A GIS Approach for Evaluating Municipal Planning Capability: Residential Built Form in Markham and Vaughan, Ontario

by

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

This research describes a methodology for measuring built form patterns using spatial data and GIS that is amenable to the study of large geographical areas. This methodology was used to investigate the capability of municipal planning to influence residential development. In the early 1990s, the Town of Markham, Ontario, Canada adopted a residential development philosophy inspired by New Urbanism. An adjacent municipality, the City of Vaughan, has employed a conventional development approach. By calculating several built form measures derived from the design prescriptions associated with New Urbanism, this study seeks to discern if Markham's adoption of an unconventional development philosophy has resulted in a residential built form distinct from that in Vaughan.

Built form measures are calculated for both municipalities for two eras. Development from 1981 to 1995 represents the "before" or baseline configuration, while development from 1996 to 2003 is used to characterize built form created when Markham's New Urbanist-inspired approach was in force. Period over period comparisons are carried out for each municipality, as are within-period comparisons between municipalities.

Findings indicate that development patterns are distinct in the two study periods. From the early period to the more recent, street networks take on a more grid-like organization while building lots and blocks become smaller. These changes are accompanied by an overall decline in accessibility to amenities. However, development patterns were found to be quite similar in both municipalities in the recent study period, exhibiting differences in degree, not in kind. The findings appear to indicate that planning's influence over residential built form is limited to moderately accelerating positive trends, and moderately retarding negative trends.

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Chapter 1
Introduction

1.1 Technology, data and their research implications

For those investigating spatial aspects of urban form, the scale and scope of research have depended upon the data that have been available or could be acquired. The choice researchers have been forced to make until recently been between taking a fine-grained and narrow approach operating at a neighbourhood level or a coarse-and-broad approach operating at a metropolitan level.

A fine-grained approach attempts to characterize the built environment by looking at the details that might emerge from a walking tour of a neighbourhood, such as street widths, the presence or absence of sidewalks and trees, the size of building lots, the connectivity of the street network and the number and diversity of businesses and retail locations. Due to the time, effort and expense involved in capturing this level of detail, and the lack of spatial data for many built form attributes, fine-grained approaches have generally been undertaken only for relatively small, neighbourhood-sized areas (hence “fine-grained and narrow”). While undoubtedly useful, such studies can be used only with great caution as a tool for characterizing the built form at the municipal scale.

Conversely, research working at a municipal or metropolitan scale has been limited to analyzing relatively coarse data due to limited coverage and availability of detailed spatial data and practical constraints imposed by computational capacity. Rather than identifying neighbourhood-scale attributes such as the diversity of retail locations or average lot sizes of single-family houses, a coarse-grained approach will be limited to, for example, classifying land uses simply as “commercial” or “residential” or “undeveloped”. Studies such as these are useful for identifying the fundamental structural components of cities and for mapping changes in these components’ location and size over time, but are ill-suited to describe built form as used and experienced by people.

Over the past ten years, a number of circumstances have combined to largely eliminate the constraints that previously forced researchers to use one of the two approaches described above. First, the computational capability of standard personal computers has reached a point where Geographic Information System (GIS) software packages will run well and carry out very complex calculations in a reasonable period of time: minutes, rather than hours. Second, the level of detail being captured with spatial data has increased dramatically as the usefulness of spatial analysis has become apparent to a growing number of public and private sector organizations. Third, the coverage of spatial data has increased. Many forms of spatial data are now available not only for large urban areas but also for small and medium sized cities. Some forms of data, such as street network files, have national coverage. Fourth, because of market demand, spatial datasets are refreshed or replaced with increasing frequency. And finally, there are many more sources of spatial data now, including every level of government. The result is that a researcher can be reasonably confident that he or she will be able to acquire multiple forms of highly detailed and recent spatial data, from street network files and building lot data to high-resolution orthophotos and satellite imagery. The combination of abundant, detailed data and relatively fast computers means that for the first time, researchers can now examine neighbourhood level attributes at a municipal level.

1.2 Applying technology to planning evaluation

One of the tasks for which this newly viable approach is well suited is an evaluation of the capability of municipal planning. This is obviously a very broad concept, and multiple streams of research exist that relate to it in varying extent. Evaluations of the quality of plans and plan implementation, for example, are numerous, as are ruminations on the roles of planners and planning. While these works discuss the many constraints on planning, and point to various reasons why certain programs have or have not succeeded, relatively few attempt to establish in an empirical fashion exactly what municipal planning is capable of accomplishing, particularly where planning's powers are more ascribed than formal. One such ascribed power of planning is the guidance of residential development.

I have chosen to examine residential built form for three reasons. First, residential built form can be evaluated using relatively small scale, fine-grain measures such as building lot size, distance from households to amenities and building lot sizes. Second, residential development has occurred continuously across over the past several decades in Canada's largest cities, meaning that a broad analysis covering many years is possible. Third, the guidance of residential development has long been an emphasis of urban planning, and it remains so today due to, among other things, concerns about the implications of sprawl such as pollution, congestion and the loss of agricultural land.

The challenge for planning is its lack of ultimate control over residential development. Planning can control many aspects of how development occurs, from street level attributes such as design and placement requirements for individual buildings up to municipal level concerns such as zoning. Yet planning does not have the capacity to actualize the final phase of the process: implementation. Planning might allow, for example, small-scale retail in residential areas, but it can neither cause a retail facility to be built nor guarantee that, if built, it will succeed. Planning, therefore, acts at one remove from the development process, operating as a structuring facilitator rather than an active agent of development. Despite this, much planning effort is expended formulating range plans that deal with issues that would appear to be beyond planning's control, such as the number and location of schools, retail and transportation facilities. This research is an attempt to understand to what degree planning is capable of influencing such aspects of the residential built environment.

1.3 The capability of planning

Since the modernist mode of "rational comprehensive" planning began to come under fire in the 1960s with the publication of Jacobs' *Death and Life of Great American Cities*, the role of planning has been continually discussed, but the capability of planning has largely been assumed.[1] Particularly in the current development context, I think it useful to question the assumption—no doubt true in the past—that planning is capable of significantly influencing residential built form. The results of such an inquiry may be able add to the continuing discourse related to planning's role.

It has theorized that planning has shifted its emphasis from "managerialism" to an "entrepreneurialism" based on "a public-private partnership focusing on investment and economic development with the speculative construction of place rather than amelioration of conditions within a particular territory" (Harvey, 1989). This shift away from traditional planning concerns is occurring at a time when the need for effective planning may be greater than it has been in decades due to a confluence of high priority urban issues. The environmental impacts of growth demand attention (Berke & Conroy, 2000; Conroy & Berke, 2004). Congestion threatens economic productivity (Weisbrod, Vary, & Treyz, 2003) while public transit use and funding struggle (Filion, Bunting, McSpurren, & Tse, 2004). Peripheral areas grow in power at the expense of core areas, where social and economic polarization is increasing (Walks, 2001, 2004). A handful of large cities are growing rapidly in size and diversity while the majority of medium-size and smaller cities and towns are stagnant or in decline (Bourne & Simmons, 2003; Filion, Hoernig, Bunting, & Sands, 2004).

Before we mourn the shift to entrepreneurialism and argue that planning should be refocused in order to deal with these and other pressing issues, we first need to explore planning's capability. There is little sense in expecting planning to deal with metropolitan and regional scale issues if, for example, it is not capable of influencing processes at a smaller scale. This study examines a relatively constrained process—the guidance of residential development—in order to assess planning's capability and comment on the implications for planning's role in future.

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[1] On the role of planning: the body of literature is gigantic and always growing. Some noteworthy examples are Lindblom (1959), Davidoff (1965), Wildavsky (1973), Friedmann (1987), Beauregard (1989), Healey (1992), Alexander (2000, 2005).

1.4 Methodology

To test the capability of planning, I have chosen to look at residential development patterns, for four reasons. First, the regulation of residential development is now, and has for past several decades, been at the core of planning at the municipal level. Second, many of the characteristics of residential development (i.e. the "built form") can be quantified with little controversy. Third, spatial data are available for many of these built form attributes. Fourth and finally, an ideal set of test subjects exists. The Town of Markham, Ontario, adopted an unconventional, design-based residential development philosophy based on New Urbanism in the early 1990s. In contrast, neighbouring Vaughan maintained a conventional development approach. The nearly identical geographic, political and economic contexts shared by these municipalities will isolate planning as an influence on the built form. My working hypothesis is that planning *does* make a difference: Markham, having many factors favourable to the successful implementation of broad planning initiatives, will exhibit a residential built form that is measurably different from that of Vaughan.

To carry out the study, I will use measures deriving largely from the several bodies of work that have operationalized aspects of the built form during the process of carrying out research that uses digital spatial data. These measures include indicators that characterize the street network, land use, and density. I will be examining development in both Markham and Vaughan over two periods: from 1981 to 1995 to capture development patterns prior to Markham's official adoption of a New Urbanist-based development philosophy; and from 1996 to 2003 to capture post-adoption patterns. This will allow both "horizontal" comparisons between municipalities for the same era, and "vertical" comparisons within a given municipality across the two time periods. If the working hypothesis is true, then each of these comparisons should exhibit measurable differences.

1.5 Document organization

This document is organized as follows: **Chapter Two** describes the few studies that have used a GIS-based approach to evaluate planning capability. The majority of work that quantifies the built form using spatial data does so for many purposes, most of which are not explicitly planning-related. Using representative articles, I discuss these streams of research and summarize the approaches that are typically taken.

Chapter Three identifies individual built form measures used by researchers across many disciplines, and groups these measures into three categories that are frequently used in characterizing the built environment with spatial data and GIS: density measures, street network organization and land use.

Chapter Four provides a brief overview of the design-based aspects of New Urbanism, and situates the Town of Markham, stressing the importance of its proximity to Toronto and its many similarities to Vaughan in order to illustrate the circumstances that allow planning to be isolated as a factor influencing built form. The chapter also outlines the sequence of events by which Markham came to adopt a New Urbanist-based development philosophy.

Chapter Five sets out the elements of my research design, discussing the rationale underlying the selection of Markham and Vaughan as study areas, how the individual study units (Dissemination Areas) were selected and the factors affecting the use of the two time periods.

In **Chapter Six**, I identify the measures I use to quantify built form. In most cases, I explain how the measures relate conceptually to New Urbanism. Some of these measures are calculated using functionality built into the GIS, such as distance and area calculations. Many of the measures required some programming or database manipulation. Because there is no applicable canon of GIS approaches that would have allowed me to describe what I had done in a kind of technical shorthand, I felt it appropriate to explain my custom work in some detail.

Findings are presented in **Chapter Seven** and examined in **Chapter Eight**, in two directions. For each measure, I look at intra-municipal findings to identify a discontinuity in development patterns before and after Markham's adoption of a New Urbanist philosophy. I also examine the results in Vaughan to ascertain if change in Markham can be attributed to planning. The second direction involves inter-municipal findings in each era. By comparing results for Markham and Vaughan for the 1981 to 1995 period, I am looking for similarities since both municipalities were guided by conventional development practices in these years. By comparing results between Markham and Vaughan for the 1996 to 2003 period, I am obviously looking for differences that would support the idea that planning has influenced the built form.

In **Chapter Nine**, I attempt to interpret the findings by discussing the study results in light of trends in suburban development and through observations made over the course of visits to the study areas. The chapter concludes with a discussion of two of the possible implications of the findings. The first is that planning may need to be refocused so that its goals and responsibilities are more in line with its capabilities and those processes over which it has direct and not merely ascribed control. The second possibility, inspired by the work of Faludi and others, is that planning, if diligently carried out, does indeed play an important role but one that cannot be evaluated properly using traditional tools.

Chapter Ten summarizes this study and suggests future research possibilities.

Chapter 2
Research Employing Built Form as an Indicator

The specifics of my research involve examining the built form attributes of relatively large geographic areas using spatial data in order to discern whether one municipality's development philosophy has resulted in built form that differs markedly from that of a neighbouring municipality. This approach, therefore, encompasses two distinct subjects, the evaluation of planning policy implementation and built form analysis. These subjects, and their remarkably few interactions, are discussed below. The majority of the discussion will be devoted to built form analysis due to its prominent role in defining the measures I use to characterize development in Markham and Vaughan.

2.1 Planning evaluation

Evaluation is here defined as an examination of the outcomes of planning activities. There can be one or two phases in this kind of evaluation. The first examines the implementation process, essentially asking "Did it happen, and with what level of quality or adherence to the plan?" A second phase may attempt to assess if the implementation has met the goals that motivated the project, or "Did it work?"

Despite the existence of evaluation as a distinct discipline (usually dealing with large public policy issues such as education and health care) and despite increasing demands on public organizations for accountability (Bernstein, 2001), very little research on planning evaluation exists (Laurian, Day et al., 2004; Seasons, 2003; Talen, 1996a, 1996b). The breadth and nature of planning activities is surely one reason for this situation. Planning works at a variety of geographic and temporal scales and creates plans with "soft" goals that resist measurement. Planning has direct and formal control over some of its activities, yet only ascribed and informal control over others. And in almost all cases, causality between plans and outcomes is impossible to identify due to the intervention of larger economic, political and societal forces (Talen, 1996b). This diversity of circumstances suggests that multiple forms of evaluation are needed and that evaluation is going to be a complex (read: time-consuming and expensive) process. Small wonder that evaluation research remains a sizable gap in the planning literature and that evaluation occurs infrequently in practice (Seasons, 2003).

2.2 Conformance and performance-based evaluation

Perhaps because of the realities of planning practice, the most common evaluation approach is the simplest and most obvious, involving a comparison of quantifiable outcomes with explicit plan or project goals. The more closely the measured outcomes conform to stated goals, the more successful the plan or project is judged to have been (as in S. D. Brody & Highfield, 2005; Ford, 2001; Lee & Ahn, 2003; Lund, 2003; Thompson-Fawcett & Bond, 2003). Often referred to as conformance-based evaluation, this approach has wide support (see for example Laurian et al., 2004; Talen, 1996b), undoubtedly due to its common sense appeal.

A different philosophy of evaluation is the "performance" approach promoted by Faludi and others (see Faludi (2000) for the most complete summary). It is frequently and inaccurately constructed by North American commentators as a polar opposite to, or replacement for, conformance-based evaluation (Baer, 1997; S. D. Brody, Highfield, & Thornton, 2006; Laurian, Day et al., 2004; Talen, 1996b). Stripped to its fundamental tenets, the performance approach to plan evaluation holds that it is inappropriate to evaluate long range plans and/or plans with goals that are abstract (Faludi calls them strategic plans) using a conformance approach (Mastop, 2000). Instead, it is argued that these kinds of plans should be judged by how useful they were in aiding subsequent decision-making (A. Faludi, 2000). The rationale is quite simple: strategic plans can fail to be implemented to a greater or lesser extent for reasons that could not have been foreseen by the planners, such as economic downturns, a change in political regimes or the outbreak of contagious disease, for example. In these circumstances, it is inaccurate and misleading to say the *plan* has failed. A "failed" plan by this definition may in fact have been a diligently created document of significant utility in the formulation of subsequent plans.

A performance based evaluation of a strategic plan would therefore first analyze outcomes, as in a conformance evaluation, but would then examine documents and conduct interviews in order to ascertain how decision makers reached their decisions (A. Faludi, 1989, 2000). A plan that was used by decision-makers in the creation of subsequent plans would be judged to have performed well; it would be deemed a "good" plan, in other words.

From a performance perspective, plans and the act of creating plans have significance beyond the documents that are the product of this process. In creating plans, particularly plans that derive from previous plans, the values and goals of the organization are being articulated and perpetuated. This is planning as institution building (Mastop, 2000), a process that can result in a strong a flexible organizational culture. Given the link between an organization's culture and its effectiveness (Denison, 1990; Kotter & Heskett, 1992), the performance perspective has implications for the capability of planning and, by extension, the role of planning.

2.3 Spatial approaches to planning evaluation

Literature on planning evaluation is meager; comparative studies evaluating planning capability and using spatial data are almost non-existent. When I began my research, I was unable to find a single article that used this approach.[2] Although large bodies of research on planning implementation and built form analysis exist, very little of it is wholly relevant to my research. Studies of planning policy implementation, for example, often evaluate by-laws, regulations and plans rather than on-the-ground results (e.g. S. D. Brody, 2003; S. D. Brody, Carrasco, & Highfield, 2006; Talen & Knaap, 2003). In the literature that evaluates the effectiveness of "sprawl" mitigation policies, on the other hand, researchers do examine changes on the ground, thus combining policy implementation and built form analysis. However, they tend to use coarse indicators of built form at a metropolitan scale (e.g. Galster et al., 2001; Pendall, 1999) or they use fine-grain built form indicators but work only at a neighbourhood scale (e.g. Song & Knaap, 2004).

One of the earliest instances of planning evaluation based on GIS and spatial data is Talen's demonstration of a method for comparing plan outcomes to plan goals (Talen, 1996a). Specifically, the study seeks to ascertain how well the goals related to the distribution of public services in the City of Pueblo, Colorado's 1966 comprehensive plan were implemented. Parks are used as a proxy for public services, with their locations as of 1990 acting as comparison points. A straightforward conformance-based evaluation would have simply compared the 1966 and 1990 locations. Seeking to achieve a more nuanced evaluation, Talen instead uses accessibility to parks at 1970 (the first census after 1966) and 1990 to gauge plan success. Four different accessibility measures are calculated for each of the 1300 blocks in the study.

To demonstrate the analytical possibilities of this approach, Talen examines the findings several ways. The first is a visual inspection of planned block accessibility in the 1966 plan and actual block accessibility as at 1990, using gravity or distance decay accessibility scores. This approach highlights an area that by 1990 had dramatically lower than planned accessibility. Findings using a "covering model" for accessibility (i.e. the number of park acres within one mile of the given block) are presented in histograms and scatterplots, the latter of which reveal a cluster of very high accessibility blocks in both 1966 and 1990. An examination of a number of socioeconomic variables from the 1970 and 1990 census indicates a link between higher income areas and increased accessibility, suggesting the plan did not create a more equitable accessibility pattern. Talen also maps accessibility against population change as well as accessibility change to highlight areas with disproportionate increases or decreases. Regressions are also run using socioeconomic and accessibility variables but the results are inconsistent; even where certain variables (e.g. proportion of Hispanic population) are found to be significant, they cannot be used to assess plan success or failure unless it could be shown that planners specifically sought to address the given issue directly.

[2] One article incorporating all three dimensions (built form evaluation, planning capability, spatial data/GIS methods) appeared after I began my research. The article, Song (2005), is summarized below.

Talen's article is unusual in going beyond a pure conformance approach, perhaps a necessary step since *none* of the parks in the 1966 plan were built at the proposed locations! Despite its nuances, the approach is fundamentally conformance-based and carried out with the purpose of declaring the original plan a "success" or a "failure". With nearly a quarter century between plan and evaluation, this is precisely the kind of exercise that Faludi and other proponents of a performance approach suggest is inappropriate, for two reasons. First, unforeseen (and unforeseeable) circumstances may have prevented and altered implementation. Second, it is impossible to ascertain causality in situations like this because of the multitude of large and small factors that influence development. Given these circumstances, it is difficult to imagine a logical argument how deviations found in 1990 from a 1966 plan can be classified as planning failures unless it can be proved that planners failed to gather data in 1966 that could have prevented deviations.

A performance-based evaluation would note that none of the planned parks were built at the locations originally specified and examine the subsequent plans used to implement parks at their new locations. If the original plan was largely discarded and simply replaced by a new plan because it failed to incorporate available data or exhibited some other flaw (rather than simply containing an inaccurate prediction), it would obviously be judged to have performed poorly. If the original plan strongly informed subsequent plans, it would be deemed to have performed well. This is where the performance and conformance approaches part company. The latter sees no value in a non-conformant plan while the former argues conformance of outcomes to goals is only one criterion by which plans should be evaluated.

In using accessibility rather than simple location comparisons of planned and actual parks, Talen's approach is also unusual in attempting to evaluate outcomes according to planning intentions—capability, in other words. This is a step in the right direction, but fails to provide useful insight into planning capability because it uses as its baseline a completed comprehensive plan. It is far from certain that a finalized comprehensive plan accurately reflects original intentions; compromises were likely introduced in many places. The act of turning intentions into a viable and acceptable plan is one component of planning capability, in other words. A more telling demonstration of planning capability would have compared the pre-plan goals and motivations with outcomes. However, as a study of implementation, the article demonstrates quite well the possibilities for using spatial data and GIS as tools for planning evaluation.

Probably the most common technique employing spatial data for the purpose of planning evaluation involves mapping values for a proxy measure (such as permits) rather than measuring the built form directly. Typically, the results are analyzed against plans in order to gauge implementation effectiveness. This technique pre-dates widespread GIS use, appearing at least as early as the late 1970s (e.g. Alterman & Hill, 1978).

Brody & Highfield (2005) in a more recent example of a proxy-based approach, study the effectiveness of environmental protection policies by comparing designated land uses (as specified in local comprehensive plans) against subsequent development, with development identified through examination of issued permits. The study area is entire state of Florida, divided into fifty-one watersheds as individual study units. Using a GIS, the study compares proposed land use classifications formulated in 1992 (the baseline) against subsequent watershed development permit data. Areas of intense development were identified using a measure of spatial autocorrelation, allowing the proposed land uses to be classified as either conforming or non-conforming. Conforming areas were those where development density was high and the proposed land use was residential, commercial, office, industrial, mining or military; or where development density was low and the proposed land use was also low (i.e. had agriculture, “estate” or “preserve” designations). Non-conforming areas were those where development density was not consistent with originally proposed land uses.

In addition to classifying the study unit as conforming/non-conforming in relation to the 1992 baseline proposed land uses, the study evaluates plan quality for all areas where a statistically significant cluster of wetland development permits were found. The evaluation considered the environmental protections the plans contained along with the strength of their implementation policies. Findings were that “nonconforming patches are almost always located adjacent to conforming development” and that intense expansion of urban areas is constrained only by nationally protected areas (p. 170). Protected areas are most likely to be violated, in other words, on the periphery of existing development.

The study finds no overall correlation between plan quality (i.e. the presence of environmental policies) and plan conformance, although certain individual indicators were found to be significant in explaining conformity and non-conformity. The existence of strong sanctions for failure to implement policies, for example, and having a strategy to monitor plan effectiveness were significantly correlated with plan conformity. The great unknown in this study is how well permits capture the development process and how strong and predictable the relation is between permits and environmental degradation.

The article purports to be concerned with implementation (a “Did it happen” perspective) while in reality it explores something different, the resilience or durability of plan implementation. The study is much more about planning capability than implementation, implicitly asking the broad question “Did it make a difference?” As with Talen’s study, this one would have had more resonance had it begun a step earlier. The land use designations in the many local comprehensive plans, for example, may already represent a significant compromise, with environmental protection losing out to development pressures. As it is, by using finalized comprehensive plans as a baseline, the study is not able to ask the lead question in the article's title, "Does Planning Work?" Nonetheless, the study is notable for its use of spatial analysis in planning evaluation.

As mentioned earlier, the literature that uses built form as an indicator of policy implementation is seldom directly relevant to my research for reasons of scale and methodology. However, recent work by Song and Knaap (2004), and subsequently by Song (2005) outlines an approach that is directly applicable to my research. The methods used in both articles are nearly identical, but I will concentrate on Song (2005) since it compares development patterns in three cities and is therefore more relevant to my work, which is also comparative in nature, whereas Song and Knaap (2004) examines only a single county in Portland.

Song examines three counties in Portland (OR), as well as Orange County (FL) and Montgomery County (MD). Each of the counties has implemented development policies that have much in common with Smart Growth principles. For the study, each county is divided into "neighbourhoods" that are defined by traffic analysis zones (TAZ). For each TAZ, measures are calculated for five categories of built form components: street design, density, land use, accessibility and pedestrian access.

The street design component includes a connectivity measure that considers the number of intersections and the number of cul-de-sacs. Block perimeter, median cul-de-sac length and median distance between block access points are the other measures used.

The density component includes median lot size, median floor space of single-family dwellings, and the proportion of single-family dwelling units in the TAZ.

Land use is captured in a ratio comparing the area of non-residential uses to residential uses. Two diversity measures are also implemented. These compare the proportions of multiple land use types.

Accessibility is captured through median distance to the nearest commercial uses, bus stops and parks.

Pedestrian access is captured by calculating the percentage of single-family housing units within one-quarter mile of commercial uses and bus stops.

Once values have been accumulated for each TAZ, the TAZ is assigned to a particular decade according the median value of the year in which the single-family homes it contains were built. By examining changes in development patterns, Song hopes to identify when a particular change occurred in order to make a causal link between policy implementation and built form change.

For each built form variable, Song analyses the mean values and identifies significant differences between each pair of counties using ANOVA and F tests. Looking at changes over time, Song notes that the study areas show similar development patterns. Over time, she notes increasing density and internal connectivity, decreasing external connectivity, largely unchanged homogeneity in terms of land use and little improvement in distance to shopping and transit. She concludes that “smart growth instruments have altered subdivision design” (p. 262) but have failed to implement foundational tenets of Smart Growth and New Urbanism such as mixed uses and regional accessibility.

The article is unusual in using fine-grained measures over broad study areas, and in being a comparative study. This approach is promising, but has limitations, some of which can be seen in Song’s measures. The street design component, for example, contains no indicator for intersection type and fails to include dead-ends, which reduce connectivity as much as cul-de-sacs. This may be due to lack of data or an inability to discover a practicable way to manipulate the data.

The lack of traditional density measures is almost certainly a data availability issue. Unless the researcher wants to use census tracts or other census units as the components of a study area, it will generally not be possible to calculate net or gross densities for population or dwelling units. The accessibility and pedestrian access measures seem meager since data on a wide variety of destinations (stores, restaurants, places of worship, schools and many more) are widely available. Nonetheless, the array of variables is likely comprehensive enough to provide a reliable characterization of the study areas.

There are problems with the research design, however. First, the study is designed to evaluate the effectiveness of Smart Growth policies, but Song fails to demonstrate that any of the study areas attempted to implement Smart Growth policies as part of a coherent development philosophy. Song lists various initiatives in the counties that align with Smart Growth philosophy, but is inconsistent in discussing whether these initiatives were enacted as legal requirements or were provided as guidelines or were simply goals that the particular counties said they were striving to achieve. The result is that it is unclear whether these counties can accurately be described as areas whose development has been guided by Smart Growth to a degree greater than any other counties.

The uncertain development approach of the study areas is made more problematic because Song did not attempt to include “conventional” or non-Smart Growth counties. Doing so would have validated her selection of the Smart Growth counties (assuming they would have differed from the conventional ones). At the same time, having control counties might have prevented Song from concluding that Smart Growth had affected recent development in the study areas. As it is, there is no causal link that can be made between the study areas and Smart Growth policy implementation.[3]

2.4 Other research that quantifies built form

While the directly relevant literature at my disposal when designing my research plan unearthed no proven and accepted approach that I could implement to achieve my goals, I did find that many researchers had created neighbourhood-level built form indicators using spatial data. Although the scale was inappropriate for my needs, there did not appear to be anything preventing me from using such indicators (adapted to the questions I was attempting to answer) and simply scaling them up to the municipal level.

Much of the substantial work that quantifies built form is intended to test the claims of New Urbanism and Smart Growth.[4] New Urbanism is largely a design-based approach to residential development, suggesting that we can create better communities by implementing many of the aspects of built form that characterize American small towns and successful inner city urban neighbourhoods. The task for researchers evaluating this development approach has been to formulate measures to capture the built form elements that are directly related conceptually to New Urbanist development. Frequently, measures that characterize "conventional" development are also needed in order to differentiate the two development types.

The following is a summary of how researchers in diverse fields have used spatial data to characterize the built form. Because research approaches and available data differ from researcher to researcher, a myriad different methods for characterizing built form have been proposed. Due to the vast volume of literature, the following is intended to be a representative rather than exhaustive summary of research on a particular theme. Subsequent sections will provide more detailed examples of how researchers have operationalized measures related to density, land use and the street network, three categories of variables frequently used to quantify built form.

2.4.1 The built form/transportation linkage

One of the most enduring and voluminous streams of spatial data-based research into the claims of New Urbanism is investigation into the relationship between built form and transportation choices.[5]

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[3] And of course, even had there been a control study area, the link between planning policy and development patterns remains speculative.
[4] I am considering New Urbanism to be a neighbourhood level implementation of Smart Growth, and will refer to "New Urbanism" alone from here on.
[5] More than 50 empirical studies have been carried out, according to an excellent review article by Ewing and Cervero (2001). See also (Badoe & Miller, 2000).

In such studies, researchers typically compare trip characteristics (among them: mode, length, frequency, order/combination) of residents of a New Urbanist neighborhood with those from residents of a “conventional” neighborhood. Researchers operationalize attributes of the built form along with travel data and, usually, a range of demographic variables in order to determine if travel choices are different in neighbourhoods whose built form is quantifiably different. A variety of statistical approaches are employed to identify elements of built form that significantly influence travel choices.

Cervero and Kockelman's Travel Demand and the 3 Ds: Density, Diversity and Design (Cervero & Kockelman, 1997) is one of the most influential articles in the genre, having been cited in at least sixty-six other works as of March 2006.[6] The article investigates the New Urbanist claims that compact, mixed-use development will reduce the number and/or distance of automobile trips. The data examined include trip characteristics along with demographic, land use, design and transportation supply data derived primarily from travel diaries, census information, and field surveys carried out in 50 neighbourhoods deemed to be representative of development styles extant in the San Francisco Bay area.

The density variable they employ includes population and employment density as well as accessibility to employment. Their diversity variable comprises seven different attributes to capture the dissimilarity and the intensity of uses as well as proximity to various uses. Their design variable establishes street and street network characteristics (among them: predominant pattern, proportion of four way intersections, number of dead-ends and cul-de-sacs), pedestrian and cycling environments, and site design attributes such as the positioning of parking lots.

Factor analysis produces an "intensity of development" factor and a "walking quality" factor that together explain more than 65% of variation in travel outcomes (47.6% and 17.9% respectively). These findings generally support New Urbanist claims that compact, pedestrian-friendly environments generate shorter automobile trips, more frequent non-motorized trips, and increased transit use. However, the overall influence of built form on travel demand is found to be relatively weak.

The study controls for socio-demographics, household and transportation characteristics and distance, but not the notion of self-selection that has split the transportation/built form research into two factions. Critics of Cervero and Kockelman contend that any difference in travel choices by people living in pedestrian or transit friendly neighbourhoods compared to those living in "conventional" neighbourhoods is a function of personal choice and not the influence of the built form (e.g. Boarnet & Sarmiento, 1998). This argument is based on the assumption that people will

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[6] This figure taken from a Web of Science “Cited Reference Search” for the article.

tend to move to neighbourhoods whose built environment facilitates their preferences. Those who prefer walking and cycling will seek out neighbourhoods with a high quality pedestrian environment and amenities within walking distance. Those who prefer driving will seek out neighbourhoods with excellent automobile access and parking.

The travel/built form issue is highly contested on both methodological and philosophical grounds. The quality of the research varies widely but remains a valuable resource for anyone seeking to quantify built form since each study in this body of work makes an attempt at capturing the most salient and influential aspects of the built form. As a result, the literature is rich with examples of built form variables and how they can be operationalized.

2.4.2 Accessibility research

Research into accessibility also entails analyzing and quantifying the built form. In broad terms, accessibility relates to the number, diversity and quality of non-residential destinations in a given area and the ease with which these destinations can be reached. Accessibility is therefore a measure of how the built form works, a function of the interaction among an area's density, street network and land use. There are many different ways in which accessibility has been defined and measured. Handy and Niemeier (1997) provide an excellent summary of the predominant conceptual approaches that have been used to study accessibility. They note that while accessibility is a longstanding concept in planning documents and literature, few attempts have been made to measure it in a sophisticated manner that incorporates what we know about how people make transportation decisions.

(Krizek, 2003) proposes a neighbourhood accessibility index to fill this gap. He summarizes the ways in which density, street network and land use have been operationalized in accessibility studies and outlines shortcomings inherent in some approaches. He proposes a very ambitious index that is designed to work at a metropolitan scale and uses readily available data to capture three elements of accessibility: density, land use mix, and street design.

Krizek's approach involves dividing the Puget Sound region into a grid of cells, with each cell corresponding to an area 150 meters per side. For each cell, he calculates values for three categories of attributes:

- Density: Census data are used to calculate population and dwelling unit density.
- Land use: Number of employees employed by businesses associated with areas of high accessibility, derived from census data and Standard Industry Codes.
- Street Design: Block size, as calculated using US Census Tiger files. Smaller block sizes are equated with higher accessibility.

To account for inter-cell influence, Krizek averages the values for cells within a quarter mile radius.

Simplicity makes Krizek's approach appealing: it promises the ability to easily assess the accessibility of a metropolitan area with very simple variables derived from readily accessible and inexpensive data. The approach seems to have promise, but the limited number of variables suggests that the results will be broad and generalized. I have additional reservations about this work, however. The first concerns the land use variable, which is exclusionary and based on an unproved assumption. Krizek's decision to map only businesses "considered to be representative of areas with high accessibility" is akin to the now-discredited intelligence tests that asked respondents for definitions of certain seldom-used words because intelligent people tended to know what those words meant. No evidence is provided to back the assumption that the selected businesses are a viable proxy for all land use patterns.

Krizek's approach would seem much more robust had a defensible validation procedure been used. Krizek asks a panel of urban-focused academics to evaluate several neighborhoods and assign them accessibility scores from 1 to 6, based on aerial photographs and the local knowledge of the panel members. This approach will only reinforce assumptions about accessibility and activity, and may overstate the theoretical accessibility of popular/busy locations and understate the accessibility of unpopular places. Krizek thus repeats his land use variable error by saying that the most accessible neighbourhoods are those that experts think are the most accessible. Rather than using the speculation of experts, Krizek should have attempted to validate his work by determining if the theoretical accessibility he calculates with his index is corroborated by real world activity. As it is, may only have created an automated method to reproduce commonly held perceptions about accessibility.

Nonetheless, while not the breakthrough that Krizek intended, his approach is a useful first step that can easily be made more sophisticated.

2.4.3 The built form/health linkage

Research into the impact of built form on human health is quite similar in concept to research into the transportation/built form linkage except that the activities being studied are walking and cycling rather than automobile or transit use. The overall approach remains the same, typically measuring activity in both a sprawling, conventional neighborhood and a New Urbanist or traditional neighbourhood. As one would expect, this literature employs many of the same variables as the built form/transportation literature, including the pattern of the street network, the size of blocks and the accessibility of amenities. In addition, however, it introduces variables that are thought to significantly influence health-related activity such as the presence of bicycle lanes, the width of sidewalks and the quality of the pedestrian environment.

Handy, Boarnet, Ewing, & Killingsworth (2002) provide a useful summary of how planners and academics have quantified the built environment in order to study its relation to physical activity. Sample measures are categorized by the characteristic they represent: density/intensity, land use mix, street network connectivity. The goal is to focus on built form attributes that are thought to influence people's decision to walk to a destination:

- Density measures include the expected population density and the ratio of commercial floor space to land.
- Land use measures include the distance from houses to the nearest store, the proportion of land dedicated to non-residential purposes, and dissimilarity indices (as seen in Cervero, above).
- Connectivity measures include intersections per unit area and the ratio of straight-line distance to network distance. The latter is designed to highlight street networks with poor connectivity and networks characterized by highly curvilinear streets that discourage walking trips.
- The street scale of the pedestrian environment is captured by the ratio of building heights to street width, and the average distance between the street and buildings (areas with small setbacks are though to provide a better pedestrian environment).
- The percentage of ground in shade at noon, and the number of locations with graffiti are intended to capture the aesthetic qualities of the pedestrian environment.

These measures reflect a common-sense approach to understanding why people choose to walk to a destination, although "common sense" often consists of untested assumptions. In this case, the assumptions are that "destinations" must exist for people to walk to them (captured by land use measures), that the pedestrian infrastructure must exist and be efficiently laid out (captured by connectivity measures), and that the pedestrian environment must be attractive (captured by scale and aesthetics measures). The reliability of the measures would seem to decrease in the order they have been listed, with the latter being somewhat controversial. While shade, for example, is equated with trees and "great streets" in sophisticated cities, it is also associated with danger and crime. Meanwhile, some of the most heavily used and popular pedestrian environments have many "graffiti locations."

This research, and to a lesser extent that of Krizek and other accessibility researchers, sets itself a major challenge in attempting to understand and ultimately predict human behavior based on a very small number of built form measures. For my purposes, however, the built form/health literature is a useful source of ideas for characterizing the built form because it considers elements that other streams of research do not.

2.4.4 Built form analysis

There is a small body of work that analyzes elements of the built form in order to understand urban growth patterns. Much of this work consists of metropolitan scale studies that measure sprawl, although there are some instances of neighbourhood-level studies of built form. In one such study, Bagley and Mokhtarian (2002) argue that a binary characterization of neighbourhoods as being either "traditional" or "suburban" is inaccurate. They hypothesize that instead of two neighbourhood types, there is a continuum, with traditional urban neighbourhoods (i.e. those built before World War II) at one extreme and conventional (i.e. postwar) suburban neighbourhoods at the other.

To test their hypothesis, the authors evaluated five San Francisco neighbourhoods for various built form elements. Data were from pre-existing surveys of neighbourhood residents along with field surveys. The measures are generally indirect, with survey questions acting as proxies for more conventional built form indicators. For example, the number of available parking spaces for a given household is used as a proxy for density. In all, eighteen measures were used.

A principal component analysis necessitated that the hypothesis be rejected. The authors expected a single "traditionalness" component to emerge and thus define one end of the built form continuum. Instead, they found that there were two different dimensions at play in the form of a "suburbanness" component that was not simply the opposite of the traditionalness component. Each neighbourhood, in other words, displayed both traditional and suburban characteristics. Neighbourhoods, therefore, should be defined according to both their traditionalness and their suburbanness. The implication is that there are shortcomings involved with characterizing neighbourhood type according to a classification or on a single-axis continuum with "traditional" at one extreme and "suburban" at the other.

While the article is an interesting attempt at evaluating neighbourhood characteristics, it has several shortcomings. One is the small set of attributes. There is, for example, only a single variable related to density: population density. In addition, many of the variables are binary, which reduces accuracy when comparing neighbourhoods. Population density, for example, is either "high" or "low." It is likely that some inaccuracy creeps in each time a survey question designed for a different purpose is used as a proxy for an element of the built form. Finally, the wording of the survey questions themselves is quite unsophisticated (e.g.: "Cycling is pleasant in your neighbourhood?"), casting doubts on the reliability of the data.

Chapter 3
Quantifying Built Form Attributes

Regardless of the approach or the phenomenon being investigated, research that quantifies the built form at a micro-level tends to employ measures that belong to one of three categories: density, street network organization and land use. In the following sections, I will discuss each of these categories, outlining the rationale for their use as defining elements of the built environment and how researchers have operationalized them.

3.1 Density

Every examination of the built form includes at least one measure of density. From the start of the Industrial Revolution, the notion of density has been inextricably joined (and frequently conflated) with the notion of cities as a result of overcrowding and consequent health implications for residents of large industrial cities. Density was equated with congestion, squalor, and disease. Even into the 1960s, "density" was understood to be shorthand for "excessively high density". Jacobs (1961), for examples, uses "concentration" instead of the heavily freighted "density." Density is of course still a concept that elicits strong responses, although for entirely different reasons than it did in the distant past (i.e. increased noise and traffic congestion rather than overcrowding and disease).

The most traditional density measure is population density, which measures the number of people per given area. In the past, geographic census units (tracts, typically) have been the "given area", with the result being labeled gross density. With an increasing amount of research taking place at other-than-census-tract scales, gross density has come to have multiple definitions. Instead of including all land in a given area, gross density may, for example, exclude "hazard lands, expressways, arterial roads, and other major utility corridors" (Gordon & Vipond, 2005).

Net population density is sometimes used as well. It measures the population density only for land in residential use, although as with gross density, the definition of what kind of land qualifies as "residential" can be fluid. Regardless, both are expressed as persons per given area measurement, typically square miles or square kilometers. Many studies use dwelling density as a counterpart and contrast to population density (e.g. Bunting, 2004; Burton, 2002). However, using dwelling or household density can restrict analysis to larger census units, as dwelling counts are suppressed or incomplete at smaller census units like Dissemination Areas.

Density measures are often used to differentiate between development types, typically to determine the presence or extent of "sprawl". Ewing, Pendall, & Chen (2003) use gross density to create measures identifying the percentage of people in a study area living at low densities (1,500 per square mile) and the percentage of people living at moderate to high densities (12,500 per square mile), defined elsewhere as “the lower limit of density needed to support mass transit” (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). A useful addition here might have been floor area ratio (Handy, Boarnet, Ewing, & Killingsworth, 2002; Moudon, Hess, Matlick, & Pergakes, 2002), the ratio of floor space to parcel area. Unfortunately, built form analysis using spatial data is predominantly done in two dimensions. Greater use of proxies for building height, such as floor area ratio, would be beneficial.

Employment density is a rarely used measure in built form analysis. Partly this is because employment density is an indirect proxy for land use that can be measured more easily using point-based data that identifies businesses. In addition, employment figures are difficult to acquire in Canada. It is primarily in the accessibility literature that researchers attempt to capture the non-residential uses of a study area through an employment density measure, typically calculated as the number of jobs per given area. The total employment and land area of the census tract or other unit of measurement are used in calculating the value.

3.2 Street Network Organization

Particularly since New Urbanism came to prominence in the late 1980s, the geometry of street networks has been a focus of built form studies. Many of the goals of New Urbanism derive from the configuration of the street network while the cul-de-sac and the curvilinear street have become iconic of conventional development. Thus any recent examination of built form must characterize the nature of the street network as being grid-like (or “traditional”) or conventional. That said, a case could be made that our current methods of analyzing the street network can be traced back to *The Death and Life of Great American Cities* (Jacobs, 1961). In that book, Jacobs argues for a grid pattern of streets and small blocks in order to create high connectivity, facilitate economic development and allow for varied (and therefore less monotonous) routes from an origin to a destination.

The most common approach to characterizing street networks involves classifying intersections according to the number of road segments they connect. Pure grids will consist only of four-way intersections, and many studies use the percentage of intersections that are 4-way intersections as an indicator of how grid dominated the street network is (e.g. Boarnet & Sarmiento, 1998; Cervero & Gorham, 1995; Filion & Hammond, 2003). Enumerating the number of cul-de-sacs and dead ends in a study area (Cervero & Kockelman, 1997) achieves the same goal, allowing the researcher to categorize a particular street network as grid-like/traditional or curvilinear/suburban. Route directness—a comparison between “network” or road distance and “as the crow flies” distance—can also be used to describe the nature of a street network (Hess, 1997; Lee & Ahn, 2003), with the ratio of network distance to direct distance being much higher in areas with looping, curvilinear streets and much lower in areas with a grid-based, small block street network.

Many attributes of blocks are used as indicators of street network characteristics, such as average block length, the percentage of “small” blocks (smaller than 0.01 square miles) and average block size (Ewing, Pendall & Chen, 2003). Similar data are captured with measures of median block perimeter (Song, 2005) and intersection density—the number of intersections per given area (Owens, 1993; Southworth, 1997).

It is thought that the quality of the pedestrian environment plays a role in travel mode choice, based on the assumption that factors other than distance affect people's decisions about when, where and if they walk or cycle. Cervero and Kockelman (1997) developed measures to assess the quality pedestrian and cycling environments of an area. These measures include:

The proportion of blocks with sidewalks, planting strips, trees, overhead lights, bike lanes, and mid-block crossings as well as the proportion of intersections with signalized controls.

- Slope.
- Distance between streetlights.
- Bike lanes per developed acre.

Unfortunately, the majority of these measures are rarely available in digital format. For this reason, comparative testing and municipal or metropolitan level testing would be near impossibilities. Apart from field surveys, the most common solution to this problem is to reverse the equation and look for areas that privilege automobile use and therefore tend to be “pedestrian unfriendly”. This is possible because digital street networks are used for numerous purposes (e.g. routing logistics, business location etc.) and are both highly detailed and widely available.

Srinivasan (2002), for example, implements a number of measures that indicate automobile dominant/pedestrian unfriendly areas, such as:

- Proportion of controlled access roads.
- Proportion of roads with speeds over 30 mph
- Proportions of intersections that meet a highway/ramp
- Proportion of local roads.
- Average cul-de-sac density.

- Proportion of roads that are cul-de-sacs.

3.3 Land Use

In the current literature, land use is most thoroughly studied in accessibility research since half the equation in accessibility deals with the attractiveness of destinations, although the more detailed transportation research also tends to work at this level. While examining the influence of built form on travel decisions, Cervero and Kockelman (1997), for example, take pains to establish the diversity of uses in the study area by looking at the proportion of dissimilar land uses and calculating entropy measures for the study area. Other measures designed to capture diversity include the proportion of commercial or retail sites with more than one land use category on site. The authors also implement proximity measures, such as the proportion of developed acres within ¼ mile of convenience stores or retail/service uses, as well as the proportion of residential acres within ¼ mile of convenience stores or retail or service uses.

Calculating the distance from households to destinations is probably the most common method of assessing land use. Researchers use one of two strategies: measuring mean distances from origin to destination, or calculating the number of origins (typically households) within a given travel time or travel distance of a destination. How the measure is implemented is frequently driven by the available data. If, for example, the researcher has no access to individual parcel data (i.e. building lots), block centroids are used as the origin points for calculations and only the first of the two strategies above (calculating mean or median distance) is possible. If parcel data are available, both methods can be used.

While parcel or origin data can be difficult or impossible to acquire, there is usually greater flexibility regarding destinations such as retail locations, transit nodes, parks, and schools. Business locations, in particular, are quite widely available in digital format because this information can be used for many purposes and is therefore frequently compiled and updated by private data vendors as well as some public bodies. Non-business destinations are far less widely available because there is little commercial value in digital data regarding community recreation centres or places of worship, for example. In general, however, the task of the researcher is to decide which of the thousands of possible types of destinations accurately capture the character of land use in the study area.

Despite the wealth of possibilities, most researchers use a very small number of origin/destination variables, frequently only a single measure per land use type. Lee and Ahn (2003) use mean distance to shopping centers, elementary schools and parks. Ewing, Pendall, & Chen (2003) use a similar approach, measuring the percentage of residents that have:

- Businesses or institutions within ½ block of their homes

- Satisfactory shopping within 1 mile.
- A public elementary school within 1 mile.

The method of establishing distance can have a major impact on calculated values and obviously the network distance should be calculated whenever possible (Handy and Niemeier, 1997).[7] Due to the simplicity of calculating network distance with a GIS, this point is almost not worth mentioning. However, there remains a largely unacknowledged methodological shortcoming of distance-based calculations in literature that examines built form from a pedestrian or cycling point of view. Walking paths, whether planned or organic in origin, are almost never considered because they are absent from most street network spatial data files since they have little commercial or practical value. Walking paths are meaningless for business location analysis, for example, and they carry no vehicular traffic, making them irrelevant for most automobile, truck or transit purposes. While it is therefore understandable why spatial data vendors exclude paths and walkways, it is disappointing that much neighbourhood level built form analysis fails to address this as a shortcoming.

The failure to consider the impact of paths and walkways on street network connectivity will disproportionately affect study areas with a conventional suburban street pattern. Paths that link streets and schools are common in conventional areas (Randall & Baetz, 2001), but rare in areas characterized by a grid-based street network, where connectivity is inherently higher and internal pathways less necessary. By using paths, pedestrians and cyclists may be able to significantly reduce their trip distance compared to following the street network. Particularly in studies that analyze relatively small geographic areas, the failure to consider paths and walkways is problematic, to say the least.

Many researchers examine land uses directly rather than measuring their distance from households or catchment areas. The measures they implement are intended to capture the diversity and/or texture of the study area and are derived by analyzing the number, type and location of land uses within the study area. A frequent approach is to divide the study area into grid cells and compare land use values between each cell and all adjacent cells (e.g. Cervero & Kockelman, 1997), although the same approach can be used with other study units, such as Transport Analysis Zones (Srinivasan, 2002). From inter-cell comparisons, it is possible to assess the dissimilarity, entropy and texture of the urban fabric. Usually these are in the form of simple indices, although these data are amenable to spatial analysis.[8] These measures characterize relatively large geographic areas with a few values and

[7] The alternatives to using network distance are: using straight-line distance to determine mean distance from an origin to a destination, or to draw a circle with the destination as its focus and count the number of origins within the perimeter.

[8] Tsai (2005) uses spatial statistics to measure sprawl and compactness

generally work with broad land use types (e.g. “residential” or “commercial”) and are therefore most useful in understanding metropolitan-level structure.

To understand local or neighbourhood-level built form, more detailed variables are constructed. Instead of having a land use type identified as “residential”, for example, research at the neighbourhood-level will break this down into different types of residential uses, and the same applies for other land uses. Burton (2002), for example, uses a number of relatively complex and fine-grain measures to capture diversity:

- The number of “key” facilities (defined as newsagents, food places, takeaway, grocery, bank, drug store, clinic) per 1000 residents.
- Horizontal mix:
- Percentage of postal code sectors with fewer than 2 key facilities; percentage with 4 or more; percentage with 6 or more; percentage with all 7).
- Variation in the number of facilities per postal code.
- Variation in the number of facilities per postal code divided by the average number of facilities per sector.
- Vertical mix:
- Percent of retail space that includes accommodation.
- Number of purpose built flats in commercial buildings as a percentage of all purpose-built flats, giving a commercial/residential mix.

To complete the picture of urban texture, she also differentiates housing types by creating measures that establish the percentage of higher density dwellings, lower density dwellings (attached and single family homes) and small dwellings with few rooms (1-3) and with many rooms (7+). As with most of the measures discussed, these may have been implemented because data were available rather than because they accurately capture a certain dimension of the built form. For this reason, we need to use caution in employing built form measures derived from spatial data for explanatory or predictive purposes.

Chapter 4
New Urbanism and Markham

The focus of my research is the Town of Markham, a municipality chosen because it is home to several communities that were (and are) being built in a manner largely consistent with the principles of New Urbanism, an unconventional, design-based development philosophy. This alone differentiates Markham from most other municipalities and makes it worthy of study. Many municipalities may claim that they support New Urbanist or Smart Growth development principles, but in very few is there evidence on the ground.

More importantly, in the early 1990s, New Urbanism became the over-arching development philosophy for all of Markham and has remained so until the present. The adoption in 1991 of a New Urbanist approach to guide the development Cornell had implications beyond this single project; it represented a fundamental shift by the municipality and planning department. Although ostensibly related only to Cornell, New Urbanist principles began to inform the municipal development philosophy. Fairly strong development instruments were created to implement this philosophy, such as the Cornell Secondary Plan in 1995, and a New Urbanist zoning by-law in 1997. And at present, a large “suburban downtown” called Markham Centre is being planned along New Urbanist lines. Over the fifteen years of its New Urbanist era, Markham’s planning department has been supported by Council and two mayors (Markham planner, personal interview, 2004). Finally, Markham’s commitment to a New Urbanist-inspired development approach has been reaffirmed on two occasions by the emergence of legislation that implicitly calls for unconventional development. Both the Oak Ridges Moraine Protection Act of 2001 and Ontario’s Places to Grow (2005) reduced the amount of developable land in Markham. Like all municipalities, Markham must plan to accommodate population increases as specified by the province and they feel that their New Urbanist approach is a useful mechanism to achieve this goal (Markham planner, personal interview, 2004).

The result, surely, is quite uncommon: Markham is a municipality that has had for the past fifteen years a unified development vision shared by its planning department, its council and its mayor. Further, Markham has had the resources, the organizational capability and the opportunity to implement its vision, thanks in part to booming population in the Greater Toronto Area and a generally positive economic climate. In short, Markham planners have had a nearly ideal set of circumstances in which to operate and thus the municipality makes an ideal study area.

In the following sections, I will provide brief overviews of New Urbanism, the Town of Markham and its adoption of New Urbanism, and the control study site, the City of Vaughan.

4.1 New Urbanism: a brief overview

New Urbanism is a development philosophy created in the 1980s as an alternative to the "conventional" development approaches that have been predominant in North America throughout the entire post WWII era. In particular, New Urbanism is critical of suburban development practices, claiming that conventional approaches have created communities devoid of interest that necessitate automobile use, and erode civic and social life (Duany, Plater-Zyberk, & Speck, 2000).

As a solution for these ills, New Urbanists such as Andres Duany argue that it is possible to create developments with a sense of place that will facilitate social and civic engagement through the implementation of design, land use and infrastructure guidelines inspired by successful neighbourhoods in American cities and small towns of the early 20th century. Among the attributes that contributed to the success of these neighbourhoods, according to New Urbanists, are:

- Attractive pedestrian environments with high connectivity
- A mixture of compatible uses
- Coherent design and thoughtful placement of structures
- Provision for a variety of public spaces

The New Urbanist vision promoted by Duany is one of neighbourhoods approximately a half-mile in diameter, each containing schools, retail, parks, public buildings and other everyday destinations easily accessible via an attractive pedestrian environment.

New Urbanists supply a suite of infrastructure and land use prescriptions to create successful neighbourhoods, including:

- Ubiquitous sidewalks
- Houses with porches facing the street, and lane-based garages
- Using of narrow streets and small blocks laid out in a grid pattern
- Eliminating dead-ends and cul-de-sacs
- Facilitating walking and cycling through the use of dedicated pathways
- Placing of buildings as close as possible to sidewalks
- Encouraging a mixture of uses: retail, small business, services and so on

- Locating schools, parks, and other frequently used amenities throughout neighbourhoods to provide convenient access and add interest
- Implementing style guidelines and/or architectural design oversight
- Positioning public buildings in prominent places
- Including various kinds of public spaces: parks, playgrounds, commons, and squares

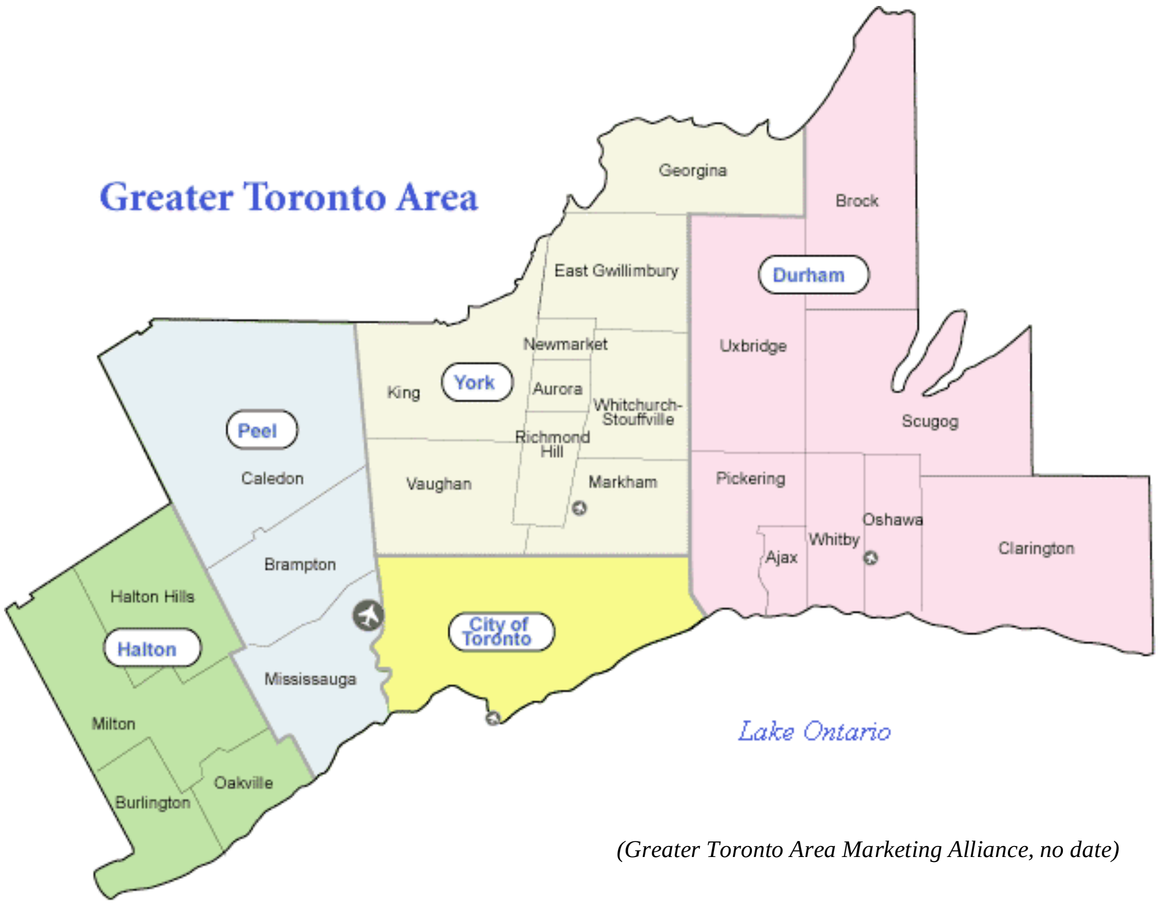
When originally presented in the 1980s, the New Urbanist philosophy was extremely well received, in part due to its media friendliness. It was a polarizing and controversial issue with a photogenic icon in Seaside, the New Urbanist resort town designed by Duany's company. Also part of New Urbanism's appeal was its seemingly miraculous promise to provide suburban environments that were more attractive, worked better and were more environmentally friendly than conventional developments. Tirelessly promoted by the charismatic Duany, New Urbanism quickly gained currency, with articles about it appearing widely in the mainstream press in the late 1980s and early 1990s (Katz, 1994).

New Urbanism was equally salient for planners and politicians, for whom New Urbanism must have been quite appealing because it promised to ameliorate a troubling problem—sprawl—with solutions that were concrete and largely within the purview of municipal planning. New Urbanist principles primarily involved zoning, land use, and transportation network layout: these are all "meat and potatoes" for practitioners. In a very short while, then, New Urbanism accumulated tremendous momentum, embraced by practitioners, politicians and the media for professional, political, environmental or ideological reasons. And unlike many issues in the public realm, this one had no compelling battle of viewpoints. With no visible opposition, no one to champion sprawl, the influence of New Urbanism grew unimpeded. In such an atmosphere, it is no surprise that New Urbanist principles "came to dominate late 20th century planning principles" (Grant, 2002), with many communities revising their policies and development philosophies to incorporate New Urbanist principles. One of those communities was the Town of Markham.

4.2 The Town of Markham

The Town of Markham is located at the southeast extremity of York Region, an area comprising several municipalities north of the former City of Toronto. Although it was at one time a discrete town, Markham is now contiguous with Toronto, with the border between them being a political symbol rather than a development demarcation. Like all areas that surround major cities, Markham has benefited from the employment, education, recreation and cultural opportunities offered by the adjacent large city. Markham's proximity to Toronto is undoubtedly the primary reason for its continual population growth, which has, in the period from 1971 through 2001, maintained an annual average increase of nearly 9% (York Region, no date).

Figure 4.1: Greater Toronto Area



(Greater Toronto Area Marketing Alliance, no date)

Markham is one of five municipalities that enclose the city of Toronto. From Table 4.1 below, it can be seen that Markham is relatively "successful". Its population is growing rapidly, and its income and educational attainment are the highest among any of the five enclosing municipalities. For all values other than total population, Markham exceeds those of Toronto and the province (Statistics Canada, 2004).

Table 4.1: Demographic comparison of GTA municipalities

Municipality	Population (2001)	1996 – 2001 Population Change (%)	Average earnings (worked full year, full time ($))	% of population aged 20-64 with a university certificate, diploma or degree	Foreign Born Population (%)
Markham	208,615	20.3	54,163	35.0	52.9
Vaughan	182,022	37.3	52.572	28.5	41.9
Mississauga	612,925	12.6	48,792	29.2	46.8
Brampton	325,428	21.3	44,100	18.2	39.9
Pickering	87,139	10.3	53,691	21.8	29.0
Mean	**283,226**	**20.36**	**40,160**	**26.5**	**42.1**
Toronto (city)	2,481,494	4.0	50,516	33.9	49.4
Ontario	11,410,046	6.1	47,299	23.7	26.8

http: www.statcan.ca

This is not to say Markham is exceptional; these are differences of degree, not of kind. Markham is subjectively little different from any of the other municipalities that surround Toronto and this is true as well for its historical approach to development. Until recently, Markham practiced a development approach that was absolutely conventional for a peripheral region, “aggressively expanding its commercial tax base, stressing single family detached homes and new roads” (Gordon & Vipond, 2005). But in the late 1980s and early 1990s, a possibly unique set of circumstances led Markham in a planning direction—one inspired by New Urbanism—that was very different from those of the other municipalities surrounding Toronto.

4.3 Markham’s adoption of a New Urbanist development philosophy

Markham’s eventual adoption of New Urbanism had its origin in a provincial plan set in motion in the 1970s. The plan’s goal was to create a community of 200,000 residents in north Pickering and east Markham, adjacent to a proposed new international airport (Ontario Ministry of Municipal Affairs and Housing, 2006). Neither the airport nor the new community were built, freeing up for development nearly one thousand hectares of land in Markham (Thompson-Fawcett & Bond, 2003). The province formed a partnership with Markham, offering planners and politicians the rare opportunity to design and build a community from scratch on publicly owned land. The mandate of the partnership between Markham and the province was to:

- Create a new, compact urban form

- Provide affordable housing
- Diversify Markham's housing stock (Markham Council, 1994; Thompson-Fawcett & Bond, 2003)

The initial and largely conventional proposals for the Cornell lands were not well received by the public, leading Markham to investigate the possibility of taking a New Urbanism approach (Gordon & Vipond, 2005). New Urbanism was at its most visible at this point in the early 1990s and offered potential solutions to problems that were priorities for both Markham and the province: sprawl and traffic congestion. It was an obvious step to bring in Andres Duany, the face of New Urbanism, to give a presentation that was funded by the province (Thompson-Fawcett & Bond, 2003). Given Duany's reputation as a charismatic speaker, it is not surprising that the presentation was a success that truly put the wheels in motion—and got his firm, Duany Plater-Zyberk and Associates (DPZ), hired to create the Cornell master plan.

As per standard New Urbanist practice, DPZ and NORR Limited, a Toronto-based design firm included in the project, held several "charettes" (Gordon & Vipond, 2005). Charettes are intensive stakeholder meetings or workshops that can last several days. The rationale is to include all stakeholders (ratepayers, builders, politicians, interest groups and so on) early in an attempt to iron out problems that would otherwise not appear until much later in the process and with possibly dire consequences for timelines and budgets. As well as being a proactive conflict resolution mechanism, charettes are intended to build consensus over design goals. Their object is to "produce results on paper in the form of drawings and plans. The object is not to produce verbiage" (Kunstler, 1996).

The charettes were wildly successful, energizing "the citizens, planners, and Council, few of whom had any experience with New Urbanism" (Gordon & Vipond, 2005) and resulting in a standing ovation for the final plans as presented by Duany (Gordon & Vipond, 2005). Subsequently, the province funded the many studies that were carried out as part of the effort rework Markham's development guidelines. In the end, New Urbanist development principles were included alongside the corresponding conventional principles, with a secondary land use plan for Cornell receiving final approval in 1995 and being implemented as a legally binding amendment to Markham's Official Plan (Thompson-Fawcett & Bond, 2003). Shortly after, the newly elected Harris government withdrew its participation and sold the Cornell lands to a private developer (Thompson-Fawcett & Bond, 2003). Although that developer subsequently went bankrupt, construction by other builders has continued through to the present.

The Cornell Secondary Plan was intended to implement regional and provincial development goals and reflects many of the principles of New Urbanism that were increasing becoming adopted as planning best practices. The stated land use objectives for Cornell illustrate this well:

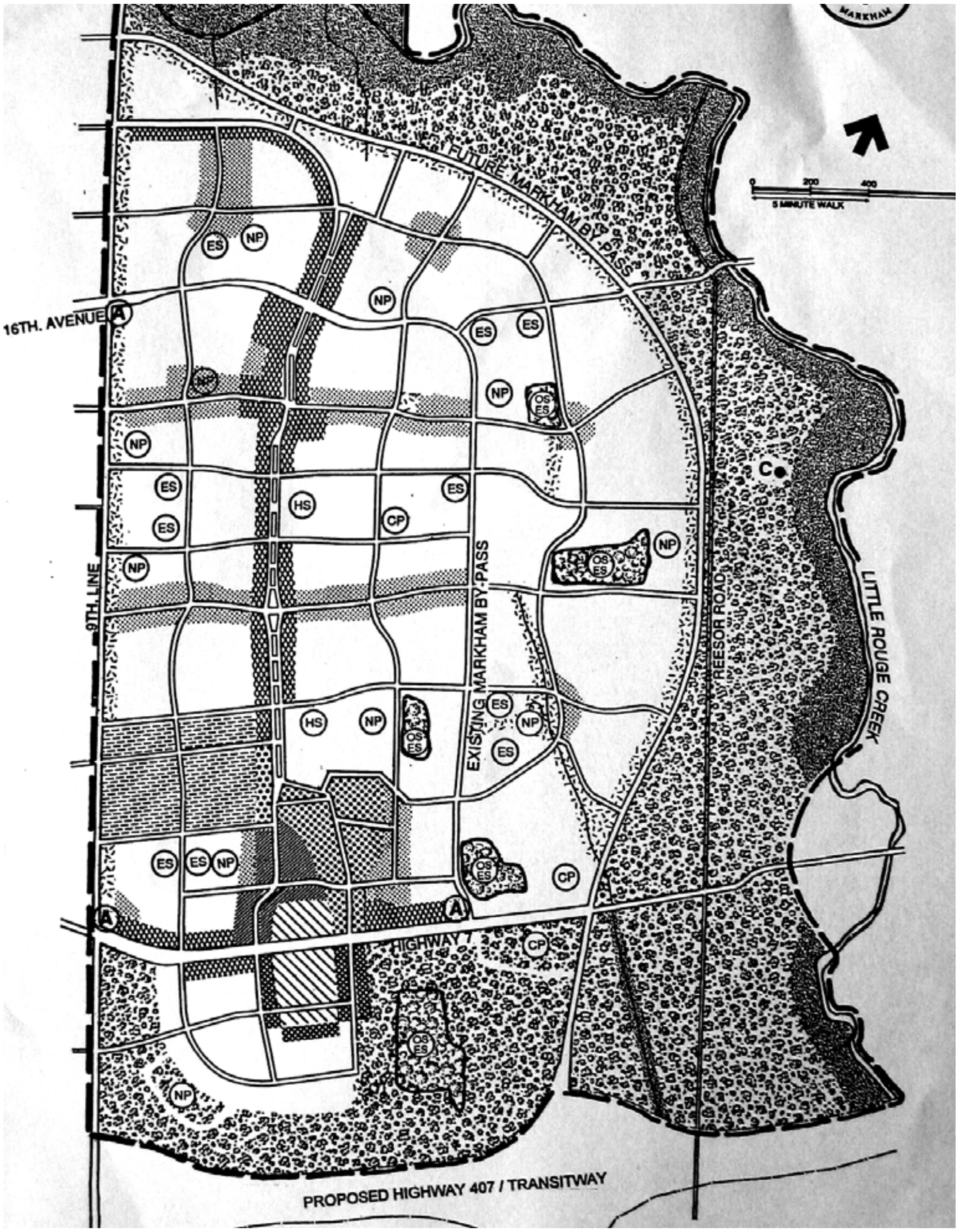
> To create a balance, pedestrian-oriented community comprised of residential neighbourhoods and mixed use and functionally specialized districts, that provide opportunities for a variety of housing types, employment and retail/commercial uses and community facilities (Markham Council, 1994).

The same is true for the transportation objectives, which include the creation of an "inter-connected network of streets", "development densities...sufficient to support desired levels of public transit service" and to "encourage transit use by locating 85% of the population within a 5 minute walk (400 metres) of an identified transit stop" (Markham Council, 1994). The street network was to be based on a modified grid pattern.[9]

Per New Urbanist principles, Cornell was designed to be a community of neighbourhoods, each of which having a "neighbourhood centre that is a focus for compatible commercial and public uses" (Markham Council, 1994). Neighbourhoods were to be defined by some form of public space, such as a park, and be approximately 400 metres from centre to edge. The central area of the neighbourhoods was "intended to accommodate higher density building forms and mixed use buildings to contain a specific range of convenience retail, personal service and business activity" (Markham Council, 1994). In keeping with the New Urbanist emphasis on pedestrian access, elementary schools were to be part of each neighbourhood. Finally, in order to make Cornell an "economically vibrant" community, the plan called for a central corridor to become Cornell's "main street". Shown running north/south in Figure 4.2 as a boulevard with a median, it was planned to include higher density residential development and mixed retail uses.

[9] "Modified" grids are those in which streets are occasionally curved or "bent" between intersections, typically to create visual interest and define the space.

Figure 4.2: Cornell land use plan



Elementary schools are indicated as "ES", with high schools appearing as "HS". Neighbourhood and community parks are indicated by "NP" and "CP", respectively. (Markham Council, 1994).

The Cornell master plan was very ambitious in attempting to create a very pure version of a New Urbanist community, one that reflected the goals of the movement better than resort towns like Seaside. The degree to which the project succeeded in reaching its goals depends on the evaluator. One study finds that Cornell scores well on implementing the physical, social and procedural aspects of New Urbanism but fails on economic aspects (Thompson-Fawcett & Bond, 2003). Conversely, in the same report, Jeff Speck, an employee of DPZ (Duany's design firm that played so large a role in Cornell's development) describes Cornell as a disappointment, while an architect says Cornell is a "pale version" of what was intended (Thompson-Fawcett & Bond, 2003).

Figure 4.3: Cornell street with front-loading garages, no sidewalks

Although Cornell is a relatively large New Urbanist development, it is possible to walk all its streets in a couple of hours, an exercise that amply displays the attributes that cause both negative and positive reactions. New Urbanists like Jeff Speck would be disappointed that several tenets that are fundamental to New Urbanism have been violated in Cornell. Some streets have been built with front-loading garages, for example, rather than being lane-based. Worse from a New Urbanist perspective, these streets also lack sidewalks. These practices reinforce automobile dependence and reduce the possibility of social interaction in public space that is strongly emphasized in New Urbanism.

Figure 4.4: Varying adherence to New Urbanist porch design principles in Cornell

Similarly, the version of New Urbanism promoted by Duany calls for small setbacks and houses with front porches where occupants can pass the time in public space and interact with their neighbours who are, it is hoped, using the ubiquitous and pleasant pedestrian network. In Cornell, it appears that many developers viewed the need for a porch as purely a design consideration without understanding the intended social role of the porch. Therefore, while there are many examples of houses with porches that New Urbanists would consider adequate, there are also a great many houses with porches that are far too small to serve any social purpose.

The greatest disappointment in Cornell is the failure to implement a mixed use main street. Its omission removes activity generators such as retail and service outlets for day-to-day activities. As a result, pedestrian activity is far lower than it might have been (again, with detrimental social impacts) and automobile use is increased. Also removed from the community are the presumably affordable rental accommodations that would likely have been built above the ground floor retail. Main streets can also be important in creating an identity for a place along with a sense of community, through everyday use and as sites of public events.

Figure 4.5: Cornell's failed "main street"

Unfortunately, this is not the case in Cornell, where the failed main street (Country Glen Road) in fact detracts from the community. Although it has only a single use, a school, on its west side, the road is still scaled for use as a main street. Its primary purpose now is as the main north-south thoroughfare through Cornell, on which cars sail uninterrupted at speeds that match the scale of the street, not the posted limit.

Street scale is another aspect where Cornell fails to adhere to New Urbanist principles. In addition to Country Glen Road, the two roads in Cornell that intersect with Number 9 are built to conventional suburban scale and may in fact be even wider than usual since they contain medians. The width of these streets and the resulting high speed of vehicular traffic severely diminish the quality of the pedestrian environment. Giant intersections are created where these streets meet others and are made significantly less pedestrian-friendly through the use of gentle curb radii that enable cars to turn corners at much higher speeds than more tightly radiused curbs would have allowed.

Figure 4.6: Oversized road in Cornell diminishes quality of pedestrian environment

One final flaw, from a New Urbanist perspective, is the failure to implement Cornell as a grouping of interconnected neighbourhoods. Instead of several smaller areas centred around schools, Cornell is simply a large development with only a single school; there are no “neighbourhoods”, per se. But the individual houses are designed to a higher than normal standard for their price range, and there is diversity in style and dwelling type that is uncommon. Certainly the lane-based parking is unusual, and the pedestrian environment found in internal streets is far superior to that found in conventional development. The public spaces are generally abundant and located throughout Cornell, whereas in conventional development, the only public spaces tend to be unwelcoming and barren places on the periphery of the development—moats, more than parks.

Figure 4.7: Extremely wide intersection in Cornell with automobile-friendly curb geometry

Due to its lack of neighbourhoods and its failed main street, Cornell fails to become the new kind of settlement it was planned to be. It remains simply a better-designed suburb, something that may disappoint some commentators but which has been popular with consumers. Houses in Cornell have sold briskly and continue to do so, and extensive construction on Cornell's periphery illustrates that builders are confident that there remains a substantial market for this kind of development. Although it fails to adhere closely to New Urbanists principles, Cornell may still represent a positive step if it is representative of a new kind of development that can work at much higher gross densities (Gordon & Vipond, 2005) and have the potential to be more environmentally sustainable than conventional suburban development (Berke et al., 2003).

Chapter 5
Research Design

The goal of this paper is to determine what influence, if any, planning has on residential built form. More specifically, I am asking if Markham's adoption of a development philosophy based on New Urbanism has resulted in measurable changes in the built environment. This stated, it is necessary to define terms and formulate basic assumptions, such as what is a "development philosophy", when was it adopted, and what are the study areas and how were they selected.

5.1 Development philosophy

As I alluded to earlier, Markham's experiment with New Urbanism was and is much more than the single project of Cornell. My interpretation of events past and present is that when Markham decided to proceed with a New Urbanist approach to developing Cornell, it changed its municipal worldview or philosophy on development. Further, this shared development worldview has been consistent and evident through to the present. Shortly after the Cornell secondary plan was integrated in the Markham's official plan, for example, the municipality introduced an "urban expansion" by-law to govern development across the municipality. The motivation was to create a new zoning framework incorporating "numerous innovative standards and provisions to implement the 'new urbanism' inherent in Markham's adopted vision of Cornell" (Markham Planning Department, 1996). More recently, the ongoing planning and design for Markham Centre, a proposed new downtown for the municipality, have been guided by the same New Urbanist principles that informed the Cornell master plan and the urban expansion by-law.

The continuing and consistent commitment to, and implementation of, a set of principles over a period of more than fifteen years qualifies Markham's New Urbanist approach as a philosophy. As a result, it is possible to at least cautiously make causal links between planning and outcomes in Markham. Put another way, it means that planning in Markham can be isolated as an independent variable much more defensibly in Markham (because of its consistent application of New Urbanist principles) than in municipalities lacking an overarching development philosophy. At the same time, the existence of a development philosophy in Markham means that built form analysis can take place at a municipal scale. In a municipality without a development philosophy, analysis would logically be limited to the implementation of individual projects.

5.2 Time frame

Because the areas being studied in this research are identified using census data, timeframes for the "early" and "recent" study periods were constructed according to census dates. The Cornell Secondary Plan, drafted in 1994, was the first tangible product of the New Urbanist development philosophy. It was incorporated into Markham's Official Plan in 1995, which can be seen as the official start of the New Urbanist period in Markham (although "unofficial" adoption took place several years earlier). The recent study period therefore begins at the next census date, 1996 and includes all development up to the present. I have labeled the period "1996 to 2003" since the largest spatial data files used in the study (identifying individual building lots) represent development as of 2003.

The early study period includes development carried out between 1981 and 1995. Here too, census dates were the limiting factor, with the options for the start of this period being 1981 or 1991. The former was selected to equalize the amounts of development in both study periods.

5.3 Study areas

A problem inherent in examining development in one geographic location over two different eras is that contexts and influences change over time. Economic, social and political conditions can change rapidly and all of these can affect development and how it takes place. This can make inter-era comparison unreliable. It is therefore beneficial to examine contemporaneous development in a second location. This of course injects new unknowns into the equation because the second site will have its own unique circumstances, but choosing an appropriate second or control site can minimize the differences.

For a control site, I selected Vaughan, a municipality to the west of Markham that is quite similar in many of its broad characteristics to Markham. Both municipalities have experienced rapid population growth in the last thirty years as a function of their proximity to Toronto. Both have major highway and rail connections to Toronto and the United States. They are relatively similar in size, and crucially, both are part of York Region, meaning that they share the same regional and political context. Finally, the development philosophies of Markham and Vaughan have diverged dramatically. While Markham in the early 1990s was seeking a new mode of residential development, and would eventually adopt an unconventional approach inspired by New Urbanism, Vaughan was content maintaining the status quo:

> Vaughan's existing residential neighbourhoods have been designed and built principally in response to the preferences of the marketplace and have emerged as stable environments which meet the needs of Vaughan's residents very well. Appropriate planning measures are needed to ensure that the integrity of these

> neighbourhoods is protected while future growth is accommodated (Vaughan Planning Department, 1990, in Vaughan Planning Department, 1991).

Table 5.1 illustrates that the two municipalities are quite similar apart from Markham's having a much higher visible minority population as well as a much higher proportion of rented dwellings.

Table 5.1: Markham/Vaughan demographic comparison

Attribute	Markham	Vaughan
Population (2001)	208,615	182,022
Land Area (square km)	212.47	273.3
Density (Persons per square km)	981.8	665.5
1996 – 2001 Population Change (%)	20.3	37.3
Visible minority population (%)	55.5	19.0
Average earnings (worked full year, full time ($))	54,163	52,572
Unemployment rate	5.4	4.0
Lone Parent Families (% of all families)	11.5	8.4
% of the population aged 20-64 with a university certificate, diploma or degree	35.0	28.5
Foreign Born Population (%)	52.9	41.9
Average gross monthly payments for rented dwellings ($)	1,280	1,265
Rental dwellings (% of all dwellings)	12.8	7.7
Average value of dwelling ($)	306,493	320,999

(2001 Community Profiles, Statistics Canada)

The latter at least partially accounts for Markham's higher gross density. Unfortunately, no net density figures are available. These would be much more informative, given that both municipalities still have significant amounts of undeveloped land included in their total land area. While there are some demographic differences between the two municipalities, they are not enough to place Markham and Vaughan at opposite ends of the spectrum. This is best illustrated by the average earnings statistic, which is essentially identical for the two. Earnings is a crucial statistic because the residential landscape is largely organized according to the income of its residents. Suburban areas with high income levels, for example, will generally feature very low densities and be dominated by detached, single family dwellings. Vaughan's earnings and unemployment statistics, therefore, make it much more viable as a control than Oakville, a GTA municipality where average earnings are some 35% higher than in Vaughan at $70,742 (Statistics Canada, 2005).

As with Markham, I will be studying development in Vaughan over two time periods: from 1981 to 1995 and from 1996 to 2003. With the resulting four municipality/era combinations, a number of useful comparisons can be made. First, development patterns in Markham can be examined to determine if there is a discontinuity between the earlier and the more recent periods. If a discontinuity *is* found, then planning may have been influential. Performing the same "between-eras" or intra-municipal comparison in Vaughan will control for contextual influences and help isolate planning in Markham as an agent.

A second set of comparisons will be carried out between municipalities for a given time period. Comparisons of development patterns in Markham and Vaughan during the 1981 to 1995 era will hypothetically result in very similar findings, since both municipalities were guided by "conventional" development policies during this era. Conversely, if planning does have an influence, it should be seen in inter-municipal comparisons of development during the 1996 to 2003 era.

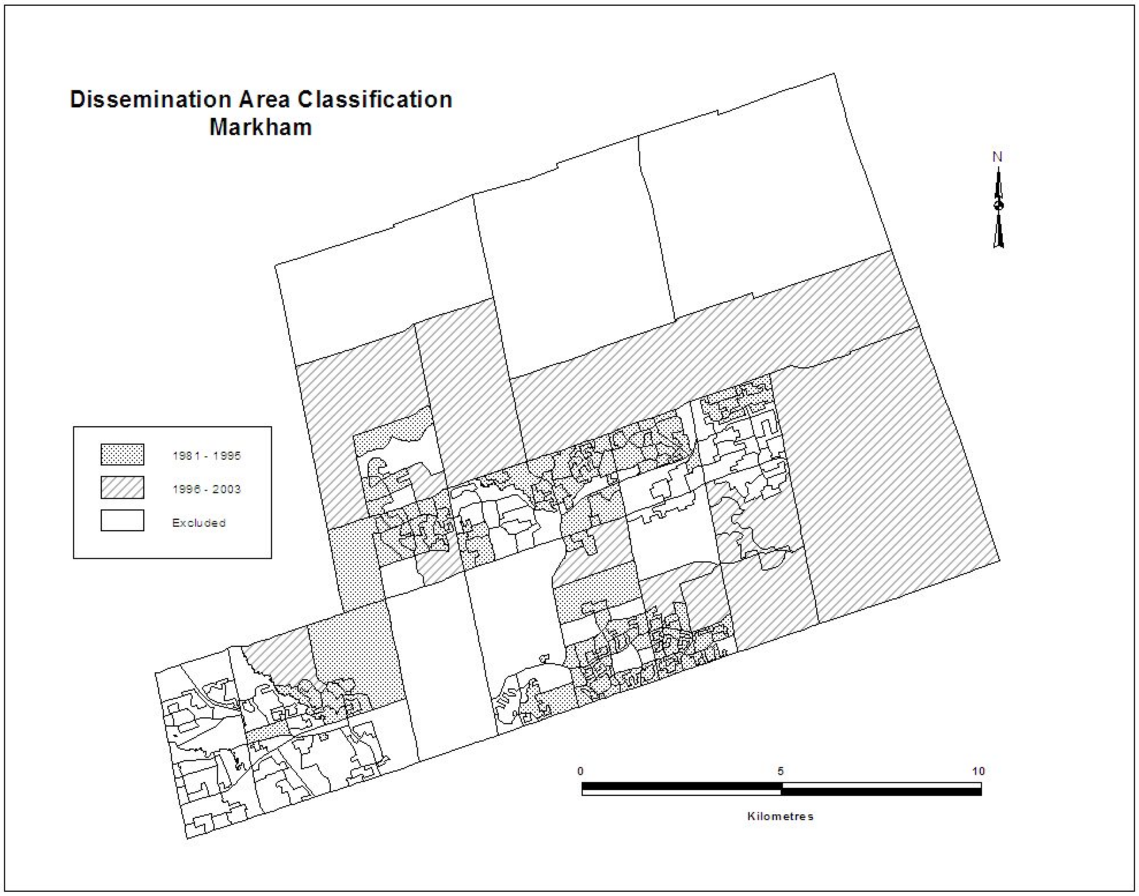
5.4 Study units

In order to link development to a particular era as precisely as possible, I used Dissemination Areas (DA) as my study units. DAs are the smallest geographic units for which Statistics Canada summarizes census data. A Dissemination Area is a "[s]mall area composed of one or more neighbouring blocks, with a population of 400 to 700 persons" as well as being a "small, relatively stable geographic unit composed of one or more blocks" (Statistics Canada, no date). For my research, I needed to identify four sets of DAs to represent development in:

- Markham, 1981 - 1996
- Vaughan, 1981 - 1996
- Markham, 1996 - 2003
- Vaughan, 1996 - 2003

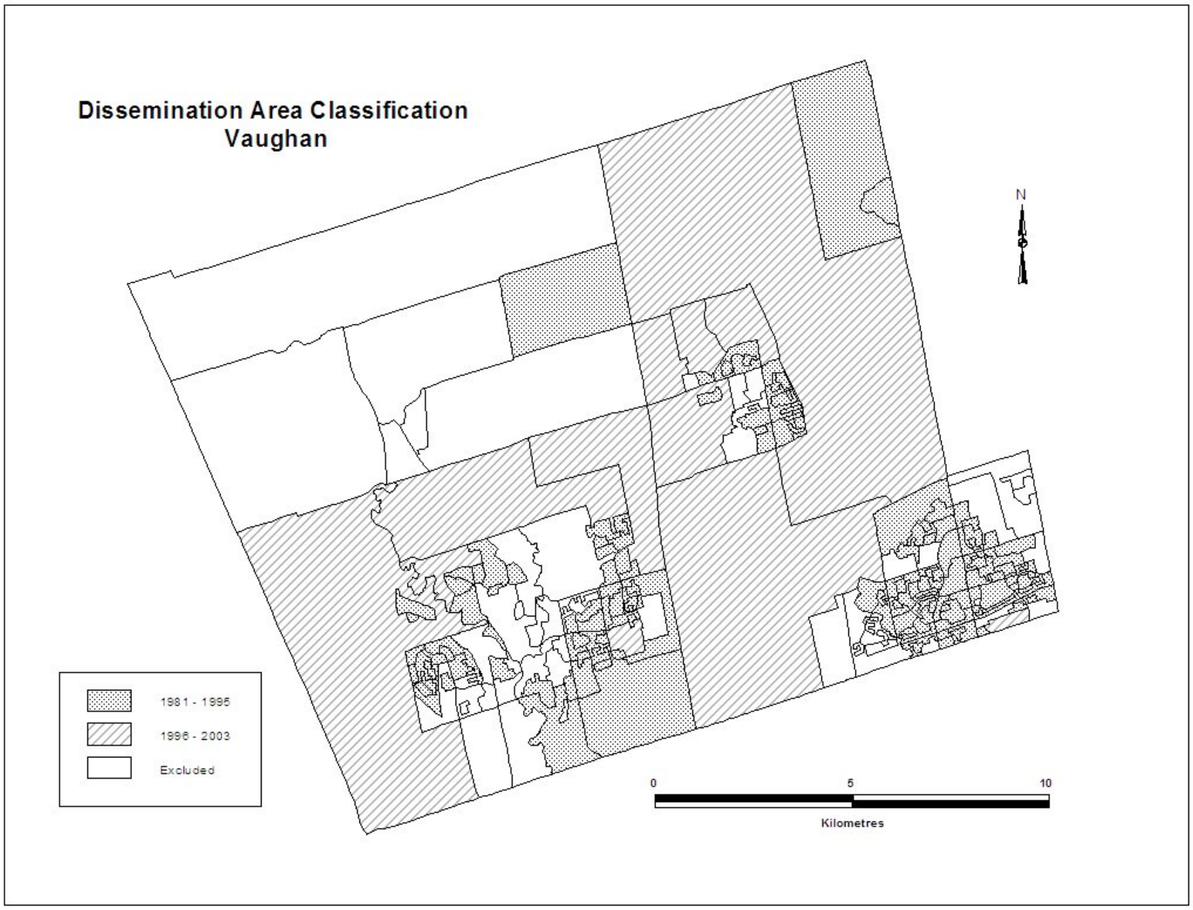
To establish the qualifying DAs for both municipalities, I used construction era data from the 2001 census. A DA qualified for inclusion in the study if 60% or more of its dwellings were constructed in one of the study eras. The use of a 60% threshold represents a compromise between the need to maximize sample size and the need to select DAs that accurately characterized development in a single era.

Figure 5.1: Dissemination Area classification - Markham



This approach has at least three limitations. The first is the accuracy of census respondents, an unknown number of whom will provide an incorrect year of construction of their dwelling. Without an exhaustive survey of municipal records, it is impossible to know how much error is introduced by respondent inaccuracy. The second limitation is the failure to account for the delay between initial site design and construction. A development constructed in 1996, for example, is here identified as belonging to Markham's New Urbanist era. However, it would almost certainly have been designed years earlier. The third and related limitation is one of duration. The primary study period consists of only seven years of development in Markham, from 1996 to 2003. Fortunately, the high rate of residential development that occurred over this period helps to mitigate its brevity and as a result, there were more than 15,000 individual parcels (building lots) belonging to the 1996 to 2003 study period in Markham.

Figure 5.2: Dissemination Area classification - Vaughan



Chapter 6
Methods

The goal of this paper is to assess the influence of planning on the residential built form, with the Town of Markham having been selected as the primary study area. Markham adopted a residential development policy inspired by New Urbanism in the early 1990s. Since New Urbanism is a heavily design-based approach to residential development, it makes sense to derive measures that best capture New Urbanist design goals.

New Urbanist built form recommendations are, theoretically at least, non-specific. New Urbanist dogma is embodied in the Charter for New Urbanism, a document that contains no design recipes or checklists of attributes. The section of the Charter entitled “The Neighborhood, The District, and The Corridor”, for example, refers only to “appropriate densities”, and the need for neighborhoods to be “compact, pedestrian-friendly, and mixed-use” (Congress For The New Urbanism, 2001).

Such broad guidelines suggest that the goals of New Urbanism can be achieved in a multitude of ways. This may be true, and appearing to have a flexible and inclusive philosophy is sensible for a young movement that seeks to grow, but the reality is that most New Urbanist developments have adhered closely to the principles Andres Duany used in the construction of Seaside and that he championed so visibly in the early days of the movement. Those principles, often bundled together under the term Traditional Neighborhood Development (TND), are inspired by the design and layout of pre-World War II American small towns and “successful” city neighbourhoods.

Perhaps the most profound change called for by TND guidelines relates to the street network. Simply put, New Urbanists feel that streets should be designed with people in mind, not cars. Among the design decisions stemming from this principle are:

- Pedestrian infrastructure (i.e. sidewalks) must exist
- Pedestrian environment must be safe, meaning that:
    - Interior streets should be narrow to keep speeds down
    - Cars and people should not share the same space: driveways should be moved to alleys behind houses.
    - There should be many people using the streets: encourage higher than usual densities
- Walking from any location to any other location should be direct and convenient:

  - Use a grid-based street network
  - Reduce or eliminate dead-ends and cul-de-sacs
  - Reduce or eliminate winding roads
- There must be “destinations” within walking distance: include a mixture of uses such as schools, retail, services and places of worship
- The pedestrian environment should be made attractive through the use of:
  - Design control for regulating buildings
  - Trees and street furniture on sidewalks
  - A variety of public spaces, including small parks and greenspace.

All of these design recommendations differ from what is found in conventional suburbs, which are frequently single-use developments with wide, wandering streets, frequent cul-de-sacs and desolate sidewalks—if sidewalks exist at all. Because of these radical differences, looking for evidence of New Urbanist design characteristics is a viable approach to evaluating the influence of planning. Any significant development inspired by New Urbanism will stand out in harsh relief on the suburban landscape.

In addition to being distinct from conventional design, many of the New Urbanist design recommendations can be measured relatively easily using spatial data in combination with a Geographic Information System (GIS). This is crucial, because it means that an automated or partially automated approach can be used to study large areas. In this study, for example, I was able to examine development characteristics in 320 Dissemination Areas that contain 2,111 blocks and more than 80,000 individual lots. This approach will provide more reliable data, as it eliminates the need for the researcher to subjectively select neighbourhoods that are thought to be representative.

The following sections discuss different categories of measures, how they were operationalized, and the data used.

6.1 Street network characteristics

Digital representations of street networks are perhaps the most common form of digital spatial data. Despite this, there are few rules or norms regarding how the many kinds of streets and intersections should be represented digitally. Instead, spatial data vendors create their own guidelines. There are some conventions, however. Single lines or segments, for example, typically represent streets with two-way traffic; even streets with three lanes of traffic in each direction are represented this way.

Divided roadways and highways are represented by two sets of segments, one for each direction. Beyond that, things get murky. Streets with medians may be represented either way: by a single line or by two segments, one for each direction. Traffic circles may be represented accurately or as simple four-way intersections. Cul-de-sacs may be represented by only a straight line, making them appear as dead ends, or they may be represented as multiple segments that correspond to their real world structure. All of these situations need to be addressed in any automated attempt to analyze street network files.

Regardless of their real world structure, all digital representations of streets consist of multiple segments joined together in a chain. A street that is several kilometers in length, which we think of as a single entity, "the street", will be digitally represented by hundreds or thousands of individual segments. Segments most commonly start and end at (real world) intersections, but this is not always the case. Long uninterrupted stretches of road, or pronounced curves, are likely to be represented by multiple segments (see Figure 6.1).

Figure 6.1: Digital representation of streets, with segment IDs shown

Data: DMTI Spatial

Each segment is assigned a unique number to identify it. In addition, the endpoints of the segment, referred to as "nodes" because multiple segments can meet here, are also identified by unique identifier numbers. One of these nodes is designated the start or "from" node and the other is designated the end or "to" node. Street information is stored in a database, with one record per segment and each record having, among other things, fields called:

- UniqueId
- Fromnode
- Tonode

By examining the values stored in these fields, it is possible to identify many components of the street network, such as intersections and their type (T intersection, X intersection and so on), and dead ends, cul-de-sacs and loops. It is also possible to calculate length, as the database record for each segment stores this value.

An implication of the database structure is that street network analysis can be carried out without GIS software and without database software, for that matter. In my research, for example, I wrote a number of UNIX Bourne shell scripts to carry out the street network analysis. The overall procedure was relatively straightforward, consisting of three main phases:

- Export data from the street network files to plain text (ASCII) files
- Run the shell script, which outputs a text file.
- Import the text file into Arc View for display and verification purposes.

The largest files to be processed by the shell scripts had fewer than four thousand records, meaning that a modestly powered Unix computer (a G4 Mac Mini) was able to complete any given run in approximately five minutes. This probably represents the threshold beyond which it would make sense to recreate the procedures in a proper programming language. This would reduce run times from a few minutes to a few seconds and obviously allow much larger datasets to be analyzed.

All measures based on street network characteristics were derived using DMTI Spatial's CanMap RouteLogistics, v2005.3, a commercial spatial data product that includes a complete street network for all of Canada along with scores of additional layers of information, such as the location of parks, schools, airports, vegetation, hydrographic features and land use among many others. In my research, I used only the Ontario street network files, which are estimated to represent the state of the actual street network as of summer, 2004.

To extract only the portions of the street network contained in my study areas (i.e. the qualifying Dissemination Areas), I used a procedure called clipping, which is conceptually identical to using a cookie cutter to punch out pieces of dough. In this case, the “cookie cutter” was my layer of DAs for a given municipality and era (e.g. “Markham post-1995”) and the “dough” was the street network.

Streets quite frequently define dissemination Areas, meaning that when configuring my clipping layer, I had to either include or exclude the streets that acted as DA boundaries. In the end, I elected to include these DA boundary streets in my analysis, using the rationale that the characteristics of these streets tell us something about the development they enclose. For example, the peripheral streets of a highly connected development will be frequently interrupted by intersections, whereas the streets that enclose a conventional development will feature few or no intersections.

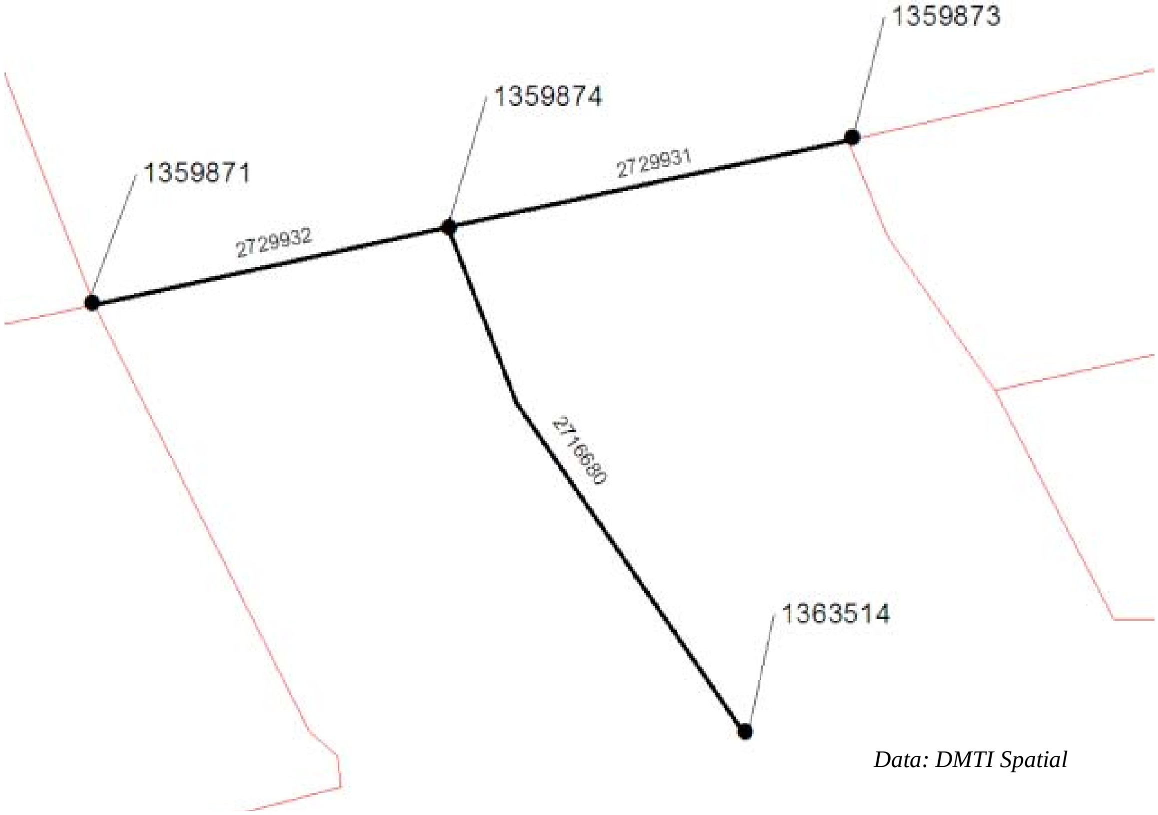
6.1.1 Intersection type

As discussed previously, New Urbanist dogma demands a street network with high connectivity. One way to measure relative connectivity is by examining intersection type. When a street network is based on a grid pattern, as in the pre-World War II cities and towns that New Urbanism seeks to emulate, the majority of intersections occur where two streets cross. Frequently called “X” intersections, these four-way intersections provide excellent connectivity by allowing travelers to proceed in a relatively direct fashion to destinations in all directions.[10] Conversely, where one street terminates as it joins another, a three-way or “T” intersection is created. This type of intersection can severely hinder connectivity because direct travel in one direction is unavailable, forcing travelers to take longer routes to their destinations, particularly if subsequent T intersections are encountered.

It is possible to classify intersections by type by executing queries on the street network database. A T intersection, for example, must consist of no more and no less than three segments. Of necessity, each of the three segments must have one node in common, which represents the point of intersection. This is illustrated in Figure 6.2, below.

[10] In some cases, a grid shot through with radials like those in Washington and Paris provides greater connectivity, but streets networks using this pattern are largely absent from American pre-World War II small towns, post-World War II peripheral areas and New Urbanist developments. Therefore, the four-way intersection is type considered to provide optimal connectivity in a suburban context.

Figure 6.2: Components of a T-intersection



Data: DMTI Spatial

Segments 2729931, 2729932 and 2716680 all meet at node 1359874. Since there are no other streets that intersect here, it means that node 1359874 will appear as a "from" node or a "to" node in these three database records only.[11] The implication is that *any* node that appears no more or less than three times in the database represents a T-intersection. By extension, any node that appears no more and no less than four times represents an X-intersection. Identifying intersections thus becomes a matter of counting how many times each unique node appears in the database.

The primary shortcoming of this approach is that it does not account for geometry. A road that splits into two forks will be classified as a T-intersection, as will a highway exit ramp that merges with a surface street. To reduce these situations, I first eliminated all highways and ramps from the dataset, using attributes included by the database vendor in each record.[12] In addition, I loaded the results into Arc View after running the intersection identification script and visually checked the results, removing incorrectly identified intersections.

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[11] That this node is defined as the "from" node in certain records and the "to" node in others is inconsequential.
[12] I converted the few traffic circles I found into X intersections, since this is their essential function.

A second shortcoming is that a very small number of irregular intersections will be ignored. For example, it is theoretically possible to have a “two way” intersection, which would have the shape of a capital letter “L”. Similarly, intersections with five or more streets will also be excluded. The former are quite rare and the no instances of the latter were found in either study area.

Measures implemented: % X-intersections, % T-intersections.

6.1.2 Mono-exits

I refer to all streets that have only one access point to the street network as “mono-exits”. This class of street includes dead-ends and “lollipop” streets: cul-de-sacs and loops (see Figure 6.3). A cul-de-sac is a dead-end with a circular area at its terminus that allows vehicles to turn around. A loop is a street that reconnects with itself. From a New Urbanist perspective, these designs have functional flaws and negative social implications. They hamper circulation—this is in fact their *raison d’etre* (Southworth & Ben-Joseph, 1995)—and in so doing, they cause greatly increased congestion on the hierarchy of streets that support cul-de-sacs (Kunstler, 1996). Critics argue that these designs are responsible for creating “a new phenomenon: the ‘cul-de-sac kid,’ the child who lives as a prisoner of a thoroughly safe and unchallenging environment” (Duany, Plater-Zyberk, & Speck, 2000). Because they are totally dependent on adults to drive them anywhere they need to go, such children (it is argued) are “robbed of the opportunity to make choices and exercise judgment” (Duany et al., 2000).

Whatever the merits of that argument, cul-de-sacs are anathema to New Urbanists on the grounds of connectivity alone.[13] Because the use of cul-de-sacs and mono-exits is such a polarizing issue that in many ways defines both New Urbanist and conventional development philosophy, it makes an excellent indicator. In my research, I created measures for both the number and length of various types of mono-exits. The number of mono-exits is an obvious measure. The length of mono-exits is helpful in characterizing development. Cul-de-sacs that exceed two hundred metres in length, for example, indicate neighbourhoods that are likely to be far more isolated than neighbourhoods with cul-de-sacs that are fifty or sixty metres in length.

Although technically each kind of mono-exit is a “dead end” due to their single access point to the street network, all are represented digitally in different ways, necessitating three distinct processes to identify them.

[13] Cul-de-sacs do not *necessarily* contribute to a poor pedestrian environment. In Radburn, for example, cul-de-sacs and other destinations are connected by walking paths (Lee & Ahn, 2003). In the modern idiom, however, all the land that encloses cul-de-sacs is given over to private use and walking paths are quite rare.

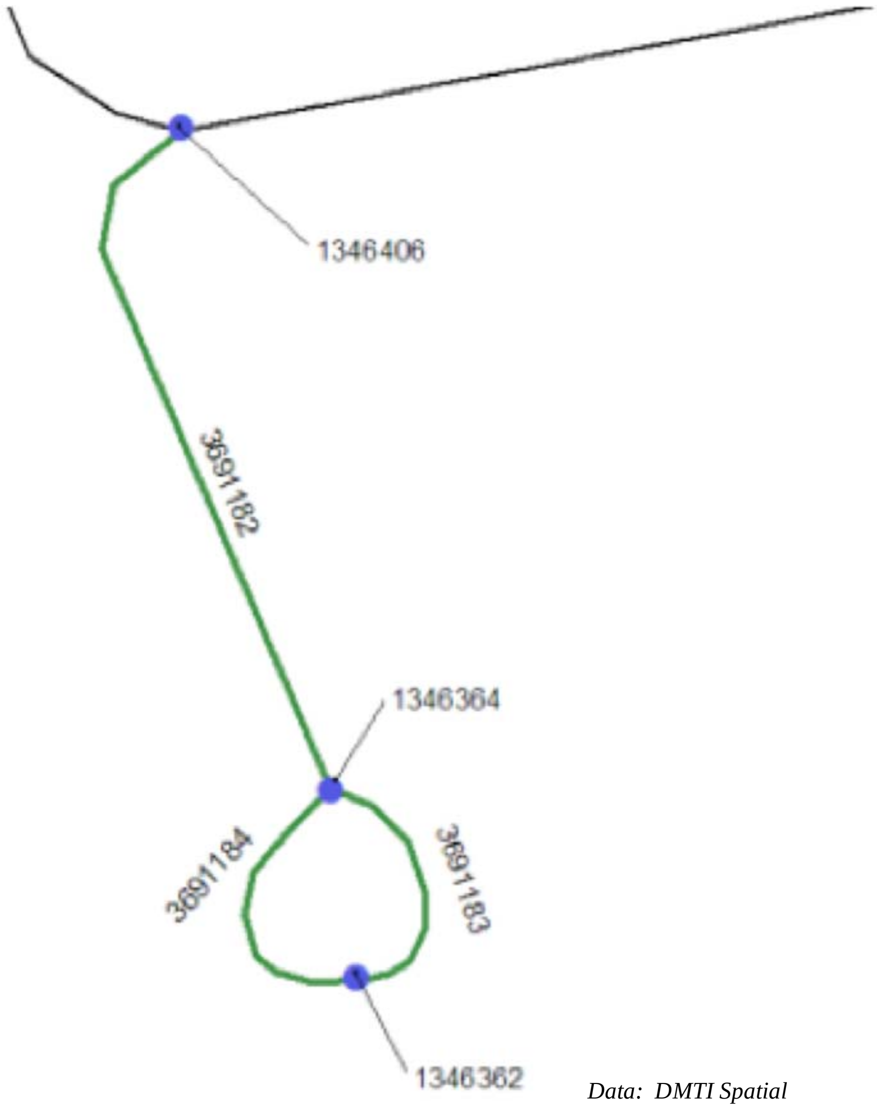
Figure 6.3: Types of mono-exits

Data: Teranet, DMTI Spatial

6.1.2.1 Cul-de-sacs

Depending on the spatial data vendor's guidelines and consistency, cul-de-sacs may be represented digitally with or without a terminating loop. Both versions can be seen above in Figure 6.3. This means that using only the street network file, it is not possible to reliably differentiate between cul-de-sacs and dead ends. Since cul-de-sacs and dead ends perform identically and are equally unwelcome in New Urbanist developments, this shortcoming is essentially irrelevant. Cul-de-sacs that are digitized as dead ends will, however, result in the length of mono-exits being slightly under-reported. Fortunately, random verification done by overlaying the street network files on high-resolution orthophotos revealed very few instances of cul-de-sacs digitized as dead ends.

Figure 6.4: Elements of cul-de-sacs



Data: DMTI Spatial

As with intersection type, identifying cul-de-sacs was carried out by analyzing three database fields for each street segment: the unique segment ID (field name UniqueId), the "from" node (fromnode), and the "to" node (tonode). When a cul-de-sac is digitized as a "stick and loop" structure, it has three segments: two semi-circular segments comprising the loop and a single stem segment. The cul-de-sac illustrated in Figure 6.4, for example, consists of three segments: 3691182 is the stem, and segments 3691183 and 3691184 form the loop or lollipop end. The two loop segments share the same "from" node (1346364) and “to” node (1346362). Table 6.1 shows how these records would look in a simplified database.

Table 6.1: Sample cul-de-sac database records (i)

UniqueId	Fromnode	Tonode
3691182	1346406	1346364
3691183	1346364	1346362
3691184	1346364	1346362

Note that the two loop segments need not have the same “from” and “to” nodes. Many cul-de-sacs are digitized with the nodes reversed, as shown (bold) in Table 6.2:

Table 6.2: Sample cul-de-sac database records (ii)

UniqueId	Fromnode	Tonode
3691182	1346406	1346364
3691183	**1346362**	**1346364**
3691184	**1346364**	**1346362**

It is therefore possible to identify cul-de-sacs in the streets database by using two steps:

1. Find the characteristic loop section by identifying all pairs of records that share the same fromnode and tonode, in whatever sequence.
2. Determine how many other segments are associated with each record in the pair. A cul-de-sac will have only one other associated segment; if any other segments join the loop, it ceases to be a cul-de-sac

An initial shortcoming of this approach is again related to digitizing inconsistency. Occasionally, large loops will be digitized as two sections and will be identified as a cul-de-sac. In Figure 6.5 below, the leftmost pattern is a loop, obviously different in structure than the traditional cul-de-sac on the right. To prevent the loop on the left from being identified as a cul-de-sac, I imposed a length threshold, retaining features meeting the “three segment” criterion as cul-de-sacs only when their combined loop length was less than 60 metres.[14]

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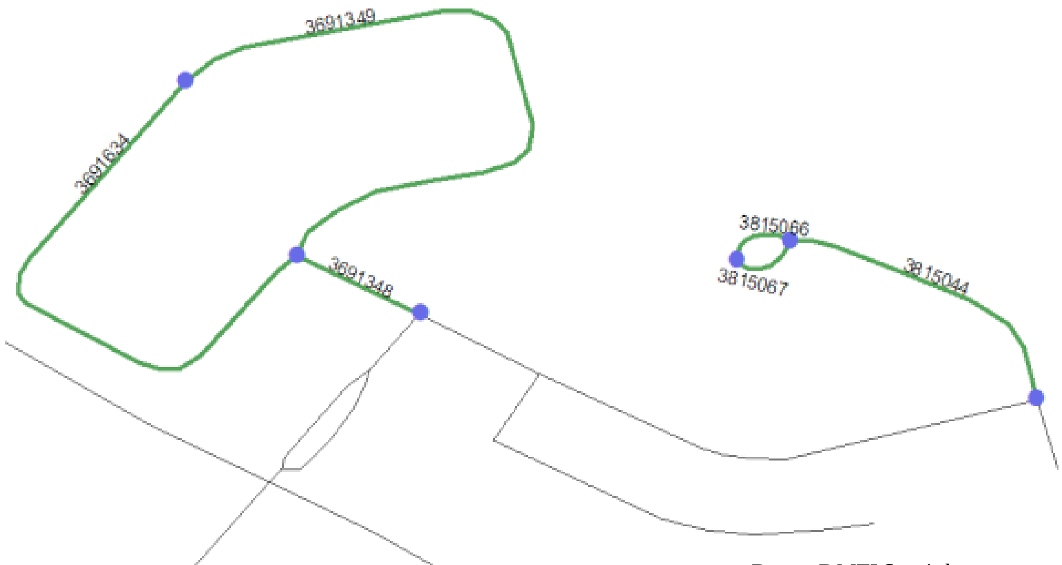
[14] I examined true cul-de-sacs using digital orthophotos and found that the loops segments did not exceed 60 metres, hence the use of this value as the threshold.

Figure 6.5: Loop digitized as a cul-de-sac



Data: DMTI Spatial

Measures implemented: number of cul-de-sacs, average cul-de-sac length, percentage of street network devoted to cul-de-sacs.

6.1.2.2 Dead Ends

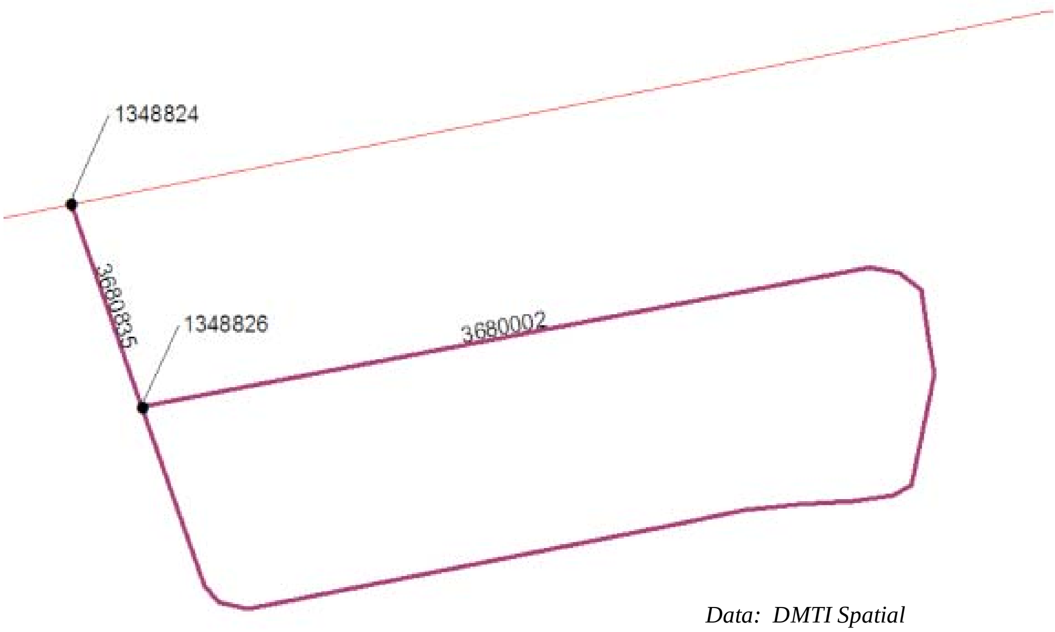
Dead ends were captured with a script based on the cul-de-sac script. Identifying dead ends was a matter of finding all nodes (either “from” or “to”) that existed only once in the database. As with cul-de-sacs, the script captured the length of each dead end for later analysis.

Measures implemented: number of dead ends, average dead end length, percentage of street network devoted to dead ends.

6.1.2.3 Loops

A loop is a street that intersects with itself at one end and whose closed area contains houses, differentiating it from a cul-de-sac. Loops were typically found to have been digitized with two segments, as illustrated in Figure 6.6 below, with a stem segment (UniqueId 3680835) and the actual loop segment (UniqueId 3680002).

Figure 6.6: Elements of a digitized loop



Data: DMTI Spatial

In the database, these two records would be represented like this:

Table 6.3: Sample loop database records

UniqueId	Fromnode	Tonode
3680835	1348824	1348826
3680002	1348824	1348824

The characteristic feature, then, as shown in the record for segment 3680002, is that the fromnode and tonode are identical. This provides an easy way to identify loops. After identifying all segments with an identical fromnode and tonode, the script scanned the database a second time to determine how many other segments were associated with it. A true loop will have only one other segment associated with it.

As mentioned in section 6.1.2.1, loops were occasionally found to have been digitized with more than two segments. The loops script was configured to recognize loops composed of three segments, but not loops digitized as four or five segments. Such multi-part loops are rare, and none were seen during a visual verification of the street network files.

Measures implemented: number of loops, average loop length, percentage of street network devoted to loops.

Cumulative measures implemented: number of mono-exits, average mono-exit length, percentage of street network devoted to mono-exits.

6.1.2.4 Block size

Block size has obvious implications for connectivity. Smaller blocks offer greater connectivity while the multiplicity of route configurations they offer encourage walking by providing a more interesting pedestrian environment (Jacobs, 1961). As such, many studies that evaluate built form at the neighbourhood level include one or more measures related to block characteristics (e.g. Cervero & Kockelman, 1997; Ewing, Pendall, & Chen, 2003; Handy, Boarnet, Ewing, & Killingsworth, 2002; Lee & Ahn, 2003; Moudon, Hess, Matlick, & Pergakes, 2002; Southworth, 1997).

The available block-level spatial data from various sources including Statistics Canada tend to be drawn using street boundaries exclusively, without regard to land use. Because the resulting blocks may include multiple land use types including undeveloped or agricultural land, the available block level data were therefore unsuitable for my research. To create my own block data, I used street network files along with parcel data (see section 6.3.1 below) along with digital orthophotographs and manually digitized blocks on screen.

I have defined blocks as areas of contiguous single-family housing development. Non-residential components, such as schools and retail, are excluded. In most cases, blocks are defined by streets or DA boundaries. Where these features do not exist, such as in the case of a development that backs onto a greenspace, rail corridor or hydro right of way, the block boundary was drawn along the periphery of individual parcels.

Block areas and perimeters were calculated using the XTools extension.

Measures implemented: average block size, average block perimeter.

6.2 Mixed use measures

A street network with high connectivity will not contribute to the vitality of a community, nor will it reduce dependence on automobiles, unless there are well-used destinations on the network. To that end, New Urbanists call for mixed use communities that include at least a corner store, although the preferred approach is to have a small retail and service complex to provide for people's daily needs such as groceries, dry cleaning, video rental, and day care (Duany et al., 2000). Neighbourhoods should be designed so that residents are within walking distance of parks and transit (Congress for the New Urbanism, 2001). Also prescribed are schools, places of employment and, when the community is large enough to support them, civic buildings such as city halls, libraries and places of worship (Duany et al., 2000).

I approached the problem of capturing these mixed use dimensions from two directions. The first is to determine the percentage of residences within walking distance of a given amenity. The second approach is to calculate the average distance from residences to amenities. My expectation is that relatively few households will be within walking distance of amenities, hence the second measure, which will quantify how significantly the target has been missed.

For both approaches, I used the following "amenities":

- Grocery stores
- Bus stops
- Elementary schools
- Eating places
- Places of worship
- Manufacturing locations

These amenities were chosen to represent the most common kinds of day-to-day destinations that might be found in or near residential areas. The extremely broad "manufacturing" category is included as a proxy for employment since the organization of the SIC code hierarchy does not allow potentially more reliable categories such as "office" employment locations to be identified.

Spatial data identifying grocery stores, eating places, and manufacturing locations were taken from a product of DMTI Spatial called Extended Points of Interest (EPOI), v2005.3. A broad array of facilities is mapped in this product, from tollbooths to gas stations to golf courses. These features appear as points in a GIS, and can be overlaid on a street network map for the purpose of calculating distances, and optimal routes.

In the EPOI database, each “point of interest” is assigned an eight digit Standard Industry Code (SIC).[15] Extracting all records of a particular type is simply a matter of querying the EPOI spatial database to find the appropriate SIC.

For grocery stores, this meant extracting all records with an SIC of “5411”. After running this procedure, I inspected the results and found that the list of extracted points was dominated by convenience/variety stores, with a relatively small number of traditional grocery stores (IGA, Dominion and so on) and a sprinkling of ethnic specialty shops. Subjectively, it appeared that the list adequately captured most of the places people would go to purchase their food staples.

To extract “eating places”, I queried the database for records with an SIC of 5812, a classification that includes restaurants and cafes as well as everything from “Automats” and “Frozen Custard Stands” to “Oyster Bars” and “Theaters, Dinner” (U.S. Department of Labor - Occupational Safety and Health Administration, no date).

Manufacturing locations were identified using only the first two digits of the SIC. The range of manufacturing-related codes runs from those beginning with “20” to those beginning with “39”. To extract manufacturing locations, I queried the database for SIC codes whose first two digits were greater than or equal to 20 and less than or equal to 39. Just under 2,300 manufacturing locations were identified in Markham and Vaughan.

York Region provided data on bus stops, elementary schools, and places of worship. No extraction or cleaning procedures were required.

The results of the entire data extraction process were 12 sets of data points, one per amenity per municipality. Using these points, distances and services areas were calculated using Arc View scripts once for each municipality/study period combination, for a total of 48 procedures. See below for details.

All calculations relied on the street network files from DMTI Spatial’s CanMap RouteLogistics, v2005.3. The full street network found in Markham and Vaughan was used for these calculations, not simply the streets included in the qualifying Dissemination Areas.

6.2.1 Distance to amenities

Most of the programming required to calculate the distance from an origin to a destination is built into Arc View and its extensions. The “Network Analyst” extension, an optional module is marketed by

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[15] The database uses the 1987 Standard Industry Code hierarchy developed in the United States. SIC codes have been implemented across North America in a variety of public and private sector applications.

ESRI, the maker of Arc View. One of the useful tools provided as part of this extension is the “find closest facility” procedure. The procedure asks the user to specify a spatial data layer containing destinations (e.g. schools) as well as an origin, such as an individual household. Arc View calculates the distance from the origin to all destinations and reports the distance to the closest one.

Useful as this capability is, its “one-origin-at-a-time” configuration makes it unsuitable for determining the closest facility for thousands of origins as I had in my research. One way around this problem is to use a script that calls the underlying functions manually, instead of through the user interface described above. Arc View users have written and made available thousands of scripts to accomplish many tasks, and I found one that perfectly suited my needs. Written by Dan Patterson of Carleton University and found on ESRI’s User Forums (http://support.esri.com/index.cfm?fa=forums.gateway), it functions nearly identically to the built-in version that is part of the Network Analyst extension, but instead of calculating for a single origin, it finds the closest facility to every origin in the user specified file. The result is shapefile with one route per origin, with the distance to the closest destination specified in metres. Average distances were calculated using these figures.

For each of the four municipality/era combinations, I ran a script six times (once per “amenity”) that determined the closest instance of the specified amenity to every block in the area of study. The typical run time on 1.7 GHz PC with 512 Mb RAM was five minutes, with calculations carried out for approximately 300 origins and the number of destinations ranging from 150 (elementary schools) to nearly 1,100 (eating places).

Initially, I had run these calculations using individual parcels (building lots) as origins, but because the number of parcels in all municipality/era combinations is well into the thousands, processing time was prohibitive, taking many hours for each run. To lower execution times to something more reasonable, I used block centroids. Since I had already created blocks (see method above in section 6.1.2.4), the only additional step needed was to calculate block centroids, which I accomplished with the XTools extension.

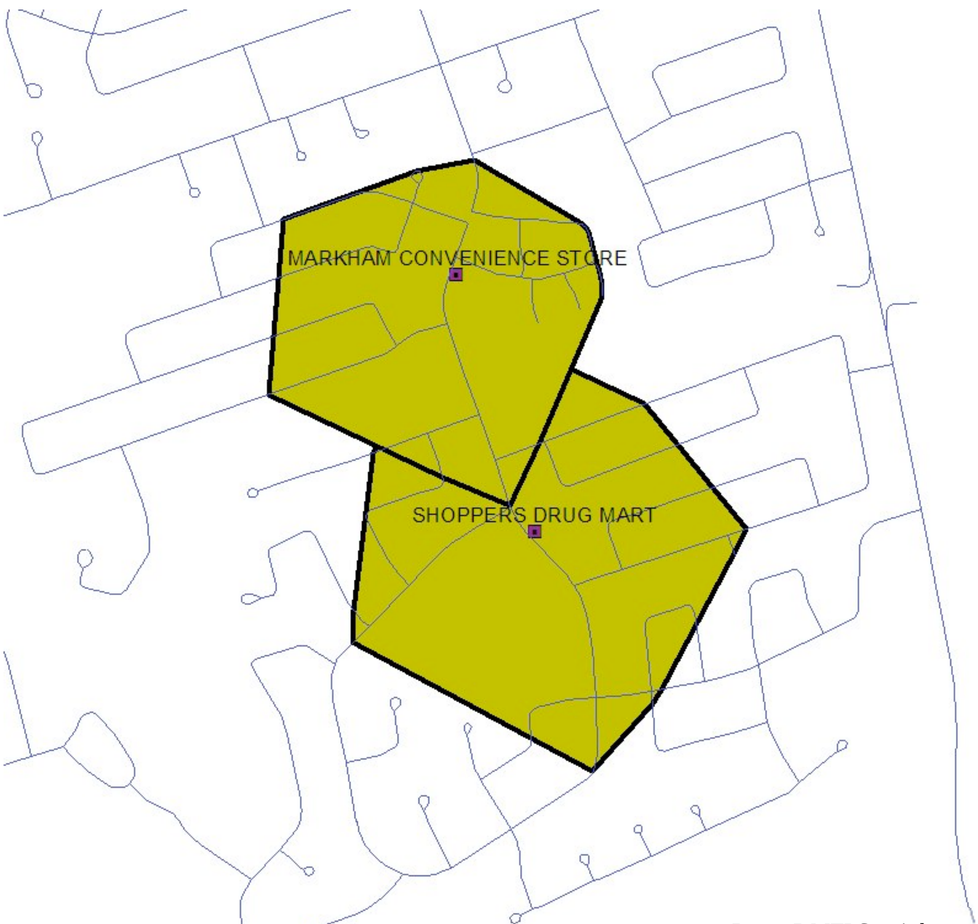
Random tests showed that using block centroids provided results nearly identical to those achieved when measuring from the individual parcels. The greatest variation observed was 2.16%. The most comprehensive test calculated the median distance to the closest grocery store using 12,596 parcels as origin points. The resulting value was 1057.23 metres. When block centroids were used, the median was found to be 1056.13 metres. These results make me confident that using block centroids as origin points has provided accurate data.

Measures implemented: average distance, for each of the six amenity types.

6.2.2 Percentage of households within walking distance of amenities

As well as the ability to find the closest facility, the Arc View Network Analyst extension can also be used to determine the "service area" of a particular facility, based on a threshold distance. A service area for a facility is analogous to a "commuter shed" for a city, but on a much smaller scale. For example, to find the service area of an ambulance station using a two-mile threshold, Arc View would calculate all routes 2 miles long or less from the ambulance station, in all directions. The "as-the-crow-flies" distance between the ambulance station and the termination points of each of these 2 mile routes will vary according to street configuration and orientation. When the terminating points of routes in all directions are connected, the result is a roughly circular zone surrounding the facility (assuming the facility is surrounded by streets on all sides). This is the service area, based on distance.

Figure 6.7: Overlapping 400 metre service areas



Data: DMTI Spatial

Service areas can also be calculated using time as the threshold. The calculation will use the speed limit of the road segments, which is included in the database, to establish how far a vehicle could travel from a facility in a given amount of time. A service area, then, is simply a geometric representation of "coverage". Calculating the service area of a facility does not, therefore, reveal how many residences or other points are included within it. However, it is possible to use the service as an intermediate step in the calculation of the number of points within a given distance (or time) from a facility.

The "calculate service area" option provided with Arc View's Network Analyst extension functions nearly identically to the "find closest facility" option. The user specifies a facility, a "cost" unit (distance or time, typically) and a distance. Arc View calculates the service area of the facility using these parameters. The problem here, as before, is the inability to find the service areas of multiple facilities. It would entail thousands of manual, individual runs to calculate services areas for all the facilities included in my study areas. I was not able to find a ready-made script that could handle batch processing, but I did find one that formed a good foundation (Moglen, 2005). I was able to modify the script so that it could calculate services areas for all the facilities in a shapefile.

For each municipality/era combination, I calculated service areas for the six indicators (grocery stores, elementary schools, bus stops, eating places, manufacturing locations, and places of worship) using distance as the "cost" field, with the threshold set at 400 metres (or approximately ¼ mile), a distance that is commonly used to define "walking distance" in built form research (e.g. Bartlett, 2003; Lee & Ahn, 2003; Lund, 2003; Randall & Baetz, 2001).

The result of any individual run was a shapefile containing one service area per facility. Since there were between 150 and 1200 facilities, and many of them within 400 metres of one another, there was usually with significant overlap of service areas. To simplify subsequent calculations, I merged the service areas for each facility type and municipality, resulting in 12 service area shapefiles. Figure 6.8 (next page) shows the service area of all Markham bus stops, after the individual service areas for each bus stop have been merged.

Figure 6.8: Merged service areas of Markham bus stops

Data: DMTI Spatial, York Region

The final step involved using these shapefiles to clip the shapefile storing individual parcels. The number of records in the clipped parcel shapefile was divided by the number of parcels in the relevant study area/era to arrive at the percentage of residences within 400 metres of a particular facility type.

Measures implemented: percentage of dwellings within 400 metres of each of six types of amenity.

One limitation of this approach needs to be acknowledged: The street network files that were used to find the closest facility and the service area of facilities were created to predict and analyze automobile-based travel. As a result, analysis of other modes of travel, including pedestrian and bicycle based, will have inherent limitations. The street network files, for example, provide no indication whether a particular segment of road has sidewalks on one side, both sides, or none at all. A further limitation is that street network files exclude walking/cycling paths between neighbourhoods as well as those through parks, fields and open spaces. Spatial data for sidewalks and paths would solve these problems, but such data are nearly non-existent. As such, in my calculations I have assumed all routes can be traversed on foot, by bicycle and by car. I would speculate that the impact on the results is not significant, working from the assumption that developments most likely to be without sidewalks (i.e. conventional, cul-de-sac and loop dominated subdivisions) are also those most likely to have walking paths that connect streets. Such walking/connecting paths are rare or absent in highly connective developments because they are not needed.

A second limitation of this approach is that it does not account for the quality of the pedestrian environment. All routes of the same length, regardless of location and complexity, are assumed to be equally attractive for cyclists and pedestrians.

6.2.3 Dwelling type mix

The detached, single-family home is an icon of post-WWII conventional suburban development. While New Urbanism does not deplore the single family home—it could hardly do so, having been strongly influenced by the American small town—it argues that diversity is necessary and calls for a broad range of housing types (Congress for the New Urbanism, 2001; Grant, 2002). This sentiment informed the objectives for Cornell, which were to “alter the urban landscape”, provide affordable housing and diversify Markham’s housing stock (Thompson-Fawcett & Bond, 2003).

Any attribute over which conventional development and New Urbanism diverge will make a good indicator, and diversity of dwelling configurations is certainly one of those. The 2001 census contains information about dwelling type, using the following categorization scheme:

- Single detached
- Semi-detached
- Row
- Duplex
- Apartments 5 or more storeys
- Apartments less than 5 storeys

To establish the “conventionality” of each of the four municipality/era combinations, I calculated the percentage of single detached houses. Although there are six different dwelling types, I felt that calculating the dwellings that were “house” -based and those that were apartment-based would best capture diversity. My rationale is that singles, semis, row houses and duplexes serve essentially the same market and all function in a manner nearly identical to single detached houses. These different types of house provide only a diversity of style. Apartments, conversely, serve a very different market and indicate an economic diversity of dwelling types.

Measures calculated: percentage of single, detached houses; percentage of house-based dwellings, percentage of apartment-based dwellings.

6.3 Density

The motivation behind New Urbanism’s design prescriptions is to create attractive, “livable” residential environments with a sense of place that support and facilitate social interaction, theoretically leading to a more engaged and civil(ized) society. Environmental concerns are not really part of the program. New Urbanism, for example, makes no claims that it will increase density (Gordon & Vipond, 2005) or reduce the conversion of land to urban uses.[16] The New Urbanist Charter refers merely to the need for “appropriate densities…within walking distance of transit stops” (Congress for the New Urbanism, 2001).

Despite New Urbanism’s lack of emphasis on density gains and environmental concerns, at least one study has shown that New Urbanist developments may have substantially higher gross residential densities and higher population densities than conventional developments without sacrificing parks and greenspace (Gordon & Vipond, 2005). The approach used in Gordon’s study was not practical in my research due to the land area in my study areas. For the same reason, net residential density measures could not be implemented. Gross density is sometimes calculated using the entire land area of a census unit (typically, census tracts). Even this crude approach was not immediately available to me since many of the DAs in my study areas had large tracts of agricultural and undeveloped land. With the aid of digital orthophotos and the parcel information, I was able to modify the DA boundaries of the study areas to exclude peripheral undeveloped land. Undeveloped land within the development boundary was retained in order to best approximate the conditions under which “census unit gross density” is usually calculated. To calculate gross density, the land area of the resized DAs

[16] Developments designed according to New Urbanist doctrine may in fact be more environmentally sustainable than conventional developments (Berke et al., 2003), partly through the use of mitigation techniques but also by combining higher than normal density residential areas with abundant greenspace and natural areas. The density gains from dwelling organization are offset by the increased greenspaces and natural areas, meaning that gross densities may be little different than in conventional developments. This may represent the best compromise we currently have between the conflicting calls to reduce sprawl by build at higher densities and to build more environmentally sustainable communities.

was calculated with the XTools Arc View extension and population and dwelling counts were taken from the 2001 census.

One additional indicator of density was calculated using parcel data: average lot size.

Measures implemented: gross population and dwelling density (based on adjusted DA area); average lot size.

6.3.1 Single family residence lot size

One of the defining characteristics of the conventional suburb is the large building lot. New Urbanist development, on the other hand, theoretically implements narrow lots like those found in big city neighbourhoods. Since the two development philosophies have polarized attitudes about lot size, it makes and ideal indicator. And given the preponderance of single-family dwellings in residential areas, calculating average lot size should provide some insight into dwelling density and the texture of the residential fabric.

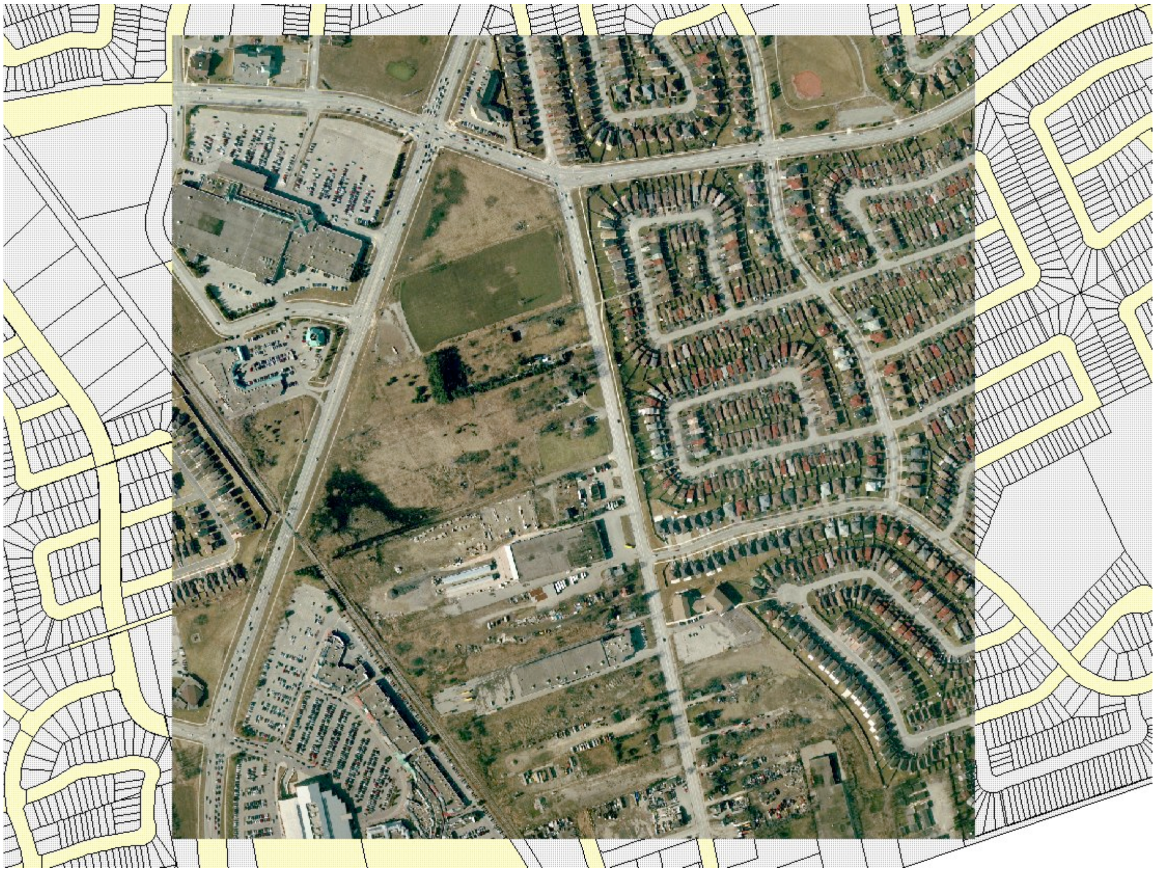
The dataset I used, provided by a commercial spatial data company, Teranet Incorporated, represented development as of 2003 and was composed of polygons representing the *entire* land areas of Markham and Vaughan. Roads, streams, reservoirs, parking lots, and so on were all present (see Figure 6.9). Before any calculations could be run, it was necessary to exclude all polygons representing non-residential land, defined as building lots for house-based dwellings. As a first step, all road and street polygons were removed by overlaying street network files and selecting the dataset for all polygons that contained a street network segment. These polygons were then deleted.

Figure 6.9: Raw parcel data before cleaning

Data: Teranet

Non single-family residential polygons were identified by overlaying the parcel layer on digital orthophotos (see Figure 6.10 below).

Figure 6.10: Using digital orthophotos to identify residential polygons



Data: Teranet, Ontario Ministry of Natural Resources

The final step involved correcting digitizing errors that had resulted in erroneously divided parcels or features with no corresponding real world structures. When only residential polygons remained, parcel areas were calculated using the XTools extension.

Measure implemented: average lot size.

Chapter 7
Findings

Findings will be examined in two dimensions. Intra-municipal comparisons will indicate if there are differences within a municipality between development in the early (1981 to 1995) and recent (1996 to 2003) study eras. Inter-municipal comparisons will indicate if there are differences in development in the two municipalities for the same era.

7.1 Street network

The following sections outline findings regarding intersection types and mono-exits.

7.1.1 Intersection type

Intra-municipal findings: In both municipalities, the percentage of X-intersections increased from the earlier study period to the more recent, as illustrated in Table 7.1. In Markham, the percentage increased from 20.1% to 27.4%, an increase of 36.2%. The proportion also increased in Vaughan, but only by 9.0%.

Table 7.1: Intersection type (intra-municipal)

	Markham		Vaughan	
	1981 – 1995	1996 - 2003	1981 – 1995	1996 – 2003
T intersections (n)	678	725	709	921
X intersections (n)	171	274	217	316
X intersections (%)	20.1	27.4	23.4	25.5

Inter-municipal findings: In absolute terms, the percentage of X intersections is quite similar for both municipalities in both eras. The only notable difference is the much higher rate of change in Markham between the earlier and later era. This might be indication that Markham's planning philosophy has had an effect. However, given the similar values found in both municipalities during the recent study period (Markham at 27.4%, Vaughan at 25.5%), it could be argued that Markham is simply "catching up". This process could be at least partially attributed to external development forces such as land economics that will tend to create a uniform residential landscape.

Table 7.2: Intersection type (inter-municipal)

	1981 - 1985		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
T intersections (n)	678	709	725	921
X intersections (n)	171	217	274	316
X intersections (%)	20.1	23.4	27.4	25.5

7.1.2 Mono-exits

Mono-exits—streets that have a single access point to the network—by definition hinder overall connectivity, regardless of their structure. They may take the form of dead ends, cul-de-sacs or loops, but all function identically in their isolation and near-exclusion from the street network. The greater the proportion of the network given over to mono-exits, the lower its connectivity.

7.1.2.1 Cul-de-sacs

Table 7.3: Cul-de-sac findings (intra-municipal)

	Markham			Vaughan		
	1981 – 1995	**1996 - 2003**	**Change (%)**	**1981 – 1995**	**1996 – 2003**	**Change (%)**
(n)	136	51	n/a	205	128	n/a
Average length (metres)	184.2	199	7.9	185	181	-2.3
Cul-de-sacs (% of network)	8.3	2.9	-64.8	10.4	4.5	-57.0

Intra-municipal findings: Over the two study periods, both municipalities show significant reductions in both the number of cul-de-sacs and proportion of the street network their combined lengths consume. The 7.9% increase in average cul-de-sac length seen in Markham suggests a more polarized pattern than in the previous era. While far fewer cul-de-sacs are being built, there are more instances of relatively long cul-de-sacs.

Inter-municipal findings: Values are very similar. In the earlier study period, average cul-de-sac lengths are nearly identical. In the later period, average length has increased somewhat in Markham and declined marginally in Vaughan. A smaller percentage of the street network is composed of cul-de-sacs in Markham than in Vaughan, for both study periods. However, Markham's greater reduction, and its initially lower proportion of cul-de-sacs, mean that the street network in 1996-2003 development in Markham incorporates 55% less network length to cul-de-sacs than in Vaughan (2.9% vs. 4.5%). Nonetheless, Vaughan cannot be described as being dominated by cul-de-sacs.

Table 7.4: Cul-de-sac findings (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
(n)	136	205	51	128
Average length (metres)	184.2	185	199	181
Cul-de-sacs (% of network)	8.3	10.4	2.9	4.5

7.1.2.2 Dead ends

Intra-municipal findings: In Markham, dramatic increases were seen period over period in the average length of dead ends (77.4% increase) and the percentage of the street network composed of dead ends (353.1% increase). In Vaughan, average dead end length diminished by 24.6% from the early to the recent study period.

Table 7.5: Dead end findings (intra-municipal)

	Markham			Vaughan		
	1981 – 1995	**1996 - 2003**	**Change (%)**	**1981 – 1995**	**1996 – 2003**	**Change (%)**
(n)	32	94	n/a	17	79	n/a
Average length (metres)	88.0	156.2	77.4	264.5	199.5	-24.6
Dead Ends (% of network)	0.93	4.22	353.1	1.23	3.04	146.9

Inter-municipal comparison: In the early study period, dead ends were much shorter on average in Markham than Vaughan, at 88.0 metres and 264.5 metres respectively (see Table 7.6). As seen with the intersection type measures, there may be a homogenizing process at work here, because values from the recent study period are much closer. Average length has increased in Markham and decreased in Vaughan, although dead ends are still longer in Vaughan.

Table 7.6: Dead end findings (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
(n)	32	17	94	79
Average length (metres)	88.0	264.5	156.2	199.5
Dead Ends (% of network)	0.93	1.23	4.22	3.04

From a connectivity standpoint, the most telling information here is again the percentage of the street network composed of dead ends. The situation is the reverse of that for cul-de-sacs, with Markham's proportion being 38.8% higher than Vaughan's (4.22% vs. 3.04%). Again, however, we are dealing with municipalities with very similar street network patterns where dead ends are concerned.

The large increases in the proportion of the street network composed of dead ends may be attributable to the incomplete state of development in the more recent period. While development is ongoing, streets are often extended only a brief distance beyond the edge of current construction, but may be fully connected to the street network at a later date. At present, however, they are classified as dead ends. In the early study period, this is not the case as the great majority of land in the study areas has long since been built out.

7.1.2.3 Loops

Loops are rare features composed of a relatively long, typically rectangular stretch of residential street that is connected to the street network by a short and typically straight segment.

Table 7.7: Loop findings (intra-municipal)

	Markham			Vaughan		
	1981 – 1995	**1996 - 2003**	**Change (%)**	**1981 – 1995**	**1996 – 2003**	**Change (%)**
(n)	16	4	n/a	8	5	n/a
Average length (metres)	546.25	641.5	17.4	590.5	540.4	-8.5
Loops (% of network)	2.9	0.7	-74.5	1.3	0.5	-59.7

Intra-municipal findings: As with dead ends, loop lengths increased period over period in Markham but declined in Vaughan (17.4% and -8.5% respectively). In both municipalities, however, the proportion of the street network given over to loops decreased.

Inter-municipal findings: Despite the changes over time, average loop lengths are quite similar for the two municipalities in both eras. Markham may now have loops that are longer on average, but they are still relatively similar to loops in Vaughan.

Table 7.8: Loop findings (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
(n)	16	8	4	5
Average length (metres)	546.25	590.5	641.5	540.4
Loops (% of network)	2.9	1.3	0.7	0.5

In the early period, Markham had more than twice the percentage of its street network devoted to loops than Vaughan (2.9% vs. 1.3%). During the recent period, however, values have dropped to become very similar, at 0.7% for Markham and 0.5% for Vaughan. Once again, it is possible that external forces are creating a more uniform residential urban landscape, although the small number of loops (24 in the earlier period, 9 in the recent) means that interpretations must be made with caution.

7.1.2.4 All mono-exits

Since all mono-exits function identically in hampering street network connectivity, it makes sense to combine their values in order to assess their impact.

Intra-municipal findings: In Markham, mono-exits are becoming shorter (-7.9%), less frequent (-29.5%) and they comprise a smaller proportion of the street network (-34.9%). These are all in accord with New Urbanist design goals. Average mono-exit length, however, has become far less uniform from the early study period to the recent, with the coefficient of variation (CV) increasing by 93%. This is the strongest evidence of a polarized development pattern in recent era Markham development.

Table 7.9: Summary of all mono-exit findings

	Markham			Vaughan		
	1981 – 1995	**1996 - 2003**	**Change (%)**	**1981 – 1995**	**1996 – 2003**	**Change (%)**
(n)	184	149	n/a	230	212	n/a
Length (avg)	198.9	184	-7.5	205.3	230.3	12.1
Standard Deviation	148.7	265.4	78.5	184.397	186.883	-1.4
CV (%)	74.75	144.28	93.0	89.8	81.16	-9.62
Mono-exits per km	0.61	.43	-29.5	.63	.41	-34.9
% of network	12.1	7.9	-34.9	12.9	9.4	-27.2

In Vaughan, mono-exits have increased in length (12.1%), become less frequent (-34.9%) and consume a smaller proportion of the street network, decreasing 27.2%. Vaughan too has seen a change in mono-exit length uniformity, but it is a change in the opposite direction than in Markham. In Vaughan, mono-exit lengths have become more uniform in the recent period, with the CV dropping by 9.62%.

T-tests were run for each municipality, comparing the difference of mean mono-exit length between the early and later study periods. The results are presented in Table 7.10 and show no significant inter-period differences.[17]

Table 7.10: Intra-municipal T-test for mono-exit length

	df	t	p
Markham	331	0.615	0.516
Vaughan	436.058	-1.41	0.159

[17] A significance level of p = .005 is used in evaluating all T-test results (Bonferroni correction).

Inter-municipal findings: In the early study period, average mono-exit lengths were quite similar at 198.9 metres in Markham and 205.3 metres in Vaughan. During the recent period, Markham mono-exits are some 25% shorter on average than those in Vaughan (184 metres vs. 230.3 metres).

Table 7.11: Summary of all mono-exit findings (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
(n)	184	230	149	212
Length (avg)	198.9	205.3	184	230.3
Standard Deviation	148.7	184.397	265.4	186.883
CV (%)	74.75	89.8	144.28	81.16
Mono-exits per km	0.61	.63	.43	.41
% of network	12.1	12.9	7.9	9.4

Table 7.12 below displays the results of independent samples t-tests for both study eras that analyze the variance of mean mono-exit length in the two municipalities. While the result from neither era is significant, the trend is certainly in that direction, with *p* dropping from 0.702 in the earlier era to 0.052 in the more recent era.

Table 7.12: Inter-municipal T-test for mono-exit length

	df	t	p
1981 to 1995	412	-0.383	0.702
1996 to 2003	359	-1.946	0.052

In the early period, mono-exits in Markham were more uniform than those in Vaughan, with CVs of 74.75% and 89.8% respectively. In the recent period, there is a dramatic difference in uniformity, with Markham lengths exhibiting far greater variation than those in Vaughan (cv=144.28% vs. cv=81.16%).

Despite these differences, the overall character of the street network in the two municipalities appears to be quite similar in the recent period. The frequency of mono-exits is nearly identical (0.43 mono-exits per kilometer in Markham vs. 0.41 in Vaughan), as is the proportion of the street network consumed by mono-exits (7.9% in Markham, 9.4% in Vaughan).

7.1.3 Block size

Intra-municipal findings: In both municipalities, block sizes have declined dramatically from the early study period to the recent period (see Table 7.13 below). Average block size has decreased by 51.7% in Markham from 37,128 square metres to 17,917 metres. In Vaughan, average block size has decreased 45.6%, from 38,129 square metres to 20,751 square metres.

Table 7.13: Average block size (intra-municipal)

	Markham		Vaughan	
	1981 – 1995	**1996 - 2003**	**1981– 1995**	**1996 – 2003**
Blocks (n)	430	521	491	669
Total area (km)	15.97	9.35	18.76	13.9
Average size (m^2)	37,128	17,917	38,129	20,751
Standard Deviation	39068.799	14172.498	41179.394	16087.925
CV (%)	105.2	79.1	108.0	77.5

With the sizable reduction in block size in both municipalities, it is not surprising that between-periods t-tests reveal significant differences in mean block size. In both municipalities, block sizes become more uniform from the earlier to recent study period, with CVs dropping from 105.2% to 79.1% in Markham, and from 108.0% to 77.5% in Vaughan.

Inter-municipal findings: In the early study period, average block sizes are very similar, being 2.8% smaller in Markham (37,128 m^2) than in Vaughan (37,129 $m^{2)}$. In recent era development, however, block sizes are notably different: 15.8% lower in Markham than in Vaughan (17,917 m^2 vs. 20,751 m^2 respectively).

Table 7.14: Average block size (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
Blocks (n)	430	491	521	669
Total area (km)	15.97	18.76	9.35	13.9
Average size (m^2)	37,128	38,129	17,917	20,751
Standard Deviation	39068.799	41179.394	14172.498	16087.925
CV (%)	105.2	108.0	79.1	77.5

These relationships are reflected in the results of t-test provided in Table 7.15, where it can be seen that there is no significant different in block size in the earlier study period (p=.706) while there is a significant difference in means for the recent study period (p=.001).

Table 7.15: Inter-municipal T-tests for block size

	df	t	p
1981 to 1995	920.000	-0.377	0.706
1996 to 2003	1172.160	-3.227	0.001

7.1.4 Block perimeter

Intra-municipal findings: Given the relatively rectangular shape of blocks in residential development, we would expect block perimeter lengths to decrease along with block areas. This turns out to be the case, with sizable reductions in mean perimeter length occurring between the early and recent periods, and again with Markham experiencing a larger decrease (see Table 7.16).

Table 7.16: Block perimeter findings (intra-municipal)

	Markham		Vaughan	
	1981 – 1995	**1996 - 2003**	**1981 – 1995**	**1996 – 2003**
Perimeter (avg, m)	997.8	610.8	982.2	679.5
Standard Deviation	694.366	309.556	628.134	348.875
CV (%)	69.952	50.677	63.955	51.343

The uniformity of mean block perimeter lengths increased in both municipalities, from CVs in the 60s in the earlier period to nearly identical values in the low 50s in the later period (50.677% for Markham and 51.343% in Vaughan). Between-periods t-tests reveal significant differences in both municipalities.

Table 7.17: Block perimeter T-tests (intra-municipal)

	df	t	p
Markham	568.42	10.711	.000
Vaughan	711.839	9.65	.000

Inter-municipal findings: In the early study period, block perimeters are essentially identical in the two municipalities (see Table 7.18). Blocks in Markham are technically longer and less uniform but the differences compared to Vaughan are negligible. In the recent study period, however, block perimeters in Markham are 11.3% shorter than those in Vaughan (610.8 metres vs. 679.5 metres respectively).

Table 7.18: Block perimeter findings (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
Perimeter (avg., m)	997.8	982.2	610.8	679.5
Standard Deviation	694.366	628.134	309.556	348.875
CV (%)	69.952	63.955	50.677	51.343

The results of t-tests shown in Table 7.19 reveal that (as expected), the difference in block size for the two municipalities in the early study period is not significant (*p*=.72). In the 1996 to 2003 period, however, the difference is significant (*p*=.001).

Table 7.19: Block perimeter T-tests (inter-municipal)

	df	t	p
1981 to 1995	920.000	0.358	0.72
1996 to 2003	1170.040	-3.593	0.00

7.2 Density

7.2.1 Gross population and dwelling density

Intra-municipal findings: From Table 7.20, it can be seen that from the early to the recent period, population density in Markham has dropped 57.5% (1282.4 vs. 3019.5 people per square kilometer) and dwelling density has dropped 54.9% (3.7 vs. 8.2 dwelling units per hectare). In Vaughan, the declines are slightly less severe, with population density decreasing by 50.3% (1192.4 vs. 2397.9 people per square kilometer) and dwelling density decreasing by 46.4% (3.7 vs. 6.9 dwelling units per hectare). It is difficult to gauge usefulness of these comparisons due to the different stages of development represented by the early period, which is nearly fully built out and mature, and the recent study era in which development is incomplete.

Table 7.20: Gross dwelling and population density (intra-municipal)

	Markham		Vaughan	
	1981 – 1995	**1996 - 2003**	**1981 – 1995**	**1996 – 2003**
Total DA Area (km^2)	28.2	78.2	48.2	102.3
*Adjusted DA Area (km^2)	28.1	29.0	38.3	40.4
Adjusted Population per km^2	3019.5	1282.4	2397.9	1192.4
Adjusted dwelling units per ha.	8.2	3.7	6.9	3.7

** Adjusted area excludes peripheral undeveloped land*

Inter-municipal findings: Same era comparisons between the two municipalities are much closer to an “apples to apples” situation and should therefore be more useful.

Table 7.21: Population and dwelling density (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
Total DA Area (km^2)	28.2	48.2	78.2	102.3
Adjusted DA Area (km^2)	28.1	38.3	29.0	40.4
Adjusted Population per km^2	3019.5	2397.9	1282.4	1192.4
Adjusted dwelling units per ha.	8.2	6.9	3.7	3.7

In the early study period, Markham's population density (3019.5 persons per square kilometer) and dwelling density (8.2 dwelling units per hectare) are notably higher than those in Vaughan (population density: 2397.9 persons per square kilometer; dwelling density: 6.9 dwelling units per hectare). In the recent study period, however, these disparities have dramatically diminished for population density (1282.4 vs. 1192.4 person per square kilometer in Markham and Vaughan respectively) and disappeared completely for dwelling unit density (3.7 dwelling units per hectare in both municipalities). This is another indication that forces other than planning exert a powerful influence on development patterns.

7.2.2 Parcel size

Intra-municipal findings: In both municipalities, lot size has diminished dramatically from the earlier period to the recent period, by 27.7% in Markham and by 32.2% in Vaughan. Lot sizes have also become more uniform in both municipalities, but especially in Vaughan, where CV has dropped from 116.0% to 57.2%. Markham's drop is more modest, from 90.8% to 80.8%.

Table 7.22: Average parcel size (intra-municipal)

	Markham		Vaughan	
	1981 – 1995	**1996 - 2003**	**1981 – 1995**	**1996 – 2003**
Parcels (n)	20379	15520	22456	22363
Average area (m^2)	555.95	401.73	581.09	394.03
CV	90.8	80.8	116.0	57.2

Unsurprisingly, the sizable decreases in mean lot size seen in both municipalities are mirrored in t-tests, which find the differences in the 1981 to 1995 and 1996 and 2003 study periods to be significant.

Table 7.23: Inter-period T-tests for mean lot size

	df	t	p
Markham	34976.605	35.117	.000
Vaughan	27231.908	39.505	.000

Inter-municipal findings: While average lot sizes have decreased in absolute terms, they have remained nearly identical in relative terms. In the early period, the average lot size in Markham was some 4.5% smaller than in Vaughan (555.95 square metres vs. 581.09 square metres respectively). In the recent study period, the difference between the two is less than 2% (Markham: 401.73 square metres, Vaughan: 394.03 square metres).

Table 7.24: Average parcel sizes (inter-municipal)

	1981 - 1995		1996 - 2003	
	Markham	**Vaughan**	**Markham**	**Vaughan**
Parcels (n)	20379	22456	15520	22363
Average area (m2)	555.95	581.09	401.73	394.03
CV	90.8	116.0	80.8	57.2

Despite these similarities, the t-test results in Table 7.25 show statistically significant differences in mean lot sizes in the two municipalities for the early study period but not for the later period.

Table 7.25: Inter-municipal T-tests for mean lot size

	Df	t	p
1981 to 1995	41363.39	-4.395	0.000
1996 to 2003	25323.71	2.573	0.01

The similar average lot size values do not tell the whole story, however. In the early period, Markham's lot sizes were more notably more uniform than those in Vaughan (cv=90.8% vs.

cv=116.0). During the recent study period, the tables have turned and lot sizes are much more uniform in Vaughan (cv=57.2%) than in Markham (cv=90.8%). This suggests that planning in Markham may have acted as a brake against homogenizing development forces.

7.3 Land use

7.3.1 Service areas

One of the fundamental principles of the New Urbanist design philosophy is that neighbourhoods should have a mixture of uses in order to facilitate social interaction, reduce automobile use, and create a sense of place—things commonly thought to be absent in single use conventional developments. Not only should mixed uses be present, they must also be easily accessible and placed so that the maximum number of residents can benefit from them. Therefore, it is necessary to go beyond simply evaluating neighbourhoods for the number of mixed uses; it is also necessary to test their accessibility. One method of doing so is by looking at the service areas of local amenities, a measure of how many households are within a given distance. The following calculations are based on a distance threshold of 400 metres along the street network.

Intra-municipal findings: In Markham, the percentage of households within 400 metres (“walking distance”) decreased markedly for four of the six amenities, as shown in Table 7.26. Only for bus stops (a 5.6% decrease) and manufacturing (a 53.5% increase) was this not true.

Table 7.26: Percentage of parcels within 400 metres of amenities (Markham)

	Markham		
	1981 – 1995	**1996 - 2003**	**Change (%)**
Bus stops	75.4	71.2	-5.6
Eating places	18.4	8.8	-51.9
Elementary schools	24.8	15.6	-37.1
Grocery stores	18.1	7.3	-59.6
Manufacturing	12.6	19.4	53.5
Places of worship	12.6	6.6	-47.6

Similar trends are visible for Vaughan (see Table 7.27), with the percentage of households within walking distance decreasing for all amenities apart from manufacturing.

Table 7.27: Percentage of parcels within 400 metres of amenities (Vaughan)

	Vaughan		
	1981 – 1995	**1996 – 2003**	**Change (%)**
Bus stops	59.8	38.1	-36.3
Eating places	19.9	11.0	-44.8
Elementary schools	31.3	26.9	-14.2
Grocery stores	15.8	5.1	-67.8
Manufacturing	18.7	19.4	4.1
Places of worship	11.8	3.9	-67.2

It is unexpected to see that the number of dwellings within 400 metres of "manufacturing" rose in both municipalities from the earlier period to the recent. With the data at my disposal, I could not determine how long the manufacturing sites in the recent era study areas had been in existence. My assumption is that they largely predated construction of residential communities in the recent period, which have simply begun to consume the land in previously outlying areas that were originally attractive manufacturing sites due to inexpensive land values. At the same time, the increase in the number of dwellings close to manufacturing sites may indicate a relaxing of zoning policies that have traditionally enforced a strict segregation of uses.

Inter-municipal findings: There is little to differentiate the two municipalities when comparing households served by various amenities in the early study period, as shown in Table 7.28. There are minimal differences for three amenities (eating places, grocery stores and places of worship). The only notable differences are the percentage of households within walking distance of bus stops, elementary school and manufacturing sites. Twenty-six percent (26.1%) more households in Markham are within walking distance of bus stops than in Vaughan (75.4% vs. 59.8%). On the other hand, 33.8% more households in Vaughan are within walking distance of elementary schools (31.3% vs. 24.8%). And 48.4% more households in Vaughan are within walking distance of manufacturing sites (18.7% vs. 12.6%). Overall, for four of the amenities, Vaughan has a higher percentage of households within walking distance.

Table 7.28: Percentage of parcels within 400 metres of amenities (1981 - 1995, inter-municipal)

	1981 - 1995	
	Markham	**Vaughan**
Bus stops	75.4	59.8
Eating places	18.4	19.9
Elementary schools	24.8	31.3
Grocery stores	18.1	15.8
Manufacturing	12.6	18.7
Places of worship	12.6	11.8

Different trends emerge from a comparison of values for the recent period. Rather than similarity, the values in Table 7.29 exhibit disparity, with only a single amenity, manufacturing sites, having a similar (or in this case, identical) percentage of households within walking distance in both municipalities. The greatest disparity in absolute terms is the percent of households served by bus stops, which is 87% higher in Markham than Vaughan (71.2% vs. 38.1%). There are also substantial relative disparities for elementary schools (72% more households within walking distance in Vaughan) and places of worship, with 69% more household within walking distance in Markham (6.6% vs. 3.9%). Overall, more Markham households are within walking distance of three of the amenities (bus stops, grocery stores and places of worship), more Vaughan households are within walking distance of eating places and elementary schools and both municipalities have an equal percentage of households within walking distance of manufacturing locations.

Table 7.29: Percentage of parcels within 400 metres of amenities (1996-2003, inter-municipal)

	1996 - 2003	
	Markham	**Vaughan**
Bus stops	71.2	38.1
Eating places	8.8	11.0
Elementary schools	15.6	26.9
Grocery stores	7.3	5.1
Manufacturing	19.4	19.4
Places of worship	6.6	3.9

The most telling results, due to their large absolute values, are those for bus stops and elementary schools. The low absolute values for the remaining amenities suggest that there is little evidence of unconventional, mixed use development on the ground.

7.3.2 Distance to amenities

The service areas discussed in the previous section provide information about a subset of dwellings: those within a specified distance of an amenity. To understand the relation between all dwellings and all amenity destinations, it is necessary to calculate in the other direction, from the dwellings to destinations.

Intra-municipal findings: As with the service area statistics, values for the 1996 to 2003 period are not fully comparable with those from the 1981 to 1995 period since development is ongoing in the more recent study areas.

Table 7.30: Mean distance (m) to amenities (Markham, intra-municipal)

	Markham		
	1981 – 1995	**1996 - 2003**	**Change (%)**
Bus stops	358.2	381.2	6.4
Eating places	879.7	1359.2	54.5
Elementary schools	778.2	1041.0	33.8
Grocery store	920.4	1256.5	36.5
Manufacturing	914.3	913.3	-0.1
Places of worship	1050.5	1285.3	22.4
All amenities (avg)	**816.9**	**1039.4**	**25.6**

Tables 7.30 and 7.31 show period-over-period changes in distance to amenities for Markham and Vaughan respectively. Results generally mirror those seen for service areas, suggesting that amenities and households in both areas are distributed evenly. In Markham, the average distance to bus stops and manufacturing sites is essentially unchanged while distances to all other amenities have risen markedly. The greatest increase seen is in the average distance to eating places, which has risen from 879 metres to 1359 metres. When all six amenities are considered, distances have increased an average of 25.6% from the early study period to the recent study period.

Table 7.31: Mean distance (m) to amenities (Vaughan, intra-municipal)

	Vaughan		
	1981 – 1995	**1996 – 2003**	**Change (%)**
Bus stops	471.4	706.3	49.8
Eating places	808.9	961.0	18.8
Elementary schools	605.4	706.7	16.7
Grocery store	885.5	1245.8	40.7
Manufacturing	818.7	908.0	10.9
Places of worship	1048.9	1566.2	49.3
All amenities (avg)	**773.1**	**1015.7**	**31.0**

In Vaughan, average distances to *all* amenities have seen double-digit increases ranging from 10.9% (manufacturing sites) to 49.8% (bus stops). Overall, distances to amenities have increased an aggregate 31.0% from the early study period to the recent study period.

Inter-municipal findings: Table 7.32 displays the findings for the early study period. The average distance to amenities is greater in Markham for five of the six measures and overall, the distance to amenities is 5.7% greater in Markham than in Vaughan (816.9 metres vs. 1048.9 metres).

Table 7.32: Mean distance (m) to amenities (1981-1995, inter-municipal)

	1981 - 1995	
	Markham	**Vaughan**
Bus stops	358.2	471.4
Eating places	879.7	808.9
Elementary schools	778.2	605.4
Grocery store	920.4	885.5
Manufacturing	914.3	818.7
Places of worship	1050.5	1048.9
All amenities (avg)	**816.9**	**773.1**

T-tests of means reveal significant (p=.005) differences for three of the six variables in the early period: bus stops, elementary schools and manufacturing sites (Table 7.33).

Table 7.33: Inter-municipal T-test for distance to amenities (1981-1995)

	df	t	p
Bus stops	857.964	-6.424	0.000
Eating places	838.79	2.561	0.011
Elementary schools	758.715	6.355	0.000
Grocery Stores	914	1.236	0.217
Manufacturing	915	3.249	0.001
Places of worship	905	0.043	0.966

Of the variables whose mean differed significantly in the two municipalities for this time period, the magnitude of difference was small for one (manufacturing), and between small and moderate for the other two (bus stops and elementary schools).

Table 7.34: Inter-municipal distance (m) to amenities (1996-2003)

	1996 - 2003	
	Markham	**Vaughan**
Bus stops	381.2	706.3
Eating places	1359.2	961.0
Elementary schools	1041.0	706.7
Grocery store	1256.5	1245.8
Manufacturing	913.3	908.0
Places of worship	1285.3	1566.2
All amenities (avg)	**1039.4**	**1015.7**

In the recent study period, households in Markham remain more distant from amenities than households in Vaughan (aggregate mean distance: 1039.4 metres vs. 1015.7 metres). Bus stops remain markedly closer in Markham than in Vaughan (381.2 metres vs. 706.3 metres) as do places of worship (1285.3 metres on average vs. 1566.2 metres).

The mean distance to manufacturing ceases to be significantly different while the mean distance to places of worship becomes significant (see Table 7.35 below).

Table 7.35: Inter-municipal T-test for distance to amenities (1996-2003)

	df	t	p
Bus stops	1061.21	-14.295	0.000
Eating places	761.929	11.209	0.000
Elementary schools	863.352	10.266	0.000
Grocery stores	939.375	0.299	0.759
Manufacturing	1159	1.125	0.261
Places of worship	1124.235	-7.306	0.000

No coherent development patterns emerge from the individual values other than a trend to reduced accessibility in the recent study era. It may be that aggregate averages best characterize development in the two municipalities. These values (1,039.4 metres for Markham, 1,015.7 metres for Vaughan) suggest that, despite differences in average distance to particular amenities, overall accessibility to amenities is essentially identical in both municipalities.

7.3.3 Dwelling type variety

Information about dwelling types is available in many digital formats from Statistics Canada and provides a level of information seldom available in purely spatial data such as parcel data from commercial vendors. The information in Table 7.36 (next page) is taken from the 2001 Census Dissemination Area (DA) profiles for Markham and Vaughan and reflects only the DAs included in the study areas.

Table 7.36: Intra-municipal dwelling type comparison (Markham and Vaughan)

Dwelling Type	Markham		Vaughan	
	1981 – 1995	1996 – 2003	1981 – 1995	1996 - 2003
Single detached	20,130	7,680	21,290	10,105
Semi-detached	135	535	335	2,390
Row house	410	1,770	1,270	2,415
Apartment -duplex	800	430	175	30
Apartment, 5 or more storeys	1,125	185	3,330	115
Apartment, less than 5 storeys	470	260	70	5
Single detached (%)	**87.6**	**70.7**	**80.5**	**67.1**
House-based dwellings (%)	**89.9**	**91.9**	**86.5**	**99.0**
Apartment-based dwellings (%)	**10.4**	**8.1**	**13.5**	**1.0**

Intra-municipal findings: In both municipalities, the percentage of single detached dwellings dropping markedly from the early period to the recent period: from 87.6% to 70.7% in Markham and from 80.5% to 67.1% in Vaughan. However, when values for all house-based dwellings are accumulated and compared to aggregate apartment-based dwellings, it can be seen that in both municipalities, the percentage of house-based dwelling increased and the percentage of apartment-based dwellings decreased.

The declining percentage of single detached houses in both municipalities indicates that at least in terms of dwelling type mix, the conventional suburb has become less conventional in a very short period of time. The percentage single detached houses has fallen to roughly 70% in both municipalities for the most recent study period, a notable drop from the 80.5% and 87.6% values for Vaughan and Markham respectively in the 1981 to 1995 era.

Inter-municipal findings: In the early study period, single detached houses dominated Markham (87.6% of all dwellings) while Vaughan was slightly more diverse, having higher proportions of semi-detached dwellings, row houses and apartments than Markham (see Table 7.37).

Table 7.37: Inter-municipal dwelling type mix (1981-1995)

Dwelling Type	1981 - 1995	
	Markham	Vaughan
Single detached	20,130	21,290
Semi-detached	135	335
Row house	410	1,270
Apartment -duplex	800	175
Apartment, 5 or more storeys	1,125	3,330
Apartment, less than 5 storeys	470	70
Single detached (%)	**87.6**	**80.5**
“House” dwellings (%)	**89.9**	**86.5**
“Apartment” dwellings (%)	**10.4**	**13.5**

A much different pattern is seen in the recent era (Table 7.38, next page). While the proportion of singles in both municipalities is similar at approximately 70%, the proportion of all house-based dwellings has skyrocketed in Vaughan. Apartment-based dwellings are almost entirely absent in recent period development in Vaughan (120 of 10,105 dwelling units, or 1.0%). In Markham, meanwhile, a reduced but still significant proportion (8.1%) of apartment-based dwellings can be found.

Table 7.38: Inter-municipal dwelling type mix (1996-2003)

Dwelling Type	1996 - 2003	
	Markham	Vaughan
Single detached	7,680	10,105
Semi-detached	535	2,390
Row house	1,770	2,415
Apartment, duplex	430	30
Apartment, 5 or more storeys	185	115
Apartment, less than 5 storeys	260	5
Single detached (%)	**70.7**	**67.1**
"House" dwellings (%)	**91.9**	**99.0**
"Apartment" dwellings (%)	**8.1**	**1.0**

The reduction in the proportion of singles and the related increase in the proportions of semis and row houses are almost certainly in response to continual increases in land prices, which have made the single detached house less affordable to a sizable portion of the market. Given the precipitous drop in apartment dwellings in Vaughan (from 13.5% in the earlier study period to 1% in the more recent), one could argue that despite relatively "new" suburban dwelling styles such as row houses, conventional suburbs are becoming *more* conventional with the near total predominance of house-based dwellings.[18]

[18] Dwelling type variety statistics for Pickering, Mississauga and Brampton are included as Appendix 1 for comparison purposes.

Chapter 8
Summary of Findings

The first step in trying to determine if planning makes a difference is to examine all intra-municipal trends in Markham during the two study periods. If development patterns in the recent (1996 to 2003) study period are not substantially different from those in the earlier (1981 to 1995) study period, the implication is that there is little reason to examine and compare development patterns in Vaughan.

8.1 Development pattern trends – Markham

Twenty-three measures were calculated in an attempt to characterize residential built form and are displayed in Table 8.1. Seven of the measures indicate change in a direction consistent with the New Urbanist principles that inform Markham's post-1995 development philosophy. These are noted in the Evaluation column of the table as positives ("+"). Five measures show essentially no change ("0"), and eleven show changes in a negative direction.[19] The positive, neutral and negative are absolute evaluations: if the score for a particular indicator from the 1996 to 2003 period is worse than the score from the 1981 to 1995 period, the evaluation will be negative.

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[19] These evaluations may be slightly misleading due to the similarity of results for service areas and distance to amenities, however. These indicators will not necessarily yield similar results. In a large area with clusters of high population density surrounded by expanses of low population density, for example, a large proportion of the population could be within the service area of many amenities yet the average distance to amenities would be high. Most residential areas are characterized by a relatively flat density gradient; the similarity results for service areas and distance to amenities in Table 8-1 shows that Markham's recent residential development conforms to this pattern. As such, the service area and distance to amenity scores are likely somewhat duplicative and overemphasize the "negative" direction of changes.

Table 8.1: Development pattern summary (Markham)

Measure	Change (%)	Significant	Evaluation
% X intersections	36.2	-	+
Intersections per km	2.3	-	0
Mono-exit length (avg)	-7.5	no	0
Mono-exits (% of total network)	-34.9	-	+
Block size (avg)	-51.74	yes	+
Block perimeter (avg)	-38.78	yes	+
Lot size (avg)	-27.7	yes	+
Population per km2 (adjusted)	-57.5	-	-
Dwelling units per ha.	-54.9	-	-
Bus stops	-5.6	-	0
Eating places	-51.9	-	-
Elementary schools	-37.1	-	-
Grocery stores	-59.6	-	-
Manufacturing	53.5	-	+
Places of worship	-47.6	-	-
Bus stops (dist)	6.4	no	0
Eating places (dist)	54.5	yes	-
Elementary schools (dist)	33.8	yes	-
Grocery stores (dist)	36.5	yes	-
Manufacturing (dist)	-0.1	no	0
Places of worship (dist)	22.4	yes	-
Single detached house %	-19.3	-	+
Apartment-based dwellings	-22.1	-	-

Positive changes, and the majority of neutrals, are related to the street network pattern. The negatives are related to accessibility, particularly indicators related to the proportion of households within walking distance of amenities and the average distance to amenities.

The suburban residential landscape has clearly not been transformed in Markham. Yet there are two reasons to continue this discussion: there is *some* indication of new patterns emerging (e.g. in the street network and lot sizes); and it may be that some of the "negative" changes are of much lower magnitude in Markham than elsewhere. Each of these, if they are unique to Markham, may be the result of the municipality's planning philosophy. A comparison of measures from contemporary Vaughan will provide some illumination on the first issue, and comparison with development patterns in the previous era will help address the second.

8.2 Development pattern trends – Vaughan

Table 8.2 summarizes the period over period findings for Vaughan. In the "Change" column, values for Markham for the same indicator appear in parentheses. As in Markham, the positive indicators are related to the street network, lot size and proportion of single, detached dwellings. And similar to Markham, negative evaluations dominate the accessibility related measures.

Table 8.2: Development pattern summary (Vaughan)

Measure	Change (%)	Significant	Evaluation
% X intersections	9 (36.2)	-	+
Intersections per km	-5.9 (2.3)	-	0
Mono-exit length (avg)	12.1 (-7.5)	no	0
Mono-exits (% of total network)	-27.2 (-34.9)	-	+
Block size (avg)	-45.58 (-51.74)	yes	+
Block perimeter (avg)	-30.82 (-38.78)	yes	+
Population per km2 (adjusted)	-50.3 (-57.5)	-	-
Dwelling units per ha.	-46.4 (-54.9)	-	-
Lot size (avg)	-32.2 (-27.7)	yes	+
Bus stops	-36.3 (-5.6)	-	-
Eating places	-44.8 (-51.9)	-	-
Elementary schools	-14.2 (-37.1)	-	-
Grocery stores	-67.8 (-59.6)	-	-
Manufacturing	4.1 (53.5)	-	0
Places of worship	-67.2 (-47.6)	-	-
Bus stops (dist)	49.8 (6.4)	yes	-
Eating places (dist)	18 (54.5)	yes	-
Elementary schools (dist)	16.7 (33.8)	yes	-
Grocery stores (dist)	40.7 (36.5)	yes	-
Manufacturing (dist)	10.9 (-0.1)	no	0
Places of worship (dist)	49.3 (22.4)	yes	-
Single detached house %	-16.7 (-19.3)	-	+
Apartment-based dwellings	-92.6 (-22.1)	-	-

Vaughan inter-period indicators. Significance relates to Vaughan only.

When using the Evaluation indicators (positive, neutral or negative), development patterns are on the whole quite similar in the two municipalities, with indicators breaking down as follows:

Table 8.3: Inter-municipal evaluation summary

Municipality	Positive	Neutral	Negative
Markham	7	5	11
Vaughan	6	4	13

An examination of relative performance paints a somewhat different picture. Table 8.4 (next page) shows Markham's 1996 to 2003 performance in absolute terms (that is, measured against development patterns in the 1981 to 1995 period) and in relative terms (compared to 1996 to 2003 development in Vaughan). A positive relative evaluation for a particular indicator is assigned under the following circumstances:

1. When the indicator is positive in absolute terms in both municipalities and Markham's score exceeds that of Vaughan.
2. When an indicator is positive in absolute terms in Markham and is neutral or negative for Vaughan.
3. When an indicator is neutral in absolute terms in Markham and negative in Vaughan.
4. When the indicator is negative in absolute terms in both municipalities and Markham's score is smaller (closer to zero) than Vaughan's.

Table 8.4: Absolute and relative performance (Markham)

	Markham Performance	
Measure	**Absolute**	**Relative**
Street network		
% X intersections	+	+
Intersections per km	0	+
Mono-exit length (avg)	0	+
Mono-exits (% of total network)	+	+
Block size (avg)	+	+
Block perimeter (avg)	+	+
Density		
Population per km2 (adjusted)	-	-
Dwelling units per ha.	-	-
Lot size (avg)	+	-
Service Areas		
Bus stops	-	+
Eating places	-	-
Elementary schools	-	-
Grocery stores	-	+
Manufacturing	0	+
Places of worship	-	+
Mean distance to amenities		
Bus stops (dist)	-	+
Eating places (dist)	-	-
Elementary schools (dist)	-	-
Grocery stores (dist)	-	+
Manufacturing (dist)	0	+
Places of worship (dist)	-	+
Dwellings		
Single detached house %	+	+
Apartment-based dwellings	-	+

For sixteen of the twenty-three indicators, Markham's relative performance is superior to that of Vaughan. That Markham would perform better in nearly 70% of the measures suggests that something—perhaps the planning approach—is different in Markham than in Vaughan.

8.3 Uniformity

Table 8.5: Summary of attribute coefficients of variance

	1981 to 1995		1996 to 2003	
Attribute	Markham CV (%)	Vaughan CV (%)	Markham CV (%)	Vaughan CV (%)
Mono-exit length	74.7	89.8	144.3	81.2
Block size	105.2	108.0	79.1	77.5
Block perimeter	69.6	64.0	50.7	51.3
Lot size	90.8	116.0	80.8	57.2
Distance to bus stops	59.4	67.2	74.5	68.2
Distance to eating places	51.3	46.5	92.2	119.2
Distance to elementary schools	60.1	54.9	62.3	63.1
Distance to grocery stores	47.3	47.2	50.7	42.5
Distance to manufacturing sites	49.3	53.6	52.9	54.3
Distance to places of worship	51.1	52.2	46.8	44.0
Overall Average	65.9	69.9	73.4	65.8

Uniformity, as captured through coefficient of variance, was calculated for all measures that had means. In the summary presented in Table 8.5, there are only two measures in the early study period with notably different uniformity: mean mono-exit length and mean lot size. In each case, Markham was more uniform than Vaughan. Otherwise, the values are remarkably alike, averaging 65.9% in Markham and 69.9% in Vaughan. This pattern generally holds true for the 1996 to 2003 period, with the same two measures (mono-exit length and lot size) showing a notable disparity and distance to eating places emerging as a third measure with a wide variance.

Interestingly, the relative uniformity of mono-exit length and lot size is reversed from 1981 to 1995, with Markham showing much less uniformity than Vaughan. It is difficult to determine why these features have resisted the push to uniformity. One possibility is that in order to implement new approaches like the use of a grid-based network of streets in a residential area, Markham has had to make compromises with developers. Thus while there are proportionally fewer cul-de-sacs, dead ends and loops in Markham in the 1996 to 2003 study period, they are now longer on average than those in the1981 to 1995 period.

The same dynamic may be occurring with lot size as well. In Markham and Vaughan during the 1996 to 2003 period, the average lot size has plummeted to nearly identical values of 401 and 394 square metres respectively. Despite this similarity, lot size in Markham is far less uniform (cv=80.8%) than in Vaughan (cv=57.2%). The values for the 1981 to 1995 period, in which lot size was much less uniform in Vaughan than in Markham, indicate that this is most definitely not the continuation of a historical trend. Again, this may represent a *quid pro quo* in the form of variances or relaxed zoning with developers who have traditionally been reluctant to deviate from a historically profitable conventional approach. The possibility of developing a limited number of sites along conventional lines may be a pragmatic "carrot" offered to developers in order to help overcome resistance to participation in implementing Markham's unconventional approach.[20]

From the findings, one can cautiously conclude that planning *can* influence the built form, although in absolute terms, planning's influence appears to be narrow and quite limited. Of the six measures returning positive results for development in Markham during the 1996 to 2003 period, for example, four are related to the configuration of the street network. In each of these cases, Markham accelerated a trend already at play in conventional development. While mean block size, for example, fell 51.74% in Markham, it also fell 45.58% in Vaughan. In only two cases did results in Markham go *against* conventional trends, and both of these are again related to the street network: the number of intersections per kilometer (5.9% decrease in Vaughan, 2.3% increase in Markham), and the mean length of mono-exits (12.1% increase in Vaughan, 7.5% decrease in Markham).

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[20] According to a Markham planner, this kind of give and take with developers is an unavoidable and expected part of the development process. Markham goes as far as managing these exchanges by being flexible over the development of less visible areas but enforcing strict adherence in the development of high visibility, high traffic areas (Markham planner, personal interview, 2004).

Of the elements of the built environment measured in this research, land use was shown to have been least influenced by planning, with results for service areas and distance-to-amenity indicators in Markham that are essentially identical to those in Vaughan. In some cases, Markham fares worse, even for measures that are fundamental to New Urbanist design philosophy such as the distance to elementary schools, which increased by 16.7% in Vaughan but 33.8% in Markham. When service areas and distance-to-amenity are considered for both municipalities, improvements were seen in only three of the twenty-four cases. This paints a portrait of residential areas that—far from exhibiting a diversified mix of uses—are becoming more homogeneous than in previous eras.

These findings are in line with those in recent studies. An examination of the impact of Smart Growth initiatives in counties in Oregon, Florida and Maryland found that mixed uses were absent from residential areas, distance to amenities and transit were increasing, and pedestrian accessibility was decreasing. Internal connectivity, conversely, was increasing (Song, 2005). A previous study returned similar results (Song and Knaap, 2004).

Chapter 9
Interpretation of Findings

In order to augment the quantitative findings, I spent two days in the dissemination areas constituting the recent study period, much of it by car (given the size of the areas involved) and some on foot. This was quite useful as subjective evaluation of the character of the two municipalities. The characteristics presented earlier in the findings were generally too subtle to be noticed, but there were some notable differences between development in Markham and Vaughan, outlined in the following sections. Although these observations were not gathered in a rigorous process, I have used some of them in interpreting the findings. Mirroring the scope of the methodology, these interpretations concentrate on the perspectives and actions of the leading stakeholders in residential development: municipal planning, developers and consumers.

9.1 Street network findings

The findings revealed connectivity gains in both municipalities as recent development has become more grid-based than in the past. The percentage of the network consumed by cul-de-sacs, loops and dead ends decreased as did average block size, while the proportion of 4-way networks increased. This has occurred despite Vaughan, unlike Markham, having no comprehensive development philosophy geared to achieving these New Urbanist goals. Among the possibilities to explain this situation is the notion that two distinct processes, planning (in Markham) and “the market” (in Vaughan), happened to result in nearly identical outcomes. Another, and I think much more likely possibility, is that Markham’s planning approach simply pushed the development dynamic a little bit farther in a direction it was already headed, particularly as the Province was advocating for grid-based street networks in its *Transit Supportive Land Use Planning Guidelines* (Ontario Ministry of Transportation, 1992).

Market and developer perceptions of the grid made the move away from curvilinear and looping streets uncontroversial. Suburban areas have traditionally eschewed the grid for meandering streets for reasons of pedestrian safety (Wang & Smith, 1997) but also as a reaction against urban areas, which have been laid out in grids for millennia (Grant, 2001). The conflation of curvilinear streets with suburban areas was likely most prevalent in the early post-World War Two years, when suburbs and suburban living were perceived as something new and different. Yet, in Canada at least, many post-War suburban areas exhibit a grid-based street network, suggesting that the association of suburban living with curvilinear streets may not have been as strong in Canada as it was in the United

States—and by extension, that a switch to grid-dominated development could be implemented with little chance of market repercussions.

Reluctance to grid-based suburban street networks may also have declined as lot widths have shrunk and dwellings have grown taller and narrower or, in other words, become more “urban” in proportion. It may be that people are more willing to see such dwellings in a grid-based environment because it mirrors the appearance of housing in urban areas—housing which is highly sought after at the moment. At the same time, the alternative would likely be more unexpected and unattractive. A curvilinear street packed with tall houses on lots twenty-two feet wide would equally fail to embody the suburban ideal. A grid-based network, then, might be perceived to be the “natural” setting for tall houses on narrow lots.

For developers, there is likely to be little or no extra cost or effort needed to implement grid-based streets. The use of a grid-based network eliminates oddly shaped lots and reduces variation in lot sizes, thus streamlining the marketing and sales processes because the customer can be offered a limited menu of lot/dwelling combinations. A grid-based network may also be less expensive to plan, survey and construct. Finally, the move to a more grid-based network does not represent a major shift away from the elements that define the notion of suburban development for consumers, who expect single family dwellings with a garage and front and rear yards in a single use, peripheral setting. Particularly when considered along with the market implications of narrow lots as discussed above, it seems inevitable that street networks in suburban areas would become more grid-oriented.[21]

9.2 Density findings

Increasing density is a goal of Markham’s development philosophy, yet for the three density measures calculated in this research (population and dwelling density; average lot size), Vaughan performed as well or better than Markham in the recent development period. Because of the incomplete state of development in recent period study areas and the constraints implicit in my broad scale and partially automated approach, the most reliable of the measures is average lot size.

In both municipalities, average lot size decrease substantially (approximately 30%) from the early study period to the later. One of the most obvious causes for this reduction is land economics. Driven by rapidly increasing population, land prices increased throughout the GTA region faster than earnings, meaning that unless lot sizes were decreased, the proportion of the market able to afford a “standard” suburban house would have continually dwindled.

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[21] Another possible explanation for a shift to grid-based street networks in Vaughan is that some of the principles of New Urbanism have been co-opted by mainstream developers.

Yet this is only part of the story. While Markham's development philosophy adheres to New Urbanist dogma by calling for a diversity of housing types, it is in Vaughan where there are proportionally more row housing and semi-detached dwellings, 32% vs. 23% in Markham. It is initially difficult to imagine why the market driven development process in Vaughan would result in nearly 40% more non-detached dwellings than in Markham, but a visual inspection of the study areas suggests market innovation and perhaps distinct planning contexts can explain the situation.

The market innovation I speak of is the aggressive use by developers in Vaughan of row housing and semi-detached dwellings, whose lots are relatively small, in all parts of subdivisions that have locational shortcomings. Row housing, for example, is used extensively around the periphery of subdivisions adjacent to heavily used streets or highways. Vehicle noise and a distinctly un-bucolic view make these locations less desirable and developers have responded by placing less expensive and higher density housing here.

Figure 9.1: Row housing on the periphery of a subdivision, Vaughan

Figure 9.1, for example, shows a lengthy stretch of row housing that faces Weston Road, a busy thoroughfare in Vaughan. Figure 9.2 (next page) shows row housing along the northern perimeter of the same subdivision. . Row housing and semi-detached housing is also used extensively in Vaughan

in locations close to schools and retail, and locations with commercial or industrial sites in their view-shed. In previous eras, these peripheral areas may have been left undeveloped or have had extremely modest dwellings constructed on them.

The current solution uses row houses to create dwellings that are similar in size and style to other houses in the subdivision, thus reducing the “other side of the tracks” stigma associated with down-market housing in less than ideal locations. At the same time, the two and three story row houses and semis act as an effective sound barrier, preventing vehicle noise from penetrating to the interior of the subdivision. Row housing also provides a sense of enclosure and separation from adjacent areas, creating an atmosphere similar to that found in gated communities, no doubt a marketable attribute.

Figure 9.2: Peripheral row housing, Vaughan

On the other hand, the location of row housing and semi-detached housing in Markham is much less segregated and predictable than in Vaughan, appearing amid detached singles as well along arterials on the periphery of subdivisions.

This is consistent with New Urbanist principles calling for a mix of dwelling types and suggests slightly different development contexts in Markham and Vaughan. The market-led approach in Vaughan has resulted in many subdivisions that are essentially walled in communities, with an interior core of detached singles and a peripheral boundary of row housing. Markham’s approach has created a more heterogeneous spatial mix of dwelling types that is generally superior aesthetically to what is seen in Vaughan, but it has resulted in a much higher proportion of house-based dwellings being detached singles.

Figure 9.3: Row housing facing a public greenspace, Markham

9.3 Land use findings

The component of Markham's New Urbanist development philosophy that departs most significantly from conventional suburban development practices is the call for a mixture of uses in residential areas. Yet for almost all measures related to land use mix, recent development in Markham fares worse than development in the earlier period. For many of these measures, recent development in Vaughan performs better than contemporary development in Markham. And the two measures in which recent development in Markham outperforms earlier development may be due circumstances unrelated to Markham's planning philosophy. More strongly than any other, these results clearly establish the limited capability of planning to influence the organization of residential built form.

The findings related to service areas of, and average distance to, amenities such as eating places, elementary schools and grocery stores can be explained in economic terms. Simply put, these uses would not be economically viable if they were embedded into the residential fabric, particularly with the frequency that New Urbanist plans often call for (Bartlett, 2003; Grant, 2002). Retail locations gravitate to high traffic areas along busy arterials and at major intersections. The theoretically greater pedestrian traffic provided by a location within a subdivision, such as the proposed high street in Cornell, is not enough to offset the loss of business inherent with an interior location. At the same time, the trend in retailing has been toward larger outlets in vast settings. It is easy to understand why there has been little enthusiasm by merchants to construct small and relatively isolated outlets within subdivisions.

Figure 9.4: High school in Vaughan

For schools, the situation is slightly different, but an identical economic dynamic is at work. The idea of children being able (and willing!) to walk to a school that is within five minutes of their dwelling is certainly attractive and it has long been part of the New Urbanist creed. The land use plan for Cornell (see Figure 4.2, page 42) indicates no less than five elementary schools and two high schools for the section of Cornell that has been developed to date. At the moment, only a single elementary school has been built.

Unless a school board has virtually unlimited funding, an arrangement like the one set out in Cornell's land use plan is not feasible, purely for reasons related to economies of scale. It is more cost effective in terms of land, construction, and staffing costs to build a small number of large schools than to build a large number of small schools.

Markham has done much better than Vaughan with regard to accessibility of residents to transit stops, but this is a function of the routes and stops implemented by York Region. If Markham's street network was better suited to public transit than Vaughan's, planning might be able to take credit for Markham's superior access to transit stops. Yet the findings showed that street networks in new development in Markham and Vaughan were quite similar. It may be that Markham has been more aggressive and persuasive with York Region in obtaining transit service than Vaughan. I did not investigate this possibility but it would be a useful exercise in a more detailed evaluation of planning capability.

Markham also does well with accessibility to manufacturing, a proxy for employment, but this appears coincidental. As mentioned previously, this appears to be a result of residential development encroaching in areas previously outlying areas that were populated by manufacturing sites due to inexpensive land.

Figure 9.5: SUV successfully navigates past pedestrian with baby stroller, Vaughan

Although not quantified in this study, one aspect of accessibility in which planning in Markham appears to have succeeded is the provision of sidewalks. Many streets in recent era development in Markham have sidewalks on both sides, and most have sidewalks on at least one side. In Vaughan, conversely, fewer streets have sidewalks on both sides, and streets entirely without sidewalks are not uncommon. The result is that cyclists, pedestrians and motorists share the same space, surely a dangerous situation.

9.4 Planning's influence on residential built form

Overall, the findings suggest that planning is but one of many factors affecting residential built form. Land economics, developer innovation, business location trends, and economies of scale all appear to have substantial influence on the development process. The causal links between increasing land prices and decreasing lot size, for example, appear to be self-evident. The same appears to be true in the relation between economies of scale, larger schools and decreased pedestrian access to schools and stores. Conversely, there is little in the findings that suggests planning has influenced the built form to a significant degree. Despite Markham's adoption of an unconventional development philosophy, its development patterns and trends over time were largely similar to those seen in Vaughan.

If the findings from Markham are indicative, it is challenging to see the results as anything but bleak where planning's influence is concerned. The results suggest that planning is, at best, capable of moderately influencing existing trends by accelerating positive ones and retarding negative ones. The move to more grid-based street networks provides a useful example of the former. With little opposition to this idea, and provincial support, Markham has been able to implement residential street networks with higher connectivity than those in Vaughan. Yet where there are countervailing forces, as in the case of economies of scale regarding school and retail location, Markham fares no better—and sometimes worse—then Vaughan.

A further cautionary note is in order: it is possible that Markham's performance *overstates* planning's ability to influence built form. For the past fifteen years, Markham has enjoyed many of the characteristics associated with plan implementation success. Many of these characteristics relate to Markham's proximity to Toronto. Due to strong and varied transportation links to Toronto, Markham has shared in Toronto's growth. This is a crucial point, since an unconventional development philosophy like the one adopted by Markham would have little chance of success in the absence of a strong housing market. In addition, Markham's council and two mayors over the past fifteen years have been strongly supportive of the new development approach. And, as I found while doing preliminary research for this study, Markham's planning department has an innovative team-based structure that provides exceptional organizational capability as well as credibility with both internal and external stakeholders. And finally, despite the continued popularity of new suburban housing, there has been relatively widespread societal discontent with the environmental, social and health costs of sprawl. In sum, Markham adopted its unconventional development philosophy during a prosperous era characterized by a booming housing market and societal support for new ideas about residential growth. Markham had adequate resources and organizational capability, full municipal and provincial support, substantial input from one of the founders of New Urbanism, and charismatic leadership in the mayor's office and the planning department. Yet, at the municipal scale, the impact of planning is difficult to discern apart from isolated projects such as Cornell.

9.5 Implications for planning

What these results tell us about planning's capability depends on one's outlook on the nature of present day planning. Taking a conformance perspective by comparing goals with outcomes and factoring in the findings from Vaughan, it would seem difficult to argue that municipal planning is capable of influencing the organization of the residential landscape to a significant degree. The implication, from this perspective, is that any planning efforts to push development in a given direction will have difficulty succeeding if those efforts are contrary to other forces and trends—especially economic ones—that influence the residential development process. Taken a step further, one could argue that planning's apparently limited capability to influence a process over which it has ascribed control means that municipal planning should be refocused to engage only those issues, or aspects of issues, over which it has direct and formal control.

9.6 The Performance perspective revisited

A different conclusion—that planning *can* be effective in areas over which it has only ascribed powers—derives from the "performance" perspective introduced in section 2.1 of this document. The performance approach holds that it is inappropriate to measure long range (or "strategic") plans solely on the conformance of outcomes to original plan goals. One reason is that unforeseen events, such as dramatic economic changes, new political regimes, the outbreak of a contagious disease or a terrorist attack can result in plans being altered or cancelled. In these cases, plan outcomes would partly or entirely fail to conform to the original plan goals, and the plan along with the planners who created it, would be judged to have failed (Mastop & Faludi, 1997).

If it is illogical to evaluate long-range strategic plans according to how closely outcomes conform to goals, what is the alternative? For Faludi and those who promote a performance approach, the answer lies in examining subsequent planning decisions. If the plan being evaluated was thought to have enough "good" qualities that it was used in the creation in subsequent plans, the original plan will be deemed to have "performed" well regardless of goal/outcome conformity.

In this regard, strategic plans are seen less as projects that can succeed or fail and more as tools that help subsequent “decision makers make sense of their situations” (Faludi, 2000). More specifically, Faludi states that a strategic plan will have performed well if two conditions are met:

> The necessary condition is that operational decision makers must know the plan. The sufficient condition is that decision makers must accept the plan as part of the definition of their decision situations (Faludi, 2000).

In other words, a plan will have done all that can be expected of it if it has been recognized by decision makers as being relevant and integral to the issue at hand and has, presumably, informed the decision-making process in some way. In this view, the plan is essentially a vehicle for the creation, articulation and perpetuation of a given planning philosophy or “doctrine,” in Faludi’s (2000) terminology.

From this perspective, the results would likely appear less discouraging for Markham because all evidence points to the continual and repeated use of its development philosophy from the early 1990s through to the present. The most salient example of this is seen in the development of a “suburban downtown” area called Markham Centre. An ambitious development that will cover more than 900 acres, Markham Centre is designed to be “an environmentally sustainable, transit-friendly, attractive home for about 25,000 new residents and 17,000 employees” (Town of Markham, 2004). It incorporates a multitude of Smart Growth and New Urbanist principles concerning the built form, transportation and transit, accessibility and environmental protection—largely the same principles that informed the creation of the Cornell secondary plan and the municipality’s New Urbanist zoning by-law. While little of Markham Centre has been developed at this point, the germane point is that the process of planning its future is entirely consonant with the development approach Markham adopted in the 1990s.

A further indication of the effectiveness of Markham’s approach is that the Cornell secondary plan is itself currently being reviewed after having been in place for more than ten years. While the review is ongoing, Markham has reaffirmed its commitment to the original vision of the plan and will extend its concept of Cornell as an “urban, compact, mixed-use, pedestrian-friendly, transit supportive node” by integrating it with “Avenue 7” (formerly Highway 7), the existing Markham Stouffville hospital and a developing business/office district on Cornell’s east boundary (Town of Markham, no date). The intent is to continue the trajectory Cornell is on, not to change it.

9.6.1 Organizational culture and planning capability

Markham’s consistent application of a New Urbanist inspired development approach suggests that this philosophy or doctrine has become a social fact for the municipality. Faludi uses Giddens’ concept of structuration to describe this process, noting that, “[d]octrine is one form of structuring modality. More specifically, it is a belief system in that it conveys meaning, in this case to actors involved in spatial development" (Faludi, 2000). In other words, the values that comprise a doctrine can become part of an organization's "culture", which can be defined as:

> A pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems (Schein, 1992).

While predominantly studied in relation to private, for-profit companies, organizational culture and its implications surely apply to the planning process as well. The obvious difference is that private corporations sell commodities or services while planning sells ideas, at least where strategic plans are concerned. This is not merely a metaphor; Markham, for example, has a "huge" marketing budget as part of a comprehensive "marketing and communication strategy" (Markham planner, personal interview, 2004). The strategy involves marketing the municipality's development philosophy through conventional approaches, such as public information sessions, along with more unusual approaches such as giving presentations at schools and trade shows, meeting with new businesses and "advertising" the municipal vision on the hoardings that enclose construction sites (Markham planner, personal interview, 2004).

Studies have found that organizational culture "can have a significant impact" on an organization's performance (Kotter & Heskett, 1992) and that there are both internal and external benefits that derive from a strong and flexible organizational culture. Internal benefits include:

- Involvement (also known as employee "ownership" or "buy-in")
- Consistency: shared philosophy leads to goals consistent with "cultural" principles
- External benefits include:
- Adaptability: a "customer" focused organization will more easily adapt to change.
- Mission: "A mission provides purpose and meaning by defining a social role and external goals for an institution and defining individual roles with respect to the institutional role" (Denison, 1990).

These benefits would accrue to a public, not-for-profit organization just as they would for a private corporation, with similarly positive results, including a relationship with clients that is closer to cooperative than adversarial. Where a private corporation would see the results in sales figures, a public institution like a planning department would see gains in credibility. In areas over which planning or any other organization has ascribed rather formal control, credibility is the only currency. This suggests that the most capable planning departments will be those with a strong and flexible organizational culture.

The implication of a conformance perspective, as mentioned above, is that planning should be curtailed. The implication of the performance perspective, on the other hand, is that planning must continue to address long-term issues and processes, even those over which it does not have direct control and despite being unable in many circumstances to produce easily measurable results. The performance perspective argues that the results or conformance of long term plans are less important than the creation and perpetuation of doctrine. Doctrine is a product of the planning process as much as plans are and through doctrine, constituent values can be articulated and relevant goals identified. Planning's participation in areas over which it has only ascribed control may therefore be more important than ever, as market forces continue to gain influence over urban processes including residential development. Planning's expertise, and it relative insulation from political cycles, make it ideally suited to the creation of strategic plans and doctrine—far better than the alternative: "to leave planning doctrine to the visionary designers and/or politicians" (Faludi, 2000).

Chapter 10
Conclusion

This research describes a methodology for measuring built form patterns using spatial data and GIS that is amenable to the study of large geographical areas. This methodology was used to investigate the capability of municipal planning to influence residential development. The study areas, Markham and Vaughan, were chosen because their many contextual similarities allowed planning to be isolated as a force influencing development. Two eras were studied: from 1981 to 1995 and from 1996 to 2003.

Findings indicate that, as hypothesized, development patterns are distinct for the two study periods, with street networks taking on a more grid-like organization and building lots, along with blocks, becoming much smaller in the 1996 to 2003 development era. Accessibility to amenities is generally much lower in the more recent study period.

It was necessary, on the other hand, to reject the hypothesis that the development philosophy in force in Markham during the more recent study period would result in substantially different findings than in Vaughan. Few notable differences were found in absolute terms between the two municipalities, although Markham's performance relative to that of Vaughan was largely positive, suggesting that Markham's philosophy may have had *some* impact.

A possible limitation of the findings is related to the length of the most recent study period. The volume of the data was sufficient; there were more than fifteen thousand parcels and three hundred kilometers of streets included in the recent study period in Markham. However, the duration of the recent study period (1996 to 2003) may have precluded fully capturing the impacts of Markham's development philosophy on built form patterns.

The obvious need is for an approach similar to the one outlined in this study to be employed at a later date, such as after the 2011 census. This would eliminate some of the compromises forced by the available data (such as the inability to calculate standard density measures) and would provide much more insight into the effects of organizational culture on planning capability. Only when studies such as these have been carried for municipalities in Toronto and other Canadian cities can we begin to answer questions about planning's capabilities with any confidence.

Appendix A

Dwelling type statistics for Pickering, Mississauga, and Brampton

Dwelling type data for the other three municipalities that border the city of Toronto (Pickering to the east, and Mississauga and Brampton to the west) are presented in Table A.1. The data were gathered in order to ascertain which situation better reflected current trends: Markham's relatively minimal loss of apartment-based dwellings, or Vaughan's conversion to almost entirely house-based dwellings. I selected Dissemination Areas (DAs) in the three other municipalities using the same criteria I used to select Markham and Vaughan DAs for this study. That is, DAs were included if the percentage of dwellings constructed between 1981 and 1995, or between 1996 and 2001 exceeded 60.0%.

Table A.1: Dwelling type mix (Pickering, Mississauga, Brampton)

	Pickering		Mississauga		Brampton	
	1981 - 1995	1996 – 2001	1981 – 1995	1996 – 2001	1981 – 1995	1996 – 2001
Single detached (%)	72.7	82.6	41.3	50.8	51.6	56.8
"House" dwellings (%)	90.1	**99.0**	63.7	**93.2**	74.4	**97.0**
"Apartment" dwellings (%)	10.1	0.2	36.1	6.6	25.6	2.6

Values may not total to 100% due to exclusion of "other" and "movable" dwelling types and census data inconsistencies.

In these three municipalities, the percentage of single detached houses has increased rapidly, but the striking results are, as in Vaughan, the near total dominance of house-based dwelling types in the recent period. Pickering's share matches Vaughan's at 99%, and even municipalities known for their high proportion of apartment-based dwellings like Mississauga and Brampton are nearly identical, at 93.2% and 97.0% respectively. Clearly, there is a very strong market push toward house-based dwellings in new residential development. It would appear, therefore, that the variety of dwelling types being built in Markham is anomalous, and that the near complete dominance of house-based dwellings seen in Vaughan is very much the norm.

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