The Impacts of Urban Growth Policies on Transportation System Usage and Performance: A Simulation Approach

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Abstract

Integrated urban models (IUM) are tools that can be used to simulate the long term impacts of transportation and land use policies. In this paper, IMULATE, an IUM for the Hamilton Census Metropolitan Area is used to investigate the impacts of several growth policies outlined in the Province of Ontario's Places to Grow plan. Several intensification strategies are simulated and evaluated with respect to transportation system usage and performance. The simulation results are investigated at the aggregate and disaggregate levels, since some impacts to the system such as pollutant emissions exhibit scale effects. While IUMs have been used to compare growth strategies world-wide, little applied work has been published before in Canada. The results indicate that in the absence of modifications to the transportation system, the proposed intensification strategies are likely to have little net effect in mitigating growing system usage and weakening system performance over the next 25 years. The growth strategies investigated do however impact the spatiality of transport related externalities.

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1.0 Introduction

Throughout time, urban form has been inextricably linked to transportation. The sizes and densities of our cities are related to the transportation technologies available at the time of development. Early cities were walkable, and naturally compact. The mechanization of transport in the form of rail transit led to the first wave of urban expansion and early suburbanization in the late 19th century. This was coupled with the modernist separation of places of work from places of residence. These trends were bolstered by the widespread availability of personal automobiles, increased affluence, and the perceived value of low density suburban living. Once again, cities expanded, further increasing the degree of separation between activity locations, thereby driving demand for travel upward. In North America, this demand was met by national scale highway infrastructure investments which provided a circulatory system that would not only satiate the postwar demand for commuter infrastructure, but also have the effect of modifying the prevailing accessibility patterns and further fuelling urban expansionism to this day.

It is startling that given the historical evidence of interdependence between urban form and transportation, the nature of this relationship continues to be a hotly contested issue (Newman and Kenworthy, 1989; Gordon and Richardson, 1989; Ewing, 1997; Miller, 2004; Wegener, 2004; and Hunt *et al.*, 2005). This is mainly due to the ongoing debate on the strength of this relationship (Timmermans, 2003). Starting with the emergence of sustainable urban planning among the political ranks in response to the 1970’s OPEC crisis, and the identification of urban transportation as a major source of greenhouse gas emissions in the early 1990’s, a culture of land use manipulation has indoctrinated physical planners at multiple levels of government. Their policies intend to exploit the land use transportation relationship to reduce transportation emissions and slow down excessive geographic expansion of urban areas. These policies are neatly packaged into the two word title, “Smart Growth”, which specifically pertains to “better coordinating and integrating transportation and land development” (Cervero, 2001). Clearly, the appropriate design and efficient implementation of smart growth policies necessitates a full understanding of the land use transportation relationship.

The adoption of smart growth is in part related to broad institutional support from higher levels of government. Kanaroglou and Scott, (2002) posit that the *Intermodal Surface Transportation Efficiency Act* and its renewal in 1998 with the *Transportation Equity Act for the 21st Century* as well as the *Clean Air Act Amendments* promoted integrated land use and transportation policies in the US by “transferring authority over transportation policy to local governments and explicitly requiring that transportation policy decisions consider the potential impacts on land use”. This requirement can be fulfilled by using integrated urban models (IUM) (Wegener and Spiekermann, 1996) and many leading scholars suggest this as a primary reason for the present resurgence in the development of IUM technologies (Kanaroglou and Scott, 2002). IUMs provide a virtual laboratory in which planners, transportation professionals, and academics can test the long term impacts of integrated land use and transportation problems (Miller *et al.*, 2004). Given an urban centre, for a variety of simulation scenarios, IUMs allow decision makers to isolate the potential impacts of a particular policy by holding other characteristics of the city constant, something that is difficult to achieve otherwise. It is worth noting, however, simulation models are not decision-making substitutes. They are tools that aid policy makers in the decision process. Also, users of simulation models must recognize that their output is strictly conditional on the assumptions upon which the model is based (Kanaroglou and South, 1999).

To this end, PROPOLIS, a multinational European initiative emerged to assess the long term impacts of integrated land use and transportation policies on urban sustainability (Lautso *et al.*, 2002). Their key contribution was to develop an indicator module that could interface with a variety of IUMs calibrated for different cities. From this, a standardized collection of sustainability indicators were produced for dozens of simulations of potential policies. The indicators were fed automatically into a multi-criteria analysis module allowing for the immediate evaluation of policy efficacy. The success of PROPOLIS has further entrenched the IUM approach in the battle towards sustainable development and the testing of smart growth strategies. However, despite the success of PROPOLIS in Europe, very little has been done to address this issue in the Canadian context. According to Hatzopoulou and Miller, (2008), the use of simulation models to inform land use and transportation policies in the Canadian context has been fairly limited. The authors' findings attribute this to "a general disbelief in the usefulness of models for decision-making, lack of resources for large-scale modelling exercises, and poor institutional integration among government departments" (page 323). Despite these challenges, there has been recent growth in research using IUMs to assess urban sustainability in Canada (Maoh and Kanaroglou, 2009; Behan *et al.*, 2008; Hatzopoulou *et al.*, 2007).

Following in this tradition, the aim of this paper is to evaluate the long term impacts new provincial growth guidelines will have in the City of Hamilton, Ontario using an integrated urban model. Two policies - *General Intensification* and *Urban Growth Centre Intensification* - are simulated in isolation and in combination with each other to determine their individual and joint effects on the usage and performance of the transportation system. In Section 2, the current growth context of Hamilton and its super-region – the Greater Golden Horseshoe – are introduced, and the features of the provincial growth plan investigated in this paper are reviewed. Section 3 contains a description of the tool IMULATE, and the procedure used to create and simulate the different growth scenarios. Section 4 contains a discussion of the results of the analysis. In Section 5 we make some conclusions and identify some areas for future research.

2.0 Hamilton, the Greater Golden Horseshoe and Places to Grow

2.1 Hamilton and the Greater Golden Horseshoe

The Greater Golden Horseshoe (GGH) is one of the fastest growing regions in North America (Province of Ontario, 2006). It is a large region surrounding the Greater Toronto Area (GTA), with the regions of Niagara, Brantford, Kitchener-Waterloo-Cambridge, Simcoe and Peterborough forming its outer extent. Consisting of approximately 8.1 million people in 2006, official provincial growth targets assume the regional GGH population will increase to 11.5 million people by 2031; an increase roughly equivalent to the present combined populations of the Cities of Toronto and Mississauga. The increase in population is forecasted to be matched by a growth in total employment of 330,000 jobs, from 870,000 in 2001 to 1.2 million in 2031 (Province of Ontario, 2006). This population growth will increase the demand for new dwellings, places of employment, services, and infrastructure amongst all the other facilities associated with North American urban settlements. Depending on the spatial arrangement and densities of new developments, the existing land supply, air supply and provincial infrastructure will be taxed to varying degrees. With this in mind, the provincial government released a regional growth plan under the new *Places to Grow Act* (P2G), for the GGH in order to encourage the efficient expansion of the urban area.

Our study area, the City of Hamilton, is one of 16 regions that comprise the Greater Golden Horseshoe. It contains 280,000 acres of land on the south side of the western tip of Lake Ontario. It is approximately 70 km from downtown Toronto, the largest urban centre in the region. Current provincial estimates show that Hamilton's population of 510,000 will grow to 660,000, an increase of 150,000 people by 2031. Their land supply estimates indicate that future development patterns must maintain at least the present density levels found throughout the urban areas of the region which include a mix of densely populated urban tracts and sparsely populated suburban ones (Province of Ontario, 2005). The maintenance of this density is in opposition to the status quo sprawling development pattern experienced in the region since the boom in post war suburbanization. Future development must be more space efficient if Hamilton is to accommodate the growing population within the land designated for urban development.

The dominant growth patterns in the region are characterized by sprawling low density suburbs and conversion of green space into higher order land uses. The sprawled urban form results in car dependent communities thereby increasing the number of vehicles on the road, congestion, and travel times, all of which lead to increased levels of noxious emissions (Kanaroglou and Anderson, 1997). The P2G plan postulates that the continuation of this trend will negatively impact quality of life and economic development in the region and provides a method for municipalities to absorb the forecasted population by using existing developed land and infrastructure efficiently.

2.2 Places to Grow

The P2G growth plan is characterized by three families of policies: residential and employment growth strategies; infrastructure to support growth; and the protection of valuable resources. At its core, the residential growth strategy consists of a general intensification strategy whereby 40% of new residential units must be built within the existing built-up area. This intensification strategy is to be focused into designated urban growth centres (UGCs) and transit and intensification corridors. Furthermore, provincially determined density targets must be achieved for UGCs and designated greenfield areas (DGAs) - areas that are within the approved urban settlement area but not within the built-boundary. Given the mixed results of the literature concerning the effects of land use on transportation, and in light of the impediments to transferability of results, it is imperative that the impacts of these land use policies are examined in the local context.

Not all policies can be effectively simulated within IMULATE, an integrated urban model for the Hamilton Census Metropolitan Area (CMA). (See Section 3.1 for a description of IMULATE). In general, policies pertaining to land-use and transportation can be examined. Of the P2G population and employment growth strategies, corridor intensification is excluded from the analysis due to scale issues related to IMULATE's aggregate census tract based structure.

Our focus is on the policies related to residential intensification and UGC intensification. These policies necessitate the creation of geographical areas to which different growth rates and density targets will be applied. (See Figure 1.) In order of land use intensity these areas are: the urban growth centre (UGC); the built-up area; the designated greenfield area (DGA); the designated settlement area (DSA); the greenbelt (GB); and other unplanned lands. Nesting also occurs such that UGCs are subsets of the built-up area, and the union of the built-up area with the DGA comprises the designated settlement area. Finally, while the greenbelt is a particular planning defined in the *Greenbelt Act*, for the purposes of P2G and this research, all land outside the designated settlement area will be considered the same and called the greenbelt zone.

Figure 1
Places to Grow Concepts

2.3 Policies for Analysis

To address the objectives of this research, the following policies are analyzed:

2.3.1 General Intensification

This policy states that by 2015 a minimum of 40% of residential growth in terms of new housing units must occur in the built-up area, and be focused within the growth centres, intensification corridors, and brownfield/greyfield sites. This approach must continue, each and every year up to 2031, the last year in the plan's horizon. The remaining new units can be built in the DGA and no units can be built in the greenbelt. Intensification should be achieved through infill development of vacant lands, brownfield redevelopment, renovations to existing structures, and general redevelopment. This policy is intended to slow down urban expansion, and minimize the need for related infrastructure investments (Province of Ontario, 2006).

2.3.2 UGC Intensification

This policy pertains to achieving and maintaining increased population and employment densities in the identified urban growth centres. Essentially, UGCs are seen as focal areas for public services, commercial, recreational, cultural and entertainment uses, as well as residential intensification. While the general locations of UGCs are identified in the P2G plan, their boundaries are to be determined in conjunction with local and regional planning authorities. Our study area, the Hamilton CMA, contains two UGCs: *Downtown Hamilton* and *Downtown Burlington*. These areas are to be planned to achieve minimum densities of 200 residents plus jobs per hectare. In stricter terms, let POP be the population in the UGC, let EMP be the number of jobs in the UGC, and let AREA be the size of the UGC in hectares, then the mixed density target for 2031 is given by:

$$MD=(POP+EMP)/AREA\geq 200. \quad (1)$$

The mixed density targets for UGCs vary by location. For example, *Downtown Toronto* must achieve a target of 400, while centres in smaller towns such as *Downtown Barrie* and *Downtown Guelph* need only achieve densities of 150 people and jobs per hectare (Province of Ontario, 2006).

The entire P2G growth plan is built on a consistent set of population and employment growth forecasts to which local governments must conform. The growth forecasts were selected by the province from a set of growth scenarios prepared by Hemson Consultants for the 2005 report, *The Growth Outlook for the Greater Golden Horseshoe*. These forecasts are based on several key assumptions, the most important being that the economic outlook is strong, and that the GGH will continue to be one of the fastest growing areas in Canada economically and demographically. Furthermore, the aging population will be an important factor and will demand the construction of new dwellings, albeit each one designed for smaller households. It should be mentioned that these forecasts fundamentally serve as growth targets, as they could not be achieved without certain governmental policy interventions. To that end, they were created with the assumption that polices to achieve the P2G objectives are implemented. Notwithstanding the current economic downtown, the Hemson employment forecasts still serve as the foundation of the P2G plan. These figures are utilized in this analysis on the basis that the economic downtown is temporary and will not reflect the long term conditions through to 2031. Provincial planners adopted the *compact* growth scenario from the Hemson report and these forecasts of population and employment growth are implemented in the simulations through exogenous manipulations of dwelling development and economic demand. (See Table 1).

The growth targets call for the development of 80,000 new households and 90,000 new jobs between 2001 and 2031 in the City of Hamilton. forecasts for Burlington and Grimsby were extrapolated from the regional forecasts for the Halton and Niagara regions respectively. Burlington's share of Halton's total population and employment is estimated to decrease according to Halton Region's projections (Regional Municipality of Halton, 2003). Niagara had not publicized forecasts for Grimsby at the time of writing, so the 2001 share indicated in the Census is assumed to be held constant to 2031.

Table 1
Hemson forecasts for new households and jobs in the Hamilton CMA

	2006	2011	2016	2021	2026	2031	2001-2031
New Households							
Hamilton CMA	19462	19462	22896	22896	19468	19468	123652
City of Hamilton	10442	10442	15546	15546	15468	15468	82912
City of Burlington	9020	9020	7350	7350	4000	4000	40740
New Jobs							
Hamilton CMA	23759	19159	27705	27105	23505	23505	144737
City of Hamilton	10009	10009	20005	20005	15005	15005	90037
City of Burlington	13750	9150	7700	7100	8500	8500	54700

Note: Forecasts for the Town of Grimsby, a separate entity in the Hamilton CMA, are very small and the quantities have been included in the forecasts for the City of Hamilton.

2.4 Critique of Policies

Two not-for-profit organizations have been highly vocal participants in the planning process for sustainable communities in Ontario - the Pembina Institute (www.pembina.org) and the Neptis Foundation (www.neptis.org). Both have published numerous policy papers on Smart Growth in the GGH in addition to releasing responses to the Ministry of Public Infrastructure Renewal's (PIR) policy papers and P2G drafts. In their reports (available for download from their respective websites), the organizations commend the province in general for taking a positive and proactive role in planning for a sustainable future, but through their research they have found some areas where policies could be improved upon. Following is a summary of their critiques of the general intensification and UGC policies.

2.4.1 General Intensification

According to Neptis' analysis (Neptis, 2006), past trends indicate that Hamilton already achieves an intensification rate of 22%. While the proposed intensification rate nearly doubles from 22% to 40%, the growth destined for greenfields drops from 78% to 60%, resulting in a real reduction in sprawl of just 23%. According to a government sponsored study (Urban Strategies Inc., 2005) other regions are aiming to achieve higher intensification rates. Both Neptis (2006) and Pembina (Winfield, 2006a) believe that the region could maintain a 60% intensification target. Neptis also suggests that an intensification rate alone will not bring about the required result of public transport supportive developments. The policy should also encourage effective intensification involving human-scale design, and the avoidance of developing on the urban fringe, leap-frogging (developing away from existing development), and then back-filling (developing on vacant land, closer to the urban core). They also suggest implementing a combination of measurable targets such as the desired number of new units per intensification area and transit catchments as well as targets relating to transit mode shares amongst residents and workers.

2.4.2 Urban Growth Centres

A report by Filion (2007) on behalf of the Neptis Foundation represents the most comprehensive history and analysis of nodal development in the GGH. Although the reasons behind it have changed, according to Filion, polycentricity has long been a popular planning paradigm in the GGH. With specific reference to P2G, Filion believes that the cities will struggle to attract new office space and retail outlets to the UGCs. He argues that the suburbs, with their cheaper parking, development costs and land taxes, are too attractive to businesses focused on their bottom line and that reinvestment in UGCs is at odds with the development trends in the GGH over the last two decades. While Filion offers best-practice suggestions to planners at the micro, meso, and macro levels, he does not comment on the efficacy of the particular density targets suggested in P2G, nor does he specifically endorse the use of other quantifiable measures. On the other hand, Pembina suggests that the density targets for second tier UGCs like downtown Hamilton and Burlington are too low "given that these areas are already urbanized, and intended to function as transit and mixed use development hubs" (Winfield, 2006b). In addition, Neptis (2006) stresses that while the plan calls for strong transportation connections between nodes, infrastructure investments to improve upon transit within nodal catchment areas may be more cost effective.

3.0 Research Methodology

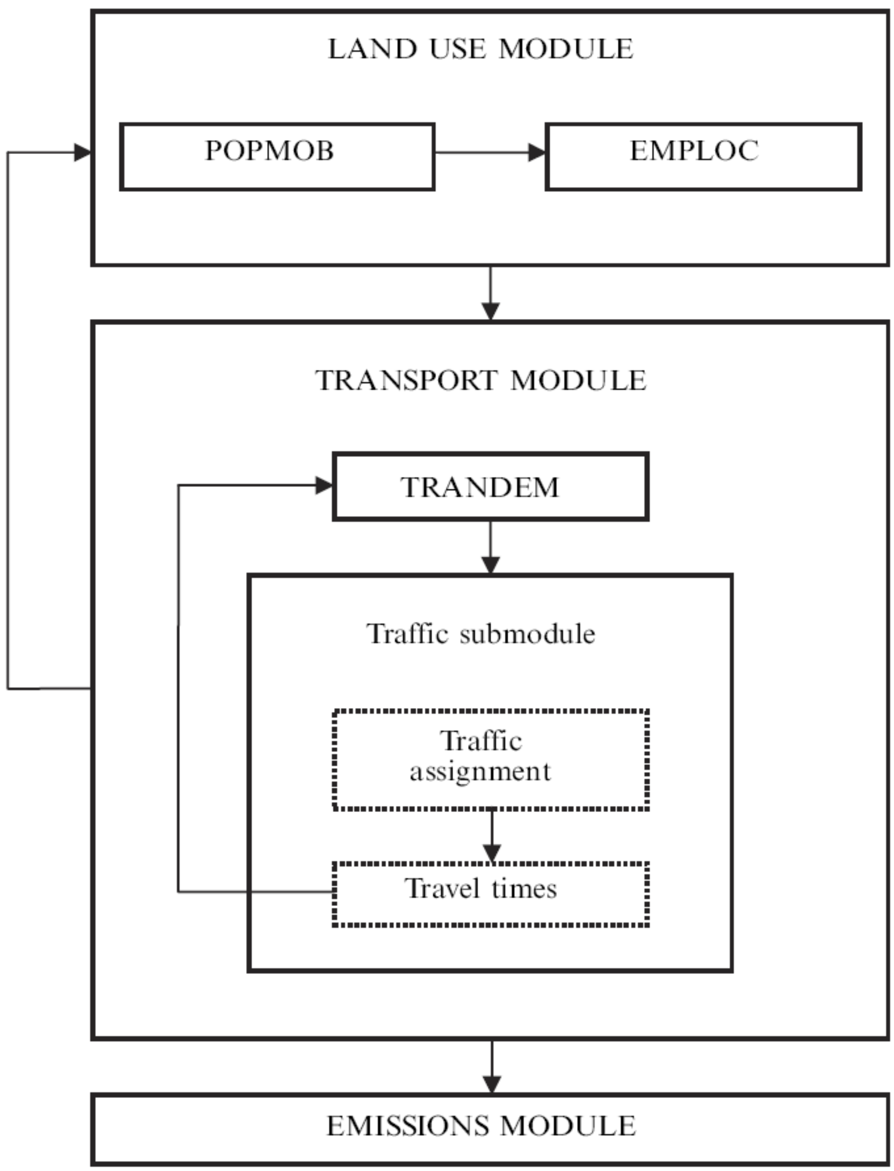
3.1 IMULATE

Following methodologies outlined in simulation projects by Kanaroglou and Anderson (1997), Scott *et al.* (1997), Kanaroglou and South (1999), Behan *et al.* (2008), and Kang *et al.* (2009) this paper reports on the simulation of the implementation of several components of the Growth Plan in the Hamilton Census Metropolitan Area (CMA) using IMULATE, an **I**ntegrated **M**odel of **U**rban **La**nd Use and **T**ransportation for **E**nvironmental Analysis. The purpose is to inform the planning process by forecasting transportation network usage, land use configuration, and quantities of automobile emissions. In addition, the individual and joint effects of these policies will be determined so that a better understanding of the complementary nature of a body of policies emerges. Finally, the results should provide insight into how to design future policies that will satisfactorily support and enhance the effectiveness of the ones tested here.

IMULATE is an aggregate and cross-sectional model, in which the Hamilton CMA is represented by 151 traffic analysis zones (corresponding to 1986 Census Tracts), 1,525 transportation links and 1171 nodes. The model predicts changes in land use and transportation demand over five year periods between 1986 and 2031. The relationship between land use and transportation is represented by land use allocation models of employment and households which employ accessibility measures endogenously determined using a traditional four stage urban transportation modelling system (UTMS) for the morning peak period. Over time (in five year periods), as land use patterns adjust due to changing accessibility, travel demand is adjusted by the UTMS to reflect changes in the locations of activities, as shown in Figure 2. This representation is fairly consistent with the theorized land use/transportation cycle popularized by Wegener (2004), except new dwelling and economic development must enter IMULATE exogenously rather than being determined by a development module within the modelling framework. For the purposes of this project, this is an advantage since we need to test how various land supply strategies will affect land use and transportation.

IMULATE operationalizes the above process with five main components, as shown in Figure 2. POPMOB and EMPLOC comprise the land use module. POPMOB is a residential location choice model which simulates residential intra-urban mobility. Several locational factors affect the choice of a tract as a destination including the amount of new residential development in the tract (Anderson *et al.,* 1994). Analogously, EMPLOC simulates the spatial distribution of firms and jobs across the census tracts comprising the city. A number of locational factors affect the destination choice of the firm. Within the model, locational factors such as population size and agglomeration economy per census tract were among the significant factors instrumental in this analysis (Maoh *et al.,* 2005). Growth in the total number of households and the total number of firms in the study area are defined exogenously by inputting a distribution of new dwellings by census tract and by defining a matrix of final demand per industry.

Figure 2
General Structure of the IMULATE model



Next, TRANDEM converts land use patterns into inter-zonal travel demand in terms of the number of trips per purpose (work, school or discretionary) and by mode (auto, autopassenger and transit) using a traditional UTMS approach (Anderson *et al.*, 1994). Afterward, the inter-zonal automobile flows are assigned to the road network by means of a logit-based Stochastic User Equilibrium model. Once equilibrium conditions have been established between link congestion and travel times, the emissions module produces estimates of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) for each link. This is achieved by an interface which can pass link level congestion and travel times through MOBILE5.C, an emissions model calibrated for the Canadian winter weather and automobile fleet (Anderson *et al.*, 1996). CO is a greenhouse gas; HC is a respiratory health hazard; and NOx is linked to cardiovascular ailments. For more information Anderson *et al.* (1994) provide a detailed overview of IMULATE; Anderson *et al.* (1996) discuss implementation details of MOBILE5.C; and Maoh *et al.* (2005) offer details pertaining to EMPLOC. In addition, energy consumption is calculated with a formula that relates the amount of fuel consumption to the total flow and average congested speed on the link. The parameters of the fuel consumption model are the same as those employed in a study of transportation emissions and energy by the City of Toronto Planning and Development Department (Cheng and Stewart, 1992).

3.2 Scenario Definitions

To examine the impacts of the P2G policies described in section 2.2, four scenarios were developed for simulation analysis: (1) *Base Case*, (2) *UGC Intensification*, (3) *General Intensification*, and (4) *Combined Intensification*. All of the scenarios start with a base distribution of land use and transportation structure representing the current 2006 urban structure. While some recent household distribution data was used to calibrate the 2006 base year configuration, firm locations were modelled within IMULATE over time from the source year of 1991. So, all scenarios start at the same time with the same distribution of firms and households, and the same transportation network. Also, across scenarios, the same number of dwellings and jobs are added to the system at each time interval. Thus the only difference between scenarios is the spatial distribution of new dwellings and jobs. Since assigning jobs to census tracts is handled endogenously for the City of Hamilton, the model determines the spatial distribution of firms and jobs in relation to the existing distributions of firms, households and accessibility levels. However, IMULATE handles employment exogenously for Burlington and Grimsby so the assignment of firms to tracts in these two jurisdictions was conducted manually to meet the forecasted aggregated levels. The relationship between the scenarios and the P2G policies are as follows.

3.2.1. The Base Case Scenario

This scenario represents the continuation of current development trends to 2031. For a given simulation period, new dwellings are assigned to census tracts according to a growth formula which incorporates a time weighted average of dwelling count growth over the last three simulation intervals and the household density calculated for the end of the previous period. The first component of the formula extends past trends into the future, while the second attracts development to rural lands as suburban tracts fill up with housing developments. After much experimentation, the following method was used to simulate the *Base Case* growth patterns for new households. For each census tract i, a time-weighted average growth in time t (AVG_{it}) was calculated such that:

$$AVG_{it} = (ND_{it-1}+0.75\ ND_{it-2}+0.5\ ND_{it-3})/2.25 \qquad (2)$$

where ND_{it} is the number of new dwellings in time t. The weights associated with the ND_{it} variables represent a time-discounted average of development activity in the tract. This weighting scheme assumes that the recent development activity is the most influential indicator of the potential for future development, followed by development activity in the two previous time periods. In an attempt to control for the remaining development capacity of a tract, a measure of households per hectare ($DENS_{it}$) was also computed for each census tract. These two measures were used to construct a growth score:

$$GS_{it}=[(1+ AVG_{it})/(1+ DENS_{it})]^{1/2} \quad (3)$$

According to this formulation, the potential for development is higher when past growth in the zone is strong, and the housing density of the tract is low. As density increases or as the development momentum decreases the potential for development also declines. Finally, the number of new dwellings added to tract i in time t is $(ND_t)(GS_{ti}/\Sigma GS_{ti})$ where ND_t is simply the total number of new dwellings added to the entire region in time t and $\sum GS_{it}$ is summed over i.

In essence, this growth scenario is characterized by urban sprawl, and is considered the open market business-as-usual development pattern in the absence of smart growth planning policies. The *Base Case* is essential to our analysis for it provides a benchmark to which the alternative policy scenarios can be compared.

3.2.2 The UGC Intensification Scenario

This scenario simulates the implementation of the UGC intensification policy for the Downtown Hamilton and Downtown Burlington UGCs. The simulation required the geocoding of UGC boundaries. The Hamilton UGC consists of the area in the Downtown Secondary Plan, which is perfectly aligned with four downtown census tracts (City of Hamilton 2004). The planners in Burlington have defined their UGC in a more obscure way, unlinked from streets and census tract boundaries. Their boundaries gerrymander around significant employment and residential lands in the downtown area. Unfortunately, due to the necessity to strictly conform to the census tract boundaries in IMULATE, the boundary was approximated in consultation with a planning official at the City of Burlington. Three tracts containing the bulk of the residential and commercial lands within the proposed UGC were designated as the UGC for the purposes of this study.

With the boundaries defined, the base case estimates of population and employment for 2031 were used to determine the additional number of dwellings and jobs to add to the UGCs in order to achieve the mixed density target of 200 people plus jobs per hectare as specified in P2G. For the lack of any official estimate or assumption, it was assumed that the ratio of jobs to population stayed constant over time in both the Hamilton and Burlington UGC. Dwellings and jobs added to the UGC tracts were subtracted evenly from those being added elsewhere in the system. This results in population and employment-dense UGCs, and slightly lower densities everywhere else. Since firm mobility in Hamilton is handled endogenously by EMPLOC, between intervals, the attractiveness of the Hamilton UGC census tracts was augmented in order for the tracts to reach their employment targets. This involved manually manipulating the number of firms in each tract (exploiting the agglomeration variable) such that EMPLOC allocated new endogenously determined firms and employment in the quantities corresponding to the exogenous UGC targets. Firm mobility in IMULATE is handled exogenously for

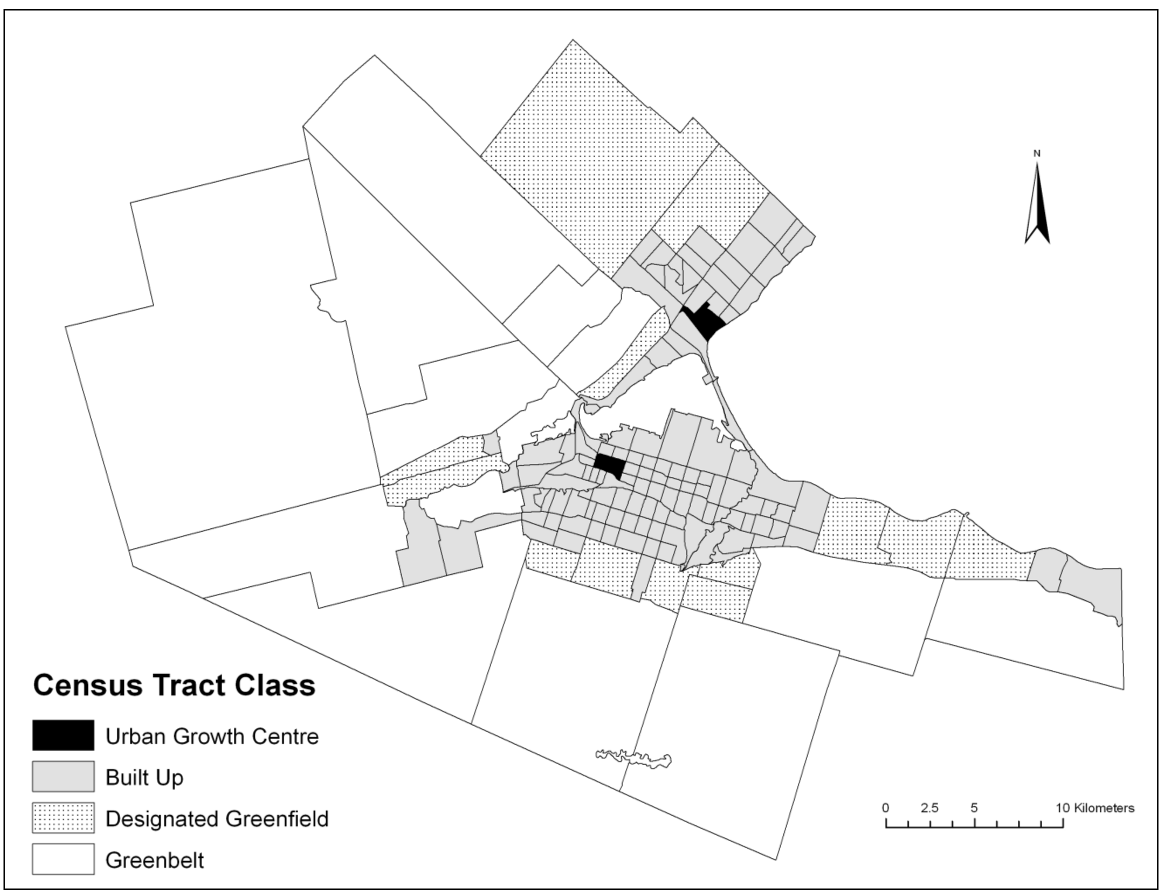
Burlington so the target number of dwellings and employees were simply added to the appropriate UGC tracts.

3.2.3 The General Intensification Scenario

This scenario simulates the distribution of new dwellings in relation to the general intensification policy outlined in Section 2.2. Once again, the first action was to assign census tracts to the relevant P2G geographies: the built-up area, designated greenfield area or the greenbelt. A draft version of the built-up area was obtained from the Ministry of Public Infrastructure Renewal website in a document entitled: *Technical Paper on a Proposed Methodology for Developing a Built Boundary for the Greater Golden Horseshoe* which was released during the course of this research. The locations of greenfield areas (undeveloped lands within the designated settlement area) were ascertained using the boundaries of planned settlement areas in existing master plans for the City of Hamilton, the Town of Grimsby, and the City of Burlington. Any land that is neither within the built-up area nor within a designated greenfield area is considered greenbelt land. Three source maps were geocoded and census tracts were uniquely assigned to each geography-type as accurately as possible. The final assignment of census tracts can be seen in Figure 3.

Figure 3

Assignment of P2G geographies to census tracts



The *General Intensification* scenario solely concerns the spatial allocation of new dwellings. The spatial distribution of new dwellings across census tracts resembles the base case except the numbers are inflated (or deflated) to match the percentage growth shares outlined in P2G. Specifically, the distributions are modified such that zero new dwellings are assigned to the greenbelt after 2006, 40% of new dwellings are assigned to the built-up area, and 60% to the designated greenfield area. Interestingly, under the base conditions for Hamilton, the built-up areas were already slated to receive nearly 40% of new growth, thus the growth pattern under this scenario consists of high levels of intensification in the DGA and development is shifted away from the greenbelt.

3.2.4 The Combined Intensification Scenario

This scenario simulates the implementation of both the general and UGC intensification policies. This is implemented by a) assigning dwellings and jobs to the UGC's to achieve density targets as before and b) ensuring that the ratios of new dwellings are assigned to the planning geographies according to the general intensification policy. The latter task involves inflating the growth shares in the DGA and built-up area. UGC intensification alone results in a development share greater than 40% for the Burlington built-up area. Since the growth plan clearly states that the 40% share for built-up areas is considered a minimum, the higher share is retained for the built-up area and the remaining dwellings are assigned to the DGA. The resulting split is roughly 52:48 for the built-up area and DGA respectively. In Hamilton however, the UGC intensification targets require fewer new households and as such the final built-up area share did not exceed 40%.

4.0 Results and Discussion

The simulation results can be categorized in many ways, but it is convenient for the purpose of this study to categorize them as measures of system usage, system performance, and changes to the spatial structure of the system. For each measure of usage and performance, the simulations are compared to the business-as-usual growth scenario which provides a pseudo-objective benchmark.[1] Additionally, the measurements are compared across scenarios such that the individual and joint effects of each land-use policy can be elicited.

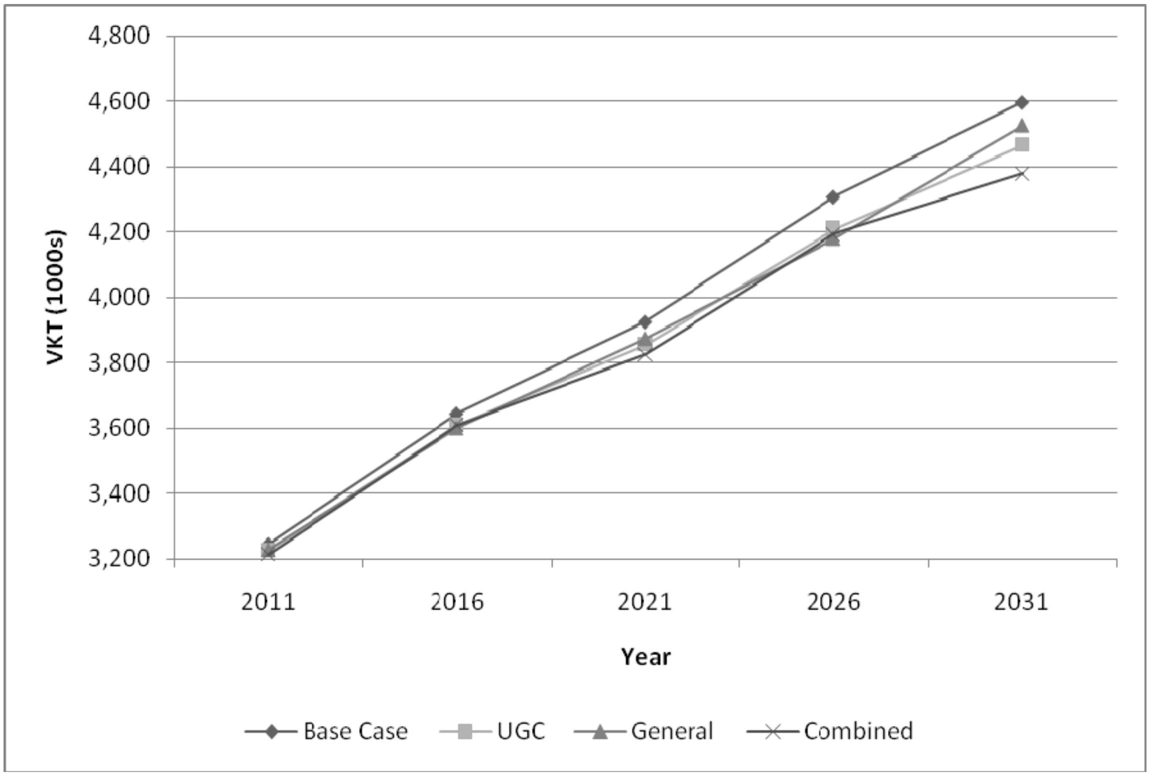
4.1 System Usage

Since the distances between activity locations are naturally shorter in compact cities, the total number of vehicle kilometres travelled (VKT) in compact cities should be smaller than in sprawled ones given the assumption that activity participation is invariant to urban form. Indeed, this expectation is corroborated by the simulations which estimate that by 2031 the *Combined Intensification* scenario generates 217,445 less VKT than the base case, an approximately five percent improvement (Figure 4). The trend over time depicts a steady increase in aggregate VKT for all scenarios as the number of people living and working in the city increases. By 2031, total VKT for the *UGC Intensification* and *General Intensification* scenarios are three percent and 1.5 percent lower than the base case respectively. Interestingly, this suggests that downtown intensification is more critical to aggregate VKT reduction than general intensification and the impedance of greenbelt development. Furthermore, since combining general intensification with

[1] "Pseudo" in the sense that the results for business-as-usual growth are simulated and are therefore not truly objective.

UGC intensification reduces VKT by more than either of the growth policies applied in isolation, we confirm the existence of positive synergies.

Figure 4
Peak period estimates of 2031 vehicle kilometres travelled (VKT)



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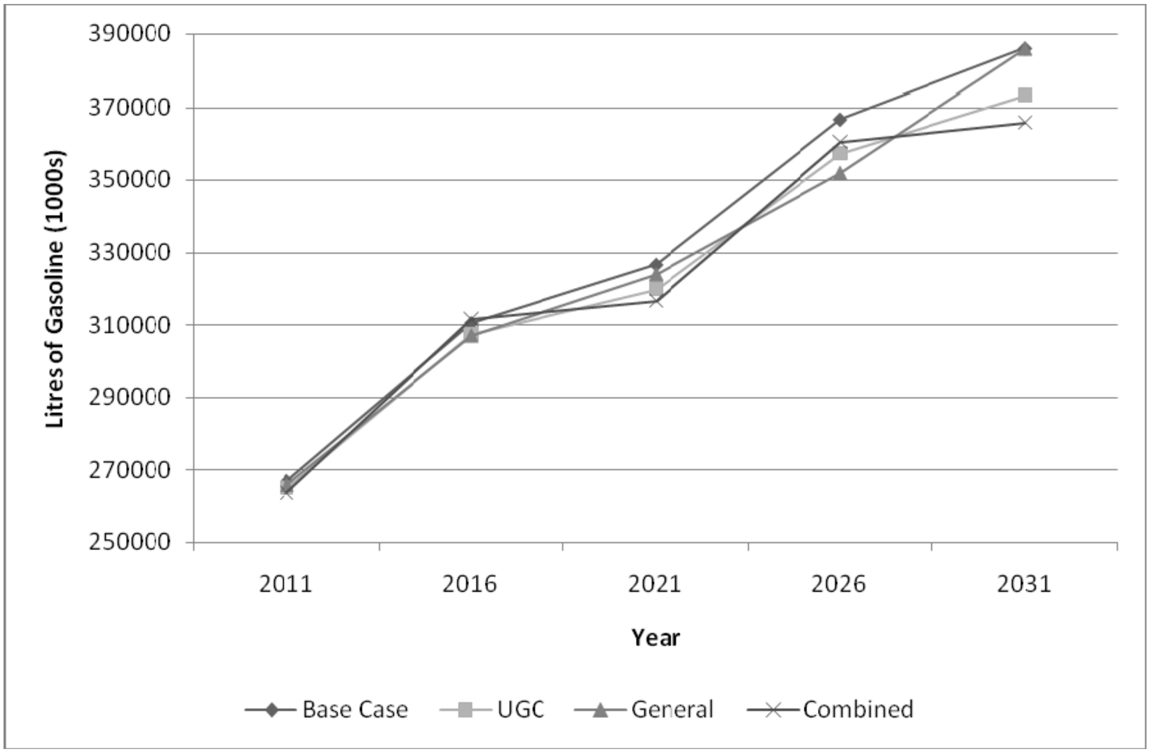
Related to VKT, but also to other factors such as link speed and congestion, fuel consumption is another important measure of system usage. It may be more pertinent to design policies which reduce consumption rather than VKT since consumption is more directly linked to vehicle emission levels and is also likely to increase in political importance as fuel supplies dwindle. According to IMULATE, the total fuel consumption over the morning peak period increases over time for all scenarios, but the increase is somewhat less rapid in the intensification scenarios. As seen in Figure 5, the combined scenario predicts five percent less consumption than the base case by 2031, which is better than both the UGC and general intensification scenarios in isolation. The rate of increase in fuel consumption differs only slightly between simulation periods and scenarios

Figure 5
Peak period estimates of 2031 fuel consumption levels



4.2 System Performance

The amount and distribution of polluting emissions are important measures of system performance. Aggregate levels of all three types of emissions are examined, but due to the localized effects that HC and NOx have on respiratory and cardiovascular health, these emissions must also be analyzed spatially (Finkelstein *et al.* 2004). At the aggregate level, UGC intensification has the largest impact on reducing emissions. It reduces 2031 CO and HC emission levels by 4.5 percent (Table 2). Strikingly, general intensification tends to perform worse than the base case in terms of CO and HC. Emissions of these compounds are inversely proportional to vehicular speed (Anderson *et al.*, 1996), implying that general intensification results in higher levels of kilometres driven under congested conditions in comparison to the Base Case and UGC Intensification scenarios.

The level of NOx emissions with respect to vehicle speeds mimic the HC and CO patterns at lower speeds but increases quickly when speeds exceed 80 kph. All the land use policies have positive impacts in reducing NOx emissions. While the combined scenario results in a 4.5% improvement in comparison to the base case, the evidence to explain this is somewhat ambiguous. Are the emissions reduced because fewer VKT are driven at high speeds, or is it due to few VKT in extremely congested speeds? The fact that NOx emissions are higher at both ends of the velocity spectrum makes answering this question difficult without examining these emissions at the link level in conjunction with travel speed and congestion (Anderson *et al.* 1996).

Table 2
2031 Peak period emissions (kg) and deviations (%) from the Base Case

	Base Case	UGC Intensification	General Intensification	Combined Intensification
HC	49373	47196 (-4.4%)	50379 (2.0%)	47539 (-3.7%)
CO	574378	549391 (-4.4%)	585707 (2.0%)	553642 (-3.6%)
NOx	24730	24043 (-2.8%)	24386 (-1.4%)	23658 (-4.3%)

Congestion is another measure of system performance valuable in comparing the various growth scenarios. The simulation results suggest that congested vehicle speeds decline over time in all of the scenarios. The UGC scenario obtains the fastest congestion speeds. This coincides with the HC and CO emissions findings. Similarly, the general intensification scenario obtains inferior results compared to the base case (Table 3). This is reasonable considering that the same number of people and jobs are condensed into a smaller area, and a significant shift in mode share is not predicted to occur. UGC intensification draws people and jobs into the central cores of Hamilton and Burlington resulting in shorter and more congested trips for some, but the majority of trips which remain in the DGA and greenbelt experience a decrease in congestion levels.

Table 3
2031 Average congested vehicle speed (km/h)

	Base Case	UGC Intensification	General Intensification	Combined Intensification
Speed (km/h)	28.71	29.06	27.68	28.32
% improvement on Base Case	-	1.22%	-3.59%	-1.36%

4.3 Spatial Impacts

To further support the above claim regarding a shift in congestion, link level congestion ratios have been cross-tabulated with P2G planning geographies (Table 4). The congestion ratio is simply the predicted flow divided by link capacity. The pattern of average congestion levels for each scenario corresponds to the average congested vehicle speeds in Table 3. While the UGC scenario results in the lowest levels of aggregate congestion, notice that the congestion in the actual UGC is forecasted to increase quite significantly from 1.23 to 1.4 compared to the base case. Under general and combined intensification, the greenbelt experiences reduced congestion, but congestion increases in all other areas. Thus, while smart growth can result in system-wide improvements to congestions, it does so at the cost of creating clusters of highly congested neighbourhoods.

Using the above framework of aggregating and cross-tabulating link level data to the P2G geographies, the spatial distribution of the hazardous HC and NOx emissions is also investigated (Tables 5 and 6). The first observation is that even though the UGC scenario produces the lowest HC levels, the UGCs themselves are forecasted to experience a 50% increase in HC emissions. The second observation is that the general intensification scenario characterized by a net gain in HC emissions results in a large reduction of emissions in the greenbelt accompanied by quite large gains in the built-up and designated greenfield areas. With such small actual improvements in HC emissions, the shift in concentrations into more populated areas is a phenomenon that should be considered in further detail.

Table 4
2031 congestion levels aggregated to P2G areas

	# of Links	Base Case	UGC Intensification	General Intensification	Combined Intensification
TOTAL	**1536**	**1.26**	**1.23**	**1.28**	**1.23**
Built Up	***828***	***1.31***	***1.29***	***1.36***	***1.34***
Hamilton	659	1.29	1.28	1.36	1.33
Burlington	139	1.62	1.57	1.63	1.57
Grimsby	30	0.31	0.31	0.31	0.33
UGC	***50***	***1.23***	***1.40***	***1.26***	***1.39***
Hamilton	37	1.06	1.14	1.08	1.16
Burlington	13	1.72	2.14	1.78	2.05
DGA	***303***	***1.37***	***1.30***	***1.56***	***1.43***
Hamilton	149	1.58	1.55	1.96	1.90
Burlington	128	1.34	1.20	1.32	1.09
Grimsby	26	0.36	0.36	0.44	0.43
Greenbelt	***355***	***1.07***	***1.00***	***0.83***	***0.79***
Hamilton	333	1.11	1.04	0.85	0.81
Burlington	5	2.04	1.86	1.50	1.45
Grimsby	17	0.12	0.12	0.11	0.11

Similar results are found for NOx emissions. The combined intensification growth scenario resulted in the lowest levels of forecasted NOx emissions. But yet again, much of the improvement is localized in the greenbelt, with slight increases in the built-up area, the UGC and the designated greenfield areas. With both NOx and congestion patterns aggregated to geographic areas, the cause of the changes in NOx emissions can be determined. Under the combined scenario, it appears that the reduction of NOx in the greenbelt is due to a total reduction in VKT, or in congested VKT, since the average congestion levels were reduced. The increase of NOx in the other areas corresponds to increased congestion, indicating that the NOx emissions there are probably a result of slower speed VKTs.

The results reported above describe the estimated impacts of several growth scenarios on congestion and emission patterns in the Hamilton CMA. To give context to these findings it is essential to characterize the travel patterns between zones. The tract-to-tract auto flows have been aggregated by P2G planning geographies for each municipality since it is easier to interpret patterns in an 11x11 matrix than in a 151x151 matrix.[2] The matrices are analyzed in several ways. First, increases and decreases in total flows between i-j pairs in the matrix will shed light on the net impact of demand on the transportation network between and within the zones.

[2] For the sake of brevity the origin-destination matrices have been excluded from this paper but will be made available upon request

Table 5
2031 Congested HC levels by P2G geography (in kg and % of total)

	Base Case	UGC Intensification	General Intensification	Combined Intensification
TOTAL	**49373**	**47196**	**50379**	**47539**
Built Up	***30989 (62.8%)***	***29787 (63.1%)***	***32491 (64.5%)***	***31149 (65.5%)***
Hamilton	22424 (45.4%)	21618 (45.8%)	24059 (47.8%)	22936 (48.2%)
Burlington	8452 (17.1%)	8056 (17.1%)	8321 (16.5%)	8099 (17%)
Grimsby	114 (0.2%)	113 (0.2%)	111 (0.2%)	113 (0.2%)
UGC	***1047 (2.1%)***	***1567 (3.3%)***	***1086 (2.2%)***	***1412 (3%)***
Hamilton	436 (0.9%)	502 (1.1%)	438 (0.9%)	500 (1.1%)
Burlington	610 (1.2%)	1065 (2.3%)	648 (1.3%)	912 (1.9%)
DGA	***10059 (20.4%)***	***9288 (19.7%)***	***12342 (24.5%)***	***10899 (22.9%)***
Hamilton	5279 (10.7%)	4995 (10.6%)	7614 (15.1%)	7103 (14.9%)
Burlington	4662 (9.4%)	4177 (8.9%)	4597 (9.1%)	3668 (7.7%)
Grimsby	119 (0.2%)	116 (0.2%)	131 (0.3%)	128 (0.3%)
Greenbelt	***7278 (14.7%)***	***6553 (13.9%)***	***4461 (8.9%)***	***4079 (8.6%)***
Hamilton	6997 (14.2%)	6305 (13.4%)	4310 (8.6%)	3939 (8.3%)
Burlington	256 (0.5%)	224 (0.5%)	131 (0.3%)	121 (0.3%)
Grimsby	25 (0.1%)	24 (0.1%)	20 (0%)	19 (0%)

Table 6
2031 Congested NOx levels by P2G geography (in kg and % of total)

	Base Case	UGC Intensification	General Intensification	Combined Intensification
Total	**24730 (100%)**	**24043 (100%)**	**24386 (100%)**	**23658 (100%)**
Built Up	**14892 (60.2%)**	**14540 (60.5%)**	**15027 (61.6%)**	**14632 (61.8%)**
Hamilton	11397 (46.1%)	11186 (46.5%)	11590 (47.5%)	11306 (47.8%)
Burlington	3311 (13.4%)	3171 (13.2%)	3256 (13.4%)	3140 (13.3%)
Grimsby	184 (0.7%)	183 (0.8%)	181 (0.7%)	186 (0.8%)
UGC	**710 (2.9%)**	**893 (3.7%)**	**710 (2.9%)**	**847 (3.6%)**
Hamilton	475 (1.9%)	533 (2.2%)	472 (1.9%)	527 (2.2%)
Burlington	236 (1%)	360 (1.5%)	238 (1%)	320 (1.4%)
DGA	**5100 (20.6%)**	**4856 (20.2%)**	**5556 (22.8%)**	**5204 (22%)**
Hamilton	2761 (11.2%)	2692 (11.2%)	3291 (13.5%)	3164 (13.4%)
Burlington	2147 (8.7%)	1977 (8.2%)	2050 (8.4%)	1831 (7.7%)
Grimsby	192 (0.8%)	188 (0.8%)	214 (0.9%)	209 (0.9%)
Greenbelt	**4028 (16.3%)**	**3754 (15.6%)**	**3093 (12.7%)**	**2975 (12.6%)**
Hamilton	3827 (15.5%)	3583 (14.9%)	2973 (12.2%)	2858 (12.1%)
Burlington	160 (0.6%)	132 (0.5%)	87 (0.4%)	85 (0.4%)
Grimsby	40 (0.2%)	39 (0.2%)	32 (0.1%)	32 (0.1%)

Second, origin standardized flow rates from i to j are analyzed so the attractiveness of destination zones relative to the origins can be quantified.

Assuming business-as-usual growth, in 2031 60% of auto trip attractions are likely to occur in the 2006 built-up areas of Hamilton and Burlington. The next most attractive destination is the Hamilton greenbelt, with 17% of trips, followed by the Hamilton and Burlington DGAs, each attracting between 8-10%. Generally speaking, the primary impact UGC intensification has on trip ends is to double the attractiveness of the Hamilton and Burlington UGCs. However, doubling one percent of all trips to two percent for Hamilton, and two percent to four percent for the Burlington UGC does not result in a large absolute change in demand on links in and around the UGCs. The small share of trips attracted to the Hamilton UGC is probably due to the existence of more prevalent, industrial employment opportunities in employment lands outside the UGC along the shore of Hamilton harbour. An analysis of firm locations in the next section will explore this issue further.

In contrast to the UGC scenario which affected net travel behaviour minimally, the general intensification scenario has several significant impacts. Under this scenario, the percent of trips destined to the Hamilton greenbelt drops from 17% in the base case to 12.5%. Similarly, the number of trips originating at this location decreases. This is understood to be a result of growth being halted after 2006. The reductions in the greenbelt coincide with large increases in trip productions and attractions in the Hamilton DGA, not surprising considering the dense intensification activities enforced there by the policy.

Finally, the combined growth scenario is characterized by aspects of each of its constituents. The number of trips destined to, or originating from the UGCs doubles, while trips associated with the greenbelt decline, and those in the Hamilton DGA increase by 50%. The unfortunate consequence of intensifying the UGCs as well as the designated growth area is an estimated increase in daytime migration out of the downtown core to the suburbs. The number of trips from the Hamilton UGC to the DGA is only 277 in the base case, but 1,016 in the combined scenario. Improved transit linkages will be necessary to reduce congestion between downtown and satellite nodes. Similarly, the number of trips from the UGC to the rest of the built-up area increases from 1,248 to 3,058. These numbers are still quite small in terms of the total trips on the network, but the pattern indicates that transit upgrades may be required to handle spatial shifts in travel demand.

Next, the analysis of origin-standardized flow rates helps quantify the impacts of intensification on the relative attractiveness of destination zones specific to each origin. The UGC growth scenario results in the UGC tracts being twice as attractive as compared to the base case according to the aggregate increase in trip ends. The distribution of trip origins destined to the UGC adds depth to the analysis. For example, while all zones experience increased shares of trips going to the Hamilton UGC, we see that the attractiveness of the Hamilton UGC more than doubled for the UGCs themselves, the Burlington built-up area, and the Burlington and Grimsby DGAs. Similarly, the attractiveness of the Burlington UGC nearly tripled in the built-up area and DGA of Grimsby, and more than doubled everywhere else except for other areas in Burlington. The general intensification scenario had one observable impact in that it increased the attractiveness of the Hamilton DGA and decreased the attractiveness of the Hamilton greenbelt according to all origin zones. Finally, as before, in the combined growth scenario, the attractiveness of zones appears to exhibit elements of each of its constituents.

The final group of spatial impacts investigated herein pertain to firm location choices. The EMPLOC module allocates firms to census tracts within IMULATE using a discrete choice framework outlined in Maoh *et al.* (2005). Table 7 summarizes the results of the simulated firm locations for the City of Hamilton categorized by industry type, growth scenario, and P2G geography.[3] Since the city-wide firm counts are constant between scenarios, it is convenient to present the firm distributions as deviations from the Base Case distribution. Each scenario has a unique impact on firm distributions and several observations can be made.

The model results confirm that *UGC Intensification* will cause a large number of firms to locate in the UGC rather than in the greenbelt; most coming from the service sector and a small but significant number coming from the retail sector as well. This increase in firm attractions is due to agglomeration effects and location preferences of the firms. Keeping in mind that the EMPLOC model was calibrated on data reflecting a period of suburban expansion of the retail environment, it is not surprising that residential intensification does not serve to attract many new retail establishments to the city's core. The more land intensive manufacturing, construction and wholesaling firms are displaced from the UGC to the outlying regions within the built-up area.

The dominant impact of the *General Intensification* scenario is to shift a large number of firms from the greenbelt to the designated greenfield area. This corresponds with the shift in residential growth that is associated with the scenario. However, not all industries are impacted evenly. The biggest effect occurs in the service sector, with roughly 3000 additional firms being allocated to the DGA, primarily deducted from the greenbelt and the existing built-up area. Wholesalers appear to react in a similar way. Interestingly however, retail firms under *General Intensification* appear to concentrate in the built-up areas, while relatively vast quantities of manufacturing and construction firms are predicted to prefer to locate in the greenbelt. Finally, and not unexpectedly, the *Combined Intensification* scenario predicts a firm location pattern that essentially combines the effects of *UGC* and *General Intensification*.

5.0 Conclusions

This paper reports on the forecasted impacts certain provincial growth strategies could have on the usage and performance of the transportation system in the Hamilton CMA with the use of IMULATE, an integrated urban model. The model also reports on employment effects, specifically the location of firms by specific industries throughout the region. Four growth scenarios relating to different policy combinations are used for comparative purposes. The *Base Case* scenario represents business-as-usual development patterns characterized by urban sprawl. The *UGC Intensification* scenario simulates growth that achieves provincially defined density targets for the Hamilton and Burlington UGCs with respect to employment and population. The *General Intensification* scenario simulates the implementation of the 40/60 split in residential growth between built-up lands and growth in designated greenfield areas. Finally, the *Combined Intensification* scenario achieves the UGC growth targets in conjunction with the 40/60 split. The gross numbers of new households and jobs added to the CMA in each simulation period is derived from provincially sanctioned growth targets produced by Hemson Consulting, and are held constant between each simulation. Thus the total number of households and jobs at each period-end is equal, only their spatial distributions differ.

[3] EMPLOC is only functional for the City of Hamilton. Firm allocations for Burlington and Grimsby are inputted exogenously.

Table 7
2031 firm allocation by industry and P2G zone, differences from Base Case

	Base Case	UGC Intensification	General Intensification	Combined Intensification
Built Up	**10,803**	**+71**	**+87**	**+103**
Manufacturing	1,197	+6	-179	-170
Construction	573	+19	-81	-81
Wholesale	221	+35	-43	-40
Retail	4,159	+49	+825	+925
Services	4,653	-38	-435	-531
UGC	**192**	**+447**	**+185**	**+461**
Manufacturing	34	-15	-15	-15
Construction	4	-3	-3	-3
Wholesale	3	-2	-3	-2
Retail	66	+14	+189	+14
Services	85	+453	+17	+467
DGA	**3,023**	**-55**	**+2,808**	**+2,478**
Manufacturing	186	+1	-124	-121
Construction	127	-4	-33	-30
Wholesale	121	+2	+112	-108
Retail	627	+6	-80	-37
Services	1,962	-60	+2,933	-2,558
Greenbelt	**5,944**	**-460**	**-3,068**	**-3,043**
Manufacturing	236	+7	-324	+309
Construction	201	-12	-118	+108
Wholesale	472	-30	-66	-67
Retail	1,250	-67	-932	-898
Services	3,785	-358	-2,512	-2,495

Business-as-usual development is likely to cause the longest driving distances, consume the most fuel, and produce the highest aggregate levels of congestion. These findings confirm the negative side effects of urban sprawl, a characteristic embodied within the simulated business-as-usual scenario. According to Smart Growth America (2006), increased traffic and congestion can be attributed to factors associated with sprawl. The findings from Hamilton support this relationship, albeit not to the same degree as in other studies. Perhaps this is due to the exclusion of transportation investments in the simulated growth scenarios. On the other hand, the combined scenario results in the lowest levels of VKT and fuel consumption, but UGC intensification alone has the most positive impact on aggregate congestion levels. This reinforces the inverse relation between energy consumption and population density proposed by Newman and Kenworthy (1989). The results of the UGC intensification scenario also support previous findings reported in Behan *et al.* (2008) on the positive implications of residential intensification in the Hamilton core.

The analysis of emissions was first performed at the aggregate level, with UGC intensification producing the lowest region-wide levels of harmful HC and CO, and the combined scenario producing the lowest levels of NOx. While the impact of CO on the environment occurs on a global scale, HC and NOx emissions have negative health effects on the local population (Finkelstein *et al.*, 2004). Thus link level HC and NOx emissions, as well as average congestion levels, were analyzed at the P2G geography level for insights into the spatial distribution of transportation externalities. This analysis reveals that while smart growth strategies reduce the aggregate levels of emissions and congestion levels, areas within the city receiving growth experience increased exposure to harmful emissions. This finding should be carefully examined in future research in order to quantify the number of people at increased risk under each growth scenario. Maoh and Kanaroglou (2009) provide a prospective tool for such analyses, and similarly find that different intensification strategies in Hamilton lead to a variety of externalities with unique spatial patterns.

Origin-destination patterns were explored spatially in terms of total changes of trips between zones, and the relative attractiveness of zones. The findings indicate that intensification has the effect of increasing the number of automobile trips to and from intensified areas. Without supporting new demand between intensification zones with increased infrastructure supply, in particular good quality public transit, intensification potentially will cause increased congestion and emissions within intensification areas. Along these lines, the Hamilton Gateway Study (HGS) illustrates that light rail public transit investment potentially offsets increased automobile demand that results from economic and residential intensification (McMaster Institute for Transportation and Logistics, 2009). Similar to the findings reported here, the HGS suggests that without the proper investment in public infrastructure, intensification alone can result in negative outcomes on the transport system within and between the targeted growth areas. This suggests that proper planning should exploit and target different elements pertaining to both land use and transportation.

Finally, an analysis of the spatial distribution of firms indicates significant differences in firm locations amongst the various growth scenarios. A significant number of firms are by nature population oriented (i.e. retail trade and services) and have the tendency to co-locate in proximity to residential areas. As such, targeted residential growth areas will attract a disproportionate number of retail and service firms. This will lead to visible changes in urban form and consequently travel behaviour. All of the intensification scenarios successfully shift new firm development away from the greenbelt, leading to a more compact and efficient load on the transport network. This is believed to be a positive outcome that combats the negative side effects of sprawl through increased land use mixing. As a result, less auto trips will be generated and a more sustainable transportation system can be realized (Behan *et al.*, 2008).

This study has shown that simulating smart growth policies can be used to inform the debate on alternative urban futures. The land use intensification simulations have been analyzed from many important viewpoints in order to provide breadth, as well as depth to the understanding of the complex impacts smart growth land use planning will have on transportation networks. Following the provincial intensification strategies outlined in P2G, the simulated scenarios imply that the intensification policies confine externalities and reduce environmentally hazardous emissions. The critiques of the policies found in section 2.3 suggest that the intensification targets set by P2G fall short of the realistically achievable rates for the Hamilton area, and that the targets should be set higher. With that in mind, we speculate that increasing the intensification targets as suggested by Neptis and Pembina would further enhance the smart growth benefits realized in the simulation.

The results derived from this analysis suggest that alternative growth strategies can induce changes to both transportation system usage and performance. While it is difficult to determine the real effect of each policy on individuals due to the modeling framework adopted here, the outcomes clearly indicate the superiority of the more compact growth scenarios in general terms. More specifically, however, the analysis discerns that compact development strategies will reduce congestion and emissions in certain locations within the city. As such, local effects with respect to emission exposure and traffic congestion will be more pronounced. From a holistic perspective, compact development can be more useful in achieving reductions at both the aggregate and disaggregate levels, while providing the additional benefit of being able to finely tune and address the spatial pattern of externalities. Smart growth strategies like those presented in this research can provide the basis for a more sustainable and viable alternative to the business-as-usual, sprawl-based urban form. The achieved results are in line with previous findings on the benefits of smart growth, and the P2G intensification policies can help the Hamilton region realize these benefits.

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