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Paul Hess, André Sorensen,
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Executive Summary

The Ontario government has recently taken a proactive approach to growth planning in the Toronto region, now known as the Greater Golden Horseshoe (GGH). To carry out and monitor its policies, the Province needs reliable ways of measuring density and monitoring how it changes over time. However, definitions of density vary and there are many approaches to its measurement.

This paper reviews common definitions and discusses methodological and data problems associated with density measurements in the GGH. The authors examine existing density distributions in the GGH using 2001 census data at the scale of municipal areas, census tracts, and census dissemination areas, and analyse 10 sample census tracts in Urban Growth Centres to compare gross and net densities for different types of development areas in the GGH. Detailed profiles are provided for five of those tracts. The authors note problems with using gross density for making comparisons between areas or time periods, and problems with using census data in density calculations.

Consistent, region-wide definitions and data are needed to develop a detailed understanding of existing trends in population and jobs density, land use, development patterns, and housing issues. The authors recommend the delineation of small census tracts with permanent boundaries for the area of the GGH that is expected to build up during the next 20 to 30 years, as well as the creation of a regional database on employment location, density, and output. They also urge the government to make parcel data, or a comparable database, available to researchers and policy analysts.

Note

This paper originated as part of a research project on existing patterns of urban density undertaken for the Ministry of Public Infrastructure Renewal (MPIR) in 2005. The research was designed to help MPIR better understand targets for densities in the GGH and determine the suitability of census data for establishing baseline densities and measuring and monitoring changes in density. This paper presents only the most significant findings, and is neither the full report submitted to MPIR, nor is it endorsed by MPIR.

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Introduction

Since 2003, the Ontario government has taken a proactive approach to regional planning in the Toronto region, now known as the Greater Golden Horseshoe (GGH). Major initiatives include the *Greenbelt Act* (2004), the *Places to Grow Act* (2005), and the Places to Grow Plan, released in June 2006.

Ontario is embarking on an ambitious experiment in regional structure management that has profound implications for future patterns of urban and rural change in the region. Of particular significance are plans to promote the intensification of urban density in existing urban areas, urban growth centres, and new greenfield developments in the GGH. Particular interest has been expressed in centres that either are, or have the potential to become, regional service providers because they have or can develop effective services, infrastructure, and transportation linkages that promote the goals of Smart Growth, including greater housing choice, and diversity in travel modes (Ontario Growth Secretariat 2005).

Population and jobs densities in urban regions are a key, but highly controversial issue for managing regional growth. The lower the overall density of new development, the more land is needed for a given amount of population increase. Given the huge scale of growth that is expected in the GGH during the next decades, even small increases in density could greatly reduce total land consumption. The new GGH Greenbelt further increases the imperative to use the remaining development land in the region as effectively as possible. Equally important, public transit is not viable in low-density communities, and large areas of the GGH simply do not have enough people within walking distance of transit stops, or enough high-density mixed-use walkable centres that make attractive destinations for transit users. Increasing public transit use will require not only better public transit facilities, but also a change in the larger patterns of density in the region.

As noted by Blais (2003), Smart Growth does not mean just a general increase in high-density urban form. Intensifying all parts of the region would be less effective in promoting transit use than selective intensification of mixed-use nodes and the corridors that join them. Similarly, it is now widely recognized that a key aspect of urban quality of life and of social and economic vitality is the existence of fine-grained walkable urban places with a mix of jobs, activities, and housing. Many of the older downtowns in the region have such places, but most of the suburbs built since the 1960s lack such destinations, and are virtually impossible to get to without a car. All these issues point to increased density as a way of improving the livability of the region. However, in order to monitor the effects of this type of policy and urban development over time, it is important to first understand the concept of density: how it is measured, and which aspects of density different measurements are able to capture.

The current Provincial efforts at managing regional growth in the GGH correctly identify density as a key issue. Policies set density targets for new areas of growth in greenfield sites as well as density targets in designated Urban Growth Centres (UGCs). Additionally, the policies set targets for the amount of new growth that should occur in already built-up areas that would benefit from general intensification.

To carry out and monitor these policies, the Province needs robust and reliable ways of measuring density and monitoring how it changes over time. This is not a straightforward matter. There are many definitions of density and many approaches to its measurement. Also, the suitability of various data sets for measuring different types of density varies widely.

Census data produced by Statistics Canada is clearly attractive for measuring density, since it is comprehensive for the entire population and is produced every five years, allowing changes in density to be monitored over time. At the same time, census data has many limitations. For one thing, it is focused on residential population counts and thus is less useful for examining employment density. For another, it uses predefined geographic units for measurement that may not capture the types of changes that are of most interest to the Province. This report evaluates the use of census data for measuring existing density and monitoring changes in the GGH.

The first section of this working paper compares existing definitions of gross density and net density. A wide variety of definitions have been and are currently employed by planners and urban analysts in the study of urban density. We review the planning literature for common definitions and discuss some of the methodological and data problems associated with density measurements in the GGH.

Section 2 examines existing density distributions in the GGH using 2001 census data. We examine the distributions and spatial patterns of gross density of population, jobs, and population-and-jobs combined in the GGH at the scale of municipal areas, census tracts, and census dissemination areas.

Section 3 analyses 10 sample Census Tracts in Urban Growth Centres to compare gross and net densities for different types of development areas in the GGH, and provides detailed profiles for five of those tracts.

A final section draws out the main conclusions.

1. Gross Density, Net Density: Concepts and Definitions

1.1 Why is Density Studied and How is it Measured?

Density is relevant to “environmental quality, transportation systems, physical infrastructure and urban form, social factors, and economic factors” (Churchman 1999, 398). Understanding urban density concerns planners, regional economists, community organizations, psychologists, and ecologists. The reasons for studying density influence how it is measured. For example, a psychologist interested in the effects of perceived density on mental well-being might use surveys to assess residents’ *perceptions* of density. As this study is meant to inform planning practice, the literature review that follows focuses on physical and quantifiable measurements of urban density.

The two major sources of data on urban density are censuses and remote sensing. Statistics Canada conducts a full population census every decade, and a slightly more limited survey every five years. The census provides a rich source of data collected in a consistent way. Census data is usually aggregated to protect the anonymity of respondents, so it cannot provide a sense of population distributions at a very small scale.

Some researchers supplement census data with data acquired through remote sensing. This data can provide details of urban form that can be integrated with census data using Geographical Information Systems (GIS) to clarify population distribution and density (Langford 2003; Donnay and Unwin 2001).

Remote sensing offers a number of ways to observe variables such as land cover, land use, and other density indicators. Dasymetric mapping uses remotely sensed images to identify residential areas within a census tract, thereby allowing for a better estimation of net densities. Images can be analyzed[1] to determine approximate land uses (Langford 2003). For a more precise classification of land uses, satellite images can be studied in raster format in GIS, allowing for the analysis of individual pixels. Land use classifications of remotely sensed data at a pixel level are carried out using “maximum likelihood classifier” statistical formulas, many of which

1 The analysis draws on spectral band reflectances and measures of variability and image texture.

have been incorporated into software packages (Mesev et al.1995). Although pixel-based approaches can reduce the effects of the modifiable areal unit problem[2] (Lo 2003), this type of classification is still imperfect, as it is only an estimation of land uses and not a direct observation (Donnay and Unwin 2001).

Longley and Mesev (2000, 2002) and Harris and Longley (2000) suggest that the use of satellite images in analyzing population data can be improved by supplementing these images with additional data sources that can be obtained commercially, such as Address Point, a product that gives the geographical coordinates of all residential and commercial mail delivery points in the United Kingdom. Harris and Chen (2005) discuss the procedures of converting these point data sets from vector to raster data to allow them to occupy an area rather than individual points, as is required for determining densities. This process is referred to as a "space-filling" technique. In carrying out this conversion, the authors use population surface modelling to estimate the density gradient at each point of observation.

GIS can also be used to display density analyses that have been computed by other means. For example, Bracken and Martin have developed a method of extrapolating densities from the centroids of census tracts to obtain localized density measures. While this process is largely based on mathematical formulas, it can provide less generalized density information that can inform public policy decisions (1989). There is also a potential to use this centroid approach with remote sensing of residential areas in order to determine localized population densities (Martin et al. 2000).

Statistics Canada has recognized the value of GIS technology. Before 2001, the land area of census tracts was manually calculated using a planimeter. Beginning in 2001, land areas have been derived from the National Geographic Base using GIS software. However, Statistics Canada (2005) warns that its own land area estimations are unofficial, and are less accurate at smaller scales. Therefore, there is a need to explore more precise methods of assessing land area. Additionally, Statistics Canada measures *gross* population density, meaning that its calculations are not specific to particular land uses (such as residential or commercial). A more sophisticated measure of density is needed to identify the potential for urban intensification.

Parcel data, which contains details about individual lots of land, can provide a comprehensive catalogue of urban land uses that can be manipulated to calculate different types of density.

Following is a discussion of various density calculations based on direct observations of land area.

1.2 Calculating Density

The main practical difficulty with population density measures is in deciding what aspects of population and land area are to be observed. Density is a ratio in which a measure of population

2 "The definition of zonal objects used for many geographical studies are modifiable and vary greatly" (Openshaw and Taylor 1981; 61). The modifiable areal unit problem (MAUP) describes how the aggregation of data divided into zones, or areas with discrete boundaries, can be problematic: "different areal arrangements of the same data produce different results" (Openshaw and Taylor 1981; 63). Additionally, it can be difficult to spatially represent meaningful units of analysis.

or built form serves as the numerator and a measure of land area as the denominator. The numerator can be total population, number of rooms or dwelling units, or available dwelling space (floor area). The denominator can be either total land area (as in "gross density"), or a pared-down measure of usable land area (as in "net density").

Table 1.1 displays the possible combinations of these numerators and denominators. Common terminology for each ratio and the authors who describe each concept are also listed. The shaded cells are those that represent gross densities; the white cells represent various forms of net density.

Table 1.1: The Diverse Terminology of Density

Land area	Population measurement	Rooms/dwelling unit measurement	Floor area measurement
Total urban land area	"Population density" (Statistics Canada 2005) "Total density" (Hall et all 1973) "Metropolitan density; Gross neighbourhood density "Gross census tract density" (Forsyth 2003) "Gross municipal area density" (Hitchcock 1994)**	"Metropolitan density; Gross neighbourhood density; Gross census tract density" (Forsyth 2003) "Gross municipal area density" (Hitchcock 1994)**	
Developed urban land	"Overall residential density" (Hall et al.1973) "City density" (Forsyth 2003)	"City density" (Forsyth 2003)	
Residential land (includes local non-residential land uses such as schools, parks etc.)	"Gross residential density" (Hall et al.1973) "Net neighbourhood density" (Forsyth 2003) "Gross residential area density" (Hitchcock 1994)**	"Net neighbourhood density" (Forsyth 2003) "Gross residential area density" (Hitchcock 1994)**	
Residential land (excluding local non-residential land uses, including streets)	"Net residential density" (Hall et al.1973) "Net residential density at city or metropolitan level; Net neighbourhood residential population density" (Forsyth 2003)*	"Net residential density at city or metropolitan level; Net neighbourhood residential dwelling density" (Forsyth 2003)*	

Land area	Population measurement	Rooms/dwelling unit measurement	Floor area measurement
Parcel area plus half of public street right-of-ways		"Street density" (Hitchcock 1994)**	
Block area / part block area (measured to the curb)	"Block density / part block density" (Forsyth 2003)	"Block density" / "part block density" (Forsyth 2003)	"Building block coverage" (ground floor footprint only) (Forsyth 2003) "Impervious surface block coverage [ground floor footprint plus all paved areas]" (Forsyth 2003)
Residential lot area/ parcel area	"Parcel density" (Forsyth 2003; Hall et al. 1973)	"Parcel density" (Forsyth 2003) "Parcel density – units per hectare" (Hitchcock 1994)**	"Floor area ratio" (all floors) (Forsyth 2003) "Building site coverage" (ground floor footprint only) (Forsyth 2003) "Impervious surface parcel coverage" (ground floor footprint plus all paved areas) (Forsyth 2003) "Parcel density – floor space index" (Hitchcock 1994)**
Floor Area	(Hall et al.1973)		

*Forsyth's "Net neighbourhood residential building type density" is calculated in a similar manner, although only residents living in a particular type of dwelling are included in the calculation. This measure can be calculated with either population or dwelling units as a numerator. Forsyth also lists building intensity measures, including building height, front setbacks, side-to-side distance between buildings, and back-to-back distance between buildings (2003).

**Hitchcock (1994) also lists alternative terms for the density measures he describes, as follows:

- Parcel density – net-net density, net site density, net density, lot density
- Street density – net density
- Gross residential area density – gross site density, residential density, residential area density, gross density, gross living area density, neighbourhood density
- Gross municipal area density – population density, community density

In addition to the above definitions, measures that use "people-plus-jobs" as a numerator can be used to assess both residential and employment land use intensity. For example, Carruthers (2002) has used "urban density" in a study assessing the effectiveness of state growth management measures in the United States, defined as the number of jobs plus people per acre of developed land.

Each of the above ratio calculations reveals a different aspect of urban density, so they are used in different situations. For example, a ratio expressing density as a function of rooms per acre may be used in residential development (Cowan 2005). A ratio of floor space to land area can be used to "define the nature of development appropriate over an area of many lots, or to control the intensity of development permitted on any given private parcel of land" (Hitchcock 1994; 4), and can therefore be useful in drawing up municipal official plans. Gross densities, on the other hand, give a bigger picture of land use as they express the amount of space a population consumes for all residential and non-residential uses (Hitchcock 1994).

Blais (2003) notes that it is important to measure and monitor both net and gross densities in order to capture the amount of development land taken up by non-residential land uses such as public infrastructure, employment lands, and protected greenspaces. Increasing net residential density alone may not lead to increased gross densities.

1.3 Difficulties in Calculating Density

A number of problems arise in calculating densities. One of the most readily apparent lies with the variety of available definitions and measurements. As there are so many ways to calculate densities using so many different units of measurement, consistency and comparability across studies can be difficult. For example, in 1995, Lehman and Associates found no consistency in the measurement of density among municipalities in the Greater Toronto Area (Churchman 1999).

Another barrier to comparing densities lies in the variation within variables. Dwelling size and household size vary from one country to another, one city to another, one neighbourhood to another, and one housing type to another (Churchman 1999; Forsyth 2003; Laplante 2005; Alexander 1993). Essentially, density is an average, and as happens with averages, local variations in density become less apparent as the area across which the average is taken becomes larger (Hitchcock 1994). To address one aspect of this difficulty, Alterman and Churchman have suggested calculating densities for each building type in an area to make explicit the variations within a site (1998, cited in Churchman 1999). Other authors have attempted to catalogue dwelling density within different housing types to make comparison easier (Alexander 1993; Fader 2000; Wentling 1988).

The scale of density measurement is another challenge to measuring density. For example, calculations of parcel density, block density, neighbourhood density, and gross density for the same area will each produce distinct results. Generally speaking, the more land is removed from the denominator (in other words, the more land that is "netted out"), the higher the density will be (Forsyth 2003). This phenomenon is related to the modifiable areal unit problem (MAUP).

The MAUP accounts for measurement errors that occur due to boundary definition and the aggregation of data. Redefining the boundaries used as the geographic unit of measurement will produce different results, *even though the underlying data is exactly the same* (Openshaw and Taylor 1981). For example, if a boundary is moved so that a large office cluster becomes part of a different census tract, neither the combined employment nor the combined land area of the two tracts will have changed. The measured employment densities of both tracts, on the other hand, will differ: one increases in measured density and the other decreases.

This may not be a problem if boundaries are drawn to capture particular phenomena of interest, but in practice it is difficult to identify meaningful units of analysis that are not simply random aggregations of space (Openshaw and Taylor 1981). Even more problematic, boundaries are often drawn in ways that systematically obscure a phenomenon of interest. If an analyst is using census tracts to identify high-density areas, for example, the way boundaries are drawn may defeat this purpose, because census boundaries are often drawn along major roads, but higher-density urban uses often cluster around major intersections. As a result, high-density clusters are often separated into several adjoining census tracts that also contain much lower-density uses. Such clusters may not show up in a density analysis, because they have been divided among several census tracts and averaged out.

Appendix A contains a list of papers on the mathematical modelling of density.

1.4 The Limitations of Using Canadian Census Data for Density Measurements

Detailed data on existing population density, recent trends in population density, and the extent of built-up areas are needed to measure trends in the density of urban development. Although a population census is undertaken every five years by Statistics Canada, Canadian data on population is surprisingly weak.

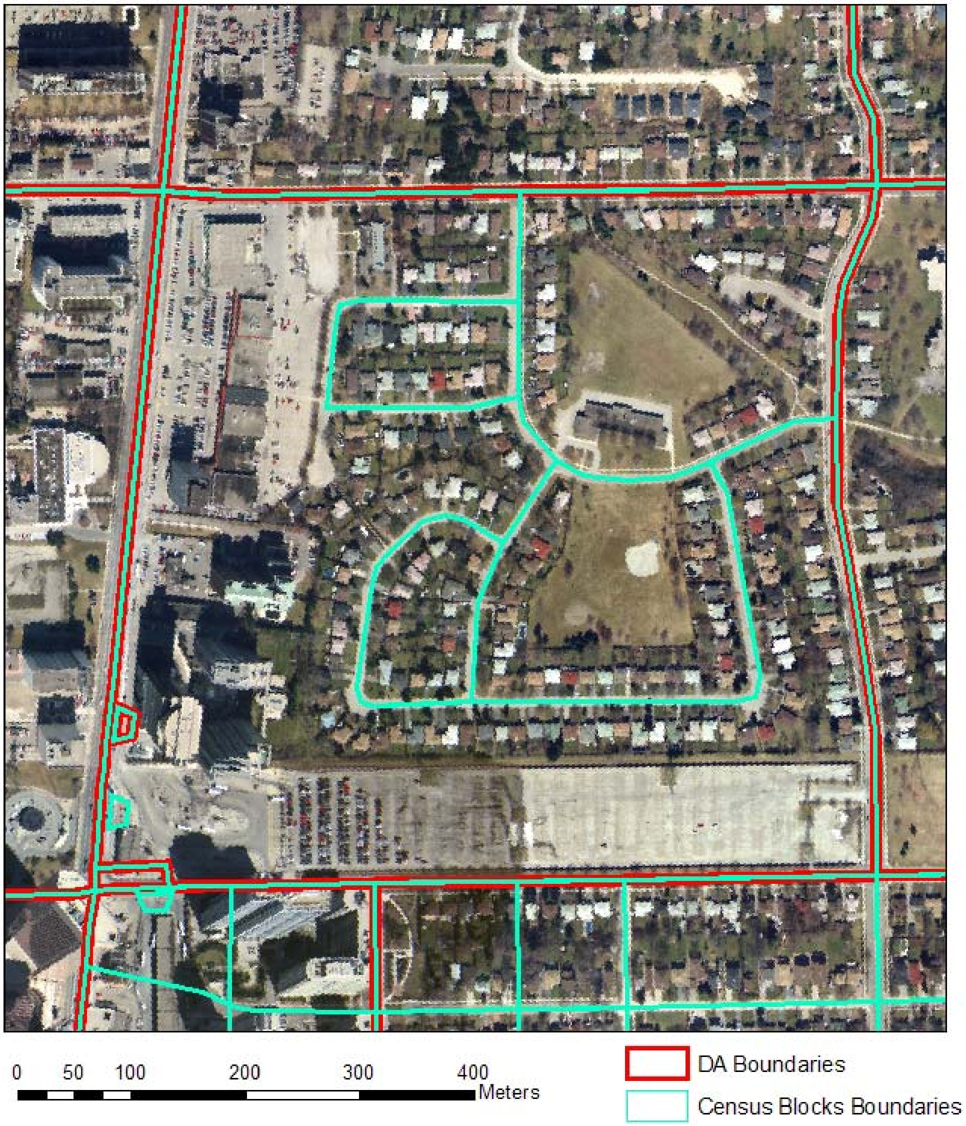
Before the 2001 census, the main, fairly stable unit of data collection was the Census Tract (CT). Areas smaller than CTs were called enumeration areas (EAs), and were defined as the area that could be managed by one enumerator. The boundaries of EAs changed from census to census, so EAs are useless for measuring changes in population density over time. To solve that problem, in 2001 EAs were replaced by Dissemination Areas (DAs) whose boundaries are intended to be consistent in future censuses. That means that in future researchers will be able to measure population change at the DA scale, which is an important gain.

Even at the level of DAs, however, serious boundary problems limit the usefulness of DAs for measuring urban population density, as illustrated in **Figure 1.1**.

The figure shows a satellite photograph of a group of DAs in North York bounded by Cummer Avenue to the north, Willowdale Avenue to the east, Bishop Avenue to the south, and Yonge Street to the west. Within this area there are three very different kinds of urban land use: (a) the strip along Yonge Street, which includes high-rise condominium blocks and low-rise commercial with extensive surface parking; (b) the large area of low-density single-family homes and public parks; and (c) the long parking lot along Bishop Avenue under the hydroelectric transmission lines.

This area is divided into three DAs, as shown with red lines: one large one for most of the area, and two small ones, apparently corresponding to the high-rise condominiums. The area is also divided into eight Census Blocks, shown in green. The two DAs associated with the high-rises are symbolically shown as trapezoids. The small DA and block fronting on Yonge Street has a population in 2001 of 379, and a notional area of 357m^2, indicating a population density of 10,608 people/ha, while the DA and block at the corner of Yonge and Bishop has a population of 503 and an area of 1,210 m^2 for a population density of 4,155 people/ha. A careful look at the satellite image shows that the geographic location and size of these two small DAs is not accurate. That will mean that the recorded population density of the larger DA that occupies most of the area bounded by Yonge, Cummer, Willowdale, and Bishop will also be inaccurate.

Figure 1.1: North York DAs and Census Blocks east of Yonge Street



In 2001 the population of this DA was recorded as 977, with a population density of 25.57 people/ha. As the two small DAs in the southwest corner are smaller than the actual building sites of the condominiums, the area recorded for the larger DA is larger than its actual area. The only way to get an accurate population density for the area would be to aggregate the three DAs. As this is impractical for analysis of any significant area, it seems fair to conclude that the current Block and DA geography is not appropriate for measuring population density, and we are left with Census Tracts, which almost always contain large variations of population density and built form.

For census data to be useful in measuring changes of population density in a detailed way, the DAs and Blocks would have to be drawn accurately to reflect the actual parcels on which these high-rise buildings were built. It would also make sense for DAs and Blocks to follow major patterns of land use and built form, so that the strip along Yonge Street would be separate from the single-family homes area and from the hydro right-of-way parking lot along Bishop Avenue. As DAs are supposed to remain stable, and have already been drawn for existing areas, this approach will not be possible for areas in which DAs have already been defined, but it would clearly be an advance for newly developing areas. It may also be possible to change Blocks to fit more tightly to major urban form types. This would allow both a more precise understanding of where changes are occurring, as well as the identification of areas and capacities for future intensification.

A second major problem with census data is that to measure change before 2001, only Census Tracts (CTs) are available, but CTs themselves have changed enormously in the urban fringe areas where the greatest changes are occurring. Within existing built-up areas, CT boundaries are kept relatively constant, although they may occasionally be divided to reflect major increases in population. On the urban fringe, however, they tend to be very large in order to include a target population of 2,500 to 8,000. As urban fringe areas are built up, CTs are divided into smaller areas. That means that while changes in population can be calculated for the larger areas of the pre-division CT by aggregating later, smaller CTs, no data is available for those smaller areas at earlier periods. As a result, the level of detail available for analysis of the urban fringe areas where change is occurring rapidly is limited. For example, a typical CT in York Region north of Markham is 20 km^2, whereas in recently built-up areas of Markham the typical area is 1.71 km^2.

Limiting the number of CTs outside the built-up area is a practical approach to data management, as for each CT there are hundreds of data points for all the variables that the census monitors. In the days before computers, creating too many CTs in rural areas with low population densities would have been a waste of resources. It does seem reasonable now, however, to define urban-sized CTs that will retain permanent boundaries for at least all Designated Urban Areas within the GGH, and perhaps the whole area inside the Greenbelt as well. The Ontario government should request that these new CTs be defined in advance of the next census in 2011, so that a stable census geography can be established to allow monitoring of change in the region in future. DAs and Blocks can be demarcated only after urbanization, but a new policy should be established to ensure that DAs and Blocks follow major types of urban form.

Although these difficulties in calculating density can be discouraging, researchers need to persist in collecting information about urban population density patterns and changes to them over time. Examining methods used in other regions to measure and monitor densities can also provide suggestions for alternative ways of calculating density. However, there are limitations in conducting this type of survey. While many authorities publish their urban intensification policies, few publish the means (and even fewer, the results) of their density monitoring. As a result, this information often cannot be translated into meaningful comparisons between different administrative units. Appendix B includes an overview of some of the more readily available density measurements used in other parts of the world, and a chart detailing a variety of growth management policies, including their definitions of density. Appendix C contains a bibliography of papers evaluating growth management policies.

1.5 Measuring Density in the Greater Golden Horseshoe

Density has occasionally been assessed in areas of the Greater Golden Horseshoe over the past 35 years. These accounts provide insight into changes in densities over time, and a series of snapshots of urban development in the area. The following literature relies largely on models of density gradients based on census data. Not all reports cover the entire Greater Golden Horseshoe; rather, they focus on the most urbanized areas, and most look exclusively at Toronto.

Latham and Yeates (1970) observed that commercial activities at the centre of the city could reduce residential densities in the Central Business District. They proposed a model (the "second degree negative exponential model") to describe this phenomenon, and used Metropolitan Toronto as a case study. The authors found that their model described Toronto's densities better than the traditional first degree negative exponential model.

In 1981, Griffith tested the theory of polycentricity on the Toronto area using a multinodal model based on 1971 census data. He found that only the Central Business District accounted for increased residential densities; no other centres did. The author speculated that this phenomenon would change over time as Toronto grew.

Edmonston et al. (1985) also used 1971 census data to examine density gradients, but his results were more generalized. He compared all CMAs in Canada and the United States, and observed that Canadian cities were more compact than American cities.

Churchman (1999) discusses the concept of "gross reurbanization density" as proposed by Berridge Lewinberg Greenberg Ltd. in their 1991 *Reurbanisation Plan for Metropolitan Toronto*. This measure of density assesses the number of residents and employed people/ha, as opposed to residents only. According to Churchman, the use of this measure encourages mixed land uses and not just residential intensification. The *Reurbanisation Plan* set density goals for different city centres:

- low-density centres should have 125-175 residents plus workers per hectare;
- medium-density centres should have 250-350 residents plus workers per hectare;
- high-density centres should have 400-500 residents plus workers per hectare.

Bunting et al. (2002) compared density gradients from 1971 and 1996 census data for the 15 CMAs in Canada with more than 250,000 people. The authors reported a number of results relevant to the Greater Golden Horseshoe:

- Toronto had the highest overall density of all Canadian CMAs in 1996 with 3,322 people/km^2; the rate for Hamilton was 2,355 people/km^2, Kitchener 1,791 people/km^2, and St. Catharines–Niagara had the lowest density of all CMAs, with 1,176 people/km^2.
- Toronto's population density had decreased 4.6 percent from 1971 to 1996, while Hamilton's decreased by 5.1 percent, Kitchener's increased 6.1 percent, and St. Catharines-Niagara's increased 4.8 percent.
- All these CMAs had major increases in urbanized land area over the period: Toronto's increased by 55.8 percent, Hamilton's by 32.3 percent, Kitchener's by 64.4 percent, and St. Catharines-Niagara's by 28.7 percent.

- Toronto had the highest core area density of the CMAs, with 8,738 people/km^2; Hamilton ranked third (after Vancouver) with a core density of 6,479 people/km^2, and St. Catharines-Niagara had the lowest density of 2,221 people/km^2.
- Toronto had the greatest increase in central area density over the observation period; this change was attributed to in-fill housing and high rates of central employment growth.
- All the Greater Golden Horseshoe municipalities had increases in suburban density from 1971 to 1996: Toronto's suburban density grew by 9.4 percent, Hamilton by 4.6 percent, Kitchener by 15.7 percent, and St. Catharines-Niagara by 17.2 percent.
- With respect to suburban population dispersal, Toronto was found to have the highest Canadian density, and St. Catharines-Niagara still had the lowest density of all of the observed CMAs. The authors conclude that Toronto's high suburban densities are related to planning controls that were enacted to encourage varied types of housing built in the suburban areas, in addition to increased densities due to high land costs.

Filion et al. (2004) modelled density gradients for twelve U.S. urban areas and three Canadian ones (Montreal, Vancouver, and Toronto). The authors used 1991 data from the Canadian census, and 1990 census data from the United States. They found that Canadian cities generally had high inner-city densities and higher inner suburban densities. Toronto also had the highest outer suburban densities of all of the observed cities. However, Canadian cities had larger gaps in density between their inner and outer suburbs. The authors speculate that this disparity in densities occurs because of poor transit services in the middle suburban areas, and the nature of the outer suburbs as self-sufficient centres in their own right.

Blais (2000) studied development densities of new suburban development as part of the Neptis Foundation's "Portrait of the Region" studies, and found that new developments were occurring at steadily higher unit densities.

Gordon and Vipond (2005) studied New Urbanist areas in Markham to assess the impact of this new – and purportedly more compact – form of urban development on residential density rates. The authors created ratios of dwelling units and population density, as reported in the 1996 and 2001 censuses, relative to developable land areas, as measured by planimeter. They found that the New Urbanist areas had mean gross residential densities that were about 76 percent higher than the mean densities of conventional suburban areas.

Clearly, researchers still have more work to do in measuring and monitoring patterns and densities of development in the GGH.