THE IMPACTS OF FUTURE ECONOMIC GROWTH ON URBAN COMMERICAL VEHICLE MOVEMENT IN HAMILTON, ONTARIO

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1. Introduction

Urban transport and land-use modeling 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; Kanaroglou and Buliung, 2008). It is estimated that 10% to 15% of urban vehicle trips are made for commercial purposes. Also CVs, particularly 'large' CVs, have a significantly greater impact, per vehicle, on traffic congestion, pollutant emissions, and road wear, 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 and Buliung, 2008).

In this report, we extend the capabilities of IMULATE, a state-of-the-practice Planning Support System (PSS) for assessing the inter-relationship between land use and transportation in the Census Metropolitan Area (CMA) of Hamilton, to account for CV movements on the urban road network. Traditionally, IMULATE accounted for passenger vehicle flows on the Hamilton road network. The model has been used in several studies to inform debates related to land use and transportation issues in the CMA of Hamilton (See for example: Kang et al. 2008; Behan et al. 2008). The new CV sub-module developed as part of this research will predict the movement of the commercial car fleet to determine CV flows on the road network. This will be achieved by extending the transportation module, and making use of the employment estimates produced by the land use module. CV traffic is assigned to the network along with passenger traffic, bringing greater realism to model forecasts. To examine the new extensions, future scenarios pertaining to economic growth in the Hamilton region and, in particular growth in industrial parks and the airport employment district are devised, simulated and analyzed.

The remainder of this paper is organized as follows. Section 2 presents a background on CV modeling, including methods and techniques, as well as related modeling issues. Section 3 outlines the methodology of our modeling approach. Section 4 discusses the simulation results. Finally, Section 5 provides conclusions to our study.

2. Background

Modeling urban CV travel can be conceptualized as comprising two stages (see: Kanaroglou 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 of the first stage are modeled as tours, which begin and end at a commercial establishment (see: Figliozzi, 2007; Hunt and Stefan, 2007). Various methodologies exist to model CV flows of 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 modeling are referred to as Origin-Destination (OD) matrix expansion, where OD matrices based on traffic counts or surveys are scaled for future years. 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 technique adapts the trip generation and distribution stages of the four-stage modeling process in order to generate OD matrices of CV flows (Ruiter, 1992; Schlappi et al. 1993). This general modeling framework is most notably presented in the '*Quick Response Freight Manual*' (QRFM), produced 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 as well as of information from the QRFM. Two notable, though less popular methods of modeling urban CV patterns are supply-chain modeling and spatially disaggregate Input-Output (IO) modeling (Hunt and Stefan, 2007). The latter is more frequently used by transportation modelers. Here, ideas and concepts related to multiregional IO modeling can be employed to model trade flows between traffic analysis zones. Despite its conceptual comprehensiveness, a major drawback of the IO approach is the need for detailed data which are usually lacking. More recent efforts apply the agent-based microsimulation framework. In this approach, trips are modeled at a disaggregate level that utilizes the business establishment as the unit of analysis. However, efforts to use the agent-based approach are still at their infancy given the lack of appropriate data to carry on such modeling exercise.

General consensus in the existing literature suggests that proper analysis of urban CV movement must be based on high quality data. Such data are currently non-existent in Canada, with the exception of Calgary and Edmonton in the province of Alberta (Hunt and Stefan, 2007), and the Peel Region of Ontario (Roorda et al., 2006). One main method of collecting urban CV data is through the use of surveys. In the past, when freight transportation studies had been undertaken in Canadian cities, the collected data had been almost exclusively on truck trips (Woudsma, 2001). These efforts to understand urban CV movement and its associated benefits and externalities were based on aggregate data (intersection truck counts) that are insufficient for analyzing and understanding the processes involved (Kanaroglou and Buliung, 2008). Several specific issues exist concerning CV data collection. First, the CV fleet is heterogeneous and thus requires some classification. A second issue in collecting CV data is the time of day. Some modeling efforts (such as Kanaroglou and Buliung, 2008) focus on peak-period morning traffic patterns, and in these cases any collected CV data must conform to this time period. Depending on the time period being modeled, the mix of CV and personal vehicles may vary, and should therefore be carefully considered. Finally, in many urban areas, some classes of CVs are restricted from using certain links in the urban transport network. These policy considerations must be incorporated into CV models, specifically in the network traffic assignment stage.

A common method of combining passenger vehicle traffic with CV traffic in transport models is through the use of Passenger Car Equivalency (PCE), which scales a given CV into a specific number of passenger cars thought to be equivalent in terms of use of network resources. In the absence of better data, PCEs may also serve as a proxy value for fuel consumption and emissions of pollutants. In this way, traditional transport models can be readily modified to include CV movements. The specific PCEs used for different elements of the CV fleet can be of consequence. As reported by Kanaroglou and Buliung (2008), model results (in this case emission estimates) "demonstrate sensitivity to PCE values." In general, PCEs have been shown to vary according to traffic conditions, link grade, number of lanes, and the percentage of trucks on a given link. Kanaroglou and Buliung (2008) estimate PCE to a value of 2.48 in their CV study for Hamilton. That is to say, they postulate that on average, one CV trip on the road network is equivalent to 2.48 passenger vehicle trips. It should be noted, however, that the above PCE value is used for all CV types. In general, PCE values should be treated with caution when modeling different classes of CVs.

3. Methods of Analysis

The travel demand model of IMULATE is extended to include a new CV sub-module (CVSM), which incorporates the contribution of Commercial Vehicle movements on the road network. CVSM generates CV trips by zone and vehicle type class using the QRFM regression parameters listed in Table 1. Estimates, by the land use sub-module of IMULATE, on the spatial distribution of jobs by economic sector, as well as on the distribution of households are used as covariates in the regression models. The QRFM parameters were adjusted to reflect CV trips during the morning period. Here, scaling was done using proportions obtained from data for the Calgary region in Alberta, Canada, as shown in the last row in Table 1. The execution of this step during simulations will produce generated trips for light, medium and heavy CVs for a typical hour in the morning peak period. The information from the trip generation model is then employed within an iterative proportional fitting (IPF) algorithm (which forms the trip distribution stage) to update base year CV trip matrices pertaining to light, medium and heavy CVs. The table elements within the resultant matrices are then translated into passenger car equivalent values using predefined PCE values. This step constitutes the trip distribution component of the CVSM. The resulting PCE matrices are then assigned to the road network to determine the flows of CVs. The traffic assignment is performed by having medium and heavy CVs assigned only to road links permitting the movement of trucks. On the other hand, light CVs are allowed to use all road links of the transportation network.

The base year matrices used in the trip generation stage were created from a 1998 CV matrix that was developed from CV traffic counts (Kanaroglou and Buliung, 2008). Two adjustments were made to incorporate this data into CVSM: (1) The 1998 CV matrix was split into three matrices that reflect light, medium and heavy CVs using 2006 split shares of CV classes for the City of Calgary in Alberta, Canada. The utilized shares were 0.59, 0.26 and 0.15 for light, medium and heavy CVs respectively; (2) elements within the 1998 CV matrices by CV class were adjusted to the 1996 CV trip generation rates produced by the trip generation model for consistency purposes. The adjusted three matrices for 1996 are used as the basis for simulations in CVSM.

Table 1: Trip generation parameters for 3 CV classes

X_i^*	Economic Sector	Light CVs β^L_i	Medium CVs β^M_i	Heavy CVs β^H_i
X_1	Construction	1.110	0.289	0.174
X_2	Manufacturing, Transportation, Communication, Utilities and Wholesale trade	0.938	0.242	0.104
X_3	Retail Trade	0.888	0.253	0.065
X_4	Office and Services	0.437	0.068	0.009
X_5	Household	0.251	0.099	0.038
Morning Scaling factors⁺		0.054	0.054	0.200

Source: (*) Quick Response Freight Manual (QRFM), (+) Calgary, Alberta 2006 CV OD database

Two scenarios reflecting possible urban futures pertaining to economic growth in the City of Hamilton, Ontario are specified and modeled:

I. Base Case (BASE) Scenario: Under this scenario economic and demographic patterns will continue in a similar fashion as they did between the years 1986 and 2006, with no major slowdowns or economic booms. Here, base case growth includes the addition of 80,000 new dwellings to the housing stock between the years 2006-2031. The allocation of the new development over space follows an urban sprawl pattern, a predominant phenomenon in the study area since the early 1990s. In addition, during this same time period, approximately 86,500 forecasted new jobs are to be created in the study area. The assumption made here is that the CMA should expect an approximate employment growth of 7.25 percent, on average, every five years starting from 2001. The spatial pattern of employment growth under this scenario will follow the existing trends that have been observed since 1991. As such, a sprawled and somewhat non-centralized pattern is likely to emerge in the future, even though some concentration of employment is expected in the case of some industries (Maoh and Kanaroglou, 2007).

II. Targeted Economic Growth (TEGS) Scenario: In comparison to the BASE scenario, TEGS assumes slightly higher levels of economic growth (91,000 new jobs) in the period 2006 – 2031. The spatial patterns and levels of forecasted residential development under TEGS will be the same as in the BASE scenario. Within this scenario, a significant portion of employment growth will be distributed to specific, designated lands in the Hamilton area, such as established business parks, the Airport Employment Growth District (AEGD), and the Port of Hamilton (Hamilton Economic Development, 2008). The anticipated growth will occur on newly developed business parks, as well as in offices, and population oriented retail and service based firms. Business parks are expected to receive 59,000 (65%) of the employees, whereas offices are expected to receive 11,000 (12%) employees. The remaining 23% of total new employees (i.e. 31,000) will be found in the population oriented retail and service based firms.

Besides the proposed AEGD future growth initiative for areas surrounding the Hamilton International Airport, plans are underway to increase development of the Port of Hamilton and its surrounding areas (The Hamilton Port Authority Land Use Plan, 2002). The development of Hamilton's airport and seaport is expected to attract a significant amount of economic activity, allowing Hamilton to become a regional inland Gateway, primarily for goods movement. The total expected employment growth in the port area is estimated to be 3,360 employees for the period 2011 – 2031. Finally, a number of existing business parks within the Hamilton area, other than the AEGD and seaport area, are also expected to experience growth in the period 2011 – 2031. The total estimated growth in these business parks is 21,316 employees. In order to deal with this anticipated growth within IMULATE, the census tracts corresponding to the different geographic areas hosting the business parks are identified. Employment growth in business parks is exogenously distributed over time (every 5 years) following the rates of growth predicted for the AEGD in the Hamilton AEGD Land use Study (2008), (i.e. 11%, 33%, 40% and 16% for the corresponding 4 "5-year based" periods between 2011 and 2031). As noted earlier, growth in employment under the BASE case follows a more even distribution among the 4 periods between 2011 and 2031.

4. Simulation Results

In order to gain a sense of the overall impact of UCVM under the TEGS and BASE scenarios, it is useful to present several basic measures at the CMA level. Table 2 provides projected employment figures for the TEGS and BASE scenarios at the CMA level over time. The TEGS scenario produces approximately 8% more jobs than the BASE scenario in the period 2026 – 2031. This is expected to generate a higher number of CV trips in the region, as shown in Table 3. Overall, the results indicate that the TEGS scenario will generate a 1 percent increase in the number of morning CV trips in the region. However, the 8 percent increase in jobs under the TEGS scenario will increase heavy CV trips by 6 percent. This is most likely due to the increase in the number of jobs from industrial sectors that depend on heavy CVs for their operation. Examples of such sectors would be transportation, warehousing and manufacturing firms, which are proposed to occupy certain business parks.

Table 2: Projected employment figures

Scenario	2001	2011	2021	2031
BASE	217,451	240,737	270,085	303,943
TEGS			261,647	328,428
Change from BASE			-8,438	24,485
Percent Change			-3	8

While the results indicate a very small difference in the overall number of generated CV trips in the region, the patterns of these trips are expected to be different. This is because urban form will be different for the two scenarios, resulting in distinct travel patterns on the transportation network. Figure 1 shows total employment, per census tract (CT), for the BASE scenario in the year 2031. The map depicts a pattern similar to the one observed in the period 1991 – 2006. This is expected since market power (agglomeration economies) is likely to attract more firms and jobs to areas that are already established within the city, other things being equal (Maoh and Kanaroglou, 2007). That being said, regulatory policy, as well as other incentives, can effectively guide economic growth over space. This theme is central to the TEGS scenario, where a significant portion of economic growth is concentrated in a small number of business parks located strategically throughout the Hamilton CMA. These initiatives can lead to a more concentrated land development pattern that encourages the emergence of a multinucleated urban form over time. Figure 2 shows total employment per CT for the TEGS scenario in the years 2031. As can be seen, there is a marked difference between these spatial employment distributions and their BASE scenario counterparts. In Figure 2, we see that a large amount of employment is located in the large southern periphery CTs containing the AEGD, as well as the North Glanbrook, Ancaster and Airport business parks. At the same time, established business areas appear to maintain healthy levels of employment under the TEGS.

Table 3: Total Generated Commercial Vehicle Trips by Class

CV Class	Scenario	2021	2031
Light	BASE	12,642	14,090
	TEGS	12,041	13,929
	Change from BASE	-601	-161
	Percent Change	-5	-1
Medium	BASE	3,323	3,690
	TEGS	3,220	3,703
	Change from BASE	-103	13
	Percent Change	-3	0
Heavy	BASE	4,489	4,963
	TEGS	4,570	5,248
	Change from BASE	81	285
	Percent Change	2	6
Total	**BASE**	**20,454**	**22,582**
	TEGS	**19,831**	**22,880**
	Change from BASE	-623	298
	Percent Change	-3	1

Intuitively, the observed variations in the spatial distributions of jobs under the two simulated scenarios will result in distinct patterns of UCVM on the transportation network. When examining the spatial distribution of generated commercial vehicle trips for 2031, a pattern very similar to the one seen in Figures 1 and 2 can be observed for both the BASE scenario and TEGS. In essence, there is a strong, direct relationship between the number of jobs and the amount of CV trips generated, for a given CT. This suggests that CTs receiving more economic development in the future will result in increased UCVM activities.

One consideration resulting from employment heterogeneity and the associated CV trips over space is their effect on infrastructure at the local level. In particular, "critical infrastructure" can be identified which bears a disproportionate (or perhaps inappropriate) share of the burden resulting from transportation activities induced by economic activity. In IMULATE, it is possible to examine individual links from the network, allowing for the identification of such critical infrastructure. Figure 3 represents, under the BASE scenario, the generated flow of commercial vehicles on the Hamilton CMA road network during a typical morning peak period for the year 2031. As can be seen, a number of major highways and expressways (namely, HWY-403, EXP-QEW, LINCOLIN PRKW and RED HILL CREEK PRKW) will receive the bulk of CV traffic under the BASE scenario in the morning peak period. Road links designating the major arteries in the core of the city (namely, Main and King) will also be affected. This is expected since many of the firms under the BASE scenario exhibit either a suburban or central preference, as can be seen in Figure 1. By comparison, an alternative traffic pattern emerges under the TEGS scenario. Figure 4 shows the road links that will receive higher traffic flow under TEGS relative to the BASE scenario. It is evident that roads in the periphery of the city, particularly in the southern area around the airport and AEGD, will experience significant increases in CV traffic.

Given that the AEGD alone is predicted to host 34,000 new jobs by the year 2031, the combination of CV and passenger traffic could threaten to overwhelm the transportation infrastructure in the area, resulting in high levels of congestion and associated tailpipe emissions in particular hot spots (see Figure 5). The map shows heavily load traffic on major arteries and highways surrounding the city, as well as apparent levels of traffic to the south of the city near the AEGD. Effective urban planning that considers smart growth and sustainability concepts can mitigate the negative side effects of economic growth. For instance, ways to tone down these negative effects could be to intensify residential development around the AEGD. Furthermore, enhancing transit level of service through the development of new infrastructure such as light rail transit (LRT) lines, to establish an East-West and North-South rapid transit connections stretching to the AEGD, can help to decrease congestion and increase the efficiency of the urban transportation system.

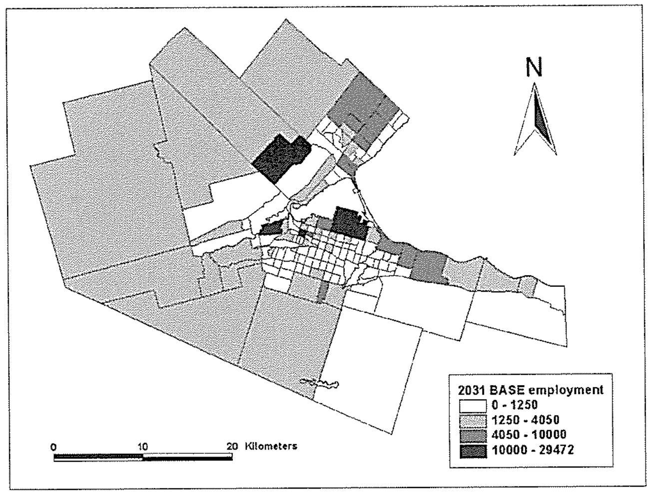

Figure 1: Employment by CT, BASE scenario, 2031

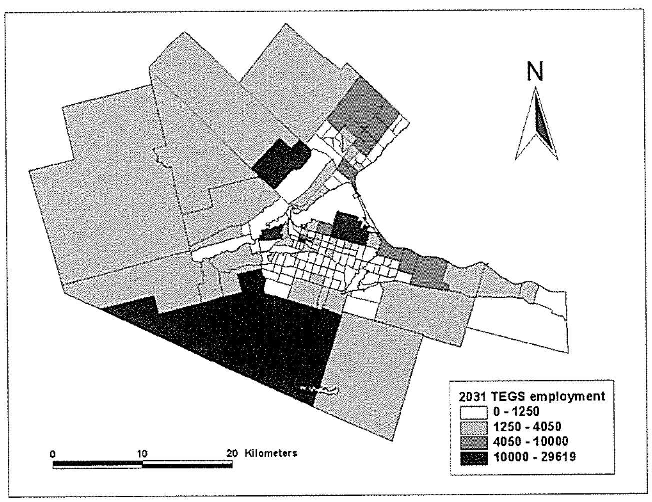

Figure 2: Employment by CT, TEGS scenario, 2031

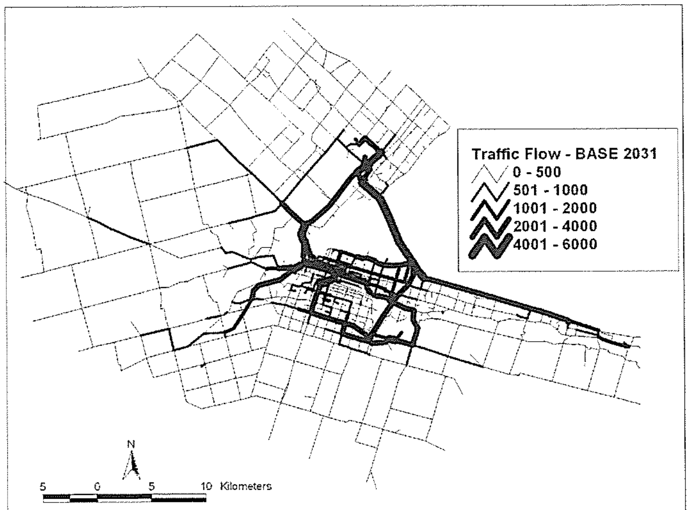

Figure 3: Commercial Vehicle Traffic Flows under the BASE Scenario, 2031

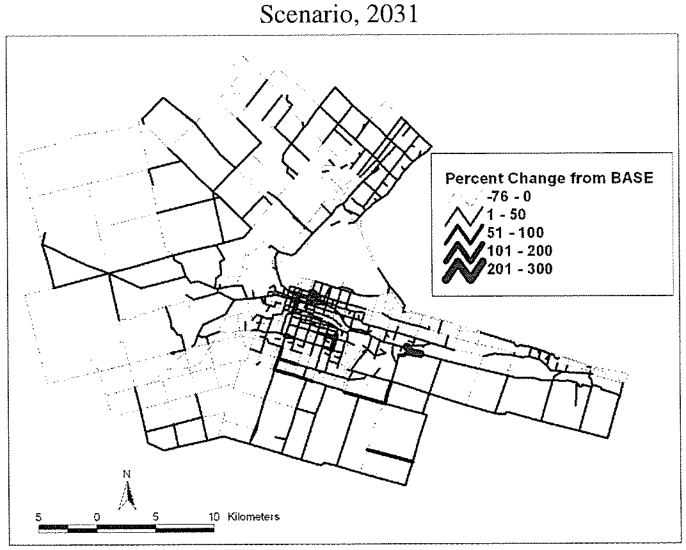

Figure 4: Percentage change in traffic flow under the TEGS, 2031

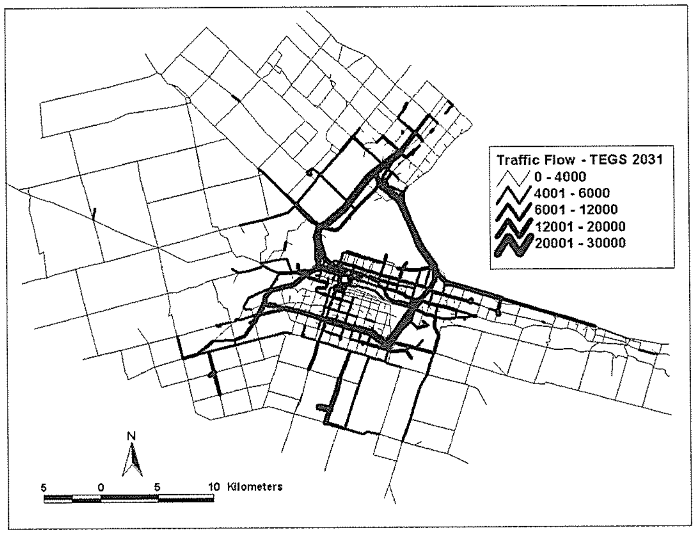

Figure 5: Combined Passenger and CV Traffic Flows under the TEGS, 2031

Finally, the analysis of system usage (e.g. VKT) and performance measures (VMT, energy consumption and emissions levels) suggests that the impacts of economic growth are more pronounced at the local level. Compared to the base, the TEGS scenario is reducing VKT, energy consumption and emission levels by 3 percent in 2021, while resulting in no virtual differences in 2031. Nonetheless, the results from Figure 4 and local level link based emission maps indicate that the impacts of TEGS are more pronounced locally.

5. Conclusions

Several main conclusions can be drawn from this work. In particular:

- Incorporating CV movements into urban transport simulation models produces improved results and allows for the incorporation of more realistic and dynamic scenario testing

- The spatial distribution of future economic growth in Hamilton has important impacts on the city, particularly in terms of urban form and mobile emissions of pollutants.
- Assuming similar overall growth levels, variations between different growth scenarios are often better observed at the census tract or link level than at the CMA wide level.
- The IMULATE system, in conjunction with the devised Commercial Trip module, is a useful tool for economic growth scenario forecasting and, more generally, for urban planning efforts

It should be noted that public transportation infrastructure investments, along with other policy initiatives, are vital means of mitigating the negative externalities associated with economic growth. As such, elaborate analysis of the effects of specific policy packages can be carried out using simulation models, under various economic growth frameworks. Some examples handling certain aspects of future urban planning policies can be seen in the works of Behan et al. (2008), and Kang et al. (2008). Future research with the new extensions of IMULATE will focus on assessing alternatives growth policy packages with elements including: (1) the development of residential neighborhoods, (2) the establishment of industrial parks and employment lands, (3) the construction of new road infrastructure, or (4) the enhancement of the level of service for the public transit system, to name a few.

6. References

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