Application of EMME3 and Transportation Tomorrow Survey (TTS) for Estimation of Zonal Time Varying Population Density Distribution in the Greater Toronto Area

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1. Introduction

This report has been prepared as part of an on-going project with the Toronto Atmospheric Fund on developing a truck emissions simulation tool for evaluating green commercial vehicle policy [1]. An integrated modelling system has been developed that includes regional travel demand models for the Greater Toronto and Hamilton area (GTHA), a microscopic traffic simulation model of the Toronto waterfront area, a model of vehicle emissions that is sensitive to vehicle driving cycles and a model of pollutant dispersion. The final phase of this project involves an estimation of population location by time of day for the assessment of personal exposure to vehicle generated emissions. By comparing pollutant concentrations and population density in a zone, aggregate population exposure observations can be made. A zone-based time varying population density distribution is developed for this purpose.

The 2006 Transportation Tomorrow Survey (TTS) micro trip-data, Data Management Group - Internet Data Retrieval System (IDRS) and EMME3, the travel demand forecasting software were extensively for this purpose. Access to all data, including EMME3 Greater Toronto Area (GTA) road network and the EMME3 network license was provided by the Data Management Group.

2. Population Exposure Assessment

The vehicle emission model and the emission dispersion model of the truck emissions simulation tool respectively generates and disperses vehicular emissions, namely carbon mono-oxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x) and hydrocarbons (HC) on the Toronto downtown waterfront network. To analyse and compare the exposure of emissions to the population, a zone based time varying population density distribution is required for the waterfront network.

The 2006 Transportation Tomorrow Survey (TTS) is used to process and estimate this distribution. TTS is a household travel survey that has been undertaken every 5 years in the Toronto region since 1986 [2] [3]. Approximately 5% of the population in the Greater Toronto Area (GTA) is surveyed telephonically where household characteristics, individual characteristics and trip characteristics for the past 24 hours are collected. The 2001 GTA zone system was used to conduct the population exposure assessment. Section 3 describes the methodology in detail.

3. Methodology

The methodology is divided into three sub-sections. Figure 1 shows a flowchart that outlines the processes involved.

3.1 Estimating travel time matrices

a) Estimating auto travel time matrix using EMME3
b) Transit travel time matrix
c) Estimating walking and biking travel time matrices

For estimating the auto travel time matrix in EMME3 the GTA road network was loaded with hourly trip matrices from the 2006 TTS data (generated using the DMG-IDRS)[4]. The auto-assignment was a fixed demand traffic assignment conducted for every hour of the day on a single class of vehicles (auto mode) with a stopping criterion for best relative gap of 0.5% or 20 iterations. The transit travel time matrix was

made available by Prof. Eric Miller, Cities Centre, University of Toronto. Figure 2 shows a snapshot of the GTA road network on EMME3.

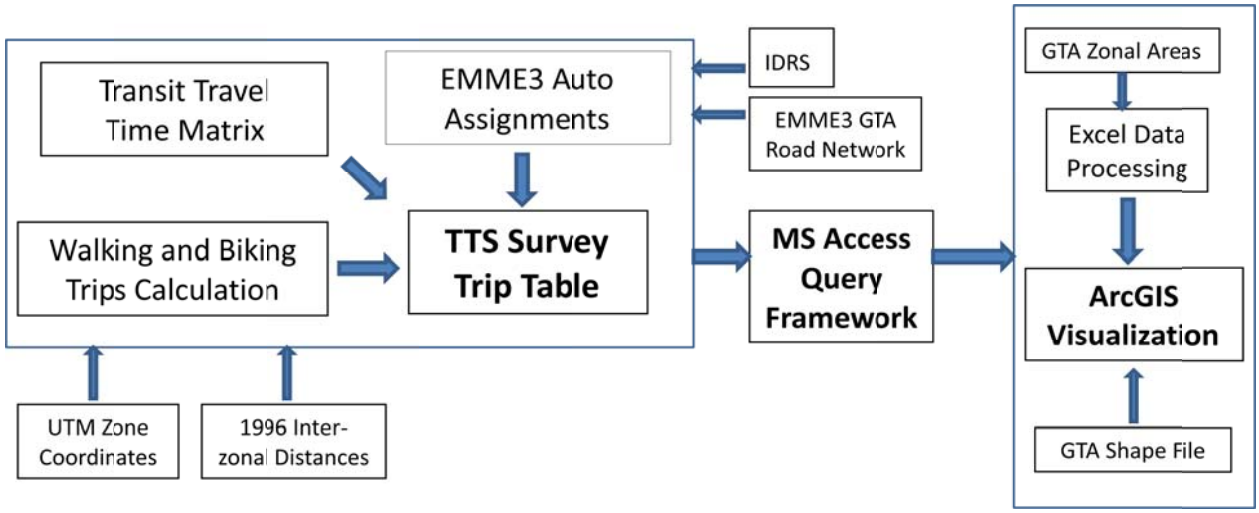

Figure 1: Methodology Flowchart

For inter-zonal walking and biking trips, a Manhattan grid network was assumed and distances between zone centroids (calculated using the UTM coordinate system) were multiplied by a factor of 1.4 to calculate average trip distances; a walking speed of 5 km/h and a biking speed of 20 km/h was assumed to calculate travel times for such trips. For intra-zonal transit trips, an average bus speed of 30 km/h and for intra-zonal auto trips, an average auto speed of 40 km/h, was assumed.

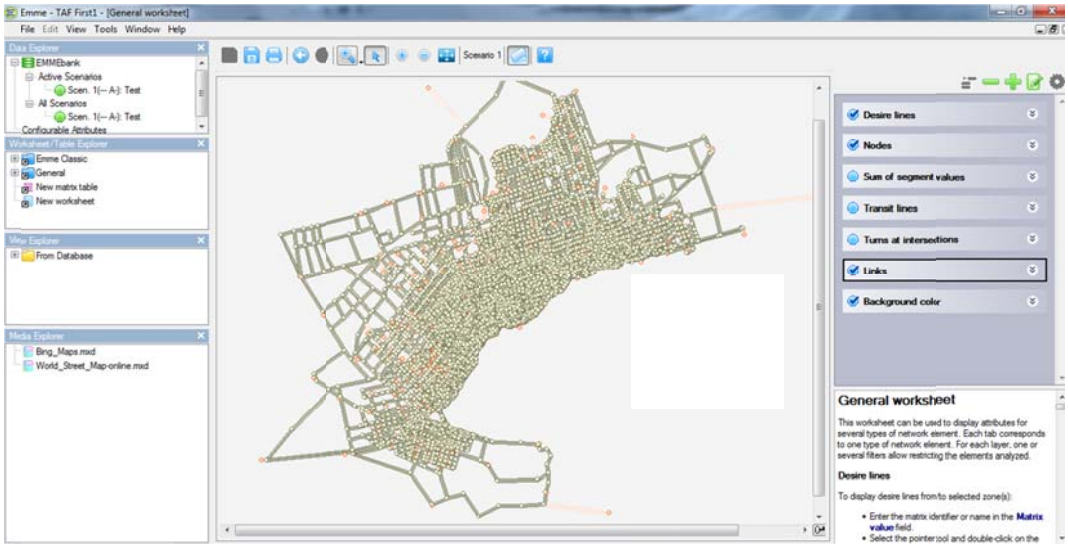

Figure 2: The Greater Toronto Area Road Network on EMME3 Environment

3.2 Determining trip arrival times

The TTS Survey only provides a start time for all surveyed daily trips. The end time of all trips is required to calculate the location of people making trips for different times during the day. The travel time matrices generated for the different modes in the first step were integrated with the TTS trip data to obtain end times for all surveyed trips. It was assumed that the auto travel times are representative of

travel times experienced by modes such as motorcycles, taxis, school buses and all 'other' miscellaneous modes as well.

3.3 Determining population distribution by time of day

A MS Access query framework was developed to estimate each person's location for each hour of the day in the GTA. A variable called 'Snaptime' was introduced indicating the time for which the population distribution is estimated. People were categorised on the basis of the number of trips they made between zonal origin-destination pairs. The assumed location at the "Snaptime", was determined as follows:

1) People making no daily trips:
   1.1) People who do not make any trip are located at their home zone.

2) People making only 1 daily trip:
   2.1) People are at their origin zone if the trip has not started before 'Snaptime'
   2.2) People are at their destination zone if the trip is completed before 'Snaptime'
   2.3) People are at the destination zone of the trip in progress, for trips occurring during 'Snaptime' (assumed)

3) People making more than 1 daily trip:
   3.1) People are at the destination zone of the last trip completed before 'Snaptime'
   3.2) People are at the origin zone of their first trip, if the trip starts after 'Snaptime'
   3.3) People are at the destination zone of the trip in progress, for trips occurring during 'Snaptime' (assumed)

The query framework was run for each of the 24 hours of the day starting at 4:30 AM. The population density (expressed in capital/sq. km) was plotted against time for different zones in the GTA. Section 4 discusses the results.

4. Results

The observed population density distributions are shown in Figures 3-6 [5]. The total population of the GTA based on 2006 TTS survey is approximately 5.87 million.

Figure 3 shows the population density distribution (in capita/sq. km) in the GTA at 4:30 AM. Higher densities are observed in downtown Toronto and the suburban city centres of Hamilton, Mississauga and Brampton. This can be attributed to the presence of numerous residential high-rise buildings in such areas. Generally higher densities are also observed in the suburban regions, since almost all people are home at 4:30 AM. Figure 4 shows the density distribution at 10:30 AM when most people have travelled to their workplace. As expected, this causes a big spike in the population density at the Central Business District in Toronto, Mississauga & Hamilton and the downtown Whitby-Oshawa area. The reverse phenomenon is observed in the evening (Figures 5 and 6) when people travel back to their home, and the population density decreases in the downtown areas for all cities, approximately to their original state from the observations made at 4:30 AM (Figure 3).

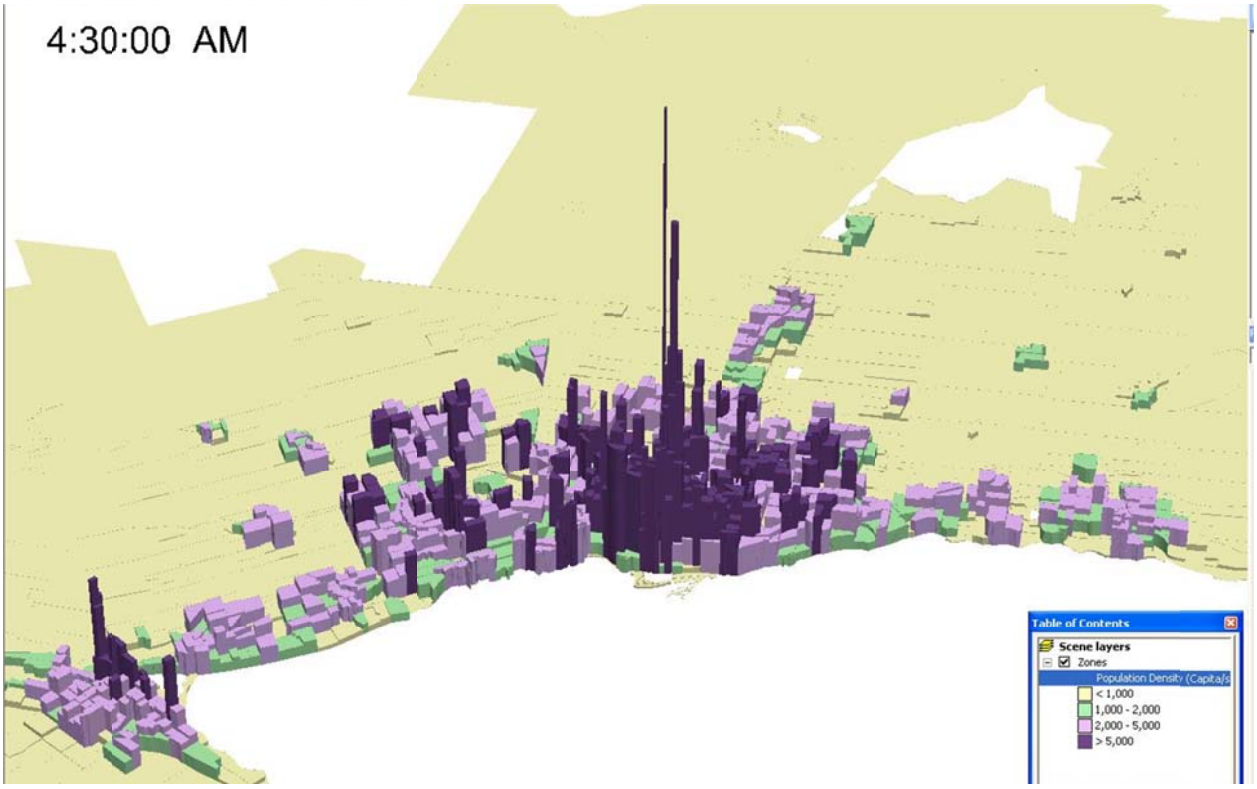

Figure 3: GTA Zonal Population Density Distribution – 4:30 AM

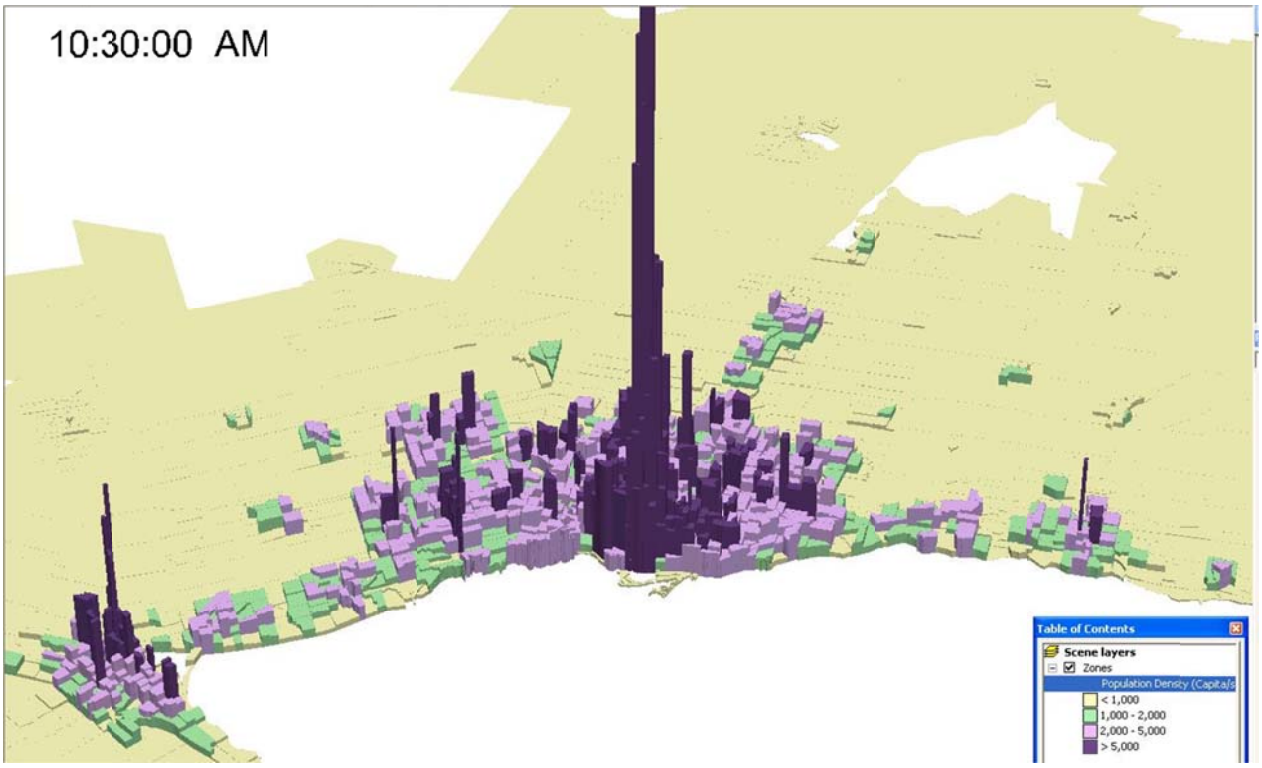

Figure 4: GTA Zonal Population Density Distribution – 10:30 AM

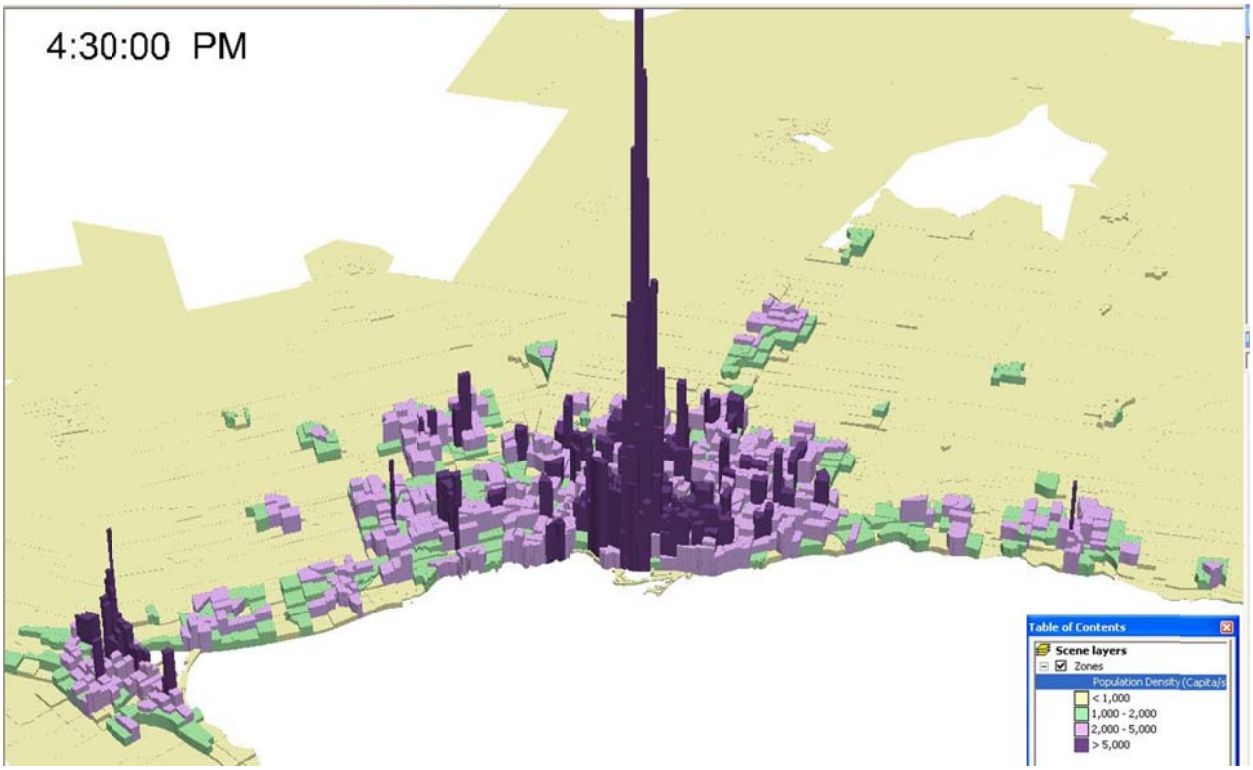

Figure 5: GTA Zonal Population Density Distribution – 4:30 PM

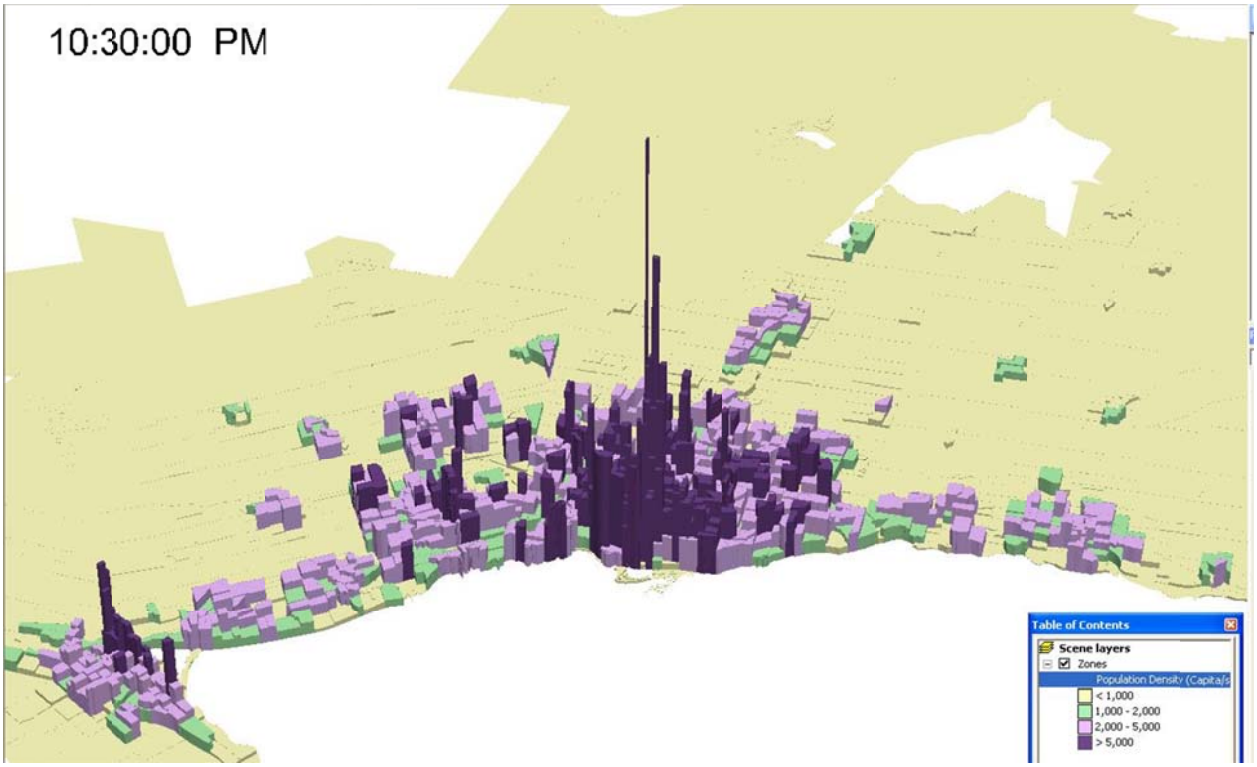

Figure 6: GTA Zonal Population Density Distribution – 10:30 PM

5. Conclusion

A travel demand model (EMME3) was used to estimate daily travel times for different origin-destination zone pairs and integrated with the 2006 Transportation Tomorrow Survey data to generate a population density distribution with hourly variations for the Greater Toronto Area. These time varying zonal population density estimates can now be compared with emission concentration values obtained using the truck emissions simulation tool to estimate population exposure as part of the Toronto Atmospheric Fund project.

Notes:

1) Approximately 12000 auto travel trips (1.9% of all daily trips) on the TTS did not have corresponding O-D zone combinations available in the EMME3 Auto Travel Time Matrices, likely due to presence of external zones - an average travel time of 35 minutes was assumed for all such trips.
2) Approximately 20000 transit travel trips (3.1% of all daily trips) on the TTS that did not have a corresponding O-D zone combination available in the EMME Transit Travel Time Matrices. The auto-travel times for the 8am-9am period were assumed to be a reasonable approximation for such trips (includes IVTT, WaitT and WalkT) - since transit is competitive with auto-travel in the rush hour period.
3) For 213 trips, where zone combinations from the auto travel time matrices were not available, an average travel time of 35 minutes was assumed.
4) The sum of the daily population distribution varies by a maximum of 0.0097% for some 'Snaptime' cases.

6. References

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