A MICRO-APPROACH TO UNDERSTANDING URBAN COMMERCIAL VEHICLE MOVEMENTS: PRELIMINARY RESULTS FROM A WEB-BASED ESTABLISHMENT SURVEY

GEORGIANA **MADAR** AND HANNA **MAOH**
Department of Civil and Environment Engineering, University of Windsor, Ontario

Introduction

The study of urban commercial vehicle movements is becoming an area of increasing interest to researchers, planners, and policy makers. The impact of commercial vehicles, especially the larger vehicle types that are used in the transport of goods, has been noted for some time; increased road congestion pavement wear, higher greenhouse gas and pollutant emissions, and a higher value of time are all associated with the presence of commercial vehicles on the road network.

Although commercial vehicles comprise between 10 and 15% of the total amount of urban vehicle trips (Hunt and Stefan, 2007), the modeling and forecasting techniques applied to this class of vehicles are still in the beginning stages. Significantly more analysis has been undertaken for private vehicle travel activities. Currently, commercial vehicle analyses are conducted on the basis of the four-stage model, which has been used extensively in the case of private vehicles (Ferguson et al. 2012). Despite its practicality, the four-stage approach suffers a number of shortcomings that impede its predictive ability (Miller et al. 2004). In the context of non-passenger travel, the 4-stage model is viewed to lack the behavioral realism needed to

handle the complexity of urban commercial vehicle movement activities (Ferguson et al. 2012). Typically, a variety of vehicle types are used for commercial purposes, ranging from small personal-sized vehicles to large multi-unit trucks. The decision-making process that gives rise to commercial vehicle trips is also non-trivial given the heterogeneity of trading industries when moving goods and/or the variety of customers when providing services. In short, the study of commercial vehicle activities and their characteristics are complex and require detailed information that is usually lacking for most jurisdictions.

According to recent literature, an effective method of studying commercial vehicle activities is through the development and application of microsimulation models (Hunt and Stefan 2007; Ferguson et al. 2012). One hindrance to development of such detailed models is the unavailability of detailed data on individual business establishments. It is believed that this is due to the reluctance of businesses of sharing information about their travel activities either because they do not have the time to participate in surveys or because they fear revealing their business approach and client information to their rivals. However, data on individual business establishments and their travel related activities have been successfully collected in few places in Canada including the Cities of Calgary and Edmonton in Alberta (Hunt and Stefan 2007) and the Peel Region in Toronto (Roorda et al. 2009)

To this end, the overall objective of this study was to develop a methodology for collecting commercial vehicle data at the business establishment level in the Windsor Census Metropolitan Area (CMA), Ontario, through a combined phone and web-based surveys. The web-survey consisted of questions related to general establishment characteristics, outbound commercial vehicles, and inbound commercial vehicles. A dataset containing contact information for businesses registered in the study area was acquired from InfoCanada for use in recruiting survey participants. This paper will describe process used in recruiting firms to participate in the web-survey through an initial phone survey. Next, a summary of

some of the preliminary statistical analysis performed on the data will also be presented.

The remainder of this paper is organized in a number of sections. The next section provides an overview of some of the existing recent literature on the topic at hand. Following will be a section devoted for describing the data collection procedures. Next will be a section describing some preliminary statistical observations made on the collected data. The final section provides a conclusion to this study and outlines future steps that will be undertaken in this research.

Literature Review

Many of the existing studies on commercial vehicle activities leave much room for improvement. A number of researchers only consider large freight carriers in their analyses, omitting the important effects of small and medium commercial vehicles used for local deliveries and service calls. A method that is commonly used to forecast commercial trips is to introduce weighting factors to the four-stage model used for personal travel, in order to inflate the values to account for the presence of commercial vehicles. These methods do not provide accurate results since they do not account for the smaller commercial vehicles and they assume that commercial trips are organized in similar ways to personal trips, which is not the case. Commercial vehicles should be studied separately and models should be developed to study their individual characteristics and effects on the transportation network. This section outlines some new study methodologies involving microsimulation of commercial vehicle movements.

Yang et al (2010) compares the different types of modeling methodologies that are currently utilized for studying and forecasting commercial activity and the input variables required. They identified seven classes of freight modeling methods, the first of which being a direct facility flow factoring method, which straightforward but requires making many assumptions. These models have a limited range of applications, mostly in shirt-term forecasts of freight volumes. The next class, O-D factoring method, requires existing trip tables as an input, which are multiplied by growth rates and used to

estimate freight truck volumes. Thirdly, a freight truck method was described, which focuses on the truck mode using land use, socioeconomic, and transport supply and demand data. The next class of models is the four-step process commodity model, similar to the four-stage model for passenger forecasting. They link commodity flows to employment, modal utility, trip patterns, and network infrastructure. Fifth is an economic activity model, applying an economic/land use model to generate zonal employment or economic activity, which are then applied to generate commodity O-D flows and truck flows. Next, a supply chain/logistics model is described, which forecasts household and economic activities across larger zones, using information about supply, demand, and cost relationships between zones and the national economy. Lastly, truck touring models are described, which forecast truck tours at the disaggregate level.

Researchers have observed that decision makers in business establishments are reluctant to share information about their commercial vehicle activities, since these decisions often play a role in giving the firm its competitive edge. Samimi et al (2013) describes how an online survey was used to overcome the low response rate. More specifically, the authors described the process undertaken to develop, implement, and collect responses from a business establishment web survey about commercial activities in the United States. They also described the issues that could arise from a non-response bias. A number of others, such as Samimi et al (2010), have utilized aggregate data from the Commodity Flow Survey (CFS) and the Freight Analysis Framework (FAF) in the United States, since data was not available about individual establishments and their commercial activities, such as that collected through web surveys.

In the Canadian context, the work of Hunt and Stefan (2007) stands as one of the few efforts to collect detailed commercial vehicle movement data at the business establishment level to develop a microsimulation model for urban commercial vehicle movements in the Cities of Calgary and Edmonton. Ferguson et al (2012) made a similar attempt at applying the methodology from Alberta to the Greater Toronto and Hamilton Area (GTHA). The original study

shows a tour-based microsimulation framework for modeling different types of commercial activities. Monte Carlo techniques were used to assign attributes to each tour, following an iterative procedure to build commercial tours for three classes of vehicles: light, medium and heavy. Utility functions were developed that would respond to changes in network capacities, truck route policies, told, household travel, and other such factors. Ferguson et al (2012) adopted the Alberta framework, with some modifications, for the GTHA study area, and the model was found to successfully describe commercial movements.

The study conducted by Xie and Roorda (2009) is another commercial vehicle application in the province of Ontario. This study focused only on heavy commercial vehicles, namely truck movements, and incorporated information from roadside interviews and input-output tables into origin-destination matrices for a gravity model approach to determine commodity flows. A preliminary O-D matrix was estimated and adjusted using commodity link flow information. The model first defined analysis zones. Next, commodity generation was estimated based on employment, population, industry types, and input, output, and demand of commodities. Truck share factors were introduced to account for the truck mode choice. Next, the O-D matrix was assigned to the transportation network. A production-constrained gravity model was applied, with an impedance function that was sensitive to travel time, and the preliminary O-D matrix was updated using a gradient method that accounted for observed commodity link flow information. This model focused on the transport of motor vehicles and auto parts but could be extended for other types of commodities.

Some activity-based models have also been developed for modeling urban freight movements. Samimi et al (2010) developed a framework consisting of five modules, using US data. Firm data was introduced into a firm generation module, followed by a supply chain replication module that used characteristics of the supply chains in place. A shipment forecasting module used characteristics of the shipments themselves. Logistics decisions, such as mode choice, the use of a consolidation centre, and others, were modeled in the fourth

module for logistics planning, using information about individual shipments. Lastly, a network analysis module evaluated the effects of the predicted freight movements on the transportation network.

Nuzzolo and Comi (2014) proposed an activity-based model with three sub-models, for quantity of goods transported, the delivery time period, and the total number of tours generated, using origin-destination matrices with applicable variables for each module. Data was obtained from traffic counts and interviews with truck drivers and retailers in the city of Rome, Italy, where the model was calibrated. This model accounted for economic characteristics of the analysis zones, location of freight centres, shipment size, and vehicle type.

Data Collection

A web survey was designed that would be distributed to firms who were willing to participate and share information about their business establishments and the travel activities undertaken by their commercial vehicle fleets. A dataset containing the entire list of business establishments, over 10,000 firms, registered in the study area was acquired from InfoCanada for the year 2013. The records on file included contact and mailing information of the establishment and the industry classification codes (NAICS code and description). A unique access code for each surveyed business establishment was generated and appended to the data. In total, the web survey consisted of 40 questions, separated into three major categories: general establishment characteristics, outbound commercial activities, and inbound commercial activities.

Recruitment for survey participants was conducted through a phone survey, where establishment representatives were asked about their interest in taking the web survey. The phone survey was conducted in two phases. The list of business establishments was divided into ten random samples, each containing approximately 10% of the dataset. The first phase of recruitment involved contacting the first five of these 10% samples in their entirety. During the phone conversations, representatives were asked whether their establishments engaged in any shipping or receiving of goods or services. If they did, the

representatives were asked if they were interested in participating in the web-survey. Those who were willing were asked to provide an email address to which a link to the web survey and a unique access code were sent. These first five samples consisted of 983 businesses, for a total of 4915 businesses.

At the conclusion of the first phase, it was noted that a significant number of firms reported during the phone calls that they did not engage in shipping or receiving of any kind, or were not interested in participating in the web survey. Prior to the second phase of phone calls, an analysis was conducted on the 4915 firms already contacted, to determine which industry types (based on the two-digit NAICS code) were the most likely to engage in shipping or receiving and to be interested in participating in the survey. A Location Quotient (LQ) calculation was undertaken, comparing the ratio of businesses that ship or receive to the total number of businesses in each respective sample, to the ratio of businesses in a respective industry category to the total number of businesses in the sample. This ratio is defined in the equation below

$$LQ = \frac{\left(\frac{F_n^S}{\sum_n F_n^S}\right)}{\left(\frac{F_n}{\sum_n F_n}\right)} \ldots (1)$$

where the variables are defined as follows

F_n^S: number of business in each industry category *n* that reported shipping or receiving of goods or services

$\sum_n F_n^S$: total number of businesses in a sample that reported shipping or receiving of goods or services

F_n: total number of businesses in the respective industry category *n*

$\sum_n F_n$: total number of responses in the sample from all industry categories

A similar calculation was also undertaken to examine the willingness of establishments to partake in the web survey, as defined in the following equation

$$LQ = \frac{\left(\frac{F_n^W}{\sum_n F_n^W}\right)}{\left(\frac{F_n}{\sum_n F_n}\right)} \ldots (2)$$

where the variables are defined as follows

F_n^w: number of business in each industry category *n* that reported being willing to participate in the web survey
$\sum_n F_n^w$: total number of businesses in a sample (from all industrial categories) that reported being willing to participate in the web survey
F_n: total number of businesses in the respective industry category *n*
$\sum_n F_n$: total number of responses in the sample from all industry categories

A value for LQ that was greater than 1 in equation 1 indicated that the respective industry categories were more likely to engage in shipping or receiving, whereas an LQ greater than 1 in equation 2 indicated that the establishments were more likely to be willing to take the survey. Tables 1 and 2 show a summary of the industry sectors that have total LQ values greater than 1.

Table 1: Location Quotients for industry sectors engaging in shipping/receiving of goods/services

2-Digit NAICS Code (in brackets) and Description	Sample					Total
	1	2	3	4	5	
(31) Manufacturing	3.67	3.47	1.77	1.75	3.62	2.60
(32) Manufacturing	1.05	5.01	2.42	2.62	3.10	2.77
(33) Manufacturing	3.36	2.15	1.73	2.29	2.27	2.32
(42) Wholesale Trade	2.38	2.61	1.11	1.28	1.86	1.71
(44) Retail Trade	1.48	1.31	1.56	1.69	1.58	1.49
(45) Retail Trade	1.69	2.03	1.42	1.35	1.13	1.48
(48) Transportation and Warehousing	0.56	1.25	1.69	1.64	1.94	1.49
(49) Transportation and Warehousing	0.00	3.76	3.99	2.10	0.00	2.58
(61) Educational Services	1.34	0.36	0.95	1.52	1.81	1.32
(72) Accommodation and Food Services	0.98	1.22	1.40	0.98	0.85	1.09

Table 2: Location Quotients for industry sectors willing to participate in the web survey

2-Digit NAICS Code (in brackets) and Description	Sample					Total
	1	2	3	4	5	
(31) Manufacturing	5.15	4.24	2.40	0.00	4.70	3.13
(32) Manufacturing	0.00	2.30	2.95	2.85	6.04	2.97
(33) Manufacturing	2.65	2.46	2.12	3.20	4.26	2.94
(42) Wholesale Trade	4.59	4.20	1.26	1.77	2.41	2.54
(44) Retail Trade	1.32	1.16	1.80	1.73	1.28	1.44
(45) Retail Trade	0.40	2.61	1.44	1.38	0.59	1.32
(48) Transportation and Warehousing	1.19	1.15	1.97	1.42	1.01	1.45
(49) Transportation and Warehousing	0.00	6.90	2.70	2.28	0.00	2.76

Following the LQ analysis, the remaining list of establishments which were broken into five random samples were sorted such that only those industry categories with LQ values indicating that they were likely to engage in shipping or receiving and likely to participate in the survey would be contacted during the second phase of recruitment via the phone survey. Of the remaining establishments not yet contacted, a total of 1823 firms were selected based on the LQ analysis to be contacted in the second phase. The industry sectors selected for contact in the second phase are 31, 32, 33, 42, 44, 45, 48, 49, 61, and 72, as defined in tables 1 and 2.

During the first phase of phone calls, a total of 4915 firms were contacted over the course of approximately six weeks, with an average of 150 to 200 firms contacted each day. A total of 359 email addresses were collected from these firms, resulting in a 7.3% response rate. During phase two, where only certain industry sectors were targeted based on calculated LQ values, a total of 1823 businesses were contacted over the course of three weeks. The second phase yielded a total of 322 email addresses to which the web survey was forwarded, constituting a response rate of 17.7%. It was noted that the executives of firms contacted in phase two seemed more willing to cooperate and participate in the survey than those contacted

during phase one. It can be seen that the response rate from the second phase of phone calls was more than two times that from the first phase, indicating that the location quotient targeting method was effective in recruiting firms to participate in the web survey. This is also supported by the fact that the total number of collected e-mails from phase 1 (which targeted 50% of all business establishments in the study area) is very close to the number of collected e0mails from phone 1 (which targeted selected establishments from the other 50% of all business establishments in the study area).

After the conclusion of the recruitment phone calls, a link to the web survey and a unique access code was forwarded to all business establishment representatives who had provided an email address. Three reminder emails were subsequently sent 2, 7, and 14 days after the original email containing the survey link. The survey received responses from firms between the dates of Aug. 26, 2013 and Nov. 22, 2013. After the survey closed, the survey responses that were received were organized and prepared for analysis. All survey responses were anonymous, only identified by the unique access code. Of the total 681 establishments who provided an email address and were forwarded the link to the web survey, 189 filled the survey (approx. 28%). Of these observations, 171 were found to be suitable for analysis (approx. 25%). The responses to the survey questions were compiled and categorized numerically wherever possible. The questions with Yes/No answers were categorized with a 1 or 0, respectively. Questions where respondents selected answers from a list had a numerical value assigned to each available alternative. The resulting dataset was used in statistical analysis and will be used further in the development of models to describe urban commercial vehicle movements in the study area. The next section will outline some of the preliminary statistical analyses that have been performed on the data.

Analysis Summary

A total of 171 establishments who completed the web survey indicated that they engage in shipping or receiving of goods or services, constituting the usable observations for this study. As previously mentioned, the survey questions were categorized into

three major sections. The preliminary statistical analysis presented in this paper consists of the data pertaining to general establishment characteristics.

A number of cross tabulations were created to examine some of the relationships existing between the variables that were used. Some observations will be presented in this section on the basis of these tables. There were 18 variables related to establishment characteristics that were analyzed, namely those listed below:

- whether the establishment engages in shipping or receiving or goods or services
- the total number of employees at the establishment
- the number of employees in each occupation type at the establishment
- the number of years at the establishment`s current location
- the establishment's total square footage
- the number of employees who make on-call service trips
- the number of employees who make truck deliveries
- whether the establishment has a supply chain/logistics operator
- whether the establishment has a supply chain/logistics specialist
- whether the establishment uses logistics software
- the number of commercial vehicles of each type owned by the establishment
- the industry that best characterizes the establishment
- whether the number of commercial trips made by the establishment varies by day of the week
- the busiest days for delivering goods or services
- whether the number of commercial trips made by the establishment varies by month
- the busiest months for delivering goods or services
- the total number of vehicles leaving the establishment on the day of the survey
- the total number of vehicles arriving at the establishment on the day of the survey

From the cross tabulations created, some observations were noted about the firms who reported shipping or receiving of goods or services. The majority of firms reported having less than 8 employees, as shown in Figure 1. The majority also reported having three or fewer employees who make on-call service trips and 4 or fewer employees who make truck deliveries. Most firms that engage in shipping or receiving reported being at their current locations for under 15 years. Of the firms who reported engaging in shipping or receiving of goods or services, the majority reported owning 4 or fewer vehicles of any type, as shown in Figure 2. The majority of respondents were characterized by the industry categories corresponding to "retail trade," "transportation and warehousing," "other services except public administration" and "other," as shown in Figure 3. The industry types are summarized in Table 3. The majority of firms who engage in shipping or receiving of goods or services reported having 0 or 1 vehicle leaving the establishment on the day of the survey and 0, 1, or 2 vehicles arriving at the establishment to deliver goods or services on the day of the survey. Most respondents indicated that their firms have square footage values between 1 to 1000 square feet, between 1001 to 2000 square feet, between 5001 to 10000 square feet, and between 10001 to 20000 square feet.

Table 3: Industry Types

Industry	Description
1	Retail trade
2	Transportation and warehousing
3	Information and cultural industries
4	Finance and insurance
5	Real estate and rental and leasing
6	Professional, scientific, and technical services
8	Admin. and support, waste mgmt. and remediation svc
9	Education services
10	Health care and social assistance
11	Arts, entertainment and recreation
12	Accommodation and food services
13	Other services (except public administration)
15	Other

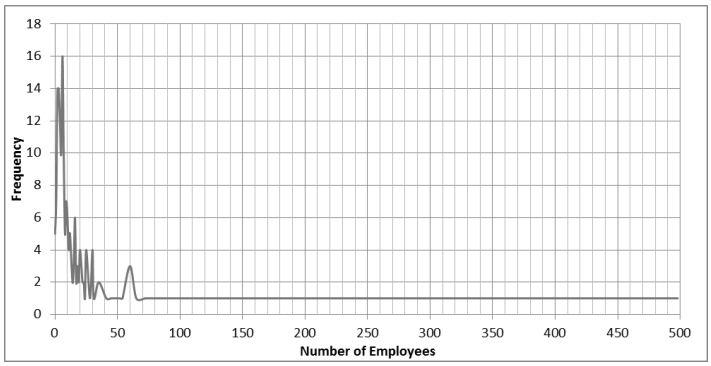

Figure 1: Frequency of Number of Employees for Firms That Engage in Shipping/Receiving

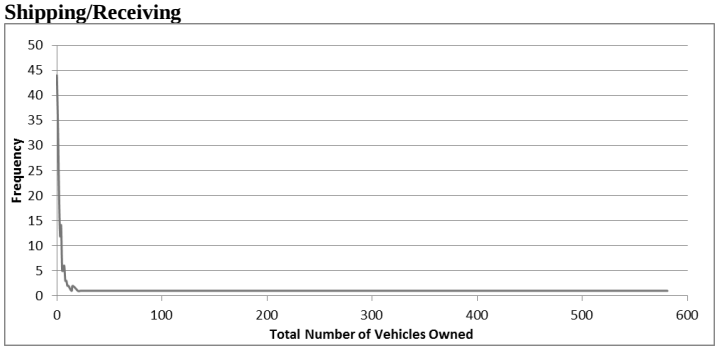

Figure 2: Frequency of Total Number of Vehicles Owned (All Vehicle Types) For Firms That Engage in Shipping/Receiving

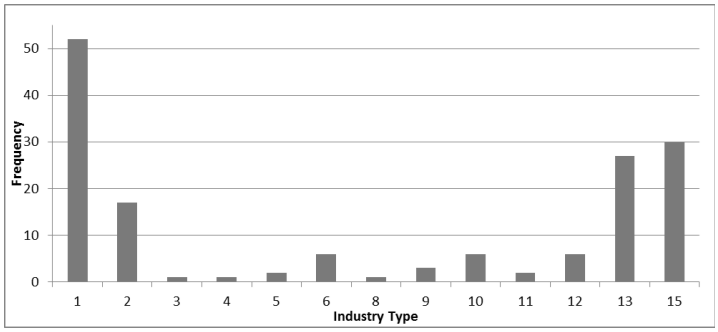

Figure 3: Frequency of Industry Types for Firms That Engage in Shipping/Receiving

A significant number of firms did not provide answers for the questions about having a supply chain/logistics operator, a supply chain/logistics specialist, and using logistics software, possibly due to not knowing to what these terms refer. Of those who did provide responses, the majority indicated not having a supply chain/logistics operator or a specialist, and not using logistics software.

Of the firms who engage in shipping or receiving of goods or services, the majority reported that the number of commercial trips does vary by day of the week and by month. Categories were created for possible combinations of days of the week during which shipments could occur. It was found that the majority reported the busiest days to be within categories of Monday-to-Tuesday; Wednesday; Monday-Tuesday-Thursday-Friday; and Monday-to-Friday. Similarly, categories were created for different combinations of months throughout the year when shipping could occur. The majority reported the busiest months to fall within categories for April-to-September; April-to-December; and January-to-December.

Additional analyses will be conducted on this data, as well as on the outbound and inbound vehicle information that was not used for the purposes of this paper, analyzing the significance of variables such as the number of employees, the number of vehicles owned, and the industry category of the firms on influencing commercial activities. Spatial analysis will also be conducted, comparing the spatial distribution of the survey respondents to the spatial distribution of the entire list of firms that were contacted. A weighting procedure based on industry type and employment size will be conducted on the survey responses to ensure that the survey responses correspond more closely with the existing characteristics of firms in the study area.

Conclusion

This paper described the design and collection of micro data on commercial vehicle movements in the Windsor CMA from a web-based establishment-level survey. A novel approach for recruiting firms to participate in the survey was undertaken, which reduced the number of contacted firms by approximately 64%. The preliminary statistical analyses conducted so far reveal some trends that are worth

exploring further regarding variables such as establishment size by employment and square footage, industry category, number and types of commercial vehicles owned, and the variability of commercial trips by days of the week and by months. The effect that these variables have on defining commercial vehicle activities will be studied further and used in the creation of ordered choice models that will attempt to describe commercial vehicle movements in the study area, also incorporating the remaining data from the web survey about outbound and inbound commercial movements at each establishment. Some land use variables that have been found to have an influence on commercial activities, as described in existing literature, will also be introduced in the future analysis. The model that will be developed has the potential to be used in urban and road network planning for the study area.

References

Ferguson, M. et al. *Transferability and enhancement of a microsimulation model for estimating urban commercial vehicle movements*. Journal of Transport Geography (2012), vol. 24: pp. 358-369

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

Nuzzolo, A. and Comi, A. *Urban freight demand forecasting: A mixed quantity/delivery/vehicle-based model*. Transportation Research Part E (2014), http://dx.doi.org/10.1016/j.tre.2013.12.014

Miller, E., J. Hunt, J. Abraham and P. Salvini (2004). Microsimulating urban systems *Computers, environment and urban systems*, vol. 28, pp. 9-44.

Samimi, A. et al. *A nationwide web-based freight data collection*. Canadian Journal of Civil Engineering (2013) vol. 40(2): pp. 114-120

Samimi, A. et al. *A behavioural freight movement microsimulation model: Method and data*. Transportation letters: The International Journal of Transportation Research (2010), vol. 2: pp. 53-62

Xie, W. and Roorda, J. *Commodity-based goods movement model for the Ontario auto industry*. Annual Canadian Transportation Research Forum (2009): pp. 411-425

Yang, C. et al. *Another view of freight forecasting modeling trends*. KSCE Journal of Civil Engineering (2010) volume 14(2): pp. 237-242