Hamilton, Ontario vs. Halifax, Nova Scotia: Comparing Urban Sustainability Measures of Two Canadian Cities

Justin RYAN, Hanna MAOH and Pavlos KANAROGLOU
Center for Spatial Analysis (CSpA), School of Geography and Earth Sciences, McMaster University, 1280 Main Street West, Hamilton, ON, Canada, L8S 4K1

Introduction:

The concept of Urban Sustainability is related to the concepts of Sustainable Development, Smart Growth, Sustainable Transport Networks and Urban Sprawl. Although an intuitive notion of the meanings of these concepts is widespread, more precise definitions and methods of operationalization are required for academic discourse. To this end, a large body of literature exists, for example: Black et. al., 2002; Song, 2005; Krizek, 2003; Pol, 2002. Pol, 2002 comments that sustainability "has to do not only with ecological concern but also with solidarity and equity, which implies a socio-physical structural network-when appropriate-(where the city is one of the main expressions) and a social fabric with formal and informal social support (where identity is one of its expressions)." What is immediately apparent from this definition is that Urban Sustainability is a complex concept encompassing a variety of physical and social factors. Thus, instead of attempting to measure the 'Sustainability' of a given city directly, researchers have focused on a variety of specific, quantifiable measures of given aspects of urban areas, which relate to Urban Sustainability. See for example: Bertaud, 2001; Krizek, 2003; Black et. al., 2002. In this paper, we apply a set of these measures of urban sustainability to the cities of Hamilton, Ontario and Halifax, Nova Scotia for the year 1996. The set of measures are taken from several sources in the literature, with the goal of covering a range of aspects of urban sustainability, with a focus on Transportation, given the available data. Along with an assessment of urban sustainability, we use the given measures to explore the two cities, with regards to urban form, population distributions, land use distributions and transport systems. This exploration will serve as a first step towards an eventual modeling effort of the two study areas. Furthermore, and more relevant to the objectives of this paper, the exploratory analysis of the study areas lends context to the results of the measures of urban sustainability. That is to say, we can compare the measures of urban sustainability of the two study areas taking into account the differences in land use, infrastructure and population distribution between them. This allows for some speculation as to the effects of urban form on measures of urban sustainability.

The remainder of the paper will be organized as follows. Section 2, Background, provides a discussion of various measures of urban sustainability from the literature, as well as some particulars of this study. Section 3, Research Methods, details the particular measures used to assess and explore the study areas. Finally, section 4, Results and Discussion, describes and discusses the results of each measure, and touches upon future research resulting from this work.

Background:

Due to the intractability of defining a particular measure of Urban Sustainability, most research efforts have instead broken the concept into a set of distinct proxy concepts which can each be associated with quantitative measures. For instance, Bannister (1996) sees land, energy and transport as the main physical components of urban sustainability. He notes that: "each of these components contributes towards the overall use of resources and levels of emissions within urban areas, and the aim of urban sustainability would be to improve the efficiency in the use of each of these three components."

Minken et al. (1999) define a sustainable system of urban transport and land use as one which:

-Provides access to goods and services in an efficient way for all inhabitants of the urban area.

-Protects the environment, cultural heritage and ecosystems for the present generation.

-Does not endanger the opportunities of future generations to reach at least the same welfare level as those living now, including the welfare they derive from their natural environment and cultural heritage.

While the breakdowns provided by Bannister and Minken et al. help to better define the concept of urban sustainability, they fail to truly break the concept into elements which can be easily operationalized, or measured. Wheeler (2000) states that "particular objectives of urban sustainability can be seen to include the following:

-Compact urban form;
-Preservation of open space and sensitive ecosystems;
-Reduced automobile use;
-Reduced waste and pollution;
-Reuse and recycling of materials;
-Creation of livable and community-oriented human environments;
-Decent, affordable, and appropriately located housing;
-Improved social equity and opportunities for the least advantaged;
-Development of a restorative local economy."

Wheeler notes that this list: "is not exhaustive but conveys the general idea of improving long-term human and environmental well-being throughout the range of planning specialties." That being said, Wheeler's list (and others like it) begins to present the abstract idea of urban sustainability as a series of elements which can be measured. For the purposes of this paper, certain elements from Wheeler's list are given more focus than others. In particular, we focus on the following: 'Compact urban form'; 'Reduced automobile use'; 'Creation of livable and community-oriented human environments'. We will briefly discuss the operationalization of each of these elements, before presenting the actual measures used in the following section.

The most obvious proxy measures for 'Compact urban form' are population density and household density (see for example Krizek, 2003 and Camagni, 2002). These measures could be misleading if the study area includes large tracts of open space. For instance, if a number of small compact communities existed in a large study area, population density would be low, though the urban areas within the study area are compact. Here, evidently, the Modifiable Arial Units Problem (MAUP) becomes an issue.

‘Reduced automobile use’, or the rates of automobile use in a study area can be estimated by directly counting cars at key intersections, or the number of cars sold in the study area, or by ascertaining the number of licenses in the study area. A further proxy measure of car use in the population is the mode choice of persons on their journey to work, which is available from the census. Also, the number of road lane kilometers in a study area gives insight into the intensity of car use.

‘Creation of livable and community-oriented human environments’ can be assessed through community questionnaires, as well as through quantitative means. Here land-use mix and the accessibility of residents to various land-uses are key issues. Krizek, 2003 develops sophisticated measures of ‘Neighborhood Accessibility’ which take into account many measures of ‘livability’, such as pedestrian access to commercial and recreational land-use. Other measures of livability might include the presence of parks and bike lanes, as well as the amount of noise generated by traffic in an area.

It is important to note that there is no temporal element to the measures in this paper. We are simply comparing sustainability measures between Hamilton and Halifax during a narrow slice of time: 1996. The character of this study would change dramatically if the temporal aspect was considered. For instance, in the case of land-use mix, the question would become, which city’s land-use mix is ‘improving’ more, as opposed to what is the land-use mix of each city in 1996.

Certainly, there are many different ways of approaching the various aspects of Urban Sustainability. In practice, it is necessary to choose among these based on the availability of data, and the most relevant issues to the particular study. This paper begins the work on a more thorough comparison between the cities of Hamilton, Ontario and Halifax, Nova Scotia.

Research Methods:

A variety of quantitative measures were applied to the Hamilton and Halifax CMAs, to fulfill the objectives of this study. Some measures exclusively describe the CMA as a whole, while most vary over the census tracts that make up each CMA. All measures employ data from the year 1996, at which time the Hamilton CMA consisted of 163 census tracts (CT), and the Halifax CMA consisted of 75 CTs. In this section of the paper each measure will be described and briefly discussed. We begin with measures that apply to the CMA as a whole.

The population and population density are reported on for each CMA. The population gives an indication of the overall level of urbanization and development that exists in the CMA, as well as being a basic exploratory measure. Population density measures the intensity of human activity in the CMA, but is highly dependent on the CMA size, which is variable in general.

Road and Lane meters are presented for each CMA. While Road meters refer to the length of road in each CMA, Lane meters refer to the combined length of all lanes in the CMA. So, for instance, a 4 lane highway 1 km long has 1000 Road meters and 4000

Lane meters. These are exploratory measures which give an idea of the amount of road based transport infrastructure in a CMA. Related to these measures are Road and Lane meters per capita, as well as the percentage of the CMA area occupied by roads. In general, a city with high Road and Lane meters per capita implies a certain degree of unsustainable urban sprawl. On the other hand, transporting people is not the only purpose of a road network, freight transport and other business interests also require road infrastructure and may influence total Road and Lane meters in a CMA. Concerning the percentage of CMA area occupied by roads, high values imply a reliance on automobiles, as well as high levels of road maintenance. This measure assumes an average lane width of 4 meters.

Several Journey To Work (JTW) measures are presented at the CMA level. These include the median JTW distance, the percentage of JTW trips less than 5 km, the percentage of JTW trips greater than 20 km, and the breakdown of JTW trips by mode of transportation. When the first three measures indicate a high proportion of the populace traveling long distances to work, urban sprawl is indicated, where residential and business land uses typically do not mix. The fourth measure, breakdown of trips by mode, helps to assess automobile dependence, where high levels of such are considered to be unsustainable.

Finally, the percentage of each CMA by land-use type is presented. There are 7 land-use types: Commercial; Government and Institutional; Open Area; Parks and Recreational; Residential; Resource and Industrial; Water-body. Here, an important consideration for sustainability is having greater proportions of Open Area as well as Parks and Recreational land-use types. In general however, this measure is exploratory.

Aside from the above measures at the CMA level, Census Tract (CT) level measures were also considered. These often give a more refined view of a phenomenon, and can allow for a more deliberate consideration of space. The first CT level measure considered is population density. This measure is a proxy for the concept of Compact Urban Form, where CTs having high population densities are more likely to be 'compact'.

The average distance between residential and commercial land-use as well as between residential and parks/ recreational land-use are calculated for each CT. Large values of these two measures are consistent with car dependency and urban sprawl. Small values, on the other hand, imply 'livable neighborhoods' with a variety of land-uses and low car dependence. Song, 2005 notes that 'walking distance' is generally defined as ¼ of a mile, or approximately 400 meters. This lends context to these measures.

The ratio of jobs to residents in each CT is presented for both CMAs. Low values of this measure indicate 'bedrooming', where residents typically commute longer distances to work, to take advantage of low cost housing in the CT. Bedrooming is a characteristic of urban sprawl. It is useful to note however, that even in the case where the Jobs to Residents ratio is greater than 1, those jobs may not be filled by the residents of that CT. Camagni et al., 2002, note that for this variable "the literature attributes considerable importance in connection with mobility demand".

Two measures of land-use mix are calculated, namely the M(XXXX) Density Index (MDI) and the Entropy index. High values of MDI imply mixing of employment and residential opportunities. High Entropy indices indicate a high level of mixing of land-use types. Land-use mixing is consistent with the ideals of urban sustainability and the 'livable city'.

Finally, the 'percentage of occupied dwellings being rented', as well as the 'average value of dwellings' per CT are presented. Both of these measures explore the distribution of wealth in the study areas. Large spatial disparities in wealth distribution are considered to be unsustainable. In addition, high values of the percentage of occupied dwellings being rented is often an indication of the presence of multi-dwelling buildings.

Results and Discussion:

The results of CMA level measures for Hamilton and Halifax can be seen in Table 1. The population of Hamilton is 624360, nearly twice the population of Halifax, namely 332518. At the same time, the Halifax CMA land area is nearly double that of the Hamilton CMA. It comes as no surprise then, that the Hamilton population density of 451.70 persons per km^2 is nearly four times the Halifax density of 120.93 persons per km^2. Despite the perhaps misleadingly large size of the Halifax CMA (2 very large and thinly populated CTs were added to the Halifax CMA in 1996), the above results nonetheless suggest that Hamilton is the more urbanized and densely populated place.

Interestingly, despite Hamilton's larger population, the total road lengths in Hamilton and Halifax are similar: 4301138 and 3919679 meters respectively. However, the total lane meters for Hamilton and Halifax are 9213404 and 6853528 respectively, which indicates the presence of more multi-lane roads in Hamilton. This could be due to Hamilton's close proximity to other large urban centers, in contrast to Halifax, which is the dominant urban center in its region. Hamilton has 6.89 road meters per capita, while Halifax has 11.79. This suggests that Hamilton is making more economical use of its road network, a sign of a more sustainable transport system. On the other hand, there could be a threshold length of road necessary to accommodate a city the size of Halifax, after which additional population do not necessarily require additional road meters. 2.666 % of Hamilton's land area is occupied by roads, while this figure is only 0.997% for Halifax. In light of the above discussion, this result is counter-intuitive; however it can be explained partly by Halifax's larger land area, and Hamilton's greater amount of multi-lane roads.

The median JTW distance for commuters in Hamilton is 7.4 km, while the median commute for Haligonians (people from Halifax) is 6.3 km. The results for percentage of JTW trips less than 5 km and greater than 20 km are more pronounced. For Hamilton, 35.7% of JTW trips are less than 5 km while 20.4% are greater than 20 km. For Halifax these figures are 41.4% and 10.6% respectively. Clearly, commuters in Halifax live closer to their workplaces than their Hamiltonian counterparts. This result indicates more urban sprawl in Hamilton than Halifax, and is certainly influenced by the large amount of Hamiltonians working outside of the Hamilton CMA. The mode choices of both cities tell a similar story, with Hamilton commuters being more auto dependent than commuters in Halifax. In Hamilton, 78.12% of commuters drive to work in a car truck or van, and 7.37% of them commute as passengers in these vehicles. These figures are 66.56% and 10.69% respectively, for Haligonians, showing their higher propensity to car pool, compared to Hamilton commuters. A mere 14.51% of Hamilton commuters use 'other methods' to get to work, compared to 22.74% of Halifax commuters.

Both Hamilton and Halifax have similar proportions of 'open area' and 'parks & recreational' land-uses. Specifically, 79.88% of the Hamilton CMA and 84.35% of the Halifax CMA are open area land-use, while 'parks & recreational' land-uses make up 2.33% of the Hamilton CMA and 1.56% of the Halifax CMA. What is striking is that 13.1% of the Hamilton CMA is devoted to residential land-use while that figure is 3.62% for Halifax. Perhaps this can again be explained by the larger area and smaller population associated with the Halifax CMA.

Summary statistics for the CT level measures can be seen in Table 2. It is important to keep in mind that the Hamilton CMA consists of 163 CTs, while the Halifax CMA consists of 75, meaning the effect of outliers is amplified in the Halifax case.

The mean population density (persons per km^2) in Hamilton CTs is 2907.64 while Halifax CTs have a mean of 1848.05. This reinforces the notion that Hamilton is more heavily urbanized than Halifax, along with the maximum population densities, which are 14416 and 8026 for Hamilton and Halifax respectively. Furthermore, this suggests that Hamilton is the more 'compact' city, or that a large subset of its CTs are compact.

The average mean distance between residential and commercial land-uses in Hamilton CTs is 894.13 meters, while for Halifax this distance is 1635.17 meters. Although both of these values exceed the walking distance of 400 meters proposed by Song, 2005, Hamiltonians seem to enjoy closer proximity to commercial opportunities. However, the standard deviation of this measure is 698.07 meters for Hamilton and 2570.84 meters for Halifax, implying an influence from outliers in the Halifax case. This is further reinforced by the fact that the minimum values of this measure are 130 meters and 56 meters for Hamilton and Halifax respectively. The two cities present a more unified picture with respect to the mean distance between residential and 'parks & recreational' land-uses. Here, the mean values of this measure are 493.33 meters for Hamilton CTs and 636.19 meters for Halifax CTs.

The mean ratio of jobs to residents over the Hamilton CTs is 79.27%, and 62.17% in the Halifax scenario. This could be due to a more vibrant economic situation in Hamilton, or a more uniform mix of economic and residential activities in Halifax CTs. Revealing the intense industrial activity that takes place in Hamilton, the maximum value of 'jobs to residents' ratio is 4166.67% in Hamilton, compared to 952.52% in Halifax.

The MDI measure specifically addresses the issue of the mix of economic and residential activities in each CMA's CTs. The mean value of this measure is similar for Hamilton and Halifax, being 596.17 and 538.59 respectively. This is an interesting result given the aforementioned intense, and necessarily isolated from resident, industrial activity in Hamilton. This is however reflected in the maximum MDI values, which are 4765.86 for Hamilton and 3470.80 for Halifax.

The summary statistics on entropy indices for the two study areas are strikingly similar. For instance, the mean value for this measure is 0.511985 for Hamilton and 0.514998 for Halifax. This indicates a similar level of land-use mix between the census tracts of the two cities. It would be helpful to compare these results to those from other Canadian or North American cities, to gauge the 'livability' indicated by this measure.

Finally, we look at measures reflecting the wealth distributions in the two CMAs. The average value of the percentage of rented occupied dwellings is 32.52 for the Hamilton CTs and 40.29 for the Halifax CTs. This shows a certain element of lower income and transience in Halifax, compared to Hamilton. Informatively, the minimum values of this measure are 0 for Hamilton and 5.61 for Halifax, meaning that no CT in Halifax is without rented dwellings. This also implies a lack of ultra rich neighborhoods, and hence sharp contrasts in income over space, which is in keeping with the ideals of sustainability. A more pointed measure of wealth distribution is the average value of dwellings per CT. Here, Hamilton has an average mean dwelling value of $158,152 across its CTs, while this figure for Halifax is $120,779. While this simply implies that the cost of living is higher in Hamilton, the ranges of this measure imply greater inequalities in the spatial distribution of wealth in Hamilton. Specifically, the max and min average value of dwellings are $327,483 and $76,233 respectively, for Hamilton CTs. In contrast, the max and min average value of dwellings are $270,462 and $71,442 respectively for Halifax CTs.

A great deal of insight can be had from studying measures of urban areas such as those presented in this paper. At the same time, it can be seen that concepts such as urban sustainability and sustainable transport systems are subtle. Measures meant to operationalize these concepts must be interpreted with care. This paper has taken steps in the direction of assessing the differences between two urban areas in terms of measures of urban sustainability. Furthermore, a great deal of useful information was gathered on both the Hamilton and Halifax CMAs, which will prove useful in future projects, including transportation modeling efforts.

A great deal of work remains to be done, perhaps including a similar comparative study which assesses the urban areas over time. Also, more explicit spatial analysis of the data gathered in this paper would be useful and informative.

Table 1: CMA level measures

Measure	Hamilton CMA	Halifax CMA
Area (square meters)	1382247494	2749734791
1996 Population	624360	332518
Population density (persons per km^2)	451.70	120.93
Road length (meters)	4301138	3919679
Lane length (meters)	9213404	6853528
Road meters per capita	6.89	11.79
Lane meters per capita	14.76	20.61
Area occupied by roads (%)	2.666	0.997
Median JTW distance (km)	7.4	6.3
JTW trips < 5 km (%)	35.7	41.4
JTW trips > 20 km (%)	20.4	10.6
JTW trips by car, truck or van as driver (%)	78.12	66.56
JTW trips by car, truck or van as passenger (%)	7.37	10.69
JTW trips by other methods (%)	14.51	22.74
Commercial Land Use Area (%)	0.48	0.06
Government & Institutional Land Use Area (%)	0.87	0.09
Open Area Land Use (%)	79.88	84.35
Parks & Recreational Land Use Area (%)	2.33	1.56
Residential Land Use Area (%)	13.1	3.62
Resource & Industrial Land Use Area (%)	2.47	0.76
Water-body Land Use Area	0.87	9.57

Table 2: CT level measures

Measure	City	Mean	Std. Dev.	Max	Min
Population density (persons/ km^2)	Hamilton	2907.64	2256.20	14416	27
	Halifax	1848.05	1787.00	8026	5
Avg. distance between residential and commercial land-use (m)	Hamilton	894.13	698.07	4085	130
	Halifax	1635.17	2570.84	14583	56
Avg. distance between residential and parks & recreational land-use (m)	Hamilton	493.33	275.99	1873	207
	Halifax	636.19	579.13	3321	168
Ratio of jobs to residents (%)	Hamilton	79.27	347.48	4166.67	0.86
	Halifax	62.17	136.10	952.52	0.65
MDI	Hamilton	596.17	747.93	4765.86	1.37
	Halifax	538.59	749.85	3470.80	0.22
Entropy index	Hamilton	0.511985	0.199020	0.957764	0.027192
	Halifax	0.514998	0.158047	0.931718	0.175596
% of occupied dwellings rented	Hamilton	32.52	22.76	92.26	0
	Halifax	40.29	26.59	96.49	5.61
Average value of dwellings (Cdn $)	Hamilton	158512	44641	327483	76233
	Halifax	120779	37518	270462	71442

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