SURVEY OF TRANSPORT-RELATED ENERGY SUSTAINABILITY OF MAJOR CANADIAN URBAN AREAS

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ABSTRACT:

The rapid development of urban 'sprawl' surrounding many North American cities has many potentially detrimental effects including enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use. Over the past 5 years in Canada a number of studies have been undertaken to address transportation-related energy consumption with the view to formulating relevant policies with regards to sustainability. These studies have led to the recommendation of a suite of indicators both to characterize the sustainability of past urban growth as well as to monitor future sustainability trends. A number of the proposed indicators are based on land-use and urban form, quantities that can be extracted from the analysis of satellite imagery. In 2003, a project was initiated at the Canada Centre for Remote Sensing to support departmental energy policy-makers by (a) developing numerical methods to quantify their recommended indicators and (b) to assess these indicators through a national sustainability survey of major Canadian urban areas. This paper presents results of the survey based on land-cover / land-use (LCLU) information derived from circa 2000 Landsat Thematic Mapper data as well as extensive ancillary information such as road networks and the national census. Four indicators (urban land use per capita, urban compactness, transport mode index and street network connectivity) are quantified for all Canadian cities with populations in excess of 200,000 as well as a selected subset of smaller communities.

1. INTRODUCTION

While Canada is generally viewed as a sparsely populated nation, it is in fact a highly urbanized one as well. According to the Statistics Canada report '2001 Census Analysis Series – A Profile of the Canadian Population: Where We Live', 64% of Canadians live in the country's 27 census metropolitan areas (CMAs) with a population in excess of 100,000 and 79.4% live in communities with populations in excess of 10,000. Furthermore, 51% now live in four large conurbations; the Golden Horseshoe, greater Montreal, B.C.'s lower mainland / southern Vancouver Island and the Calgary-Edmonton corridor. This concentration is being further accentuated by the settlement choices of recent immigrants. Approximately 78% of immigrants select to reside in one of the first three conurbations mentioned above.

Urban issues and concerns have recently come to the forefront in the Canadian Federal agenda (NRTEE, 2003; FPRI, 2002). An area of major concern relates to energy issues associated with rapid urban growth. The adverse effects associated with the development of 'sprawl' include;

(a) Increased transportation-related energy consumption and greenhouse gas (GHG) emissions arising from increased private vehicle use. Today, approximately 34% of Canada's GHG emissions arise from transportation activities, two-thirds of which occur in urban areas.
(b) Health concerns associated with increased levels of air pollution.
(c) Loss of valuable agricultural land to low-density residential developments.
(d) Loss and encroachment upon eco-sensitive lands such as forests and wetlands.

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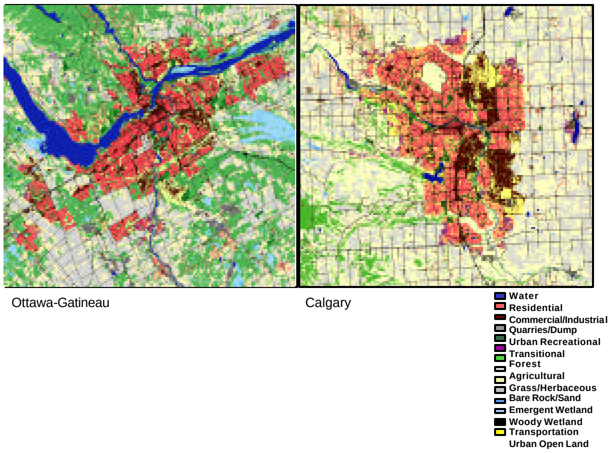

Figure 1. Population density as function of urban population

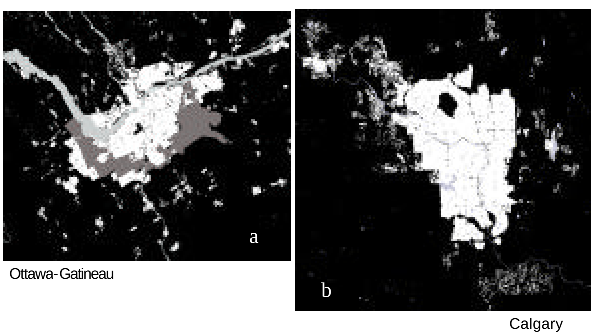

Figure 1. Population density as function of urban population

CMA/CA Name	Code
Toronto	A
Montreal	B
Vancouver	C
Ottawa-Gatineau	D
Calgary	E
Edmonton	F
Quebec City	G
Winnipeg	H
Hamilton	I
London	J
Kitchener	K
St. Catharines-Niagara	L
Halifax	M
Victoria	N
Windsor	O
Oshawa	P
Saskatoon	Q
Regina	R
St. John's	S
Barrie	T
Abbotsford	U
Kingston	V
Guelph	W
Chatham	X
Peterborough	Y
Sarnia	Z
Brantford	AA
Woodstock	AB

Table 1. Code of CMAs and major Census Agglomerations used in figures 1 and 2.

A number of national associations and agencies including the Centre for Sustainable Transportation (CST) and the Transportation Association of Canada (TAC) have convened workshops inviting both government and private sector experts to address urban growth. The concerns receiving attention include transport-related energy consumption and impacts of transportation corridors on eco and human health. These discussions and studies have led to the recommendation of a suite of relevant indicators to monitor urban sustainability. A key example is the work of the CST. A team of transportation experts and government policy-makers, including members of the Energy Sector of Natural Resources Canada, complied a recommended list of Sustainable Transportation Performance Indicators (STPI) for the Canadian urban context (CST, 2002). Many of these indicators encapsulate aspects of urban form and land use mix within urban landscapes, characteristics that can be quantified through analysis of land cover / land use (LCLU) information derived in part from satellite image s.

As a consequence of these studies and in an effort to support energy sector policy makers, a project has been initiated within the Earth Sciences Sector of Natural Resources Canada to identify and fill current geospatial information gaps associated with the STPI and other transportation-related indicators. This paper describes initial progress towards that goal including quantified measures of 4 key indicators for 28 Canadian metropolitan areas, including all 17 with populations in excess of 200,000 according to the 2001 census (Table 1). Land-cover/land-use (LCLU) digital products have been assembled based upon interpretation of Landsat 7 scenes acquired during the 1999-2001 timeframe. A new methodology has been developed for this purpose that combines pixel-based and segment-based classifications to exploit both spectral and spatial information (Guindon et al., 2004). These information layers have then been augmented with other federal sources including road networks, additional digital topographic classes and demography from the 2001 census.

2. INDICATOR RESULTS

2.1 Land Use per Capita (LPC)

Land use per capita is a fundamental measure of urban sprawl and hence both typical trip length and the feasibility of public transit. The urban area component of this indicator is a challenge to define because it consists not only of built-up land but extensive open areas as well including parkland and extensive grassy areas associated with modern industrial parks. Figure 1 illustrates a plot of LPC versus city size for our Canadian sample. A trend of increasing density with size is apparent, smaller communities exhibit a relatively broad range in values.

2.2 Transport Mode Index

This indicator is based on a measure of land use mix within the urban environment. Cities with highly mixed land use can be considered more 'sustainable' because they are more likely to provide local or neighborhood access to services. Different modes of transportation have differing 'travel horizons' for trips of typical duration (e.g. 20 minutes). As such, each has a corresponding scale over which mixing needs to be assessed. For example, for non-motorized travel (e.g. walking, cycling), a mixing scale of 3km is appropriate.

For transportation, the mix of residential and commercial/industrial land units is of particular interest since significant travel demand is based on work and shopping. We have developed the Transport Mode Index to measure the 'accessibility' of a city for these travel requirements. For non-motorized accessibility, the index is equal to the proportion of residential land that exhibits a commercial/industrial to built-up land ratio in excess of the city average for a travel horizon of 3km. Figure 2 illustrates this mode index. While there is no apparent correlation with city size, cities whose urban form reflect the 'old' manufacturing economy of southern Ontario score high in this indicator. Their industries of tend to be sited near their city cores within easy walking distance of dense residential areas. On the other hand, cities that have grown substantially in the recent past, e.g. Toronto, Vancouver, Calgary and Edmonton exhibit lower scores. This reflects the decentralization of employment to large-scale (i.e. greater than 3km in extent) industrial parks.

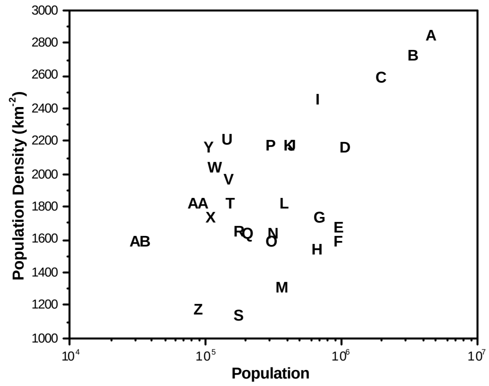

Figure 1. Population density as function of urban population.

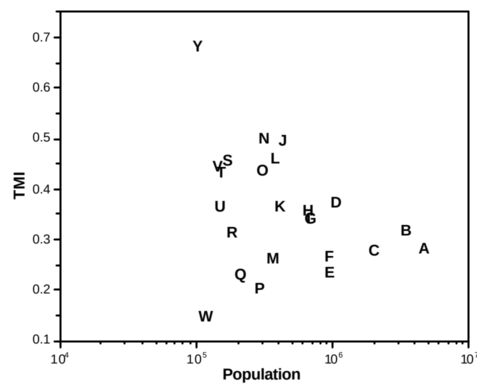

Figure 2. Transport Mode Index (TMI) as a function of population.

2.3 Compactness

Compactness measures the residential concentration of a city relative to a reference point, in our case the city centre. As such it can encapsulate rudimentary aspects of contemporary urban form such as spatially isolated suburban communities that are separated from the main urban core by green-space. A measure of compactness that is relevant to travel distance is the accumulated distances from each residential pixel to the reference point. This measure is applicable to mono-centric cities with employment concentrated in a compact central business district. To inter-compare the compactness levels of different cities, normalization must be applied to take into account population differences, land-use map quality, variations in the proportions of land use categories and topographic constraints. Atlantic coast cities such as Halifax and St. John's exhibit low compactness due to the fact that outside the urban core areas, growth is concentrated along a few major arterial routes.

2.4 Road Network Connectivity

Many street networks in suburban areas exhibit poor connectivity and are characterized by the presence of numerous deadends, winding streets and large block sizes. These features can impact vehicle energy consumption they restrict accessibility and route choices as well as discourage walking and cycling. We have utilized the internal connectivity indicator proposed by Song and Knapp (2004) to inter-compare the overall connectivity levels of cities. As well, we have assessed trends in connectivity change as a function of distance from each city centre. These spatial trends should be indicative of temporal changes in suburban design. Two points of this study are of particular note. First, not surprising, the cities with the highest overall connectivity are those prairie cities that have not experienced significant growth in the past 20 years. The traditional prairie urban form is one built upon a simple rectangular street grid. Second, 87% of the cities exhibit decreasing levels of connectivity with distance from the city centre indicating that recent network developments are less sustainable from a transportation point of view.

3. CONCLUSIONS

This paper has described first results of a survey of energy sustainability of major Canadian cities. A number of key challenges remain with respect to gauging relative urban sustainability based on indicators. These include how to (a) weigh relative indicator importance (b) gauge their relative information independence and (c) rationalize conflicting results. Research dealing with these issues will be presented elsewhere.

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