A Framework for Quantifying Suburban Parking Maxima

by

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Authors Declaration

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

I understand that my thesis may be made electronically available to the public.

James T. LaPointe

Abstract

The provision and pricing of parking are recognized as important tools for achieving transportation demand management (TDM) objectives. Much of the existing literature on the topic concentrates on downtown cores and calls for the application of maximum parking allowances to limit supplies. This thesis presents an analysis of existing suburban parking supplies in order to quantify parking maxima. The total number of spaces provided, footprint required to accommodate the spaces and the employment to which parking is providing are quantified. The totals are separated by different land use categories and quantities of employment are normalized to account for high trip-generating jobs such as retail. Parking supplies are examined as a function of traditional land use market theory and across primary land use categories. The results indicate that employment is a fairly weak indicator of parking supply, while weighted employment that considers the effects of retail is a much stronger indicator. On average, very high and very low land use densities have the lowest parking requirements per employee (0.39 spaces per employee) while moderate land use densities have the least diversity of land use, yet the highest supply of employee parking (4.01 spaces per employee). The methodology applied may be used to produce quantitative maxima to be incorporated into local parking bylaws that are recognized as potentially strong TDM tools. Further research that compares the observed parking supply patterns across a series of mid-sized cities is recommended to make stronger conclusions regarding the range of maximum values.

Acknowledgements

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I would like to thank my family for supporting me throughout my seven-year university career and whose love has sustained me all these years.

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Definition of Terms

Building Footprint

Also known as lot coverage, it is a measurement in hectares of land area consumed by buildings and structures (Waterloo, 2006b). It is used in this study to measure the footprint of employment buildings for which parking lots are providing.

Geographic Information System (GIS)

GIS is a system specifically designed to work with data referenced by spatial or geographic coordinates. It is both a database system with specific capabilities for spatially referenced data, as well as a platform for analytical operations for working with the data (DeMers, 1997). In this study, GIS is used to capture areas allocated to various land uses with spatial references.

Gross Leasable Area (GLA)

The available floor area of a building for lease. Often used to calculate standard minimum parking space provision requirements per thousand square feet of GLA (Smith, 2005).

High-Resolution Aerial Photographs

High-resolution aerial photographs are very detailed digital images taken via satellite photography offering a top-down view of a landscape. A 50 centimetre resolution aerial digital photograph shows the details of objects 50 centimetres in size or larger while a 10 centimetre resolution aerial digital photograph will show the details of objects 10 centimetres or larger. Created by Northways Photomap Inc, 12 centimetre resolution digital orthomosaic photographs are accessed in this thesis. The images used for this study are the orthomosaic digital photographs representing the existing 2006 topography. These digital images are provided to and accessed through the University of Waterloo's Map Library from the Region of Waterloo.

Land Use Density

A calculated measurement used as a tool to measure the density of uses in a given area. It is calculated by totalling the number of residents (population), plus the number of jobs (employment) per unit area of land (hectares) (Waterloo, 2006b). Used in this study, it is calculated at the *Traffic Analysis Zone* level.

Parking Density

A measure of total parking spaces provided per hectare of parking footprint. In this study, parking density is calculated by dividing the total number of parking spaces in a TAZ by the total *Parking Footprint* of all lots in a TAZ.

Parking Footprint

A measurement in hectares of all land area consumed by surface parking lots and parking structures in a *Traffic Analysis Zone*.

Parking Maxima

A term referring to bylaw or zoning limits of the number of parking spaces which may be supplied by a developer.

Parking Minimums

Set through zoning bylaws, it is the minimum supply of parking, which may be supplied by a developer. Usually a function of *Gross Leasable Area,* employees or dwelling units (Smith, 2005) the supply may be provided beyond the minima.

Parking Restrictions

Provisions of local ordinances that fully or partially restrict on or off-street parking (Urban Land Institute, 2000).

Parking Structure

A building located above and/or below grade, that is used for parking motor vehicles (Urban Land Institute, 2000).

Parking Supply

The total number of parking spaces that serve a land use. It may included spaces that are off site, on street, or shared with other uses (Smith, 2005).

Traffic Analysis Zone (TAZ)

A unit of geography most commonly used in conventional transportation planning models (Miller & Shaw, 2001), Traffic Analysis Zones (TAZ) contain tabulated traffic flows, land uses, employment attributes, and public transit characteristics.

Transportation Demand Management (TDM)

Transportation demand management (TDM) is a term given to a variety of measures used to improve the efficiency of existing transportation systems. TDM includes services that encourage the use of alternative transportation modes to the single-occupant vehicle including but not exclusive to carpooling, transit, cycling and walking. Strategies such as flexible work-hour programs and telecommuting are also TDM strategies as are parking management strategies such as parking pricing and controlled parking supplies (Winters, 2008).

Weighted Employment

Used to calculate the attraction in suburban areas based on job sectors, weighted employment provides an estimation of total trips generated per number of jobs in a TAZ (Casello & Smith, 2006). Founded on the understanding that different job types generate various numbers of trips, weighing employment helps to consider the effects a job generates on transportation networks.

Chapter 1 - Introduction

1.1 - Context

Parking provision is gaining significant attention in urban transportation planning due to its potent ability to affect transportation systems, mode choice and land use densities. Often, business owners and those interested in economic development believe that parking is essential in order to provide convenient access for both employees and customers. Planners however, challenge this conviction and argue that extensive parking can change the fundamental character of urban centres, generate greater automobile dependency, and create an extensive list of transportation problems. Furthermore, contemporary transportation planning encourages an appropriate supply of parking that provides sufficient access while still facilitating transportation demand management (TDM) plans.

Research addressing automobile dependency examines transit, with parking receiving little attention (Bianco, 2000). Those researchers studying parking provision suggest that limiting supply may be an effective tool to discourage automobile use due to the very purpose parking provides, a place to put a car when it is not in use (Marshall & Garrick, 2006; Shiftan & Eden, 2001). As a result of these findings, parking research appears to be gaining popularity in transportation research.

Despite the increase in attention to parking research, recent work focuses primarily upon parking in downtown city centres of large cities (Marshall & Garrick, 2006), where higher land values and densities heighten parking importance relative to suburban areas. However, as North American cities have continued to decentralize, suburban parking now consumes the majority of land devoted to parking in an entire city (Litman, 2007). Thus managing the supply of parking in suburban areas becomes more important in achieving regional transportation goals. Although some suburban parking research exists, it mainly examines parking in regards to parking pricing, search and choice models and parking design (Lambert, 2007). Due to the scarcity of parking research outside of downtown cores, significant room exists for the expansion on parking research in suburban areas of mid-sized cities.

1.2 - Research Question and Objectives

The main purpose of this research is to establish an understanding of the relationships between suburban parking supplies, a traditional market force of decreasing land values and principle land use characteristics. Thus, the primary research question for this study is as follows:

> *What opportunities exist to use observed existing parking supplies to develop parking maxima as a TDM tool?*

To develop a methodology to complete this study, two specific objectives are established to help assist in answering the research question:

i. What is the relationship between suburban parking supply in a Traffic Analysis Zone (TAZ) as a function of a traditional market force?

ii. *What is the relationship between suburban parking supplies in a TAZ and its primary land use characteristics?*

1.3 - Exploring *a priori* Ideas

To analyze suburban parking supplies in a TAZ as a function of a traditional market force and primary land use characteristics, two approaches are taken.

First, parking supplies are examined following a traditional distance/market theory as outlined by (Hanson & Giuliano, 2004) and grounded in (Alonso, 1964). This approach looks at parking supplies in a TAZ as a function of land use densities, distances from central business districts, and measures of commercial activity.

Second, parking supplies in TAZs are investigated across other TAZs with similar primary land use characteristics. This approach explores parking supplies as a function of defined land use categories which the parking supplied intends to serve.

To investigate these parking supplies through these two approaches, the following *a priori* hypothesises are made. Through this authors general intuition, observations and experience, it is hypothesized that the amount and type of parking supplied in a geographic area varies as a function of:

1. the quantity and mix of employment present. As employment in a TAZ increases, the quantity of parking increases (Figure 1.1). Traditional application of parking minimums requires parking supplies to be a ratio reflecting floor space and/or employees (Smith, 2005). Likewise, it is assumed that substantial supplies of parking are provided for employee use. It is further hypothesized that parking supply increases with high trip-generating employment types, such as retail employment.

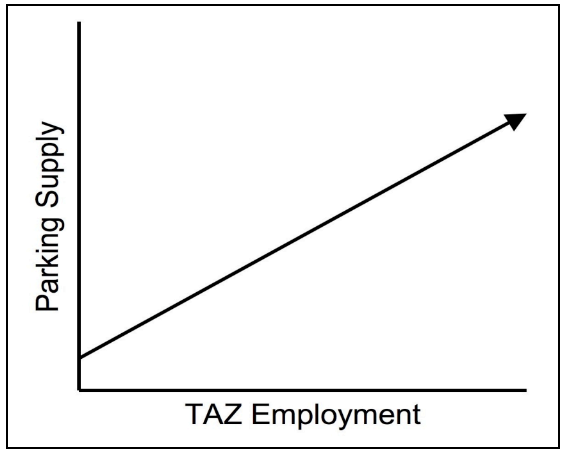


Figure 1.1: Parking Supply as a Function of TAZ Employment

2. the value of the land on which parking is allocated. Central location theory suggests that the highest land values exist in central business districts with decreasing land values as the distance from the CBD increases (Hanson & Giuliano, 2004). It is hypothesized that as land values increase, the allocation of land to parking decreases or parking density increases (Figure 1.2).

3. the overall land use density of an area, considering land allocated to employment areas, residential areas, and open spaces. Land use density is defined by the Province of Ontario's as: the sum of population and employment divide non-open space land area (Ontario, 2005). It is hypothesized that as land use density increases, land values may warrant decreased total parking supply, parking supply per employee or higher parking density.

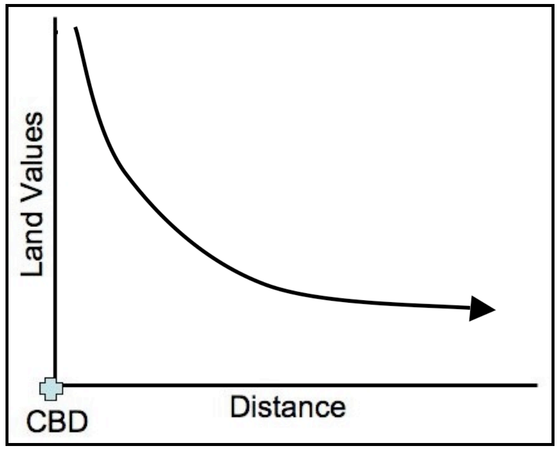


Figure 1.2: Land Value as a Function of Distance from CBD. Adapted from Hanson & Giulliano, 2004.

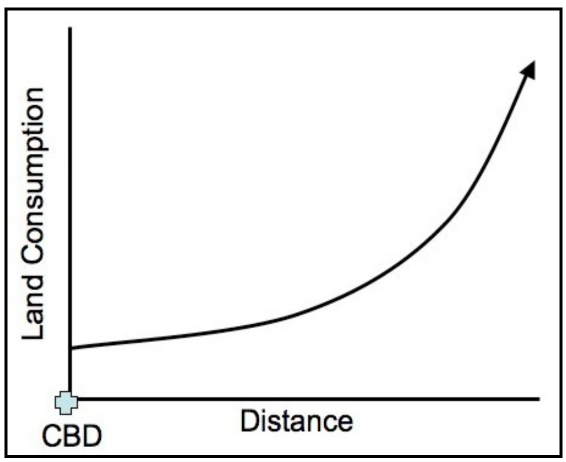


Figure 1.3: Expected Land Consumption for Parking per Economic Activity as a Function of Distance

Typically, the quantity of suburban parking supplied is bound by two extremes. The minimum quantity supplied is that required by local bylaws on a parcel-by-parcel basis. These minima may be a function of the developed building area or the number of employees. The maximum parking supplied is that which is economically viable for a site, considering that parking has an opportunity cost (less developable land) and increases maintenance costs.

1.4 - Organization of Thesis

Chapter 1 has provided an introduction into the existing research relating to parking and role of parking in transportation planning. Chapter 1 has also presented an overview of the research question and research objectives engaged in this thesis. Chapter 2 provides a detailed overview of the literature with regard parking research to which this thesis attempts to contribute. Chapter 3 presents the methods used in this study for measuring suburban parking and the associated additional measurements and calculations used in this study. Chapter 4 demonstrates the methodology in the Regional Municipality of Waterloo. Chapter 5 contains the analysis of the results of the thesis and describes the interpretation of the data through the examined relationships. Chapter 6 discusses the conclusions of this thesis and provides recommendations for further research in the area of suburban parking.

Chapter 2 - Literature Review

A number of authors explore the roles, impacts and theories of parking. The literature presented in this chapter draws from these investigations.

2.1 - Research on Existing Parking Bylaws & Motivation for Parking Supply

Parking bylaws are typical responses to contemporary planning policies to provide an appropriate supply of parking. This supply intends to provide sufficient access for automobile users and is typically identified by business owners as an essential service to facilitate economic development (Dunphy, Myerson, & Pawluukiewicz, 2003; Dunphy & Porter, 2006; Ulberg, Etchart, & Whitaker, 1992). To provide an adequate supply, parking bylaws often require minimum parking requirements based on employment types present and their strength to generate parking demand (Smith, 2008). As a result, these bylaws (Mukhija & Shoup 2006) are negative impacts on a city's physical landscape and transportation systems. Specifically, excessive supplies encourage increased automobile dependency. As a response to automotive dependency, and problems that arise from parking, such as supply shortages, are often attempted to be mitigated by planners by increasing supply (Litman, 2007; Yan, Hollingworth, & Anderson, 2007).

Despite its importance, the inclusion of parking supply analysis within transportation planning, as Balijeplli *et al.* (2008), Hendricks (2008), and Gihring (1999) note, in most cases, is not explicitly integrated into modelling or planning processes. Moreover, Shoup (1997) argues that parking is the most understudied link between transportation and land use by planning students. Furthermore, although newer forms of transit-oriented high density planning policies have evolved recently, parking policies and methods of provision have remain fairly unchanged (Highways and Transportation, 2005). Consequently, this sustains the provision of oversupplied, under priced parking, inconsistent with the goals of high-density development.

2.2 - Impacts of Oversupply

Through the application of minimum requirements, the oversupply of parking can, as Mukhija & Shoup (2006) argue, negatively impact a city's urban form and transportation systems.

Research illustrates how parking can greatly affect transportation systems, particularly traffic congestion, through studies by Arnott & Rowse (1999), Shoup (2005), and Balijepalli *et al.,* (2008). More specifically, these researchers estimate that vehicles searching for available parking spaces in a busy downtown contribute to between 25 and 59 percent of traffic congestion.

Abundant parking supplies also affect land use planning. Litman (2006) argues that alongside auto-oriented transport planning, providing abundant free parking creates a cycle of automobile dependence (Figure 2.1). This dependence then steers land use planning to cater the automobile, and creates dispersed development patterns and suburban cities. This cycle then feeds the greater need for generous parking supplies and ongoing automobile dependency.

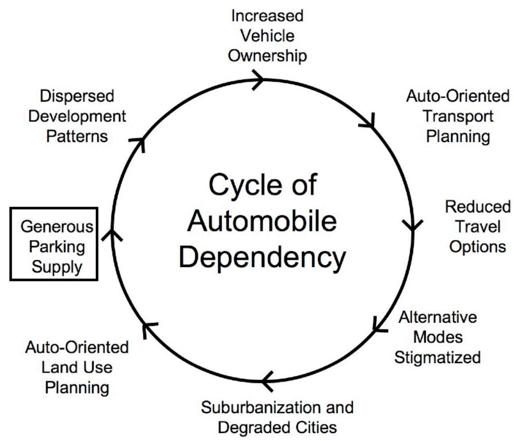


Figure 2.1: Cycle of Automobile Dependency
Adopted from Litman, 2006.

Shoup (1999, 2005) further explores how the economics of free parking result in an artificial dispersion of land values. Shoup illustrates that the costs of leasing and maintaining parking facilities are distributed throughout the goods and services provided on the property. In turn, Shoup displays that these costs increase sale prices in order to generate revenue to cover the costs of the land consumed by parking. For example, a suburban mall pays for all the land it occupies, including the parking lot. Thus, those goods sold in the mall have a hidden 'fee', whereby the good is priced to include the costs of the property or lease rate of that shopping mall. In addition to Shoup, Litman (2006) also demonstrates how constructing parking facilities using the traditional application of parking minimums can cost between 9 and 25 percent of total development costs for new mixed-use developments.

In a response to this research and the application of traditional minimum standards, Shoup (1999, 2005), Yan *et al.,* (2007) & Dunphy (2008) generally criticize that:

- free or below-cost parking only encourages more automobile use and single occupancy vehicles;

- parking provision is not based on sound principles and standards are often inflexible, resulting in parking oversupply;
- parking standards, and ‘free’ parking provision hides the full costs of parking to developers and imposes hidden costs that inequitably force non-drivers to pay some of the cost of parking;
- excessive parking discourages development and redevelopment, particularly in older areas with existing buildings and limited land supplies; and
- excessive parking increases the costs of development and decreases housing affordability.

As a result of these criticisms, Frost & Ison (2009) and Ziemann (2009) highlight that there is an increasing necessity to balance parking policies with other transportation agendas. Research shows that through supply management, parking can effectively influence transportation demand management strategies. Through studies, Shiftan & Eden (2001) and Hess (2001) show that parking supply and pricing measures may be an effective way to reduce congestion and increase an individual’s alternative mode preference.

2.3 - Concepts of Parking Maxima as a Transportation Demand Management Tool

Controlling the supply of parking to influence transportation habits and mode choice is often citied in the context of Transportation Demand Management (TDM) (Marshall & Garrick, 2006; Shiftan & Eden, 2001). As a method of reducing automobile use, while increasing transit ridership and walking, parking supply management is considered to be one of the most effective tools in TDM for planners.

As a result of the criticisms of conventional parking policies, and the strong influence parking has in TDM, several new policy ideas have arisen. Broaddus (2009) summarizes these changing approaches to parking policy. Her summary is reproduced as Table 2.1.

Table 2.1: Parking Policy Reforms

	Old Paradigm	New Paradigm
Parking Considered as a:	Public Good	Commodity
Demand Assumed:	Fixed/Inelastic	Flexible / Elastic
Supply Should:	Always grow	Be managed in response to demand
Costs should be:	Bundled with Goods	Transparent to Users
Government Regulations:	Set Minimums	None / Set Maxima

Feeding off of these new reform approaches, academic research on parking has grown in recent years. Leading academic research with new approaches to parking policies tends to be grounded in two subsets: 1) the price of parking, and 2) the supply of parking.

In addition to the work done by Shoup (as noted above), pricing parking is shown to combat not only road traffic congestion but also in parking lots (Balijepalli, Shepherd, & May, 2008). Furthermore, as Shiftan & Eden (2001) point out, parking pricing is one of the most effective ways to reduce automobile trips and increase transit ridership.

Additionally, strong emphasis throughout the literature calls for the strategic reduction or elimination of parking minimums and implementation of parking maxima (Broaddus, 2009; Hess, 2001; Litman, 2007; Yan, et al., 2007) as part of comprehensive multi-modal transportation strategies. These reseachers argue that maxima can cause a reduction in the mandatory amount of parking supplied, thereby saving developers money and capping the maximum amount of parking space available. Researchers also argue that limiting supply and availablity, can help encourage alternative transportation choice and help the market establish a 'truer' cost of parking (Hess, 2001; Marshall & Garrick, 2006).

Although these authors encourage the application of parking maxima, upon a review of the literature, no research is found addressing what strategies or achievements regarding the establishment of maxima. However, a list of cities that have applied or are planning on applying maxima can be found. In the United States for example, Washington D.C, New York City and San Francisco, California recognized the potential of parking maxima to reduce automobile use and are applying these maxima in their downtowns (Ziemann, 2009). Portland, Oregon implements parking maxima in the downtown core and some surrounding areas that are well served by transit (Broaddus, 2009; Hess, 2001; Mallard-Ball, 2002). In Ontario, maximum parking standards are specified for downtown Toronto and town centres in North York, Scarborough, and Etobicoke, but are yet to be applied.

2.4 - Parking & Land Use Theory

Traditional land use and market theories delineate that areas with high amounts of economic activity and land use densities have the highest land values (Alonso, 1964). These theories also highlight that for monocentric cities, as distance increases from the Central Business District (CBD), these activities and densities decline and therefore land values also decline.

As a result of these land uses and prices, parking supplies in CBDs are equally affected. Higher land use densities and competition for land in CBDs limit the opportunity to allocate land for parking uses. These factors also create much higher parking prices than in suburban areas. Furthermore, a large city's downtown tends to be very walkable and well served by transit, reducing the need to supply large amounts of parking to cater the automobile. However, competing land uses and higher land prices has focused parking research primarily on downtowns of large cities (Marshall & Garrick, 2006).

Contrary to CBDs, suburban areas have lower land values and far more ubiquitous sprawling land use densities. In turn, making it difficult for alternative transportation to compete against the automobile (Voith, 1998). As a result of these land uses and dependency on the automobile, suburban areas provide the majority of parking for a city. Thus, the focus of parking research on downtown city centres appears insufficient.

2.5 - Summary

From the literature presented in this review, four key findings are found:

1. The literature on parking supply management as a TDM tool focuses heavily upon parking policy in downtown city centres or central business districts of large cities;
2. Land use and market gradients affect parking supplies to be limited and costly in CBDs, and increasing in supply with reduced cost as distance increases away from CBD;
3. The most parking supplied is that which is economically viable for a site, considering that parking has an opportunity cost (less developable land) and increased maintenance costs; and
4. Although considered a highly influential TDM tool, the methods and strategies of applying parking maxima have not been explored. Particularly in Canada.

Thus, the purpose of this thesis is to explore observed market-driven suburban parking supplies across market gradients (distance) throughout a metropolitan area. This research is undertaken in an effort to provide quantitative maxima to be incorporated in local parking bylaws as part of balanced comprehensive multi-modal transportation strategies.

Chapter 3 - Methodology

3.1 - Objectives

As described in Chapter 1, the purpose of this thesis is to explore what opportunities exist to use observed existing parking supplies to developed parking maxima as a TDM tool. To help answer the primary research question and develop the methodology of this study, two objectives are established:

- *What is the relationship between suburban parking supplies in a TAZ as a function of a traditional market force?*
- *What is the relationship between suburban parking supplies in a TAZ and a TAZ's primary land use characteristics?*

Also described in Chapter 1 are the *a priori* ideas that help to analyze suburban parking supply. These *a priori* assumptions include that the amount and type of parking in a geographic area varies as a function of:

1. the amount of employment. As the quantity of employment increases, the quantity of parking increases. Where high trip-generating employment types exist, parking supply is expected to further increase.
2. land use density. As land use density increases, land values may warrant decreased total parking supply, parking supply per employee or higher parking density.
3. the value of land. As land values increase, the allocation of land to parking decreases or parking density increases. Where land values are the highest in the CBD and values decrease with increased distance from CBD.

3.2 - Study Design

For this research, parking supplies are examined using Geographic Information Systems (GIS). As a platform enabling analytical operations of spatially referenced data, GIS can be used to manage and plan for various transportation models.

Within ArcGIS software, data are gathered at the Traffic Analysis Zone (TAZ) level of geo-spatial reference. The TAZ is well integrated within GIS displaying geospatial transportation data modules, which contain tabulated traffic flows, land uses, employment attributes and public transit characteristics For these reasons the TAZ has been adopted as the standard level of disaggregating for transportation studies. TAZs are also readily accessible and the data easily extracted for this study. Upon consultation with the Region of Waterloo's Planning Department, the use of property-specific data such as site plans or zoning ordinances were dismissed. The use of these data were dismissed as acquisition of the data was deemed too difficult and time consuming for the period of this study. Specifically, TAZs are a chosen above property-specific or zoning-specific data due to any likelihood of multiple-properties and supplies of shared parking between properties. For this study, the TAZ data modules are sourced from the Region of Waterloo's 2006 streets and planning data and contain 2006 Canadian federal census data for employment and population characteristics.

3.3 - Identifying TAZ Candidate Sites

Within GIS software, the Central Business District(s) (CBD) of a city or region are identified in order to validate central location theory. CBDs are not geo-spatially represented by a TAZ.

Therefore, it is necessary to set boundaries for each CBD in a study in order to continue these methods. In the case of this study the CBDs are defined by the planning district boundaries set by the Region of Waterloo's Visualizing Densities Study (Waterloo, 2006b). Once defined, the CBD's geographic centre is then marked with a centre point feature. Concentric circles are then drawn at 500 metre buffer intervals from each centre point feature until the boundary of the urban form is reached. Close proximity circles that overlap each other are dissolved and joined (as illustrated in Figure 3.1). This allows suburban sites to be located by varying distances from each CBD.

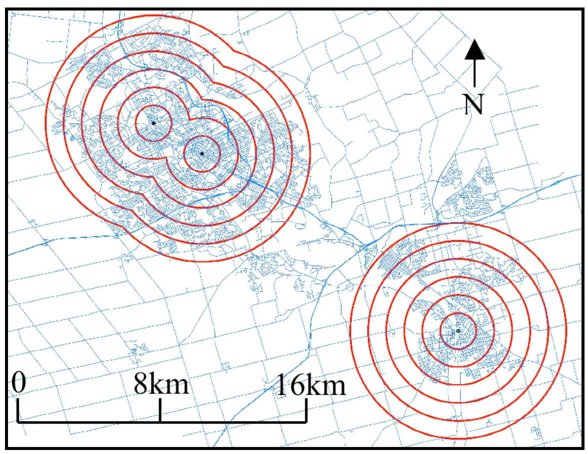


Figure 3.1: Example CBD Locations with Concentric Circles
Source: (Waterloo, 2006a).

High-resolution aerial photographs are then employed within GIS to identify suburban candidate TAZs. Beginning from the outer most circle and moving inwards, each equally distanced buffer interval is examined for as many candidate sites with various general land use characteristics and measurable parking supplies existing in the buffer to encourage randomness for candidate site identification.

3.3.1 - Defining TAZ Primary Land Use Characteristics

It has been illustrated that an area's primary land use characteristics and distance from CBD affects parking supply (Anderson & de Palma, 2004; EPA, 2006). Thus it is important to define a candidate TAZ's land uses in order to understand TAZ parking supplies.

Land uses are first defined by distance from CBD. Using the GIS distance measuring tool, measurements are made in Euclidian distances (kilometres). Distances are measured between each TAZ and its respective CBD. If more than one CBD is defined, distances can only be measured between each CBD and those TAZs located within the municipal boundary in which each CBD is located (such as towns/cities). The distance a TAZ is from the CBD is then measured between the centroid of the TAZ and the central point feature of the CBD.

Next, observed urban forms and land use densities are used to further define TAZ primary land use characteristics. Although land uses may be assigned specific districts or zoning designation through official plans and bylaws, TAZs are not. A TAZ also may not conform to official boundaries of districts or land use zones. Therefore in this study, candidate TAZs land use must be assigned based on observed urban form, land uses and densities.

Using the aerial photographs in GIS, TAZ urban forms are first observed. TAZs are examined for the presence of land uses, structures and open space. To observe a TAZ's general land use, a TAZ is examined for any combination of shopping centres, large industrial or manufacturing facilities, or residential units. TAZs are also observed for any open spaces within or surrounding its boundaries. Furthermore, the mixture and compactness of buildings and neighbourhoods of a TAZ are examined. Lastly, the land use density of a

TAZ is measured. This is the sum of the total population and jobs in the TAZ divide non-open space land area in the TAZ. In this study, a TAZ's hectarage, population and employment are contained in the data set. Open space is measured with the GIS area tool and subtracted from the total TAZ's hectarage.

Examining the land use density requires accounting for the population of a TAZ. While this study examines parking supplies as a function of distance and employment, accounting for the population in order to calculate land use density appears unnecessary. However, beyond the necessity to include population as part of the Government of Ontario's formula to calculate land use density, this author believes accounting for population is important. The presence of a residential population changes the character and transportation systems of any neighbourhood. Likewise, population will also increase the expected amount of parking to serve that population. Thus, it appears necessary to account for population when calculating land use density to understand the general land use characteristics of an area.

$$\textbf{\textit{land use density}} = \frac{pop + emp}{ha_{TAZ} - ha_{openspace}}$$

Where:	
pop = Population	ha_{TAZ} = TAZ's Hectarage
emp = # Jobs	$ha_{openspace}$ = TAZ's Open Space

Equation 3.1: Formula to calculate Land Use Density

From these observations, distinct primary land use categories of a TAZ are then defined. These categories are as follows:

- Central Business Districts: Core downtown areas with high land use densities (100 or more people + jobs per hectare), little open space and mix uses.
- Fringe Areas: TAZs adjacent to CBD with lower land use densities (35-75) and lower diversity of land uses.
- Residential / Plaza Mixes: TAZs characterized by mid- to low-density (20-45), residential land uses with a large, integrated commercial plaza typically containing retail strip stores.
- Concentrated Commercial: TAZs dominated by big box developments distanced well away from the CBD with mid- to low-densities (20-55).
- Industrial: TAZs distanced well away from the CBD containing low-density (25-35) manufacturing land uses.
- Exurban: TAZs adjacent to undeveloped lands with very low densities (15-30), typically office parks.

(See Table 4.1 for images and descriptions of these land uses)

3.3.2 - TAZ Parking Supply Characteristics

Once candidate TAZs primary land use characteristics are defined through the above criteria, those TAZs with measurable supplies of parking are observed. Measurable parking supplies are those that are both visible in the aerial photographs and measurable with the GIS area measuring tool. Parking that is supplied via above- or below-grade parking structures are noted and require ground-truthing to measure the parking supply.

Using GIS and the aerial photographs, candidate TAZs that meet the land use characteristic criteria listed in section 3.3.1 and display quantities of parking that are measurable in spatial area and in parking space provision are then selected as the TAZ study sites.

3.4 - Study Site Data Collection

Having chosen TAZ study sites (CBD & Suburban) data is then collected. Two approaches are taken to analyze parking supplies: 1) as a function of traditional land use market theory; and 2) as a function of primary land use characteristics.

Supplies are first examined following traditional land use market theory. This examines parking supplies in a TAZ as a function of land use densities, distances from CBD and measures of commercial activity. Parking supplies in a TAZ are then investigated across TAZs with similar primary land use characteristics. This approach explores parking supplies as a function of the defined land use categories (listed in section 3.3.1) which the parking supplies intend to serve.

3.4.1 - Traditional Land Use Market Theory & TAZ Data Collection

To investigate parking supplies following traditional land use market theory, TAZs are examined for their distance from CBD, land use densities and measures of commercial activity.

3.4.1.1 - Measuring Distance From CBD

Using the GIS distance measuring tool, measurements are made in Euclidian distances (kilometres). Distances are measured between each TAZ and its respective CBD. Meaning that if more than one CBD is defined, distances can only be measured between each CBD and those TAZs located within the municipal boundary in which each CBD is located (such as towns/cities). The distance a TAZ is from the CBD is then measured between the centroid of the TAZ and the central point feature of the CBD.

3.4.1.2 - Measuring Land Use Density

In this study, the hectarage, population and employment of a TAZ are contained in the data set. Open space is measured with the GIS area tool and subtracted from the total TAZ hectarage. The density is calculated by totalling the population and employment and divide non-open space (see section 3.3.1 for land use density equation).

3.4.1.3 - Measuring Commercial Activity

As a factor of measuring traditional land use gradient models, employment is considered a reasonable representation of land rent usage by Hanson & Giuliano (2004). Thus, to measure the commercial activity of a TAZ, a TAZ's total employment is used. The total TAZ employment contained in the data set can then be paralleled as a measure of economic activity that, through the *a priori* assumptions listed, would decrease as a function of distance from the CBD.

However, as the *a priori* hypotheses state, parking supplies increase with high trip-generating employment types. Employment is normalized to account for the highest trip attracting employment sector in a TAZ. Casello & Smith (2006) propose a method that equates transportation impacts of different employment types (retail, agricultural, commercial, etc) by converting all employment types to a hypothetical average trip attracting employment type. In their analysis, they find that one retail job is equivalent to 2.9 "mean trip attracting" jobs. Consider two TAZs each with total employment of 100 jobs. If one TAZ has 100 mining jobs while the other has 100 retail jobs, it is obvious that the retail-focused TAZ requires substantially more parking. Disaggregate TAZ employment for various sectors are also contained in the GIS data set. However, the TAZ data set does not disaggregate all employment in the TAZ. For example, agricultural or government employment is not listed in a TAZ. Unfortunately, Casello & Smith's 2006 study lists weighted trip attractors for employment sectors that differ from those listed in a TAZ such as agriculture. Thus, for both simplicity and the lack of data within TAZs data set for some employment sectors only the strongest trip-attracting sector that is listed and also provided by Casello & Smith (retail) is weighted. The total employment and retail employment data of a TAZ are converted to weighted employment numbers as follows:

$$wtd_{emp} = nonret_{emp} + ret_{emp} \times 2.9$$

Where:

$\mathrm{wtd}_{\mathrm{emp}}$ = Normalized Employment

$\mathrm{ret}_{\mathrm{emp}}$ = # Retail Jobs

$\mathrm{non}_{\mathrm{retemp}}$ = # Non-Retail Jobs

Equation 3.2: Formula to equate Weighted TAZ Employment

3.4.2 - Primary Land Uses & TAZ Parking Data Collection

To investigate parking supplies across TAZs with similar primary land use characteristics, TAZ study sites are measured for parking data. This includes the number of parking spaces, parking footprint, parking density and the employment density served by parking.

3.4.2.1 - Measuring Parking Spaces

Parking space provision is measured in a TAZ by incorporating the aerial photographs within GIS and manually counting the number of spaces provided in a parking lot facility. Parking spaces are counted in all parking lot facilities within a TAZ and totalled. Parking facilities that are above- or below-grade (such as a parking garage) require ground-truthing which is accomplished by counting all parking on one floor and scaling up by the number of stories the facility has.

3.4.2.2 - Measuring Parking Footprints

To measure parking footprints in a TAZ the GIS area measuring tool is employed to measure the total land area consumed by a parking lot facility. Lot footprints include all area devoted to landscaped amenities, service and access roads, and parking spaces. Areas not measured are facilities such as delivery bays, loading areas, or transit terminals. Measured in hectares, the land area consumed is measured for all parking lot facilities within a TAZ and totalled.

3.4.2.3 - Measuring Parking Density

Calculating the parking density illustrates on average how many parking spaces are supplied per hectare of parking lot in a TAZ. To measure the parking density in a TAZ, the total measure of parking spaces in a TAZ (section 3.4.2.1) is divided by the total parking footprint of that TAZ (section 3.4.2.2).

$$parking\ density\ =\ spaces/ha_p$$

Where:
spaces = Total Parking Spaces ha_p = Total Parking Footprint

Equation 3.3: Formula to equate Parking Density

3.4.2.4 - Measuring Employment Area Served by Parking

To measure employment as a function of various TAZ land uses, the employment density of a TAZ is measured. To measure the employment density of a TAZ, two variables are required, total TAZ employment and total TAZ employment footprint. Total TAZ employment is contained in the data set. To measure TAZ employment footprint, all employment structures and business buildings in a TAZ are located visually via the aerial photographs. For industrial, concentrated commercial and exurban TAZs, visually locating employment structures can be straightforward (due to the single land use and low densities). However, locating employment structures in higher density areas such as fringe CBD and CBD can be more complex. For these areas, local knowledge and ground-truthing is required to confirm the use of buildings. GIS is then employed to measure the total land area consumed by all employment areas and measured in hectares. Employment footprints include all buildings devoted to employment or business. Areas not measured are facilities such as sidewalks or entranceways. This allows for all employment footprints to the quantified in a TAZ. Employment density of a TAZ is then calculated by dividing a TAZ's total employment by the total employment footprint.

$$\textbf{\textit{employment density}} = \frac{emp}{ha_{emp}}$$

Where:
emp = # Jobs ha_{emp} = Total Employment Footprint

Equation 3.4: Formula to equate Employment Density

3.4.3 - Measurements Summary

Table 3.1 summarizes qualitatively and quantitatively the measurements in a TAZ as described in above sections.

Table 3.1: Parking Statistics & Measures

Measurement	Description	Quantitative Measure
Number of spaces	The total number of spaces supplied in a TAZ	$spaces$
Parking density	The number of spaces divided by the parking footprint in a TAZ	$spaces / ha_p$
Population	Number of residents in a TAZ	pop
Employment	Total number of jobs in a TAZ	emp
Retail employment	Total number of retail jobs in a TAZ	emp_{ret}
Weighted employment	An equivalent number of jobs which considers the influence of retail jobs	$nonret_{emp} + ret_{emp} \times 2.9$
Parking footprint	The land area allocated to commercial parking in a TAZ	ha_p
Employment footprint	The land area allocated to employment in a TAZ	ha_{emp}
Residential footprint	The land area allocated to residences in a TAZ	ha_{res}
Land use density	The amount of population and employment divided by the non-open space land area in a TAZ	$\frac{pop + emp}{ha_{TAZ} - ha_{openspace}}$
Employment Density	The total employment divided by the total employment footprint in a TAZ	$\frac{emp}{ha_{emp}}$

Chapter 4 -Application of the Methodology – A Case Study

The methods described in Chapter 3 are applied to the Regional Municipality of Waterloo. Located approximately 100 km west of Toronto in southern Ontario, the Region is comprised of three cities – Kitchener, Waterloo and Cambridge – and four rural townships. The Region has a population of approximately 500,000 but is expected to reach 730,000 by 2031 (Waterloo, 2008). As an upper-tier regional municipality the Region is responsible for broad issues that concern more than one distinct municipality or township such as water supply and waste management. The Region is also responsible for planning issues such as Regional Official Plans and transportation planning. Furthermore, the Region administers the delegated responsibilities from the Provincial government that aim to apply plans and goals on a province-wide scale. The local municipalities that make up the Region are responsible for specific local planning issues such as site plan approvals and minor variances. These local municipalities have their own Official Plans that implement the goals and agendas of the Regional Official Plan through specific details such as zoning bylaws.

The Region's economic core is distributed between three central business districts (CBD), concentrated along a central axis shown in Figure 4.1. The Region arguably has four to five various 'cores' where significant business and employment activities occur. However, this study chose to examine the three downtown cores defined by the 2006 Region of Waterloo's Visualizing Densities Study due to their historically and municipal designation as the three core areas of the Region. Because of the three CBDs, the Region presents an interesting case to analyze parking supply as a function of distance from CBD. The influence of the CBDs can overlap in the areas between them (moving north/south along the central corridor); or the influence can be isolated moving away from individual CBDs (east and west) (see Figure

4.1). Furthermore, TAZ data, GIS software and the high-resolution aerial photographs of the Region were readily accessible for this author. For these reasons, the study sites within the Region were chosen within the confines of the urban areas of Kitchener, Waterloo and Cambridge. The three urban areas were also chosen for the presence of measurable parking structures and surface lots, which are not present in the remaining rural townships within the Region.

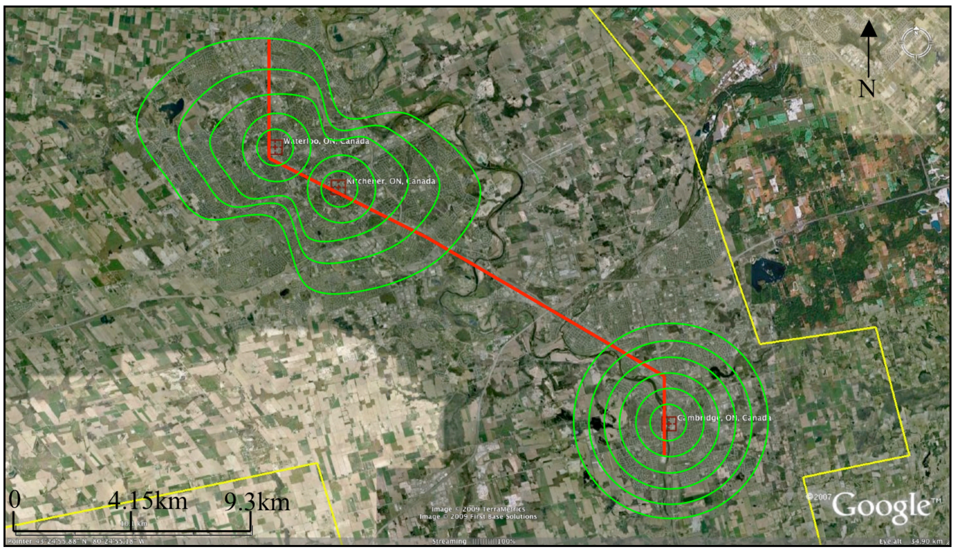


Figure 4.1: Region of Waterloo Central Axis & Three CBD's
Source: Google, 2008.

Recently, the Region has focused planning policies on increased transit ridership and greater density in urban form through planning documents such as the Regional Growth Management Strategy and Regional Transportation Master Plan. However, many of the Region's reports, policies and studies make little to no reference to parking provision and the impact parking has on transportation. Given the important role parking plays as part of transportation choices, systems, densities and urban form for any particular area, it would appear that there is value in clearly understanding the supplies of parking in both intensified cores and suburban areas of the Region of Waterloo.

4.1 - The Region & *a priori* Expectations

Following the *a priori* ideas described in Chapter 1, it is assumed that the amount and type of parking in the Region of Waterloo varies as a function of:

- the amount of employment. As the quantity of employment increases, the quantity of parking increases. Where high trip-generating employment types exist, parking supply is expected to further increase.
- land use density. As land use density increases, land values may warrant decreased total parking supply, parking supply per employee or higher parking density.
- the value of land. As land values increase, the allocation of land to parking decreases or parking density increases. Where land values are the highest in the CBD and values decrease with increased distance from CBD.

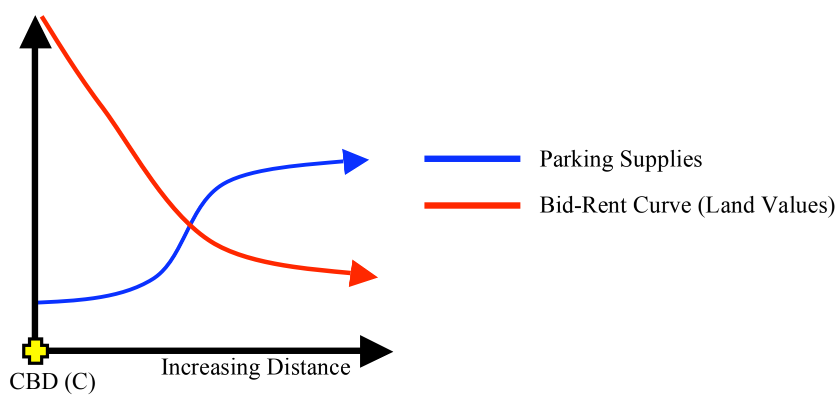


Figure 4.2:Theoretical Trends for Land Values and Parking Supply as a Function of Distance from a Mono-Centric CBD (Cambridge).

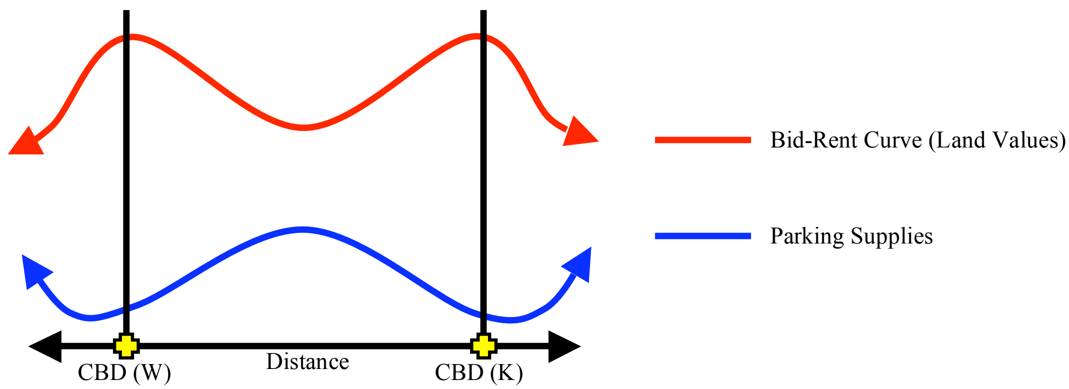


Figure 4.3: Theoretical Trends for Land Values and Parking Supply as a Function of Distance between two close-proximity CBDs (Waterloo & Kitchener)

4.2 - Study Sites

The methodology is applied to a total of 26 study sites. These study sites are chosen for their variety of land uses and spatial locations across the region. Three Central Business Districts (CBDs) and twenty-three suburban sites are chosen. The CBDs are defined by the planning district boundaries set by the Region of Waterloo's Visualizing Densities Study (Waterloo, 2006b). The CBDs are chosen in order to measure the validity of the central location theory. The remaining 23 suburban sites are grouped into 5 different land use categories (Table 4.1) and measured at the TAZ level. Figure 4.4 shows the 26 sites in the study.

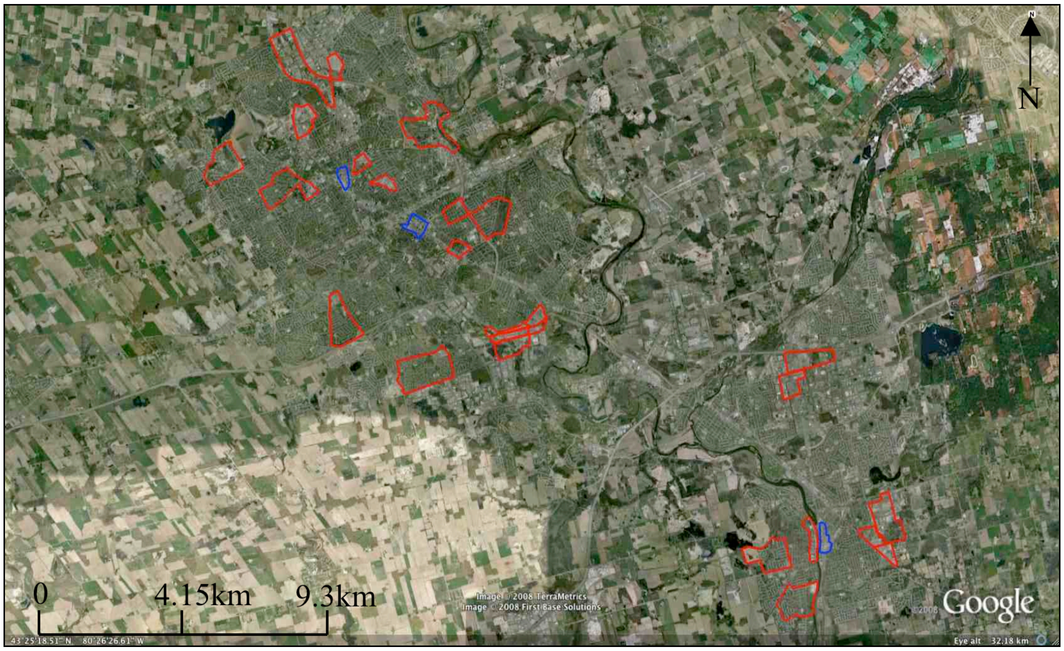
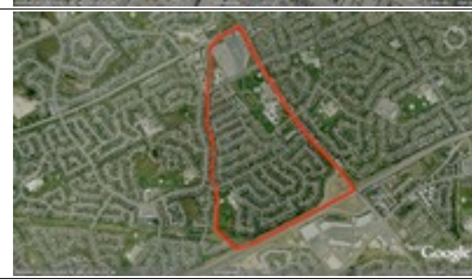
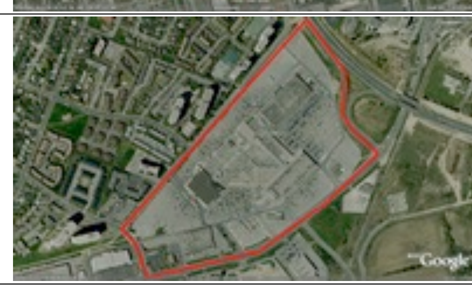


Figure 4.4: Study Sites
Source: Google, 2008.

Table 4.1: Land Use Categories

Category	Description	Image
Central business district (CBD)	Core downtown areas consisting of high density, mixed use development with little open space	
Fringe of the CBD	Areas of mid to high density mixed use within 2.5 km of the CBD	
Residential / plaza mix	Areas containing strip malls (plazas) with various retail outlets and residential neighbourhoods, typically with single-family detached housing.	
Industrial	Areas of mid to low density containing manufacturing facilities and production offices	
Concentrated commercial	Areas dominated by large retail shopping malls and "big box" outlets with little to no residential	
Exurban	Areas dominated by low density commercial office space at the edge of the developed portion of a metropolitan region, adjacent to undeveloped areas	

For 24 of the 26 sites, parking spaces are measured by manually counting all parking spaces in each TAZ. However, in the remaining 2 cases, the number of spaces is estimated by counting the spaces in a subset of the area and "scaling up." The parking footprint of each study site is measured using GIS by manually tracing all parking structures and surfaces in hectares with an area-measuring tool. This allows for the total surface consumption by parking at each site to be tallied. Table 4.2 summarizes the data collection for all the 26 sites.

4.2.1 - Example TAZ Study Site

Figure 4.5 illustrates an example delineation of a TAZ study site. The example shown is TAZ number 200, a concentrated commercial site in Kitchener commonly known as Fairview Mall. Table 4.3 illustrates the various statistics measured in this example study site that have also been applied to all 26 study sites.

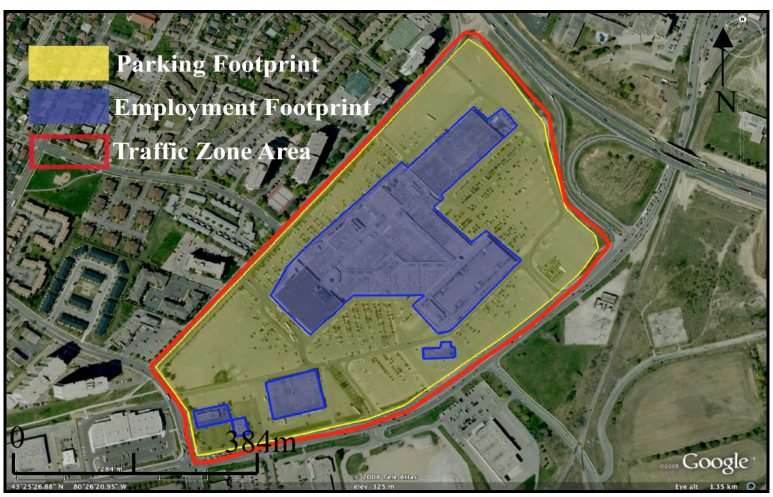


Figure 4.5: Example Delineation of TAZ
Source: Google, 2008.

Table 4.2: Data from Study Sites

Land use category	Designation	Spaces	Employ-ment	Parking per employee	Retail Employ-ment	weighted employ-ment	Parking per weighted employee	Land use density	Area (ha)	Parking footprint	Parking density	Employ-ment density	Distance from CBD (km)
CBDs	Waterloo	1,719	3,770	0.46	n/a	3,770	0.46	196.9	20.3	5.1	338.5	199.5	n/a
	Kitchener	4,526	6,482	0.70	n/a	6,482	0.70	224.9	35.0	10.1	449.5	196.4	n/a
	Cambridge	1,743	2,543	0.69	n/a	2,543	0.69	125.6	28.0	6.2	280.2	113.6	n/a
	average	2,663	4,265	0.61		2,663	0.61	182.4	2,663	7.1	356.0	169.8	
Fringe of CBD	F1	1,006	995	1.01	127	1,236	0.81	57.5	28.4	3.8	267.6	42.2	0.4
	F2	1,540	951	1.62	599	2,089	0.74	61.8	28.8	4.8	320.8	97.4	0.8
	F3	1,786	980	1.82	262	1,478	1.21	59.1	17.8	6.8	262.6	75.9	1.5
	F4	611	396	1.54	117	618	0.99	78.8	23.3	2.9	210.7	76.7	1.6
	F5	826	603	1.37	147	882	0.94	53.0	23.7	3.0	276.3	56.4	1.8
	F6	6,009	3078	1.95	103	3,274	1.84	49.4	67.6	16.0	375.1	61.2	2.4
	average	1,963	1,167	1.55	226	1,596	1.09	59.9	32	6.2	285.5	68.3	1.4
Residential Plaza	RP1	1,171	1111	1.05	279	1,641	0.71	39.1	130.4	4.6	254.6	162.7	2.0
	RP2	375	348	1.08	96	530	0.71	43.1	61.8	1.2	312.5	128.9	2.0
	RP3	263	365	0.72	92	540	0.49	49.8	51.1	0.8	346.1	123.3	2.8
	RP4	1,753	1061	1.65	522	2,053	0.85	49.3	98.9	5.1	343.1	62.7	4.1
	RP5	476	533	0.89	315	1,132	0.42	30.8	86.5	1.6	297.5	106.6	4.2
	RP6	1,330	807	1.65	182	1,153	1.15	34.3	214.0	4.6	289.1	42.7	4.7
	average	895	704	1.17	248	1,175	0.72	41.1	107	3.0	307.1	104.5	3.3
Industrial	I1	9,982	5,150	1.94	208	5,545	1.80	34.9	148.2	36.1	276.5	79.4	1.5
	I2	2,568	1,321	1.94	318	1,925	1.33	79.6	17.0	10.4	246.9	27.5	5.1
	average	6,275	3,236	1.94	263	3,735	1.57	57.2	83	23.3	261.7	53.4	3.3
Concentrated Commercial	C1	3,385	1,648	2.05	1,629	4,743	0.71	74.6	22.1	9.3	364.0	74.6	1.6
	C2	1,333	414	3.22	310	1,003	1.33	56.9	14.5	5.9	227.6	25.2	2.3
	C3	1,955	508	3.85	213	913	2.14	39.1	14.7	7.2	273.0	35.8	4.8
	C4	2,095	935	2.24	579	2,035	1.03	40.1	23.3	7.2	289.0	39.9	4.9
	C5	5,752	1,434	4.01	1,235	3,781	1.52	38.3	37.4	13.5	426.1	56.9	5.3
	C6	4,270	1,793	2.38	997	3,687	1.16	34.1	57.3	14.8	289.3	27.1	5.7
	average	3,132	1,122	2.96	827	2,694	1.32	47.2	28	9.6	311.5	43.2	4.1
Exurban	X1	1,953	971	2.01	32	1,032	1.89	28.7	79.1	6.9	283.0	24.5	3.6
	X2	347	881	0.39	12	904	0.38	38.7	89.6	1.5	231.3	112.7	1.3
	X3	1,193	2,167	0.55	66	2,292	0.52	36.7	59.4	4.4	268.7	38.8	2.2
	average	1,164	1,340	0.99	37	1,409	0.93	34.7	76	4.3	261.0	58.6	2.4

Table 4.3: Example TAZ Site 200 - Parking Statistics & Measures

Statistic	Quantitative Measures	Measure
TAZ identification number	200	200
Land use category	-	concentrated commercial
TAZ size	ha_{taz}	27.0
Distance from local CBD	km	5.3
Number of spaces	spaces	5752
Employment	emp	1434
Retail employment	ret_{emp}	1235
Weighted employment	$nonret_{emp} + ret_{emp} \times 2.9$	3581.5
Parking footprint	ha_p	13.5
Employment footprint	ha_{emp}	11.7
Residential footprint	ha_{res}	0
Other footprint (open space)	ha_{oth}	1.8
Spaces per employment area	$\frac{spaces}{ha_{emp}}$	491.6
Parking % of total employment land	$\frac{ha_p}{ha_{taz} - ha_{res} - ha_{openspace}}$	54%
Employees per TAZ area	$\frac{emp}{ha_{taz}}$	53.1
Employees per employment area	$\frac{emp}{ha_{emp}}$	122.6
Spaces per employee	$\frac{spaces}{employee}$	4.0
Land use density	$\frac{pop + emp}{ha_{TAZ} - ha_{openspace}}$	53.1
Spaces per parking footprint (parking density)	$\frac{spaces}{ha_p}$	426.1

4.3 - Descriptive Statistics

A total of 59967 spaces are counted across the 26 study sites representing the six separate land use categories as illustrated in Table 4.1. Each TAZ is located at various distances from their local CBD (Either the Kitchener, Waterloo, or Cambridge CBD). Ranging from 0.0 km (the CBD sites) to 5.7 km from each TAZ's local CBD, TAZ sites average a distance of 3.6 km with an average of total of 2682 spaces.

Table 4.4: Parking Statistics & Measures per Land Use Category

	CBDs	Fringe of CBD	Residential Plaza	Industrial	Concentrated Commercial	Exurban
Spaces Counted	7789	11778	5368	12550	18790	3493
Average	2663	1963	895	6275	3132	1164

Chapter 5 - Analysis

To help answer the research question "What opportunities exist to use observed existing parking supplies to develop parking maxima as a TDM tool?" the methodologies outlined in Chapter 3 are applied. The following sections examine the relationships between parking supplies in a TAZ, a traditional market force, and a TAZ's primary land use characteristics. The relationships examined in this chapter are presented using linear regression analyses. It is noted that the data collected from the study sites are not a completely randomized sample of the population of interest. It is also noted that the variables examined may not be independent of each other. Simple linear regression is used in an effort to describe the general trends observed and any possible relationships. The relationships or correlations discussed do not constitute causation.

5.1 - Expected Results

When examining the relationships between parking supplied in a TAZ, a traditional land use market force and a TAZ's primary land use characteristics, there are expected relationships that follow the *a priori* ideas. These relationships are listed in Table 5.1.

Table 5.1: Expected Relationships Amongst Parking Supplies in a TAZ and Traditional Land Use Models

Dependent Variable	Independent Variable	Expected Relationship with Increasing Independent Variable
Parking density	Distance from the CBD	Decreasing
Employment Density	Distance from the CBD	Decreasing
Parking spaces per employee	Distance from the CBD	Increasing
Parking spaces per weighted employee	Distance from the CBD	Increasing

5.2 - Relationships Amongst Parking Supplies in a TAZ and a Traditional Market Force

The following sections explore parking supplies in a TAZ as a function of a traditional market force. Parking density, employment density, and spaces per employee are explored.

5.2.1 - Parking Density as a Function of Distance

As described in Table 4.1, the *a priori* ideas hypothesized that higher land values in the CBD create higher density parking facilities than lower valued suburban lands. Therefore, it is expected that parking density decreases with increasing distance from the CBD. To test this, the parking density data are plotted against distance from CBD as shown in Figure 5.1.

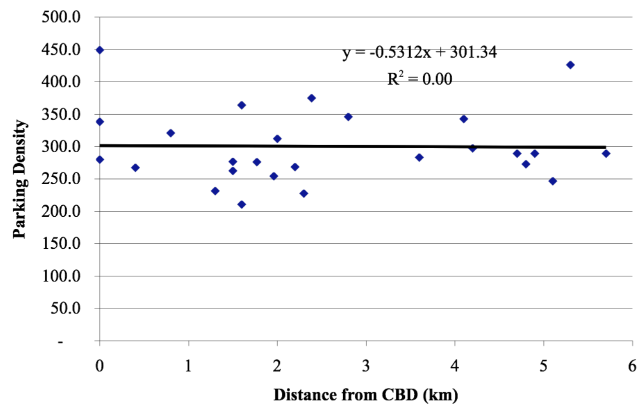


Figure 5.1: Parking Density over Distance from CBD

The added trend line in Figure 5.1 illustrates no statistical correlation between parking density and distance from CBD. The absence of correlation strength is believed to be caused by the small number of existing structured parking facilities throughout the Region (few found in the CBDs) and the standardized sizes of parking spaces. Structured facilities provide numerous parking spots and consume small footprints. However, having measured very few of these, there are few sites with very high parking densities. Furthermore, standardized sizes for parking spots mandated by bylaws and engineering manuals may also have influence on parking densities. These standards mandate that each parking space must be approximately 8’6” by 20’ or 172 square feet (Urban Land Institute, 2000). Therefore, when applied to a surface-grade parking lot, these sizes cannot be smaller than required. Thus, a surface-grade parking lot is limited to the highest number of standard sized spaces that can fit onto that lot. A parking lot cannot create amounts of parking with smaller space sizes than required and therefore cannot increase in density. Likewise, parking spot sizes cannot be made larger than required due to any likelihood of wasting lot space.

5.2.2 - Employment Density as a Function of Distance

Following the *a priori* ideas of traditional land use market models for monocentric cities, it is assumed that the highest land values exist in CBDs and land values decrease with distance from the CBD. Increased land values suggest that more land is allocated to high-revenue generating land uses, such as employment. It is expected, therefore that as distance from the CBD increases, decreasing land values generate decreasing employment densities. To test this, the employment density data are plotted against distance from CBD as shown in Figure 5.2.

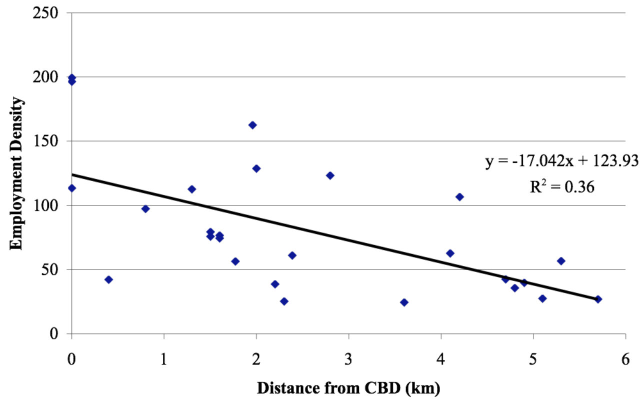


Figure 5.2: Employment Densities versus Distance from CBD

In this case, the linear trend line in Figure 5.2 displays decreasing employment density with increasing distance from the CBD. This supports the *a priori* hypotheses. With distance explaining approximately 36% of the variance for this relationship, the statistical regression shows some meaningful relationship between this measures and distance from CBD.

5.2.3 - Parking Spaces per Employee

When examining parking spaces per employee in a TAZ, the *a priori* ideas hypothesise that increasing employment in a TAZ generates an increasing demand for parking. Therefore it is hypothesized that as employment in a TAZ increases, the quantity of parking spaces provided increases. To test this hypothesis, parking spaces supplied are plotted as a function of total employment as shown in Figure 5.3.

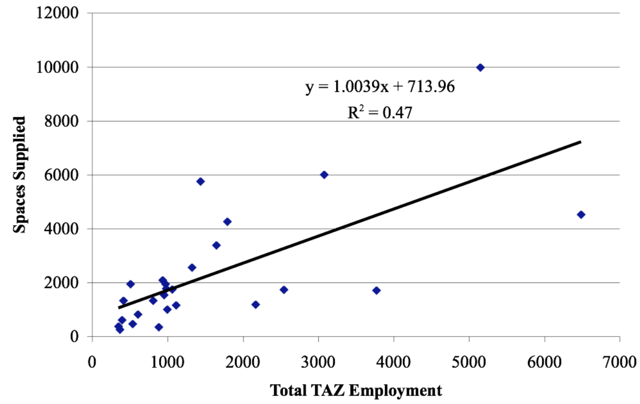


Figure 5.3: Spaces per TAZ Employment

Using regression analysis, the added linear trend line in Figure 5.3 explains proximally 47% of the variance in this relationship. This relationship supports the *a priori* hypothesis by displaying increasing trend of parking supply as total employment increases.

5.2.4 - Parking per Weighed Employee

The linear trend line in Figure 5.3 corroborated the *a priori* hypothesis that parking supplied increases as employment increases. Employment explains 47% of the variance in parking supply, a moderate correlation strength. The *a priori* hypothesis also posits that high trip-generating employment types produce increases in parking supply. To test the sensitivity to type of employment, parking supply is assumed to vary as a function of the type employment present. It is also hypothesized that retail employment is the highest trip-generating employment sector. Account for retail trip-generation, the total employment and total retail employment data in a TAZ are converted to total weighted employment as follows:

$$wtd_{emp} = nonret_{emp} + ret_{emp} \times 2.9$$

Where:
wtd_{emp} = Normalized Employment
ret_{emp} = # Retail Jobs
non_{retemp} = # Non-Retail Jobs

Equation 5.1: Formula to equate Weighted TAZ Employment

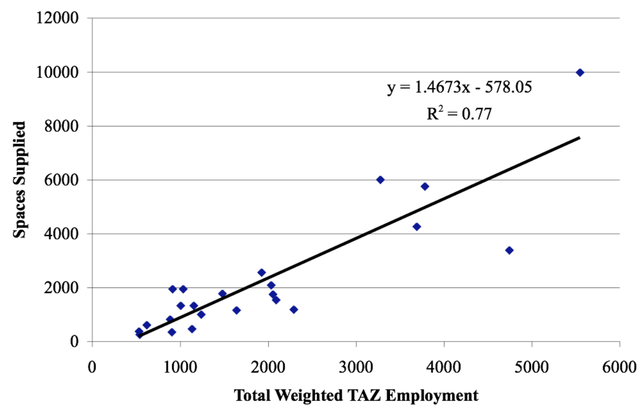


Figure 5.4: Spaces per Weighted TAZ Employment

The number of parking spaces provided as a function of weighted employment is plotted in Figure 5.4. A linear trend line is added in Figure 5.4 and in this case the weighted employment accounts for 77% of the variance in this relationship. This supports the *a priori* hypothesis and suggests that weighing the employment in a TAZ by the presence of retail produces far better estimates of the quantity of parking expected in a TAZ.

5.2.5 - Spaces per Employee as a Function of Distance

When examining parking per employee as a function of distance from the CBD, the *a priori* hypothesis states that as distance increases from the CBD, lower land values allow greater parking supplied per employee. Therefore it is expected the number of spaces per employee increases with distance from the CBD. To test this hypothesis spaces per employee is plotted against distance from CBD as show in Figure 5.5.

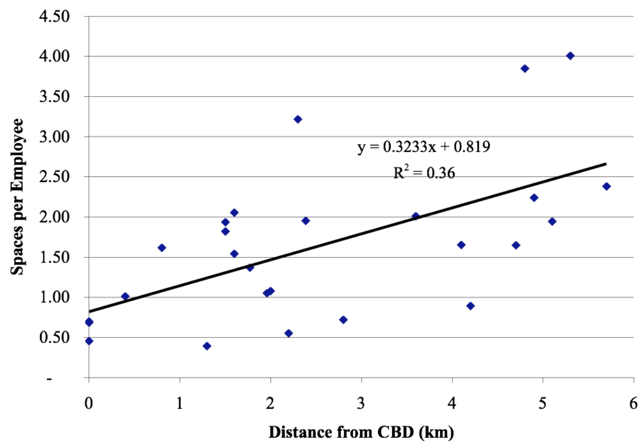


Figure 5.5: Spaces per Employee over Distance from CBD

In this case, the linear trend line in Figure 5.5 displays increasing spaces per employee as distance increases from the CBD. This supports the *a priori* hypothesis. In this plot, the linear trend line accounts for approximately 36% of the variance in this relationship.

5.2.6 - Spaces per Weighted Employee as a Function of Distance

The linear trend line in Figure 5.5 corroborates the *a priori* hypothesis that spaces per employee increases as distance from CBD increases. Distance explains 36% of the variance in spaces per employee, a moderate correlation. However, as section 5.2.4 illustrates, weighing employment by the presence of retail produces far better estimates of the quantity of parking expected in a TAZ. Thus, it is hypothesized that as spaces per weighted employee increases with a strong correlation when plotted as a function of distance from CBD. To test this hypothesis, spaces per weighted employee is plotted against distance from CBD as show in Figure 5.6.

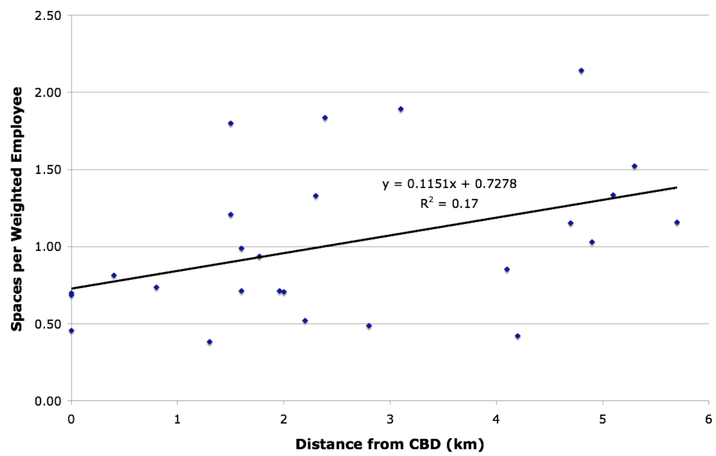


Figure 5.6: Spaces per Weighted Employee over Distance from CBD

The added trend line in Figure 5.6 illustrates some unexpected results. The trend line supports the hypothesized expectation displaying increasing spaces per weighted employee as a function of distance. Contrary to the expectation, distance explains only 17% of the variance. This weak correlation is unexpected as spaces per weighted employee is found to be a far better estimate of the quantity of parking expected in a TAZ.

The data are interpreted as follows. Although spaces per weighted employee is found to be a strong estimate of the quantity of parking supplied in a TAZ, it does not correlate over distance. Thus the amount of a TAZ's supplied parking may not be a function of distance. The primary land use of a TAZ is suspected to influence spaces supplied. The plotted data in Figure 5.6 is dispersed, illustrating some TAZs located close to a CBD having high spaces per weighted employee. This suggests that for areas outside of the CBD, land values may not be sufficiently high to motivate minimal parking supplies. However, the *a priori* ideas hypothesized that areas characterized by different land uses will exhibit different rates of parking supply even when normalizing for the predominate employment type. Thus, parking supplies are explored for each of the land use categories defined earlier.

5.3 - Relationships of Parking Supply and Primary Land Use Categories

With confirmation of decreasing employment density, and increasing spaces per employee as a function of increasing distance from the CBD, the following sections explore parking as a function of TAZ primary land use characteristics. Parking supplied per weighted employee as a function of land use densities are explored as well as parking density per land use category.

5.3.1 - Spaces per Weighted Employee as a Function of Land Use Density and Category

The *a priori* hypothesis is that areas characterized by different land uses will exhibit different rates of parking supply as a function of land use density, even when normalizing for the predominant employment type. To test this, the supply of parking per weighted employee for each of the land use categories defined in Table 4.1 is plotted against land use density. The results are shown in Figure 5.7.

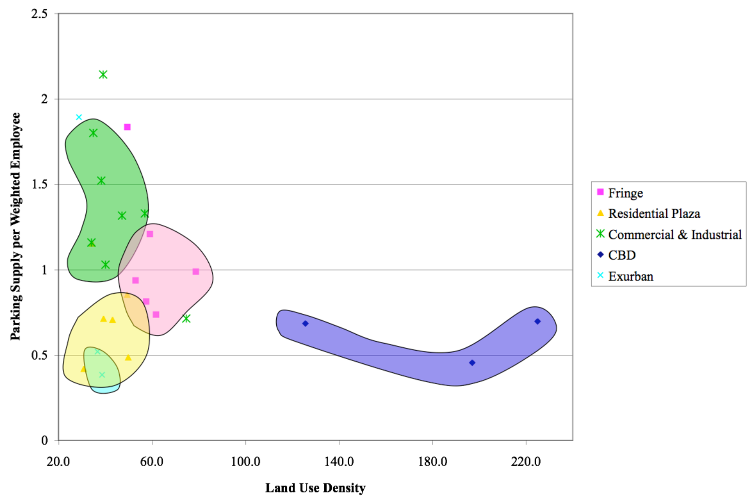


Figure 5.7: Parking Supply per Weighted Employment versus Land Use Density

Figure 5.7 confirms the hypothesis that land use densities characterized by different land use categories display different rates of parking supply. The data are interpreted as follows. TAZs with residential plazas have land use densities that range from approximately 30 to 50 (units defined above) and parking supplies that range from 0.4 to 1.1. The fringe CBD areas have similar parking supplies, from 0.7 to 1.2, but have generally higher land use densities, ranging from 53 to 79. Commercial and industrial areas have land use densities that span values from 35 to 80; these areas, however, have much higher rates of parking supply per employee with values observed from 1.3 to 2.1. Exurban areas have land use densities that range from 28 to 36, with low parking supplies, from 0.3 to 0.5. Finally, the TAZs containing CBDs have the highest land use densities but parking supplies that are similar to residential plaza areas.

These results are interpreted as follows for each land use category. The first interpretation in each category is this author's most likely beliefs behind the reasoning and causations between supplies per weighted employee and land use densities. The additional interpretations are listed with decreasing likelihoods.

The CBD areas have the highest concentration of employment, greatest propensity for shared parking, and the highest mode share for transit and non-motorized trips. This explains the very low parking supply per weighted employee. Although CBDs have the highest propensity for non-motorized trips, they exhibit supplies similar to residential plaza areas, as CBDs still require parking to serve their non-employment amenities such as retail shopping and restaurants.

Fringe areas, due to the proximity to a CBD, are influenced by the CBD's urban form, making land less available for parking while retaining employment similar to that of a CBD, driving down the necessity for additional parking.

In residential plaza areas, there is a social motivation to minimize the number of spaces, to maintain the character of the neighbourhood. Thus, lower supply of parking per employee is observed. Furthermore, a residential plaza is intended to serve the local residential neighbourhood. Thus, the low average spaces supplied in a residential plaza are affected by the ability for neighbourhood residents to walk to the plaza, reducing the need to travel via a car.

In industrial and concentrated commercial areas, there are very few limits to the quantity of parking supplied and due to the areas emphasis on commerce they have the highest parking supply per weighted employee. Therefore providing abundant supplies to attract commercial activity. These areas low land use densities are believed to be a function of their single use and very low residential populations.

The low land use densities of exurban areas are influenced by the lack of any surrounding urban forms that promote higher densities. Likewise, low populations and jobs in exurban areas equally affect parking supplies, generating the low number of parking spaces per employee.

5.3.2 - Parking Density as a Function of Land Use

In section 5.2.1, parking density is found to be relatively stable as a function of distance from CBD. Furthermore, section 5.3.1 illustrates that parking supplies varies as a function of land use densities characterized by different land use categories. To help gain further insight on the parking density and land use relationship, the average parking density per land use category is calculated and displayed in Figure 5.8.

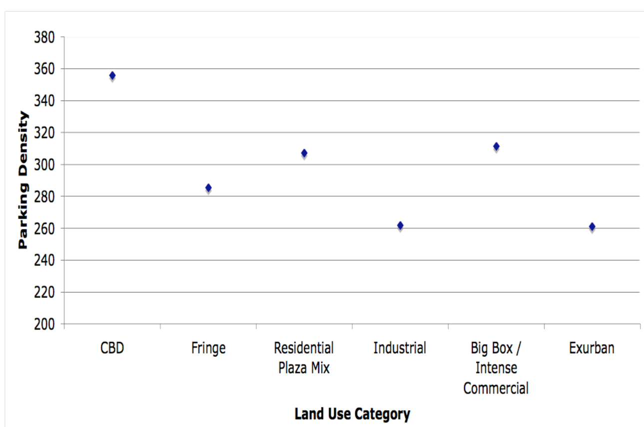


Figure 5.8: Land Use Category Parking Density

Figure 5.8 displays the range of average parking densities per land use category and shows average densities ranging from approximately 261 spaces per hectare to approximately 365.

The highest averages outside of the CBD exist within Residential Plaza Mixtures and Concentrated Commercial land uses with nearly the same average of 310 spaces per hectare. The lowest averages also fit into two land use categories shared between Industrial land uses and Exurban with the same average of 261 spaces per hectare. The Fringe land uses fall between these high and low averages with average spaces per hectare of approximately 285.

These results are interpreted as follows for each land use category. The first interpretation in each category is this author's most likely beliefs behind the reasoning and causations between average parking densities and each land use category. The additional interpretations are listed with decreasing likelihoods.

The CBD has the highest average parking density for obvious reasons such as expensive land costs that motivate the necessity for efficient land use for parking and the use of parking garages.

Fringe areas, having lower land use densities than their neighbouring CBDs have more leeway to exhibit lower parking densities, but higher land use densities than residential plazas or concentrated commercials areas. Thus fringe areas have a greater diversity of land uses, employment and populations then those other areas, increasing the demand for multiple parking lots and spaces. However, with fewer financial motivations to reduce large parking footprint than those areas with single uses, fringe areas have an ability to decrease in parking density. Furthermore, with greater amounts of uses, parking demand is believed to be more ubiquitous across the various uses, increasing the need to provide amenities such as access roads for increased number of parking lots. Therefore increasing the amount of land devoted for multiple lots serving multiple uses and decreasing the overall parking density of a fringe area.

Commercial and Residential Plaza Mixtures are commerce driven and use parking as an means to attract customers, yet have a financial motivation to reduce large parking footprints as a means to reduce retail lease rates and the trickle-down costs to consumers (Shoup, 2005). This leads to the provision of a high number of parking spaces on the least amount of land in order to attract customers without raising prices.

The lowest average parking densities, existing in Exurban (orange outlines in Figure 5.8) and Industrial (green outlines in Figure 5.8) areas are believed to be a result of location. When observing the geographical locations of these exurban and industrial sites, although their locations are not the furthest in distance from their respective CBDs, they are in fact located at the outlying boundaries of the urban form (blue outline) of their cities and the Region as illustrated in Figure 5.8. Understanding that these sites exist on the edge of the urban form is key to understanding their low parking densities. With no land uses or urban forms surrounding these sites that promote higher density developments or increased land costs, there is no monetary, social or communal pressure to motivate higher parking densities.

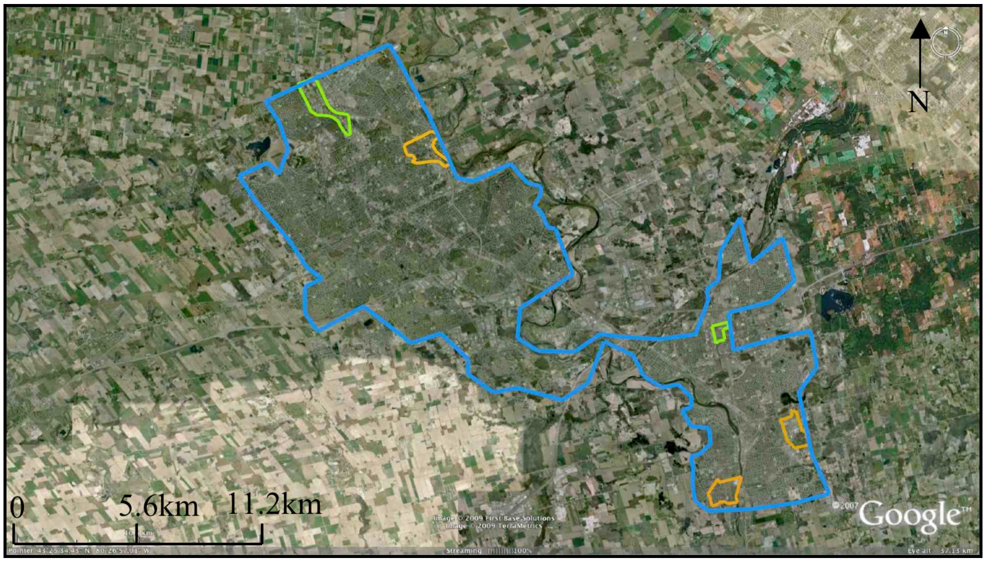


Figure 5.9: Regional Urban Boundary & Highlighted Outlaying Sites
Source: Google, 2008.

5.4 - Summary of Findings

From these results, some conclusions can be drawn that may provide guidance on parking policies going forward and their integration into TDM strategies. Particularly, the ability to set measurable, defendable parking maxima.

In regards to parking policy, the minimum values for parking supply per employee in each category may be used to provide targets as maxima for future developments. While many researchers have proposed the implementation of maximum parking supply bylaws, this data may allow quantitative targets to be set. For example, new developments may currently be required to meet the minimum spaces per square footage of gross leaseable area. In the case of this study, rather than the use of square footage, a maximum can be set for spaces per employee or spaces per weighted employee. Table 5.2 summarizes these maxima values for each land use category.

Table 5.2: Maximum Parking Supply Values per Employee for using the Minimum Observed Parking Supplies

Land Use	CBD	Fringe	Residential Plaza Mix	Industrial	Concentrated Commercial	Exurban
Spaces per employee	0.46	1.01	0.72	1.94	2.05	0.39
Spaces per weighted employee	0.46	0.74	0.42	1.33	0.71	0.38

Alternatively, the maximum target for spaces per employee may be established as the mean value of similar TAZs. Table 5.3 summarizes these maxima values.

Table 5.3: Maximum Parking Supply Values per Employee using the Mean Value of similar TAZs

Land Use	CBD	Fringe	Residential Plaza Mix	Industrial	Concentrated Commercial	Exurban
Supply per employee	0.61	1.55	1.17	1.94	2.96	0.99
Supply per weighted employee	0.61	1.09	0.72	1.57	1.32	0.93

Furthermore, the data from this study can be used to set minimum parking densities. The data in this study suggests that parking supplies per employee is least in CBDs. However, for areas outside of the CBD, land values may not be sufficiently high to motivate developers to increase parking density by minimizing their parking footprint. While many cities are attempting to achieve intensification, restricting parking footprints may have positive impacts. The data from this study range from 210 to 450 spaces per hectare allocated to parking, with the median value being approximately 280 spaces per hectare. Thus, minimum parking densities can be set using the highest observed parking densities. Table 5.3 summarizes these minimum values for each land use category.

Table 5.4: Minimum Parking Densities using the Highest Observed Densities

Land Use	CBD	Fringe	Residential Plaza Mix	Industrial	Concentrated Commercial	Exurban
Parking Density	449.5	375.1	346.1	276.5	426.1	283.0

By setting policies that require minimum parking densities to be achieved, municipalities may be able to not only control the supply of parking through applications of parking maxima, but also influence the form of parking provided.

Chapter 6 - Conclusions & Future Work

6.1 - Study Goals

This thesis explored parking supplied in Traffic Analysis Zones through a case study of the Region of Waterloo. The main purpose of this research was to understand the relationships between suburban parking supplies, a traditional market force and primary land use characteristics. Understanding these relationships was intended to help answer the primary research question of "*What opportunities exist to use observed existing parking supplies to develop parking maxima as a TDM tool?*"

To develop a methodology to complete this study, two specific objectives were established to assist in answering the research question:

- What is the relationship between suburban parking supply in a Traffic Analysis Zone (TAZ) as a function of a traditional market force?
- What is the relationship between suburban parking supplies in a TAZ and its primary land use characteristics?

The following sections discuss the successes of each of these goals and the opportunities for future research in suburban parking that arose from this study.

6.2 - Accomplishment of Goals

At the onset of this study, it was expected that traditional land use market models affect parking supplies. It was expected that the traditional market force of decreasing land values as distance from CBD increased would allow parking supplies to increase. It was also expected that decreasing land values would also warrant decreased employment densities and decreased parking densities. Due to these factors, it was assumed that parking on a per-employee basis would then increase with distance from CBD, especially in areas with high trip-generation employment types such as retail.

To test these hypotheses parking supplies were examined in the Regional Municipality of Waterloo and data was collected using GIS at the Traffic Analysis Zone level of geo-spatial reference. The total number of spaces provided, the footprint required to accommodate those spaces and the amount of employment to which the parking provided access was quantified.

It was found that much of the data supported the *a priori* ideas. Examining the study's parking relationships between decreasing land values and primarily land use characteristics, was done through a linear regression analysis. Linear regression analysis was used in an effort to describe the general trends observed.

Employment densities decreased as distance from CBD increased while parking spaces per employee increased. Additionally, it was found that the number of spaces provided is a function of the amount of employment in a TAZ. This was found to be a somewhat weak indicator of parking supply as the range of values in the study was from 0.39 to 4.01 spaces per employee. However, when the supply of parking was normalized for to control for the influence of retail employment, weighted employment offered much stronger indicators of parking supplies. When normalized for the quantity of retail employment, the range narrowed between 0.38 and 2.14 spaces per weighted employee. As previously illustrated, the highest provision of parking was for industrial areas, likely because the opportunity cost of higher allocation would be very low in these areas. Similarly, concentrated commercial areas had very high parking per weighted employee. This is believed to be the influence of developers' efforts not to risk undersupplying parking in heavily retail-oriented areas. The range of supply per employee suggests that government minimums are not a major factor for developers in creating parking areas. Additionally, the data suggests that land values do very little in controlling the supply of parking outside of CBDs, especially those areas with very little diversity of land such as commercial and industrial areas.

It was further discovered that the number of spaces provided per employee increased as a function of distance with moderate correlation strength. However, when normalized for, the number of spaces provided per weighted employee over distance from CBD displayed and unexpected weak correlation strength. It was suspected that the number of spaces provided per employee correlated not as a function of distance but as a function of land use density.

Upon examining the relationship between parking supplies and primary land use characteristics, was discovered that areas with either very high or very low land use densities tend to have the lowest diversity of land uses (purely commercial or industrial) yet have the highest supply of parking per employee. This is suspected to be due to a general unwillingness to experience the case where parking is undersupplied in these areas.

From these results, conclusions were drawn that can provide a framework on setting measurable, defendable parking maxima in parking policies and further their integration into TDM strategies. It is noted that application of parking maxima into bylaws an TDM strategies must coincide with well-balance transportation strategies that promote multi-modal transportation alternatives to the automobile. It was illustrated that the minimum values for parking supply per employee or spaces per weighted employee in each category can provide targets as maximums for future developments. The maximum target for spaces per employee or weighted employee could alternatively be established by using the mean value of TAZs with similar land use characteristics.

The results also illustrated that the data from this study can be used to set minimum parking densities to help achieve increases urban intensification by restricting parking footprints. By setting minimum parking densities, municipalities may be able to control the supply of parking as well as form of parking provided. Alongside setting parking maxima, policies that require parking densities to local land uses may be another quantifiable measure to manage suburban parking supplies as part of comprehensive multi-model transportation polices.

The results of this framework are only meant to be a preliminary stopping stone in the research of quantifying parking maxima and using maxima as a TDM tool within transportation planning policies. Setting measurable, defendable parking maxima by applying this study's framework. Increased research on parking maxima should be aggressively engaged.

6.3 - Future Research

Several of these issues were identified during the period of this study, yet were considered too great an errand to accomplish within the scope and timeline of this study. The following sections contain a number of suggestions for increased research in suburban parking that arose from the identification of these issues.

6.3.1 - Increased Scale

The first and most prominent research issue that arose during the period of this study has been the scale of the study. Limited by available resources and time, the study was constrained to the geographical boundaries of the Region of Waterloo. Having no additional regions or cities to compare measures against has left this study in a preliminary stage of suburban parking analysis. Future research should identify similarly sized cities and regions comparable to the Region of Waterloo and replicate the methodology of this study in those cities. This can increase comparable levels of data and assist in further developing frameworks for this level of research.

6.3.2 - Greater Parking Inventory

The second research issue that arose out of this study regarded the chosen methodology. Limited to the data resources available, the methodology only allowed for measurements of visible lots within the aerial photographs. Any hidden or unknown parking lots were not measured, leaving the study with an incomplete parking supply inventory. As demonstrated by Broaddus (2009), a complete inventory of the supply is required to develop appropriate policies to counter the issues caused by parking. Thus, this potentially serious limitation in the study should be addressed for future research that harnesses greater detailed inventories.

Furthermore, future research should not only explore truer catalogued inventories of parking at regional or city scales, but the parking lot occupancy rates as well. This can then develop an understanding of the usage of parking lot supplies. In turn, this can help to compare how parking supplies are provided versus their use over time.

6.3.3 - Residential Parking Supplies

This study attempted to understand the supply of off-street parking lots that are considered end-of-trip destinations such as shopping centres and workplaces. The study did not, however, examine parking supplies at the residential beginning-of-trip locations. This lesser understood and practically non-researched 'second half' of parking has a great deal of potential to help researchers understand the transportation effects of the residential side of parking (Weinberger, Seaman, & Johnson, 2009). In fact, Weinberger, Seaman, & Johnson (2009) have illustrated that parking located in residential areas such as home garages and on-street parking increases automotive commutes far more than commercial destination off-street lots. This demonstrates that in order to fully inventory parking supplies and understand their the effects parking has on transportation policies, residential parking supply inventories should also be examined.

6.3.4 - Application of Framework

As this study's methods and results are intended to be a general framework to help form parking policy, research remains regarding its application. In particular, there are three key areas that merit further research:

i. the application of the framework in changing transportation policy;

ii. setting maximum parking requirements for weighted employment; and

iii. footprint restriction and minimum densities.

6.3.4.1 - Application in Changing Planning Policy

Transportation policies throughout Ontario and Canada are undergoing significant changes. These changes are the result of transit-supportive initiatives the Federal and Provincial governments are promoting. In light of these initiatives, the use of transit, automobiles and alternative forms of transportation are fluctuating. How regional level governments take into account these changes in transportation seems uncertain. The provision of increased rapid transit may invite more automobile users to leave the car at home and take transit more frequently. However, this may leave large commercial parking lots in less demand. This highlights the necessity for continued parking research to be undertaken throughout any regional municipality or city undergoing transportation investments that intend to reduce automobile use. It is not sufficient for governments to introduce transit and continue to provide ample parking that seemingly opposes transit use and attracts continued automobile use. Conversely, it would seem appropriate, if not essential, to undergo continuous parking analysis as part of any transportation master plan to appropriately control parking as an ongoing process to provide influential and balanced parking supplies.

Furthermore, the methodology of this study is intended to be a framework easily adoptable to similar cities or regions. Unfortunately, the application of this current framework's methodology is a timely process. Automation for accessing parking supply inventories for sites is desperately required. Thus further research is required to develop automation for the frameworks application for inventorying parking supplies and weighting employment sectors.

6.3.4.2 - Setting Maximum Parking Requirements for Weighted Employment

Although this study offered a method to set quantitative targets for maximum parking requirements, the process for setting those targets is based on weighted employment. This process can easily be applied for sites that have high employment of one particular sector. However, the weighting of employment has not been fully developed for a wide range of employment sectors. This can become problematic if attempting to derive appropriate parking maxima in a mixed-use area with many different job types. Thus, further research is required to develop a wider range of weighted employment algorithms to equate maximum parking targets.

Furthermore, the quantitative targets listed in Section 5.4 are derived from the case study. These targets may not be applicable or appropriate for different municipalities as they may have different parking bylaws and provisions. Therefore maximum targets should be quantified by applying this framework to local parking conditions and supply management.

6.3.4.3 - Footprint Densities

While this study also suggests the use of restrictive parking footprints (or increasing parking densities) as a means of achieving intensification, the study does not provide any means of calculating such minimum densities for new developments. Although this study illustrates a simple way to measure parking density, an approach to set minimum parking densities across a region remains to be explored. Similarly, further research can explore a quantifiable method to format parking densities tailored to local land use densities in an effort to manage suburban parking supplies.

6.3.5 - Continued Research

While current parking research revolves around the policies and pricing of CBD parking, the research in suburban parking and maximum parking allowances remains relatively undeveloped, and a considerable amount of suburban parking research issues remain. It is essential that parking research stretch beyond end-of-trip supplies and demands. Similar to monitoring traffic to ensure smooth flows or recording transit passengers to identify routes requiring increased service, regular monitoring and inventorying of parking supplies should be developed. With this in mind, the research opportunities identified in this chapter will certainly stimulate years of future research in the realm of parking.

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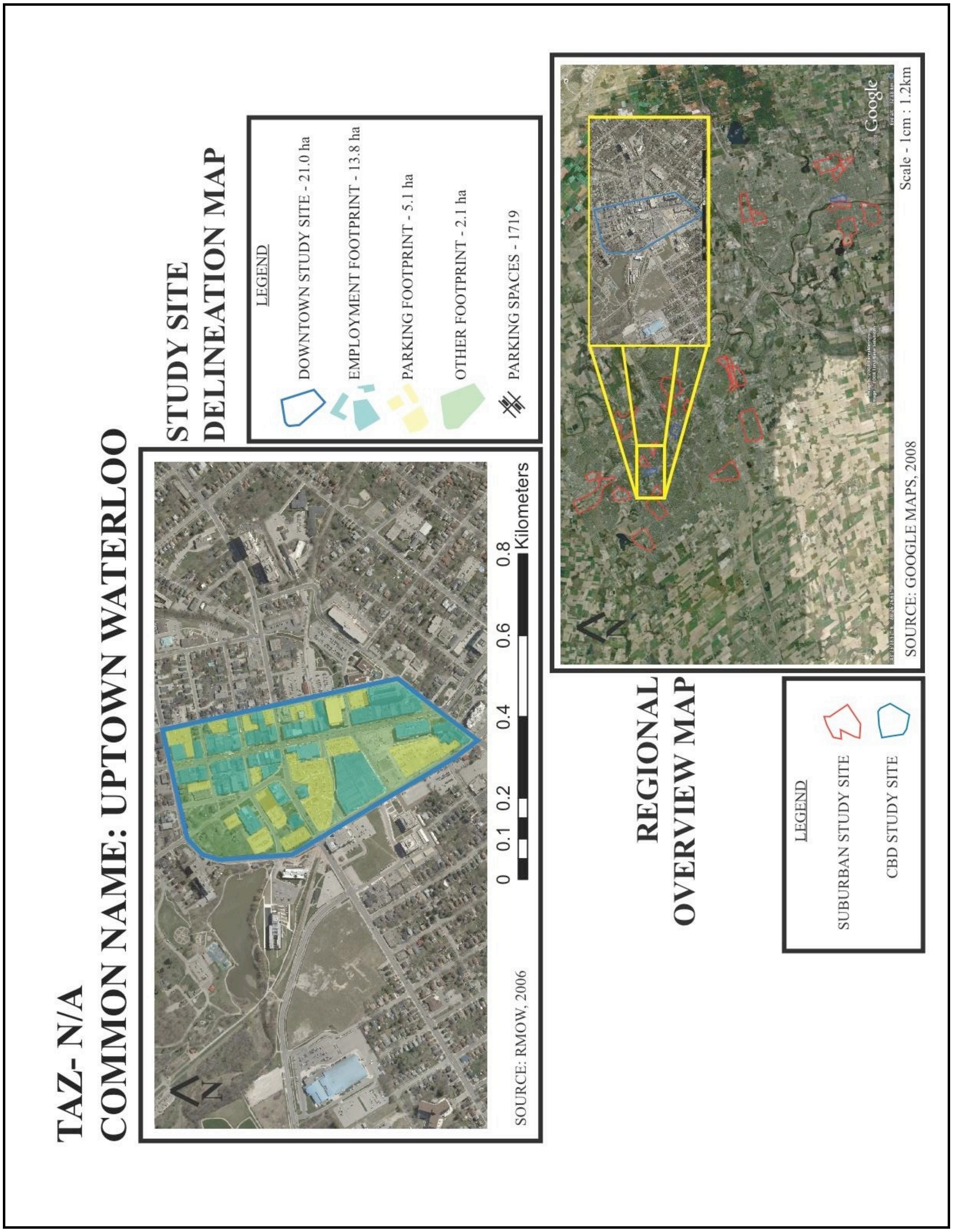
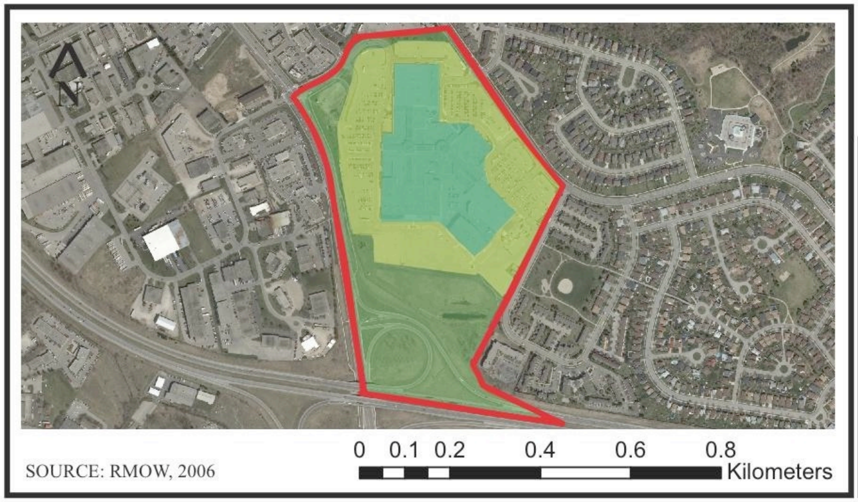
Appendix A – STUDY SITES



TAZ 34
COMMON NAME: CONESTOGA MALL

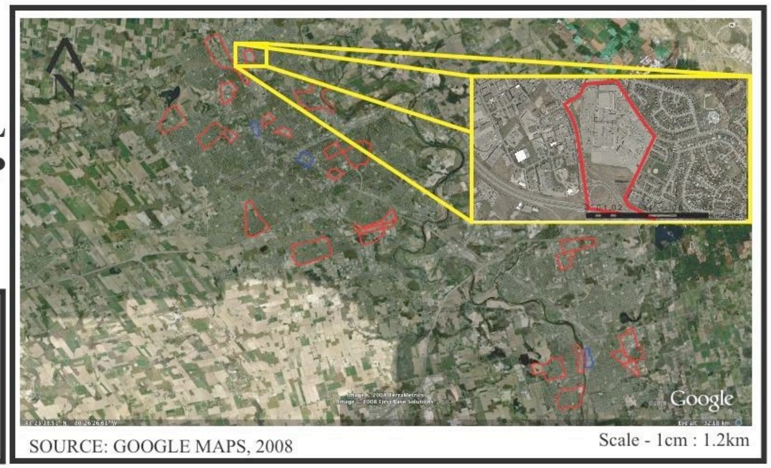


STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 31.5 ha
- EMPLOYMENT FOOTPRINT - 12.8 ha
- PARKING FOOTPRINT - 9.3 ha
- OTHER FOOTPRINT - 9.4 ha
- PARKING SPACES - 3385

REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 38-41
COMMON NAME: NORTHFIELD

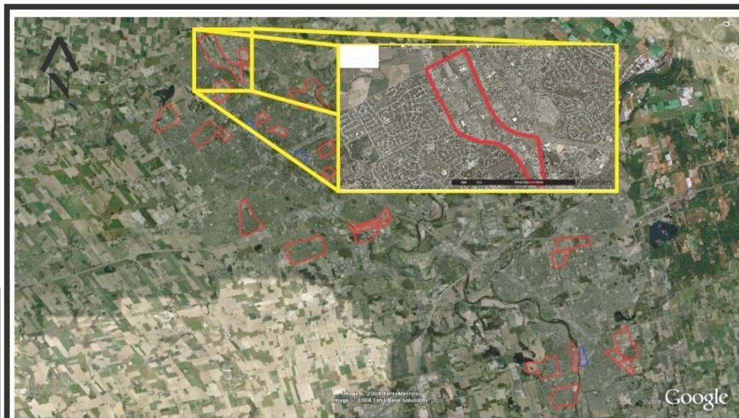
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 184.8 ha
- EMPLOYMENT FOOTPRINT - 28.4 ha
- PARKING FOOTPRINT - 36.1 ha
- OTHER FOOTPRINT - 119.9 ha
- PARKING SPACES - 9982

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 52
COMMON NAME: RIM AREA

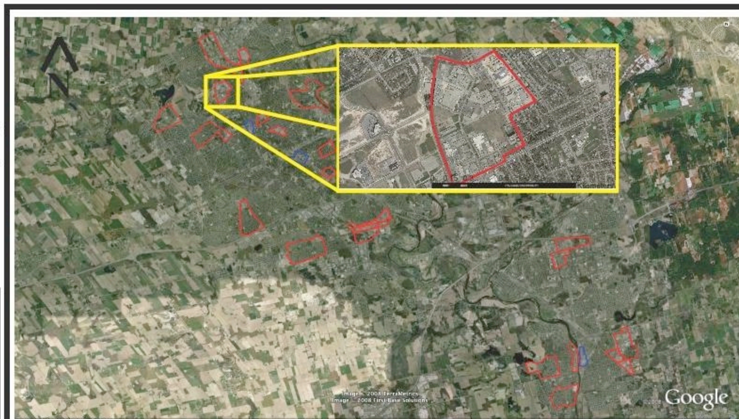
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 63.4 ha
- EMPLOYMENT FOOTPRINT - 34.3 ha
- PARKING FOOTPRINT - 16.0 ha
- OTHER FOOTPRINT - 13.1 ha
- PARKING SPACES - 6009

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 129
COMMON NAME: NA

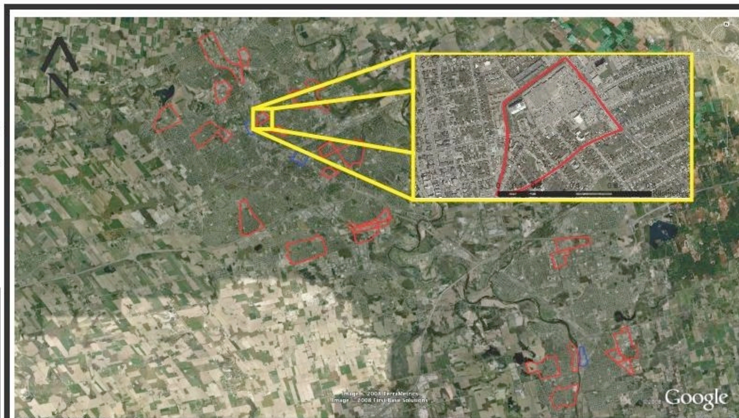
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 23.6 ha
- EMPLOYMENT FOOTPRINT - 5.0 ha
- PARKING FOOTPRINT - 4.7 ha
- OTHER FOOTPRINT - 13.9 ha
- PARKING SPACES - 1540

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 143
COMMON NAME: N/A

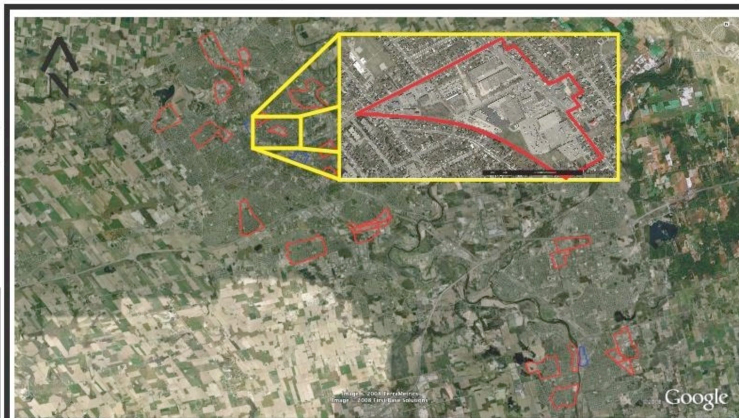
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 22.8 ha
- EMPLOYMENT FOOTPRINT - 6.1 ha
- PARKING FOOTPRINT - 6.8 ha
- OTHER FOOTPRINT - 9.9 ha
- PARKING SPACES - 1786

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 269
COMMON NAME: NA

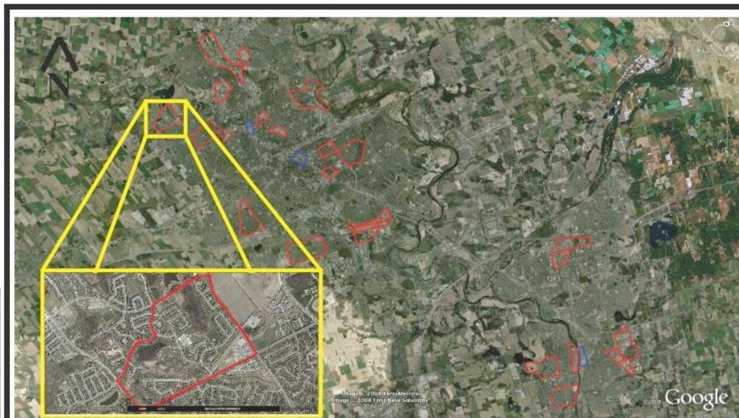
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 106.2 ha
- EMPLOYMENT FOOTPRINT - 3.4 ha
- PARKING FOOTPRINT - 1.6 ha
- OTHER FOOTPRINT - 101.6 ha
- PARKING SPACES - 476

REGIONAL OVERVIEW MAP



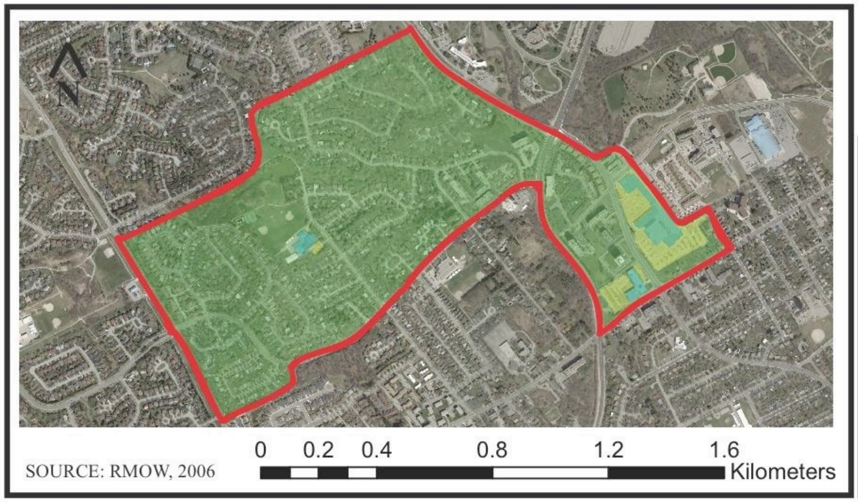
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 278
COMMON NAME: N/A

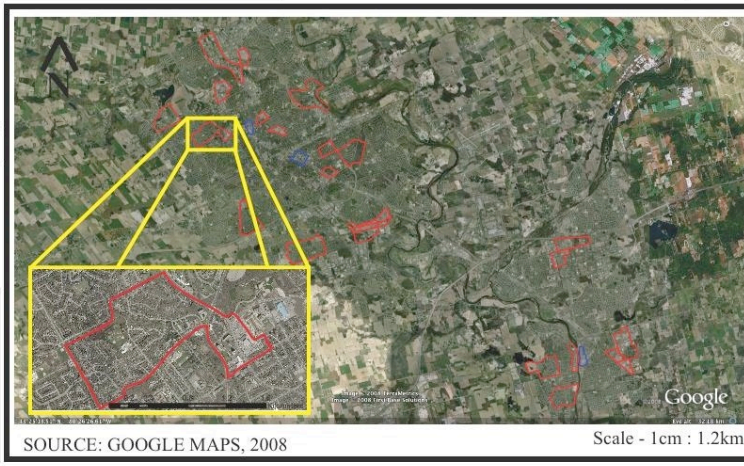


STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 118.5 ha
- EMPLOYMENT FOOTPRINT - 2.2 ha
- PARKING FOOTPRINT - 4.6 ha
- OTHER FOOTPRINT - 110.7 ha
- PARKING SPACES - 1171

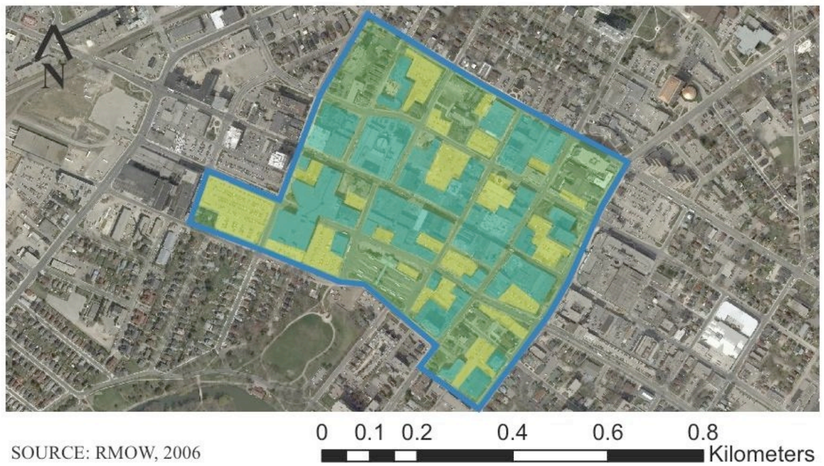
REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ N/A
COMMON NAME: DOWNTOWN KITCHENER



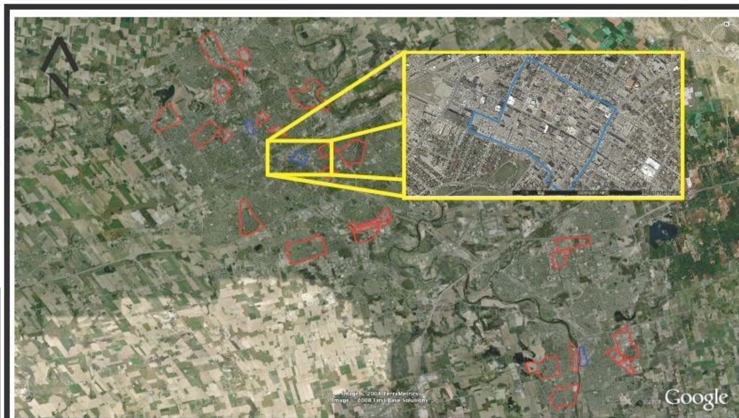
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- DOWNTOWN STUDY SITE - 35.0 ha
- EMPLOYMENT FOOTPRINT - 22.9 ha
- PARKING FOOTPRINT - 10.1 ha
- OTHER FOOTPRINT - 2.0 ha
- PARKING SPACES - 1719

REGIONAL OVERVIEW MAP



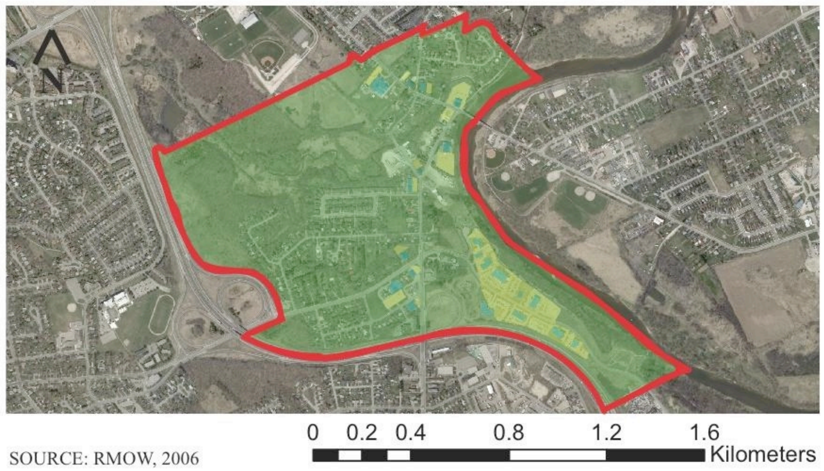
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 118
COMMON NAME: N/A



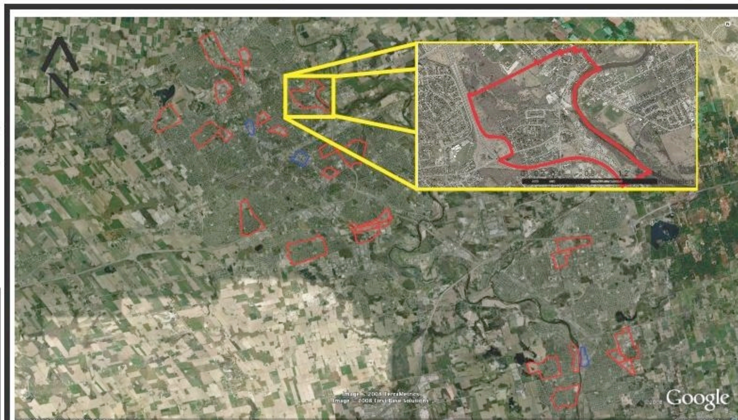
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 154.1 ha
- EMPLOYMENT FOOTPRINT - 32.8 ha
- PARKING FOOTPRINT - 6.9 ha
- OTHER FOOTPRINT - 114.4 ha
- PARKING SPACES - 1953

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

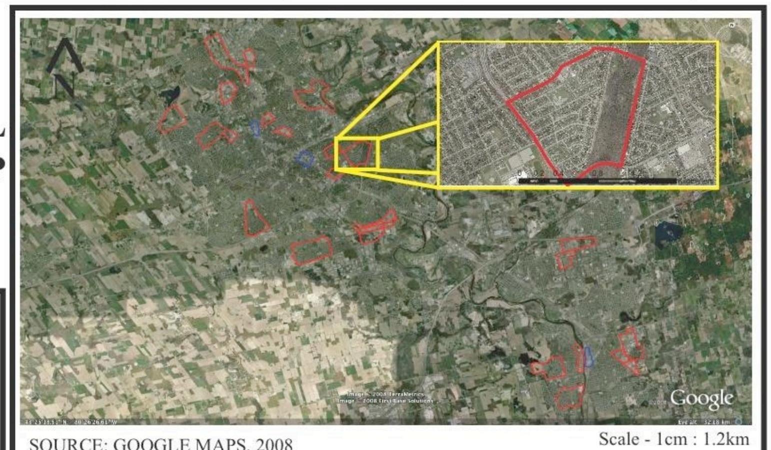
TAZ 172
COMMON NAME: N/A

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 113.4 ha
- EMPLOYMENT FOOTPRINT - 2.2 ha
- PARKING FOOTPRINT - 0.8 ha
- OTHER FOOTPRINT - 110.4 ha
- PARKING SPACES - 263

REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

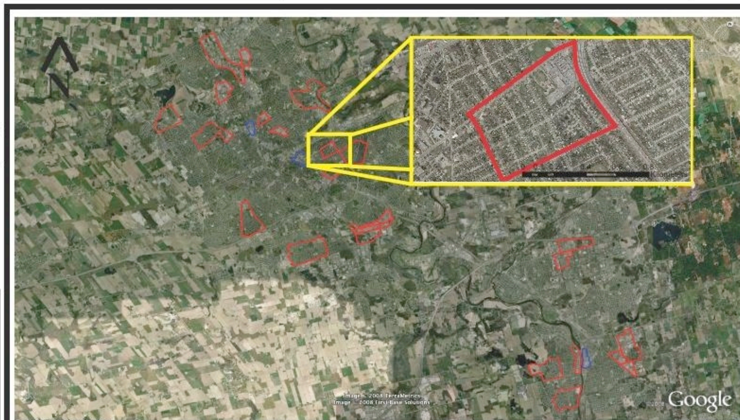
TAZ 171
COMMON NAME: N/A

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 40.6 ha
- EMPLOYMENT FOOTPRINT - 2.3 ha
- PARKING FOOTPRINT - 2.9 ha
- OTHER FOOTPRINT - 35.4 ha
- PARKING SPACES - 611

REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 181
COMMON NAME: N/A

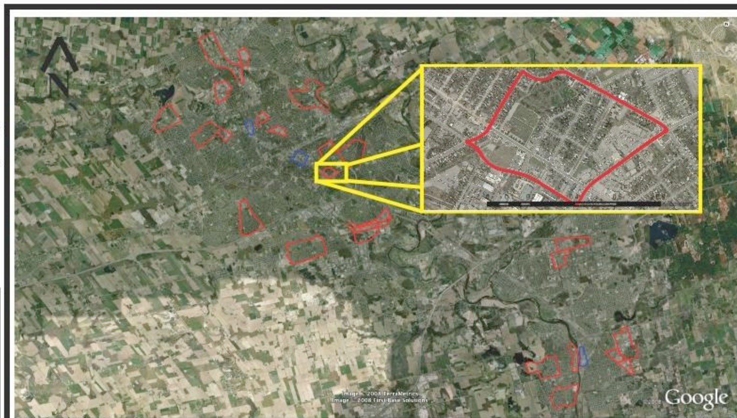
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 27.4 ha
- EMPLOYMENT FOOTPRINT - 7.7 ha
- PARKING FOOTPRINT - 3.0 ha
- OTHER FOOTPRINT - 16.7 ha
- PARKING SPACES - 826

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 200
COMMON NAME: FAIRVIEW MALL

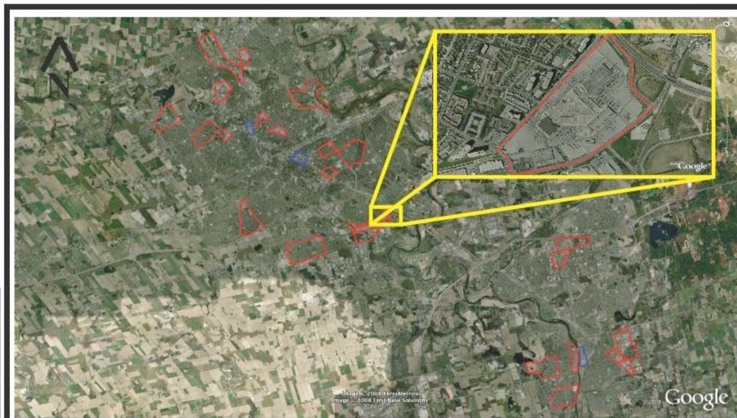
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 27.0 ha
- EMPLOYMENT FOOTPRINT - 11.7 ha
- PARKING FOOTPRINT - 13.5 ha
- OTHER FOOTPRINT - 1.8 ha
- PARKING SPACES - 5752

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 202
COMMON NAME: N/A

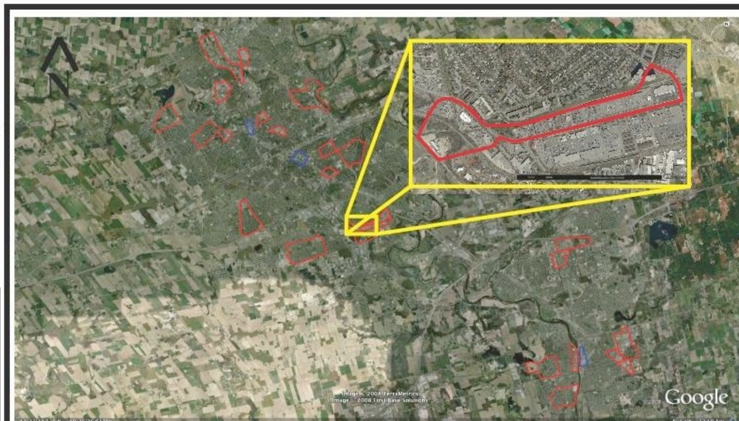
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 21.0 ha
- EMPLOYMENT FOOTPRINT - 7.0 ha
- PARKING FOOTPRINT - 7.2 ha
- OTHER FOOTPRINT - 6.8 ha
- PARKING SPACES - 1955

REGIONAL OVERVIEW MAP



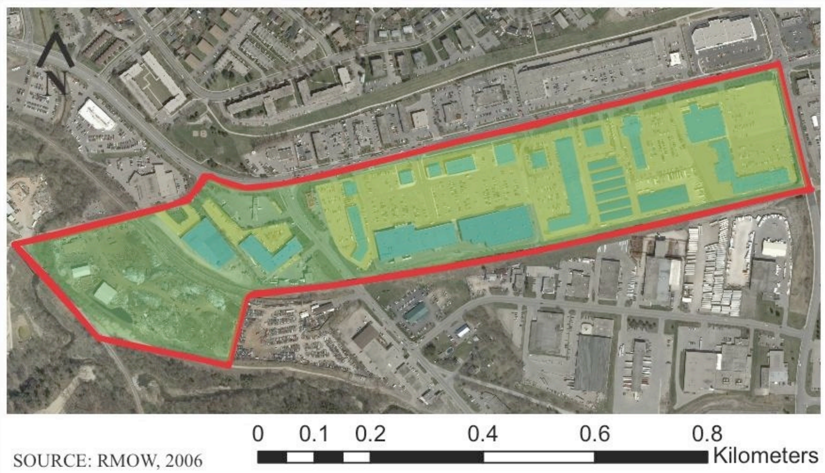
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 218
COMMON NAME: N/A



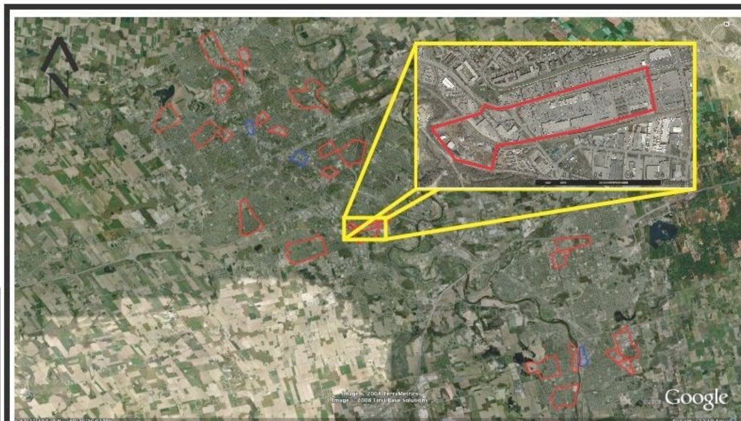
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 29.9 ha
- EMPLOYMENT FOOTPRINT - 16.1 ha
- PARKING FOOTPRINT - 7.2 ha
- OTHER FOOTPRINT - 6.6 ha
- PARKING SPACES - 2095

REGIONAL OVERVIEW MAP



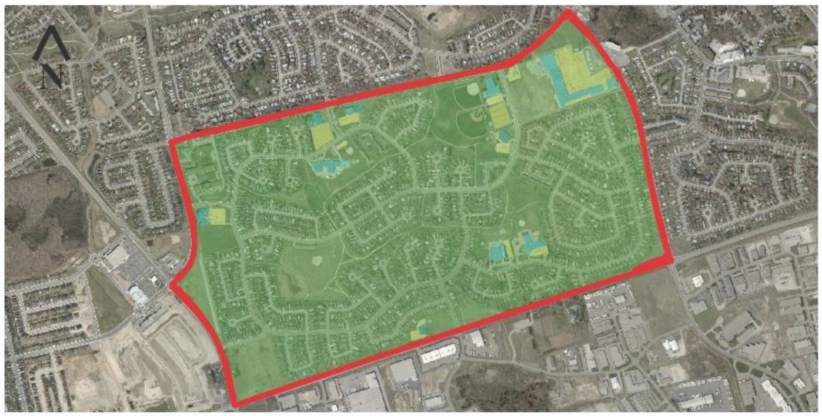
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 233
COMMON NAME: N/A



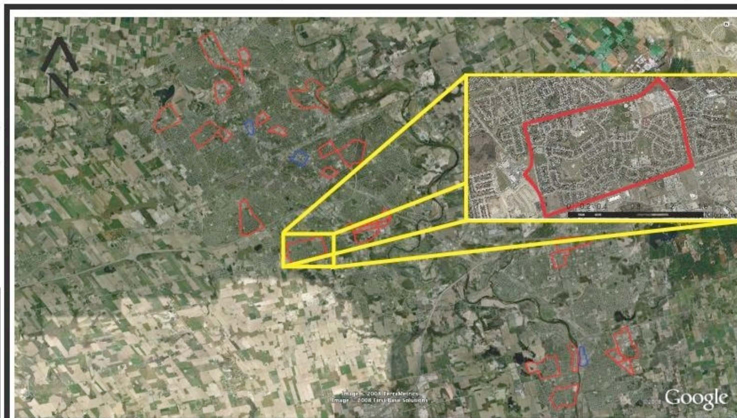
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 188.3 ha
- EMPLOYMENT FOOTPRINT - 14.3 ha
- PARKING FOOTPRINT - 4.6 ha
- OTHER FOOTPRINT - 169.4 ha
- PARKING SPACES - 1330

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 305
COMMON NAME: N/A

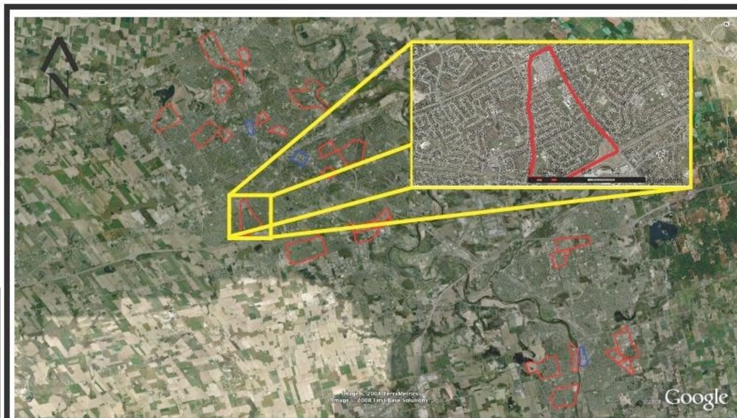
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 122.6 ha
- EMPLOYMENT FOOTPRINT - 11.8 ha
- PARKING FOOTPRINT - 5.1 ha
- OTHER FOOTPRINT - 105.4 ha
- PARKING SPACES - 1171

REGIONAL OVERVIEW MAP



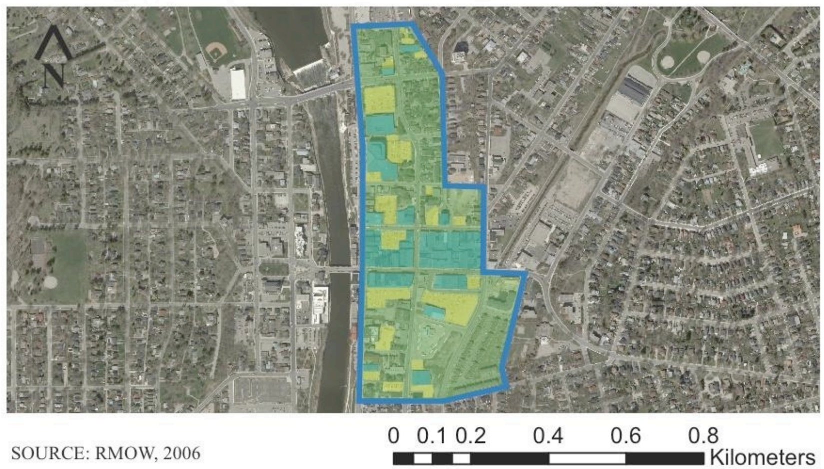
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ N/A
COMMON NAME: DOWNTOWN CAMBRIDGE



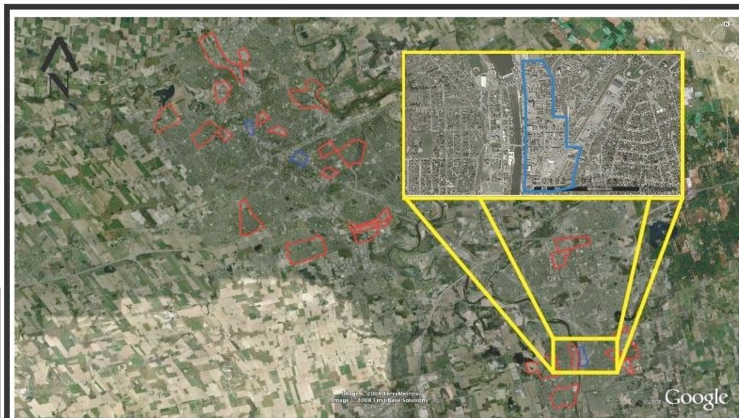
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- DOWNTOWN STUDY SITE - 28.0 ha
- EMPLOYMENT FOOTPRINT - 16.2 ha
- PARKING FOOTPRINT - 6.2 ha
- OTHER FOOTPRINT - 5.6 ha
- PARKING SPACES - 1743

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 368
COMMON NAME: N/A

SOURCE: RMOW, 2006

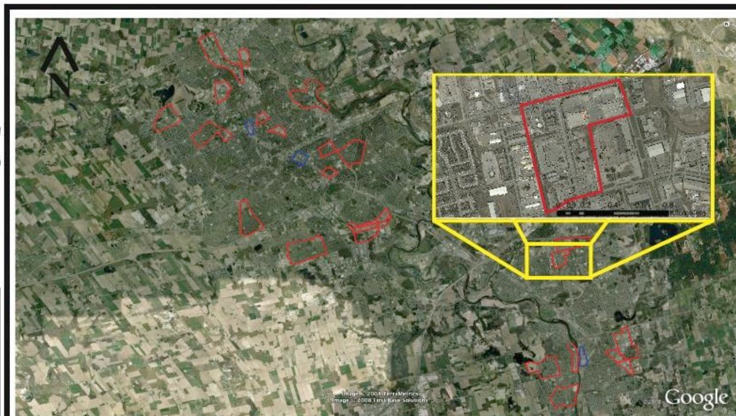
0 0.1 0.2 0.4 0.6 0.8 Kilometers

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 39.9 ha
- EMPLOYMENT FOOTPRINT - 28.4 ha
- PARKING FOOTPRINT - 10.4 ha
- OTHER FOOTPRINT - 1.1 ha
- PARKING SPACES - 2568

REGIONAL OVERVIEW MAP

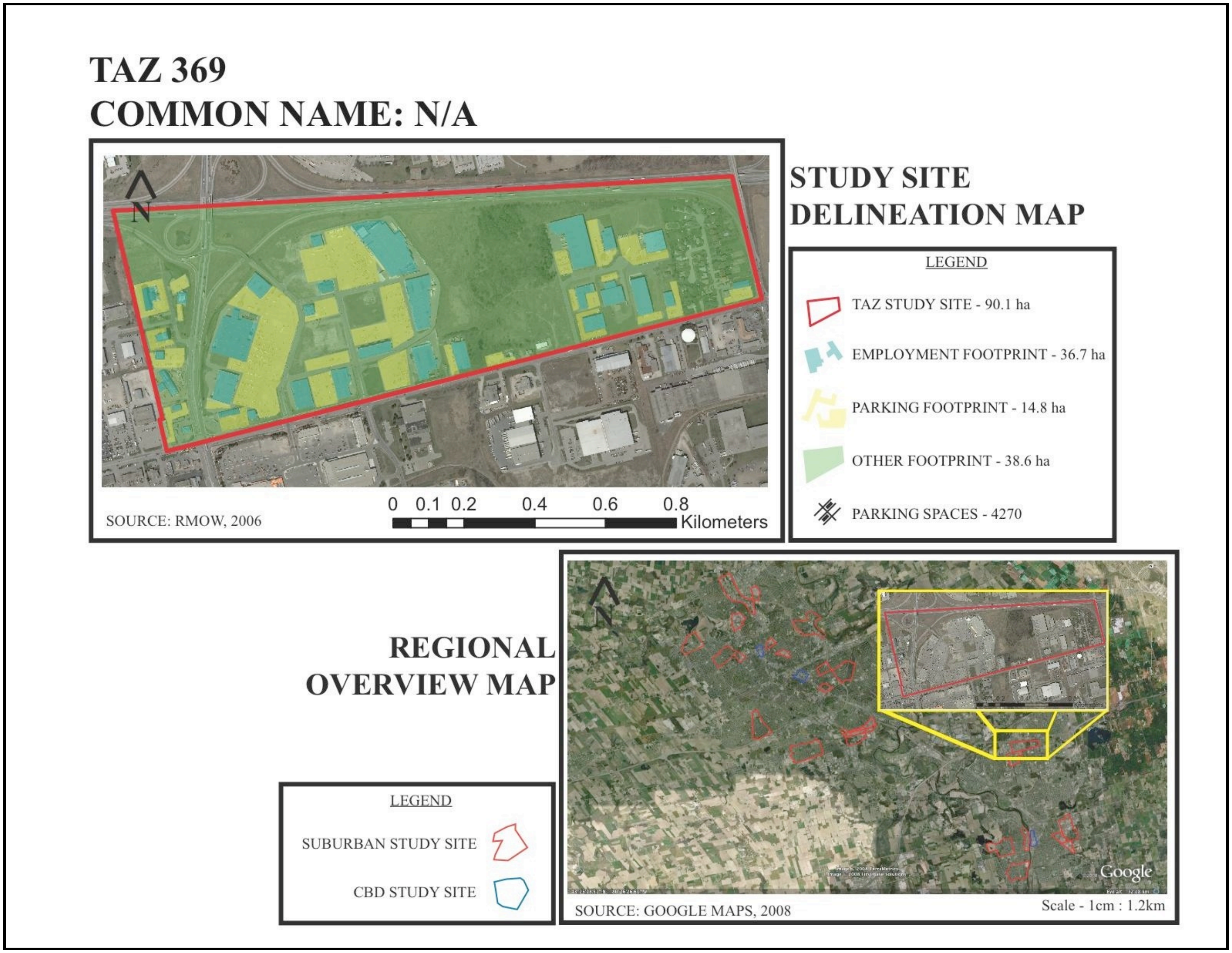


SOURCE: GOOGLE MAPS, 2008

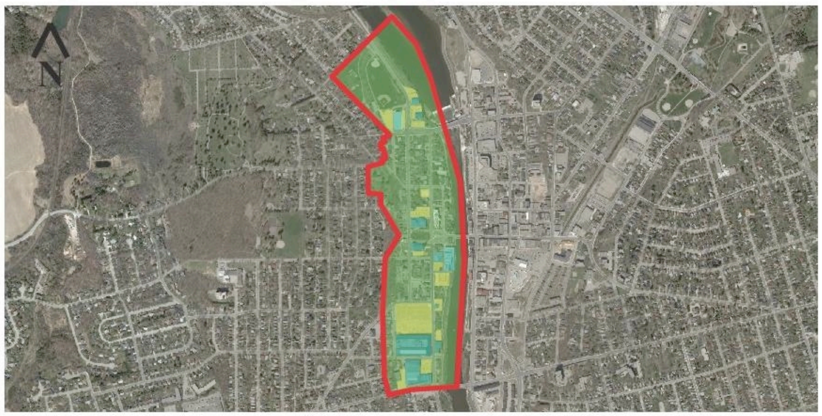
Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE


TAZ 369
COMMON NAME: N/A
STUDY SITE
DELINEATION MAP
LEGEND
TAZ STUDY SITE - 90.1 ha
EMPLOYMENT FOOTPRINT - 36.7 ha
PARKING FOOTPRINT - 14.8 ha
OTHER FOOTPRINT - 38.6 ha
PARKING SPACES - 4270
N
0 0.1 0.2 0.4 0.6 0.8
Kilometers
SOURCE: RMOW, 2006
REGIONAL
OVERVIEW MAP
LEGEND
SUBURBAN STUDY SITE
CBD STUDY SITE
Google
SOURCE: GOOGLE MAPS, 2008
Scale - 1cm : 1.2km

TAZ 408
COMMON NAME: N/A

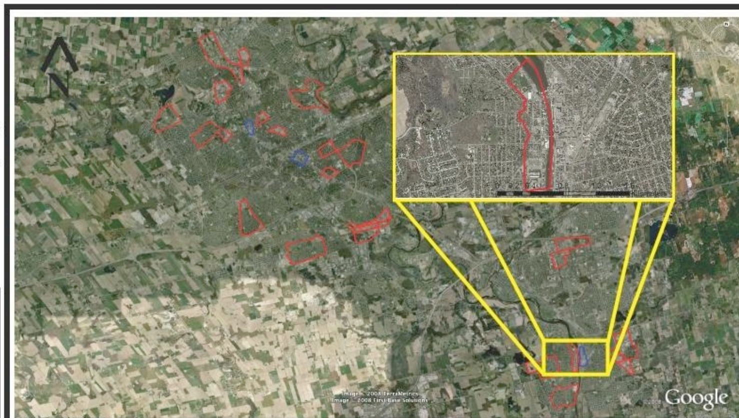


STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 45.7 ha
- EMPLOYMENT FOOTPRINT - 19.8 ha
- PARKING FOOTPRINT - 3.8 ha
- OTHER FOOTPRINT - 22.1 ha
- PARKING SPACES - 1006

REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 414
COMMON NAME: N/A

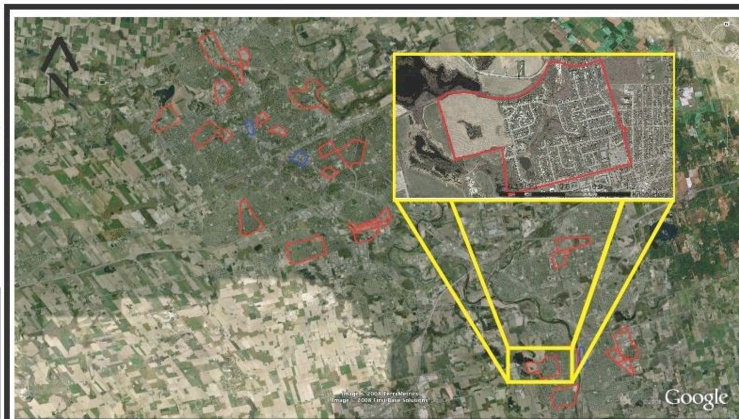
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 127.6 ha
- EMPLOYMENT FOOTPRINT - 1.5 ha
- PARKING FOOTPRINT - 1.2 ha
- OTHER FOOTPRINT - 124.9 ha
- PARKING SPACES - 375

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 417
COMMON NAME: N/A

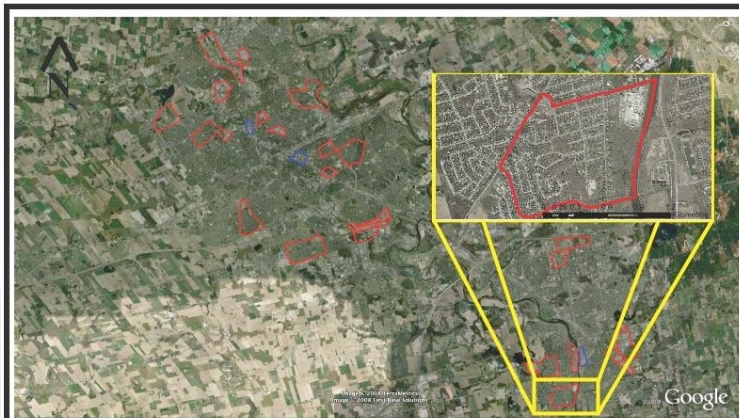
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 119.0 ha
- EMPLOYMENT FOOTPRINT - 6.3 ha
- PARKING FOOTPRINT - 1.5 ha
- OTHER FOOTPRINT - 111.2 ha
- PARKING SPACES - 347

REGIONAL OVERVIEW MAP



SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 435
COMMON NAME: N/A

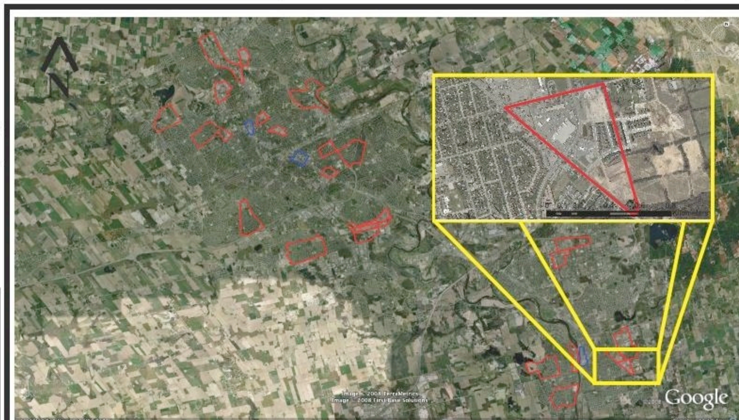
SOURCE: RMOW, 2006

STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 29.2 ha
- EMPLOYMENT FOOTPRINT - 10.5 ha
- PARKING FOOTPRINT - 5.9 ha
- OTHER FOOTPRINT - 12.8 ha
- PARKING SPACES - 1333

REGIONAL OVERVIEW MAP



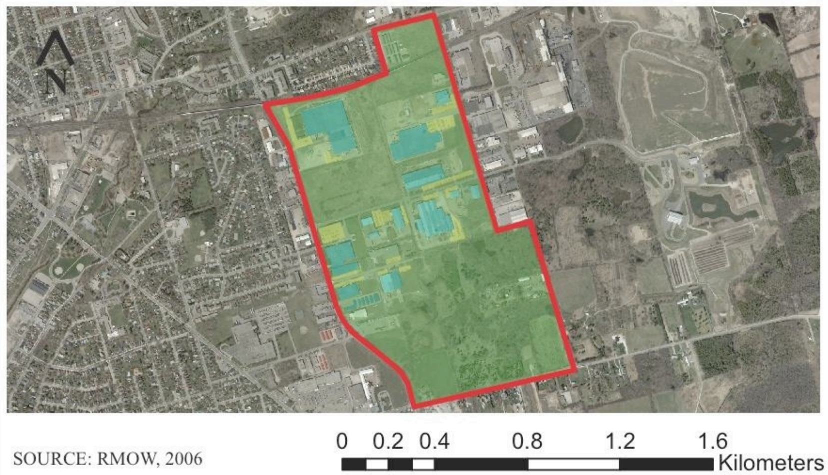
SOURCE: GOOGLE MAPS, 2008

Scale - 1cm : 1.2km

LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE

TAZ 443
COMMON NAME: N/A

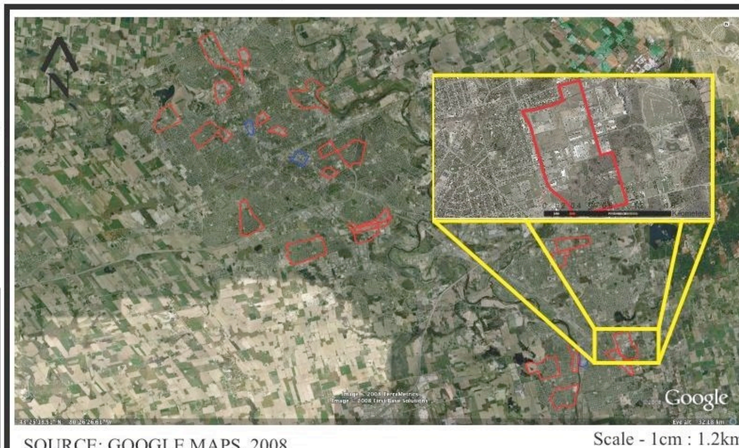


STUDY SITE DELINEATION MAP

LEGEND

- TAZ STUDY SITE - 117.0 ha
- EMPLOYMENT FOOTPRINT - 51.4 ha
- PARKING FOOTPRINT - 4.4 ha
- OTHER FOOTPRINT - 61.1 ha
- PARKING SPACES - 1193

REGIONAL OVERVIEW MAP



LEGEND

- SUBURBAN STUDY SITE
- CBD STUDY SITE