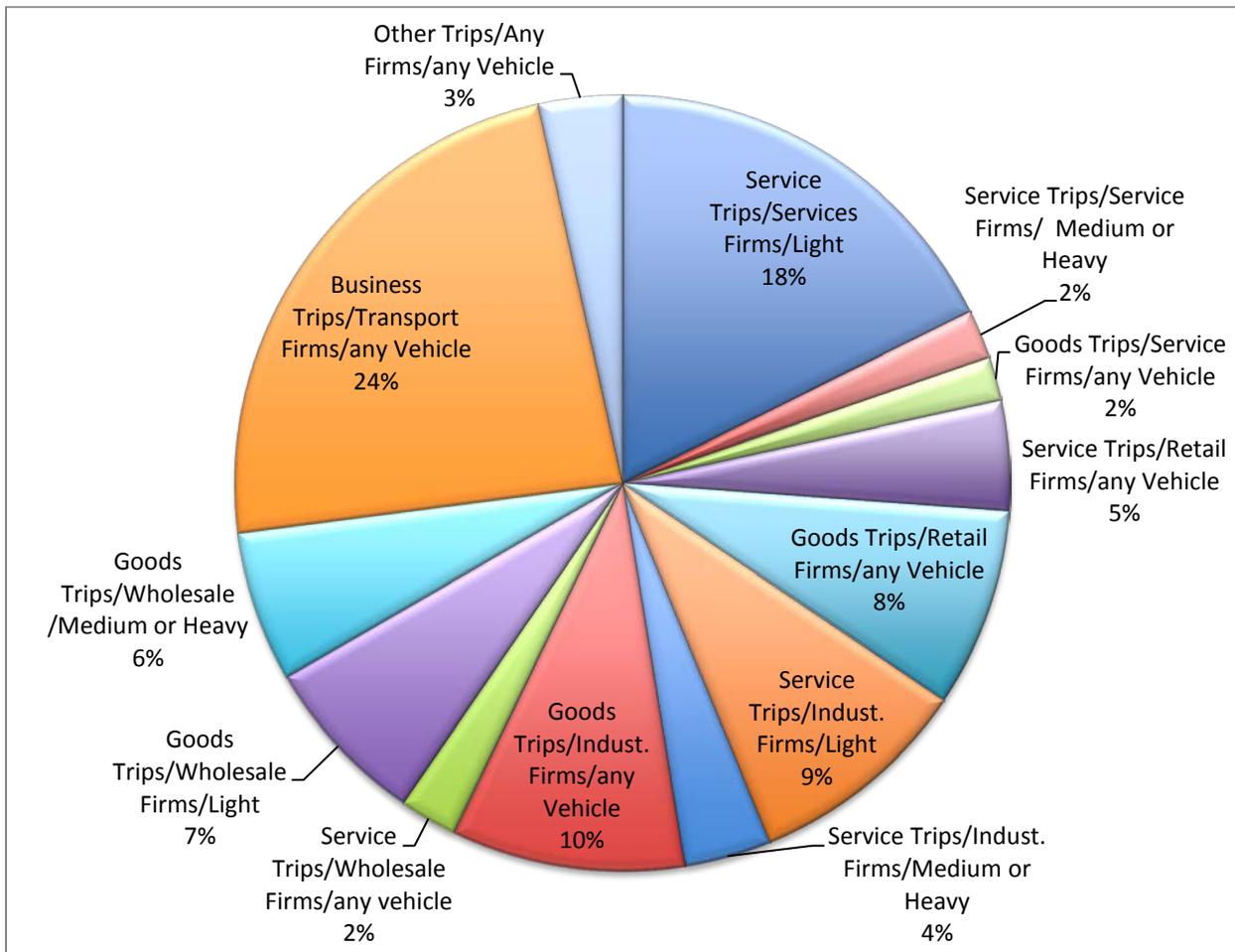


Exhibit 27 shows the percentage breakdown of tour-based trips by the 13 tour segment types (see Exhibit 22 for the detailed list of segments). This distribution of trips across segments was obtained through an iterative process. Actually, one of the main criteria to determine whether to terminate the iterative process was to judge whether the distribution in Exhibit 27 seemed reasonable in its own right and in comparison to results from the Calgary application. Key aspects of the final distribution of trips, as derived from the tours, are that transport firms are generating a substantial proportion of commercial trips as is the case with service oriented trips using light vehicles.

Exhibit 27: Distribution of Tour-based Trips by Tour Segment Types



4.2 Estimation of Fleet Allocator Trips

Fleet-allocators are CVs which are dispatched to cover territories of urban areas. Examples would include road maintenance vehicles, courier, mail delivery or garbage trucks. In this project, the modelling of fleet-allocator movements is handled using conventional trip generation and trip distribution methods. This approach is not in any way tour-based or establishment-based. It is not particularly innovative but accomplishes the main goal of deriving some fleet-allocator estimates in the absence of any detailed data on the topic. Stefan et al (2007) explore the implementation of fleet-

allocators within a tour-based framework in some preliminary research. In this paper, they provide some trip generation equations which we have utilized in the context of the GTHA.

Trip Generation:

Fleet-Allocator daily trip totals were estimated separately for light, medium, and heavy CVs using existing regression models. The model coefficients were taken from Stefan et al (2007) while explanatory variables to drive the models were derived from InfoCanada firm data and the census. Exhibit 28 illustrates the parameters that were used to generate the trips; each row of results is associated with a separate regression model. From the table we can see that population is associated with only the generation of light vehicle trips. Industrial employment seems to be a good relative predictor of light vehicle trips while wholesale and retail employment are more strongly associated with the prediction of medium vehicle trips.

**Exhibit 28: Edmonton Fleet Allocator Trip Generation Parameters
(source: Stefan et al (2007))**

Vehicle Type	Population	Industrial Employment	Wholesale Employment	Retail Employment	Services Employment	Transport Employment	GTHA Predicted Trips
Heavy	-	0.0040	0.1551	0.0047	-	-	37,588
Medium	-	0.0937	0.5221	0.1231	0.0118	0.0342	271,700
Light	0.0004	0.1927	0.1257	0.0547	0.0313	-	235,490

Upon application of these models to each of our 2,252 zones in the study area, the result is a 2,252*3 matrix of fleet allocator trips. The final column in Exhibit 28 is a new result for this study and shows the 24 hour fleet allocator trip totals which are predicted for the entire GTHA. The results suggest that fleet allocators are particularly associated with commercial vehicles of medium size.

Trip Distribution:

Bearing in mind that the end-product sought are O-D matrices, it is necessary to distribute the trip totals from each of the 2,252 origins to each of the 2,252 destinations. To do so, a set of multinomial logit models was employed. Since there was no particular information on the actual trip patterns of fleet allocators, an assumption was made that the tour-based results might provide some guidance. For the derived tour-based O-D matrices, logit models were calibrated for light, medium and heavy vehicles in each case across the aggregation of 24 hours. The variables used in the models are: zonal population, sectoral employment totals across a range of sectors, and inter-zonal drive distances. The resultant models were applied appropriately to the light, medium and heavy fleet allocator trip origination totals to derive the three 2,252*2,252 O-D matrices of fleet allocator trips. Given that tour-based trips are typically significantly longer than fleet-allocator trips on average, the distance decay parameters for the three models were significantly steepened until an appropriate average trip length was obtained. The final average trip lengths obtained were: 7.8km for heavy vehicles, 8.8km for medium vehicles and 9.0km for light vehicles. These results were in line with the results obtained in Alberta by Stefan et al (2007).

For the purposes of the subsequent traffic assignment and validation, it was necessary to turn these 3 fleet allocator matrices into 72, by splitting each into 24 hours. To this end, the tour-based results were utilized to tabulate an hourly proportional distribution of trips. Application of these proportions resulted in a full set of 72 fleet allocator O-Ds.

Exhibit 29: Daily Heavy vehicle fleet allocator originations

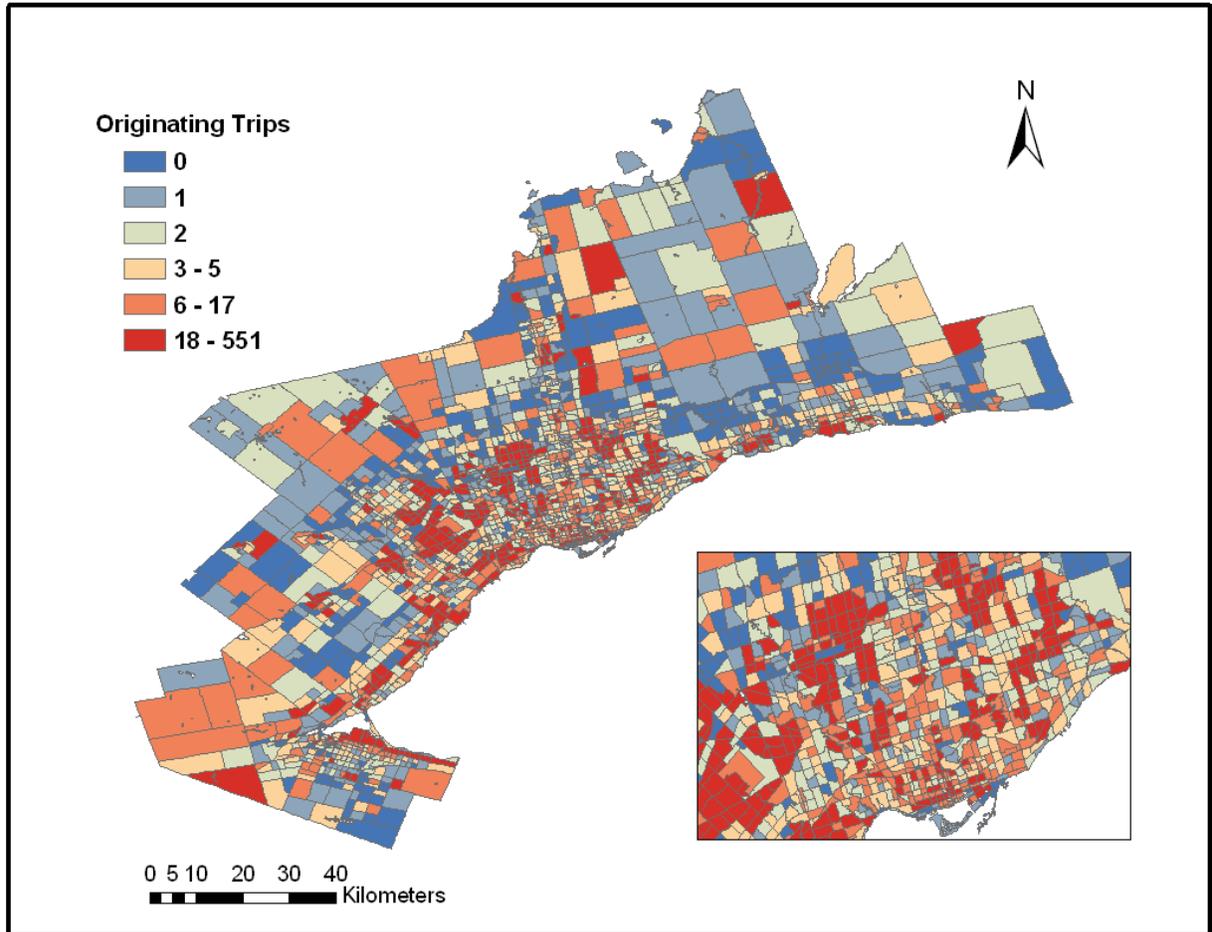


Exhibit 30: Daily Medium vehicle fleet allocator originations

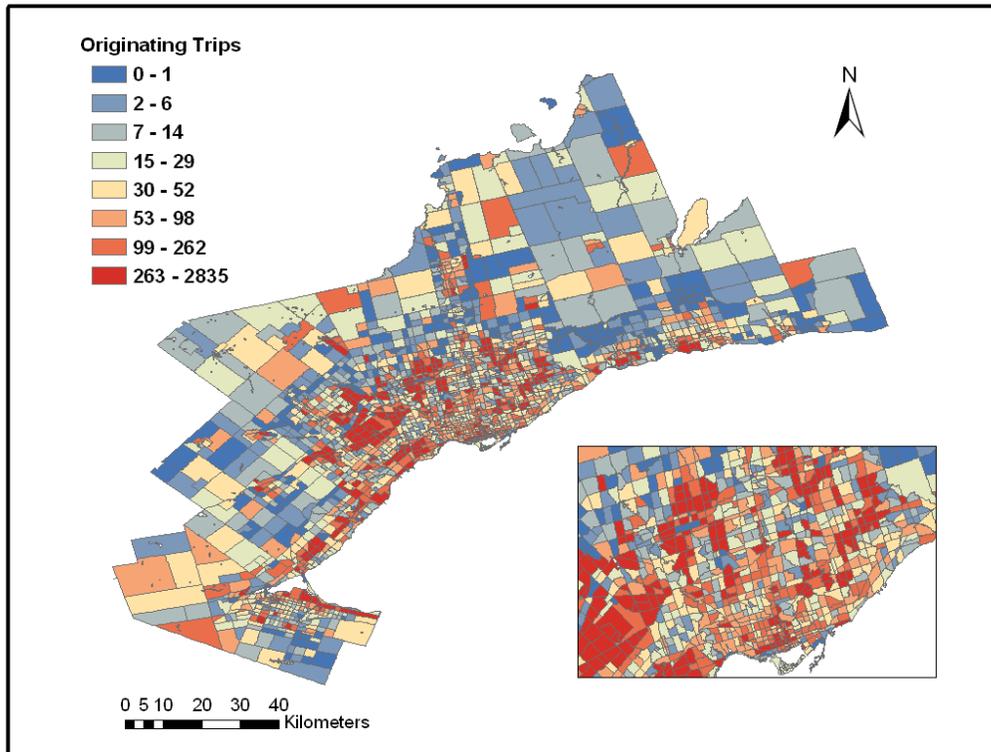
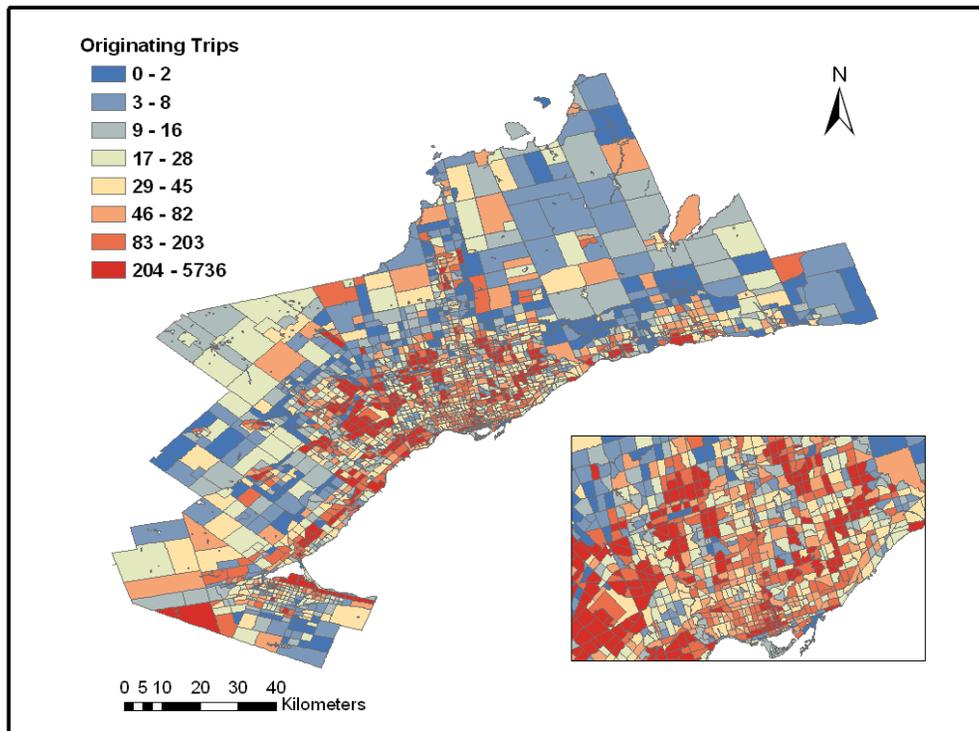


Exhibit 31: Daily Light vehicle fleet allocator originations



Exhibits 29, 30, and 31 show fleet allocator trip origins over space, for heavy, medium, and light CVs, respectively. These can be compared to the trip origin maps for tour-based UCVM (see Exhibits 24, 25, and 26). Note that fleet-allocator trip origins are far more dispersed throughout the study-area than their tour-based counterparts. Also, among the fleet-allocator CVs, heavy CVs show a greater pattern of dispersion over the study area than medium or light CVs.

4.3 Estimation of Trips with External Origins or Destinations

For estimates of commercial vehicle trips with external origins or destinations, the process relied totally on the 2006 Ontario Ministry of Transportation Commercial Vehicle Survey, which was provided by MTO to assist in these efforts. The CVS is carried out as a truck intercept survey where questions are posed to the driver about the nature of the cargo and the origin and destination of the trip. The data were received as a collection of O-D information for “straight” trucks and “multi-unit” trucks. The former were interpreted as medium size trucks and the latter as heavy trucks.

The zones on which the O-D information is based is the zonal system associated with the Greater Golden Horseshoe Model. As such, there is representation from Niagara and the Kitchener-Waterloo area, for example, which goes beyond the spatial scope of the GTHA study area. The GGHM zonal system contains several hundred more zones than the subset which defines the GTHA zonal system but certainly the majority of zones overlap.

The MTO data handles the issue of external origins or destinations with the concept of a traffic “gateway”. Since the data are intended to paint a picture for the GTHA, there is little point in explicitly recognizing some originating zone that is hundreds of miles from the study area. A trip that originated in Michigan, for example, would have been represented as entering the GTHA through the western Highway 401 gateway – this particular gateway was essentially coded as if it were a zone rather than a traffic link. Meanwhile, the other end of the trip, which terminates somewhere within the GTHA, is explicitly associated with one of the 2,252 zones in the study area. In this manner, trips that might have been associated with hundreds of distinct zones throughout large parts of North America were briefly summarized through a handful of traffic gateways and the associated zones internal to the study area.

With respect to the original GGHM zonal system, the CVS deals with internal-external, external-internal, internal-internal and external-external trips. The first denotes an internal zonal origin and an external destination, the second defines the converse, the third defines trips with origins and destinations entirely within the GGHM system and the latter case defines trips with origins and destinations entirely outside the GGHM study area.

One complication was the fact that the gateways received were quite appropriate for the full GGHM zonal system but somewhat less appropriate for the smaller GTHA zonal system. As a result, some of the gateway locations were “further out” than the external boundaries of the GTHA study area. In addition, the MTO data dealt in detail with intra-GGHM zones that were peripheral to the GTHA study area. The overall effect of this issue was that the GTHA based MTO data would lead to a higher proportion of the trips having an external origin and/or destination.

The tabulations for the various trip and truck types as derived from the CVS data are presented in Exhibit 32. The totals reflect a GTHA-based interpretation of what is internal or external. Therefore, there are many trips that would be considered, for example, internal-external in the table which would have been internal-internal using the full GGHM zonal system. Overall, the table shows that heavy trucks are relatively much more prominent for external trips. Meanwhile, those trips with at least one origin or destination in the GTHA are about twice as prevalent as trips that pass through the GTHA all together.

Exhibit 32: Estimated Truck Flows with an External Origin or Destination

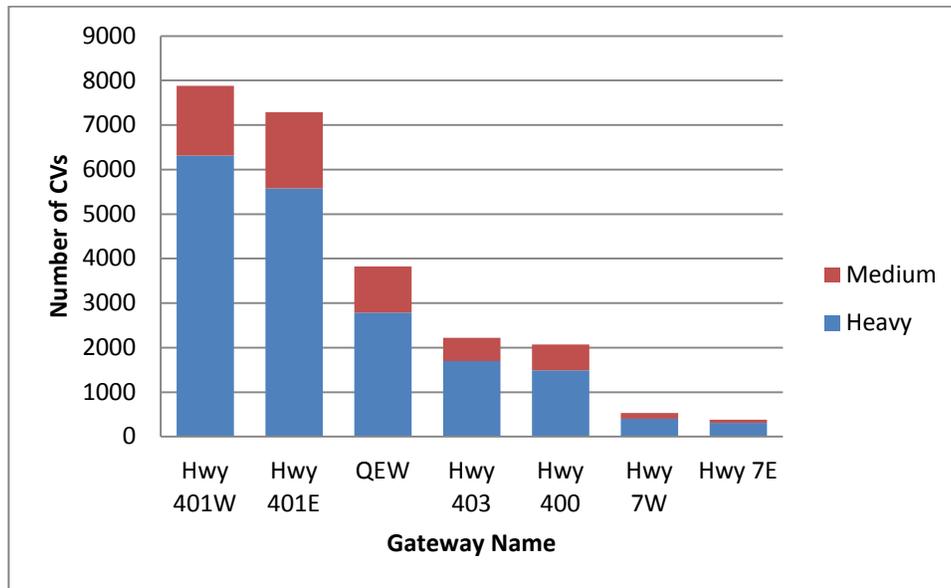
Vehicle Type	Internal-External	External-Internal	External-External	Total
Heavy	18,931	18,321	14,127	51,379
Medium	5,940	4,913	3,664	14,517

A further issue was how to assign flows for zones that were external to the GTHA system but were internal for the GGHM system. Such zones included areas such like the Niagara Peninsula and Kitchener-Waterloo. In order to work with the gateways that were given, an inventory of these flows was done and their totals used to scale up the various gateway totals. In essence, these additional flows which had become “external” were added to the gateways in proportion to the “pure” gateway flows associated with the strict definition of the GTHA. The net result was an appropriate set of totals but slightly altered spatial flow patterns only for those zones that switched from internal to external.

It is important to note that, not surprisingly, the MTO CV survey does not include light CVs. It is probable that non-trivial amounts of internal-external, external-internal, and through trips are carried out by light vehicles, but unfortunately there is no obvious basis on which to measure these trips.

Exhibit 33 shows the number of heavy and medium internal-to-external trips exiting at various gateways out of the study area. In all cases, the majority of CVs are heavy, and the higher proportion of heavy CVs becomes more pronounced on the lower volume gateways. As expected, the 401E and 401W gateways handle a disproportionately high volume of exiting CV traffic. The QEW, Highway 403 (towards Brantford), and Hwy 400 play important secondary roles.

Exhibit 33: Gateway Used to Exit GTHA for Internal-External Trip (by Truck Type)



Exhibits 34 and 35 show the volumes of heavy and medium CVs making Pass-through trips, as they enter and exit the study area, respectively. As in Exhibit 33, the majority of Pass-through trips are made by heavy CVs, and the 401E and 401W gateways tend to contain the highest volumes of trips. It is interesting to note that the QEW is relatively more important for pass-through trips that are exiting the GTHA as opposed to entering it.

Exhibit 34: Gateway used to enter GTHA for a Pass-thru trip (by truck type)

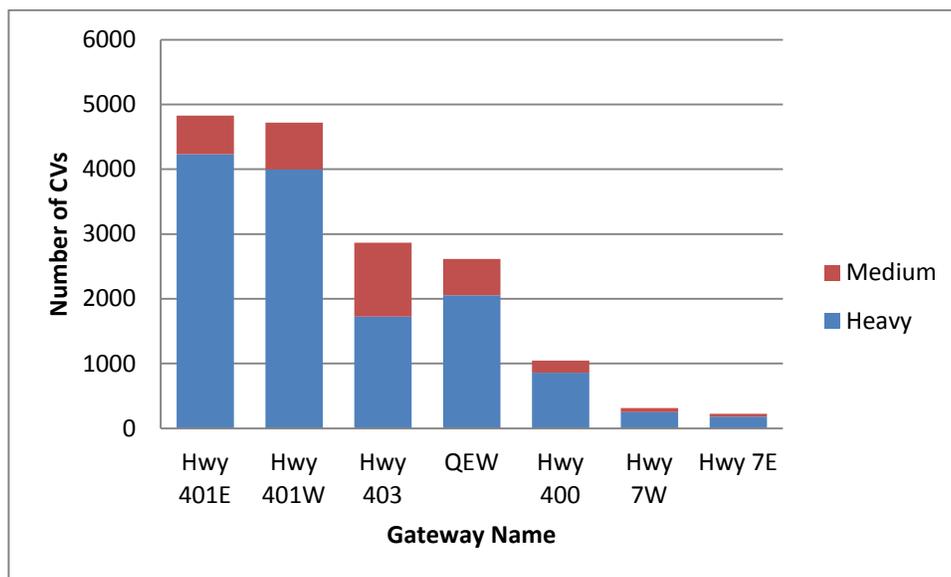
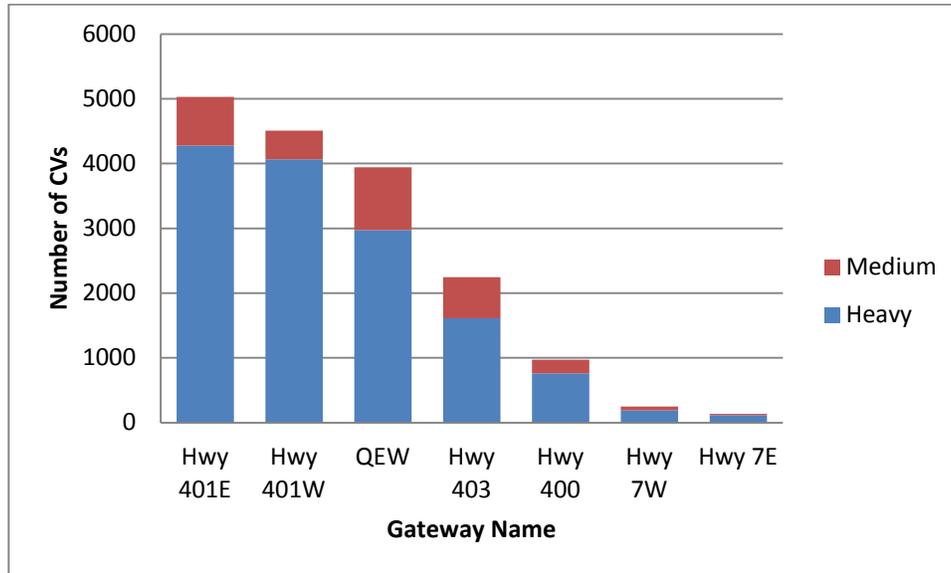


Exhibit 35: Gateway used to exit GTHA for a Pass-thru trip (by truck type)



Exhibits 36 and 37 show CV originations over space, for all-day internal to external trips, for heavy and medium CVs. It is interesting to note that the pattern for heavy vehicles is more dispersed than that for medium vehicles. The results suggest that there are only select areas that will send medium-sized trucks for trips outside the GTHA. This is in contrast to the tour-based results which relate to intra-GTHA trips and which suggest that the pattern of medium patterns originations is more dispersed than the one for heavy vehicles. For the most part, the CVS results show that the pattern for medium vehicles is a spatial subset of the pattern for heavy vehicles.

Exhibit 36: Estimated daily heavy vehicle origins for internal to external trips

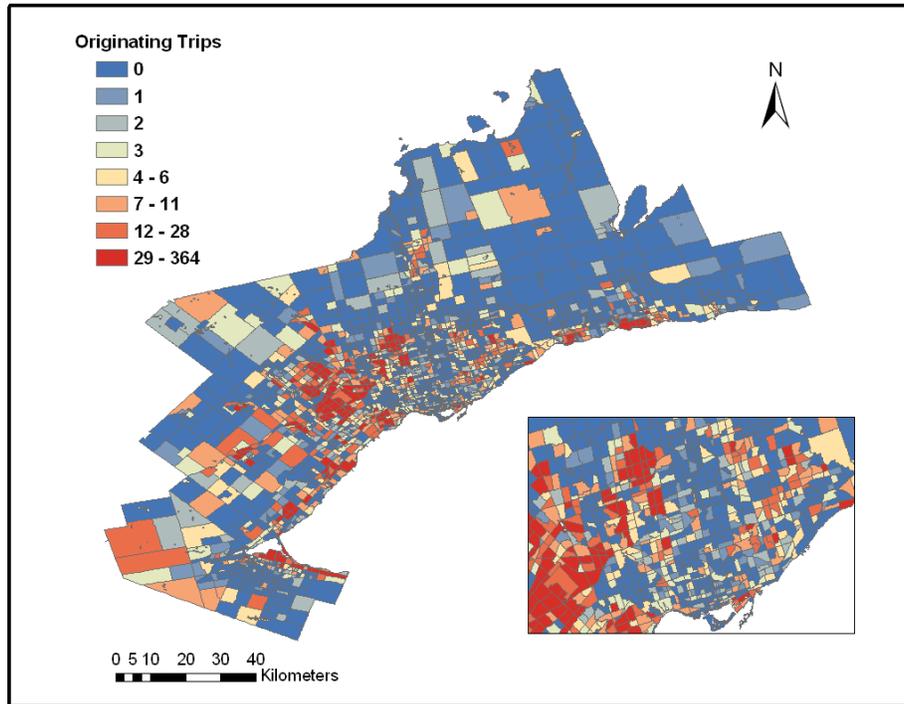
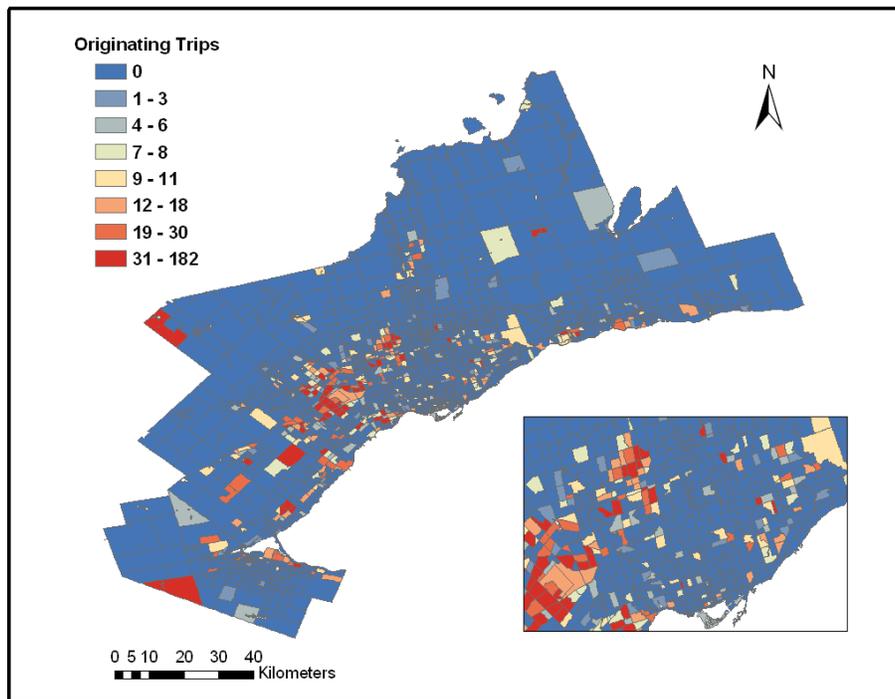


Exhibit 37: Estimated daily medium vehicle origins for internal to external trips



4.4 Overall Results

While previous sections presented results for tour-based UCVM, fleet-allocator UCVM, and internal-external movements individually, this section presents final results of all UCVM summed together.

Exhibit 38 shows the breakdown of CV trips in the study area by vehicle type and trip type. Note that tour-based UCVM make up the majority of UCVM in the study area. Also note that light UCVM are not estimated in the internal-external framework (see Section 4.3). In aggregate, approximately 2 Million commercial trips are estimated to take place in the GTHA during the typical business day when all trip and vehicle types are considered together. Some of these trips are short in terms of distance and duration and others, particularly some of the internal-external trips, will cover a large distance within the GTHA. Also, some of the trips tabulated will relate to non-business purposes such as stopping for lunch or some other type of personal trip. It is worth comparing Exhibit 38 to Exhibit 54 where the latter provides some estimate of the vehicle kilometers travelled in carrying out these trips. Exhibit 54 is saved for the validation section because it is associated with one of the methods used to verify these results.

In terms of the end-products of this analysis, 72 O-D matrices were produced that relate to tour-based commercial movements (24 hours by light, medium and heavy vehicles). There are three matrices that relate to fleet allocator movements and there are three smaller matrices that capture internal-external movements. The aggregate results of all these are represented in Exhibit 38.

Exhibit 38: Aggregate movements by trip type and vehicle type

Trip Type	Heavy Vehicle	Medium Vehicle	Light Vehicle	Total
Tour Based	199,381	323,547	842,820	1,365,748
Fleet Allocator	37,589	271,700	235,490	544,779
Internal-External	51,379	14,517	-	65,896
Total	288,349	609,764	1,078,310	1,976,423

Exhibit 39 provides some descriptive statistics for daily trip productions across the GTHA 2252 traffic analysis zones. In a sense, the zonal trip origination mean is not too meaningful in the current context because the distribution across zones is strongly, positively skewed. Especially for heavy vehicles, there are relatively few of the zones associated with large origination totals. The apparently large maximums associated with certain zones are partially explained by zones being used as surrogates for highway gateways and associated internal-external trips. In other words, the zone associated with the entrance of the 401 from the west is shown to originate a large number of trips that in reality have come from outside the GTHA.

Exhibit 39: Descriptive Statistics of All-Day CV Trip Productions

	Heavy CV Trips	Medium CV Trips	Light CV Trips
Sum Total	288,348	609,764	1,078,310
Mean	128	271	479
Standard Deviation	371.2	360.8	425.1
Maximum	11,142	3,836	6,940
Minimum	3	3	4
Count	2,252	2,252	2,252

Exhibit 40 shows the proportions of trips being made by light, medium, and heavy CVs. These proportions are consistent with those observed from surveys of the cities of Edmonton and Calgary, as reported in Hunt et al. (2006). In particular, the proportions of light, medium, and heavy CV trips were 65%, 22%, 13%, respectively, for Edmonton and 61%, 28%, 11%, respectively, for Calgary. The larger “heavy” percentage for the GTHA is likely appropriate given the strong industrial base in the GTHA. Also, there is some clear evidence in the Canadian Vehicle Survey (2009) that heavy vehicles are more predominant in Ontario than they are in Alberta.

Exhibit 40: Proportions of CV Trips made by Heavy, Medium, and Light CVs

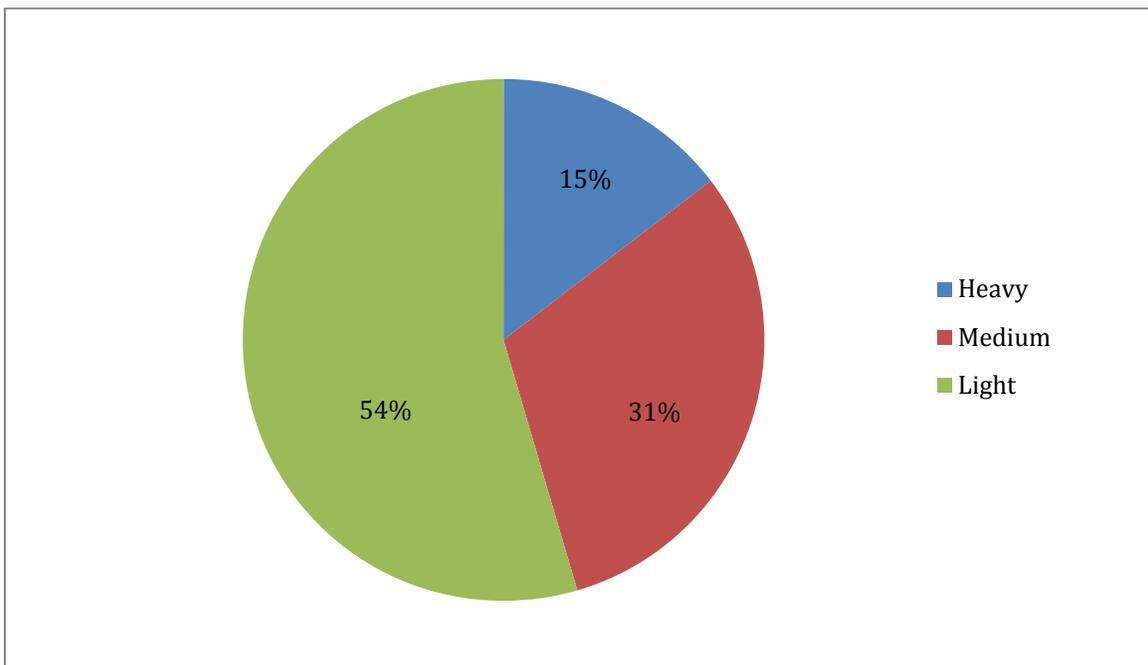
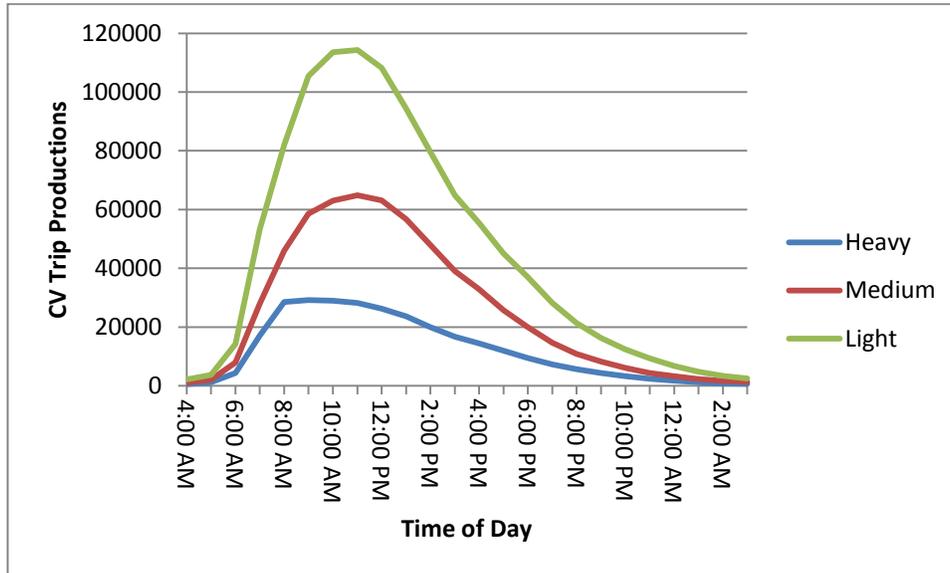


Exhibit 41 examines these trip results from the temporal perspective. In particular, trip productions are shown for light, medium, and heavy commercial vehicles for each hour in the day. These trip production curves are consistent with those from CV surveys of Edmonton and Calgary, as reported in Hunt et al. (2006). In particular, the curve shapes, the distribution of peak hour start times and the relationship between heavy, medium and light vehicles are consistent. One notable aspect of these commercial movement is that they are indicative of the effort made by firms to do as much of their work as possible

between the AM and PM peak periods to avoid the rush hours. Nevertheless, many tours are shown in this work to actually originate during the AM peak and then often continue on for several hours.

Exhibit 41: GTHA CV Trip Productions over Time





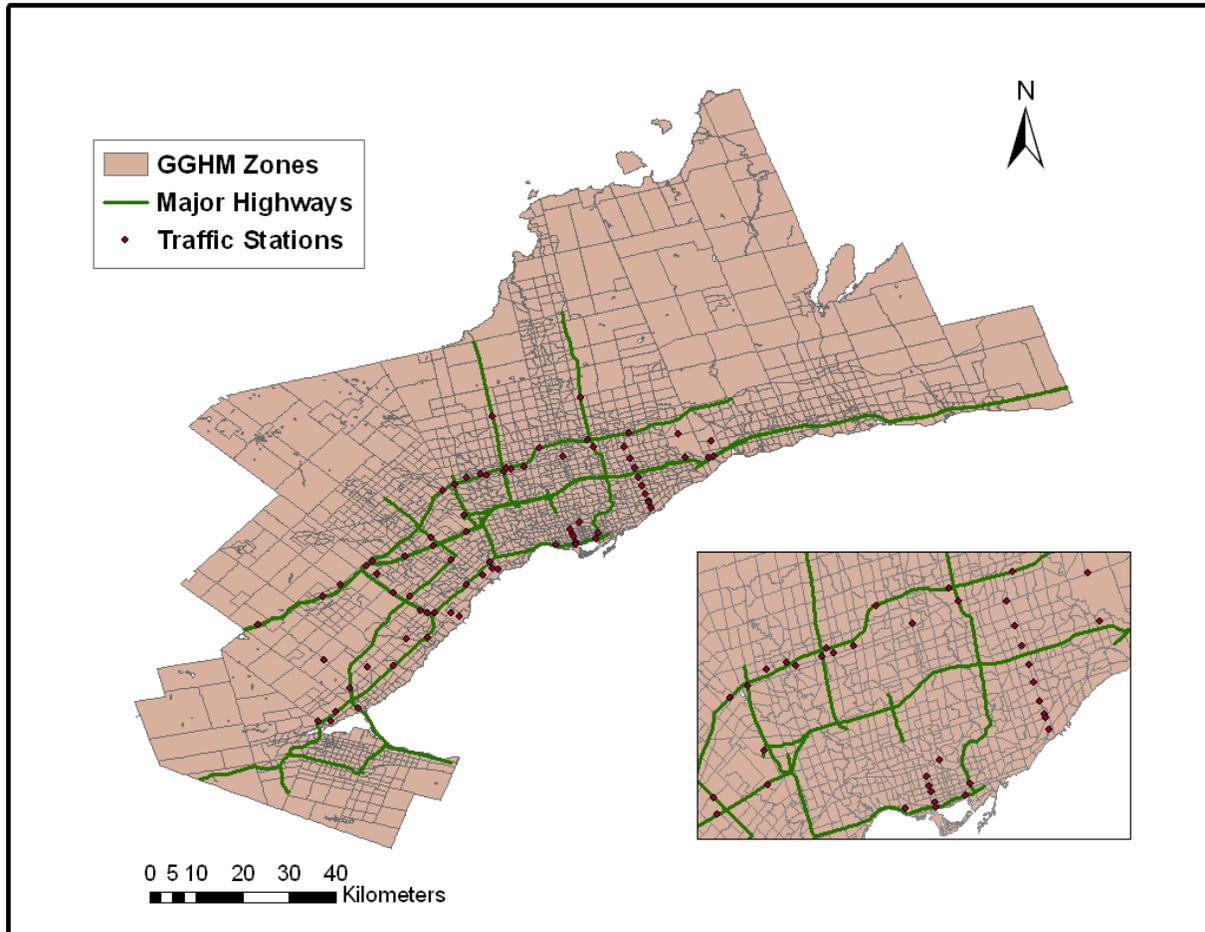
Validation

The purpose of this validation section is to outline the evidence that the results conform reasonably well to reality. One useful approach to this end is the assignment of our O-D results to the road network and then the comparison of these results with observed commercial vehicle flows. This process was carried out for light, medium and heavy vehicles in the GTHA with the exception of Durham Region. Trips could not be assigned to that region of the road network because MITL was not in possession of a “traffic assignment ready” road file for that area. However, the road network was complete for the vast majority of the GTHA and is quite adequate for this test.

In order to consider the quality of traffic assignment results, some observed data are required for traffic stations. Traffic count data from the Data Management Group at the University of Toronto was obtained. In particular, light, medium, and heavy vehicle counts were obtained from 73 Traffic Stations located on key links throughout the GTHA. Exhibit 42 shows the station locations on the GTHA road network. There were some limitations in terms of the data which were available. For example, data were not available for large stretches of the 401 and the Don Valley Parkway in Toronto and for other major arterials. Also, the Data Management Group does not maintain traffic counts for Hamilton. Finally, note that observed data at the traffic stations was available only between the hours of 6 AM and 9 PM which is sufficient for capturing the vast majority of commercial movements. Despite these gaps,

the 73 stations that were considered represent a reasonable cross-section of the GTHA and formed the basis for the traffic assignment component of our validations.

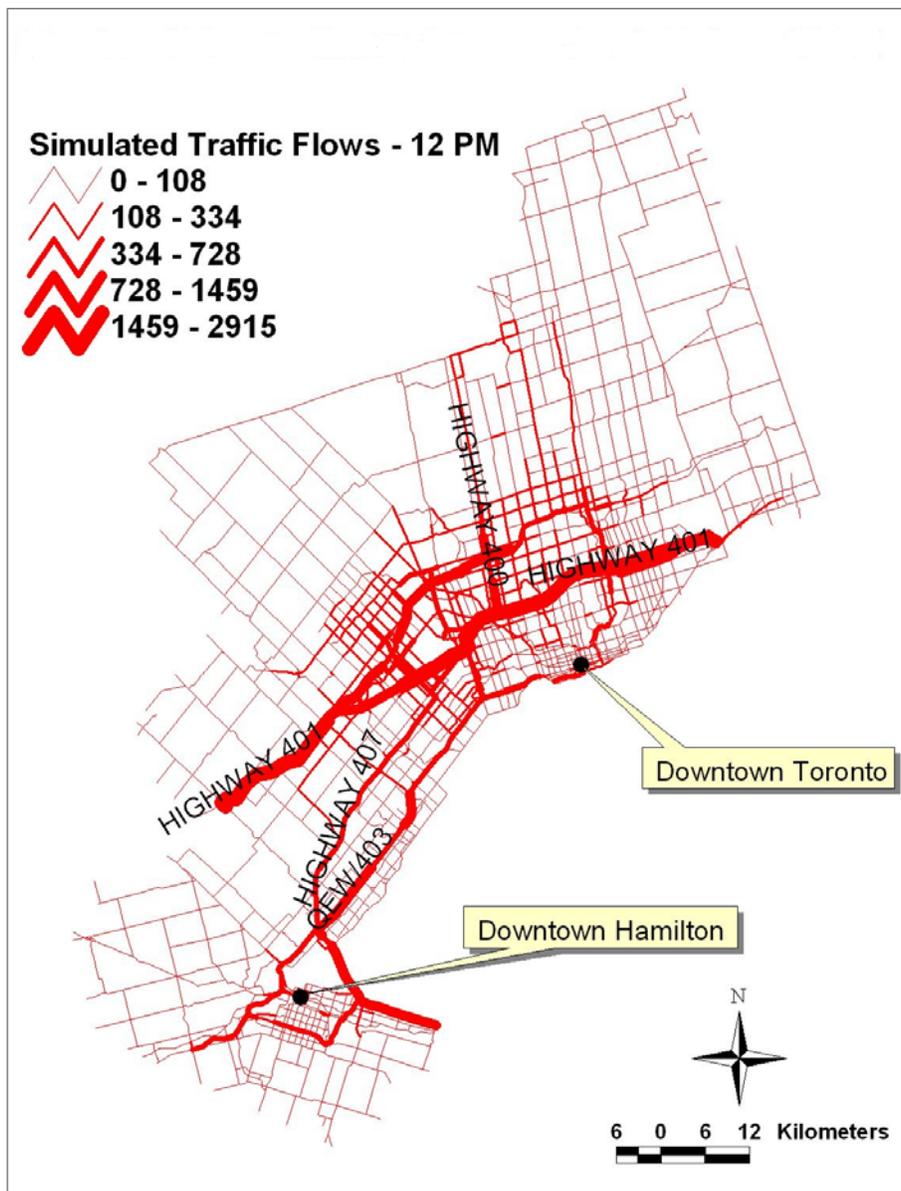
Exhibit 42: Selected GTHA Traffic Monitoring Stations



Having established the empirical or observed side of our validation, it was necessary to obtain some predicted or simulated results on the road network. MITL is in possession of its own stochastic user equilibrium traffic assignment algorithm and this was applied to ensure that the O-D matrix trips were assigned to the road network in a logical way. Such an algorithm takes account of aspects such as road capacity and posted speed limits to ensure that drivers pick the routes that are optimal for them. One thing to keep in mind is that traffic assignment is a model itself and is based on its own set of assumptions. As a result, there is the potential for traffic assignment to add sources of error on top of the prior modelling exercise which was associated with developing the O-D matrices. Another point is that there can be errors in actually linking trips to the road network as centroids associated with trip origins and destination will not be located right on the network. Finally, there is the potential for errors in the actual data representations of the road network itself which could result in misleading simulated traffic flows.

Exhibits 43, 44, and 45 show simulated noon hour traffic flows for heavy, medium, and light vehicles, respectively, upon assignment of trips by the algorithm. Note that Durham Region is excluded from these maps because the traffic assignments were not linked to the road network there. In these schematics, the thickness of lines on the routes is taken as a measure of implied traffic volume. Based on the heavy vehicle map, the 400 series highways are playing a dominant role in accommodating trips. The observed pattern on the highways is in keeping with earlier maps showing the origination of tours and trips and the high concentrations in Peel Region, for example.

Exhibit 43: Simulated Flows of Heavy CVs – 12 PM



With respect to medium and light vehicles in Exhibits 44 and 45, the pattern is somewhat more moderated which is consistent with what was observed for medium/light vehicle trip and tour originations. Nevertheless, the 400 series highways are still very prominent in the traffic assignment patterns. We see that highways of a more secondary nature, such as the Gardiner expressway, appear to be relatively more important for the movement of light/medium vehicles than for heavy vehicles.

Exhibit 44: Simulated Flows of Medium CVs - 12 PM

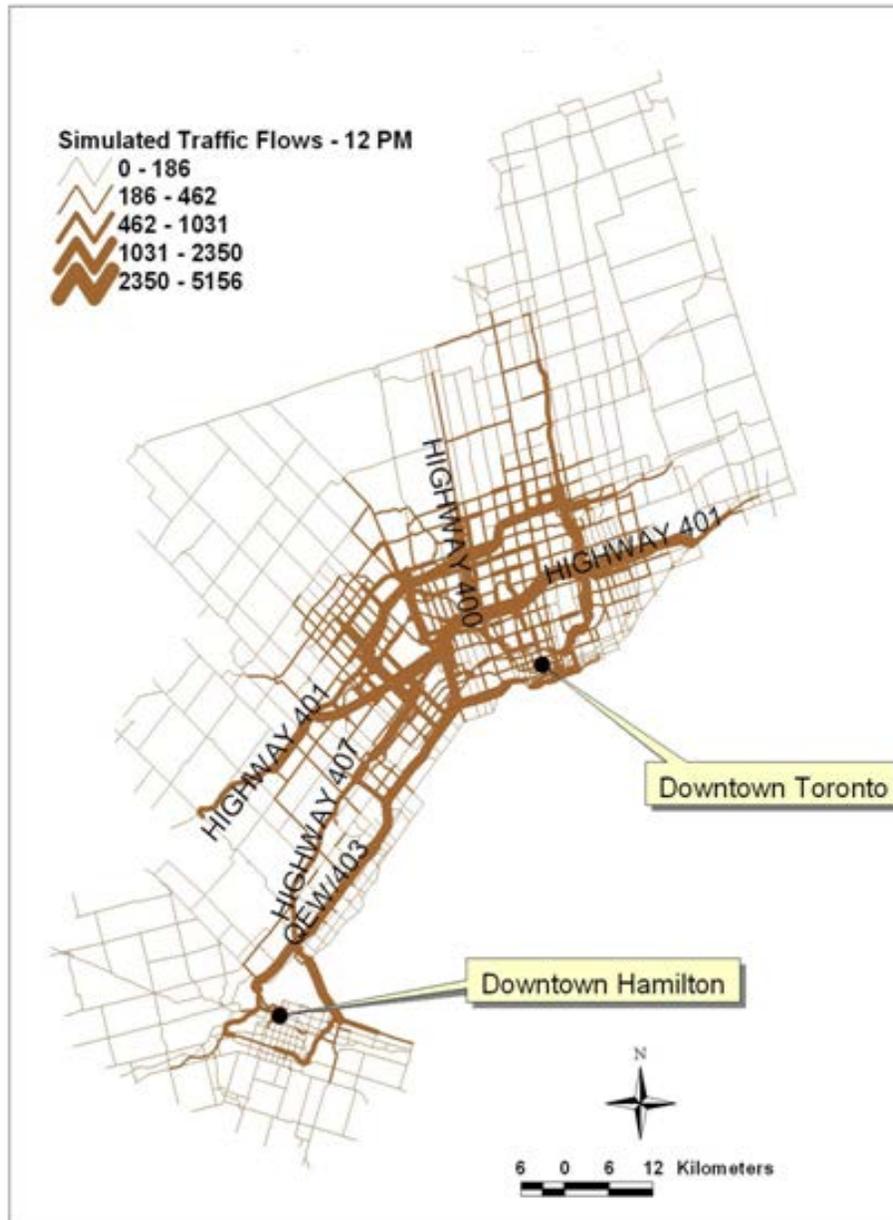
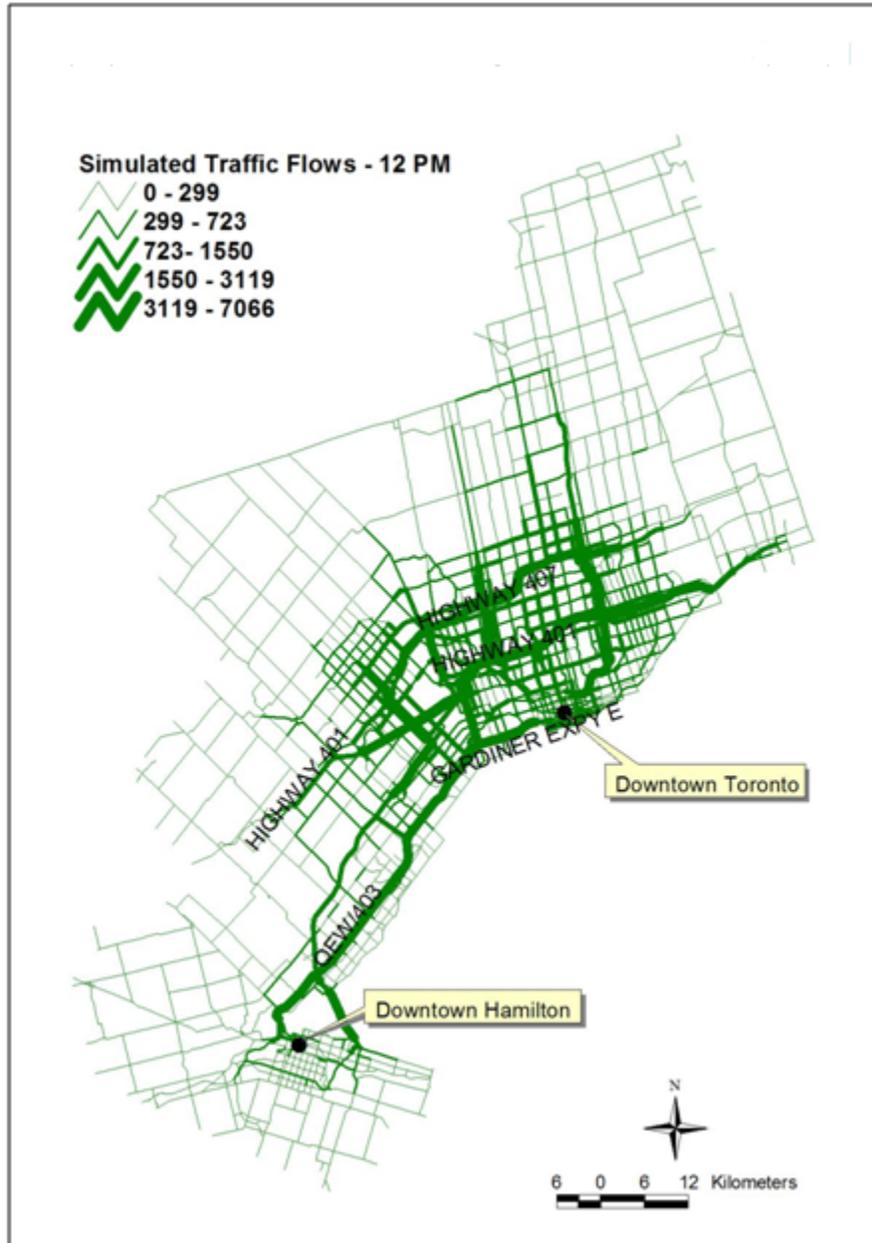


Exhibit 45: Simulated Flows of Light CVs - 12 PM



While the traffic assignment maps are useful to communicate an overall feel of the simulated results, it is only a case-by-case comparison with traffic station results that facilitates validation. In the first instance, it is interesting to compare the observed versus predicted traffic counts on an absolute basis as is done in Exhibit 46. According to these results, the simulated results across the various traffic monitoring stations closely replicate reality for heavy vehicles but vastly overestimate reality for medium and light vehicles for the period 6 AM to 8 PM.

It is important to note that the results of Hunt and Stefan are very clear that, in the intra-urban context, many more trips will be carried out by light vehicles than by medium vehicles and that there will be many more trips by the latter than heavy vehicles. The results apparent in the simulated flows column are consistent with the results from this imported framework. According to the Canadian Vehicle Survey (2009), there is a basis to think that there will be more heavy vehicle trips in Ontario than Alberta because there is more heavy industry in Ontario. So it might be expected that heavy vehicle flows would make up a larger percentage of total flows and trips in Ontario than in Alberta where Hunt and Stefan carried out their work. However, the observed flows in Exhibit 46 are beyond anything that might reasonably be expected using this criterion.

In particular, consider that the observed results for the stations suggest that the traffic counts between heavy and light vehicles are more or less identical. Such a result is completely out of step with the Hunt and Stefan results which of course are survey based. One hypothesis is the likelihood that traffic count procedures are not very good at identifying light commercial vehicles. Many commercial trips take place in cars, minivans and SUV's and would be very difficult to separate from non-commercial trips utilizing vehicles of a similar type. Even with manual traffic counting techniques, the screening would be very difficult. As a result, with respect to light vehicles, it is not difficult to conclude that light commercial vehicles could be severely underestimated by "observed" traffic counts. On the other hand, in a firm-based survey context, light commercial vehicles would be far less likely to be overlooked.

In addition, there may be some definitional issues at play. The observed flows seem to suggest that the medium vehicle observed counts, if taken at face value, are disproportionately low. Hunt and Stefan suggest that medium vehicles are typically "single-unit trucks with six tires" while light vehicles are four-tire vehicles along the lines of cars, vans, pick-ups and SUVs. Meanwhile, the Data Management Group at the University of Toronto, in a communication with MITL, suggests that their light truck category includes small panel trucks and courier vehicles, for example. The upshot of this comparison is that many of the light trucks in the observed category are perhaps more properly classified as medium vehicles in the Hunt and Stefan framework. Even the addition of observed counts for light and medium vehicles is less than the predicted count for medium vehicles.

Overall, the absolute results predicted for heavy trucks are encouraging. Heavy vehicles are likely to be quite accurately counted compared to their light commercial counterparts so the close correspondence between simulated and observed puts the modelled outcomes on a solid footing. While the apparent results for light and medium are some cause for concern, there are legitimate explanations and also, there are significant reasons to consider the baselines established in the Calgary work to be considered more reliable. Finally, it is quite legitimate to consider the light and medium results in terms of how they correlate with observed results. This framing of the problem permits the focus to be on degree of association rather than absolute scale. Note, however, that the final trip and tour results for this project are represented in an unscaled fashion for the reasons mentioned above.

Exhibit 46: Total CV Flow Volumes across all Traffic Stations, 6 AM to 8 PM

CV Type	Observed Flows	Simulated Flows
Heavy	246,672	266,863
Medium	118,631	449,826
Light	248,825	719,319
All CVs	614,128	1,436,008

Exhibits 47, 48, and 49 shift the emphasis of the validation to the station level. The graphs depict the relationship between simulated and observed traffic flows over space, for heavy, medium, and light commercial vehicles, respectively. Each point on the graph represents the traffic volumes at a given traffic monitoring station, with observed flows measured along the horizontal axis, and simulated flows measured along the vertical. While the whole concept of correlation is independent of the scale of the variables, the axis for observed flows was scaled here to have identical counts on the x and y axes. The scale factors are provided on each correlation graph along with the correlation result. The scale factors were easily derived from the results displayed in Exhibit 46.

Exhibit 47: Observed & Simulated Volumes at Traffic Stations (Heavy CVs)

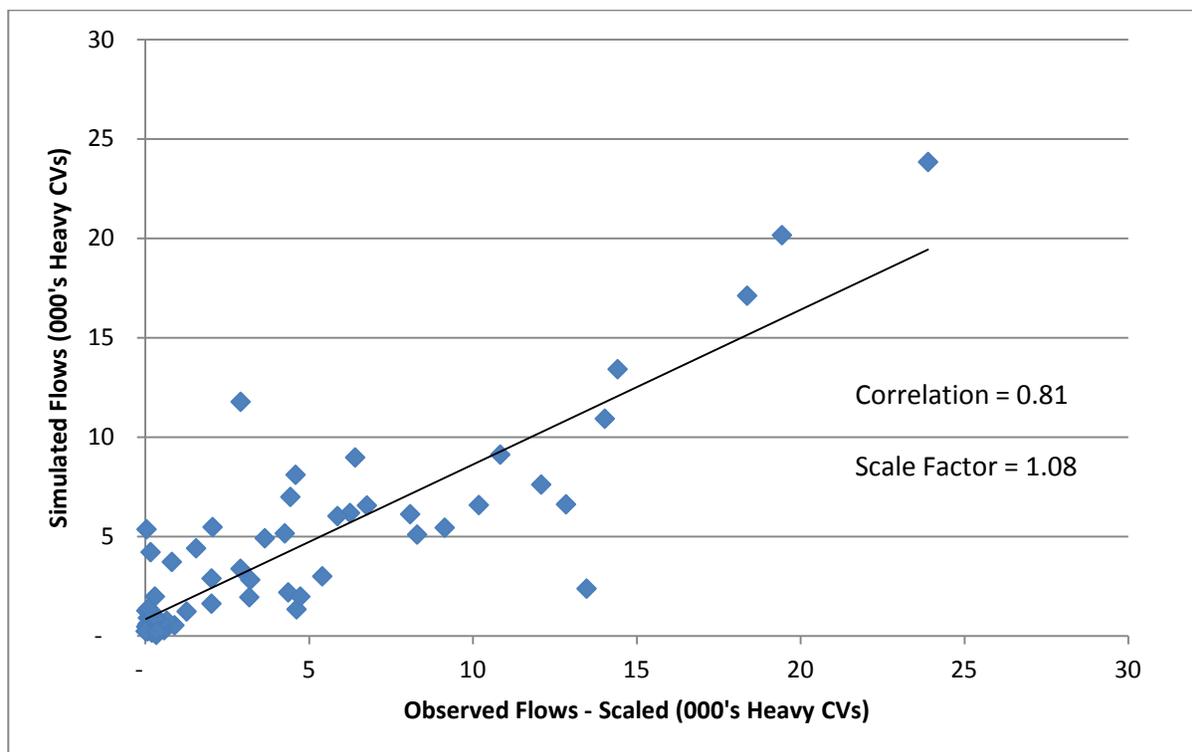


Exhibit 48: Observed & Simulated Volumes at Traffic Stations (Medium CVs)

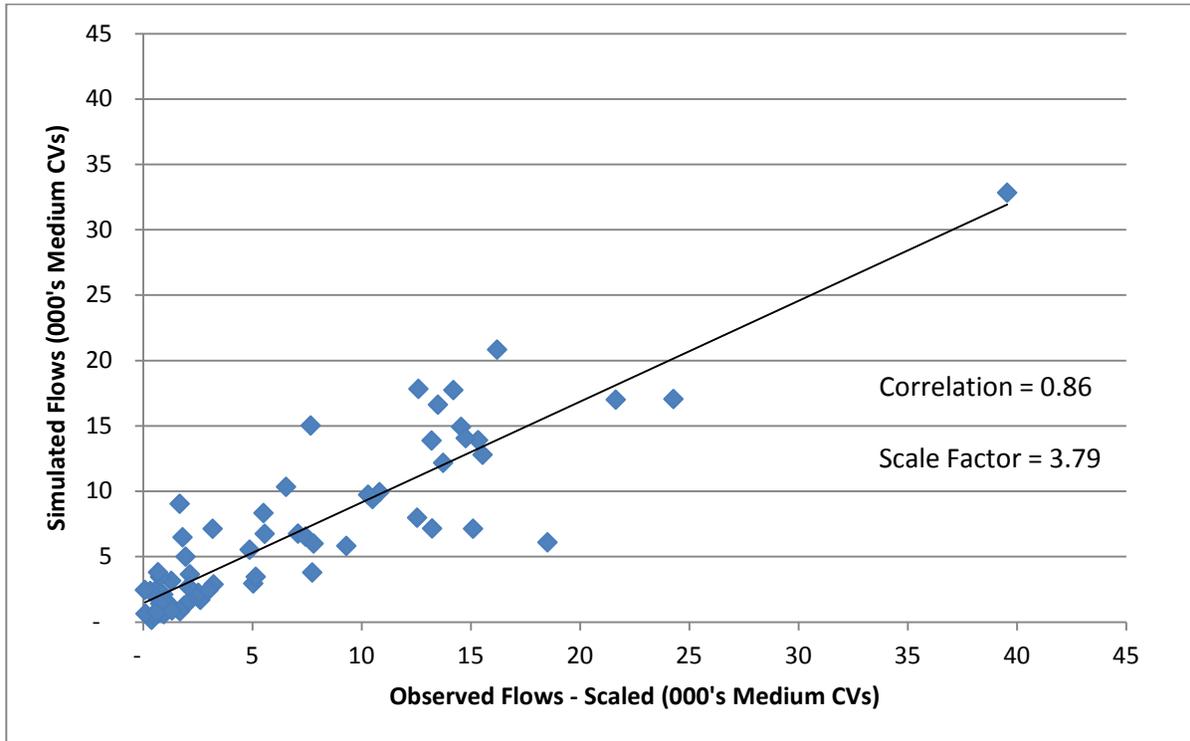
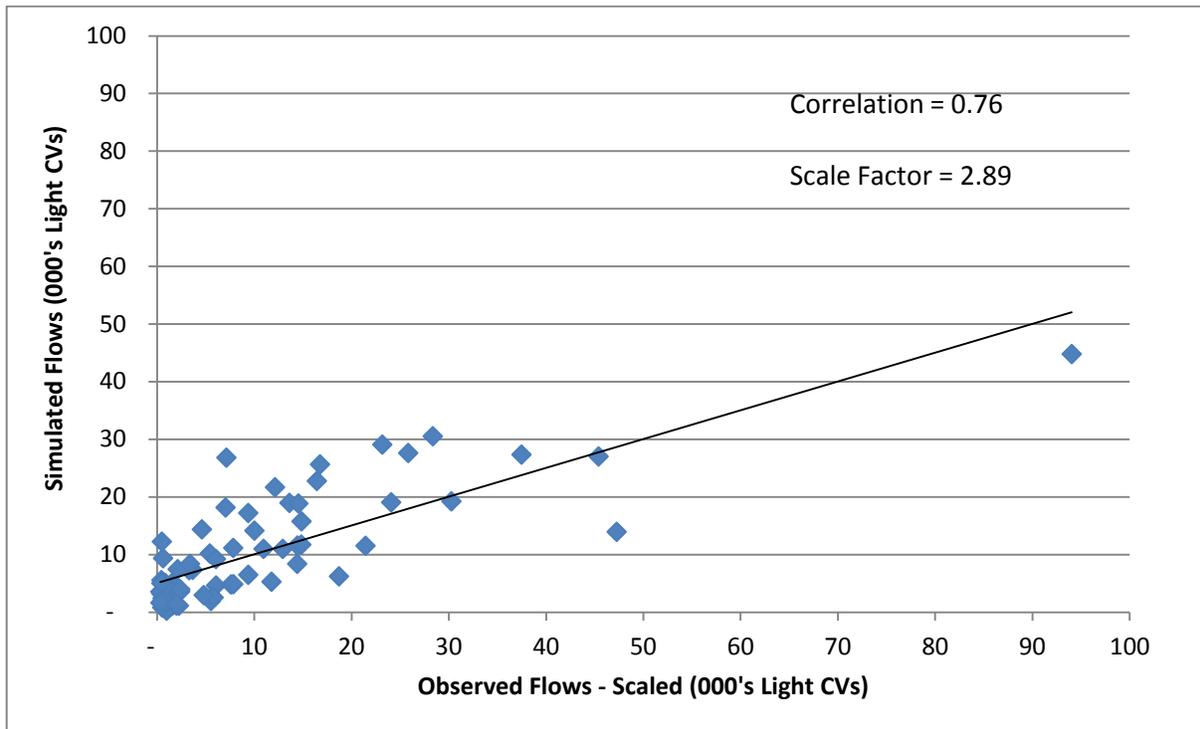


Exhibit 49: Observed & Simulated Volumes at Traffic Stations (Light CVs)



Traffic station results across the three exhibits are generally favourable. After rescaling, those stations with low actual flows are typically predicted to have low flows and so on for higher flow stations. For heavy, medium and light vehicles, the correlations are 0.81, 0.86 and 0.76 respectively.

It is worth mentioning at this stage that MTO provided MITL with some link-level estimates of daily truck traffic. These data did not provide any temporal patterns during the day or any separation between commercial vehicle types. Nevertheless, comparisons were carried out between the traffic assignment results and the MTO traffic flow results. Overall, a correlation of 0.80 was obtained across 204 links which is in keeping with the correspondence to the other observed traffic results. Also, total simulated flows on the 204 links turned out to be 24% higher than the MTO data.

Exhibits 50, 51, and 52 represent the results of validation from the temporal perspective for heavy, medium and light vehicles, respectively. Here, the curves on the graph show the total volume of commercial vehicle flows at all stations combined, between 6 AM and 8 PM. Identical scale factors as before apply for the three vehicle types so that the curves are on common ground. For heavy and medium vehicles (exhibits 50 and 51), the observed and simulated flows follow a similar pattern over time, as reflected by their correlations (0.79 and 0.88, respectively). For heavy vehicles in particular, the observed pattern of flows in the early morning changes less abruptly than is the case with the simulated totals and seems to peak a little bit later. Possibly, this result might reflect differences in early morning behavior between Calgary and the GTHA. In the latter, AM peak traffic conditions may be viewed as more burdensome for the typical heavy truck driver who will get a tour or trip underway earlier in the GTHA as a result. The predicted results for the GTHA are, of course, influenced by modelled results from the Hunt and Stefan work in Calgary.

For light vehicles (Exhibit 53), there is a disconnect between the observed and simulated flow curves, especially between the hours of 7 AM and 4 PM; and this is reflected by a relatively low correlation of 0.42. In particular, where we would expect a convex (or mountain-top) shape to the observed flow curve, we find something of a concave (or valley) shape. It is interesting to note that the observed light vehicle pattern shows evidence of an AM peak and a PM peak. Such a pattern is more typically associated with the movement of workers between their place of residence and place of work whereas results in Calgary suggest that commercial vehicle movements are scheduled to avoid these peak times to the largest extent possible. This same result would be expected for light vehicles in the GTHA and the fact that it does not, serves to underlie the problems in properly identifying light commercial vehicles via traffic counts. Moreover, during the period 7 AM to 4 PM, there is a high volume of all types of traffic, which further camouflages light commercial vehicles from observation at traffic stations.

Exhibit 50: Observed and Simulated Heavy CV Flows over Time (All Stations)

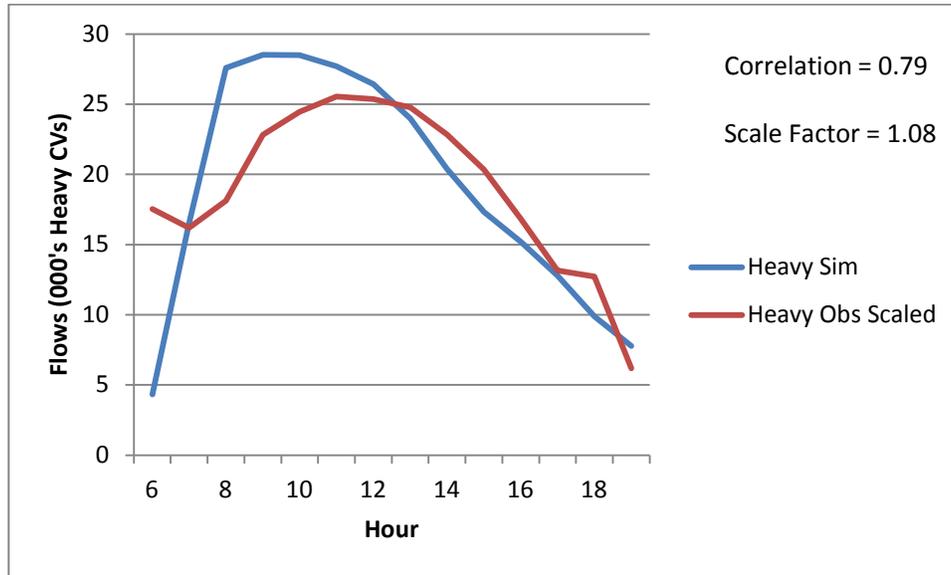


Exhibit 51: Observed and Simulated Medium CV Flows over Time (All Stations)

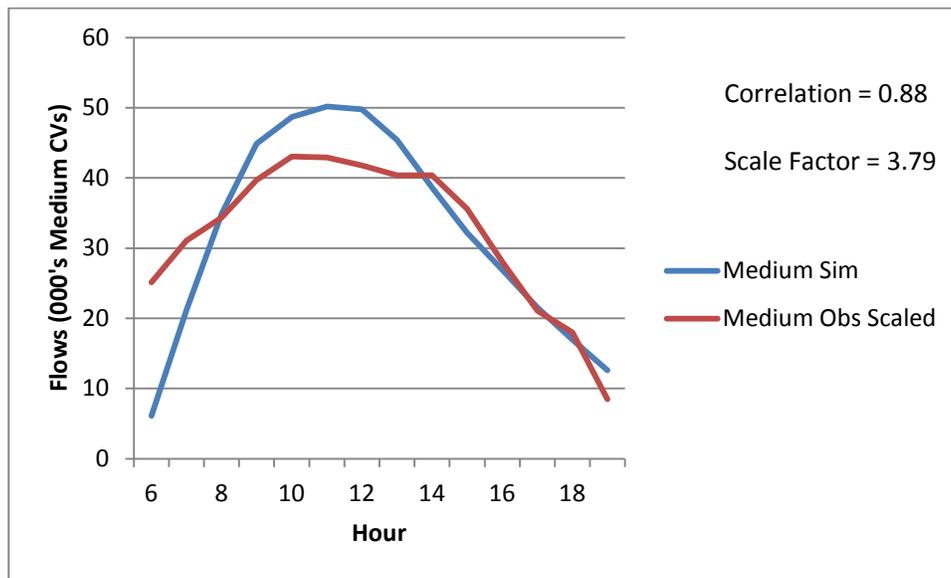
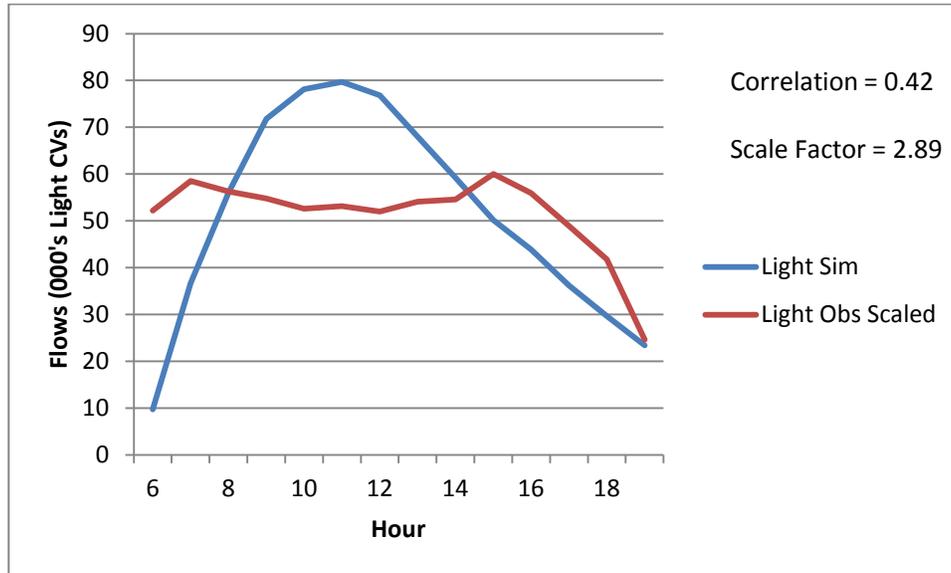


Exhibit 52: Observed and Simulated Light CV Flows over Time (All Stations)



Finally, Exhibit 53 summarizes the set of correlation results that were measured over the different locations and also over time. As was noted, the correlations over all the stations are reasonable while the correlation over time suffers for light vehicles, most likely for the reasons discussed.

Exhibit 53: Correlations over Space and Time between Observed and Simulated Flows at Traffic Stations

CV Type	Correlation Over Space	Correlation Over Time
Heavy	0.81	0.79
Medium	0.86	0.88
Light	0.76	0.42

Another useful lens through which to view the results is that of Vehicle Kilometres Travelled (VKT). In Exhibit 54, the final trip results shown in Exhibit 38 are translated into VKT to give some idea of total distance travelled by commercial vehicles in the course of the typical day. Note that these VKT calculations were done on the basis of shortest path distances and thus may be underestimates from that perspective. There are some interesting things to note. In terms of VKT, heavy vehicles account for about 45% of internal-external trip VKT whereas in terms of trip counts, the result is 17.8%. Thus the intra-GTHA distances associated with internal-external trips for heavy vehicles are much larger than for other heavy vehicle trips within the GTHA.

Exhibit 54: Estimated VKT by Trip and Vehicle Type

Trip Type	Heavy Vehicle	Medium Vehicle	Light Vehicle	Total
Tour Based	3,249,380	5,892,670	15,564,506	24,706,556
Fleet Allocator	292,960	2,398,484	2,124,767	4,816,211
Internal-External	2,952,876	719,481	-	3,672,357
Total	6,495,216	9,010,635	17,689,273	33,195,124

The 2007 Canadian Vehicle Survey (2009) provides some useful pieces of information relating to VKT. This survey estimates a total national VKT of 23.9 billion for heavy vehicles and 8.15 billion for medium vehicles. In addition, for Ontario the survey provides an estimate of 125.3 billion for all vehicle types which can be compared to our overall commercial total of approximately 9.3 billion. This latter total is obtained by multiplying the daily total of 33.1 million km by 255 business days and then scaling up by 10% to account for weekend commercial movements. With respect to our daily total of 6.495 million for heavy vehicles, it can be estimated that the corresponding annual total might be approximately 1.8 billion. A similar conversion for medium vehicles would yield a total of 2.5 Billion for the year.

For heavy vehicles, the results would imply that something in the order of 7.5% of national VKT take place within the GTHA. For medium vehicles, the corresponding percentage would be nearly 31% which seems fairly high. Using generally accepted ratios of 10 to 15% for commercial VKT relative to total VKT, the annual commercial VKT total for Ontario might be expected to fall within the range of 12.5 billion to 18.8 billion. Given that the GTHA accounts for nearly half of Ontario’s population, we might assume that it also accounts for about half of Ontario’s commercial VKT. If so, then the total estimate of 9.3 billion for the GTHA would fall into the upper range of what we would expect for the GTHA given the Ontario figures.

Overall, based on VKT, the results are within reason but perhaps tending to the high side, especially with respect to medium vehicles. It is interesting to note that the thirteen tour segments defined by Hunt and Stefan do not distinguish between medium and heavy vehicles in terms of tour behavior. The two vehicle types tend to be lumped together in terms of tracing out the tours, leading to similar VKT patterns for the typical tour. This is one potential reason why medium VKT appears high since, in addition, their framework also strongly suggests that a lot more medium trips are taking place than heavy.

Conclusions and Recommendations

Overall, this work has been somewhat experimental but has been reasonably successful in deriving estimates of urban commercial vehicle movements on an origin-destination basis and at a fairly detailed level of disaggregation. Results have been developed for tour-based movements, fleet-allocator movements and for internal-external movements. At this stage, the results should be viewed as giving “ball park” estimates of the general level of commercial vehicle movements. While we know that commercial vehicle movements likely decreased during the recent recession, there are no particular attributes of any of the input data used that would help us to discern such changes. These results might be better thought of as representing a typical day during a typical week within the 2005 to 2010 timeframe. With further work and refinements and the use of more empirical or survey-based data, a much stronger effort could be made to capture these types of more detailed realities.

It is worth reviewing some of the potential sources of error in this work and then using these insights to define some future research directions. Some error sources are as follows:

- InfoCanada data are not associated directly with urban commercial vehicle movements and meanwhile there are some issues with respect to accurate representations of employment patterns within the data (e.g. head office issues, specifying employee counts as a range)

- Peel Survey data are not too disaggregated by industry types which hindered our ability to fully leverage the industry detail in the InfoCanada data. In addition, sample sizes with respect to tours in particular, were quite small.
- On average, the Peel data tends to represent tours with a larger number of stops than what has been seen in the literature. This may lead to calibrated “next stop purpose” models where the probability of returning to establishment at any particular point in the tour is lowered. In the end, this might lead to somewhat inflated trip totals for those trips associated with tours.
- To the extent that models were used which were calibrated in Calgary/Edmonton and applied in the GTHA, the results are subject to transferability biases and issues. Even if models were built on GTHA data, there would nevertheless be prediction errors.
- The framework utilized does not differentiate the tour behavior associated with medium or heavy vehicles in terms of the characteristics that make up tours
- The classification and micro-simulation process used to generate tours from the InfoCanada data possesses ad hoc elements and also is dependent on the Peel Survey being representative. To some extent this is due to insufficient data.
- The trip distribution models which underlie the creation of origin-destination matrices for the fleet allocator vehicle movements are an adjusted version of models developed from the tour-based results. Since fleet-allocator movements are somewhat distinct from tour-based movements, there is little doubt that some biases will have been introduced. The chosen course of action resulted from a void of data on fleet-allocator movements.
- Internal-external trip behavior associated with light vehicles is not covered in this study essentially because it is not a focus of the Ontario Ministry of Transportation (MTO) Commercial Vehicle Survey. This study depended very much on that survey for the representations of internal-external commercial vehicle movements. In the future, it might be beneficial if MTO extends the mandate of this survey to have some representation of light vehicles. Such an enhancement would also help to shed further light on commercial vehicle movements associated with the provision of services in particular.

Bearing these sources of error in mind, what are some possible directions for this type of work? The modelling of commercial vehicle movements would be improved by additional collection of data on the firms which generate such movements. Firm surveys might well include similar types of information as was present for the Peel Survey but tools such as the InfoCanada data could provide considerable insight as to how surveys could be structured by industry SIC/NAICS codes to get optimal representation. With reasonable representation across SIC codes, researchers could be much more confident that scaled-up results to the GTHA level would be a good representation of reality. Increased availability and improved technology with respect to GPS data will be useful in enhancing further such efforts. These types of data lower the burden on drivers with respect to survey demands and lead to more accurate results in the end. Knowledge of tour behavior by SIC segments will benefit as a result.

More extensive survey data for the GTHA on urban commercial vehicle movements will lead to greater capability to model these movements and thus develop the types of insights that models provide. In the GTHA, for example, we would not need to rely on statistical parameters imported from elsewhere since there would be considerable capability to derive our own. Discrete Choice Frameworks provide a rich environment in which to quantify the relative importance of different factors in determining why shippers make the underlying choices that they do; choices that lead to movements of commercial vehicles. It might be possible also, with a solid background of survey data, to design alternative choice frameworks and find a combination of models which appears to work very well.

The one inescapable conclusion of this work is that goods movement and the commercial provision of services leads to huge intra-urban and inter-urban flows of commercial vehicles in the course of the typical business day in the GTHA. Delays and congestion that impact these flows are not good for the businesses involved or for the GTHA as a whole. It is in the best interests of the GTHA to collect high-quality information on commercial vehicle movements to 1) facilitate the highest quality research on this topic and 2) to maximize the chances that sound commercial vehicle movement policies are adopted.

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