QUESTIONING DENSITY: AN APPRAISAL OF THE THEORETICAL AND EMPIRICAL BASIS FOR SMART GROWTH IN THE TORONTO CENSUS METROPOLITAN AREA

by

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A Major Research Paper

Presented to Ryerson University

in partial fulfillment of the requirements for the degree of

Master of Planning
in
Urban Development

Toronto, Ontario, Canada, 2011

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ABSTRACT

Smart Growth-densification is an essential element of the local planning ethic. However, little research has been undertaken on impacts of densification in the Toronto Census Metropolitan Area (CMA). Accordingly, the first component of this MRP presents a critique of Smart Growth theory that is divided into two strands. The first strand identifies four methodological limitations in the foundational density research upon which Smart Growth theory is based. The second strand concludes that much of reviewed density research has been over-interpreted and appropriated to serve the Smart Growth rationale. To appraise the empirical basis for Smart Growth in the Toronto CMA, four hypotheses are tested using a cross-sectional and quasi-longitudinal design. Although 2006 census tract (CT) density and CT densification (1986-2006) demonstrated a relationship to sustainable outcomes, the nature of these relationships did not conform to predictions of Smart Growth theory. The study also indicated that the relationship between density and outcomes was largely non-linear and partially attenuated by household-level factors. When all sections of this MRP are taken into account, the basis for Smart Growth-densification, according to its present definition, appears increasingly tenuous.

Key Words: Smart Growth, Density, Densification, Toronto Census Metropolitan Area, Sustainability

Acknowledgements

I would like to thank my MRP advisor, Dr. Murtaza Haider. I am also grateful to Dr. Steven Webber for his feedback and support.

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1. Introduction

The recent emphasis on sustainability has brought about profound shifts in planning discourse and practice. In the last three decades, neo-traditional planning paradigms such as Smart Growth have gained prominence in planning discourse. Although Smart Growth encourages a suite of urban reforms and target objectives, proponents of Smart Growth contend that densification (elsewhere, *intensification, compaction, concentration* or *urbanization*), more than any element of urban design, remains the principal driver of wide-ranging, positive and durable urban change (Transportation Policy Institute, 2010a; Smart Growth Network 2009). Smart Growth finds its theoretical and empirical roots in a substantial and widely cited corpus of density research published during the 1980s and 1990s. Accordingly, the primary concern of the present discussion is Smart Growth to the extent that it is a platform for densification policy. A more complete appraisal would consider the theoretical and empirical basis for all Smart Growth pillars such as income integration and tenure mixing policies.

Today, densification constitutes normative practice and is an essential element of the prevailing land use ethic. Features of Smart Growth are evident in planning policy in the Toronto Census Metropolitan Area (CMA) and across North America. However, there is a decided lack of experimental evidence that corroborates Smart Growth theory in the local planning context. Therefore, the chief objective of this MRP is to query the theoretical and empirical basis for Smart Growth-densification in the Toronto CMA. This paper is divided into several components to serve this objective. The first section establishes an operational definition of *density*. The second section surveys the foundational literature on density to identify the scope of positive planning outcomes purported to be associated with density. In so doing, the theoretical and empirical foundations for Smart Growth policies become evident. The third component of this paper critically re-evaluates density research as well as its interpretation and application to Smart Growth theory. The fourth component of the paper reviews Smart Growth policy in the Toronto CMA and across North America. This section illustrates the degree to which planning policy rests on densification as the principle driver of durable urban change. The fifth section presents the results of a cross-sectional and quasi-longitudinal empirical study of density in the Toronto CMA (Map 1). This empirical component is designed to test four relevant hypotheses that emerge in the theoretical and empirical discourse on density. Taking all earlier components into account, the paper will conclude by questioning whether densification is the key determinant of durable change or simply aspect of some pervasive planning orthodoxy.

2. What is Density?

Density is an amorphous, often problematic, term in planning research. First and foremost, there is no accepted measure of density between and within urban environments (for example the Greater Toronto Area)(as cited in Churchman, 1999). Planning literature and policy reveal several different measures of density. For example, people per given land area (that is, population density) or number of dwelling units per given land area (that is, residential density). Some planning research and policy references a composite index of density that accounts for people *and* jobs per given land area. Although it is common to distinguish between *net* and *gross* density, the definition of *net* and *gross* density also vary across jurisdictions (Churchman, 1999). As such, researchers are required to adopt the definitions used by jurisdictions under study or those made available in census or geographical survey data. The empirical component of this MRP uses census data and therefore adopts Statistics Canada's definition of density. Density is computed by dividing number of Census Tract (CT) residents (not residences) by net CT land area measure in square kilometers (with hydrological features omitted).

Adding to the difficulty of comparative density analysis, researchers have tended to refer to density in relative terms, such as *high* or *low*, without offering any absolute measure. The terms *high-* and *low*-density hold different meanings in different planning contexts. This MRP will resist the use of terms such as high-density and low-density except where making specific reference to computed relative density groupings (in density change tertiles, see section 6).

There is also the essential question of *perceived* vs. *real* density. According to Churchman (1999) perceived density is defined as, "an individual's perception and estimate of the number of people present in a given area, the space available, and the organization of that space" (pp. 390). Perceived density is inherently subjective and offers no evaluative component (Churchman, 1999). Nevertheless, perceived density may factor heavily in the success or failure of policy. The current empirical research is limited to measures of *real* density.

3. Density in Planning Literature: The Foundations of Smart Growth

Facing profound urban challenges, the contemporary planner is compelled to reconsider the intersection of land use policy, urban liveability and the environment. During the 1980s and 1990s, particular consideration was paid to the potential effects of urban density on sustainable outcomes. The purported relationship of density and outcomes arising in this research served as the theoretical and empirical substrate of Smart Growth logic. According to one of the progenitors of neo-traditional planning, Andres Duany, Smart Growth is largely defined according to its objective outcomes; neighborhood-level livability, ease of travel, quality places, increased social equity, lower costs, and retention of open space (*The Smart Growth Manual,* Duany et al., 2010). However, as densification is the operative design element in each of these critical outcomes it appears that Smart Growth is defined by its promotion of densification. This section of the MRP surveys the foundational theoretical and empirical research from 1980s and 1990s to create a composite list of specific outcomes that researchers have linked to density. Purported outcomes are broadly classified as transportation-related, social, and economic outcomes (Table 1).

a. Density and transportation-related outcomes

Some of today's profound urban transportation-related challenges such as congestion and air pollution have prompted researchers to reconsider the link between land use and travel behavior (Ewing and Cervero, 2001; Melia et al., 2011). Seminal density studies by Newman and Kenworthy (1989a, 1989b), Spillar and Rutherford (1990), Newman (1992), Holtzclaw (1994), Frank and Pivo, (1994), Cervero and Gorham (1995), Cervero and Kockelman (1997) and Greenwald and Boarnet (2001) have found that density exerts a strong cross-sectional influence on outcomes such as decreased energy consumption for transportation, decreased auto-dependency, increased transit use and alternative mode shares.

Newman and Kenworthy's (1989a) study of 32 metropolitan areas on four continents found a strong correlation between overall per-capita petroleum consumption and urban density (per-capita petroleum consumption is a proxy measure for vehicle kilometres travelled (VKT) and auto-dependence). Newman and Kenworthy (1989a) concluded that non-environmental variables such as fuel price account for just 40 percent of the variation in energy consumption across the 32 study areas. The remaining 60 percent of the variation was attributed to density. In Newman and Kenworthy's (1989b) study, auto-trip generation was found to increase exponentially below a density threshold of 30 residents per hectare (Newman, 1992). In addition, these researchers provide evidence of a relationship between density and modal splits (1989b). Once again, Newman (1992) found that transit mode share diminished significantly in geographies where residential density dropped below a threshold of 30 residents per hectare.

Numerous empirical studies echo Newman and Kenworthy's essential findings. The association between urban density and transit use, for example, has been replicated in various temporal and geographic contexts. Taylor et al. (2009) found that a range of environmental factors, in particular density, explained the majority of variation in transit ridership across 265 US urbanized areas included in a cross-sectional study ($r^2 = 87.5$). Spillar and Rutherford (1990) found that transit ridership increased with density across five western US metropolitan areas. Studies by Cervero and Gorham (1995) and Greenwald and Boarnet (2001) found a positive association between density and alternative modes (cycling and walking). Citing this body of research, proponents of Smart Growth contend that densification is an essential process in achieving three transportation-related outcomes: (1) reduce the number of motorized trips (2) shift modal splits toward transit and alternative modes (3) reduce travel distances and encourage increase vehicle occupancy levels for motorized trips, and in general, reduce congestion (Berridge Lewinberg and Greenberg Ltd., 1991a, 1991b; Ontario Smart Growth, 2003; Southern California Associations of Governments, 2003; Urban Land Institute, 2005; Smart Growth Network, 2009; Victoria Transportation Policy Institute, 2010a).

b. Density and social outcomes

Social objectives are a cornerstone of Smart Growth theory. In *The Death and Life of Great American Cities* (1961), popular urban theorist Jane Jacobs articulates her vision of the functional and vital city. The operative element in Jacobs' vision is density. Today, Jacob's commentaries are offered as self-evident in contemporary planning and constitute compulsory reading for proponents of Smart Growth. Since first published in 1961, many studies cite Jacobs' essential observations (Calthorpe, 1989; Katz et al., 1994); others have set out to corroborate her assertions with empirical study (Brown and Cropper, 2001; Duany, 2001; Talen, 2006).

A survey of the empirical landscape reveals a range of effects of density on social and behavioral outcomes. According to Duany (2001), an increase in density is associated with an increase in social cohesion, face-to-face interaction and other markers of 'neighbourliness'. Katz et al. (1994) found more social activity in higher relative density neighbourhoods than in the conventional suburban areas in their study.

Other researchers have found an association between transportation mode choice and measures of community cohesion. For example, Leyden (2003) found that neighbourhood walkability was a predictor of social interaction as well as "knowing one's neighbors". Similarly, Glynn (1981) found that auto dependency was inversely correlated with a "sense of community" (pp. 2120). Given that density is strongly related to walkability in a wide range of literature, walking in Leyden (2003) and Glynn (1981) is a proxy measure for density.

More than just *sociability* and *social cohesion*, some researchers have found an association between density and *social equity*. Studies by Collie (1990) and Fyfe (1994) found a positive association between density and an individual's ability to access essential services, facilities and employment (as cited in Burton, 2000). In these studies, *access* is measured by proximity. Density, the argument continues, promotes social equity as individuals from lower income strata (i.e. those that typically exhibit lower car ownership rates) incur a disproportionate sum of the accessibility burden in low-density environments (as cited in Burton 2000).

In a study of Chicago and Cook County, Illinois, Talen (2006) also found that change in density predicted a change in social diversity (that is, household type diversity such as family vs. single or no child household, as well as ethnic diversity). These studies comprise a large part of the social rationale of Smart Growth and are widely referenced in Smart Growth literature (for example Katz, 1994; Kalinosky, 2001; Duany et al., 2010)

c. Density and economic outcomes

According to the Victoria Transport Policy Institute (1998; 2010a) and the Smart Growth Network (2009), the affordable housing needs of a community are best met with a mandate of densification. The argument in favour of densification is simple; greater residential density means that more housing is made available on a given parcel of land - decreasing the land value component in final housing price (Danielsen et al., 1999). Furthermore, Carruthers (2002) argues that densification, when complimented with policies mandating housing stock diversity (as is typical in Smart Growth), increases the likelihood that demand in the affordable housing submarket is met (Knapp, 1985).

Density and positive economic outcomes have also been correlated at the jurisdictional level as well as at the household level. Employing basic economic principles, studies have identified that infrastructural economies of scale as well as other agglomeration externalities are realized in jurisdictions characterized by higher than average densities (see Newman, 1992; Graham, 2007). Newman (1992) found that infrastructure and service costs demonstrate an inverse association with density. The Victoria Transportation Policy Institute (2008) and Hemson Consulting (2003) also concluded that the marginal cost of infrastructure provision is significantly reduced where high residential and commercial densities exist. Other research has shown that the provision of soft services in dense areas benefits from economies of scale. These studies conclude that there are likely to be more private sector services and facilities in dense urban environments, as a minimum density threshold must be met to ensure economic viability (Bunker, 1985; Rees, 1988; Collie, 1990; Bromley and Thomas, 1993; as cited in Burton, 2000).

4. Density Research and Smart Growth Theory: A Critical Second Look

Neuman (2005) captures the growing uncertainty amongst planning researchers about the findings of research into the effects of densification. He questions, "How effective are [densification policies] in attaining a deep-seated shift in community building toward truly sustainable communities?" (pp. 11). This section is not intended to condemn density research *per se;* rather it aims to critically reconsider whether the foundational density research reviewed above offers sufficient basis for planning theory and practice. There are several major strands to this critique. The first considers four salient methodological limitations in the reviewed density literature; (1) cross-sectional study design, (2) under-specification bias, (3) failure to control for the presence of a moderating variable, and (4) locational self-selection bias. The second strand critically deconstructs the empirical and theoretical rationale for Smart Growth, in particular its appropriation of foundational density research to serve Smart Growth logic. The final strand reassesses the highly political debate on Smart Growth and its impacts on housing affordability.

a. Methodological limitations

The most significant limitation of density studies such as Newman and Kenworthy, (1989a; 1989b), Spillar and Rutherford (1990), Cervero and Gorham (1995), Frank and Pivo (1995), Handy (1993; 1996) is their cross-sectional design. Elementary statistics dictates that when two variables, for example density and transit use, are correlated it is not possible to ascertain whether density influences transit use, whether transit use influences density or whether both transit use and density are associated because of the presence a third factor that influences both density and transit use. Moreover, any effort to establish even partial causality necessitates longitudinal research whereby change in density (Δ density) is measured against change in a given outcome (ex. Δ housing affordability). Given the general absence of the longitudinal data, one might reasonably argue that existing cross-sectional density studies ought to be taken as merely exploratory and not indicative of causality.

Cross-sectional density studies are highly susceptible to under-specification bias. Any number of individual or global level variables have been hypothesized to interact with key planning outcomes (Taylor et al., 2009). For example, individual socio-economic characteristics, household characteristics, fuel costs, gender, transit system service level could vary with density. Despite the fact that many such variables have been identified, the cross-sectional studies reviewed above have relied on a limited range of potential predictors. For example, beyond density (jobs and residents per acre), Newman and Kenworthy's (1989a) accounted for just two potential confounders, *average to-work trip length* and *proportion of population in inner city*. The resultant under-specification of research models can obscure the most powerful predictors of a given outcome and generate inconsistent findings. For example, more recent cross-sectional studies such as Hall (2001) and Handy (2005) find that a diverse range of factors demonstrates a stronger relationship with auto-trip generation and mode choice than does density as an isolated factor.

The studies reviewed in section 3 have generally failed to consider the *interaction* (often referred to as *vulnerability*) between aggregate density data (typically census tract or metropolitan area) and individual demographic characteristics. Studies such as Newman and Kenworthy, 1989a; 1989b, Cervero, 1989, Cervero and Gorham, 1995; Kulkarni et al., 1995) have not systematically controlled for socio-demographic variables.

This research has, therefore, done little to consider how the effects of density, predicted or not, could be unequally distributed across socio-demographic clusters (i.e. how they moderate the effects of densification) or how variables such as socio-demographic clusters account for the relationship between predictor and outcome.

Moreover, foundational density studies have failed to consider the role of potential mediators. Mediation refers to the case where the effect of densification has its supposed impact on outcomes because it has an effect on some intervening variable and that it is the mediating variable that impacts positive planning outcomes. If an undetected mediator is playing a significant role in accounting for the effects of densification, one could incorrectly attribute the positive outcome to densification. On the one hand, densification might well have an impact on a mediator and through its effect on the mediator it might have an impact on planning outcomes. On the other hand, there may be many ways to impact the mediator and change outcomes other than through densification. Mediation has not been considered adequately in cross-sectional density research. For example, Haider (2010) has hypothesized that, in mature urban environment such as Montréal and Toronto, the prevalence of small households (two individuals or less) may at the very least attenuate or exaggerate the isolated effects of density on key planning outcomes. A failure to specify mediators can leave models susceptible to both under-specification and over-generalization.

Another confounding mechanism, entirely unaccounted for in foundational density literature, is self-selection bias. In planning research, self-selection occurs when individuals or households with particular characteristic or characteristics (for example, behavioral predispositions, preferences or socio-economic status) select residential location on the basis of that characteristic. Several studies have sought to address self-selection bias by controlling for behavioral predispositions, personal preferences and socio-economic status. Recent studies of locational self-selection by Handy and Clifton (2001), Cao et al., (2009) and Ewing and Cervero (2010) found that the effect of increasing density is partially explained by locational self-selection. In general, these studies conclude that individual-level factors and preferences may be more important than built form (Schimek, 1996; Handy and Clifton, 2001; Schwanen and Mokhtarian, 2005; Ewing and Cervero, 2010). These studies cause doubt about the magnitude of benefits associated with density as self-selection may reduce the effect of a policy targeting sustainable outcomes with a program of densification. Self-selection cannot be controlled in observational studies such as those reviewed above. Nevertheless, self-selection must be considered if we are to develop a complete understanding of densification and its impact on key planning outcomes.

b. Deconstructing Smart Growth theory

Despite the various empirical limitations in density research, Smart Growth has become an authoritative paradigm in planning practice. Smart Growth maintains its authority in planning discourse for several reasons. Firstly, Smart Growth positions higher relative density as an alternative to typical suburban form (Victoria Transport Policy Institute, 2010a; IMCA/Smart Growth Network, 2008; Central Ontario Smart Growth Panel, 2003; Canadian Urban Institute, 2001). In so doing, Smart Growth makes deliberate appeal to the contemporary planner's dissatisfaction with rising congestion, infrastructure costs and environmental degradation – each commonly construed as symptomatic of urban sprawl. Secondly, it provides a compelling theoretical and empirical rationale to the planning profession. By declaring theories in which densification can cause sustainable planning outcomes, Smart Growth dictates policy and action. Thirdly, the purported explanatory power of Smart Growth theory generates it own axioms. These axioms appear to absolve Smart Growth planners of research that consider the range of key determinants of urban sustainability. The result is an overgeneralization of existing evidence and an appropriation of density research to serve Smart Growth logic.

As referenced, even simple statistics dictates that cross-sectional analyses are incapable of establishing causality. Yet, the most basic rationale for densification takes its empirical roots in cross-sectional research. Proponents of Smart Growth broadly interpret correlational results as indicative of the positive effects of densification. In reality, one may only ascertain the correlates of *density* from cross-sectional study, but not establish a causal relationship between *densification* and target planning outcomes. Despite the prominence of Smart Growth in contemporary practice and policy, very little is known about the longitudinal effects of densification. At the same time, proponents of Smart Growth density doctrine over-generalize conclusions about the local effects of densification based on empirical evidence from disparate temporal and jurisdictional contexts. Even in those study areas where density has been shown to correlate with favourable planning outcomes, little is known of the specific relationship between the two variables. Like modernist planners before them, advocates of Smart Growth believe that human behaviour is conditioned by environmental factors. Proponents of Smart Growth have, once again, failed to recognize that the effects of density or densification are tempered by a distinct, often indefinable, set of behavioral, socio-demographic and political circumstances. As such, the local effects of density are not generalizable to all planning contexts

The Smart Growth movement has paid little attention to the limits of densification. Even if the relationship between positive planning outcomes and densification were established, it would be quite another matter to conclude that the shape of this relationship is linear. If density has a linear relationship with outcome, it would support the general view of Smart Growth theory that all environments demonstrate a similar treatment response to densification regardless of existing density levels. In other words, densification would generate the same outcomes if applied to an environment with 6000 people per square kilometre or to an environment with 1000 people per square kilometre. Conversely, densification could have a non-linear relationship with outcomes whereby densification has less of or a different effect at various levels of initial density (threshold of diminishing returns to density). For example, densification could have a positive impact on urban environments, but only within a specific range.

A growing body of research suggests non-linearity in the density-planning outcomes relationship (see for example Giffford, 1997; Churchman, 1999; Neuman, 2005; Graham, 2007). These studies identify two mechanisms by which diminishing returns to density may be realized in the urban environment (1) *the transportation paradox of densification* (elsewhere, the *paradox of intensification*) and (2) *town crowding.*

As mentioned, studies find a cross-sectional relationship between density and lower relative auto-dependency rates at the individual and national level. However, when jurisdictions attempt to achieve a reduction in auto-dependency through increasing density, a different pattern emerges. As environments densify there is a corresponding concentration in the spatial distribution of vehicular trip origins and trip destinations. In this context, existing road users compete for a decreasing share of total roadway kilometers. Competition gives rise to yet more congestion. Herein lays the *paradox of densification*. Graham (2007) and Melia et al. (2011) demonstrate that while aggregate auto-dependency decreases with increased density, this does not imply and reduction in congestion due to the elasticity vehicle use with respect to density (Melia et al., 2011). Mindali et al., (2003) attributed this elasticity to the failure of major transit infrastructure to offer a viable alternative to the private automobile even in the context of densification.

Furthermore, basic urban economic theory holds that positive agglomeration externalities and congestion tend to coincide in space (Graham, 2007; Melia et al., 2011). Agglomeration externalities are dependent on the concentration (that is, density) of firms. As demonstrated above, congestion is a consequence of concentration. To test this essential hypothesis, Graham (2007) studied the extent to which agglomeration externalities are constrained by congestion in a range of UK industrial sectors. Like Mindali et al. (2003), Graham observed distinct nonlinearities in the productivity-density relationship. The shape of this relationship indicated that, for many UK business sectors, congestion gives rise to diminishing returns to densification.

Crowding is yet another outcome posited to constrain the outcomes of densification (see Churchman, 1999; Gifford, 1997). Churchman (1999) defines crowding as, "the subjective state of psychological stress that accompanies density that is evaluated" (pp. 390). Churchman cites a number of studies that have found that the experience of crowding demonstrates a relationship to relative urban density. While research into the effects of crowding has yet to produce generalizable findings, these studies suggest that psychosocial outcomes may be another mechanism by which diminishing returns of densification arise. Should non-linearity be confirmed in future study, the empirical basis for Smart Growth would appear to be increasingly inadequate.

Adding to this critique, Burton (2000) reports that social benefits are still ascribed to density with, "little or no verification" (pp.1970). The purported relationship between indicators of social cohesion and density has been subject to inconsistent and largely inconclusive evidence (Nasar & Julian, 1995; Brown and Cropper, 2001; Churchman, 1999; Burton, 2000, Bunker et al., 2005). Recent empirical studies on density and densification indicate that there may not even be a cross-sectional relationship between density and purported social outcomes (for example Smyth, 1996; Williams, 1999; Churchman, 1999; Burton 2000). For example, Williams (1999) surveyed 7600 residents of areas in the UK that have recently undergone densification. She found that these communities are yet to witness any of the positive social outcomes purported to be linked to densification such as increased *neighbourliness* or some indicator of social cohesion. Studies such as Smyth (1996) suggest that density may, in reality, prevent some of the purported correlates planning outcomes (as Cited in Burton 2000). For example, Burton (2000) found that social equity (as measured by 44 social equity indicators) was negatively affected by densification. When the entire oeuvre of density research is considered, the empirical evidence for Smart Growth and densification policy appears increasingly narrow.

c. Revisiting the Smart Growth housing debate

Despite this inconsistent and even contradictory body of evidence, the planning profession appears to presuppose the transportation-related and social benefits of higher relative density urban form (see Smart Growth Network, 2009; City of Toronto, 2011). The impact of densification on housing affordability, however, remains subject to a fervent and highly factional debate. Unsurprisingly, much of this debate has centered on Portland, Oregon, home to North America's oldest and most prescriptive Smart Growth mandate. Randall O'Toole, one of the most vocal critics of Smart Growth, contends that Portland's rigid density policies (Urban Growth Boundaries (UGBs) and restrictions on new single-family detached homes) have caused profound shifts in housing affordability across all housing sub-markets. O'Toole (2001) points out that Portland transitioned from one of the United States' most affordable markets for single-family housing in 1989 to one of the least affordable in 1996. In 1989 more than 66 percent of Portland households could afford the median-priced home, while in 2001, that figure had dropped to 30 percent (National Association of Homebuilders, 2010 as cited in Victoria Transportation Policy Institute, 2010b). O'Toole (2001) concludes that whereas densification may intend to encourage the development of affordable housing, these policies have reduced the supply of developable and made home ownership less accessible to the average household.

In response to O'Toole's criticism, proponents of densification and growth management argue that land availability is just one of many factors that impact housing affordability. Moreover, Nelson and Dawkins (2004) argue that market competitiveness, rather than prescriptive land use policy, is the leading factor in housing price. Nelson and Dawkins (2004) contend that the increase in median housing prices in Portland is attributable to an increase in housing market competitiveness, itself a consequence of rising employment rates and average incomes (2004). Nelson and Dawkins (2004) also note that despite regulating the amount of developable land, Portland's growth management strategies have increased housing supply relative to demand (for both owner-occupied and rental accommodation). Furthermore, Todd Litman of the Transportation Policy Institute refutes O'Toole's arguments for being rooted in the "assumption that everybody wants to live in automobile-dependent suburbs" (pp. 64, 2010b). Other supporters of densification note that housing market manipulation is, in fact, an explicit objective of densification policy (Bohl, 2003; Victoria Transportation Policy Institute, 2010a; 2010b).

Regardless of the effects of prescriptive land use policy on housing price, housing-type demand across North America has demonstrated a strong resistance to change. In the Toronto CMA and across North America, households continue to reject high-density due to personal preference as well as the space demands of a typical family (Audirac, 1990; City of Toronto, 2003; Pisarski, 2009). Pisarski (2009) states, "It is clear that most people, excepting a small but often very loud minority, opt for lower density living when income permits" (as cited in Victoria Transportation Policy Institute, pp. 13, 2010b). Several recent housing demand surveys found that 85 to 90 percent of North American consumers indicate a preference for single-family housing (as cited in Victoria Transportation Policy Institute, 2010b). Furthermore, the City of Toronto has estimated that demand for low-density housing already exceeds supply by 70,008 units or 6.6% (2003).

The elasticity in housing demand rates casts doubt on the long-term feasibility of any densification policy intended to decrease the relative proportion of low-density housing in a given jurisdiction. Even if future empirical study substantiates the claims of Smart Growth advocates, one might reasonably question whether Smart Growth planners promote an urban form that North Americans appear willing to endorse. Consider that despite the sharp increases in the median price of a single-family detached home in Portland in 1999, vacancy rates in high-density apartment complexes stood at 7 percent, the highest in the decade, and reached 11 percent for apartments built in the 1990s (O'Toole, 2001). In a market where single-family home prices have nearly doubled, the uptake of high-density units has stagnated or decreased. The demand for single-family detached homes is highly elastic even in a context of Smart Growth. Against this backdrop, it would appear that Portland's growth management policies have made housing more expensive for the typical homebuyer who, for the most part, expresses a preference for lower-density housing typologies. As a result, typical households are required to spend an increasing proportion of their income to satisfy housing needs.

This critique has raised a number of questions about the empirical research that underpins Smart Growth theory. Nevertheless, the impulse for Smart Growth planning endures despite an incomplete, methodologically limited even ambivalent empirical rationale.

5. Smart Growth in Action: Land Use Policy in the Toronto CMA

Even though the effects of densification are not as well established as Smart Growth theory purports, this research has underpinned the emergence of the Smart Growth in mainstream practice across North America. In 1993, Breheny and Rockwood had already noted a near consensus amongst planning professionals about the efficacy of densification. This consensus is evident in many past and present land use policies from Toronto CMA, in particular, the *Reurbanization Plan for Metropolitan Toronto* (1991a, 1991b), and *Official Plan of the Municipality of Metropolitan Toronto* (1994). This section reviews evidence that the Toronto CMA has, in fact, undergone policy-driven densification aimed at redressing those urban concerns that are the typical focus of Smart Growth policies.

Since the early 1990s, the City of Toronto (formerly, the Municipality of Metropolitan Toronto) has undergone policy-driven densification that predates Provincial Smart Growth initiatives and arose as a matter of municipal rather than provincial interest. Smart Growth is evident in the *Reurbanization Plan for Metropolitan Toronto* (1991) consisting of the *Study of the Reurbanisation of Metropolitan Toronto* (1991a) and the *Guidelines for Reurbanisation of Metropolitan Toronto* (1991b) (both prepared for Council by Toronto-based planning consultancy Berridge, Lewinberg and Greenberg Ltd). The study, once again, linked densification to several broad Municipal planning objectives such as, the reduction of automobile dependency, the preservation of the public realm, the promotion housing type diversity and the provision of a range of high density employment areas (Berridge, Lewinberg and Greenberg Ltd., 1991b). The plan recommended that densification take place in four designated urban zones; *Major Metropolitan Centres*, *Centres*, *Corridors* and *Infill Areas*. Three years after its publication, the *Reurbanization Plan for Metropolitan Toronto* took force in the Official Plan of the Municipality of Metropolitan Toronto (1994). Section 2.1 ("Reurbanization") of the Official Plan of the Municipality of Metropolitan Toronto (1994) further enshrined the tenets of Smart Growth in Municipal policy. *Policy 2.1.1.3* dictates that lower-tier "municipal plans and zoning by-laws shall facilitate the concentration of new housing and employment in *Metropolitan Centre* and *Metropolitan Corridors*".

The *Provincial Policy Statement 2005* (PPS 2005) and the *Growth Plan for the Greater Golden Horseshoe* (2006) (GPGGH) continue to dictate densification in the Toronto CMA. The PPS 2005 is the predominant provincial land use policy in Ontario. It expresses the provincial government's broad objectives for *efficient* planning (Ministry of Municipal Affairs and Housing, 2005). The PPS 2005 sets forth Ontario's high-level objectives for urban growth through "*intensification* and *redevelopment*". Policy 1.1.3.3 (under Section 1.1 *Managing and Directing Land Use to Achieve Efficient Development and Land Use Patterns*) stipulates that:

> "Planning authorities shall identify and promote opportunities for ***intensification*** and *redevelopment* where this can be accommodated taking into account existing building stock or areas, including *brownfield sites*, and the availability of suitable existing or planned *infrastructure* and *public service facilities* required to accommodate projected needs" [emphasis added]

Although the PPS 2005 does not reference a specific link between densification and target outcomes (for example, reduced auto-dependency), it represents a clear statement of the Province of Ontario's endorsement of densification policy.

On the other hand, the GPGGH articulates specific land use policies and density targets. All single, upper and lower tier municipal official plans in GGH must conform to and implement the policies in the plan. The plan stipulates that all future population and employment growth must take place within *built boundaries* (2.2.3.5) as delineated by the Ministry of Municipal Affairs and Housing. Built boundary expansion may only occur as part of a five-year official plan review and with ministry approval.

More than just a strategy for managing future growth in the region, the GPGGH aims to redress existent urban problems through a program of densification (Ministry of Public Infrastructure Renewal, 2006). Unlike, the PPS 2005, the GPGGH draws a clear link between densification policy and objectives such as the reduction of auto-dependency, infrastructure costs and a range of positive social and behavioral outcome (i.e. the stated objectives of Smart Growth).

Similarities between GPGGH and the State of Oregon's State Senate Bill 100, clearly demonstrate the Smart Growth authority in GPGGH. In 1973, the State of Oregon, USA adopted State Senate Bill 100, which required all municipalities to adopt UGB. Like Built Boundaries, UGBs prescribed firm geographic limits to urban development. Ostensibly, both Smart Growth Portland and the GPGGH express the principle objective of limiting the consumption of agricultural lands for urban development. However, both mandates go beyond the preservation of farmland. For example, the GPGGH delivers policies that dictate where and at what density urban development must take place. In particular, the plan calls for the majority of future growth to occur by way of densification in designated Urban Growth Centres. Urban Growth Centres must, "serve as high density major employment centres" (Ministry of Public Infrastructure Renewal, 2006). Section 2.2.4 specifies that:

> "Urban Growth Centres will be planned to achieve, by 2031 or earlier, a minimum gross density target

> of 200 residents and jobs combined per hectare for each of the Downtown Brampton, Downtown Burlington, Downtown Hamilton, Downtown Milton, Markham Centre, Mississauga City Centre, Newmarket Centre, Midtown Oakville, Downtown Oshawa, Downtown Pickering, Richmond Hill/Langstaff Gateway, Vaughan Corporate Centre, Downtown Kitchener and Uptown Waterloo urban growth centres."

Similarly, policy 2.2.3.1 mandates that, "By the year 2015 and for each year thereafter, a minimum of 40 percent of all residential development occurring annually within each upper and single-tier municipality will be within the built-up area." Meaning, a minimum of 40 percent of all new development must contribute to the densification of a given municipalities' existing developed area. As such, the GPGGH mandates a specific level of density. The City of Portland expanded the scope of the State's Smart Growth mandate to go beyond the preservation of agricultural land. In Portland, two specific Smart Growth densification policies have been in effect for the past two decades; increasing city-wide densities through the use of UGBs at the urban fringe; and minimum density zoning which requires new development to include multifamily dwellings or multiuse developments. Both mandates aimed to redress urban problems such as congestion, the overconsumption of agricultural and natural resources, and increased water and air pollution (Transportation Policy Institute, 2010a).

This brief comparison to Oregon's Smart Growth mandate and that of GPGGH demonstrates the wide-ranging influence of Smart Growth logic on local policies. While the term *Smart Growth* may be largely absent from this group of policies, this policy review reveals the extent to which the local planner rests on densification to remedy some of the urban environment's most exigent problems. Therefore, the need to gain a more comprehensive understanding of the effects of densification is acute.

6. Empirical Analysis: Density and Densification in the Toronto CMA

The exploratory empirical component of this MRP tests several basic hypotheses about the effects of densification in the Toronto CMA using a cross-sectional design and a quasi-longitudinal study in which CT density change (Toronto CMA from 1986 to 2006, the independent variable) is related to key outcomes from the 2006 census data. In general, this research will determine whether some of the fundamental predictions of Smart Growth theory and practice hold true in the Toronto CMA. This section of the MRP addresses several of the methodological limitations described in the prior critique. Six key variables from 2006 census data have been selected for study because each measures (or measures by proxy) the correlates of density (Table 2, Table 3). Specifically, 2006 CT density will be related to those planning outcomes purported in foundational density research and predicted by Smart Growth theory; Reduced Auto Dependency, Increased Transit Use, Increased Social Diversity, Housing Affordability for Owner-occupier, Rental Housing Affordability and Homeownership Opportunity.

a. Hypotheses and Analyses

Hypothesis 1: *Density is correlated to sustainable planning outcomes in the Toronto CMA.*

In order to test Hypothesis 1, 2006 CT density (residents per square kilometre) was correlated with each of the six key outcomes from 2006 data. In order to test the effect of increasing specification in predictive models of planning outcomes, a predictive model of Driving Modal Split by Density Change was contrasted with a model of Driving Modal Split by Density Change, Percentage of Small Households, and Median Household Income.

Hypothesis 2: *When compared to CTs that show little or no relative change in density between 1986 and 2006, those CTs that show substantial relative increases in density will demonstrate outcomes as predicted by Smart Growth theory.*

In order to test Hypothesis 2, CTs were grouped according to the extent of density change from 1986 to 2006 and mean outcome scores of the nine resulting density change groups were compared using Oneway ANOVA with post hoc tests. This analysis will assess whether difference in means were statistically significant across density change groups and whether those with the highest 2006 CT density demonstrated the predicted increase (or decrease where appropriate) in outcomes. In this quasi-longitudinal portion of the study, Smart Growth predicts that those CTs that have undergone the greatest increase in density would have the same characteristics as CTs that were dense in 1986 and remained dense in 2006.

Hypothesis 3: *The relationship of density and planning outcomes are essentially linear.*

The relationship of each planning outcome and the measures of density were calculated, plotted and inspected for linearity. Linear and quadratic lines of best fit were compared to determine which model yielded the highest *R square* value.

Hypothesis 4: *The effects of densification on key outcomes are mediated by household-level characteristics, in particular the CT prevalence of small households (1 and 2 persons) (as per Schimek, 1996).*

The empirical test for mediation requires that (a) the initial variable in this case density be associated with the outcome and with the hypothesized mediator and that (b) the magnitude of the statistical relationship between the initial variable i.e. density be eliminated (complete mediation) or substantially reduced (partial mediation) when the mediator is introduced into the regression or correlational equation (Baron and Kenny, 1986). As such, to test the role of household size as a mediator of the relationship of density change and planning outcomes this study examined the relationship of density change and each key outcome with household size as a covariate using partial correlation analysis. For this analysis, density change from 1986 to 2006 was the dependent variable. Complete mediation would be evident if the correlation between density and key variables was eliminated with the introduction of household size as a mediator. If the magnitude of the correlation were substantially reduced, it would indicate that household size was, at least, partially mediating the relationship of density and key planning outcomes contrary to the predictions of Smart Growth or at least unconsidered by Smart Growth theory.

b. Methods

The 1986 census year was chosen as the base case for empirical analysis and the 2006 census year was taken as the end point. A 20-year interval was thought to be long enough to reveal concrete statistical patterns as well as variation in independent and dependent variables. The CT was chosen as the census geography because it offers a higher degree of data fit and is less susceptible to aggregations biases than more aggregated census geographies. As a result of growth (and indeed densification) in the Toronto CMA, 266 new CT were created between 1986 and 2006. To allow for sound longitudinal density analysis, boundary realignment was accounted for through a process of overlay and data disaggregation process using Geographical Information Systems software (GIS). 18 CTs with an invalid zero entry for land area or population in 1986 or 2006 cases were excluded from the total sample size, leaving a total *n value* equal to 719 CTs.

Calculating mean CT density change

Change in density (change in residents per square kilometre) was calculated as the difference between 1986 CT density and 2006 CT density (Table 4).

Constructing a Relative Density Change Group (DCG) Matrix

CT Density (residents per square kilometre) scores were sorted into relative density tertiles; low, medium and high density for 1986 and for 2006 respectively (Table 5). Next, low, medium and high-density tertiles from both cases were cross-tabulated and longitudinal density change groups (DCG) were assigned (DCG 1 to 9) in a density change group matrix (Table 6). DCG 1, for example, occupied the low-density tertile in both 1986 and 2006 cases. DCG 9 occupied the high-density tertile in both 1986 and 2006. DCG 7 was omitted as no high-density base case CTs became low-density in 2006.

There was an overall densification trend in the Toronto CMA. The mean absolute density change across all CTs was 621.1 residents per square kilometre (Table 6). Nevertheless, approximately 80% of CTs remained in the same relative density tertile. Just 20% of CTs changed tertiles from 1986 to 2006. Contrary to an overall trend toward increased density, DCG 4 was the largest (6.4% of total CTs) of all groups that change relative density tertiles. DCG 4 consists of those CTs that had *medium* density in 1986, but *low* density in 2006.

c. Results

Cross-sectional correlations identified statistically significant relationships between 2006 CT density and all six key 2006 outcomes (Hypothesis 1) (Table 7). However, observed correlations were contrary to Smart Growth predictions for three household-level economic outcomes; Homeownership decreased with increasing CT density ($r = -.601$, $p < .000$), Rental Housing Affordability decreased with increasing CT density ($r = .181$, $p < .000$) and Affordability for Owner-occupiers decreased with increasing CT density (r = .477, p < .000). Although individual variables were significantly correlated with density, they accounted for little of the variance in outcome. In order to see if a more comprehensive model could explain key outcomes, additional variables were added to the model. The predictive model which included Driving Modal Split by Density Change, Percentage of Small Households, and Median Household Income accounted for 51% of the variance in Driving Modal Split whereas the model with Density Change alone predicted only 36% of the variance in 4 this same outcome suggesting that the inclusion of more variables in the model can increase prediction of key outcomes.

Quasi-longitudinal correlations showed that mean outcomes scores of the 9 DCGs differed significantly for each outcome as evident in the Oneway ANOVAs (Table 8) for nature and interpretation of relationships). Moreover, DCGs 3, 6, and 9 (i.e. those with the highest 2006 density) did not differ from one another in any of the outcomes indicating that the DCG with the greatest increase in density i.e. DCG 3 acquired the attributes of DCG 9 which had high density in both 1986 and 2006. For all outcomes DCGs 3, 6 and 9 differed from the lowest density groups (1, 4) with the exception of Rental Housing Affordability (Table 8, Table 9). Contrary to Smart Growth theory, DCG categories were not related to Rental Housing Affordability. Moreover, in 2 of the remaining 5 comparisons, the results did not conform to Smart Growth predictions. Instead of finding that the densest CTs had the most affordable housing and the highest percentage of home ownership, the current results show that DCG 3 i.e. the CTs which showed the greatest increase in density took on the characteristics of existing high density CT i.e., DCG 6 and 9 whether these characteristics were sustainable or not.

Compared with DCG 1 and 4, DCGs 3, 6 and 9 had statistically significantly higher percentage of households with owner-occupied dwelling that spent 30 or more percent of annual household income on shelter costs. For each of the six key outcomes, the quadratic model revealed a modestly better data fit than did the linear fit, as indicated in the model R^2 value (Table 10).

The mediation model showed that the prevalence of small household (1 or 2 persons) in a CT was a potential mediator. Small households were significantly correlated both with density change (r = .107, p = .004) and with 5 of the 6 key outcomes. The exception was Rental Housing Affordability. With household size as a mediator variable, the magnitude of the observed correlation between density change and outcomes decreased for 4 of the remaining 5 outcomes. The exception was Social Diversity (Table 11). However, in each case, the relationship of CT density change and outcome remained significant. This pattern suggests partial mediation by just a single household level factor.

d. Discussion

The overall objective of this MRP was to appraise the theoretical and empirical basis for Smart Growth with particular emphasis on the Toronto CMA. As argued in the introduction, Smart Growth is not defined by the objective it seeks. What planner or planning movement does not aspire to neighborhood-level livability, ease of travel, quality places, increased social equity, lower costs, and retention of open space (Duany et al., 2010)? In reality, Smart Growth is defined by its defence of density as the primary mechanism by which sustainable outcomes are realized. With regard to transportation, for example, Smart Growth hypothesizes that low density neighbourhoods inherently favour *mobility* (an individual's ability to overcome distance) over *accessibility* (an individual's ability to efficiently reach destinations) resulting in dependence on private automobiles for move (Handy, 2002). When density is increased, the distances between regular destinations is reduced-supporting both the use of alternative modes of transportation and an overall decrease in automobile VKT (Woodhull, 1992).

Because of the inordinate emphasis on densification in Smart Growth theory, the movement leans heavily on the research literature that evaluates the link between density and positive planning outcomes. Therefore, an initial step in this MRP was a critical appraisal of existing density research. This review demonstrated that the Smart Growth literature is methodologically limited in various ways. In particular, existing research is heavily dependent on cross-sectional designs although Smart Growth theory consistently draws conclusions about the *causal* relationship between *changes* in density and *changes* in planning outcomes. Moreover, the models guiding existing research tend to be subject to various limitations and sources of bias which have not been adequately addressed in Smart Growth theory. For example, existing literature has placed too great an emphasis on a single predictive variable namely density and it has failed to take into account other potentially important predictors. This is the under-specification problem that was addressed in section two. Moreover, the density research upon which Smart Growth theory rests has inadequately addressed the potential for diminishing returns for density. More specifically, Smart Growth theory does not consider whether or not certain urban environments have met or exceeded a critical density threshold whereby any further increase in density would have unspecified effects. Additionally, cross-sectional density research does adequately investigate the possibility of locational self-selection. Smart Growth implies that increasing density will result in behaviour change for existing residents and therefore achieve sought-after outcomes such as greater transit use. Smart Growth may, in part, be based on the assumption that environmental factors, above all else, condition human behaviour. It inadequately considers the possibility that neighbourhoods that become denser select for residents of a specific behavioural predisposition (i.e. self-selection). Whereas Smart Growth intends to achieve positive outcomes for all socio-demographic clusters, it may in fact do so for just a subset. Self-selection is an example of mediation whereby some key intervening variables such as household size may be influenced by densification and that these variables in turn influences outcomes rather than densification having a direct effect on outcomes. Facing this criticism, proponents of Smart Growth would undoubtedly point out that densification is promoted along with supplementary policies such as those that foster the creation of multiple housing types and tenures. Nevertheless, density research has not done an adequate job of specifying the range of mediating variables and therefore policy options. Further research is required to address this limitation.

The empirical research reported in this MRP confirms some but not all of the purported correlates of density and of densification in the Toronto CMA. Although preliminary, the restricted range of these findings may have serious implications for the validity of the Smart Growth theory and practice. In general, density was correlated with all of the outcomes that were included in this study. However, for 3 of 6 outcomes increasing density was correlated with a *decrease* rather than a predicated *increase* in desired outcomes. These cross-sectional findings do not confirm or disconfirm the predictions of Smart Growth theory. Adding additional predictors into the model allowed for a substantially increased explanatory power. This observation confirms that density alone only accounts for a limited proportion of the variance in planning outcomes (as per Handy, 2005). Optimal planning interventions should be based a complete predictive model, not determined by an isolated urban design factor variable such as density.

The quasi-longitudinal design allowed for the examination of the characteristics of CTs that became increasingly dense over the 20 year period. It is important to note that few CT showed a substantial increase in density. The results showed that these newly dense CTs took on the characteristics of those traditionally dense CTs. This observation lends a measure of support to the contention inherent in Smart Growth that with a program of densification, the characteristics of a higher density neighbourhood can be manufactured in a previously low relative density neighbourhood. Once again, the direction of the observed relationships was not always as predicted in Smart Growth. For example, indicators of household level economics did not relate in the predicted manner to increased density.

The empirical study also found tentative evidence for a non-linear relationship of density and outcomes. For all six key outcomes, the quadratic model offered substantially greater data fit. These findings suggest that the relationship of densification and planning outcomes might indeed be non-linear. Without question, the possibility of non-linear relationships between density and outcomes requires further study, however these preliminary results indicate that the shape of the density-planning outcomes is more complex that presently conceived. Should non-linearity be confirmed in future study, it would not be appropriate to uniformly assign density targets to jurisdictions.

Although the empirical study did not find definitive evidence of mediation (as only one potential mediator was tested) analysis did find to some extent that the relationship between density and the six key outcomes is, at the very least, attenuated by the presence of small households. Planning practice requires a thorough understanding of the possible role of mediators of outcomes. In some cases, mediators may indicate that self-selection is at play in determining the link between planning interventions such as densification and outcomes such as transit use. In other cases, a mediator could signal the possibility that the mediating variable could be modified more directly and efficiently than through policies such as densification.

e. Study Limitations

This study has several limitations. First and foremost, the absence of a complete range of comparable outcomes for the 1986 and 2006 studies necessitated a quasi-longitudinal design whereby only change in dependent variable (CT density) was accounted for. It was not possible to assess the extent to which predictor variables changed. An optimal design would relate changing density to changing CT characteristics. Having stated the challenges of gathering longitudinal census data, even a completely longitudinal design would only partially establish causal relationships. Secondly, density change tertiles are relative (not absolute) measures of density. Consequently, all analyses utilizing DCGs from the density change matrix will, to some degree, obscure trends. For example, a CT that exhibited the mean CT density change from 1986 and 2006 (an increase of 621.1 residents per square kilometre) may or may not change tertiles from one case to another. This limitation can partially obscure statistical trends in key outcomes. Housing affordability is a complex outcome which is confounded by income and possibly several other variables. Consequently, a multivariate modeling of predictors and outcomes would provide the clearest interpretation of data. Therefore, future research requires access to a wide array of CT level variables and it must evaluate models of various levels of complexity.

Although offered as a critique of existing density research, the present empirical component does not operationalize a measure for self-selection in either cross-sectional or quasi-longitudinal tests of density and densification. As with all CT level analyses, the present study is subject to the Modifiable Arial Unit Problem ("MAUP").

6. Conclusions

Smart Growth espouses broad and important goals (Duany et al., 2010) which are not unique, but rather shared by all planners and planning theories. Consider that objectives such as ease of travel, retention of open space, and neighbourhood liveability formed the initial impulse for suburbanization and the proliferation of low-density urban forms. Smart Growth, therefore, is distinguished not by the outcomes it seeks, but by the belief that densification, more than any other intervention targeting urban form, gives rise to sustainable outcomes.

Smart Growth's fundamental contention that relatively dense neighbourhoods have unique characteristics holds true in the Toronto CMA but with several major caveats. The empirical component of this MRP confirmed that density, at the very least, had some cross-sectional relationship with reduced auto-dependency, increased transit use and a measure of social diversity. Yet, even the cursory examination afforded by this MRP gives rise to doubt about the validity of densification and Smart Growth theory and practice.

What maintains the planner's belief in Smart Growth density doctrine? First and foremost, in the absence of a ready alternative to conventional suburban form and its attendant problems, Smart Growth, ostensibly the antithesis of sprawl, gains intuitive appeal. Smart Growth policy's rapid leap from conjecture to mainstream practice occurs as well-intentioned planners search for a means to ameliorate some of the urban environment's exigent concerns. Without a ready alternative to urban sprawl, Smart Growth theory and practice reinforces, enhances and even justifies the continued role of the planner in shaping land use. Second, the interests of private development harmonize with Smart Growth theory. As the City of Toronto and other regions of the

Toronto CMA advance toward fully *built out* status, avenues for development become increasingly restricted. The dense neighbourhood is easily commodified based on romanticized notions of quality of life. It is argued that high-density is a prerequisite for local *vitality*, *vibrancy*, cultural dynamism and Jacobsian social interaction.

On one hand, the planning profession cannot advocate unrestrained consumption of prime agricultural land and natural heritage features at the urban fringe. Nor is it possible for planners to espouse policies that target outcomes other than those associated with the Smart Growth planning movement. On the other hand, Smart Growth constitutes a pervasive planning orthodoxy that rests on incomplete empirical grounds. Therefore, there is an acute need for planners to recognize that sustainability is conditioned by a range of factors of which urban form may be the least important. Future research will require more specified and complex models to determine which factors (built form, behavioural, economic and their interactions) influence sustainable outcomes. And future research will also be needed to determine the extent to which policy initiatives can actually manufacture sustainable outcomes. These conclusions also speak to the divergence of planning theory and planning practice as well as the need for the planning profession to practice evidence based decision-making to a far greater degree.

7. Tables and Maps

Map 1: Southern Ontario, 1986 Toronto CMA

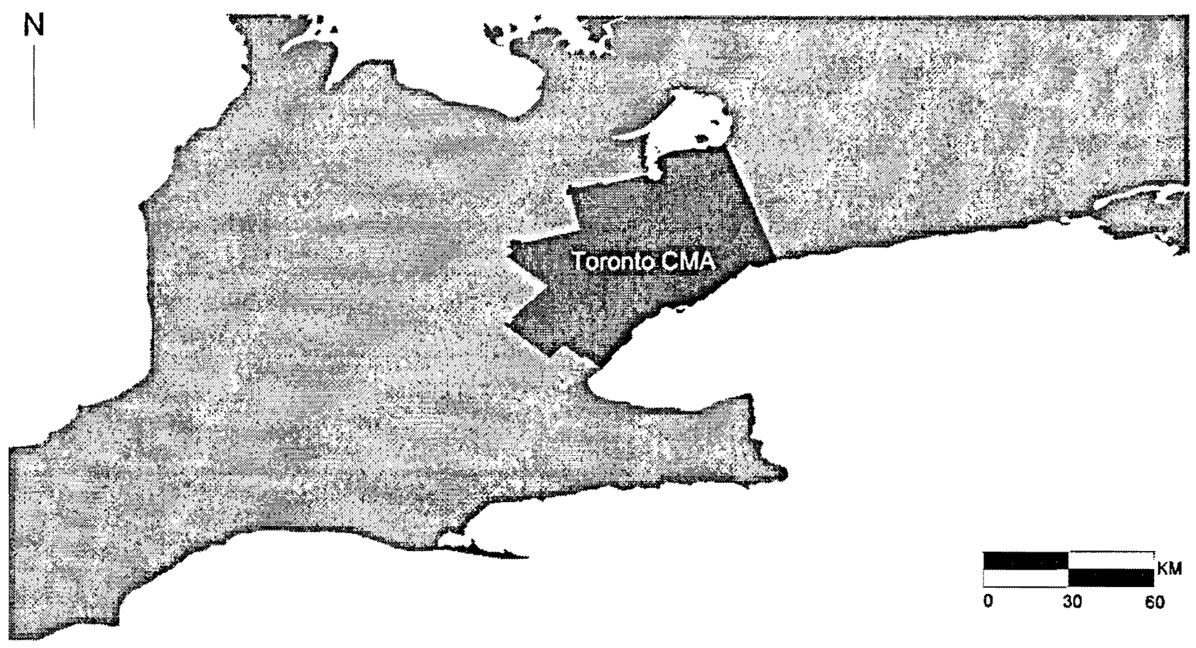

Table 1: Purported outcomes of high-density with citation

Transportation-Related Outcomes	Social Outcomes	Economic Outcomes
Reduced auto dependency (Newman and Kenworthy, 1989a, 1989b; Frank and Pivo, 1995; Cervero and Kockelman, 1997; Holtzclaw, 1994)	**Increased social diversity** (Talon, 2006)	**Agglomeration economies** (Bunker, 1985; Rees, 1988; Collie, 1990; Bromley and Thomas, 1993)
Increased transit use (Spillar and Rutherford, 1990)	**Increased social cohesion** (Glynn, 1981; Calthorpe, 1989; Katz et al., 1994; Krier, 1998; Duany, 2000)	**Lower marginal costs for infrastructure** (Newman, 1992)
More walkable and cycle-friendly city (Cervero and Gorham, 1995; Cervero and Ridisch, 1996; Greenwald and Boarnet, 2001)	**More equitable access to services** (Collie,1990; Bromley and Thomas, 1993; Fyfe, 1994)	**More affordable housing** (Danielsen et al., 1999; Victoria Transportation Policy Institute, 2010)
		Homeownership opportunity (Victoria Transportation Policy Institute, 2008, 2010; Nelson and Dawkins 2004)

Table 2: Key Outcome Variables

Purported Smart Growth Outcome	Output Variable Name	Outcome Type	Derived Measure
Reduced Auto Dependency	**Avg P_Drive**	Transportation-related	Measured as auto mode split for daily work trips
Increased Transit Use	**Avg P_Transit**		Measured as transit mode split for daily work trips
Increased Social Diversity	**p_immigrant**	Social	Measured as percentage of total CT population who identified as immigrants was used as a proxy measure for social diversity (Schimek, 1996)
Affordability for Owner-occupier	**p_30plus_owned**	Household-level economic	Percentage of CT households spending 30 or more percent of annual household income on shelter costs
Rental Housing Affordability	**p_30plus_rent**		Percentage of CT households spending 30 or more percent of annual household income on gross rent
Homeownership	**p_own**		Expressed as owned dwelling as a percentage of total CT dwellings

Table 3: Explanation of Other Computed Variables

Variable Name	Meaning	Explanation
Density_Change_Q	CT density change 86-06	CT density 2006 – CT density 1986
popdens_sqkm	CT density 1986	1986 residents per km^2
Avg Popdens_sqkm	CT density 2006	2006 residents per km^2
P_Small_HH	CT prevalence of small households	% of CT households that are 1 or 2 persons

Table 4: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Densit_Change_Q	719	-8249.54	20272.53	621.1497	2021.93859
popdens_sqkm	719	.0	59266.7	4474.616	4268.0922
Avg Popdens_sqkm	719	1.0909E1	6.47577E4	5.0957E3	4.6324E3
Valid N (listwise)	719				

Table 5: Relative CT Density Tertiles

Density 1986 CT density tertiles		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	241	33.5	33.5	33.5
	2.00	240	33.4	33.4	66.9
	3.00	238	33.1	33.1	100.0
	Total	719	100.0	100.0	

Density 2006 CT density tertiles		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	240	33.4	33.4	33.4
	2.00	241	33.5	33.5	66.9
	3.00	238	33.1	33.1	100.0
	Total	719	100.0	100.0	

Table 6: Relative Density Change Matrix			Density 2006 tertiles			Total
			1.00	2.00	3.00	
Density 1986 tertiles	1.00	DCG # (Count)	1 (194)	2 (40)	3 (7)	241
		% within Density 1986 tertiles	80.5%	16.6%	2.9%	100.0%
		% within Density 2006 tertiles	80.8%	16.6%	2.9%	33.5%
		% of Total	27.0%	5.6%	1.0%	33.5%
	2.00	DCG # (Count)	4 (46)	5 (170)	6 (24)	240
		% within Density 1986 tertiles	19.2%	70.8%	10.0%	100.0%
		% within Density 2006 tertiles	19.2%	70.5%	10.1%	33.4%
		% of Total	6.4%	23.6%	3.3%	33.4%
	3.00	DCG # (Count)	7 (0)	8 (31)	9 (207)	238
		% within Density 1986 tertiles	.0%	13.0%	87.0%	100.0%
		% within Density 2006 tertiles	.0%	12.9%	87.0%	33.1%
		% of Total	.0%	4.3%	28.8%	33.1%
Total		Count	240	241	238	719
		% within Density 1986 tertiles	33.4%	33.5%	33.1%	100.0%
		% within Density 2006 tertiles	100.0%	100.0%	100.0%	100.0%
		% of Total	33.4%	33.5%	33.1%	100.0%

Table 7: 2006 Correlations

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

		Avg Popdens_sqkm	Avg P_Drive	Avg P_Transit	p_immigrant	p_own	p_30plus_rent	p_30plus_owned	Density_Change_Q
Avg Popdens_sqkm	Pearson Correlation	1	-.668**	.625**	.312**	-.601**	.181**	.477**	.391**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000
	N	719	719	719	719	719	719	719	719
Avg P_Drive	Pearson Correlation	-.668**	1	-.888**	-.303**	.681**	-.190**	-.408**	-.155**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000
	N	719	719	719	719	719	719	719	719
Avg P_Transit	Pearson Correlation	.625**	-.888**	1	.427**	-.675**	.197**	.365**	.104**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.005
	N	719	719	719	719	719	719	719	719
p_immigrant	Pearson Correlation	.312**	-.303**	.427**	1	-.303**	.242**	.568**	.168**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000
	N	719	719	719	719	719	719	719	719
p_own	Pearson Correlation	-.601**	.681**	-.675**	-.303**	1	-.212**	-.379**	-.117**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.002
	N	719	719	719	719	719	719	719	719
p_30plus_rent	Pearson Correlation	.181**	-.190**	.197**	.242**	-.212**	1	.215**	.084*
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.024
	N	719	719	719	719	719	719	719	719
p_30plus_owned	Pearson Correlation	.477**	-.408**	.365**	.568**	-.379**	.215**	1	.264**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000
	N	719	719	719	719	719	719	719	719
Density_Change_Q	Pearson Correlation	.391**	-.155**	.104**	.168**	-.117**	.084*	.264**	1
	Sig. (2-tailed)	.000	.000	.005	.000	.002	.024	.000	
	N	719	719	719	719	719	719	719	719

Table 8: Correlates of DCGs * NA = not applicable because the DCG groups did not differ.	Do density change groups 3, 6 & 9 differ from each other?	Do density change groups 3, 6 & 9 differ from density change groups 1 & 4?	Does direction of relationship conform to Smart Growth predictions?
Homeownership	no	yes	no
Social Diversity	no	yes	yes
Rental Affordability	NA*	yes	no
Affordability for Owner-occupiers	no	yes	no
Auto Dependency	no	yes	yes
Transit Use	no	yes	yes

Table 9: Post Hoc Test Homogenous Subsets, Rental Housing Affordability (p_30plus_rent)

* Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 28.634.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

	Density_ change	N	Subset for alpha = 0.05	
			1	2
Student-Newman-Keuls[a,,b]	1.00	194	.4114	
	4.00	46	.4259	.4259
	8.00	31	.4263	.4263
	5.00	170	.4412	.4412
	2.00	40	.4478	.4478
	3.00	7	.4553	.4553
	9.00	207	.4636	.4636
	6.00	24		.4930
	Sig.		.434	.150
Tukey HSD[a,,b]	1.00	194	.4114	
	4.00	46	.4259	.4259
	8.00	31	.4263	.4263
	5.00	170	.4412	.4412
	2.00	40	.4478	.4478
	3.00	7	.4553	.4553
	9.00	207	.4636	.4636
	6.00	24		.4930
	Sig.		.503	.184

Table 10: Curve Fit Model Summary for Key Outcomes

*Independent variable is 2006 CT density, (all models p = .000)

	R^2	
Outcome Variable	**Linear**	**Quadratic**
Reduced Auto Dependency	.391	.491
Increased Transit Use	.447	.554
Increased Social Diversity	.097	.134
Affordability for Owner-occupier	.227	.237
Rental Housing Affordability	.033	.047
Homeownership	.361	.423

Table 11: Test of Mediation Models

Note: * Independent variable is density change and all models except for rental affordability were significant. Neither the models with nor those without mediation were significant.

	r	
Outcome Variable	**unmediated**	**mediated**
Reduced Auto Dependency	-.16	-.11
Increased Transit Use	.10	.06
Increased Social Diversity	.17	.2
Affordability for Owner-occupier	.26	.26
Rental Housing Affordability*	.08	.07
Homeownership	-.12	-.07

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