Journal of Transport Geography 24 (2012) 358–369

Contents lists available at SciVerse ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Transferability and enhancement of a microsimulation model for estimating urban commercial vehicle movements

Mark Ferguson [a,*], Hanna Maoh [b,1], Justin Ryan [c,2], Pavlos Kanaroglou [c,3], Taha Hossein Rashidi [d,4]

[a] McMaster Institute for Transportation and Logistics, McMaster University, Hamilton, Ontario, Canada L8S 4K1
[b] Department of Civil and Environmental Engineering, University of Windsor, 401 Sunset Avenue, Windsor, Ontario, Canada N9B 3P4
[c] Centre for Spatial Analysis, School of Geography and Earth Sciences, McMaster University, Hamilton, Ontario, Canada L8S 4K1
[d] Centre for Urban Freight Analysis, Department of Civil Engineering, University of Toronto, Toronto, Ontario, Canada M5S 1A4

ARTICLE INFO

Keywords:
Commercial vehicles
Microsimulation
Goods movement
Fleet allocator
Model transferability
Greater Toronto Area

ABSTRACT

This study examines the transferability of a microsimulation framework to estimate the movements of commercial vehicles in urban areas. We build on the pioneering efforts of Hunt and Stefan (2007) from Calgary, Alberta by considering three types of movements: tour-based; fleet allocator; and internal/external. Some sub-models from Calgary are transferred, while others are newly developed. The framework is implemented and validated for the Greater Toronto and Hamilton Area (GTHA) as a case study. A list of 185,790 records of individual business establishments in the GTHA was acquired from InfoCanada to conduct the microsimulations. The achieved results are promising with favorable correlations between observed and simulated commercial vehicle flows. We conclude that the modeling framework from Calgary can be transferred and used to depict the travel patterns of commercial vehicle movements in other urban areas. This can be beneficial when refined and costly data are unavailable to study urban commercial vehicle movements.

1. Introduction

Traffic analysis of various surface transportation modes is a fundamental component of urban planning. However, transportation research efforts have tended to focus on passenger vehicle movements (Hesse and Rodrigue, 2004; Rodrigue, 2006). Research in recent years has revealed that the omission of Commercial Vehicles (CVs) from transportation planning models can compromise their predictive abilities (see: Waddell et al., 2002; Holguín-Veras and Patil, 2007; Kanaroglou and Buliung, 2008). Stefan et al. (2005) report that "an estimated 10–15% 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 than personal vehicles.

This study is driven by the need for reliable hourly trip data describing the movement of CVs in the Greater Toronto and Hamilton Area (GTHA), Canada. The latter is the largest metropolitan region in Ontario and Canada. It is also among the most dynamic areas in terms of CV movement in North America. As in the case of passenger travel, the state of practice to handle CV movement is to use a version of the conventional four-step approach. However, this approach has been widely criticized for its weakness to capture the travel behavior of people and freight. The agent-based micro-analytical approach has been proposed in recent years as an alternative (Stefan et al., 2005; Hunt and Stefan, 2007). Using the firm as the micro unit of analysis, the agent-based approach is believed to more accurately represent the travel behavior process and as such is expected to produce more reliable results.

Motivated by these recent ideas, we introduce a practical approach to handle CV movements in the GTHA. In the proposed framework, individual business establishments (firms) are used as the unit of analysis to represent and simulate the commercial vehicle movement activities associated with each firm. Both aggregate and disaggregate travel demand modeling approaches are employed to estimate CV movements. These estimates are then validated against real traffic flow data. Building on the pioneering efforts of Hunt and Stefan (2007) for Calgary, we will concern ourselves with commercial vehicle flows of three types: (1) tour-based; (2) fleet allocator; and (3) internal/external. For the GTHA implementation, some sub-models from Calgary are used as is or slightly modified while other components are newly developed.

This work makes two distinct contributions: to the best of our knowledge, this is the first attempt to implement and validate the behavioral modeling framework of Hunt and Stefan for another

* Corresponding author. Tel.: +1 905 525 9140x20131; fax: +1 905 546 0463.
E-mail addresses: fergumr@mcmaster.ca (M. Ferguson), maohhf@uwindsor.ca (H. Maoh), j.dcv.ryan@gmail.com (J. Ryan), pavlos@mcmaster.ca (P. Kanaroglou), thosse2@uic.edu (T.H. Rashidi).
[1] Tel.: +1 519 253 3000; fax: +1 519 971 3686.
[2] Tel.: +1 905 525 9140x26949; fax: +1 905 546 0463.
[3] Tel.: +1 905 525 9140x23525; fax: +1 905 546 0463.
[4] Tel.: +1 416 978 0120; fax: +1 905 546 0463.

0966-6923/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jtrangeo.2012.04.013

urban area and certainly our efforts to create hourly Origin–Destination (O–D) trip matrices for the GTHA from micro-simulated CV tour-based activities is a useful new addition. Secondly, the use of a commercially available firm-level database to assist in the generation of CV movements is novel.

The remainder of this paper is organized as follows. Next, an appraisal of the existing literature on modeling commercial vehicle movement is provided to set the context for our work. Section three provides an overview of the datasets employed in the analysis. It also describes the implementation of the modeling framework. Section four reports on the results from the microsimulations as well as the validation work conducted to examine the simulated results. A final section provides some concluding remarks.

2. Literature review

Relative to passenger transportation research, the CV movement process has not been studied extensively (Joubert and Axhausen, 2011; Rodrigue, 2006; Hesse and Rodrigue, 2004). As in the case of passenger vehicle movement, there are aggregate and disaggregate modeling approaches for handling CV travel. However, the conventional four-step modeling approach is still the commonly used method for developing freight models. Many researchers believe that the four-step approach cannot adequately capture the complexity of local and regional CV movements (see for example: Hensher and Figliozzi, 2007; Southworth, 2002). Another caveat in the four-step approach is the lack of proper representation of light commercial vehicles, which are especially relevant in the intra-urban context. Meanwhile, the development of disaggregate CV movement models is not very common although such models received more attention in recent years.

While the application of aggregate techniques in freight modeling has its drawbacks, the benefits are lower data collection costs and an overall reasonable compromise between modeling quality and project expenses (Liedtke and Schepperle, 2004). The requirements of non-intensive data and simple historical trends are important reasons for the use of such models (Pendyala et al., 2000). One of the earliest freight modeling exercises was done by Oum (1979) who introduced a family of aggregate models using data from the Census of Transportation. To date, the four-step framework is still used in many of the forecast tools developed by the various US Departments of Transportation at the state level (Cambridge Systematics Inc., 2008).

A four-step intermodal freight forecast framework was developed for the state of Ohio (Ohio Department of Transportation, 2010) to assess current and future freight movements on the major regional corridors. Similarly, aggregate freight models were developed for other states including: Virginia (Brogan et al., 2001), Wisconsin (Proussaloglou et al., 2007), Mississippi (Zhang et al., 2003), Texas, Pennsylvania, Iowa, Oregon, Alabama (Cambridge Systematics Inc., 1997) and Indiana (Black, 2006). A technique used in the first stage of modeling is Origin-Destination (OD) matrix expansion, where OD matrices based on traffic counts or surveys are scaled for future years (see: Cambridge Systematics Inc., 1997; Holguín-Veras and Patil, 2007). However, 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.

Our review of the literature suggests two types of disaggregate freight models: inventory and behavioral. The inventory method has a longer history than the behavioral approach. In one of its earliest applications, Baumol and Vinod (1970) investigated the optimal mode choice for faster and more reliable freight service. Typically, shipment size and mode choice decisions are endogenously treated in the inventory approach (Pendyala et al., 2000). Other studies utilizing the inventory approach include Abdelwahab and Sargious (1992), Nam (1997), Catalani (2001), Norojono and Young (2003) and Patterson et al. (2008).

On the behavioral side, many researchers have emphasized the need for a better understanding of the decision-making process in a freight model via an "actor-based" micro-level model (Liedtke and Schepperle, 2004). Here, simulation-based models might better account for the interactions among the decision makers (for example: firms, suppliers, shippers and carriers) and could be integrated with passenger microsimulation models (Wisetjindawat et al., 2005). One of the early commodity-based freight microsimulation was GoodTrip (Wisetjindawat and Sano, 2003). Hunt and Stefan (2007) were pioneers in introducing an agent-based commercial vehicle microsimulation model. The latter was developed for the Calgary region in Canada, based on information from roughly 37,000 tours and 185,000 trips (see also Stefan et al., 2005).

A notable, though less widely used, behavioral method for modeling freight movements is the spatially disaggregate input–output framework. This economic-based approach 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 input–output (MRIO) modeling have been employed to model trade flows between traffic analysis zones. This approach is also known in the literature as the RUBMRIO model, short for the Random Based Utility MRIO model. Within the RUBMRIO model, firms acquire their inputs (goods) from origins that are more advantageous in terms of the price of the acquired good and the cost for transporting the goods. Typically, firms will choose markets (destinations) that provide lower prices and transportation cost (Maoh et al., 2008). Despite its conceptual profoundness, a major drawback of the input–output approach is the need for detailed and spatially disaggregate technical coefficient data that are usually lacking. A recent example of a microsimulation model which uses the spatially disaggregate input–output approach is the PEACS model developed by Hunt and Abraham (2005).

The Oregon Department of Transportation developed a Transportation and Land Use Model Integration Program (TLUMIP). Other than the commercial travel model component (Donnelly, 2007), this program integrated passenger and road freight to simulate micro-level truck movements more effectively. Kumar and Kockleman (2008) proposed a conceptual freight modeling framework for simulating firm entry, exit, evolution, and location in Texas. They used employment point data and some aggregate statistics for the local businesses to enhance their modeling framework. Recently, Samimi et al. (2010) introduced and developed FAME (Freight Activity Microsimulation Estimator) which is a behavioral freight movement model. The authors utilized a cost-effective online establishment survey that was completed by a sample of establishments.

Unlike passenger trips, a considerable portion of freight trips, particularly intra-urban, are not simple trips starting from an origin and ending at a destination (Rodrigue, 2006). Instead, once they are initiated, they are structured in a tour with multiple destinations in a trip chaining convention (Holguín-Veras and Patil, 2005; and Holguín-Veras and Thorson, 1999; Figliozzi, 2010). One of the unique research attempts to study properties of urban tours was performed by Figliozzi (2006). Tours are classified in Figliozzi's research according to the commercial activity that generates the tour and the routing constraints set by the carriers. Due to the significant importance of tour chaining in goods movement, it has become an inevitable requirement of freight surveys to acquire information about the tour behaviors to capture the complex