Using a GIS approach to identify GO Transit route alternatives to service between the GTHA and Niagara region, and measuring their return-on-investment.

FINAL REPORT

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LJ GEOMATICS

EXECUTIVE SUMMARY

The Niagara Region and the Greater Toronto Hamilton Area (GTHA) has been experiencing a steady growth in population over the last decade. The rise in population can also be attributed to the rising cost of living within the GTA, causing more people to take up residence within the City of Hamilton and the Niagara Region. As a result, traffic congestion at various points between the two regions have significantly increased and have become a source of concern for rising levels of carbon emissions and extended travel time for commuters.

Political discussions and public demand for a more reliable and regularly serviced public transit system between GTHA and Niagara has also increased. Despite the fact that there are existing public and private transit service options connecting the two regions, the service does not operate in a sufficient, convenient, or satisfactory manner due to the changing demographic landscape of the GTHA and Niagara Region. In addition to the growing number of working professionals travelling between the two regions, there are also other stakeholder groups that have been identified whom would benefit from having an inter-municipal transit system that caters to their specific needs. This group that have been identified are primarily the increasing number of students, new families, and young professionals that have relocated to the area and are frequently commuting between the GTHA and Niagara Region.

The following report outlines the research of the project. The final cost of the project is **$30,050 (CAD)** (not including the tax or consultation fee) which came under the total budgeted cost of **$32,100 (CAD)** (not including 13% tax and one time consultation fee). *LJ Geomatics* completed the project by the scheduled completion date of June 12th, 2016, and spent a total of **417.75 hours** which came 2% under the total budgeted work of **425.75 hours**.

LJ Geomatics formally recommends the introduction of a weekday GO Bus express service, that will makes stops at McMaster University, Hamilton GO Centre, Brock University, and Niagara Falls as the most cost-effective route option. Upon the final analysis, it is concluded that this is the most suitable option, and has the most potential to meet the needs of the demand for service within the GTHA and Niagara Region.

In summary, it is crucial that there are significant implications to public transportation planning between the GTHA and Niagara Region. Introducing public transit service that adequately satisfies the commuter profile of the study suited for a student who has no access to their own personal vehicle, may or may not be employed, willing to commute 15 to 30 minutes to work and makes less than $13,650 annually will have a profound affect. This requires the collaboration of policy-makers, public transit advocates, and transportation planners alike in order to prioritize this type of project. By doing so, the two regions can be linked together to capture many of the socioeconomic benefits associated with this initiative.

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GLOSSARY OF TERMS

AADT	Annual Average Daily Traffic
GIS	Geographic Information Systems
GTA	Greater Toronto Area
GTHA	Greater Toronto Hamilton Area
IDW	Inverse Distance Weighting
LAP	Lincoln Alexander M. Parkway
MCE	Multi-Criteria Evaluation
RHVP	Red Hill Valley Parkway
QEW	Queen Elizabeth Way

1.0 PROJECT OVERVIEW

1.1 Client Overview

LocalPoint Technologies & Consulting, Ltd. is a consulting company based in Coburg, Ontario, Canada that services businesses, governments, and transportation agencies. The company uses a comprehensive approach to deliver transportation, land-use, environment, export or location information data, reports, and maps to its clients, who can in turn use this data to derive critical decisions and recommendations. Its Founder and Principal Analyst, Richard D. Quodomine, is a geographic and transportation data analyst who holds a Bachelor's and Master's in Geography with a concentration in International Business and World Trade from the State University of New York, Buffalo. He has published several articles on transportation, data analysis and demographics and is currently a member of the Canadian Association of Geographers, American Association of Geographers, and the Royal Canadian Geographic Society.

1.2 Project Team Overview

The project team consists of three primary members. Michael Wallace, who serves as the project advisor for this research, has over 30 years of experience at Bell Canada in IT operations support, business intelligence, geomatics/telecom operations, and is currently a professor in the *'Geographic Information Systems – Geospatial Management'* (GIS-GM) post graduate program at Niagara College of Applied Arts and Technology. Mr. Wallace has had previous experiences in developing and implementing business processes, including feasibility, design, cost, and risk management.

Alice Lin serves as the project manager for this research, and is enrolled in the 2015-2016 cohort of the GIS-GM post-graduate program at Niagara College. She has a B.A. degree from the University of Guelph, focusing on environmental governance, GIS analysis, and land-use planning policy/education. She was Canadian Delegate at the One Young World conference in 2012 on be-half of Syngenta, and had also previously been involved with environmental non-profit organizations such as the Ontario Farmland Trust, the Oak Ridges Moraine Conservation Land Trust, and the North Dufferin Agricultural and Community Taskforce. Ms. Lin is an advocate for sustainable communities and businesses, and is experienced in researching land-use planning initiatives that focuses on improving policy implementation, resource management strategies, stakeholder engagement, and program delivery.

Jasmine Joy serves as the principal data analyst for this project, and is also enrolled in the 2015-2016 cohort of the GIS-GM post-graduate program at Niagara College. She has a B.Sc. degree from the University of Toronto in physics (major), mathematics (minor), and philosophy of science (minor). Ms. Joy is a recipient of the Brampton Rotary Youth Leadership Award in 2009, and has been involved with the International Summer School for Young Physicists at the Perimeter Institute of Waterloo. Her experience in working with large complex scientific and technical datasets have been an asset to the project team's ability to assess and model ridership potential and cost of operations by applying her statistical knowledge as well as analytical expertise.

1.3 Project Problem Context

The primary issue that serves as the fundamental basis for carrying out this project is that **the current public transit services between the GTHA and Niagara regions are inadequate**. Currently, there are three existing options for those who wish to travel between the GTHA and Niagara Region: VIA Rail, GO bus, and a seasonal GO train/bus service. These services are not satisfactory, and as a result, people tend to opt to drive their own vehicles, leading to increasing traffic congestion along the QEW. Table 1 outlines the range in travel time, range of costs, and the names of the stations that each of these public transit providers services.

Table 1: Existing Public Transit Service between the GTHA and the Niagara Region.

Service Provider	Travel Time	Travel Cost (in $)	Stations/Stops
VIA Rail	1.25 hours	$45 to $50	Union, Oakville, Aldershot, Grimsby, St. Catharine's, Niagara Falls
Description	Perhaps the most expensive option, and only runs one round trip per day on a weekly basis. This option is more appropriate for those who take the whole trip to New York, such as tourists and maybe some professional business trips. It is however, not efficient nor satisfactory for daily commuters.		
GO Seasonal Service	2 hours	$18 to $20	Union, Exhibition, Port Credit, Oakville, Burlington, St. Catharine's, Niagara Falls
Description	Only available during specific summer months that runs only on the weekends and holidays. It runs a maximum of 4 round trips during days in which they are operating. This service is an extension of the GO Lakeshore West line. Although this is a viable and cost efficient option, it is not sufficient as it only operates seasonally on weekends and holidays.		
GO Bus	1.5 to 2.5 hours	$13 to $18	Burlington, Stoney Creek, Grimsby, St. Catharine's, Niagara Falls
Description	Runs about 15 to 18 round trips regularly, and offers peak service hours. However, it takes three times as long to travel a certain distance, and thus riders would often opt to drive their own vehicles, causing an increase in traffic congestion. In 2006, the annual average daily traffic between the GTHA and Niagara Region was 589,200 and is expected to rise to 791,600 in 2031 if no efforts are made to alleviate congestion (Ontario Ministry of Transportation, 2013).		

In summary, there is significant potential for GO Transit to serve and meet the needs of frequent travelers/users/commuters to the region (i.e. working professionals and students) that finds it difficult to travel between GTHA and the Niagara Region without a vehicle. Furthermore, there is also a great economic opportunity for GO Transit to capitalize on the tourism industry in the Niagara Region (a key economic sector), especially since it is able to provide a more cost-effective alternative to VIA rail for frequent riders (particularly through reduced rates with Presto).

1.4 Project Business Goal

The goal of this project is to identify ridership potential between the GTHA and Niagara region. By achieving this, appropriate route alternatives to service the demand within the study area can then be developed and evaluated in terms of its costs and possible revenues. Conducting this cost-benefit analysis modelled after the ridership potential that has been identified within the study area, provides an inclusive and realistic analysis which aids in determining the most cost-effective route alternative. The municipalities and transit agency can then utilize the findings in this project as a preliminary basis to further their consideration to increase transit service levels that are better suited for the commuter profile within GTHA and Niagara. Doing so will also alleviate traffic congestion on the QEW, and ultimately leading to a reduction in carbon emissions, thereby creating a more healthy and sustainable environment.

1.5 Project Objectives

The research approach of this project are divided into six main objectives (as outlined below in Table 2).

Table 2: List of Project Objectives

Objective	Description
#1	To understand public transit expansion costs and developing an argument that supports the project in a political defensive manner.
#2	To identify, investigate and define ridership potential and other relevant factors, in order to assess no-build route options, level of service alternatives, and ROI between the GTHA and Niagara region.
#3	To develop a GIS-based model that effectively analyzes and evaluates ridership potential and other relevant factors identified in objective #2.
#4	To apply the GIS-based model developed in objective #2 to evaluate ridership potential and other relevant factors in order to assess route options and level of service alternatives between the GTHA and Niagara region.
#5	To conduct analysis on return-on-investment on the different GO Transit route options and level of services based on the results gathered in objective #4.
#6	To evaluate the strengths and weaknesses of the model/methodologies applied in this project.

First and foremost, is to understand public transit expansion costs and the mechanisms behind it. The second and third objectives of this project are to identify and assess factors affecting ridership potential, then develop and apply a GIS-based model to assess those factors within the GTHA and Niagara Region. Next, based on the analysis, is to develop route options that are appropriate to the ridership potential within the study area. This is followed by a cost-benefit analysis to narrow down and determine the most cost-effective route alternative. Finally, the last objective is to evaluate the strengths and weaknesses of the model/framework that was applied in this research.

1.5.1 Objective 1

Understanding public transit expansion costs and the mechanisms behind an expansion/increase in level of service for public transit system is crucial in determining the scope of *the* research. This was done by conducting preliminary research and a review of academic literature, government documents, transportation operations reports and other relevant news articles related to the subject.

1.5.2 Objective 2

The second objective consists of identifying ridership potential and other relevant factors in order to assess route options, level of service alternatives, and return-on-investment within the study area. This consisted of reviewing additional academic literatures, government documents, transportation operations reports, and any other relevant data that supports this objective.

1.5.3 Objective 3

The third objective was to identify appropriate GIS-based model(s). This is done by conducting literature review of similar research projects/efforts to narrow down what model(s) are appropriate. The analysis procedures that had been reviewed were: network analyst, route analysis, EMME, and a corridor analysis.

1.5.4 Objective 4

The fourth objective is to apply the appropriate GIS-based model(s). Maps of the area were made after appropriate model(s) have been applied to each of the factors. The data preparation and data processing phases is depicted using a diagram resembling the model-builder application in ArcGIS.

1.5.5 Objective 5

The fifth objective is to identify the most cost-effective route option. This was done by conducting an analysis of different route options and different levels of services. A cost-benefit-analysis will also be conducted to determine return-on-investment values for the different route options. The final deliverable as a result of this objective are several maps that were created to map and visually present these areas within the study area.

1.5.6 Objective 6

The final objective was to evaluate and assess the strengths and weaknesses of the methodology and model that has been applied in *the* research. It is important to highlight both the advantages and challenges associated to further support the reasoning behind a rail expansion project. Additionally, reflecting on the challenges and shortfalls are also essential in identifying some of the opportunities that are available to address these problems.

1.5 Project Study Area

The project's study area is located between the Greater Toronto-Hamilton Area (GTHA) and the Niagara Region as shown in Figure 1 below and in Figure 2 on the next page. The map depicts the location of the QEW, stemming from the skyway bridge in Hamilton, extending all the way down south towards Fort Erie then into the United States. The QEW is the main route that is used by commuters travelling between the Niagara Region and the GTHA. Running parallel to the QEW, is the rail line (owned by CN Pacific Railway), in which GO Transit utilizes to operate the current Niagara seasonal train. The Niagara seasonal train is an annex of the GO Lakeshore West line, where this line is extended for a specific period of time in the summer months and during specific holidays.

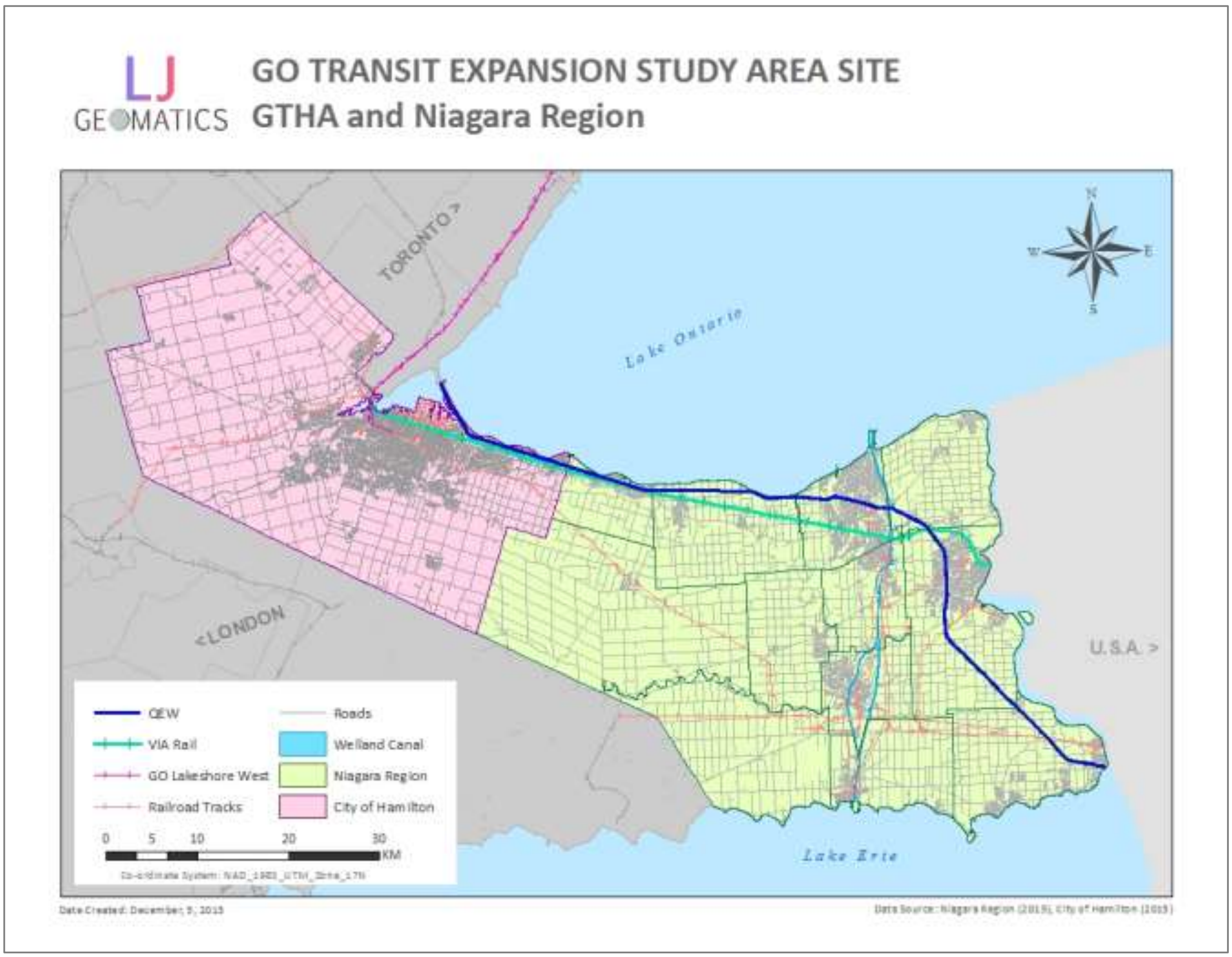

Figure 1: Project Study Area

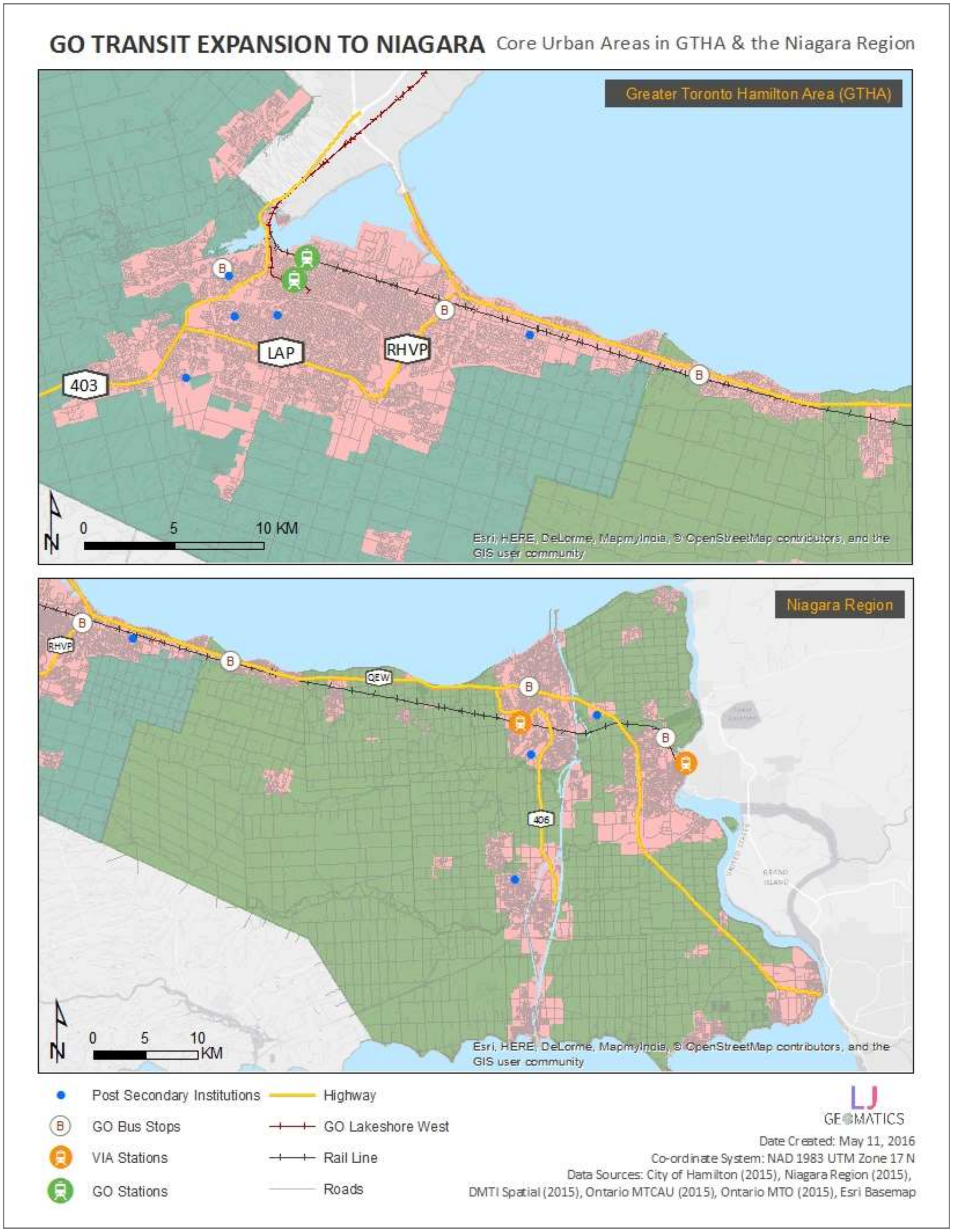

Figure 2: Project Study Area Depicting Urban Core Areas and Points of Interests.

1.6 Project Assumptions

Prior to conducting the project analysis, *LJ Geomatics* develop a list of important project assumptions. These assumptions were made as they were outside the scope of the project and beyond the capacity of the project team. The assumptions made are accepted as true, and assisted in the development of the project's overall methodological approach. Table 3 details the list of project assumptions that *LJ Geomatics* have made.

Table 3: List of Project Assumptions.

Assumptions	Item Description
1	No new railway tracks will be built.
2	Go Transit will be utilizing/leasing times on existing track infrastructure owned by CN Pacific Railway.
3	Existing tracks have been maintained and that no additional costs are associated with major repairs.
4	Freight trains are not a factor in determining level of service.
5	Service will not interfere with the schedule of the St. Lawrence Seaway at the Welland Canal.
6	Environmental Assessments have been completed and all associated costs are covered.
7	Published annual/financial reports that are publically available are accurate in its statistical models.
8	Project funding for expansion/extension has been approved by the Government of Ontario.

Establishing research assumptions are necessary to ensure the success of the project. *LJ Geomatics* understood that these assumption have a significant impact on the project, and have established them in agreement with the project advisor and client during the proposal period.

1.7 Project Deliverables

There are a total of 6 primary deliverables that had been established for this project. They are outlined in Table 4 below. The deliverables will serve as supporting visualization of results from the analysis of this research project, which are essential in aiding the communication component of this project.

Table 4: List of Project Deliverables

Deliverable	Item Description
1	Finalized maps of factors and variables influencing transit expansion options between the GTHA and Niagara Region.
2	ArcMap Maps depicting the different levels of ridership potential (past 5 years and projected 5 years ahead) and where they are located between the GTHA and Niagara Region.
3	Finalized project methodology accompanied with a depiction using ModelBuilder.
4	Summary of at least 3 different route options and different levels of services based on analysis.
5	Finalized map of the most cost-effect route option between the GTHA and Niagara Region.
6	Project final presentation/report summarizing the overall project, findings, results, costs, recommendations, and an evaluation of the assessment.

1.8 Research Data & Equipment Utilized

The following tables outline the data, hardware and software requirements for the project that has currently been identified as a necessity in order to complete this project.

Table 5: Data Requirements

Data Description	Format	Provided by:
Commuter Data	Any	Ontario Ministry of Transportation Metrolinx, Niagara Region, City of Hamilton
Student Enrollment Numbers Differentiating Permanent Address of Origin	Raw Excel or CSV	Niagara College, Brock University
National Household Survey Census	Any	Statistics Canada
Traffic Flow Data	CSV	Ontario Ministry of Transportation, City of Hamilton, Niagara Region

Table 6: Hardware Requirements

Hardware	Required For	Provided by:
Laptop	PASCO, Adobe CS6 compatible	Personal
Computers	ArcGIS, AutoCAD, Python compatible	Niagara College

Table 7: Software Requirements

Software	Required For	Provided by:
PASCO	Plotting, regression analysis and extrapolation	Niagara College
ArcGIS 10.3	Mapping and spatial analysis	Niagara College
Python	Plotting and curve fitting, and for writing a script to collect traffic data	Niagara College
R x64 3.2.1	To conduct statistical analysis	Open Source
Microsoft Office Suite	Presentation (PowerPoint), estimating trend lines (Excel) preparation of Gantt Charts (Project), database management (Access) and report preparation (Word)	Niagara College
Adobe Creative Suite	To create and refine final deliverables i.e. graphics/posters (Illustrator & Photoshop) and formal documents (InDesign).	Personal

2.0 LITERATURE REVIEW

The literature review conducted *LJ Geomatics* included researching travel-demand/transportation management approaches, identifying factors affecting inter-municipal ridership, researching GIS based methods of conducting travel-demand analysis, current ridership totals and traffic conditions, as well as a review of public discussion with respect to the Niagara GO Transit expansion.

2.1 Transportation Demand Management for Canadian Communities

To help provide a fundamental understanding of the research project, *LJ Geomatics* followed the Transportation Demand Management (TDM) for Canadian Communities prepared by Transport Canada (2011). The model in which they recommended is depicted in Figure 3 on the right.

Figure 3: TDM for Canadian Communities Model (Transport Canada, 2011)

First is to gather information to allow a solid understanding of the existing landscape. This includes a scan of municipal activities, stakeholder interests, and market research, which will in turn help to establish the groundwork for identifying appropriate recommendations. The second component of the model is to establish an overall direction for the project, which will help to identify what the service will do for the community, why it is important, and who will benefit from it. *LJ Geomatics* followed this approach to build a vision around community values and needs that will be identified in the analysis component of this project. This will then help to identify appropriate route options for the study area, which is the last two component of this model. Steps three and four will consist of evaluating the feasibility of the options identified, as well as a cost-benefit analysis, and a final recommendation.

Following the TDM for Canadian Communities established by Transport Canada (2011), *LJ Geomatics* will then have a better understanding of how to utilize best practices with regards to evaluating travel-demand of inter-municipal transit systems. From this, the overall project analysis has been organized into three major components: Assessing the current landscape of the GTHA and Niagara Region; assessing the factors affecting ridership; assessing ridership potential. These analyses will help to set the direction and help determine appropriate route options for the study area which will then be evaluated with regards to its costs versus benefits. Finally, this will support the process of determining the most cost-effective route for the study area, whereby suitable actions and comprehensive recommendations can be then made.

2.1 Factors Affecting Ridership

Prior to carrying out the TDM model *LJ Geomatics* has adopted from Transport Canada (2011), a literature review of factors affecting ridership were conducted. This is essential in building the project team's understanding of where and how to identify travel-demand (i.e. who is demanding service, what services are being demanded, and how they choose to travel).

Two major categories of factors were identified: Direct/internal factors and indirect/external factors (Armbruster (2010), Kohn (2000), Miller (2001), Taylor et al. (2003)). Direct factors are those in which transit agencies have control over, where indirect factors are those that they do not have control over. Table 8 below outlines a list of crucial factors that have been identified.

Table 8: Direct and Indirect Factors Affecting Ridership

Direct (Internal) Factors	Indirect (External) Factors
Transit Fares	Increasing Population Density
Increasing Levels of Service	Medium City Size/Travel Time
Increasing Reliability of Services	Rising Costs of Car Ownership
Increasing Convenience & Ease of Access	Increasing Public Transit Use
Variability of Transit Modes (Bike Racks)	Increasing Employment
Targeted Marketing (Presto, Loyalty Programs)	Public Policies (Land Use Planning, Area Specific Car Restrictions, Parking Fees)
Building Better Facilities/Modern Technology	

Due to the data intensive and complex process of analyzing transit ridership, *LJ Geomatics* have chosen to examine strategies and factors that has a positive and encouraging effect on ridership within the study area. By evaluating and assessing the external factors affecting ridership, *LJ Geomatics* can obtain a better understanding of how specific changes in the surrounding landscapes affects transit use within the study area. Furthermore, this information can then be indexed and provided to the transit agency, to serve as supporting documentation which can assist them in catering the direct factors they have control over to influence ridership behavior.

2.1.1 Relationships of Indirect Factors and Increasing Transit Use

A preliminary assessment of transit demand was conducted by examining the relationship between transit commuter numbers and population density as it is a major indicator of transit demand (CUTA, 2010). Commuter data from the Transportation Tomorrow Survey Area (DataManagement Group, 2011) were compared to the optimal scenario for transit supply (CUTA, 2010). It was found that the average annual volume of traffic flow along the QEW between the Hamilton GO Center and Niagara Falls within the project study area was 589,000 in 2006, and predicted to be 791,600 in 2031 (Burnside & Associates, 2011; Ontario Ministry of Transportation, 2013). Since rising population density directly correlates to increasing economic activity and employment opportunities, it has been established as prime indicator of ridership potential/demand. Furthermore, this will also be weighed against other factors accordingly as it is important to note that increasing population density is not a single direct cause of increasing ridership.

It can also be understood that the introduction of GO transit between GTHA and the Niagara Region will be inevitable due to the rising demand for affordable and reliable means of transportation (Burnside & Associates, 2011; Niagara GO, 2015; Ontario Ministry of Transportation, 2013). Therefore the relationship between the rising cost of car ownership versus transit use are correlated, and thereby establishing an understanding that the decrease in car ownership is positively correlated to increasing ridership. Next, employment and income can be weighed against evaluating increasing transit use. Since unemployed populations do not have the ability to purchase their own vehicles, it is likely that they would opt to take public transit (Taylor et al., 2003). Furthermore, employment and income can be directly related to one another, and thus those who are employed are likely to be able to purchase their own vehicle (Kain et al., 1999; Taylor et al., 2003). However, depending on the population's employment and income, it is not a likely indicator of ridership. Though it is important to note surrounding points of interest regarding employment density to identify other factors such as the profile of the demographic, in order to gain a better understanding of their mode of transportation choices (Kain et al., 1999; Kohn, 2000; Taylor et al., 2003).

Developing an understanding the landscape of how indirect factors such as changes in population density, will support in the modeling of future trends to indicate how to cater and provide better transit services between the GTHA and Niagara Region. Table 9 below summarizes each of the indirect factors evaluated, and its relationship to increasing public transit use.

Table 9: Summary of Indirect Factors and its Effects on Ridership

Factor	Description of Factors and its Relationship to Ridership Potential
Population	Increasing population density is positively correlated with ridership potential.
Vehicle Ownership	Decreasing vehicle ownership is positively correlated with ridership potential.
Transit Use	Increasing transit use is positively correlated with ridership potential.
Income	Low income levels are positively correlated with ridership potential.
Employment	Increasing employment density is positively correlated with ridership potential.

2.1.2 Other Factors Affecting Transit Use and Commuter Behavior

Commuting time, public policies, and the concept of "The Last Mile" also have an effect on how an individual chooses their mode of transportation (Kain et al, 1999). These factors correlates to the convenience factor of the individual (Kain et al, 1999; Taylor et al., 2003). The more difficult or costly the mode of travel, the less likely that the individual will select that choice. For example, areas where parking fees are enforced, individuals are more likely to take the bus versus driving. On the opposite spectrum, if an individual has to walk 20 minutes to a bus stop and commute 60 minutes by bus to work and take a similar amount of time to get back home, they would likely prefer to drive to work if that takes 40 minutes (Liu et al., 2012).

2.2 Assessing the Current Landscape

Previous efforts in travel-demand and assessing demographics utilized census tracts to provide a more detailed analysis (Baum-Snow et al., 2000; Hsiao, 1997; Taylor et al., 2003). Census tracts were used as they limited to a population between 2,500 and 8,000 persons. It provides a more detailed analysis that narrows down where these factors and travel-demand are sourced from, and is a relatively small and stable geographic area as determined previously in the literature review. In total, there are 149 number of census tracts in the GTHA region, and 94 number of census tracts in the Niagara Region.

2.2.1 Current Discussions of Ridership Demand

According to the 2007 report conducted by Metrolinx (Burnside & Associates, 2007), the population of Niagara is expected to increase by 11.5%, along with an increase in employment by 8.5% in the next 10 to 20 years. Daily travel demand within the Niagara-Hamilton area is forecasted to increase by 15% to 20% between the years 2011 to 2031. This statistic supports the fact that there is a definite need for more reliable and regularly serviced public transit system between the GTHA and the Niagara Region.

Demand for reliable and regularly serviced public transit system along with the statistics presented by Metrolinx (2015) positively correlates with population growth (CUTA, 2010). Furthermore, the Canadian Urban Transportation Association also reported that cities with population sizes less than 2 million, saw an increase in ridership of 7%, where smaller cities such as Niagara Falls and Niagara-on-the-Lake saw the greatest increase in ridership of 67% and 75% (2014). It is also important to note that the correlation between an increasing population and increasing demand for regular public transit service also correlates with increase in traffic congestion (Ontario Ministry of Transportation, 2013).

CUTO further reported that smaller cities such as Niagara Falls and Niagara-on-the-Lake saw the greatest increase in ridership of 67% and 75% (2014) respectively. These statistics are relevant to *the* research primarily because they help *LJ Geomatics* identify where ridership comes from and can therefore help determine the necessity and possible locations for new stations. Since Hamilton is a rapidly growing, medium to large sized Canadian city, increasing the level of rail service, or a combination of bus and train service is necessary to relieve traffic congestion and to facilitate work-travel time for those travelling from the Niagara Region. This section will be further expanded in the literature review.

As for the current commuting conditions, the Transportation Tomorrow Survey carried out by DataManagement Group from the Department of Civil Engineering at the University of Toronto (2011) found that there were on average 29,100 trips made from the Niagara Region to Hamilton area in 2011, and 29,200 trips made from Hamilton to Niagara within a 24 hour period. Furthermore, according to Statistics Canada's National Household Survey (2011), 2.9% of Niagara Region's commuting population utilizes public transit as a means of getting to work and 90.3% either drive or carpool. The remaining 6.8% either walk or bike. For the Hamilton Region, 9.3% of the commuting population utilizes public transit as a means of getting to work and 84.4% either drive or carpool. The remaining 6.3% either walk or bike.

2.3.2 Current Traffic Conditions and Forecasts

A study conducted by the Ontario Ministry of Transportation regarding the GTA West Corridor Planning and Environmental Assessment (2009) revealed that traffic congestion along the QEW will increase significantly between 2006 and 2031 if no immediate measures are taken to alleviate the congestion. Figure 4 and Figure 5 depicts where the expected weekday congestion spots will be facing major time delays within the GTHA.

Figure 4: Weekday Traffic 2006 (Ontario Ministry of Transportation, 2013)

Figure 5: Projected Weekday Traffic 2031 (Ontario Ministry of Transportation, 2013)

Figure 4 and Figure 5 on the previous page appropriately visualizes the level of traffic congestion along QEW within this project's study area in 2006 and 2031. The expected weekday congestion spots that would face major time delays within the GTHA are indicated in red. Upon comparing the two figures, it is clear that if no immediate measures are taken to combat the issue of traffic congestion, most or all of the QEW and surrounding expressways will face major congestion issues.

2.3 Assessing Benefits of GO Transit

Quantifying benefits is an important aspect of this project's literature review, as it serves as a supporting factor in justifying how and why the transit expansion is profitable/feasible and if increase in levels of services is necessary. There are two primary factors that were explored: benefits associated with a reduction in traffic congestion, and benefits associated with a reduction in carbon emissions.

Preliminary research showed that introducing regular rail service between the GTHA and the Niagara Region will alleviate traffic congestion, especially during rush hour, as it would remove approximately 50 cars off the road (Metrolinx, 2014). Likewise, introducing a 10-car GO train would remove 1,400 cars while; introducing a 12-car GO train would replace 1,670 cars (Metrolinx, 2014).

Additional literature review revealed that travel time and fuel costs are also relevant factors in assessing benefits associated with a reduction in traffic congestion (APTA, 2007). Introducing public transit systems into regions of varying population sizes, have the potential to improve mobility and save residents not only millions of hours in travel time, but also millions of dollars in fuel costs. Table 10 below shows the impact of public transportation depending on the size of the population.

Table 10: Impact of Public Transportation on Travel Time and Fuel Costs of Varying Population Sizes (TTI, 2005)

Population Size (in millions)		Travel Time Saved (hours)	Fuel Costs Saved ($)
Very Large	3 or more	52 million	$6 billion
Large	1 to 3	6 million	$566 million
Medium	0.5 to 1	1.3 million	$73 million
Small	0.5 or less	189,000	$3.5 million

In addition to reducing traffic congestion, it has been estimated that carbon emissions for commuter rail ranges between 108 to 206 grams-per-mile and a vehicle ranges between 184 to 499 grams-per-mile (Bradley & Associates, 2007). This information helps to determine, quantify and compare annual carbon emissions produced within the project's study area. It can then be determined that the annual average daily traffic between the GTHA and Niagara Region would produce anywhere from 11 to 14 billion grams of carbon emission for cars, and 5 to 7 billion grams of carbon emission for rail (Bradley & Associates, 2007; Ontario Ministry of Transportation, 2013).

Furthermore, it can be understood that benefits associated with a reduction in carbon emission will promote environmental sustainability. Likewise, it will also improve air quality which ultimately promotes health benefits. This causes a chain of benefits that does not necessarily need to be quantified, but should be noted. These additional benefits are outlined in Table 11 below.

Table 11: Outline of Inter-Municipal Transit Benefits

Benefits	Detail of Benefits
Reduced Traffic Congestion	The expansion will provides accessible transit options to commuters that will allow for fewer drivers on the road, thereby reducing congestion and potential vehicular collisions during the winter months;
Reducing Carbon Emissions	A long-term benefit of expanding GO Transit between the GTHA and Niagara region include providing an alternative way to commute and with fewer cars on the road, it will reduce carbon emissions thus cleaner air and creating a more sustainable, healthy environment;
Increasing Economic Activity	Additionally, affordable and accessible transportation also provides a means to expand tourism in the Niagara Region thus promoting GDP growth, allowing for regional expansion;
Increasing Employment Opportunities	Municipalities within the Niagara region can expect a surge in employment and population as a result of the GO Transit expansion increasing availability of convenient public transportation services;
'Investment Ready'	Expanding the GO train service will also allow developers to incorporate better land-use planning practices to build well planned subdivisions near GO Stations that would in turn reduce urban sprawl, manage growth and make the region more 'investment ready' (creating a more welcoming environment for new businesses in the regions);
Connecting the GTHA and the Niagara Region	Expanding the GO transit service between the GTHA and the Niagara region will connect Niagara College directly to other educational institutions such as University of Toronto, Ryerson, Sheridan, McMaster and Ontario Institute of Technology;
Other Possible Benefits	Expanding the Go train to service and connect the GTHA and the Niagara region will provide greater incentive to the smaller municipalities within these regions to introduce and implement already existing 'Presto' system within their municipal transit systems, which is compatible with GO services.

2.4 Review of TDM Cost-Benefit Analysis Approaches

Upon research, *LJ Geomatics* was not able to determine a distinguishable source of literature that was able to conduct cost-benefit analysis relevant to this project. This is primarily due to the confidentiality of the detailed financial statements from Metrolinx (as concluded after a meeting with a Metrolinx GIS analyst). However, information regarding VIA rail and annual reports from Metrolinx that were publically available were used in place of determining costs.

Furthermore, upon reviewing transportation operations reports, financial statements proved to be detailed enough for the project team to compose and conduct a preliminary cost-benefit assessment to determine feasibility of the expansion project. The reports that were utilized to conduct the appropriate cost-benefit analysis are detailed in Table 12 below.

Table 12: Summary of Operation Reports Reviewed and their Use.

Literature/Report Titles	Description of Use
VIA Rail Annual Reports	Used to determine rail operations costs. The VIA rail costs were used to later subtract from the total bus/rail operation costs from the Metrolinx reports.
Metrolinx Annual Reports	Used to determine rail operation costs, as well as maintenance fees, and facility costs. This information was used to cross-reference and compare between the maintenance fees, fuel costs, and facility costs of VIA Rail reports.
GO Transit Annual Reports	Used to determine ridership numbers and forecast differences between rail and bus. This information was also cross-referenced with VIA Rail reports to compare fare fees and operation fees.
GO Niagara Technical Report	Used as reference to determine proposed costs and forecasts.
GO Niagara EA Expansion	This report was prepared by Burnside and Associates. This report detailed information regarding ridership, revenue, and costs anticipated to operate a regular GO Train service between Hamilton and Niagara Falls.

From this assessment, *LJ Geomatics* found a constant distinction between operation costs and revenue. Thus the project team was able to determine the percentage of revenue target to reach in order to justify operation cost. Further research revealed that revenue from ridership made up of approximately 40% of the total revenue, and 15% of the total expenditure was made up of operations costs. Thus by converting between the two percentages, a revenue target could be established to help provide a preliminary justification of return-on-investment (this conclusion could be made since the final costs were provided and that the total costs versus total revenues were standardized). Finally, by utilizing other reports from other sources identified in Table 12, the numbers could be cross-referenced to assess the validity of this finding, increase the integrity of the analysis, and further support *LJ Geomatics*' assessment.

2.5 Review of GIS-Based Approaches

The last component of the literature review for this project consisted of researching the best GIS-based approaches to conduct the TDM analysis. Some previously identified applications are outlined in Table 13.

Table 13: Researching GIS-based Approaches and Applications to Utilize in the Analysis

Application	Description of Use	Relevance
Network Analyst	Determining accessibility of transit systems	Yes
Route Analysis	Analyze shortest route	No
Inverse Weighted Distance	Predicting traffic surfaces	Yes
MCE	Determining the area best suited to the commuter	Yes

EMME was also determined early on in the project to be of a valuable software to utilize. However, due to licensing agreements and limited access to functionalities, *LJ Geomatics* chose to utilize network analyst to determine service areas of existing stations.

Literature review determined that network analyst can be used for a variety of application beyond transportation planning. It can indeed be used to assess social factors and other commuting behaviors based on time and convenience (Larsen & Gliiiland, 2008; Miller & Wu, 2000; Nicholls, 2001). However, the best use of this tool was for determining service areas as a preliminary means of providing a general framework to evaluate and predict travel-demand of public transport systems (Liu & Zhu, 2000; 2004). Furthermore, it was important to differentiate between the ability for an individual to arrive at a particular facility, and behavior (Makri & Folkesson, 1999) which *LJ Geomatics* have taken into the consideration to determine commuter choice. From this analysis, it was determined that there was no need to conduct a route-distance analysis, a route analysis, or a cost-path distance analysis. Finally, *LJ Geomatics* chose to only use network analysis to determine whether or not the accessibility of current stations fell within the urban core areas of the study regions.

Furthermore, a geo-statistical analysis of the AADT volume was determined to be necessary to cross-reference the Ontario Ministry of Transportation's claim in their GTA West Corridor traffic congestion prediction. This was done to assess and visualize traffic congestion over the period of 1988 to 2010, which was the data that was made publically available. Hot-spots could then be mapped and depicted using this method.

Finally, a multi-criteria evaluation was not necessary as it was beyond the scope of this research to determine suitable sites for stations. However, a framework based on commuter behavior and commuter profile were developed instead to help transit agencies decide what services to provide to the demand of the region as indicated as part of the TDM for Canadian Cities (Transport Canada, 2000).

3.0 METHODOLOGY

LJ Geomatics has organized the project research into three main phases detailed in Table 14 below.

Table 14: Description of the Core Project Analysis Phases.

Phase	Description
Assessing the Current Landscape	Evaluating current traffic conditions and evaluating the accessibility of the current existing transit services.
Assessing Factors Affecting Ridership	Evaluating factors that have an encouraging effect on ridership and developing a framework to identify the ideal ridership/commuter profile based on those factors for the study area.
Assessing Ridership Potential	Model and forecast ridership potential in terms of numbers for the overall GO system, and then narrowing it down to the GTHA and Niagara Region.

This process was modelled after the TDM guide for Canadian Communities prepared by Transport Canada (2011) previously depicted in Figure 3. Following this portion of the project analysis, *LJ Geomatics* modelled and forecasted ridership of the entire GO Transit systems based on statistics published within their annual reports, financial reports, and quick facts. These statistics are also cross-referenced with annual reports, operations reports, and financial reports published by VIA Rail, to differentiate costs for bus and rail.

The full depiction of the analysis is shown below in Figure 6, detailing the input and output data, the tools used, and the output dataset. The following sections of this report details the changes and QA/QC data processing that was conducted.

NOTE: It is important to emphasize that the spatial analysis portion of this project was very data intensive. The diagram created resembles one from ModelBuilder, an application within ArcGIS. The intention is to help the public visualize what data was assessed, and where sources of error may be derived from, and in which areas QA/QC of datasets were conducted. *LJ Geomatics* would be glad to provide this information, as everything derived was publically available.

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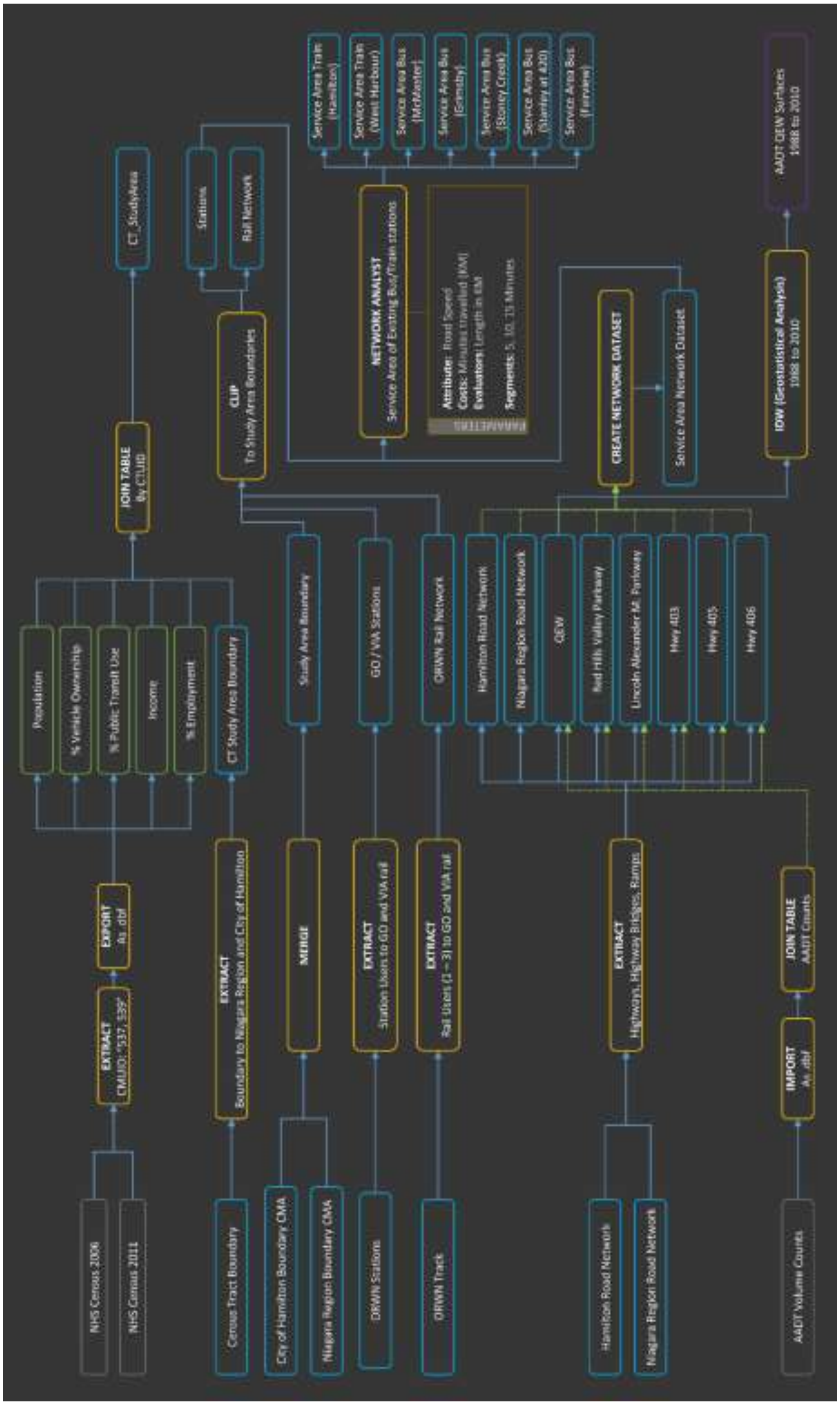

Figure 6: Full Diagram of the Project Methodology. See Appendix for Detailed and Larger View.

3.1 Assessing the Current Landscape

First and foremost, is to understand public transit expansion costs and the mechanisms behind it. The second and third objectives of this project are to identify and assess factors affecting ridership potential, then develop and apply a GIS-based model to assess those factors within the GTHA and Niagara Region. Next, based on the analysis, is to develop route options that are appropriate to the ridership potential within the study area. This is followed by a cost-benefit analysis to narrow down and determine the most cost-effective route alternative. Finally, the last objective is to evaluate the strengths and weaknesses of the model/framework that was applied in this research.

3.1.1 Traffic Analysis

AADT volume for the QEW were gathered from the Ministry of Transportation, and IDW surfaces were created for all of the data sets. Figure 7 depicts the process in which data were processed and inputted to conduct the geo-statistical analysis for visualization.

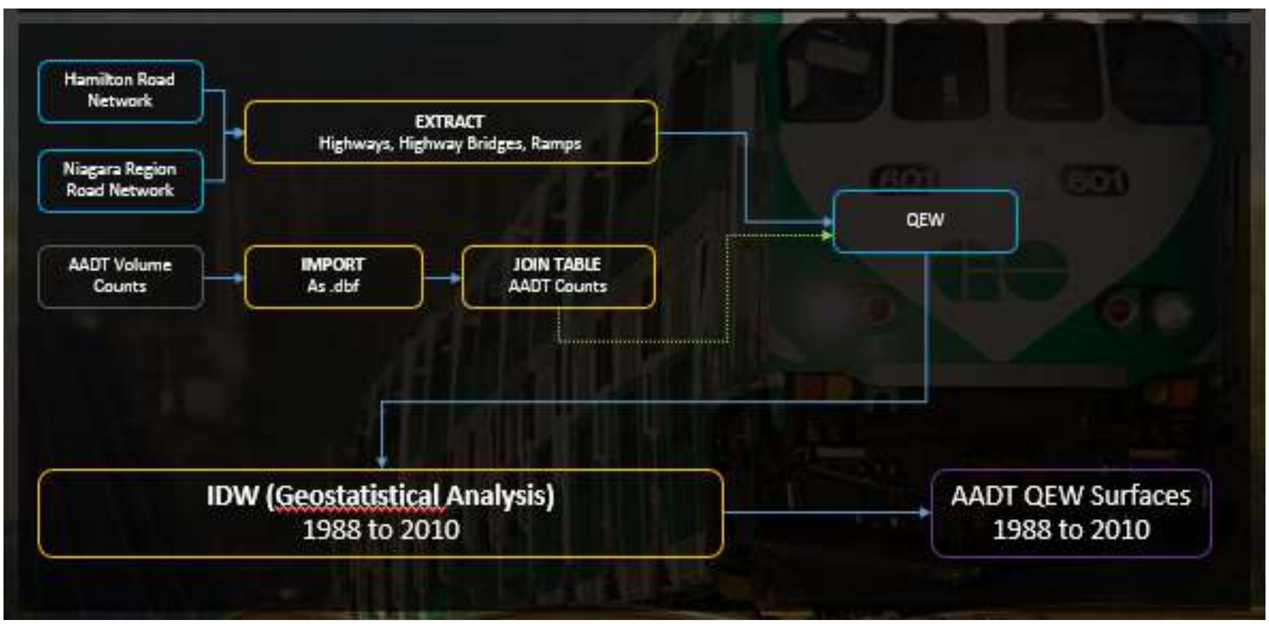

Figure 7: Model of Processing the Road Network and AADT Volume Counts.

This was completed by digitizing the individual segments in which the data was found. Each segment was entered its AADT Volume for that specific year. After the data has been created, an IDW surface was created for each respective year. Using Photoshop CS6, the results were processed and clipped to the area surrounding the QEW. This helped to show and visualize how traffic volume progressed and changed since 1988 until 2010. Figure 8 below show the comparison from 1988 to 2010. Refer to appendix no. 3 for all years that IDW surface was created.

Figure 8: AADT Volume Comparison from 1988 to 2010.

Likewise, traffic congestion along the QEW was also determined. This was done by considering the 2 second rule; by which an average driver maintains a safe following distance at any speed. That is; there can only be 1 car per-lane-per-two -seconds passing through any given point. The concept encompasses both the merging and bottleneck behaviors observed in traffic; where for every car that merges adds 2 seconds to every following vehicle, and flow rate is halved when two lanes merge into one. Hence, using the AADT volumes, the following equation was obtained:

$$y = AADT * \frac{1}{24}\left[\frac{hrs}{day}\right] * \frac{60}{1}\left[\frac{min}{hr}\right] * \frac{60}{1}\left[\frac{sec}{min}\right] * \frac{1}{2x}$$

…where y is the number of cars per 2 seconds; and x is the number of lanes.

Hence, the traffic congestion within each segment of QEW (as recorded by Ministry of Transportation) was determined and graphed from 1988 to 2010. Figure 9 and Figure 10 below depicts the data that were derived for 1988, where Figure 11 and Figure 12 depicts the data that were derived in 2010.

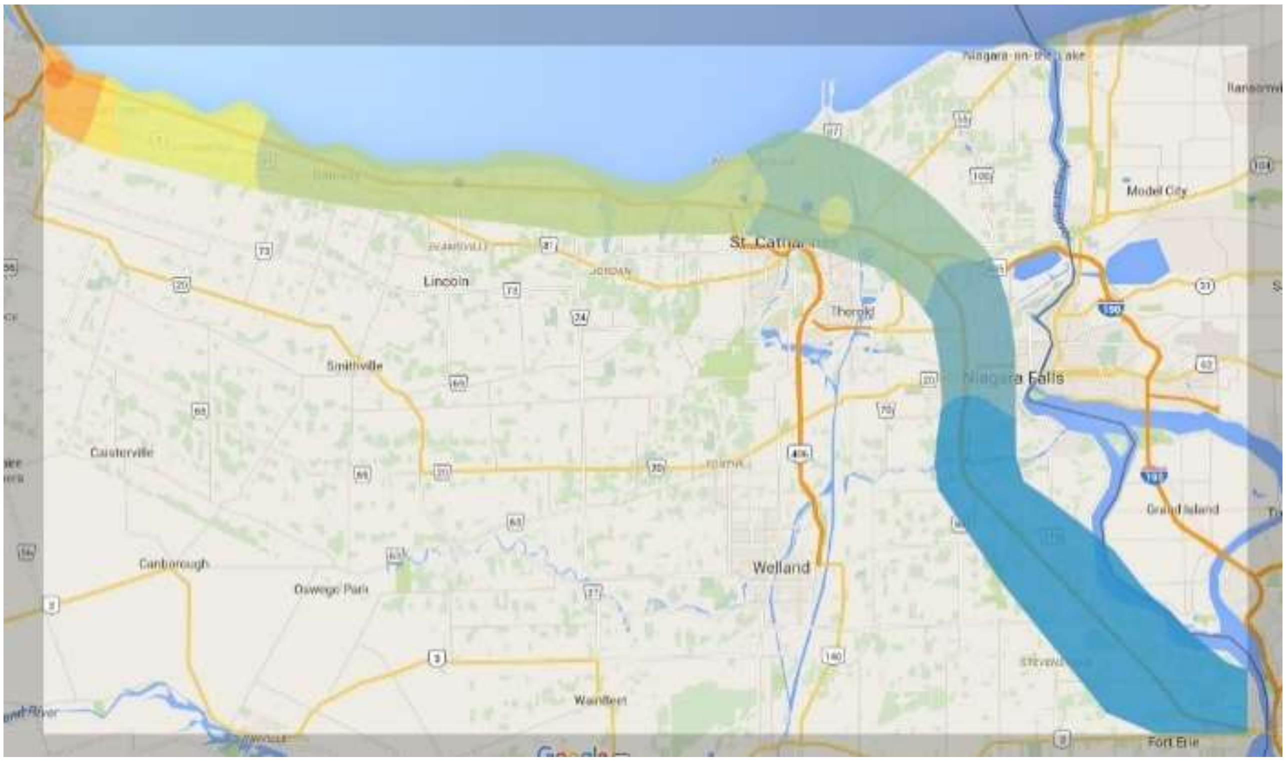

Figure 9: Visualizing Traffic Volume of the QEW from the GTHA to Niagara Region in 1988 (IDW).

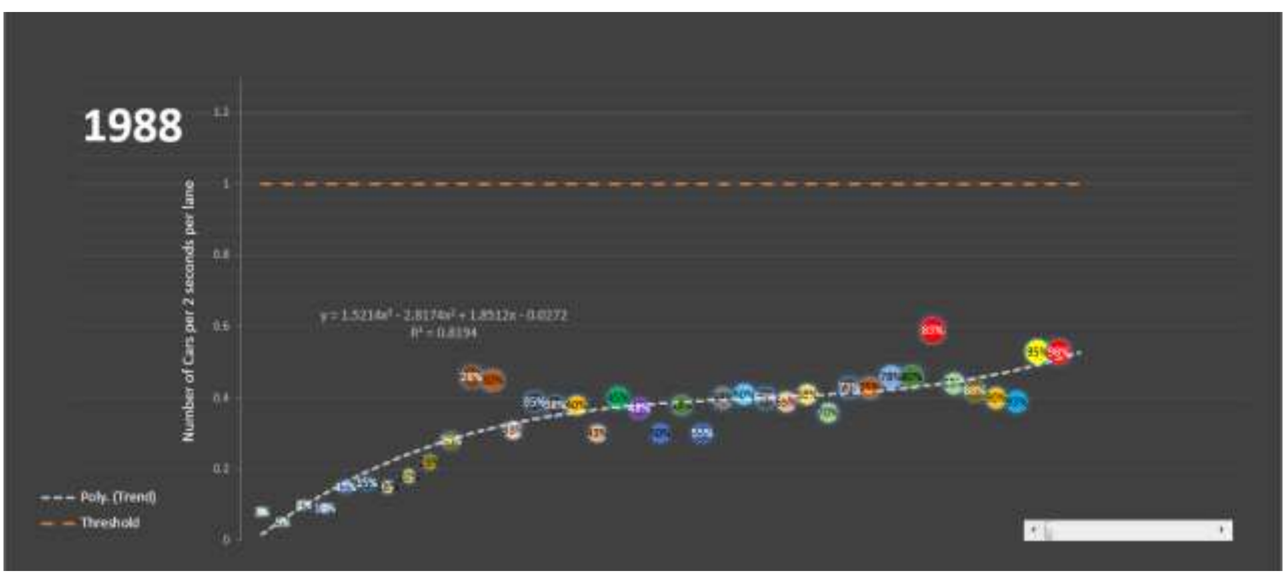

Figure 10: Visualizing Traffic Volume of the QEW from the GTHA to Niagara Region in 1988 (graphed).

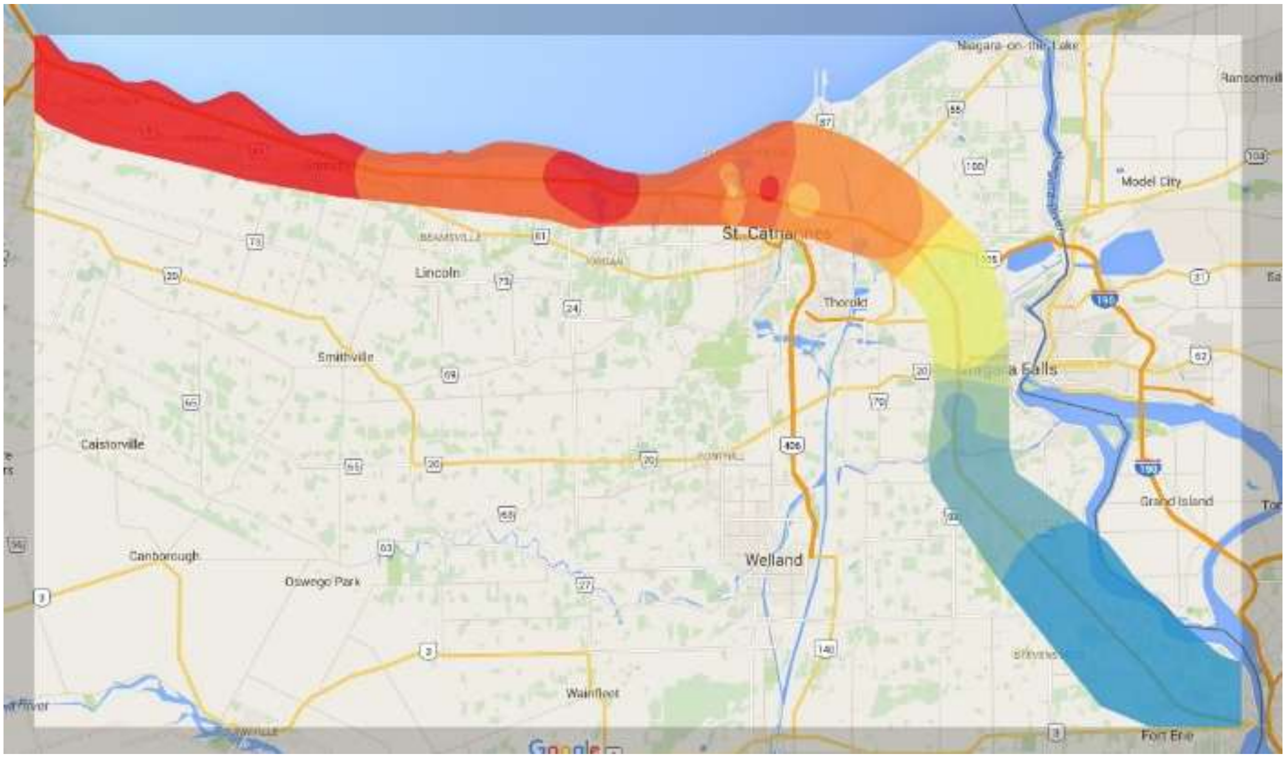

Figure 11: Visualizing Traffic Volume of the QEW from the GTHA to Niagara Region in 2010 (IDW).

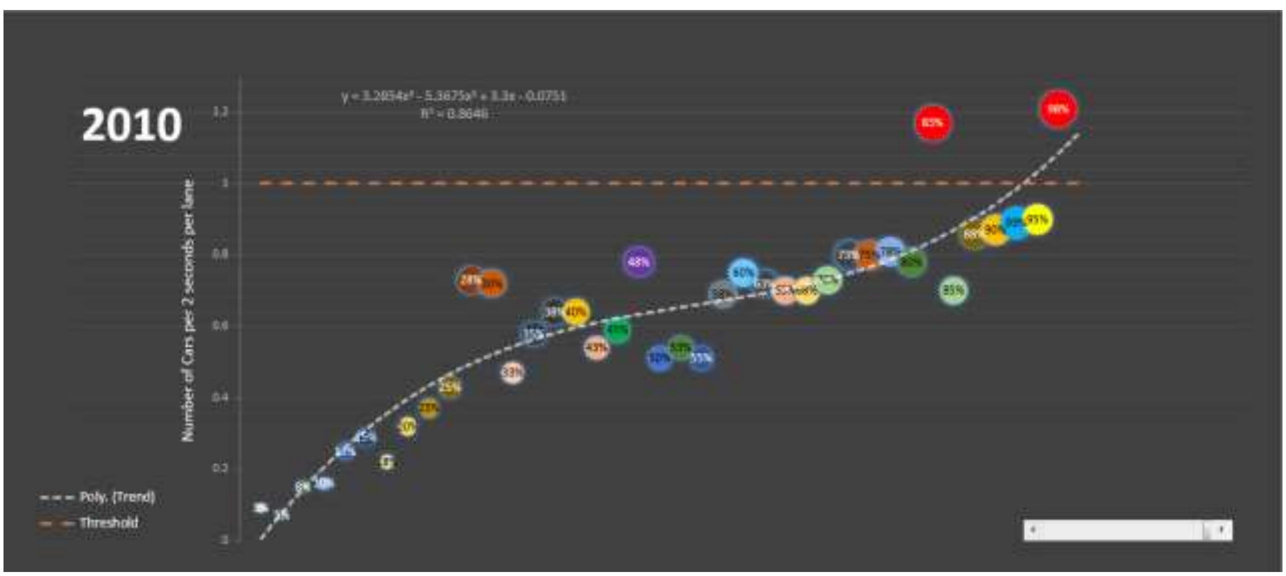

Figure 12: Visualizing Traffic Volume of the QEW from the GTHA to Niagara Region in 2010 (graphed).

The segments of QEW from Hamilton to Niagara Falls that were considered in the figures 9 to 12 can be referred to on the next page (Figure 13).

OBJECT_ID	Distance	From	To
3%	0.6	PEACE BRIDGE	CENTRAL AVE/ NIAGARA RD 124
5%	0.9	CENTRAL AVE/ NIAGARA RD 124	CONCESSION RD - IC
8%	1	CONCESSION RD - IC	NIAGARA RD 122/THOMPSON RD
10%	2.5	NIAGARA RD 122/THOMPSON RD	GILMORE RD
13%	2.1	GILMORE RD	BOWEN RD
15%	5.5	BOWEN RD	NETHERBY RD
18%	3.3	NETHERBY RD	SODOM RD
20%	6.6	SODOM RD	LYONS CREEK RD
23%	4.5	LYONS CREED RD	MCLEOD RD
25%	2.9	MCLEOD RD	HWY 420
28%	2	HWY 420	THOROLD STONE
30%	2.5	THOROLD STONE	MOUNTAIN RD
33%	2.5	MOUNTAIN RD	HWY 405
35%	1.3	HWY 405	GLENDALE AVE / HWY55
38%	4.3	GLENDALE AVE / HWY55	END OF GARDEN CITY HWY
40%	0.6	END OF GARDEN CITY HWY	NIAGARA ST SERVICE
43%	1.2	NIAGARA ST SERVICE	NIAGARA ST
45%	1.7	NIAGARA ST	LAKE ST
48%	1.3	LAKE ST	ONTARIO ST
50%	0.8	ONTARIO ST	MARTINDALE RD
53%	0.7	MARTINDALE RD	HWY 406
55%	2	HWY 406	SEVENTH ST
58%	4.3	SEVENTH ST	JORDAN RD
60%	2.9	JORDAN RD	VICTORIA AVE
63%	6.7	VICTORIA AVE	ONTARIO ST / NIAGARA RD 18
65%	3.8	ONTARIO ST / NIAGARA RD 18	BARTLETT AVE
68%	2.5	BARTLETT AVE	MAPLE AVE
70%	3.6	MAPLE AVE	CASABLANCA BLVD
73%	2.2	CASABLANCA BLVD	NIAGARA REGION LIMIT
75%	1.4	NIAGARA REGION LIMIT	FIFTY RD
78%	5.1	FIFTY RD	FRUITLAND AVE
80%	5.2	FRUITLAND AVE	CENTENNIAL PKWAY
83%	1.7	CENTENNIAL PKWAY	BURLINGTON ST
85%	4	BURLINGTON ST	EASTPORT RD
88%	0.9	EASTPORT RD	HWY 2
90%	2.4	HWY 2	FAIRVIEW ST
93%	1	FAIRVIEW ST	HWY 403/407
95%	0.8	HWY 403/407	BRANT ST
98%	1.9	BRANT ST	GUELPH LINE RD
100%			

Figure 13: Segment of the QEW AADT Volume Data Set.

3.1.2 Assessing Accessibility of Current Existing Transit Services

Accessibility of current existing transit services were conducted using an application within ArcGIS. The application used was Network Analyst, where service areas were solved upon creating the network dataset. This was done by first creating a new feature class dataset that included road network files, as well as the bus and train stations that will be assessed. After this was established, QA/QC of the data were conducted. The line segments of the roads where they were not split at particular intersections were split. After this was completed, roads were categorized into either highways, major roads, minor roads, or private roads. Each road classes were assigned a particular speed. This was done by referencing random areas using Google street view. This information allowed for the minutes traveled to be calculated, based on the length of the road segment. Figure 14 depicts this process and Table 15 on the next page details the classes and speeds that were assigned.

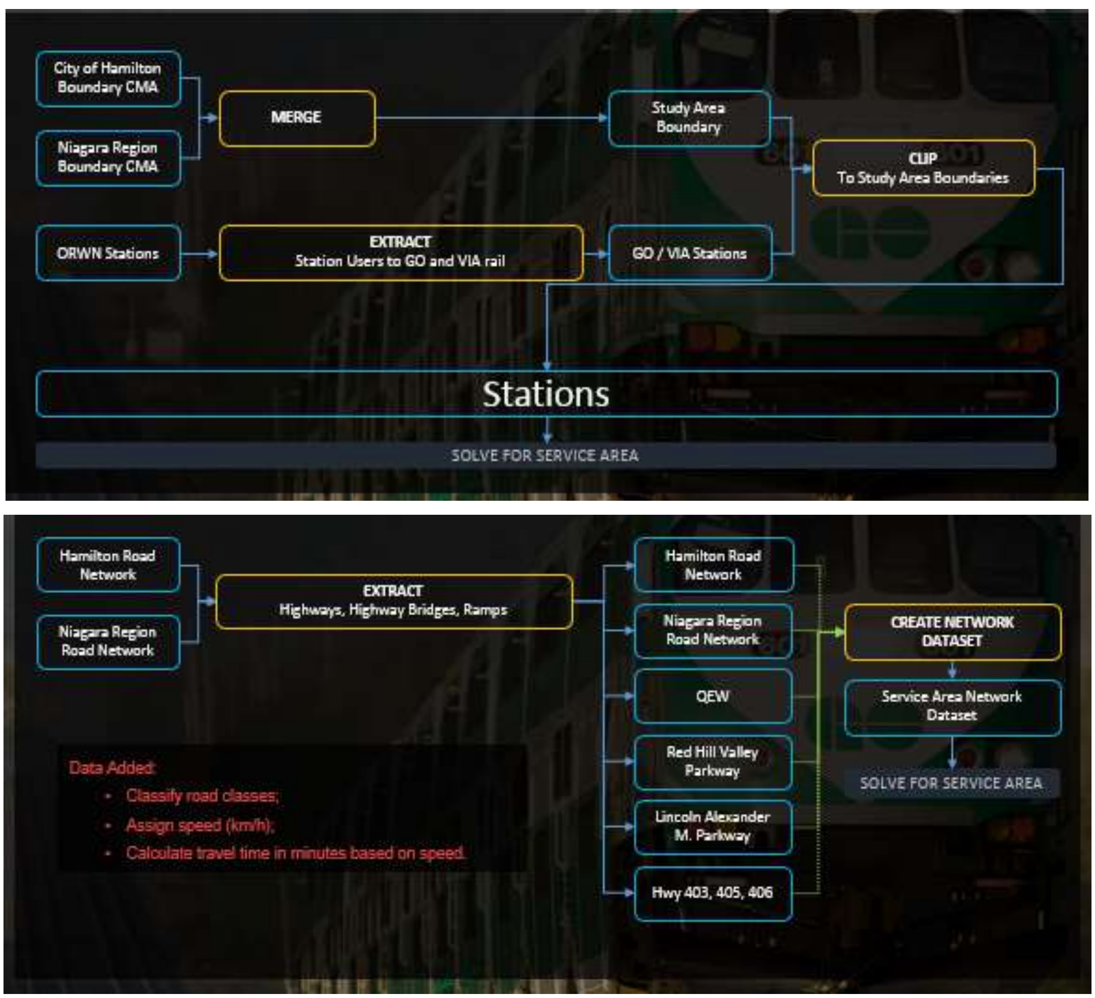

Figure 14: Model of Processing the Road Network and Stations (Facilities) Prior to Creating a Network Dataset.

Table 15: Attributes of Road Class, Speed, and Minutes Assigned prior to Solving the Network Dataset.

Field Name	Field Description			
LengthKM	Calculated using 'calculate geometry' in Kilometers.			
RoadClass	Class numbers were assigned for each different highway series. Depending on the type of highway, they are assigned with different series numbers.			
	Class No.	**Class Description**		
	1	QEW		
		Series No.	**Series Description**	
		01	Highways, Highway Bridges	
		02	Highway Ramps, Highway Bridges Ramps	
	2	403		
		Series No.	**Series Description**	
		01	Highways, Highway Bridges	
		02	Highways, Highway Bridges between Hwy 6 to Main Street Hamilton	
		03	Highway Ramps, Highway Bridges Ramps	
	3	Red Hill Valley Parkway		
		Series No.	**Series Description**	
		01	Highways, Highway Bridges	
		02	Highway Ramps, Highway Bridges Ramps	
	4	Lincoln M. Alexander Parkway		
		Series No.	**Series Description**	
		01	Highways, Highway Bridges	
		02	Highway Ramps, Highway Bridges Ramps	
	5	405, 406		
		Series No.	**Series Description**	
		01	Highway	
		02	Ramps	
	6	Other Major Highways		
		Series No.	**Series Description**	
		01	Highway No. 6, Highway 140, Highway 3, 58, East Main Street	
		02	Peace Bridge, Rainbow Bridge	
	7	Major Roads		
		01	Hamilton Major Roads (and bridges)	
		02	Hamilton Minor/Residential Roads (and bridges)	
	8	Niagara Municipal Roads		
		01	Niagara Municipal Owned Roads	
		02	Major Roads	
		03	Arterials	
		04	Minor	
		05	Residential	
	99	Private Roads		
		01	Hamilton	
		02	Niagara	

Field Name	Field Description	
Speed	Each road class has a specific speed associated with it.	
	RoadClass	**Speed**
	101, 201, 501	100 km/h
	202, 301, 401	90 km/h
	601, 802	80 km/h
	803	70 km/h
	701, 806	60 km/h
	602, 801	50 km/h
	702, 805	45 km/h
	102, 203, 302, 402, 502, 804	30 km/h
	9901, 9902	20 km/h
Minutes	This field is calculated with the following equation: **=(lengthKM/speed)*60**	

Upon establishing the attribute tables, the network dataset could then be solved using Network Analyst. The 'create new service area' option was chosen, where 5, 10, 15 segments were created, using each of the stations as facilities. Figure 15 depicts the model diagram of this process.

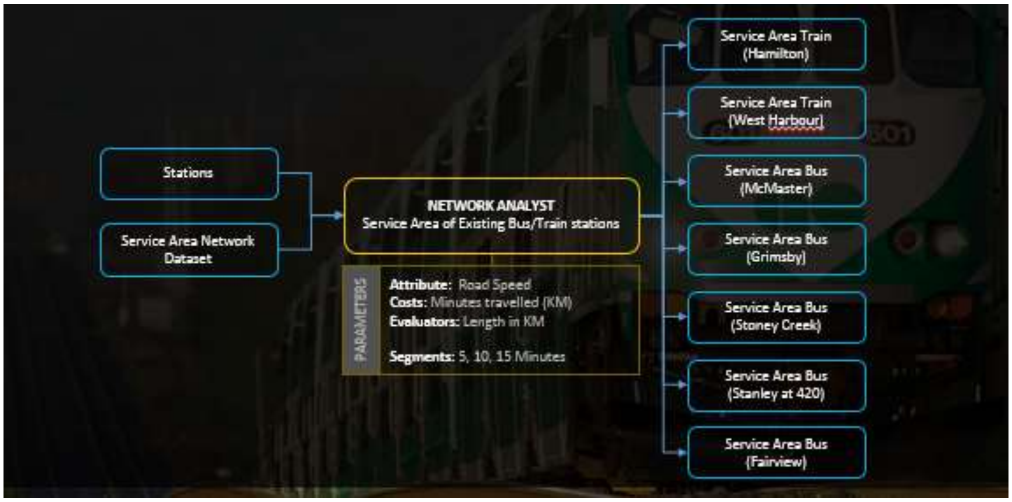

Figure 15: Inputs to creating the Network Dataset and the Outputs.

Polygons were created with detailed trimmings, to identify the accessibility of each station based on the speeds and travel time that was previously established. Note that U-turns were not allowed, turns were not modelled, and no elevation values were considered upon the creation of the network dataset.

3.2 Assessing the Factors Affecting Ridership

Transit use cannot be explained and justified solely on transit service accessibility. In fact, there are a multitude of factors that come into effect when it comes to how and why an individual may choose to take transit. The approach utilized was to evaluate factors encouraging public transit use. Demographic information from the National Household Survey conducted by Statistics Canada in the years 2006 and 2011 were used. Census tracts were used as they limited to a population between 2,500 and 8,000 persons. It provides a more detailed analysis that narrows down where these factors and travel-demand are sourced from, and is a relatively small and stable geographic area as determined previously in the literature review. Table 9 in the literature review section helped to identify the relationship of each factors and how to process the information to proceed with the analysis.

3.2.1 Population and Population Density

In 2006, Hamilton had a census metropolitan area population of 692,911 that increased to 721,053 in 2011 (Statistics Canada, 2012). It is currently the 3rd largest metropolitan area in Ontario (Statistics Canada, 2012) and the municipalities that make up Hamilton are: Ancaster, Dundas, Flamborough, Glanbrook, Hamilton, and Stoney Creek (City of Hamilton, 2015). The Niagara Region consists of 12 municipalities: Grimsby, Lincoln, St. Catharine's, Niagara-on-the-Lake, Niagara Falls, Thorold, Welland, Pelham, West Lincoln, Wainfleet, Port Colborne, and Fort Erie. In 2011, Niagara Region had a total population of 431,346 (Statistics Canada, 2012), indicating a slight steady growth from the 2006 Niagara Region population size of 427,410 (Statistics Canada, 2012). Table 16 below outlines the population for each specific region in their respective years. The population changes were calculated for each census tract and can be viewed in the appendix section no. 7 and 8.

Table 16: Details of the Study Area's Population (StatsCan. 2006, 2011)

Region	2006	2011
	Total Population	Total Population
City of Hamilton	554,254	552,807
Niagara Region	374,851	369,476
Total	929,105	922,283

The change in overall population of Niagara Region was modelled using the data from different sources to build an error limit to the data sets as well. This was done because the data sets obtained during literature review provided varying numbers for populations. Since, it is possible that the reports may have been too optimistic about the numbers and could have used the upper or lower limits of the population data and the trends that were suited to their conclusions.

The overall population of Niagara Region seems to have an exponential growth by a factor of 0.008. Although the growth is slow, the population is expected to reach 555100±3800 by the year 2041 (see Figure 16 below).

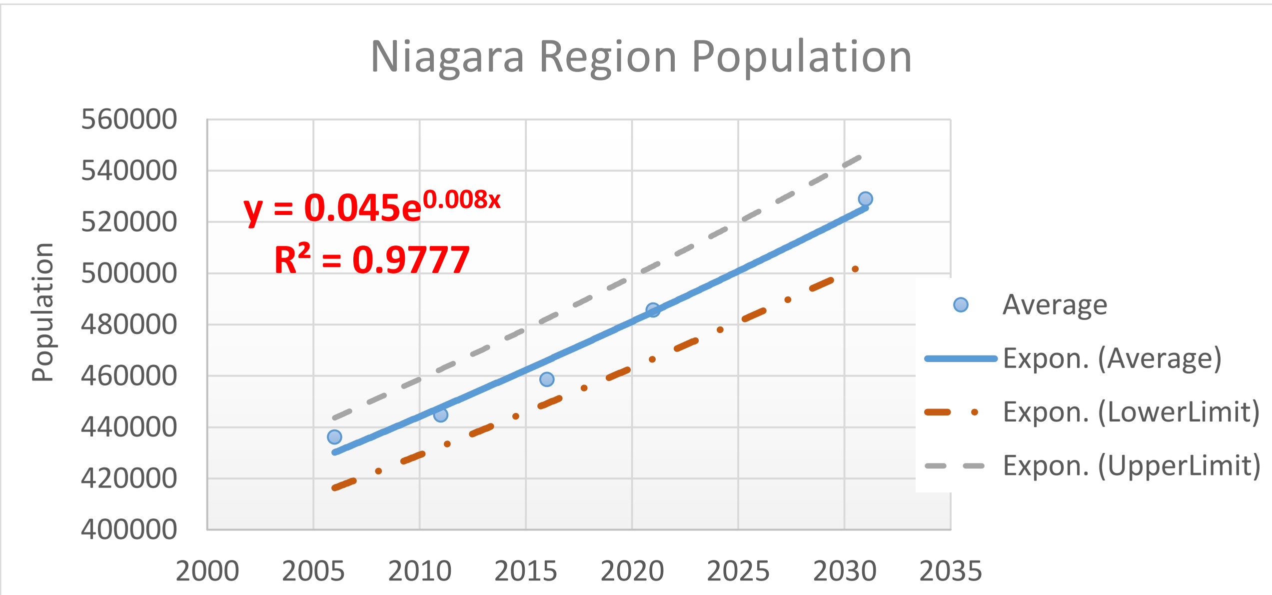

Figure 16: Niagara Region Population Trend

It is also important to note that the projected population obtained from the model above is as predicted by R. J. Burnside & Associates Limited in the Niagara Rail Service Expansion Environmental Study Report Go Transit report. Hence, this model along with the previously mentioned Environmental report published by R. J. Burnside & Associates Limited can be used in conjunction with each other for future analyses.

3.2.2 Vehicle Ownership

LJ Geomatics followed the characteristics from the National Household Surveys regarding the number of population that either drives to work (as a driver or as a passenger) to assume vehicle ownership. The percentage numbers were calculated based on each region, divided by the total population of the respective year. Table 17 below outlines the results. The percentages were also calculated for each census tract and can be viewed in the appendix section no. 7 and 8.

Table 17: Details of the Study Area's Car Ownership Statistics (StatsCan. 2006, 2011)

Region	2006		2011	
	Total Population	Travel to Work (as a Driver or Passenger)	Total Population	Travel to Work (as a Driver or Passenger)
City of Hamilton	554,254	202,325 (37%)	552,807	201,260 (36%)
Niagara Region	374,851	162,552 (43%)	369,476	149,095 (40%)
Total	929,105	364,877 (39%)	922,283	350,355 (38%)

3.2.3 Public Transit Use

In the same characteristic of the National Household Surveys regarding the mode of transportation that the population takes to travel to work, the population that takes public transit to work were utilized. Table 18 below outlines the statistics. Similarly, the percentages were derived from the total population of the region for that respective year. The percentages were also calculated for each census tract and can be viewed in the appendix section no. 7 and 8.

Table 18: Details of the Study Area's Public Transit Usage (StatsCan. 2006, 2011)

Region	2006		2011	
	Total Population	Travel to Work (using Public Transit)	Total Population	Travel to Work (Using Public Transit)
City of Hamilton	554,254	21,405 (4%)	552,807	20,745 (4%)
Niagara Region	374,851	4,430 (1%)	369,476	4,645 (1%)
Total	929,105	25,835 (3%)	922,283	25,390 (3%)

3.2.4 Income

LJ Geomatics followed the characteristics from the National Household Surveys in comparison to the provincial median income level. The average of the median income between the two years were used to determine income levels for census tracts within the study area. Table 19 below shows the specific statistics between the two years for the regions separately.

Table 19: Details of the Study Area's Median Income (StatsCan. 2006, 2011)

Region	2006		2011	
	Ontario Median	Median Income	Ontario Median	Median Income
City of Hamilton	$27,258	$28,416	$27,319	$28,305
Niagara Region		$25,498		$31,497

Table 20 depicts how the income levels were divided up to determine and streamline the analysis of income per census tract.

Table 20: Details of How Income Levels were Distinguished (StatsCan. 2006, 2011)

		Income Levels	Description
Average Provincial Median Income (2006 and 2011)	$27,289	$13,644 and less	Low Income
		$13,645 to $27,289	Below Ontario Median
		$27,289 to $40,933	Above Ontario Median
		$40,933 and more	High Income

The final results of the income levels for each census tracts were calculated and can be viewed in the appendix section no. 7 and 8.

3.2.5 Employment

LJ Geomatics followed the characteristics from the National Household Surveys regarding total number of employed population. To determine employment density changes between 2006 and 2011, the total employed population were divided by the total population of the respective region in the same year. Table 21 below details the results for each region. The percentages were also calculated for each census tract and can be viewed in the appendix section no. 7 and 8.

Table 21: Details of the Study Area's Employment Statistics (StatsCan. 2006, 2011)

Region	2006		2011	
	Total Population	Employed (Full/Part-Time)	Total Population	Employed (Full/Part-Time)
City of Hamilton	554,254	251,470 (45%)	552,807	237,395 (43%)
Niagara Region	374,851	168,210 (45%)	369,476	162,205 (44%)
Total	929,105	419,680 (45%)	922,283	399,600 (43%)

3.2.6 Education – Student Ridership

In order to further examine the contribution of youth and students to ridership demands, the Total Annual Ridership and the Total U-pass Ridership were further examined. On plotting the Total Annual Ridership against the years between 2012 and 2015 (inclusive), a general upward trend was noted for the points plotted. Hence, a regression analysis was performed with a linear fit, $[ridership] = 18095 * [year] - 36266830$ of adjusted $R^2 = 0.64$. Likewise, as the Total U-pass ridership was plotted against the years between 2012 and 2015 (inclusive), a general upward trend was once again noted for the points plotted. On performing a regression analysis with a linear fit, $[ridership] = 11379 * [year] - 22849221$ of adjusted $R^2 = 0.59$. This implies that there is strongly positive growth in ridership annually.

On plotting the Total Annual Ridership against the Total U-pass Ridership between 2012 and 2015 (inclusive), a general upward trend was once again noted for the points plotted. On performing a regression analysis with a linear fit, $[ridership] = 1.55 * [year] - 71010$ of adjusted $R^2 = 0.99$, one can conclude that an adjusted R^2 value of 0.99 implies that the Total Annual Ridership is strongly correlated with the Annual U-pass Ridership, and that a large majority of the Total Annual Ridership comes from U-pass holders, i.e.; students.

The Annual U-pass Ridership numbers included the U-passes distributed to Niagara College and Brock University students. 40% of the ridership, were from Niagara College students (Niagara Region, 2015) alone, whereas Brock University did not sign a U-pass agreement in 2015. Although this statistics is for the local Niagara Region transit, the statement that post-secondary students are more likely to take public transit can be supported by the fact that Niagara Region is currently working on fixing the routes to re-establish the Brock U-pass for the following academic year (Figure 17). Hence, that the percentage of ridership from Brock University is likely to increase in future.

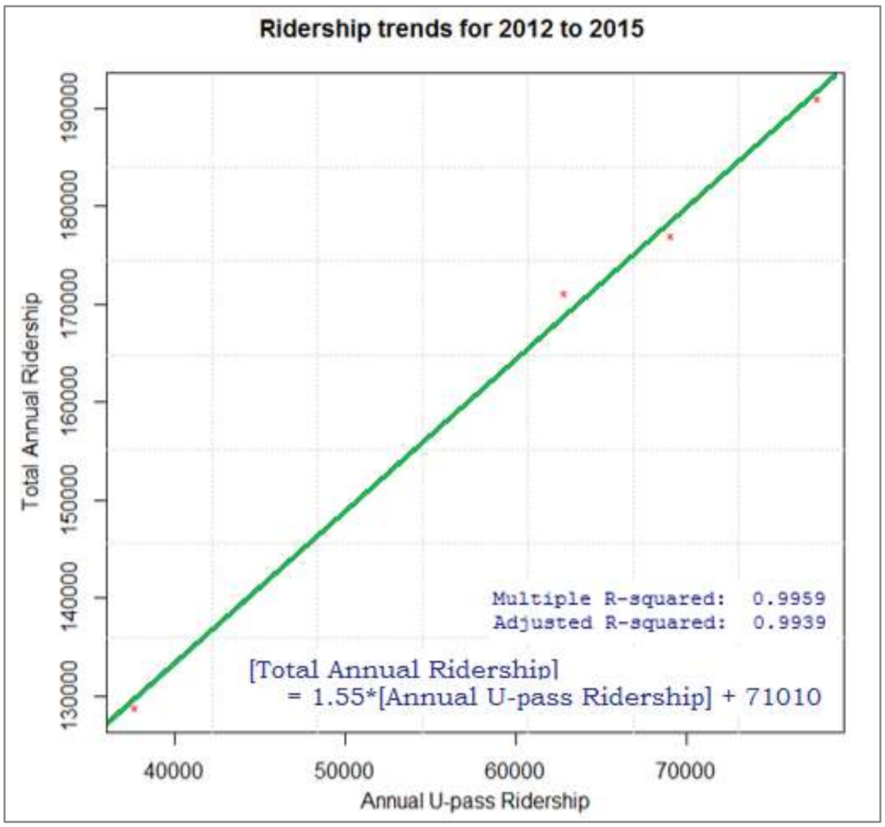

Figure 17: Annual Ridership Mostly Consisting of Students.

The enrollment profile of Niagara College was also examined spatially, where students that attend the college and do not have a permanent address within the Niagara Region were separated from the students with a permanent address within the Niagara Region. It was found that the number of students from outside the region is steadily increasing by 2.15% or approximately 6500 students annually. It is likely that these students would need a reliable source of public transportation to take them into the GTHA or GTA and thus are major contributors to ridership potential especially due to their increasing enrollment. Therefore, one can conclude that there is a significant demand for better transit options from the college/university student community, especially since there is an increasing number of students that are willing to travel form outside the region to attend Niagara College.

Hence, post-secondary students is the primary group that would benefit significantly from an efficient inter-municipal transit system.

3.3 Assessing Ridership Potential

The following section details the method in which was used to assess ridership of the overall system and for the study area.

The rail, bus and total (rail and bus) ridership from 2007 to 2015 and the expected ridership from 2016 to 2020 obtained from Metrolinx Annual reports (2010-2011 and 2011-2012) were graphed in order to observe the trend in commuter demand. Figure 18 shows the ridership trends by service type.

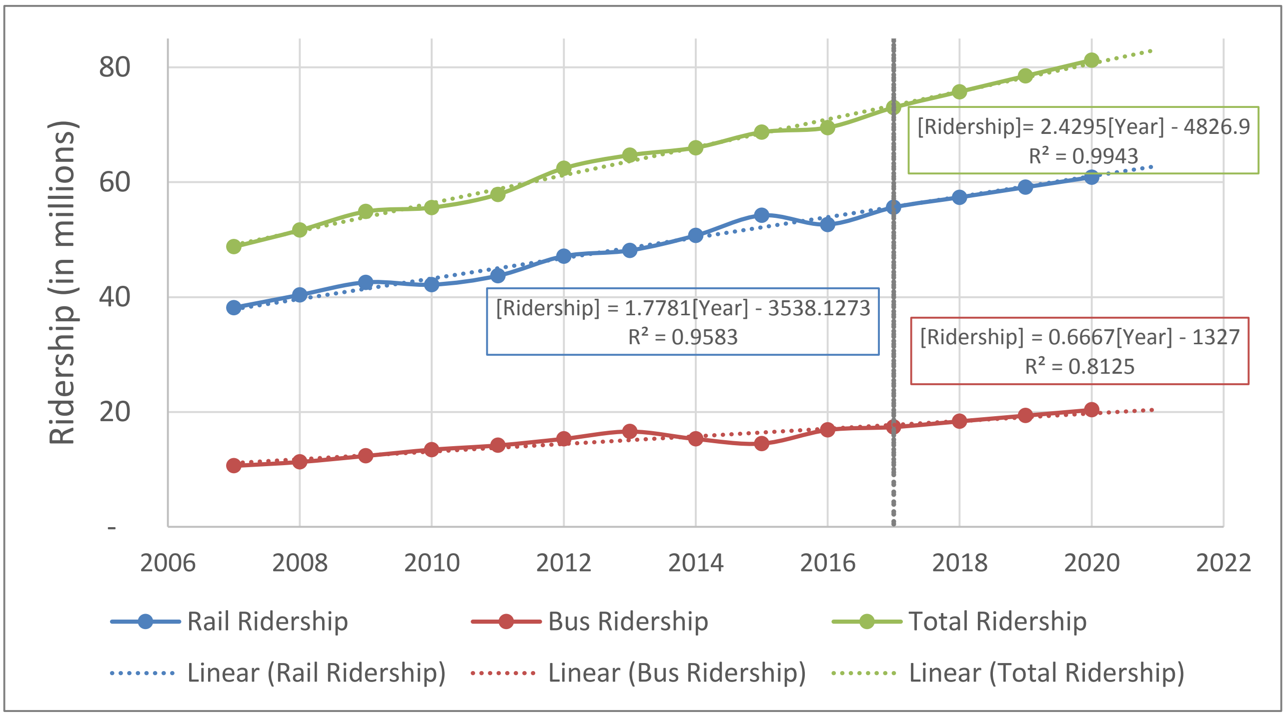

Figure 18: Ridership Forecast by Service.

The ridership trend for rail services was observed to be on an incline. On performing a regression analysis, from the quality of fit as described by the coefficient of determination R^2 was found to be approximately 0.96, a linear fit would best describe the ridership trend in rail services. Hence, the equation of the line of fit can be described by Equation 1:

Equation 1

$$[Ridership] = 1.7781 * [Year] - 3538.1273$$

Likewise, the ridership trend for bus services was also graphed, and consequently observed to be increasing steadily. On performing a regression analysis, the coefficient of determination R^2 was found to be approximately 0.81, and hence a linear fit would best describe the ridership trend in bus services. Therefore, the equation of the line of fit can be described by Equation 2.

Equation 2

$$[Ridership] = 0.67 * [Year] - 1327$$

Similarly, the ridership trend for rail and bus services combined were also graphed and observed to be increasing. The coefficient of determination R^2 found on performing a regression analysis was approximately 0.99. Therefore a linear fit as described by Equation 3 would best define the trend in total ridership demands.

Equation 3

$$[Ridership] = 2.4295 * [Year] - 4826.9$$

On observing the graphs in Figure 18 it can be noted that the trends in rail ridership and total ridership are somewhat parallel; hence, one can conclude that the rail ridership comprises of a significant portion of the total ridership.

3.4 Cost-Benefit Analysis

The following section details the method in which was used to assess expenditures and revenues. It is imperative to note that there may be errors associated with cost estimations since no literature was obtained that contained the break-up of the relevant components of the associated costs. Hence, this necessitated the use of apt judgement calls. To view the details of the expenditure and revenue assessment, refer to appendix no. 8 and 9.

3.4.1 Expenditures

The net total expenditure for Metrolinx was derived from operating expenses. Operating expenses include labour and benefits, operations, facilities and track, equipment and maintenance, supplies and services, and Presto implementation costs.

Since the recent annual financial reports published by Metrolinx did not provide a clear distinction between expenditures for from rail services and expenditures for from bus services, the expected expenditures for rail was determined by projecting the rail ridership in VIA Rail. The cost of bus operations was then determined by taking the difference of the total cost and the rail expenditures as projected by VIA Rail financial reports.

3.4.1.1 Fuel Cost Evaluation

In order to study the costs associated with rail and bus operations, the relationship between the fuel costs for the period of April 2014 to March 2015 was considered. The average monthly fuel costs for rail operations, the average monthly fuel costs for bus operation, and the monthly average of the rail and fuel costs as per the 2014-2015 Annual Report published by Metrolinx were compared against the average monthly diesel costs in Toronto (Ministry of Transportation). In order to observe the trend of the fuel costs and identify any inter-dependency between the parameters mentioned above, the ratio between the parameters was calculated and plotted as show below.

Figure 19 below describes the relationship between fuel costs for rail, fuel costs for bus, and the monthly average diesel price in Toronto in price-per-litre respectively.

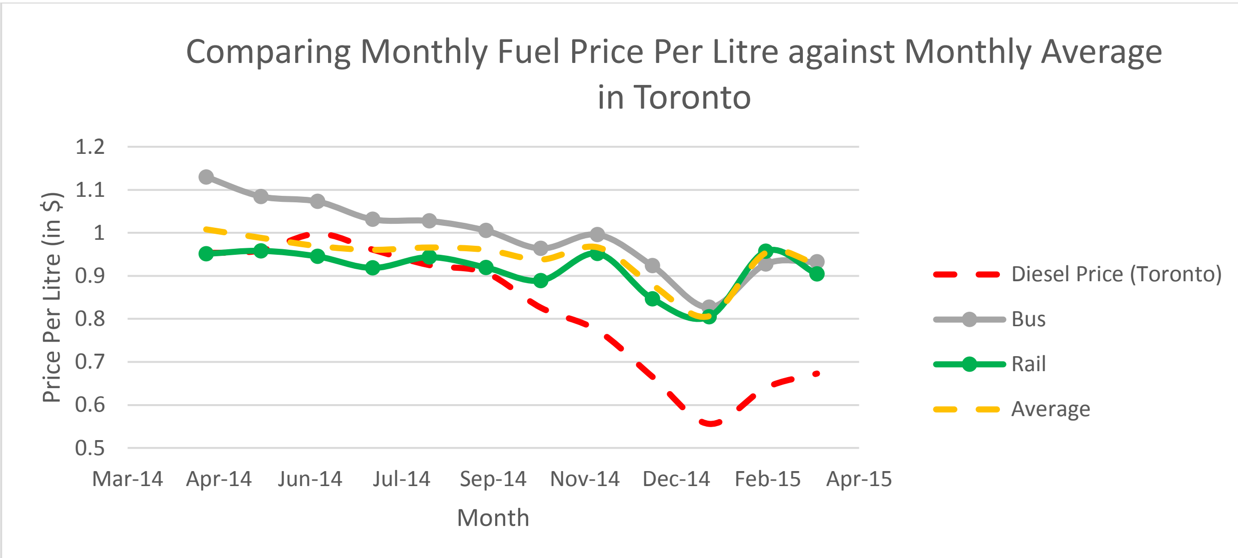

Figure 19: Comparing Monthly Fuel Price per Litre against Monthly average in Toronto.

On considering the trends of the graphs above, it can be observed that the rail and bus fuel costs are not strongly dependent on the price of diesel in Toronto, however they are proportional. Hence, it was concluded that there were other factors that contributed to the cost of the operation of rail or bus. From the above graph, one must also note the fuel prices for rail and bus operations respectively have converged within the duration of 12 months such that one can assume that the fuel type required for buses and trains are not the same. On further research, it was determined that GO trains are pulled by MPI MPXpress MP40PH-3C model locomotive that runs on diesel, and that GO buses run on diesel-electric hybrid.

Hence, this implied that GO trains were more challenging to maintain and GO buses were more expensive to operate.

3.4.1.2 Train Operation Costs from VIA Rail Annual Reports

In order to determine the operations cost for GO Rail services, the operations cost for VIA Rail services was considered. The Train operation cost from 2003 to 2015 were obtained from the VIA Rail Annual reports for the respective years and then graphed in order to observe the trend in operations costs.

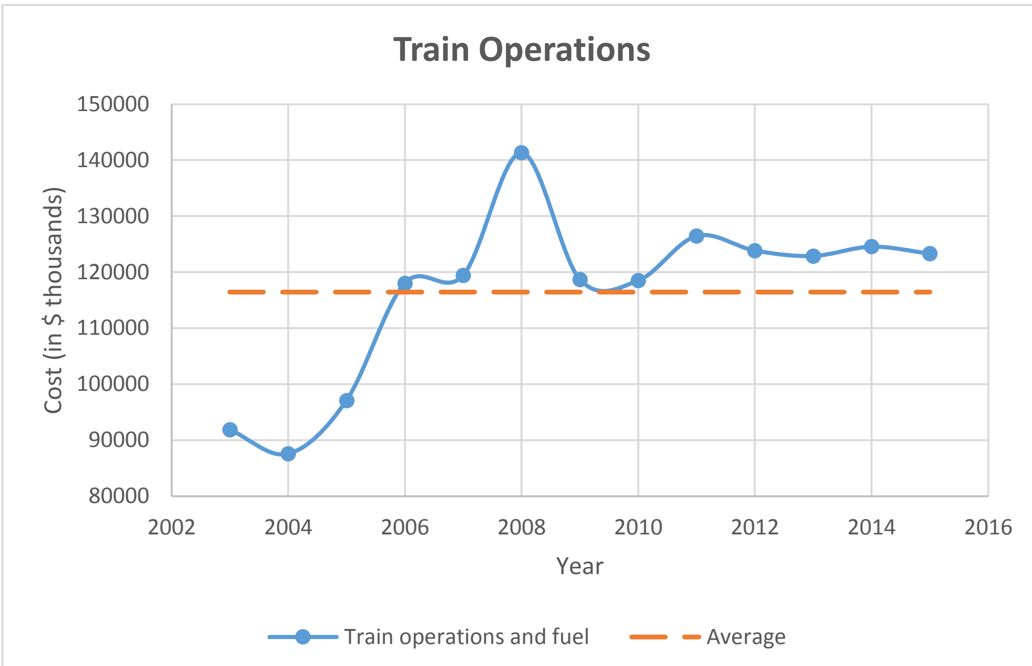

Figure 20: Graph of Cost of Train Operation (VIA Rail).

Figure 20 depicts the cost of train operations as per the annual VIA Rail Financial Reports, wide fluctuations were observed for the train operations trend. Since, the cause of the fluctuations are unknown, the average of the cost was obtained to be $116 million.

The train operations cost for Hamilton and Niagara Region was then obtained by proportionally scaling the total operations cost to the respective distance from the total distance travelled in the fiscal year of 2014-2015. The resulting train operation cost for GO Rail was regarded to be the same as VIA Rail.

The speculation on oil price by financial traders was the cause of the prices of commodities, including oil to skyrocket in 2008. This may have also proportionally affected the train operation costs in 2008, hence this data point may be treated as an outlier.

However, removing the 2008 data point by considering it as an outlier did not a considerable change in analyses since the removal of the data point did not yield a suitable model to describe the trend in train operations costs over the years. This indicates that there is no relationship between the two variables, and that the train operations depend on factors that are beyond the scope of this report. Therefore, LJ Geomatics cannot make any relevant prediction with regard to train operation costs, therefore LJ

Geomatics consultants were convinced that using average train operations costs for the years from 2003 to 2015 was a good estimate.

3.4.1.3 Equipment Maintenance Costs – Rail Services

The Equipment-Maintenance cost for GO Rail services was determined from the Maintenance Material costs of VIA Rail services. The Maintenance Material cost for GO services for the years from 2003 to 2015 were obtained from the Financial Statements within the Annual Reports of 2010 to 2015 that were published by VIA Rail Canada.

On graphing the cost associated with maintenance materials for each consecutive year, it was noted that no distinct trend can be derived from the distribution of the values (as seen in Figure 21).

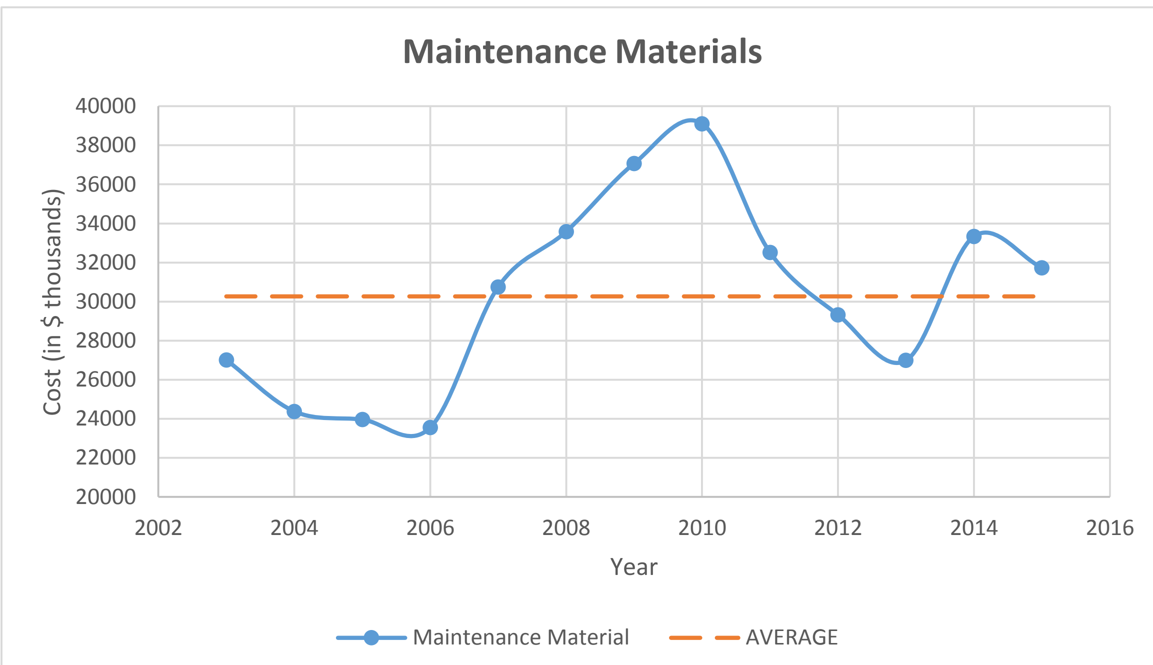

Figure 21: Maintenance Material Costs

On graphing the cost of maintenance materials as per the annual VIA Rail Financial Reports, wide fluctuations were observed for the maintenance material costs trend. Since, the cause of the fluctuations are unknown, the average of the cost was obtained to be $30 million.

The maintenance cost for Hamilton and Niagara Region was then obtained by proportionally scaling the total maintenance material' cost to the respective distance from the total distance travelled in the fiscal year of 2014-2015. The resulting equipment-maintenance cost for GO Rail was regarded to be equal to the maintenance cost for VIA Rail.

3.4.1.4 Equipment Maintenance Costs – Bus Services

The Equipment Maintenance cost for GO services for the years from 2010 to 2015 were obtained from the Financial Statements within the Annual Reports of 2010 to 2015 that were published by Metrolinx. On graphing the Equipment Maintenance costs for each consecutive year, it was noted that the graphed values followed a linear trend (as seen in Figure 22).

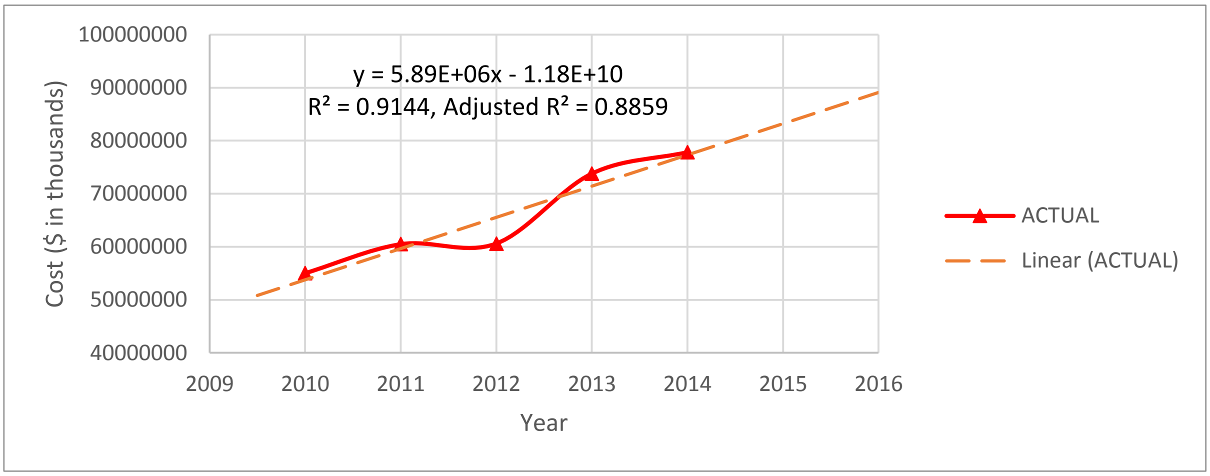

Figure 22: Equipment and Maintenance Costs

The coefficient of determination (R^2) of the linear fit for the graph in Figure 22 was determined to be approximately 0.89; thereby indicating the linear fit to be a good regression model for the given dataset. Hence, the equation of the line of fit can be described by Equation 4.

Equation 4

$$[Cost] = 5.89e6 * [Year] - 1.18e10$$

Since the values are in thousands and millions, the parameters in the above equation are extremely sensitive in the thousandths and hundredths places. Although this may indicate that the system is perhaps chaotic and unpredictable, the values obtained from the trend fitting were utilized due to the limitation faced by *LJ Geomatics* with respect to receiving poor quality dataset. The net equipment-maintenance cost for 2016 that was predicted using the linear model (see Equation 4) was $92.2 million.

The equipment-maintenance cost for Hamilton and Niagara Region was then obtained by proportionally scaling the equipment-maintenance cost to the respective distance from the total distance travelled by train or bus respectively in the fiscal year of 2014-2015. The equipment-maintenance costs for buses was then obtained by subtracting the equipment-maintenance cost for trains (as per VIA estimates) from the projected total equipment-maintenance cost as modelled by Equation 4.

It is also important to note that the results obtained for equipment-maintenance costs from the above mentioned calculation has been supported by the conclusions derived in section 3.4.1.1 Fuel Cost Evaluation.

3.4.1.5 Stations and Facilities

The cost associated with Stations and Facilities for VIA Rail services for the years from 2003 to 2015 were also obtained from the Financial Statements within the Annual Reports of 2003 to 2015 that were published by Metrolinx. On graphing the Stations and Facilities costs for each consecutive year, it was noted that the graphed values followed a linear trend (as seen in Figure 23).

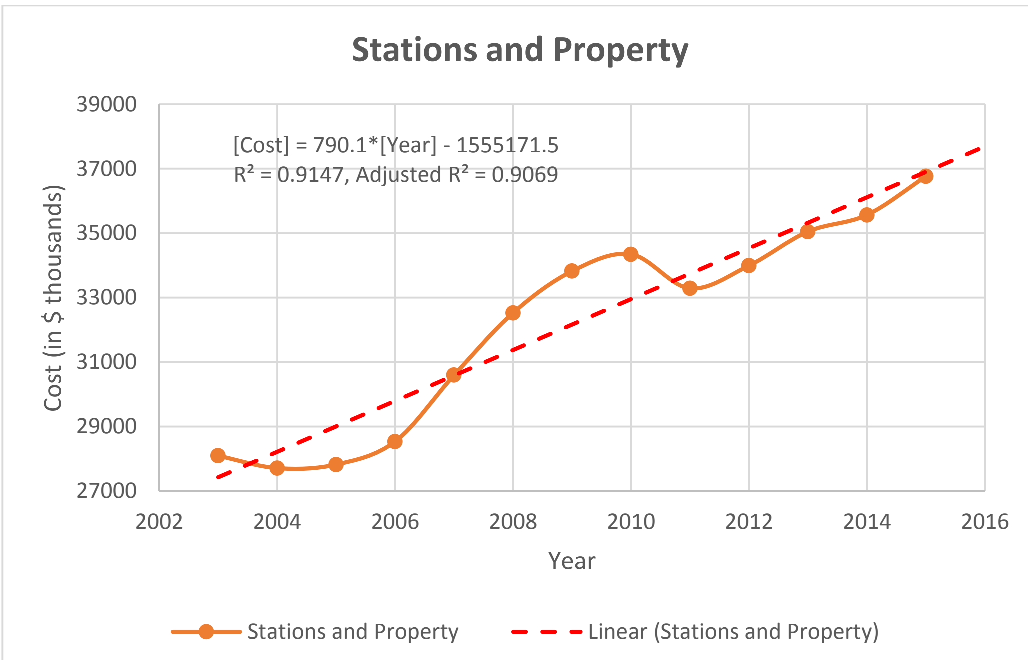

Figure 23: Cost Estimation of Stations

The coefficient of determination (R^2) of the linear fit for the graph in Figure 23 was determined to be approximately 0.91; thereby indicating that the linear fit is a good regression model for the given dataset. Hence, the equation of the line of fit can be described by Equation 5.

Equation 5

$$[Cost] = 790.1e6 * [Year] - 1555171.5$$

The net cost of stations and property for 2016 was estimated to be approximately $38 million. There are also 600 VIA Rail stations in Canada. Hence, cost-per-station was calculated to be approximately $65,000. Since the values are in thousands, the parameters in the above equation are extremely sensitive in the thousandths and hundredths places. Although this may indicate that the system is perhaps chaotic and unpredictable, the values obtained from the trend fitting were utilized due to the limitation faced by *LJ Geomatics* with respect to receiving poor quality dataset.

In this assessment, bus and train stations are not distinctly identified since most VIA Rail stations in Canada are located with the premises of a GO rail Station or a GO bus station.

3.4.2 Revenues

The net total revenue for Metrolinx is derived from commuter revenue and non-fare revenue. Revenue derived from commercial space, tracking fees, reserved parking, advertising, interest income, PRESTO, provincial and federal contributions, amortization of deferred capital contributions, etc. comprises of non-fare revenue. Likewise, the revenue obtained from ridership demands make up the section of commuter revenue.

For the purposes of this report, since the sources and percentage of contribution of the other resources cannot be estimated for the study area between Hamilton and Niagara region specifically, only the revenue obtained from commuter ridership has be analyzed and calculated. The revenue obtained from ridership demands were determined by scaling the revenues obtained from older GO Annual reports to the Hamilton-Niagara corridor.

3.4.2.1 Fare Calculation

In order to determine the possible future fare for using the GO train from Hamilton GO Center to Niagara Falls, the existing fares for traveling from the cities serviced by GO train to the Union Station and the estimated time taken to reach the destination were collected. The fare for one-way travel to Union Station was determined using the Fare Calculator app accessible through their online '*Fare Calculator*' application. The estimated time taken to reach the respective destination was determined (Table 22).

Table 22: Overview of Fare Statistics

	Fare (in $)	Time (in Minutes)
Minimum	5.3	11.0
Maximum	14.05	108.0
Mean	8.21	43.6
Median	8.10	40.0
Standard Deviation	2.23	21.5

As seen in the overview of the far statistics above, the mean is greater than the median for the fares and the time taken to reach the destinations. This implies that the dataset has a tendency to cluster to the left.

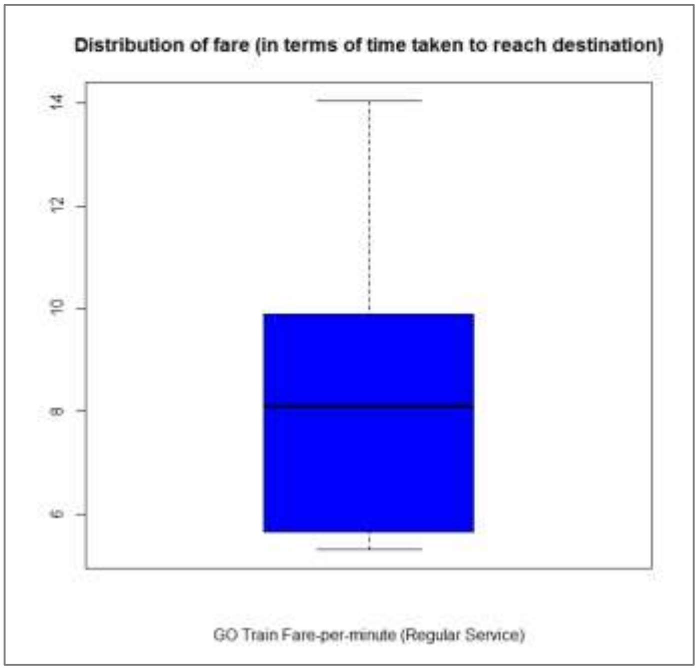

Figure 24: Boxplot of Fare Distribution.

A boxplot of the fare values was generated in order to confirm the nature of distribution as indicated in the overview of statistics.

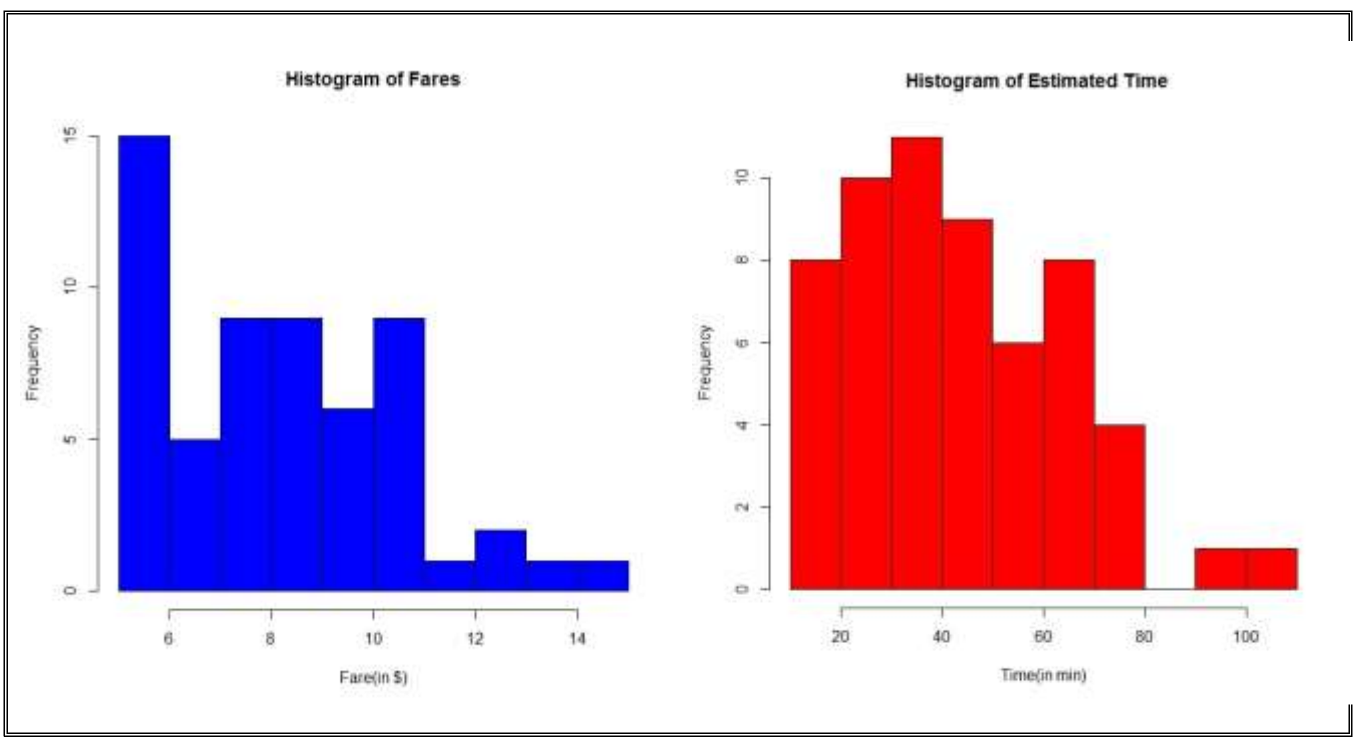

Figure 25: Histogram of Fare versus Estimated Times.

Likewise, histograms for the fares and the estimated time were also generated in order to visualize the trend in passenger boarding. The high frequency in fare costs of less than $6 indicate that a large portion of the passengers that board the GO train are within less than 30 minutes of commute, as the data reflects the number of GO stations within the 30 minute radius of Union Station. This is as expected as the traffic density of Toronto (surrounding Union Stations) is a strong incentive for commuters to use for public transit.

The above observation is further supported by the Histogram of Estimated Time, where the highest number of stations are within a 20-50 minute radius to Union Station. Similarly, the general tendency of the histogram of fares is to the left, as is indicated by the overview of statistics where, mean is greater than the median). Since GO Rail services are directly proportional to the number of passengers boarding the train, this implies that GO Rail services are mostly in demand for passengers who commute for less than 40 minutes.

Since a significant portion of the annual revenue is derived from passenger fares, the expected fare for regular GO train service from Hamilton GO Center to Niagara Falls was determined by graphing the fares against the time taken to reach the destination.

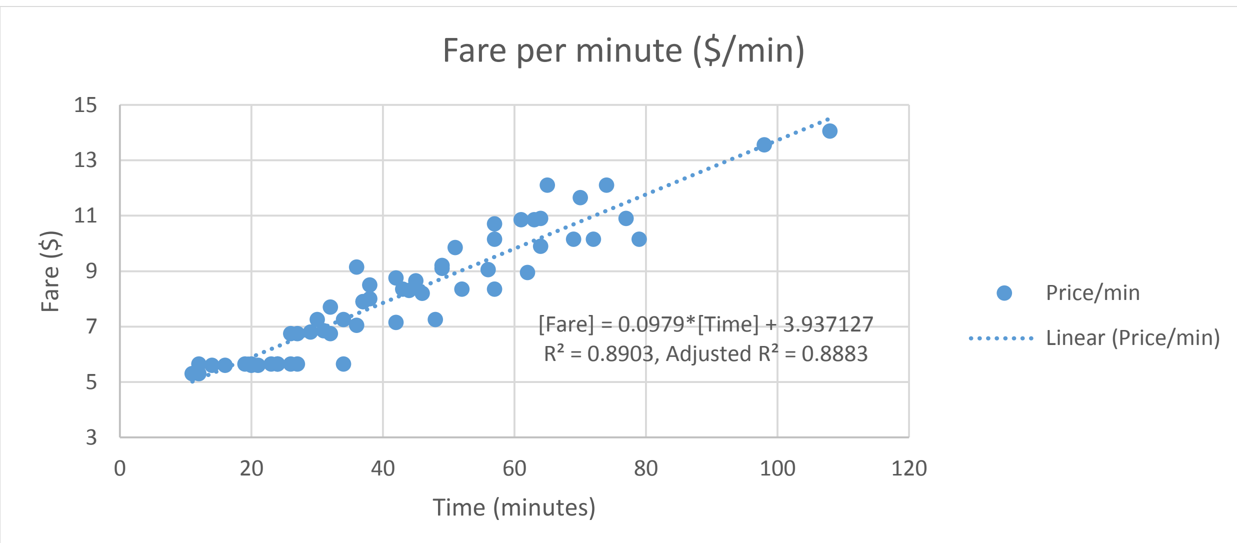

Figure 26: Fare Estimation by observing relationship between fare and time travelled.

A line of best fit was then constructed in order to study the relationship between the fare price and the estimated time taken to reach the destination. An adjusted R^2 value of approximately 0.89 indicate that there is a strong correlation between the two variables. Therefore, fare prices are directly proportional to the time (or distance) to arrive at the destination.

The line of best fit has a slope of 0.0979 and a y-intercept of 3.93. The y-intercept of 3.93 implies that there is a base fare which one pays to board the train. Likewise, the slope of approximately 0.1 indicate that for every minute of using the service, a sum of $0.01 is added to the total fare.

Hence using this model, the cost of the trip between Hamilton GO Center and Niagara Falls is estimated to be at least approximately $9.00, as the estimated time for commute between Hamilton GO Centre and Niagara Falls is at least 55 minutes.

Therefore, for the purposes of the report using the fare for summer seasonal services of $14.35 for rail services, and $12.65 for bus services was justified.

3.4.2.2 Ridership Revenue from Metrolinx Annual Reports

The financial reports published by Metrolinx in for the 2010-2011 and 2011-2012 fiscal years indicated the rail and bus ridership numbers distinctly for the periods from 2005-2006 to 2011-2012. The values provided were graphed in Figure 18, and the trend was extrapolated to 2016 in order to obtain the annual ridership numbers for rail and bus services respectively.

To arrive at the revenue obtained for every kilometer of rail and bus serviced respectively, the total revenue for 2016 was divided by the annual distance travelled by trains and buses as per the financial report for the fiscal year of 2014-2015. The ridership for Hamilton and Niagara Region was then scaled proportionally with respect to the total distance travelled by trains and buses in the fiscal year of 2014-2015.

The ridership from rail service was estimated to be 188,516 and the ridership from bus service was estimated to be 115,921. Assuming the total number of working days in a year is 240, the daily ridership for rail services was estimated to be 785, and the daily ridership for bus services was estimated to be 483 for the Hamilton and Niagara regions. Therefore, using the fare for summer seasonal services of $14.35 for rail services, and $12.65 for bus services, the total revenue to be obtained in 2016 from bus and rail services for the Hamilton-Niagara region were then estimated to be $2.7 million and $1.5 million.

3.4.2.3 Determining Revenue Targets

In order to determine revenue targets, an assessment of operation costs versus revenues from ridership were assessed (Metrolinx Annual Reports, 2015; 2014; 2013; 2012).

Table 23: Assessment of Expenditure vs. Revenue to Determine Revenue Targets.

	2014	2013	2012	2011
Expenditure Assessment				
Rail/Bus Operating Costs	$165,485,000	$156,383,000	$138,346,000	$129,388,000
Total Expenditure	$1,044,137,000	$908,356,000	$774,328,000	$728,612,000
Percentage	15.85%	17.22%	17.87%	17.75%
Revenue Assessment				
Revenue from Ridership	$437,939,000	$393,574,000	$357,333,000	$338,359,000
Total Revenue	$1,026,324,000	$891,398,000	$757,101,000	$703,269,000
Percentage	42.67%	44.15%	47.20%	48.11%

From this assessment, the project team utilized these statistics to standardize and determine revenue targets to justify rail/bus operation costs. The most recent year of the 2014 percentage (15% for cost and 40% of cost) was used for the assessment as it was the most representative of current conditions and projections. This statistic was used to standardize and determine the appropriate revenue target as a means to justify the rail/bus operation costs. For example if the operating cost was $10, the revenue target would be $26.67. In summary, the ratio between revenue and expenditures were standardized to determine revenue target and thus justifying rail/bus operating costs.

3.4.2.4 HOV Lanes

The high occupancy vehicle (HOV) lane costs were derived from a document discussing the costs of implementing the lanes for the PanAmerican Games. The total lengths in kilometers of the HOV lanes were totaled up to reveal a total length of 265 KM. This statistic supported in determining the cost per kilometers to paint the lanes. Additionally, the PanAM games also included costs to implement two different signs. For the purpose of this research, only the original signs were required, and thus those costs were halved. Table 24 below details the costs.

Table 24: Details of Deriving HOV Lane Costs.

Pan-American Games Costs	Cost in $
Painting HOV Lanes	$306,000
HOV Lane Signs	$950,000
Total HOV Lane Length	265
HOV Lane Implementation (paint and signs)	$1,256,000
Cost per KM	$4,740

3.4.3 Social Benefits

3.4.3.1 Carbon Taxes

Since GO trains are pulled by MPI MPXpress MP40PH-3C model locomotives that run on diesel, and Honda Civic is the most common car used in Canada, the average fuel consumption rate of a GO train engine and that of an average Honda Civic was determined. The Gallons-per-Hour (GPH) for a train engine and a car engine was calculated using Equation 6.

Equation 6

$$Gallons\ Per\ Hour\ (GPH) = \frac{Specific\ Fuel\ Consumption * Horse\ Power\ (HP)}{Fuel\ Specific\ weight}$$

The specific fuel consumption for diesel engines is 0.40 lb/HP and 0.50lb/HP for gasoline engines. Likewise, the fuel specific weight for an average diesel engine is 7.2lb/gallon and for an average gasoline engine is 6.1lb/gallon. The average horse power of a diesel locomotive was determined to be 300 HP and 185HP for a Honda Civic.

Since the Province of Ontario does not currently impose carbon taxes, the revenue from the carbon taxes included in this report takes into account the carbon tax of 7.67 cents-per-litre for diesel and 6.67 cents-per-litre for gasoline, as outlined by the Province of British Columbia.

The net value was then multiplied by the average time taken to travel from Hamilton to Niagara region in order to determine the expected annual revenue from carbon taxes.

3.4.3.2 Time Saved/Lost in Traffic

The time lost in traffic was determined by finding the average of the difference between the current AADT volumes at the congestion points and average traffic threshold values. The traffic threshold values were estimated by calculating the expected maximum threshold value of the congestion points from two second rule. The traffic threshold values range from 170,000 to 180,000 cars.

If the differential volume that causes the congestion were displaced in trains or buses; the time saved is determined by multiplying the median wage in Hamilton and the number of annual working days (240 days) to the differential volume.

4.0 SUMMARY OF PROJECT ANALYSIS AND FINDINGS

Following the collection and analysis of the data sets, it is clear that there are although there are demand for regular GO Train service to operate between the GTHA and Niagara Region, the ridership numbers are not enough to justify the operation costs. However, there are other clear benefits that should be taken into consideration in which would align with other Provincial initiatives in terms of minimizing traffic congestion on GTA West Corridor of the QEW, improving the overall environmental as well as health benefits of the citizens, as well as practicing good planning policies by following the guidelines set out by the Growth Plan of Ontario. The following sections will discuss the findings in detail.

4.1 Significant Traffic Congestion on the QEW

Literature review revealed that traffic congestion is a major issue along the QEW on the Burlington skyway. This area is prone to bottle-neck during peak time travel hours, and it had been suggested by the Ontario Ministry of Transportation (2013) to implement means of traffic relief. In the same study, it was reported that if no means to alleviate traffic were implemented, and if the current conditions remained at the current state, traffic will back up all the way into Niagara Region in 2031. From this claim, *LJ Geomatics* conducted an IDW geo-statistical analysis based on publically available AADT volume from the MTO. Appendix no. 3 depicts the data from the years 1988 to 2010 using an IDW geo-statistical analysis.

From this visualization, it can be confirmed that the Ontario Ministry of Transportation's predictions are indeed accurate. This supported the basis of the GO Niagara expansion feasibility, as increasing public transit service is a direct means to alleviating traffic congestion.

4.2 Current Existing Stations are Accessible by Urban Core

The next component of the analysis that *LJ Geomatics* conducted was the accessibility of current stations. This analysis revealed that the accessibility of each station are accessible by the majority of the urban core within the GTHA and Niagara Region. Figure 27 to 33 depicts accessibility of the current existing stations with 5, 10, and 15 minutes increments based on the current road speeds which is measured in kilometers per hour. There were a total of 7 stations that were assessed. They are: Hamilton GO Train Station (Figure 27), West Harbour GO Train Station (Figure 28), McMaster Bus Station (Figure 29), Stoney Creek Bus Station (Figure 30), Grimsby Bus Station (Figure 31), Fairview Bus Station (Figure 32), and Stanley Bus Station (Figure 33).

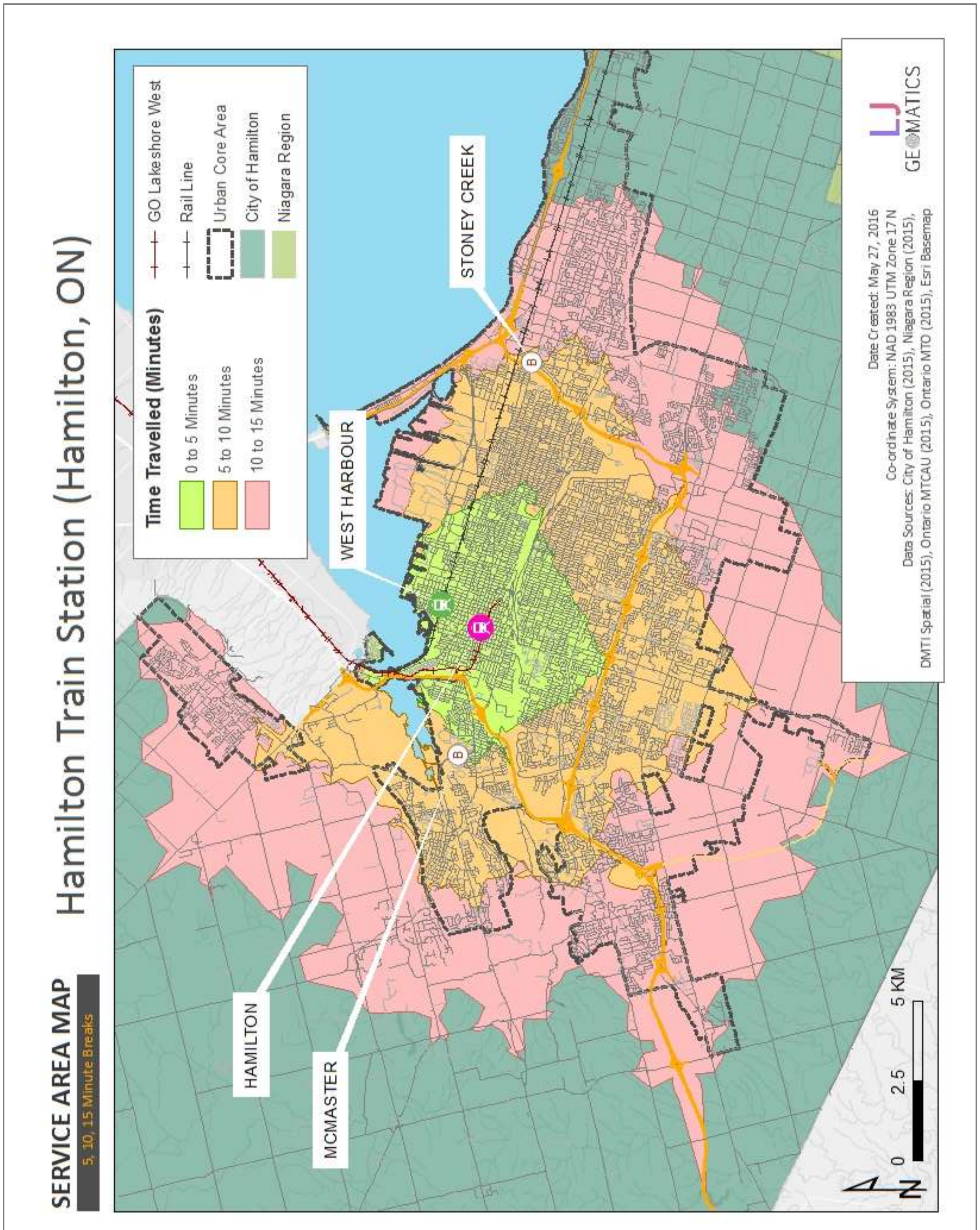

Figure 27: Accessibility of the Hamilton Train Station in 5, 10, 15 Minutes Segments.

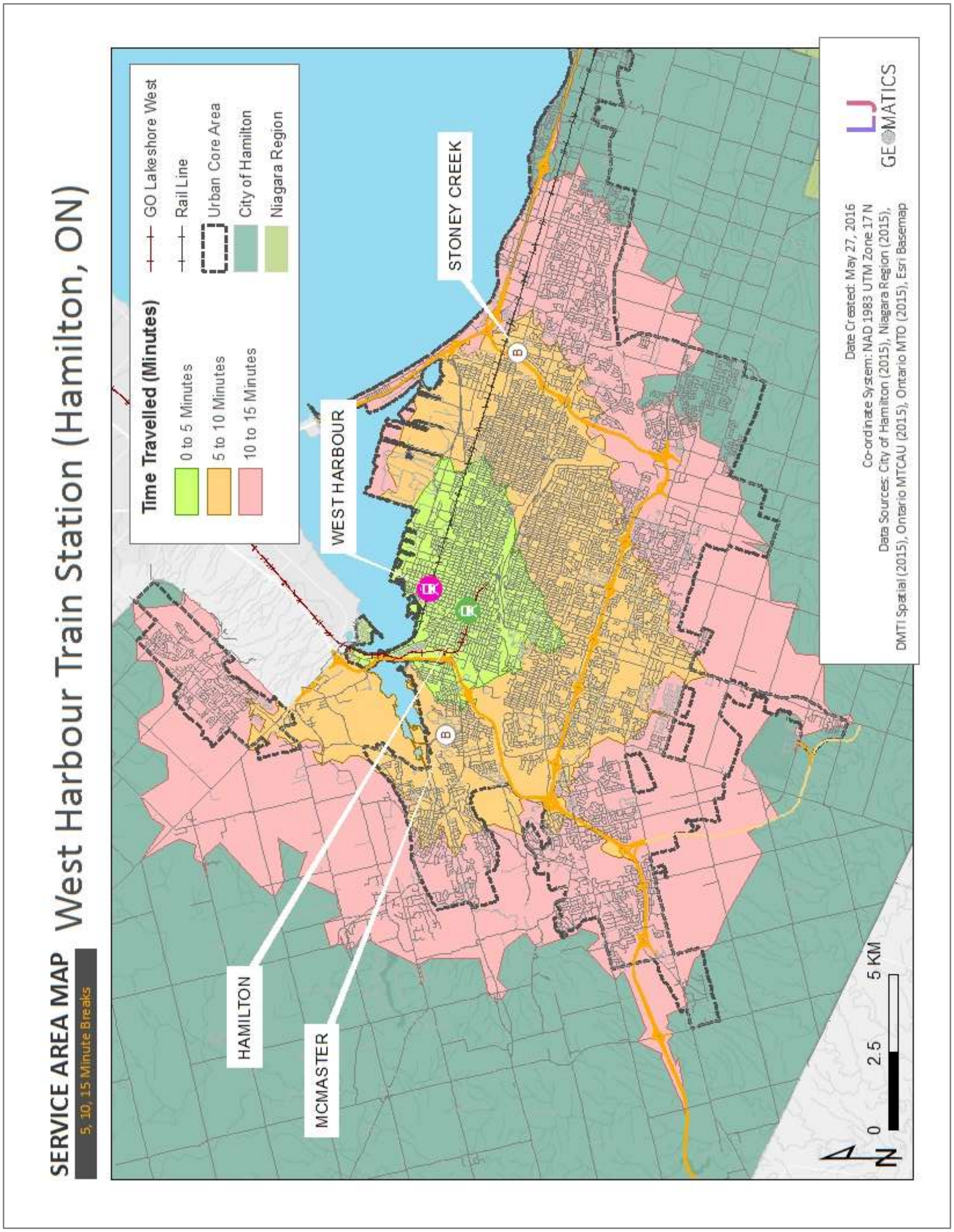

Figure 28: Accessibility of the West Harbour Train Station in 5, 10, 15 Minutes Segments.

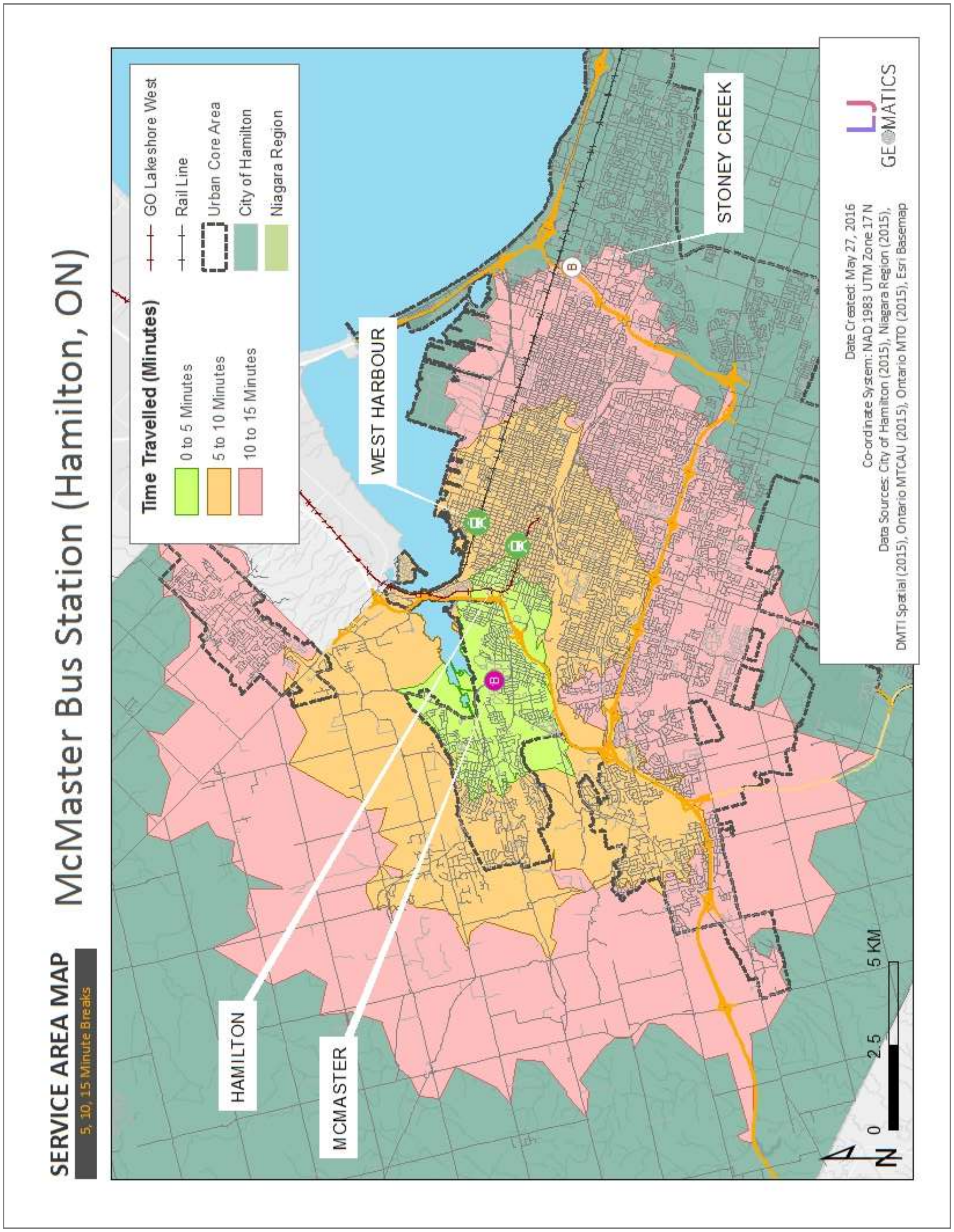

Figure 29: Accessibility of the McMaster Bus Station in 5, 10, 15 Minutes Segments.

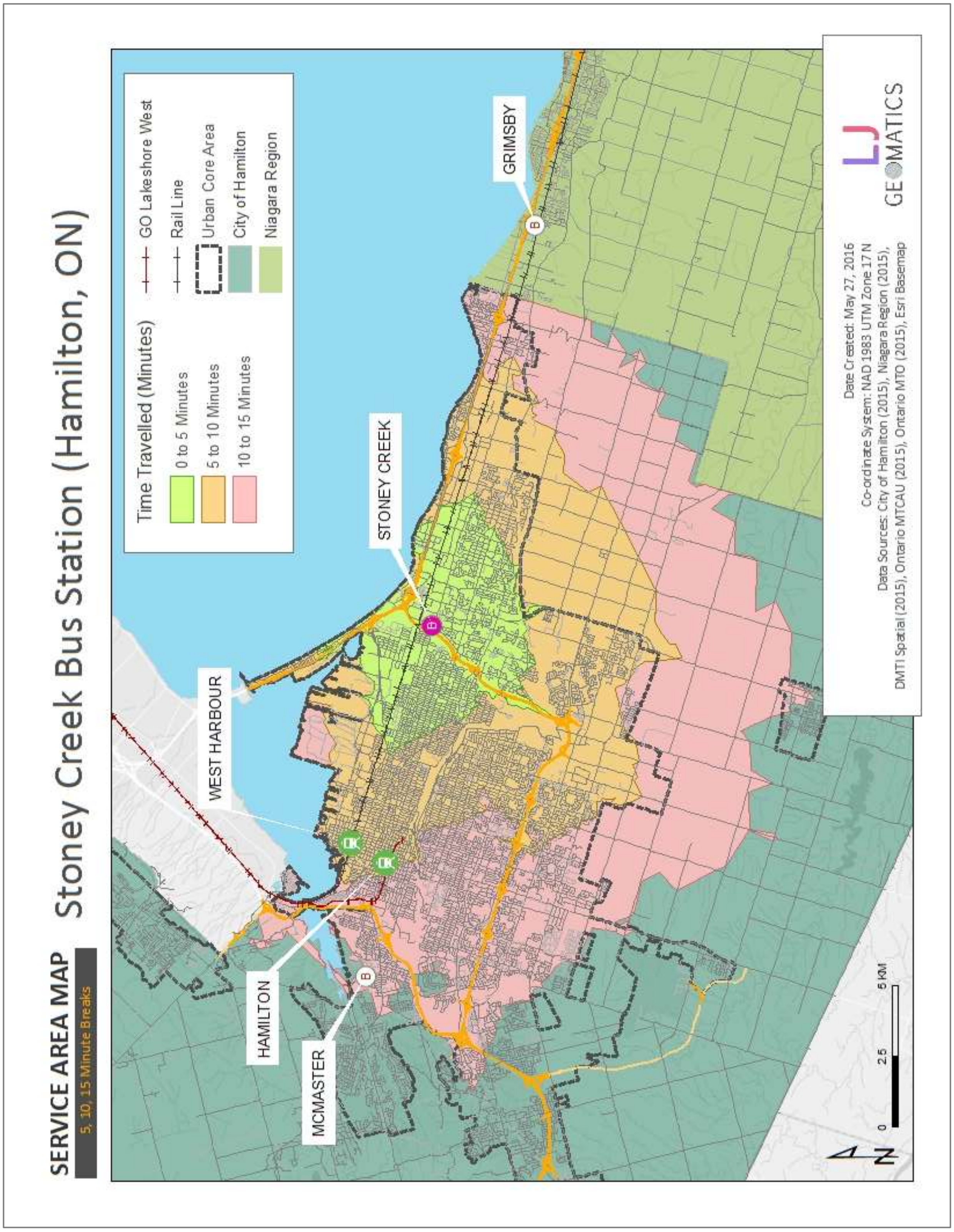

Figure 30: Accessibility of the Stoney Creek Bus Station in 5, 10, 15 Minutes Segments.

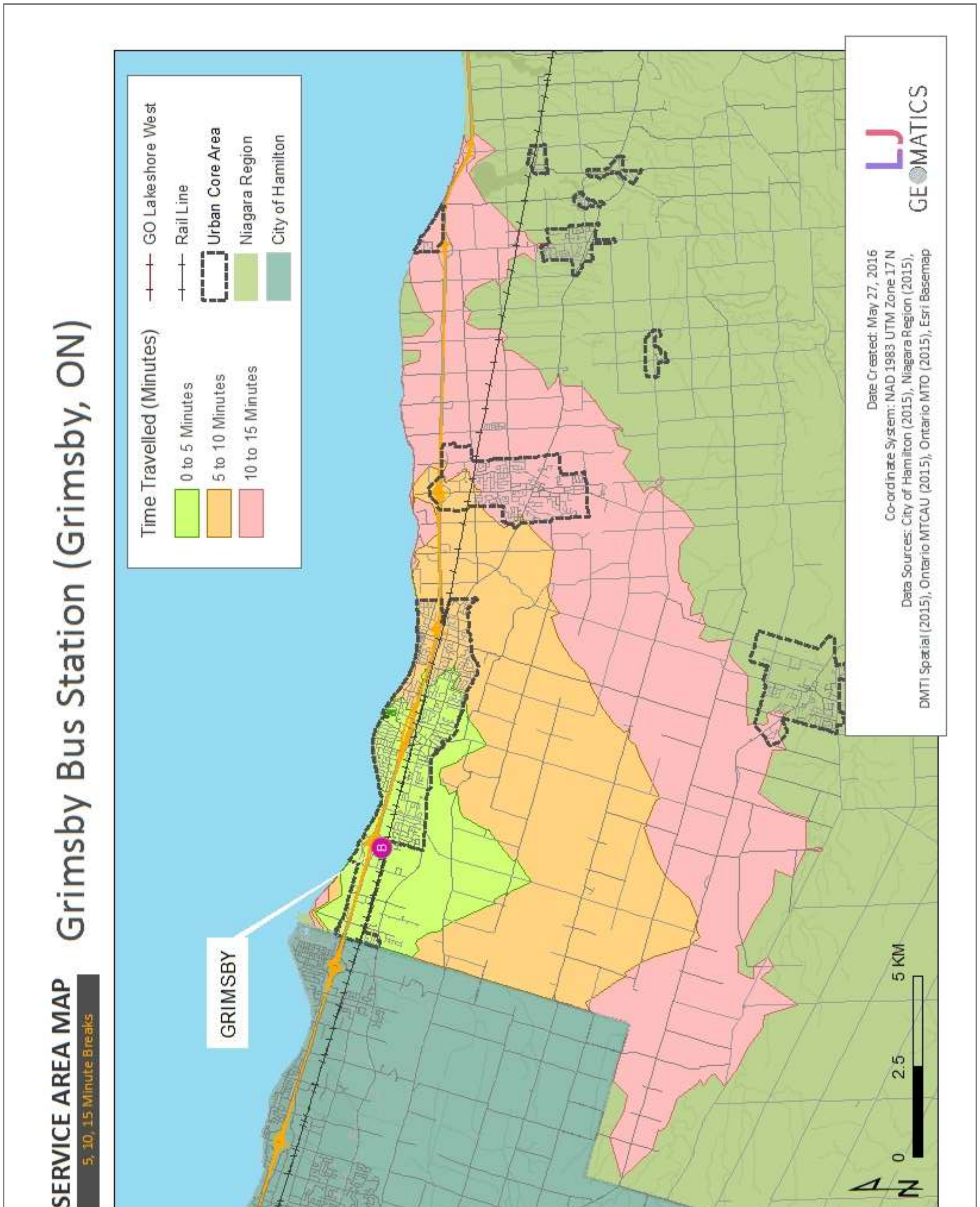

Figure 31: Accessibility of the Grimsby Bus Station in 5, 10, 15 Minutes Segments.

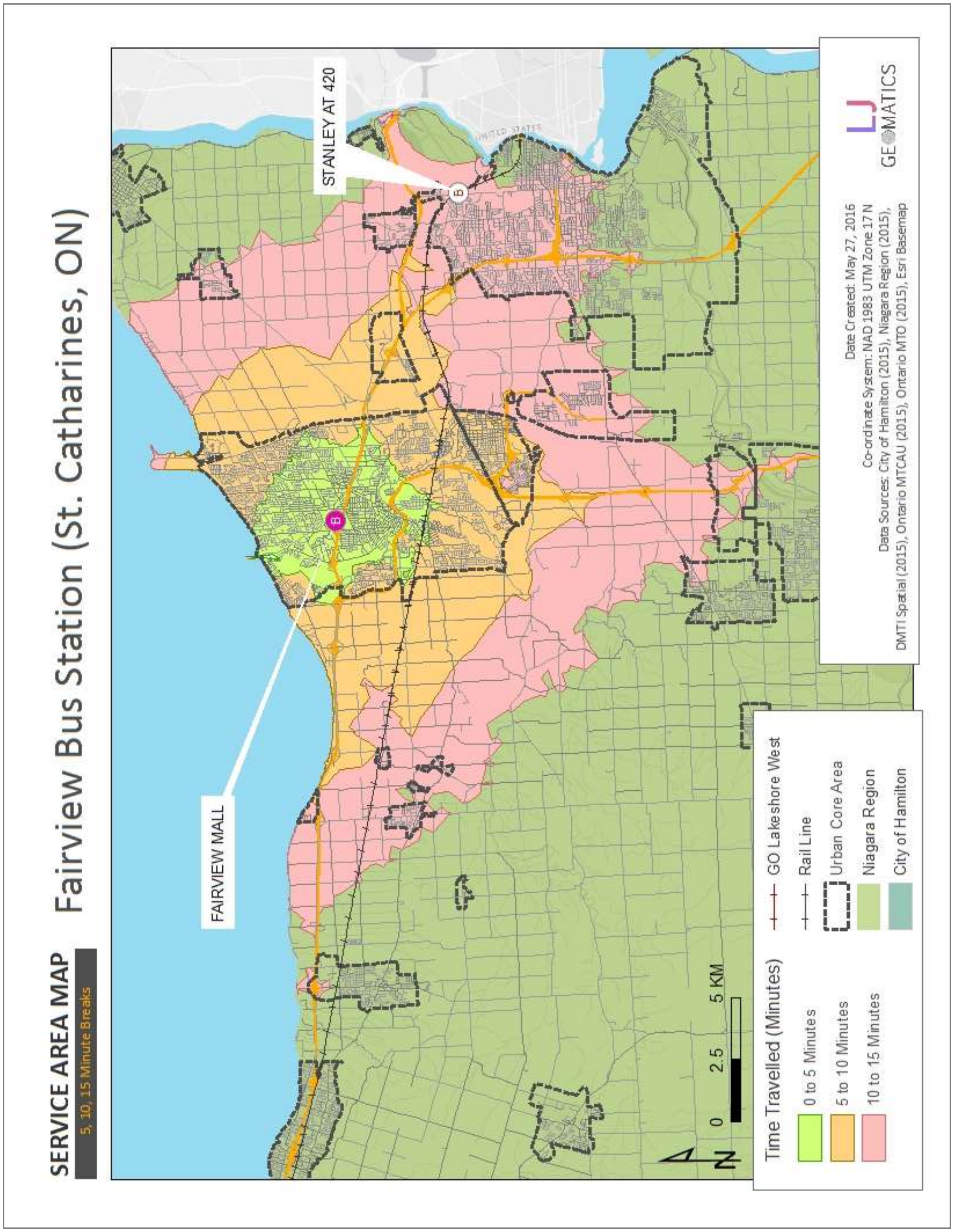

Figure 32: Accessibility of the Fairview Bus Station in 5, 10, 15 Minutes Segments.

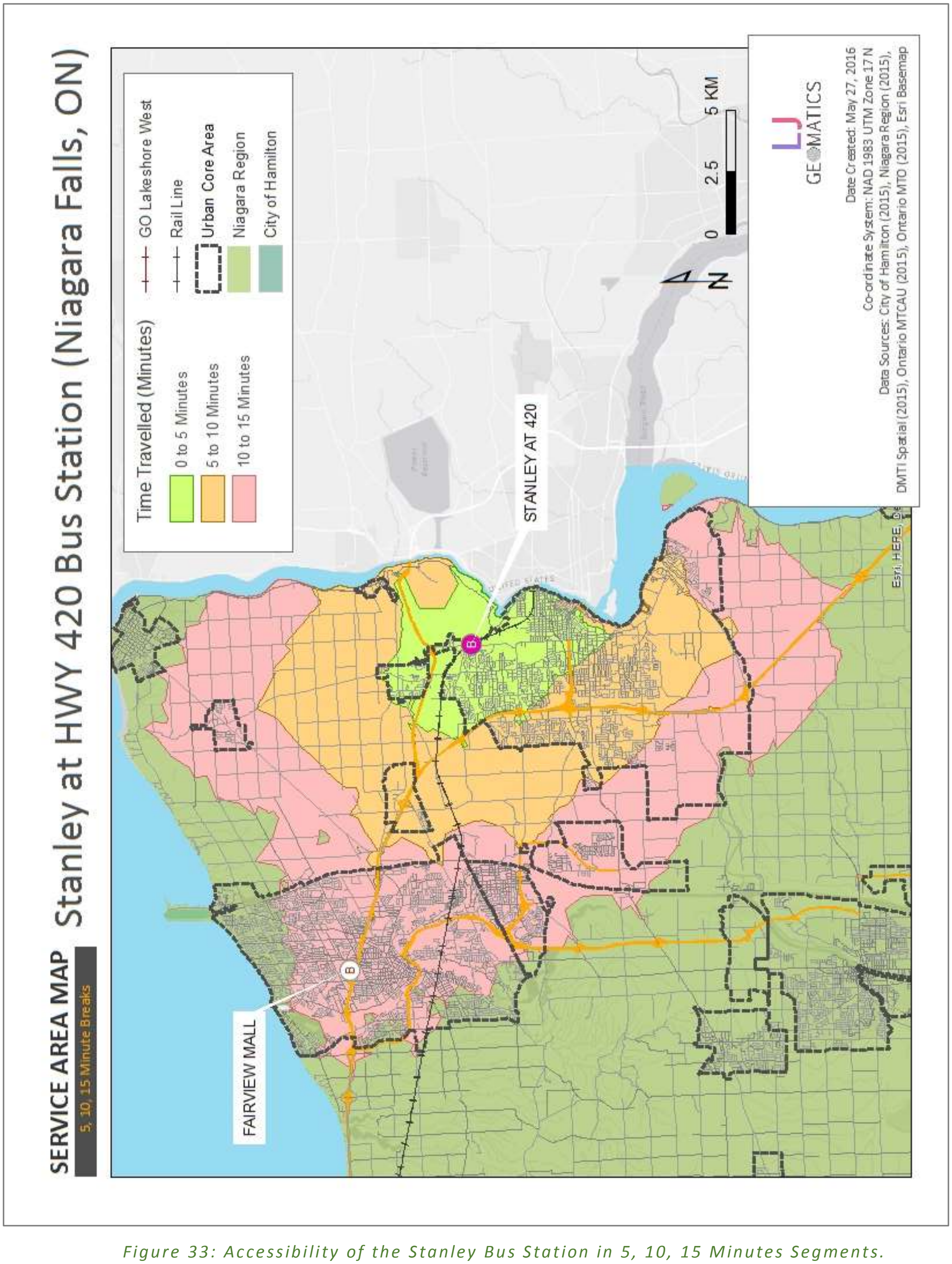

Figure 33: Accessibility of the Stanley Bus Station in 5, 10, 15 Minutes Segments.

4.3 Assessment of Factors: Census Demographics

The methodology in which *LJ Geomatics* chose to conduct this analysis, was to assess factors encouraging transit ridership (Taylor et al., 2003). This was chosen primarily due to the fact that transit use cannot be explained and justified solely on transit service accessibility as previously analyzed and assessed during the network analysis portion. In fact, there are a multitude of factors that come into effect when it comes to how and why an individual may choose to take transit. The approach utilized was to evaluate factors encouraging public transit use. Demographic information from the National Household Survey conducted by Statistics Canada in the years 2006 and 2011 were used. The findings are detailed in the following sections and the factors analyzed were population, vehicle ownership, public transit use, income, and employment. Table 25 below details the relationship of each factors assessed and how they related to ridership.

Table 25: Factors and its Effect on Ridership.

Factor	Description of Factors and its Relationship to Ridership Potential
Population	Increasing population density is positively correlated with ridership potential.
Vehicle Ownership	Decreasing vehicle ownership is positively correlated with ridership potential.
Transit Use	Increasing transit use is positively correlated with ridership potential.
Income	Low income levels are positively correlated with ridership potential.
Employment	Increasing employment density is positively correlated with ridership potential.

4.3.1 Increasing Population Density

As previously established in Table 25, population within the GTHA and Niagara Region were found to be decreasing between 2006 and 2011. However upon close examination, it can be seen that there are three census tracts with significant increase of population density, indicating that these areas are prime candidates to possibly locate new transit stations Figure 34. Furthermore, preliminary research also revealed that the overall population of Niagara Region have an exponential growth by a factor of 0.008 (shown previously in Figure 16). Therefore, it can be concluded that the areas with increasing population density, will have increasing demand for public transit use.

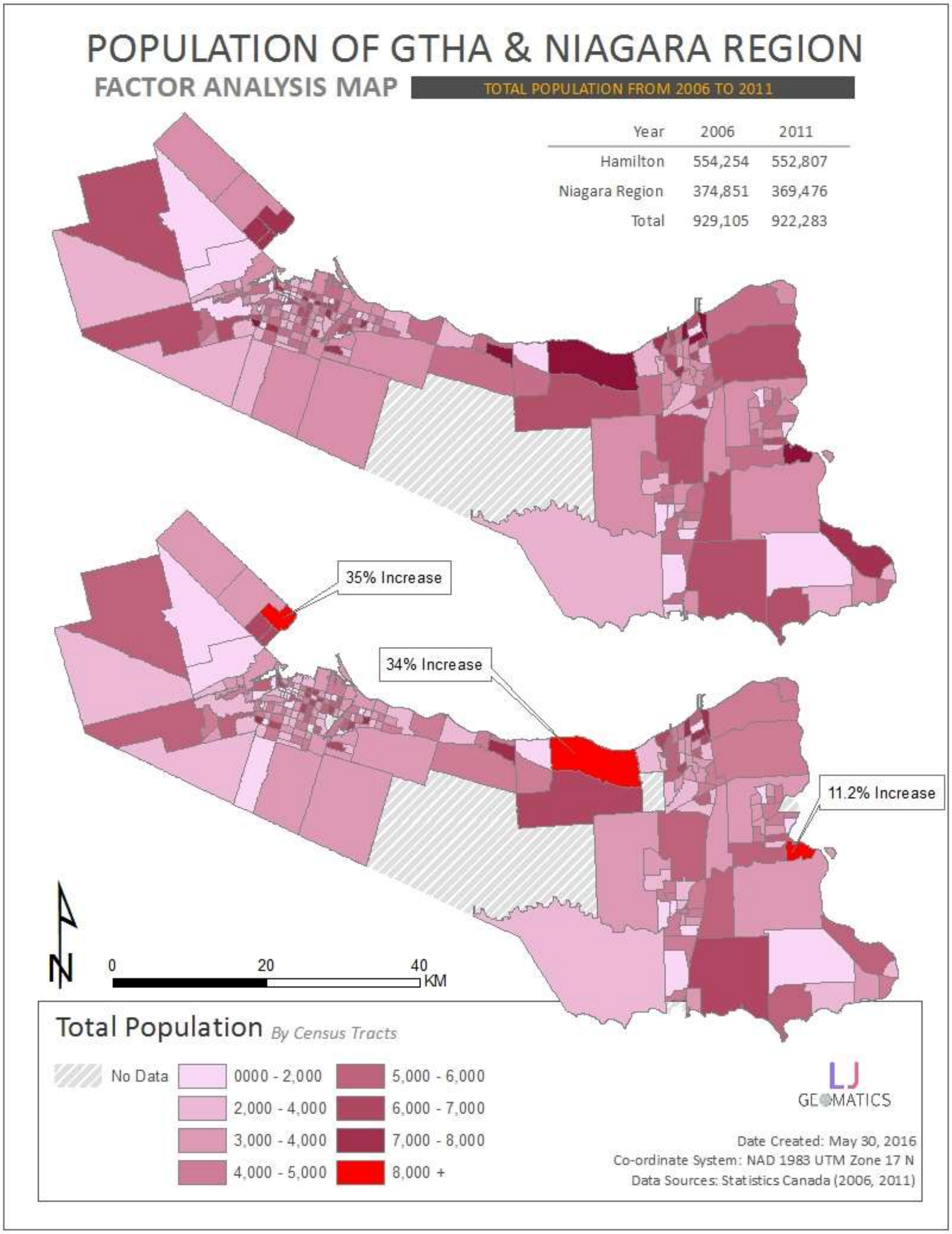

Figure 34: Factor Map of Population within the GTHA and Niagara Region from 2006 to 2011.

4.3.2 Decreasing Reliance Indicated by Decreasing Vehicle Ownership

Between the years 2006 and 2011, it was found that overall vehicle ownership decreased from 364,877 to 350,355. Table 17 previously indicated that there was an overall decrease of vehicle ownership statistics derived from the National Household Survey census data. This is a prime indicator of ridership potential and transit use, as decreasing vehicle ownership can be directly attributed to the rising cost of car ownership.

Upon assessing this factor by census tracts within the study area, it was found that areas on the outskirts of study area such as Wainfleet, Port Colborne, Niagara-on-the-Lake, and Town of Lincoln (Figure 35). Rural areas beyond the urban core of the GTHA also saw an increase of vehicle ownership. This can be explained by the fact that these areas are not often serviced by public transit and also by the fact that rural roads are not walkable distances thus residents in these areas often require a personal vehicle.

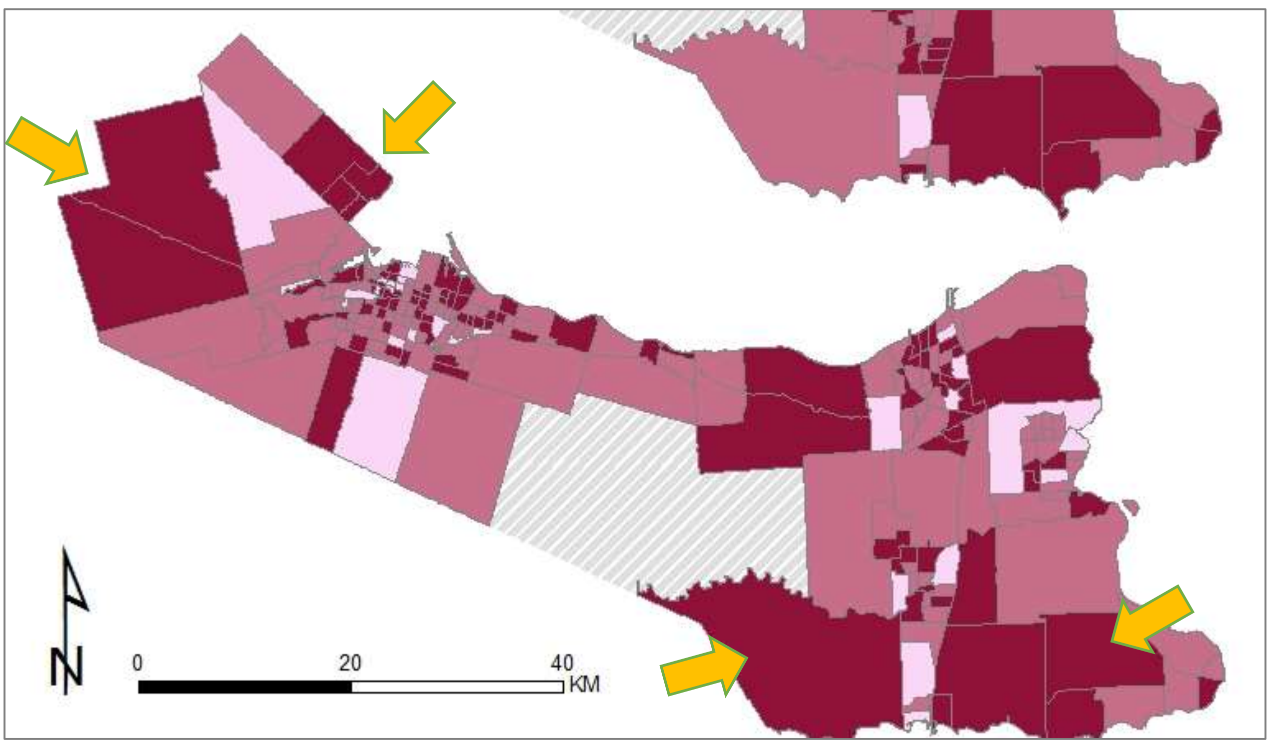

Figure 35: Areas of High Vehicle Ownership Largely Situated on the Outskirts.

Furthermore, a clear relationship can also be gathered from the urbanized areas saw a decrease in vehicle ownership. This further supports and identifies areas where public transit services could consider expanding, to ensure that the supply can meet the demand. Figure 36 on the next page depicts the results of this analysis.

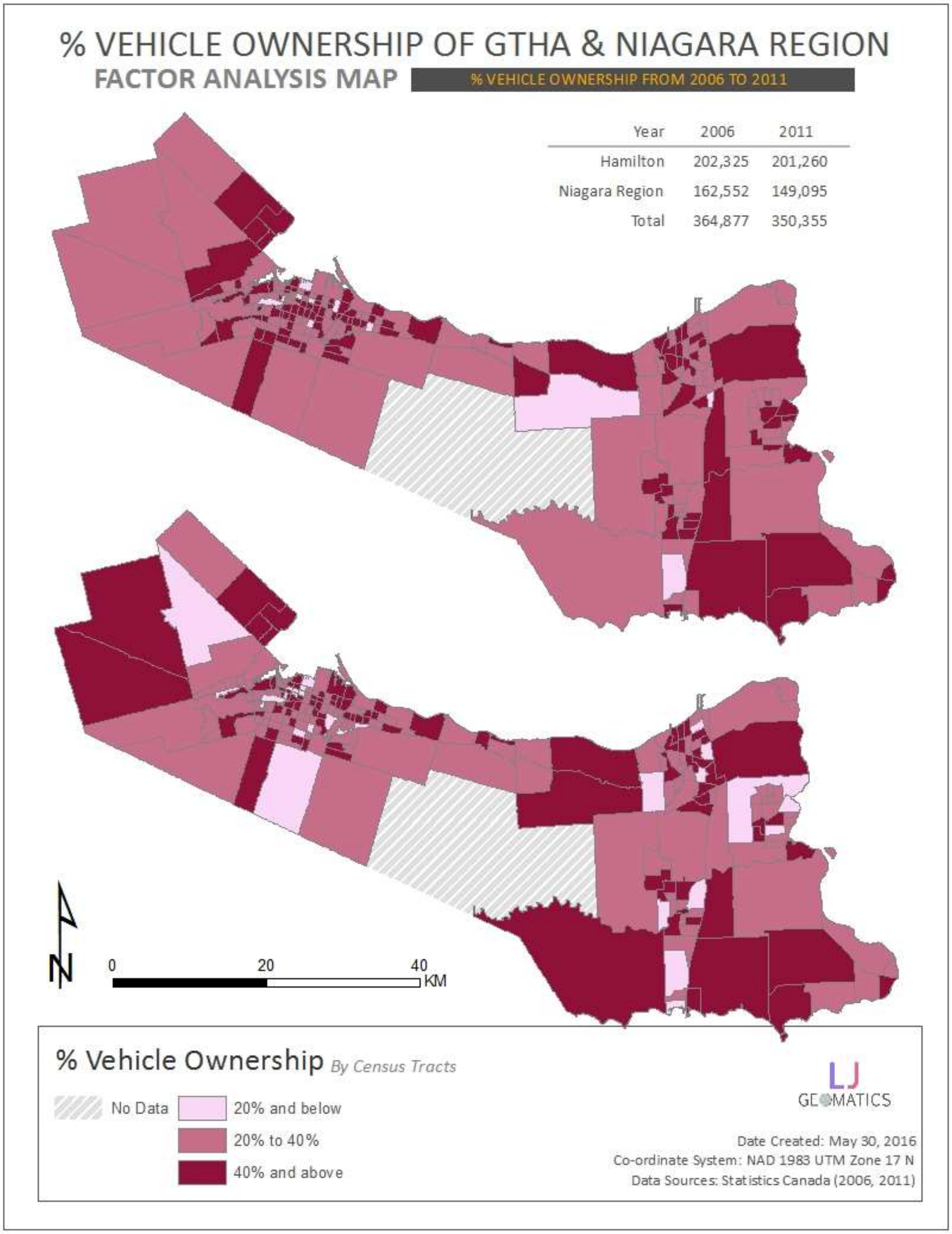

Figure 36: Factor Map of % Vehicle Ownership within the GTHA and Niagara Region from 2006 to 2011.

4.3.3 Steady Public Transit Use

Upon analyzing transit use between 2006 and 2011 (review Table 18), *LJ Geomatics* found that the use of public transit remained relatively steady between 2006 and 2011 (Figure 37). However, mapping this statistic can identify where transit use is the highest in demand. Furthermore, there are areas in which that increased in public transit use within the urban cores of the Niagara Region and GTHA. Again, this information helps to support and identify areas in which to consider expanding transit services to.

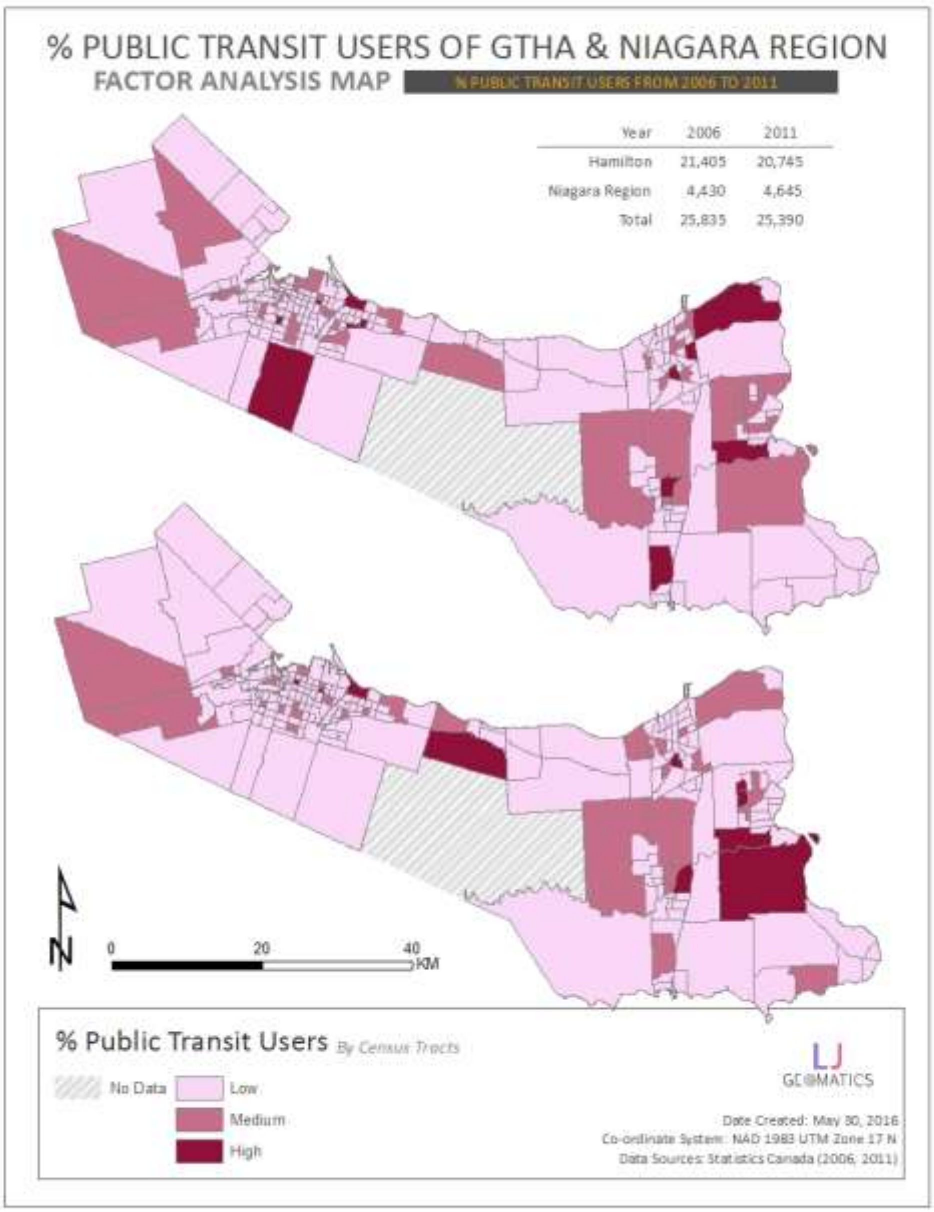

Figure 37: Factor Map of Public Transit Use within the GTHA and Niagara Region from 2006 to 2011.

4.3.4 Relationship of Income Level, Transit Use, and Vehicle Ownership

Upon assessing the income levels, it was found that the correlation between income levels and car-ownership were positively related meaning that the higher the income (median) of a census tract, the higher the vehicle ownership. Furthermore, it also correlates with transit use, where the lower the income area, the higher the transit use. Figure 38 depicts the analysis.

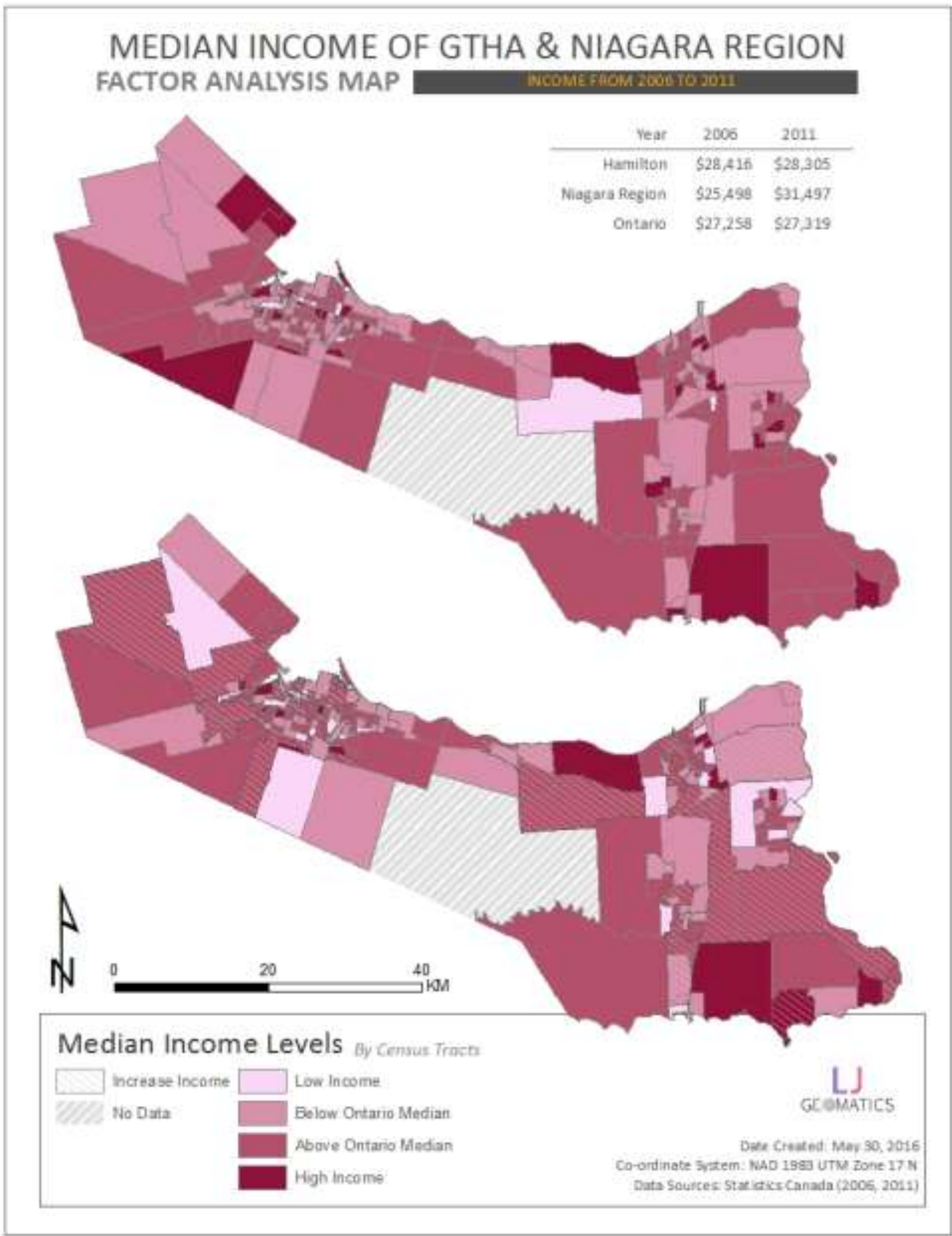

Figure 38: Factor Map of Income Levels within the GTHA and Niagara Region from 2006 to 2011.

4.3.5 Increasing Employment Density around Post-Secondary Institutions

Upon assessing the employment percentages within the study area, it was found that there was an increase in employment from 2006 to 2011. However, Figure 39 depicts the area in which revealed an increase in population density.

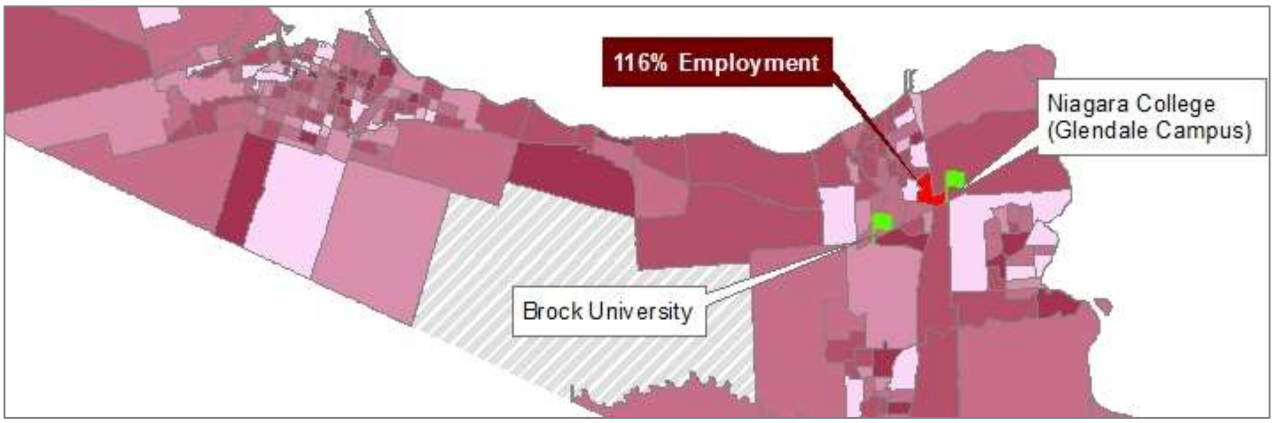

Figure 39: Area Highlighting over 100% Employment with Post-Secondary Institutions (CTUID: 5370007.2)

LJ Geomatics assessed the surrounding points of interest with regards to the census tract ID '5370007.2' and found that it was situated within two post-secondary institutions: Niagara College (Glendale Campus) and Brock University. This provided grounds to believe that the reason for 116% employment within this census tract are due to the student population that resides within this area during the school year working part-time. Figure 40 on the next page depicts the percentage of employment within the GTHA and Niagara Region from 2006 to 2011.

From this, the project team was able to conclude that a major source of demand must be coming from the student population. This coincided with the rest of the analysis thus far since students fit the demographic of those who do not have the income level to have direct access to their own vehicles. The next section details the findings of the student ridership in which were examined.

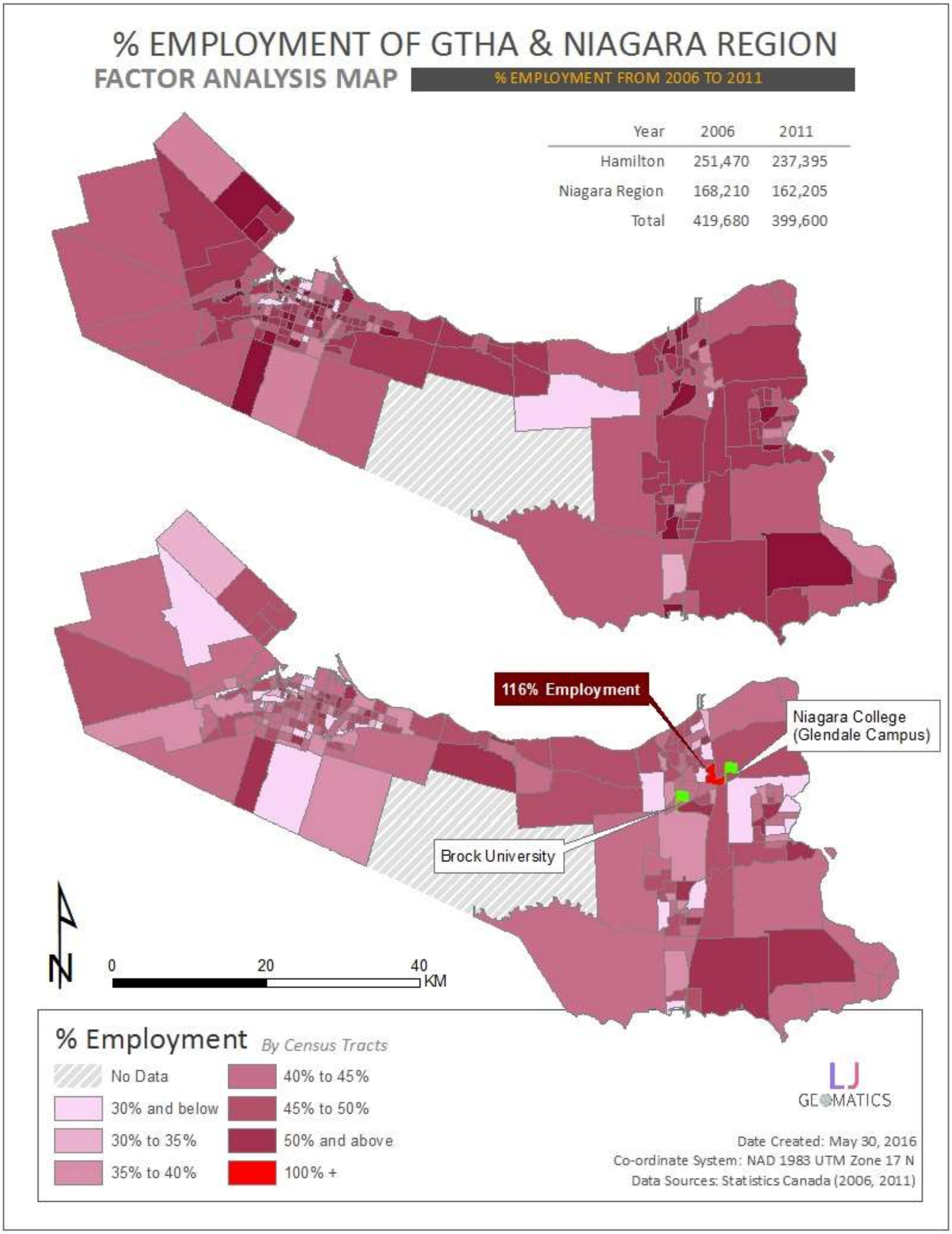

Figure 40: Factor Map of % Employment within the GTHA and Niagara Region from 2006 to 2011.

4.3.6 Education – Student Ridership

In order to further examine the contribution of youth and students to ridership demands, the Total Annual Ridership and the Total U-pass Ridership were further examined. The methodology of the analysis were outlined previously in section 3.2.6 Education – Student Ridership. A general upward trend was noted and it was found that a large majority of the Total Annual Ridership comes from U-pass holders whom are students.

Furthermore, it was found that 40% of the ridership were from students alone. Although this statistics is for the local Niagara Region transit, the statement that post-secondary students are more likely to take public transit can be supported by the fact that Niagara Region is currently working on fixing the routes to re-establish the Brock U-pass for the following academic year. Hence, that the percentage of ridership from Brock University is likely to increase in future.

The enrollment profile of Niagara College was also examined spatially, where students attending post-secondary institutions and do not have a permanent address within the Niagara Region were distinguished from the students with a permanent address within the Niagara Region. It was found that the number of students from outside the region is steadily increasing by 2.15% or approximately 6,500 students annually. It is likely that these students would benefit from an inter-municipal transit system to allow them to travel to and from the GTHA or GTA. They are indeed major contributors to ridership potential especially due to their increasing enrollment.

In summary, there are grounds to believe that there is a significant demand for better transit options from the college/university student community, especially since there are an increasing number of students that are willing to travel from outside the study area to study within the GTHA and Niagara Region.

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4.4 Determining Commuter Profile

Upon assessing the factors that have an encouraging effect on ridership, the idea commuter profile for the GTHA and Niagara Region was determined. This profile was established by assessing statistical correlations between certain demographics (National Household Survey Census, 2006; 2011), regional ridership data, and post-secondary enrollment student attributes. From this assessment, *LJ Geomatics* developed a framework in which can be applied to any region to identify commuter profile (Figure 41).

Figure 41: Framework to Identify Commuter Profile.

The purpose of the commuter profile identification, is important in determining ridership potential. By assessing and identifying who is demanding the service, *LJ Geomatics* and other transit agencies can better understand how to cater services, and determine what supply. Following this, ridership potential can then be quantified in terms of being able to determine the appropriate level of service to cater to the needs within the study area. To view a full version of the framework and score sheet, refer to appendix no. 10.

5.0 SUMMARY OF ROUTE OPTIONS

Upon quantifying how much ridership is present within the overall GO Transit system, ridership potential for the GTHA and Niagara Region were quantified. Further the analysis, alternative routes were developed based on the needs of the commuter profile for the GTHA and Niagara Region. An assessment of expenditures and revenues were then conducted for each of the options below.

In order to calculate the Net Operation Costs, the train operation costs (section 3.4.1.2), equipment maintenance cost (section 3.4.1.4), and stations and facilities (section 3.4.1.5) were considered. For the costs associated with train operation and equipment maintenance were calculated by estimating the respective costs per kilometer, and then scaled to the proposed route distance.

The stations and facilities cost was derived from VIA Annual Reports since most VIA Rail stations in Canada are located with the premises of a GO Rail or Bus station.

As mentioned in section 3.4.2.3; the Total Ridership for Hamilton and Niagara regions was obtained by proportionally scaling the proposed distance travelled by a bus to the total distance annually covered by buses. Since a significant portion of the revenue for public transit is derived from fares paid.

In order to appropriately determine the Total Revenue Target required to off-set the cost, the ratio between operation costs and total revenue for the 2014-2015 fiscal year was calculated, and then multiplied by the operation costs. Therefore, it is important to note that this does not imply the profit margin.

The forecasted revenue was obtained from by multiplying the fare of the travel (as determined in section 3.4.2.1) to the expected ridership. For more details, please refer to section 3.4.2.3.

5.1 Option A: Weekday GO Train Service

This option is an extension of the currently existing Lakeshore West Line that goes from Union Station to Burlington GO Station. Four additional stops in the Hamilton-Niagara region include Hamilton GO Center, Stoney Creek, St. Catharines and Niagara Falls.

Table 26: Summary of Option A Details of Cost and Revenue Targets.

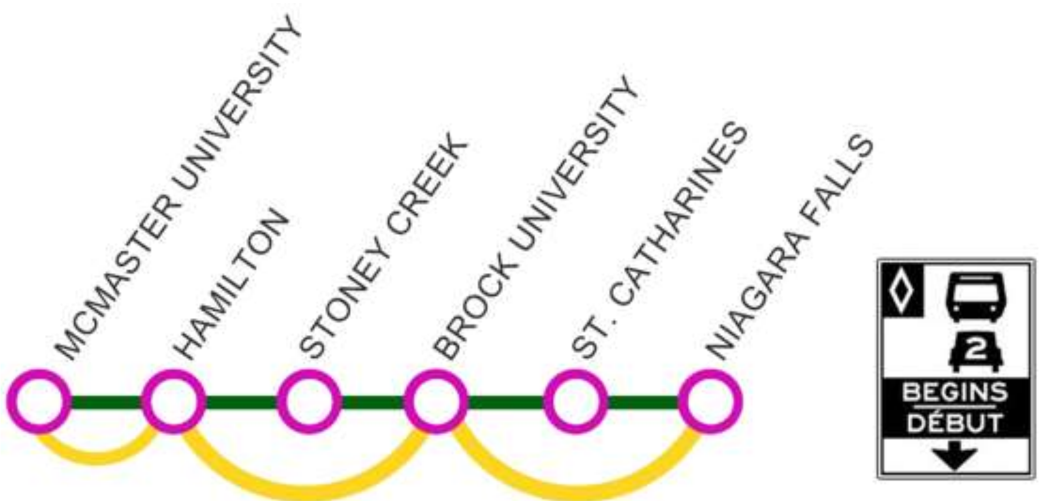
Details		Return on Investment	
Distance of Proposed Option (km)	70	Operations Costs	$1.04 - $1.5 million
No. of Trips per Day	4	Forecasted Revenue	$460,000
Total Distance Travelled per Day	280	Revenue Target	$2.7 million
Annual No. of Trips	1,265	Forecasted Ridership	32,000
Total Annual Travelled Distance	88,550	Ridership Target	188,600

This option would cost about $1.04 million to $1.5 million. The revenue target required to off-set the cost is $2.7 million. However, the forecasted ridership is 32,000 and makes up only 17% of the annual ridership target required to off-set the cost. Likewise, the forecasted revenue would also be only 17% of the target revenue which is $460,000 of the $2.7 million.

5.2 Option B: Weekday GO Bus Express Service and HOV Lane

Option B is the weekday peak time bus service option with the implementation of HOV lanes. Since the ideal commuter was previously established (in section 4.4) to be a post-secondary student, Option B proposes an express bus service that connects the major education institutions within the Niagara-Hamilton regions, such as McMaster University, Mohawk College, Brock University, and Niagara College.

Table 27: Summary of Option B Details of Cost and Revenue Targets.



Details		Return on Investment	
Distance of Proposed Option (km)	94	Operations Costs	%564,000 to $601,600
No. of Trips per Day	4	Forecasted Revenue	$120,000
Total Distance Travelled per Day	376	Revenue Target	$1.5 million
Annual No. of Trips	800	Forecasted Ridership	9,500
Total Annual Travelled Distance	75,200	Ridership Target	116,000

Option B would cost about $564,000 to $601,600. And the revenue target required to off-set the cost is $1.5 million. HOV lane implementation from Grimsby to Red Hill Valley Parkway would cost an additional $71,100. In implementation the HOV lanes within this stretch of 15 km; 192 out of 450 cars will be removed from traffic during the average weekday peak time.

The forecasted ridership is 9,500 and makes up only 8% of the annual ridership target required to off-set the cost. Likewise, the forecasted revenue would also be only 8% of the target revenue, i.e.; $120,000 of $1.5 million.

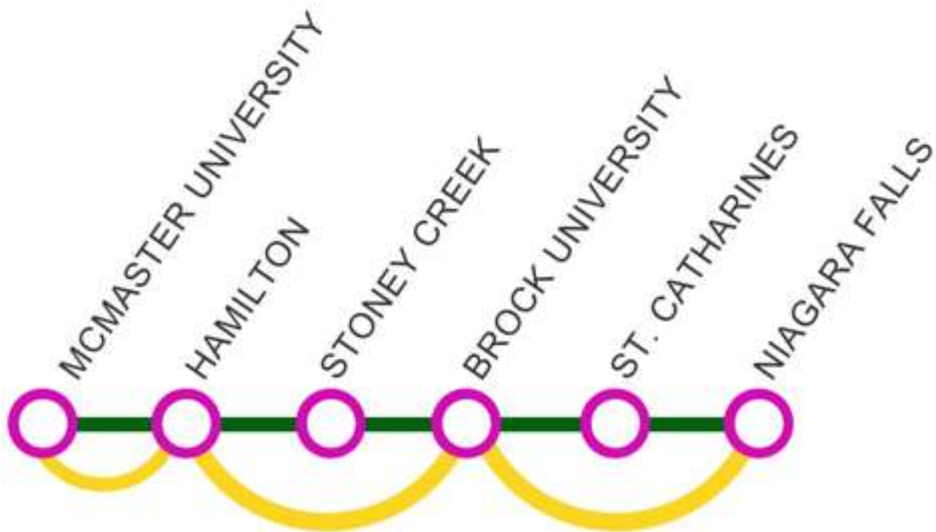
On average, congestion occurs at the threshold point of 1 car per-lane-per-two-seconds. Hence, from the threshold point, the number of additional cars within the segment of the QEW can be determined. Since on average there are 1.15 persons travelling in a car, the number of buses required to displace these people can be determined to be four.

5.3 Option C: Weekday GO Bus Express Service

In Option C, the implementation of the HOV lanes are not included. Despite the exclusion of the HOV lanes, Option C suggests proposes to retain the express bus services that connects the major education institutions within the Niagara-Hamilton regions, such as McMaster University, Mohawk College, Brock University, and Niagara College.

The calculation of Operation Costs, Forecasted Ridership, Ridership Target, Forecasted Revenue, and Target Revenue have been prepared in the same manner as Option B.

Table 28: Summary of Option C Details of Cost and Revenue Targets.



Details		Return on Investment	
Distance of Proposed Option (km)	94	Operations Costs	$564,000 to $601,600
No. of Trips per Day	4	Forecasted Revenue	$120,000
Total Distance Travelled per Day	376	Revenue Target	$1.5 million
Annual No. of Trips	800	Forecasted Ridership	9,500
Total Annual Travelled Distance	75,200	Ridership Target	116,000

Option C would cost about $564,000 to $601,600. And the revenue target required to off-set the cost is $1.5 million. However, the forecasted ridership is 9,500 and makes up only 8% of the annual ridership target required to off-set the cost. Likewise, the forecasted revenue would also be only 8% of the target revenue which is $120,000 of $1.5 million.

5.4 Option D: Do Nothing

Option D is a *'Do Nothing'* option, where nothing will be expanded, no new routes will be put in place, and the existing services between the GTHA and Niagara Regions will remain as is.

Under Option D, the only train servicing the Niagara and Hamilton regions belong to VIA Rail Canada. The stations in Niagara Region include Grimsby, St. Catharines and Niagara Falls, and the only station being serviced by VIA in the Hamilton Region is Aldershot. The VIA Rail only services one round trip every weekday. It costs $45 to $50 and takes about 1.25 hours.

The currently existing Summer Go Rail service from Union Station to Niagara Falls will remain. The stations in Niagara Region include St. Catharines and Niagara Falls, and there are no stations being serviced in the Hamilton Region. There are a total of 4 round trips every day. It costs $18 to $20 and takes about 2.0 hours.

Additionally, under Option D the currently existing GO Bus Services will remain. The stations in Niagara Region include Grimsby, St. Catharines and Niagara Falls, and the only station being serviced in the Hamilton Region is Stoney Creek. There are 15-18 trips and other peak service hour trips. It costs $13 to $18 and takes about 1.5 to 2.5 hours.

5.5 Choosing the Best Suitable Option

The options were developed based on the needs of the commuter profile that had been previously identified for the type of commuter that is likely to take public transit. Table 29 below details a checklist to identify how the new options satisfy the demand within the GTHA and Niagara Region.

Table 29: Checklist to Identify Suitable Option.

	Option A	Option B	Option C	Option D
Demographic	✔	✔	✔	✔
Accessibility	✔	✔	✔	✘
Time/Convenience	✔	✔	✔	✘
Affordability	✔	✔	✔	✔
Cost-Effectiveness	?	?	?	?

As mentioned in previous sections, option D, which is the current existing service levels, did not satisfy the demand of the current existing landscape within the GTHA and Niagara Region. The resulting options (A to C) were developed to ensure that the demand is adequately supplied for the commuter profile that has been identified. To re-iterate, the commuter profile of the GTHA and Niagara Region are those individuals that are students, who has no access to their own vehicles, are either employed or unemployed, and am willing to travel 15 to 30 minutes to work, and has an annual income of less than $13,650.

To continue with the analysis and to identify the best suitable option that is the most cost-effective, an assessment of expenditures and revenues were conducted. A full breakdown of the expenditures and revenues can be found in appendix no. 9.

Table 30: Overview of Assessment of Cost.

	A	B	C	D
Equipment Maintenance	$17,710	$90,240	$90,240	-
Facilities	$250,000	$65,000	$65,000	-
Operation Costs	$1,040,463	$564,000	$564,000	-
Station Site Development	$11,200,000	$5,950,000	$5,950,000	-
Other Costs	-	$71,100	-	-
Sub-Total	$12,518,173	$6,740,340	$16,669,240	-
Contingency (10%)	$1,251,817	$674,034	$666,924	-
Grand Total Expenditures	**$13,769,990**	**$7,414,374**	**$7,336,164**	**-**

Since it had already been established that government funding were approved for expansion/extension projects, the station site development can be then entered into the revenue line as per government funding shown below in Table 31. The revenue assessment also took into consideration the evaluation of social benefits.

Table 31: Overview of Assessment of Revenues.

	A	B	C	D
Ridership Outlook	31,000	9,413	9,413	-
Revenue Outlook	$444,850	$119,068	$65,000	-
Government Funding	$11,200,000	$6,021,100	$5,950,000	-
ASSESSMENT OF SOCIAL BENEFITS				
Carbon Emission Reduction	$43,948	$4,852	$4,852	-
Time Saved in Traffic ($)	$1,680,840	$1,680,840	$1,680,840	($1,450,000,000)
Grand Total Revenues	**$13,769,990**	**$7,414,374**	**$7,336,164**	**($1,450,000,000)**

Table 32 details the assessment of the revenues of each option, identifying that the best and most suitable option is option C which is a weekday express bus service.

Table 32: Overview of Cost-Benefit Analysis of Route Options.

	A	B	C	D
Total Expenditure	$13,769,990	$7,414,374	$7,336,164	-
Total Revenue	$13,369,638	$7,825,860	$7,754,760	($1,450,000,000)
Net Difference	**($400,352)**	**$411,486**	**$418,596**	**($1,450,000,000)**
Cost-Effective	✗	✓	✓	✗

From this assessment, it can be identified that option D is indeed, not the most effective option. In fact, continuing on with the current existing level of service, will result in a loss of nearly $1.45 billion just in first year. This value can be expected to increase over the years if nothing is implemented to alleviate traffic congestion.

6.0 SUMMARY OF RECOMMENDATIONS

From the analysis, LJ Geomatics is able to conclude that the most cost effective route alternative was a proposed by Option C. Option C is a weekday, express bus service that will make a total of 4 stops between McMaster University, Hamilton Centre, Brock University, and Niagara Falls. The recommended fare for this option is $13.50, with two trips in the morning peak time (between 6 to 9 AM) and two trips in the evening peak time (between 4 to 6 PM).

In terms of operation and set up costs, Option B and Option C were concluded to be the most effective; since buses are more cost-effective than trains in general. Despite there being more maintenance costs associated with buses, due to the fact that net operation costs are higher than maintenance costs, and since the expected ridership target is not met by a large margin; train service (Option A) was not a viable option. Additionally, since the expected commuter is an out-of-Niagara-Region post-secondary student, it is imperative to note that the mode of travel should have to means to connect the post-secondary institutions within municipalities.

A bigger challenge that the expected commuter will face if Option A was implement is the issue of unreliable, infrequent or non-existent municipal transit systems. This would encourage the commuter to opt for personal vehicles instead of public transit, which would only further increase the traffic congestions and reduce public transit ridership. Since, vehicle ownership and most post-secondary students are neither vehicle-owners.

Hence, Option A is not recommended unless the municipalities within the Niagara region improve their municipal transit systems and service times to cater to the needs of the expected commuter.

Although Option D does not reflect any immediate costs, on taking into account the economic loss and carbon emissions with increasing traffic; doing nothing to improve the situation is the least desirable. This is because not taking any mitigation strategies will not improve the financial and economic conditions of the Niagara Region.

Option B and Option C differ only in terms of costs associated with HOV lanes. The net profit margin between the two options only differ by approximately $7,000; where Option C creates revenue of approximately $7,000 since Option C has no HOV lanes. Although, it is also important to note that the cost associated with implementation of HOV lanes is a one-time cost. Otherwise, the grand total revenue for Option B and Option C would be the identical.

HOV lanes was estimated to reduce the traffic volume by approximately 7%, resulting in a removal of about 192 cars during rush hour, and creating a profit of approximately $3,000. However, the effects of implementing of HOV lanes was not studied in detail and was beyond the scope of this report, as the results may vary with location, time of day, direction of traffic flow, etc.; and therefore, the above mentioned profit was not included in the analyses.

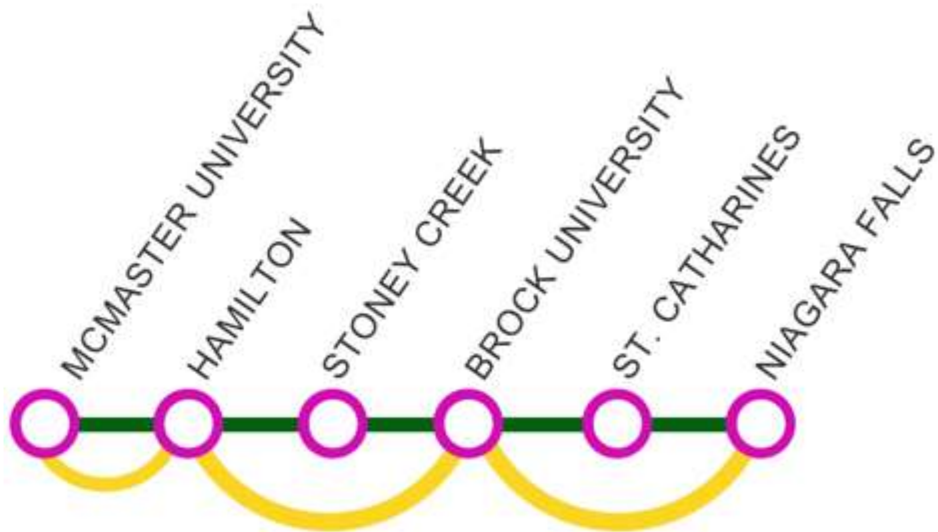


Figure 42: Depiction of the Recommended Route Alternative.

Therefore, this option is ideal as it is the most suitable for the commuter profile of the GTHA and Niagara Region. It is also an affordable and accessible addition to the existing services, and promotes 'investment-readiness' in the regions.

6.1 Recommended Future Studies

If any research or consulting team chooses to perform further analyses on section(s) of this report, or reassess the results obtained in this report; *LJ Geomatics* recommends that in order to produce more accurate results with a better estimation the data sets used needs to updated.

An updated traffic volume data (AADT) that includes traffic volumes for 2011 to 2016 can be included for more accurate modelling of traffic flow analyses.

Likewise, in order to obtain a better perception of the qualitative factors affecting ridership, it is recommended that the 2016 census data be included in the analyses pertaining to the census profiles in this report.

Additionally, the cost and revenue estimations may be performed with updated values, or a different approach may be taken to estimate the costs and revenue depending on the available data acquired by the respective team.

Also if Option B is to be considered, LJ Geomatics consultants would recommend that a detailed study be conducted into the benefits and costs associated with the implementation of HOV lanes in the Niagara and Hamilton Regions.

7.0 PROJECT MANAGEMENT

The project began on **October 1st, 2015** and will continue through to **June 10th, 2016**. The total cost of this research project was previously estimated at **$29,535 (CAD)** (not including the Ontario Provincial tax rate of 13% HST) at the proposal phase of the research. However, during the progress update, *LJ Geomatics* realized the challenges and issues regarding data acquisition, which results in an increase in budget to **$32,050 (CAD)** (not including the Ontario Provincial tax rate of 13% HST). Table 33 below details difference.

Table 33: Overview of Project Activity Budgeted versus Actual Costs

Summary of Estimated Work and Cost of Resources	Work Estimated	425.75 hours, 200 days	
	Resource Costs (per hour)	Alice Lin – Project Manager	$80.00
		Jasmine Joy – Principal GIS Analyst	$60.00
		Mike Wallace – Project Advisor	$110.00

	Initial Budget	New Budget	Actual Final Cost
Meetings	$2,650	$3,340	$3,420
Project Proposal	$3,360	$2,460	$2,455
Data Acquisition & Analysis	$6,930	$11,700	$10,610
Select GIS-Based Model	$2,450	$1,120	$1,200
Progress Report	$2,040	$4,040	$3,735
Apply GIS-Based Model	$3,780	$3,100	$2,690
Identify Cost-Effective Route(s) & Options	$3,875	$3,470	$3,220
Final Report	$2,450	$2,870	$2,720
Consultation Fee	$2,000	$2,000	$2,000
Sub-Total	$29,535	$34,100	$32,050
Provincial Taxes (13%)	$3,840	$4,433	$4,167
Total	**$33,375**	**$38,535**	**$36,220**

It can be seen that although the project team had initially proposed an increase in budget, most of it was dispersed to the data acquisition and analysis phase, and that actual final cost of the project turned out to be the same as the initial proposed budget. What was realized was the during the progress phase, *LJ Geomatics* was able to gauge better in terms of how much time specific tasks will be taking, and thus was able to stay on budget and on schedule. Figure 43 and Figure 44 depicts the breakdown of the budgeted versus the actual costs. **Important Disclaimer: This aspect of the proposal is for educational purposes and in no way does the client have to pay for these services. This project has been donated by the students and staff of Niagara College.*

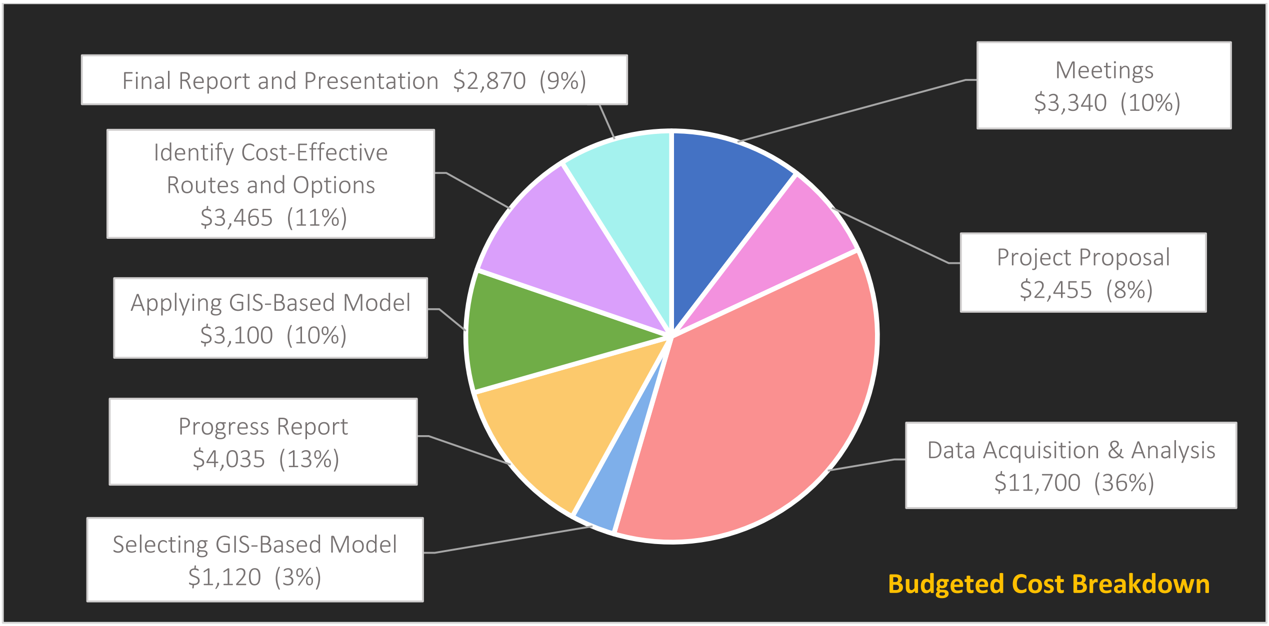


Figure 43: Overview of Budgeted Cost Breakdown.

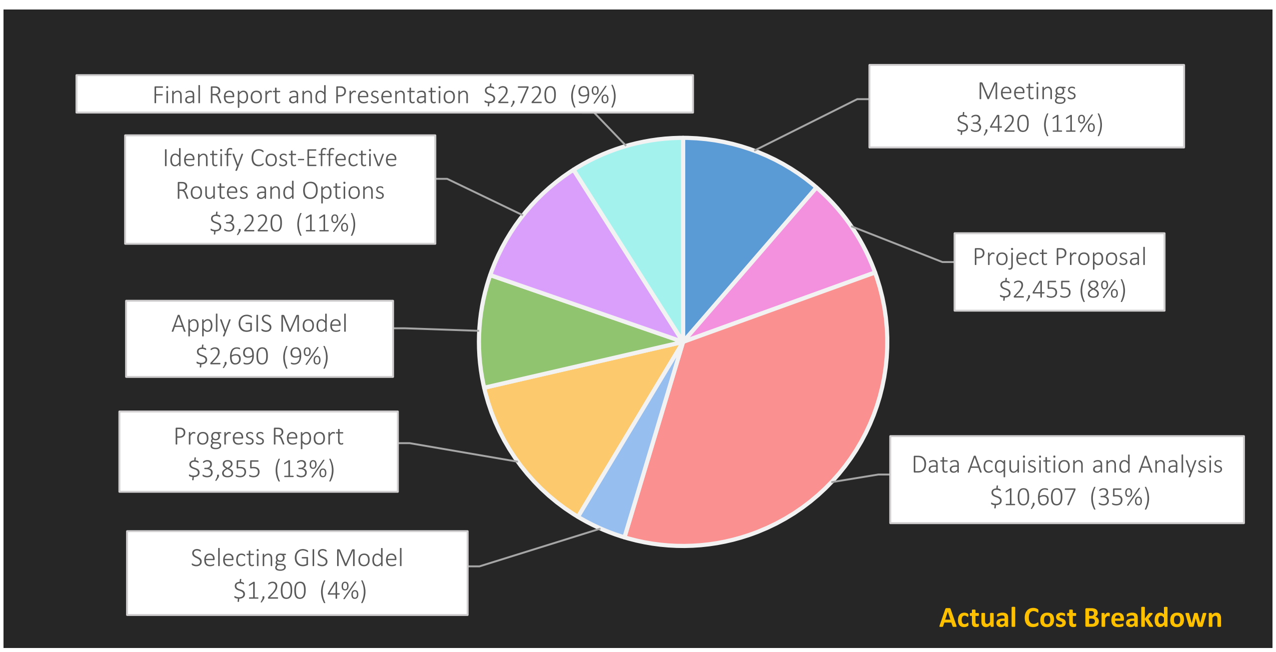


Figure 44: Overview of Actual Cost Breakdown.

Furthermore, the development of the project schedule is an important component in completing a successful research project as it allows the project team to effectively manage time and resources. A new and updated budget has been included along with a new estimate of costs/budget to account for challenges encountered. Detailed breakdowns of the project schedule are discussed in the following pages, and the full work breakdown structure document can be found in the appendix.

7.1 Meetings

The *LJ Geomatics* team had met periodically throughout the year with the client and project advisor. Client meetings were less than originally anticipated due to client's business and travel schedule. However, advisor meetings continued to take place regularly on a bi-weekly basis at the Niagara College. Table 34 below details the budgeted and actual cost and times.

Table 34: Overview of Meeting Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Client Meetings	18	$1,340	14	$1,020	-24%
Advisor Meetings	24	$2,000	26	$2,400	+20%
	42	$3,340	40	$3,420	+ 2%

7.2 Project Proposal

The project proposal had already been completed as it was scheduled to run from October 1, 2015 to December 11, 2015. Table 35 below outlines the major tasks of this activity's tasks.

Table 35: Overview of Project Proposal Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Understanding Project	6	$420	10	$700	+67%
Establishing Work Plan Schedule	5	$380	1.75	$140	-63%
Completing Project Overview Statement	7	$570	4	$280	-51%
Identifying Data Needs/Literature Review	16	$1,120	8	$560	-50%
Determining Boundaries for Study Area	5	$380	4	$300	-20%
Proposal Presentation	7	$490	6.5	$455	-7%
TOTAL	45	$3,360	35	$2,455	-27%

7.3 Data Acquisition & Data Analysis

This activity is with regards to identifying ridership potential and other relevant factors affecting ridership. This activity officially commenced on November 16, 2015 and was previously scheduled for completion on February 5, 2016. However, data desired for this component was not officially acquired and fully analyzed until March 11, 2016. Table 36 below details the breakdown for this activity.

Table 36: Overview of Data Acquisition & Data Analysis Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Identifying Ridership Potential	80	$5,600	70	$5,100	-9%
Identifying Relevant Factors	75	$4,900	70	$4,550	-7%
Creating Maps	15	$1,200	12	$960	-20%
TOTAL	170	$11,700	152	$10,610	-9%

7.4 Select GIS-Based Model

This activity was composed of a series of literature review of similar research projects/efforts to narrow down what GIS-based model can be applied to this research. Some models, such as EMME, turned out to not be necessary for this project and thus were not used. The analysis methods that were reviewed are cost-benefit analysis and a list of spatial analyst extension tools based in ArcGIS. They are: network analysis, route analysis, path distribution analysis, and corridor analysis. The only extension that was used in the end was the network analysis to identify accessibility of current existing stations. The other one that was not on the list but was utilized was the IDW surface analysis of the Geostatistical Analyst. Table 37 outlines the details of the budget and actual time/cost of this activity.

Table 37: Overview of Selecting GIS-Based Model Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Review Necessity of GIS-Based Models	16	$1,120	17	$1,200	+7%

7.5 Progress Report

The progress report included summarizing the percentage of work completed, and identifying remaining work. It was also crucial in identifying areas where the budget had needed to be re-assessed. During this part of the project, a mitigation plan was also developed as a precautionary measure to ensure that data integrity can be maintained, and that the overall project remains on schedule and on budget. Table 38 below details the complete task breakdowns and a comparison of the budget and actual final costs.

Table 38: Overview of Progress Report Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Work Completed	1	$80	1	$80	0%
Work Remaining	1	$80	1	$80	0%
Summary of Challenges and Issues	20	$1,300	21	$1,420	+9%
Bi-Weekly Status Reports	15	$1,080	12	$860	-20%
Cost of the Research Thus Far	4	$320	2	$160	-50%
Progress Report and Presentation	16.5	$1,175	16	$1,135	-3%
TOTAL	57.5	$4,040	53	$3,735	-7%

7.6 Applying GIS-Based Model

This activity included a visualization of the data preparation and data processing phases of the project by creating a diagram that is similar to how model builder diagrams are structured. It also included creating factors maps, which visualized population, vehicle ownership, transit use, and employment within the GTHA and Niagara Region. Table 39 below details the complete task breakdowns and a comparison of the budget and actual final costs.

Table 39: Overview of Applying GIS-Based Model Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Factor Maps	50	$3,500	31.75	$2,540	-27%
Depicting Data Preparation Diagram	2	$150	1	$75	-50%
Depicting Data Processing Diagram	2	$150	1	$75	-50%
TOTAL	54	$3,100	33.75	$2,690	-13%

7.7 Identifying the Most Cost-Effective Route Option

This last activity was the final stretch of the research project. A significant amount of time were used to assess the most cost effective route option as the data obtained through open sources were not standardized and not accessible. Table 40 outlines the details of the budget and actual time/cost of this activity.

Table 40: Overview of Identifying Most Cost-Effective Route Options Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Analyzing Route Options	25	$1,625	40	$2,600	+60%
Identifying Most Cost-Effective Route	20	$1,400	8	$520	-63%
Creating Map of the Best Option	6	$420	1	$80	-80%
TOTAL	51	$3,470	49	$3,220	-7%

7.8 Final Report and Presentation

The final task of this project is to compost this final report and create a presentation which took place on June 8, 2016. Table 41 below outlines the details of the previously budgeted costs and actual costs of the specific tasks.

Table 41: Overview of Final Report and Presentation Time & Cost Breakdown.

TASK	Budget		Actual		Variance
	Time	Cost	Time	Cost	
Write Final Report	28	$2,100	24	$1,680	-20%
Bi-Weekly Reports	4	$320	4	$320	0%
Final Presentation	6	$450	10	$720	-60%
TOTAL	45	$2,870	38	$2,720	-5%

8.0 SUMMARY OF PROJECT CHALLENGES

There were a number of challenges in which *LJ Geomatics* encountered during this research. A major challenge was during the data acquisition process where the project team had originally wanted to incorporate the use of a Google Traffic API with Python scripting to gather traffic flow information. However, that was not possible as this data was private and distributing time stamps from the individual mobile devices in which Google colleges will be a violation in their Terms of Services. This issue was however, mitigated with the use of current AADT volume data that was provided by the Ministry of Information. Traffic information for the Niagara Region and Hamilton Region were not used at the end due to a delay in delivery of data sets from both parties. The Hamilton Region data set was also inaccessible, and was only available in a 'read-only' format online. *LJ Geomatics* only modelled traffic information from the Hamilton Region for the Lincoln M. Alexander Parkway, and the Red Hill Valley Parkway.

Another major challenge, is the reliability of the demographic data provided by Statistics Canada. It can be seen that during the analysis phase, significant information for certain census tracts were missing and not collected. Another major challenge in which threatened the integrity of the project team's analysis, was the low global response rates of the 2011 census data due to the removal of the long-form questions. However, throughout the course of this research, the long-form census was re-introduced and *LJ Geomatics* has recognized the importance of this data and would recommend for future analysis to take this into consideration and weighed accordingly to appropriately assess the external factors and landscape of the study area.

8.1 Mitigation Plan

LJ Geomatics has developed a comprehensive mitigation plan during the half-way point of this project to tackle the data acquisition component of the project. Since there is a time constraint on this project, the mitigation plan takes into account the reliability of the data that will be assessed, and the accuracy of the trends and models that will be predicted. Three (3) scenarios have been developed, where appropriate recommendations will be made based on the different levels of trends and models that will be projected.

This plan ultimately helped the project team to narrow down the research to what can be used and cross-referenced for data integrity, and kept the project under budget and on schedule. Furthermore, the different scenarios had also indicated a level of 'error' that may or may not be inherent in the analysis. By doing so, the findings provided a range (i.e. low versus high ridership) that is able to then provide the client with a comprehensive analysis, and to further inform the recommendations with regards to what additional research should be conducted.

9.0 CONCLUSION

This goal of this project is to determine the ridership potential within the GTHA and Niagara region, and to identify the most cost-effective route with the highest return-on-investment. The implementation of this project has been proven to improve the business environment and pave the way additional economic development in this region according to *LJ Geomatics*' research and analysis. Additionally, this project will also help with the reduction and control of traffic congestion and carbon emissions that contribute to the loss of time and money for municipalities, the province of Ontario and the residents of the region.

Overall, this research serves as a strong preliminary analysis regarding the feasibility of expanding and increasing level of services between the GTHA and Niagara Region. It has the potential to also serve as a strong motive for the implementation of more reliable and accessible local public transit systems; thereby making the transit system with the GTHA and Niagara regions more sustainable, economical, accessible, reliable and 'investment ready'.

Upon the successful completion of this project, the formal recommendation of a weekday express bus service that stops from McMaster University, Hamilton GO Station, Brock University, and Niagara Falls, adequately services the demand that are sourced from the GTHA and Niagara Region. The commuter profile identified within the study area is that the individual is likely a student with no access to a vehicle, are neither employed nor unemployed, and are willing to commute 15 to 30 minutes to work, and makes less than $13,650 annually. By catering services to this specific commuter profile within the GTHA and Niagara Region, the weekday express bus service will have the potential to increase economic activity, and gain additional ridership. This is anticipated to serve as a stepping stone to increase level of service to a GO Train service in the future.

In summary, this project was completed on **June 10th, 2016** with the actual net cost of **$36,220 (CAD)**. This cost includes a 13% provincial tax, as well as a one-time consultation fee. The project was completed in 417.25 hours which was under the budgeted 425.75 hours. Furthermore, the collaboration of policy-makers, public transit advocates, and transportation planners alike are recommended to prioritize this type of project to appropriately link the two regions together to capture the socioeconomic benefits associated with implementing a regular weekday express service between major post-secondary institutions.

10.0 ACKNOWLEDGEMENTS

LJ Geomatics would like to thank the Project/Thesis Advisor, Mr. Michael Wallace for all of his efforts in guiding the project team with the research, development and management of this project. We would also like to thank the client, Mr. Richard D. Quodomine for providing the students with this challenging project and the guidance to bring it to its fruition. Additionally, this could not have been done without the help of these following individuals:

Ryan Clark, *Ministry of Transportation*

Mr. Clark is the Geographic Information Systems Specialist at Ministry of Transportation. His support during the data acquisition stage was invaluable as he offered the project team support and direction in accessing relevant traffic commuter statistics between GTHA and Niagara Region.

David Cook and Tanya Detmar, *Region of Hamilton*

Mr. Cook and Ms. Detmar work at the Infrastructure department at Region of Hamilton. We thank them for providing information regarding the AADT Volume Data for the Lincoln Alexander Pkwy and Red Hill Valley Pkwy that was otherwise not readily available.

Sarah Holmes, *Regional Municipality of Niagara*

Ms. Holmes is the Niagara Region Transit Coordinator at the Public Works Department at Region of Niagara. She provide us with crucial information with respect to transit ridership and U-pass distribution that in turn helped us build the profile of the ideal commuter. We thank her for the guidance, support and understanding she showed us throughout the development of the project.

Chris Livett and Andrea Corken, *Metrolinx*

Mr. Livett is the Transportation Planning Analyst at Metrolinx and Ms. Corken is the Client Customer Representative at Metrolinx. Mr. Livett provided us some insight into some typical Metrolinx uses of GIS with the project team. We thank Mr. Livett and Ms. Corken for the time that they took to advise us on our research.

Viola Mueller, *Region of Hamilton*

Ms. Mueller is the Supervisor of Cartographic and Graphics Services at Region of Hamilton. Her guidance and direction for research in rail commuter statistics between GTHA and Niagara Region is deeply appreciated.

Clair Price, *Niagara College*

Ms. Price is the Administrative Assistant of the Enrolment & Registration Services at Niagara College. We thank her for the prompt responses to our communications and data requests regarding acquisition of student enrollment data.

David Pritchard, *Metrolinx*

Mr. Prtichard is the Manager of Modelling and Geomatics at Metrolinx. We would like to thank him for providing us resources pertaining to commuter data and ridership forecasting. We thank him for connecting us with Chris Livett.

Constatin Urma, *Metrolinx*

Mr. Urma is the Systems (Electrification) Supervisor at Metrolinx. We thank him for connecting us with Chris Livett, David Pritchard, and Andrea Corken.

Class of 2015 – 2016 of the Niagara College *Geographic Information Systems – Geospatial Management program* for their steady support and consideration throughout the development of the project.

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APPENDICES

PROJECT OVERVIEW STATEMENT

LocalPoint Technologies & Consulting

Project Name	Using a GIS approach to identify GO Transit route alternatives to service between the GTHA and Niagara region, and measuring their return-on-investment.	**Project ID**	201516-05
Author(s)	Alice Lin & Jasmine Joy	**Last Updated Date**	December 1, 2015
Project Manager	Alice Lin	**Project Member**	Jasmine Joy
Client Organization	LocalPoint Technologies & Consulting Ltd.	**Client Name**	Richard D. Quodomine
Client Contact Information	5272 Daintry Crescent, Cobourg ON. K9A 4Y3 rdquodomine@localpointcan.ca		

Project Business Case

Business Issue/Potential/Opportunity

The primary issue that is the fundamental basis for carrying out this project is that there are currently **no regular weekday <u>public</u> transit services between Hamilton and Niagara regions**. However, there is a lot of potential for GO Transit to meet the needs of many frequent travelers/users/commuters to the region (i.e. working professionals and students) that finds it difficult to travel to-and-from the Greater Toronto Hamilton Area (GTHA) to Niagara region without a vehicle. Furthermore, there is also a great economic opportunity for GO Transit to capitalize on the tourism industry in the Niagara region (a key economic sector) and can even provide a more cost-effective alternative to VIA rail for frequent riders (especially through reduced rates with the Presto Card).

Project Business Goal

The goal of this project is to determine the ridership potential between the GTHA and Niagara region, and to further identify the return-on-investment for increasing no-build route alternatives (i.e. utilizing existing rail tracks and determining new bus routes) servicing between those regions. The possibilities of implementing this project will improve the business environment by inviting and attracting more prospects for economic growth and development into this region. By achieving this goal, the government (and Metrolinx) can provide the appropriate services in linking the communities between the GTHA and the Niagara regions (for those without a vehicle). It will also alleviate traffic congestion on the QEW which ultimately leads to a reduction in carbon emissions and thereby creating a more sustainable environment.

Primary Project Objectives

Objective 1: To <u>understand</u> public transit expansion costs and developing an argument that supports the project in a political defensive manner.

Objective 2: To <u>identify, investigate and define</u> ridership potential and other relevant factors, in order to assess no-build route options, level of service alternatives, and ROI between the GTHA and Niagara region.

Objective 3: To <u>develop</u> a GIS-based model that effectively analyzes and evaluates ridership potential and other relevant factors identified in objective #2.

Objective 4: To <u>apply</u> the GIS-based model developed in objective #2 to evaluate ridership potential and other relevant factors in order to <u>assess</u> route options and level of service alternatives between the GTHA and Niagara region.

Objective 5: To <u>conduct analysis</u> on return-on-investment on the different GO Transit route options and level of services based on the results gathered in objective #4.

Objective 6: To <u>evaluate</u> the strengths and weaknesses of the model/methodologies applied in this project.

Project Benefits

There are a number of benefits to expanding and providing direct GO Transit service to the Niagara region.

Reduce Traffic Congestion	The expansion will provides accessible transit options to commuters that will allow for fewer drivers on the road, thereby reducing congestion and potential vehicular collisions during the winter months;
Reducing carbon emissions	A long-term benefit of expanding GO Transit between the GTHA and Niagara region include providing an alternative way to commute and with fewer cars on the road, it will reduce CO_2 emissions thus cleaner air and creating a more sustainable, healthy environment;
Increasing Economic Activity	Additionally, affordable and accessible transportation also provides a means to expand tourism in the Niagara Region thus promoting GDP growth, allowing for regional expansion;
Increasing Employment Opportunities	Municipalities within the Niagara region can expect a surge in employment and population as a result of the GO Transit expansion increasing availability of convenient public transportation services;
'Investment Ready'	Expanding the GO train service will also allow developers to incorporate better land-use planning practices to build well planned subdivisions near GO Stations that would in turn reduce urban sprawl, manage growth and make the region more 'investment ready' (creating a more welcoming environment for new businesses in the regions);
Connecting Niagara Region	Expanding the GO transit service between the GTHA and the Niagara region will connect Niagara College directly to other educational institutions such as University of Toronto, Ryerson, Sheridan, McMaster and Ontario Institute of Technology;
Other Possible Benefits	Expanding the Go train to service and connect the GTHA and the Niagara region will provide greater incentive to the smaller municipalities within these regions to introduce and implement already existing 'Presto' system within their municipal transit systems, which is compatible with GO services.

Primary Project Deliverables

Milestone 1 Completing the Project Proposal

- **Deliverable 1.1:** Setting the project scope and defining problem context by conducting a S.W.O.T. analysis;
- **Deliverable 1.2:** Determining boundaries for the project study area;
- **Deliverable 1.3:** Identifying academic literature, government documents, and transit operations reports to be reviewed;
- **Deliverable 1.4:** Identifying data needs;
- **Deliverable 1.5:** Establish work plan schedule.

Milestone 2 Identifying ridership potential and other relevant factors to be assessed

- **Deliverable 2.1:** Summary of relevant academic literature, gov't documents and transit operations reports to identify factors;
- **Deliverable 2.2:** Summary of relevant data sets to determine ridership potential;
- **Deliverable 2.3:** Summary of relevant literature, government documents, data sets and transit operations reports.

Milestone 3 Selecting an appropriate GIS-based model/framework to assess factors identified in Milestone #2

- **Deliverable 3.1:** Conducting literature of similar research project to narrow down what GIS-based model is appropriate;
  - **Deliverable 3.1.1:** Conduct review on the following analysis methods and determine its appropriateness for the project; - Network analysis, route analysis, path-distance analysis, corridor analysis, cost-benefit analysis.

Milestone 4 Applying the appropriate GIS-based model to assess the factors identified in Milestone #2

- **Deliverable 4.1:** Applying the appropriate GIS-based model to assess relevant factors;
    - **Deliverable 4.1.1:** Depicting the appropriate phases (data preparation and data processing) in the form of a flow-chart using model builder;
- **Deliverable 4.2:** Depicting the data preparation phase in a flow-chart using model builder;
- **Deliverable 4.3:** Depicting the data processing phase in a flow-chart using model builder.

Milestone 5 Identifying the most cost-effective route option

- **Deliverable 5.1:** Summarize data of different route options and different levels of services based on analysis from Milestone 4;
- **Deliverable 5.2:** Conduct a cost-benefit analysis (and other relevant route/path/corridor/distance analysis) on the route options;
- **Deliverable 5.3:** Identify the most cost-effective route that has the highest return-on-investment.

Milestone 6 Final Report and Presentation

- **Deliverable 6.1:** Map of ridership potential and where they are located within the study area;
- **Deliverable 6.2:** Map of the most cost-effective route option;
- **Deliverable 6.3:** Evaluation of strengths and weaknesses of the methodologies applied;
- **Deliverable 6.4:** List of recommendations to relevant stakeholders (the client, the Ontario Ministry of Transportation, Metrolinx, Niagara region, City of Hamilton).

Project Conditions

Project Assumptions and Risks

- Assumption that no new railway tracks will be built;
- Assumption that GO Transit will be utilizing/leasing time on existing track infrastructure provided by the CN Pacific Railway;
- Assumption that existing tracks have been maintained and that there are no additional costs associated with its repair;
- Assumption that freight trains are not a factor in determining level of service for this project;
- Assumption that project funding has been approved by both the province and municipalities involved;
- Assumption that necessary Environmental Assessment has been completed and all associated costs are covered;
- Risk that data may be outdated and not complete or reliable;

Project Issues and Constraints

- Issue: Data provided by Statistics Canada may not be accurate since it is voluntarily completed instead of mandatory;
- Issue: May not have immediate ridership after the introduction of the route options;
- Constraint: Lack of parking spaces and pedestrian safety at existing stations along railway lines;
- Constraint: Freight train schedule may interfere with commuter train schedule;
- Constraint: If rail line was going across canal, it may run into the bridge lock/shipping seaway schedule;

Project Critical Success Factors

- The ability to duplicate the methodology applied in this research to another research of a similar scope and study size;
- Group members are able to communicate effectively with the client;
- Client is able to provide clear and detailed list of tasks they would like to be achieved;
- That there is constructive and meaningful feedback/communication between the clients and the project members;
- Timeline follows the milestone dates, that objectives are met, and that deliverables are completed on-schedule;
- Client is satisfied with the overall research project;

Project Duration Estimates

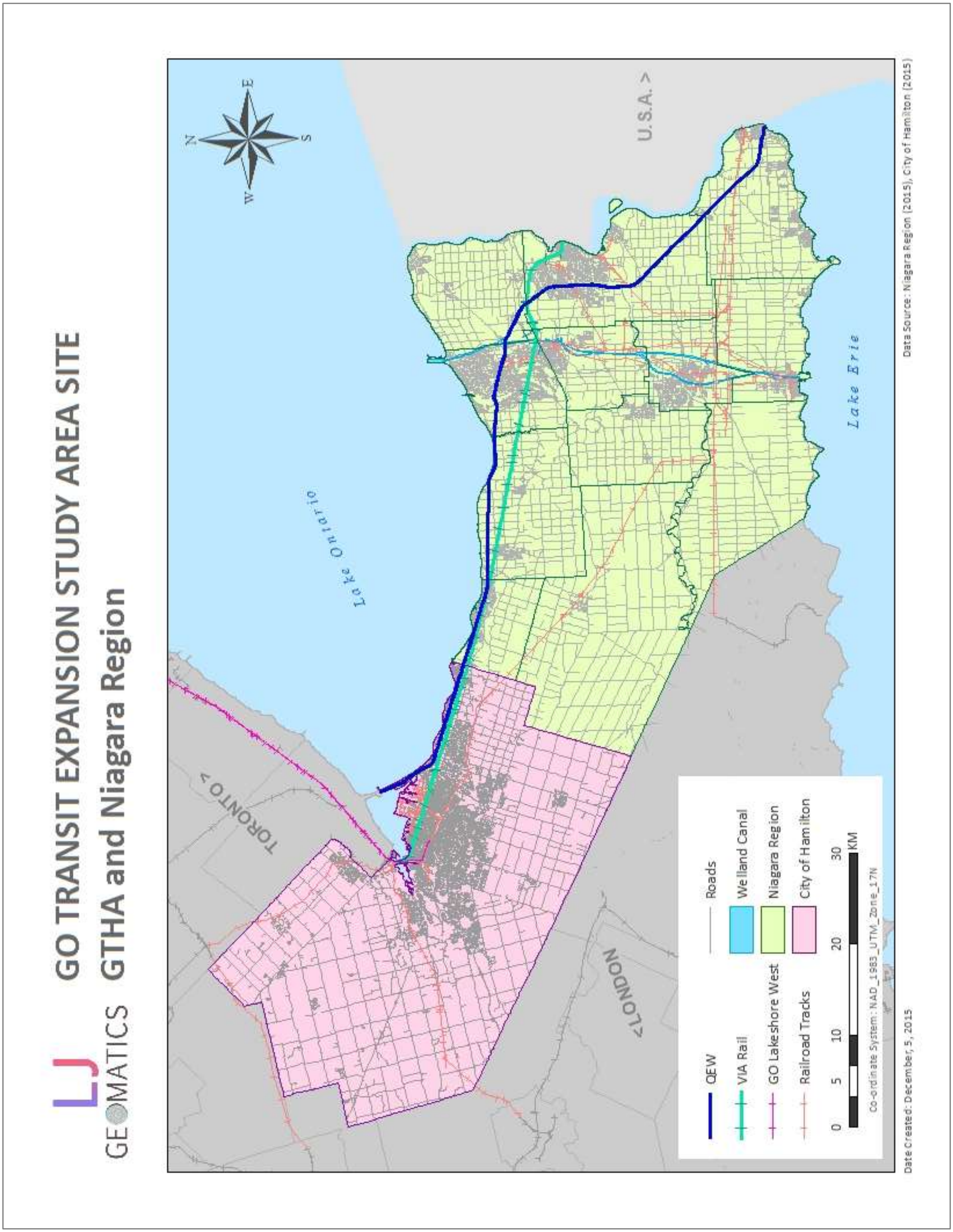
PROJECT PHASES	DATE ESTIMATES
Project Start Date	*October 1, 2015*
Milestone 1: Completing Project Proposal	December 11, 2015
Milestone 2: Identifying ridership potential and other relevant factors to be assessed	February 5, 2016
Milestone 3: Selecting an appropriate GIS-based model/framework to assess factors identified in Milestone #2	March 21, 2016
Milestone 4: Applying the appropriate GIS-based model to assess the factors identified in Milestone #2	April 22, 2016
Milestone 5: Identifying the most cost-effective route option	May 2, 2016
Milestone 6: Final Report and Presentation	June 10, 2016
Project End Date	*June 10, 2016*

APPROVALS (sign on the dotted lines)

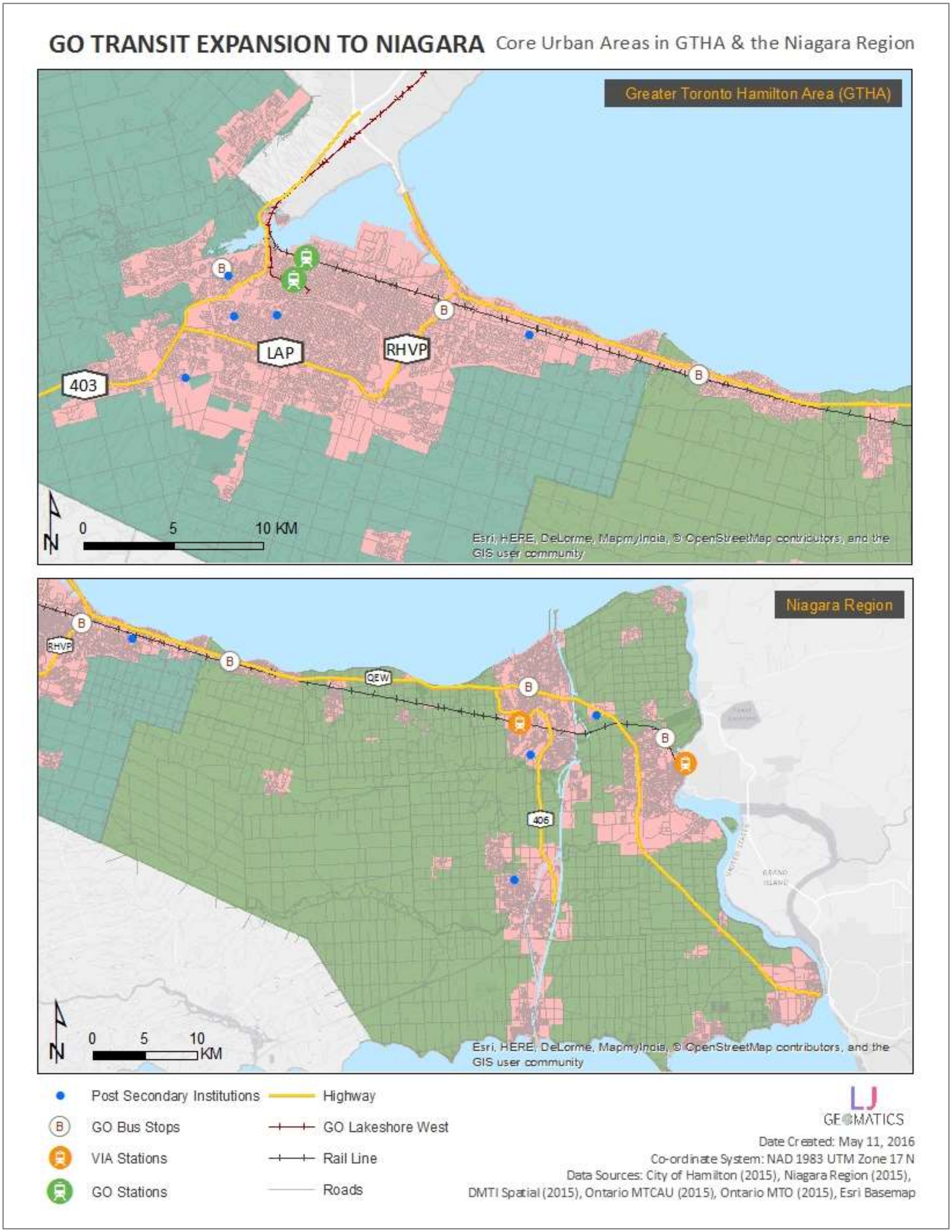
PREPARED BY	Alice Lin (Project Manager)	DATE	January 29, 2016
APPROVED BY	 (Project/Executive/Client Sponsor)	DATE	

By signing this document, the above objectives, statements and dates have been agreed upon. However, due dates are only an estimate and are qualified to change based on certain situations and issues.

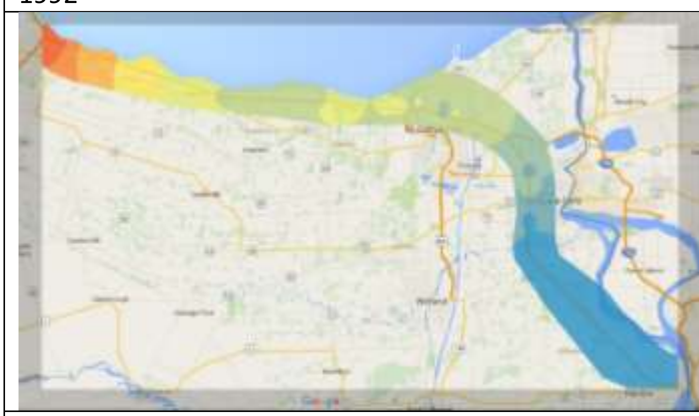
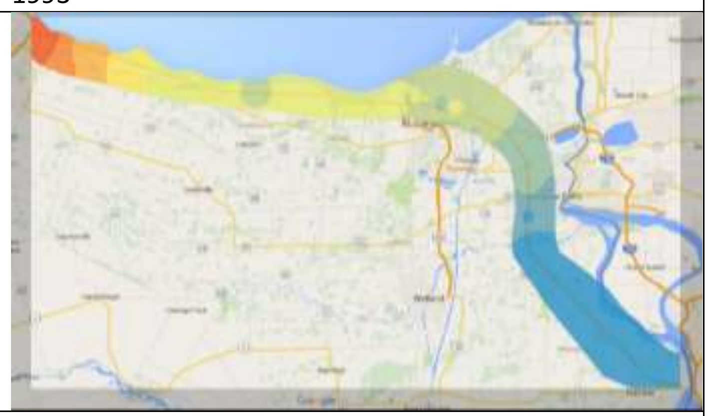
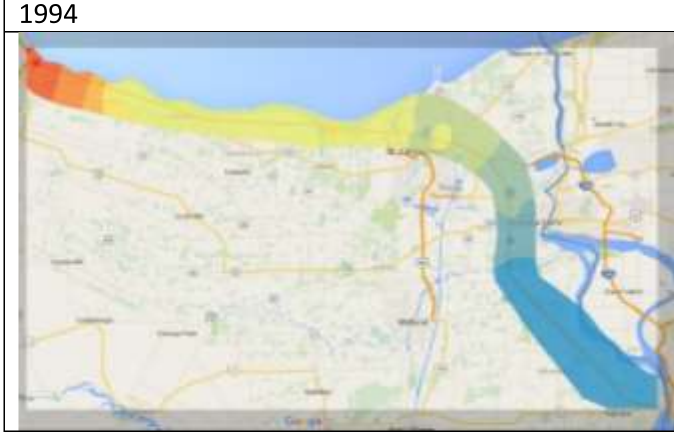
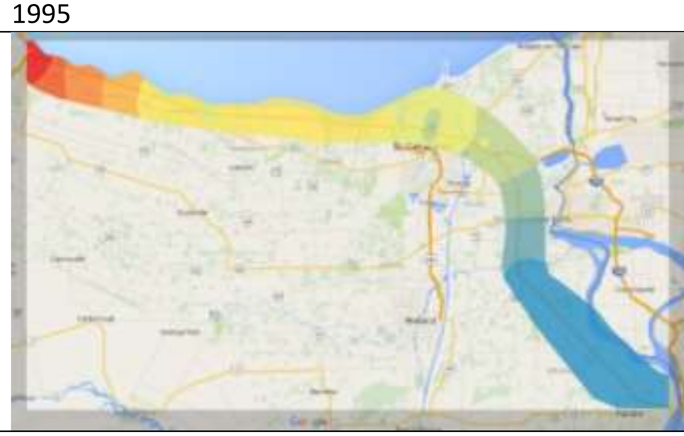
Refer to http://www.tenstep.com/open/miscpages/94.3Glossary.html for terms used in this document.



Appendix 2 – Study Area Map



Appendix 2 – Study Area Map

1988	1989
	
1990	1991
	
1992	1993
	
1994	1995
	

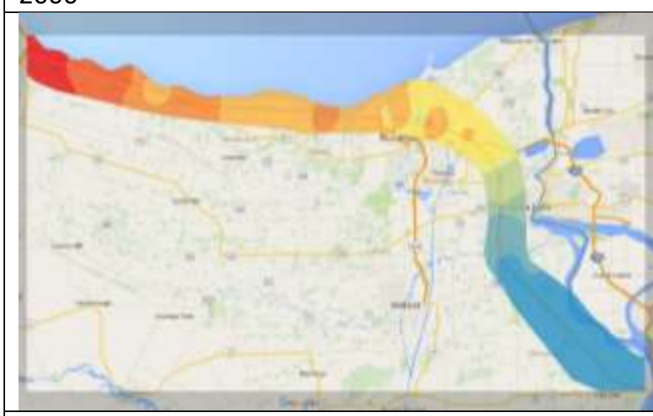
1996

1997

1998

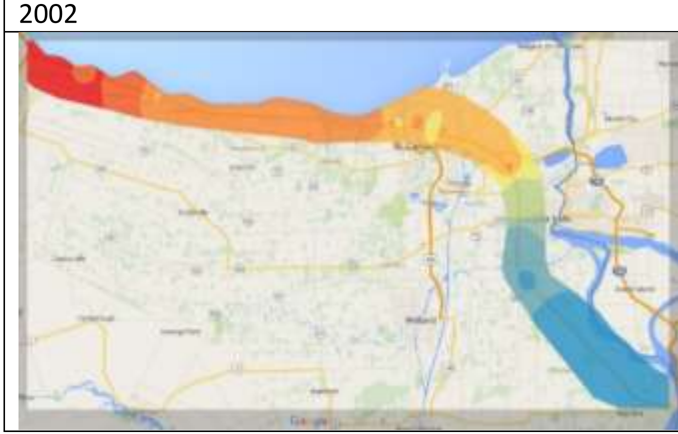
1999

2000

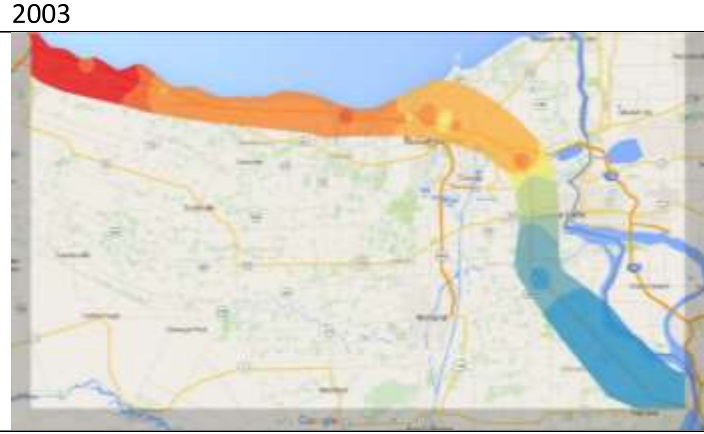


2001

2002



2003



2004

2005

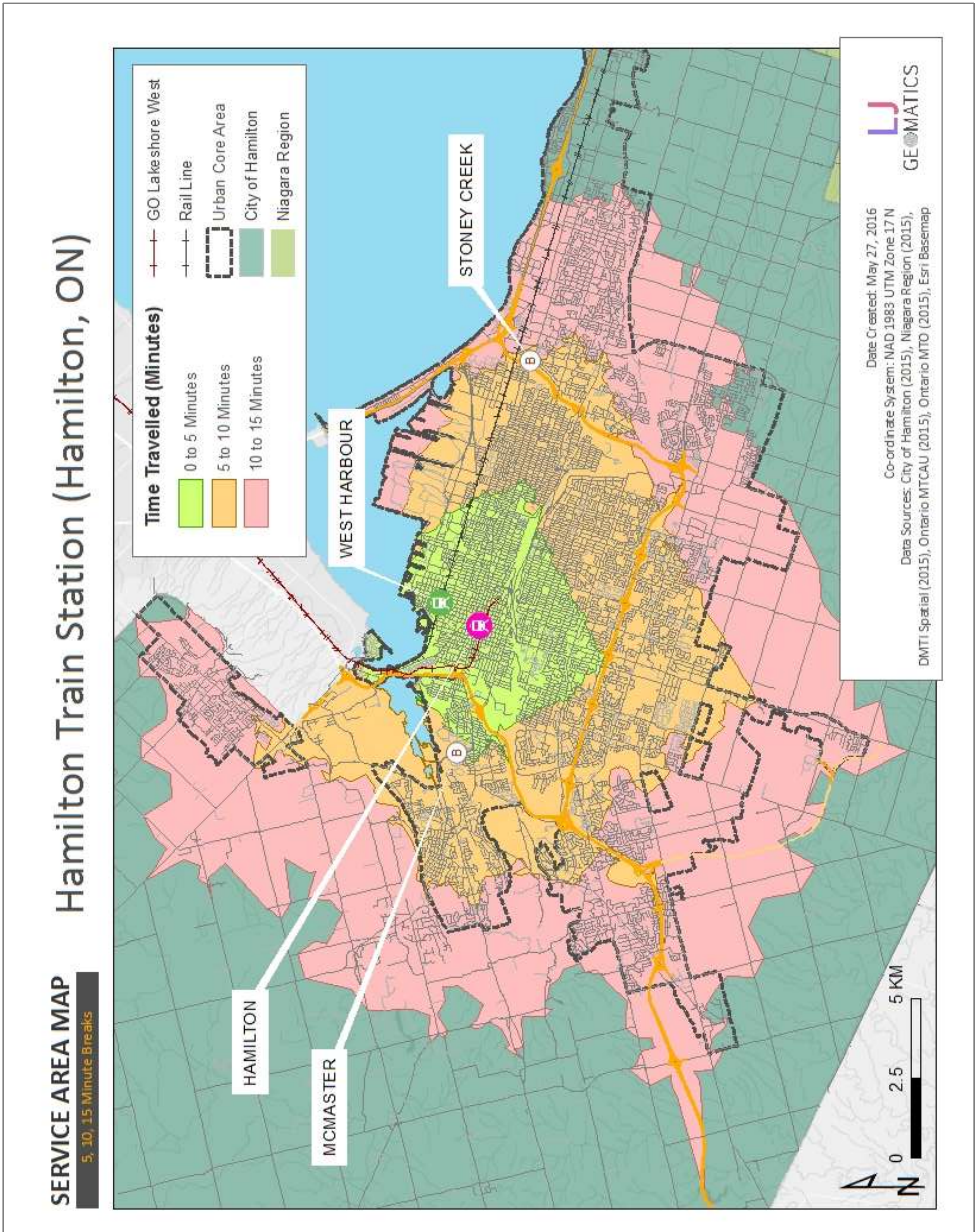
2006

2007

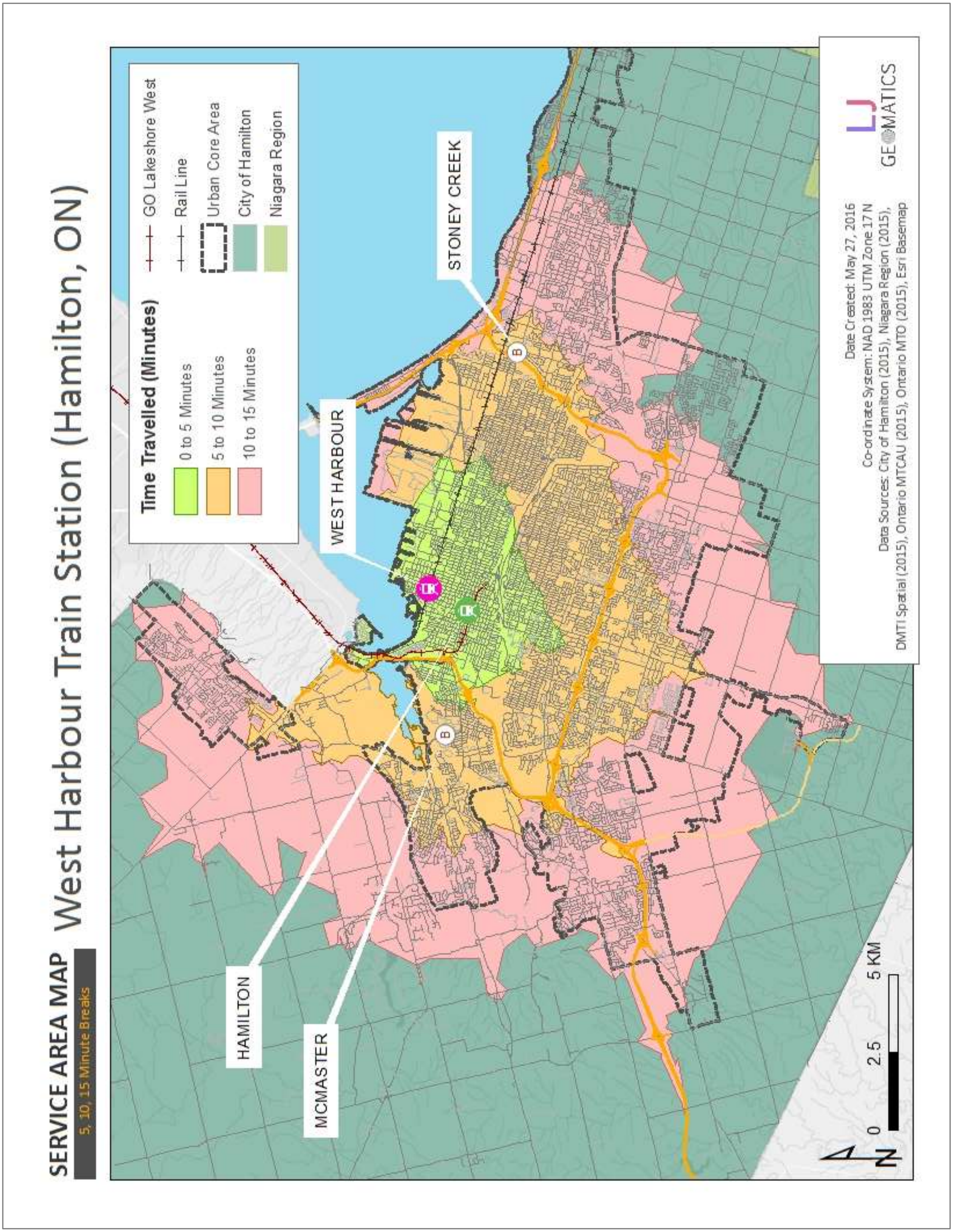
2008

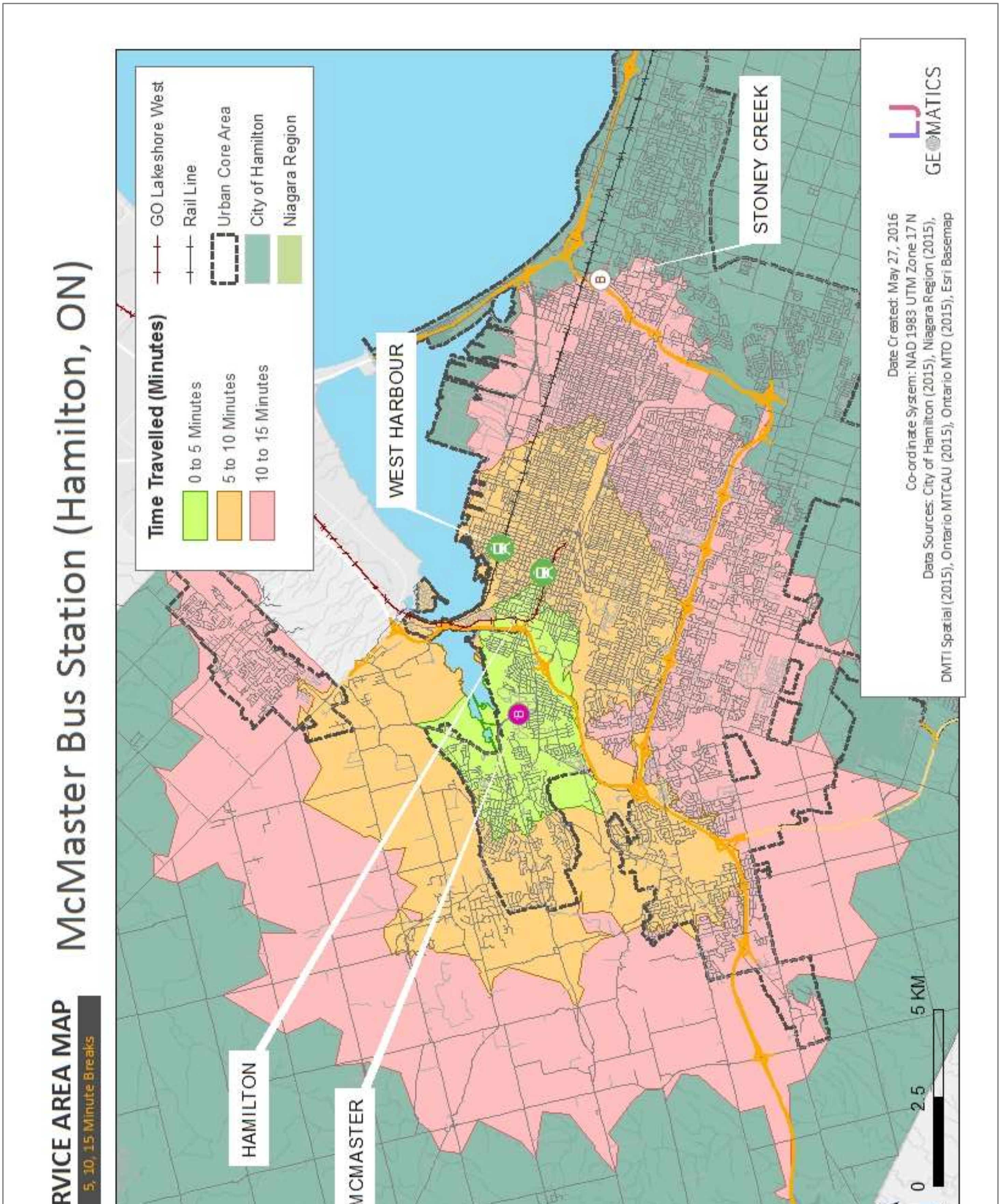
2009

2010

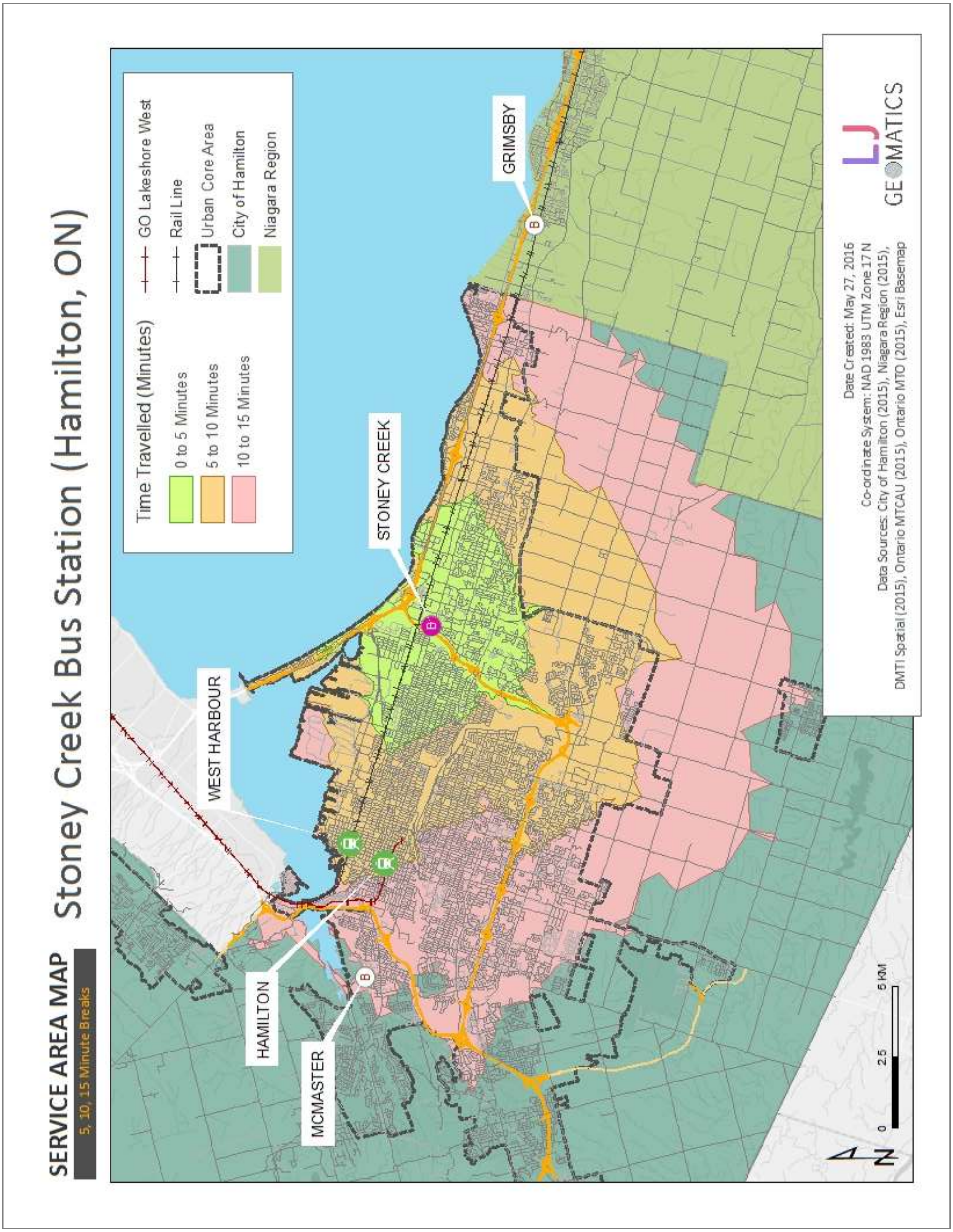


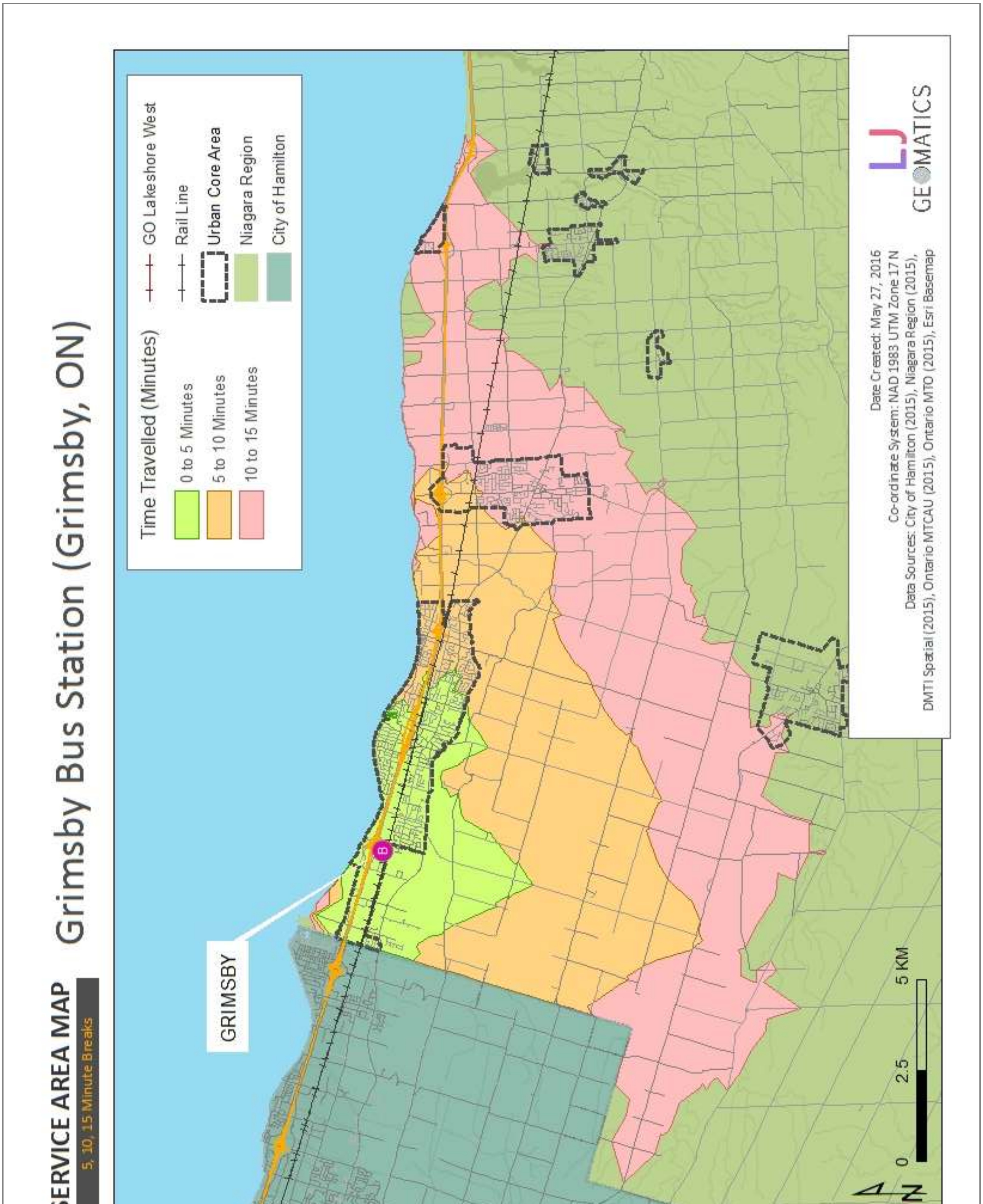
SERVICE AREA MAP
5, 10, 15 Minute Breaks
Hamilton Train Station (Hamilton, ON)
Time Travelled (Minutes)
0 to 5 Minutes
5 to 10 Minutes
10 to 15 Minutes
GO Lakeshore West
Rail Line
Urban Core Area
City of Hamilton
Niagara Region
STONEY CREEK
WEST HARBOUR
HAMILTON
MCMASTER
0
2.5
5 KM
Date Created: May 27, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: City of Hamilton (2015), Niagara Region (2015),
DMTI Spatial (2015), Ontario MTCAU (2015), Ontario MTO (2015), Esri Basemap

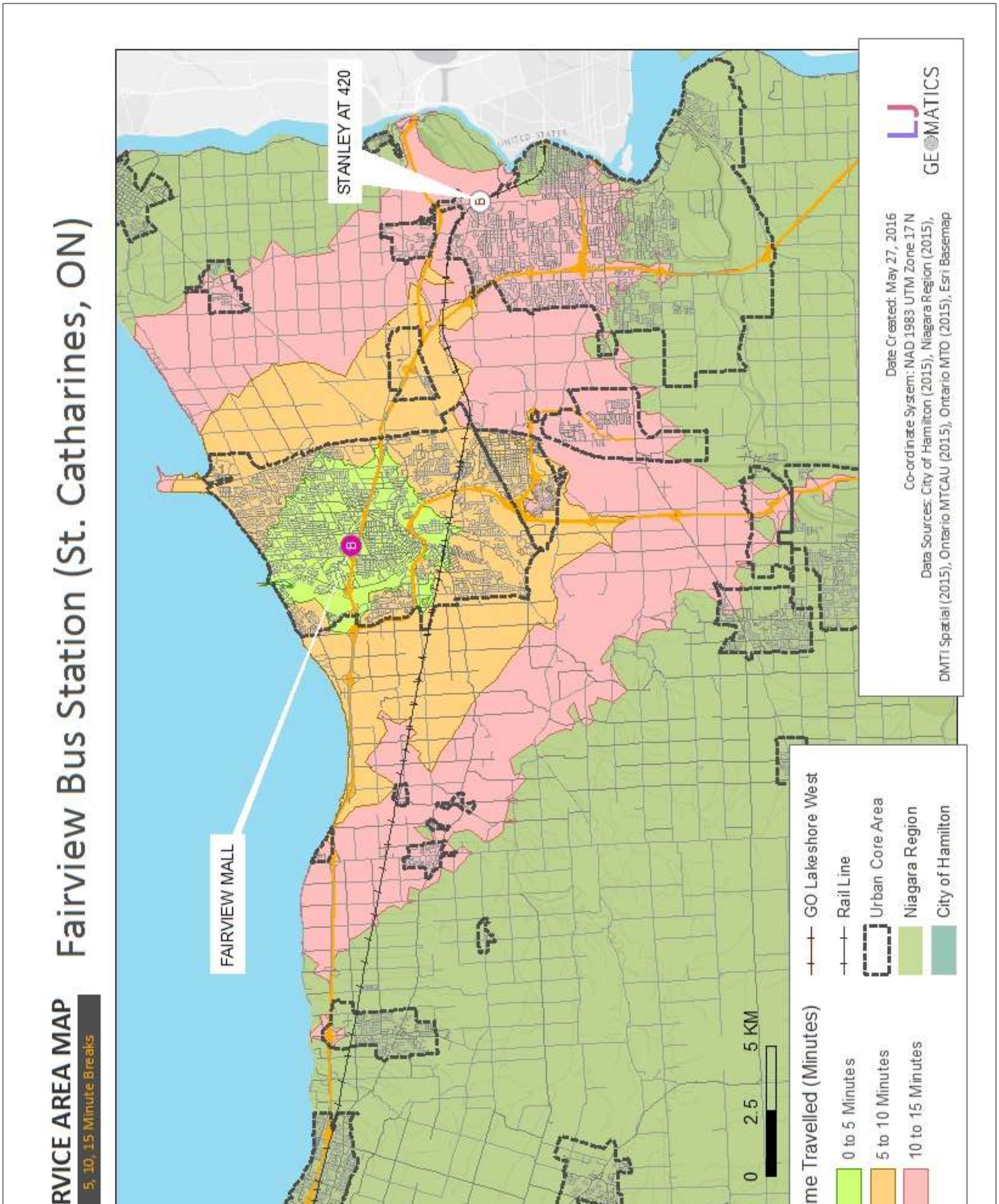

SERVICE AREA MAP
5, 10, 15 Minute Breaks
West Harbour Train Station (Hamilton, ON)
Time Travelled (Minutes)
0 to 5 Minutes
5 to 10 Minutes
10 to 15 Minutes
GO Lakeshore West
Rail Line
Urban Core Area
City of Hamilton
Niagara Region
STONEY CREEK
WEST HARBOUR
HAMILTON
MCMASTER
B
0
2.5
5 KM
N
Date Created: May 27, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: City of Hamilton (2015), Niagara Region (2015),
DMTI Spatial (2015), Ontario MTCAU (2015), Ontario MTO (2015), Esri Basemap
GEOMATICS



Appendix 4 – Service Area Maps


SERVICE AREA MAP
5, 10, 15 Minute Breaks
Stoney Creek Bus Station (Hamilton, ON)
Time Travelled (Minutes)
0 to 5 Minutes
5 to 10 Minutes
10 to 15 Minutes
GO Lakeshore West
Rail Line
Urban Core Area
City of Hamilton
Niagara Region
WEST HARBOUR
STONEY CREEK
GRIMSBY
HAMILTON
MCMASTER
0
2.5
5 KM
N
Date Created: May 27, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: City of Hamilton (2015), Niagara Region (2015),
DMTI Spatial (2015), Ontario MTCAU (2015), Ontario MTO (2015), Esri Basemap
GEOMATICS

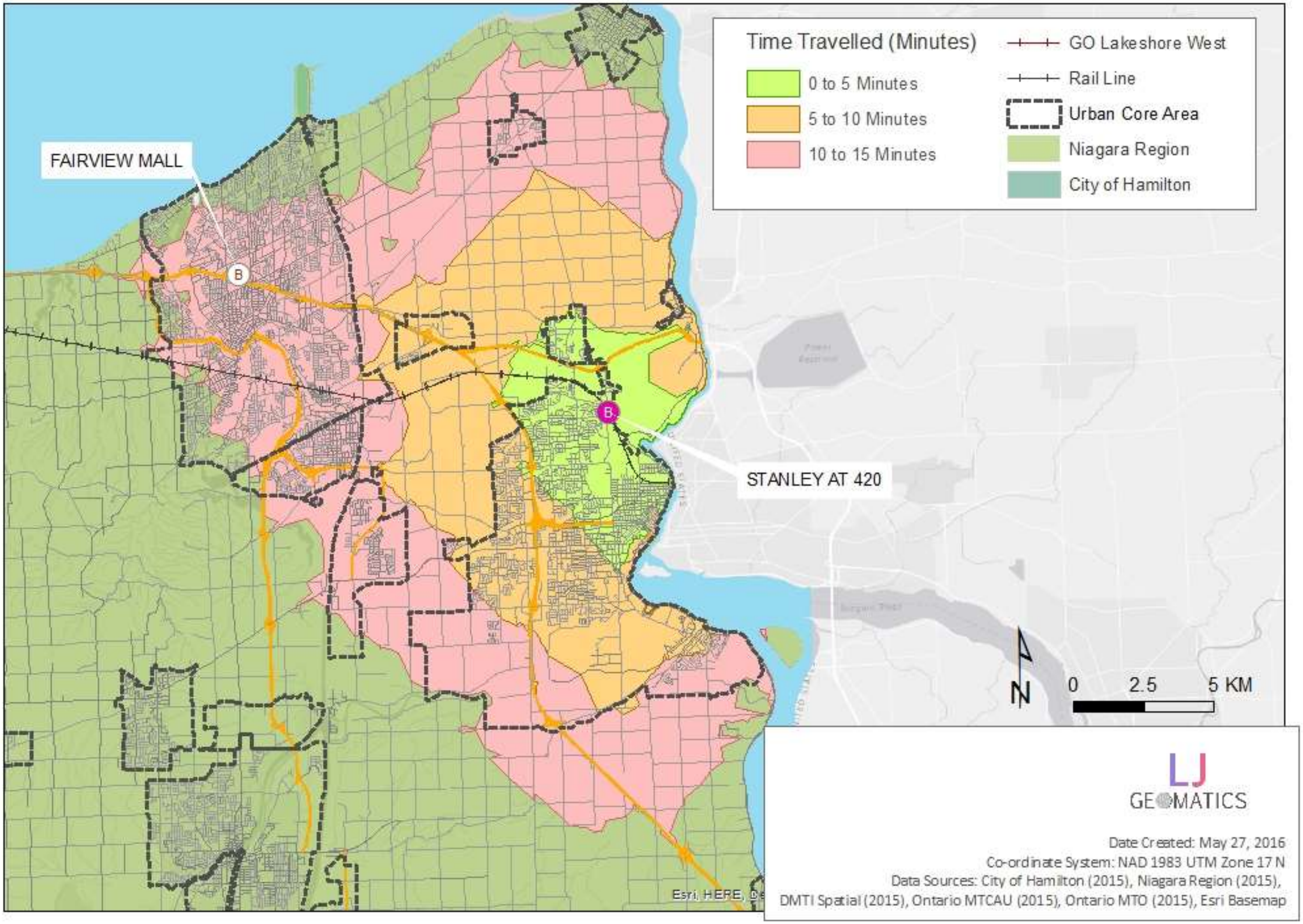

SERVICE AREA MAP
5, 10, 15 Minute Breaks
Grimsby Bus Station (Grimsby, ON)
Time Travelled (Minutes)
0 to 5 Minutes
5 to 10 Minutes
10 to 15 Minutes
GO Lakeshore West
Rail Line
Urban Core Area
Niagara Region
City of Hamilton
GRIMSBY
Date Created: May 27, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: City of Hamilton (2015), Niagara Region (2015),
DMTI Spatial (2015), Ontario MTCAU (2015), Ontario MTO (2015), Esri Basemap
0
2.5
5 KM
N

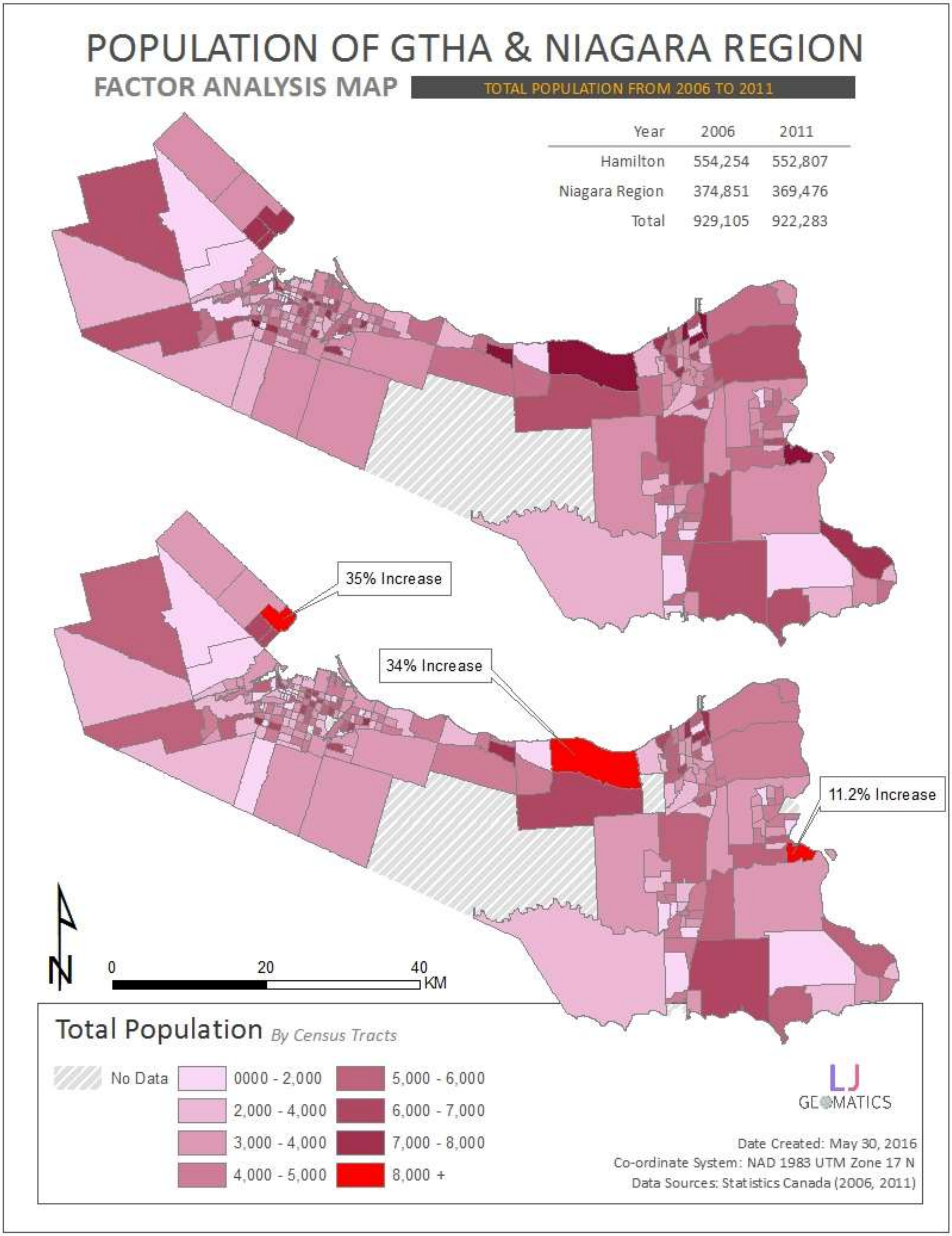


Appendix 4 – Service Area Maps

SERVICE AREA MAP
5, 10, 15 Minute Breaks

Stanley at HWY 420 Bus Station (Niagara Falls, ON)




POPULATION OF GTHA & NIAGARA REGION
FACTOR ANALYSIS MAP
TOTAL POPULATION FROM 2006 TO 2011

Year	2006	2011
Hamilton	554,254	552,807
Niagara Region	374,851	369,476
Total	929,105	922,283

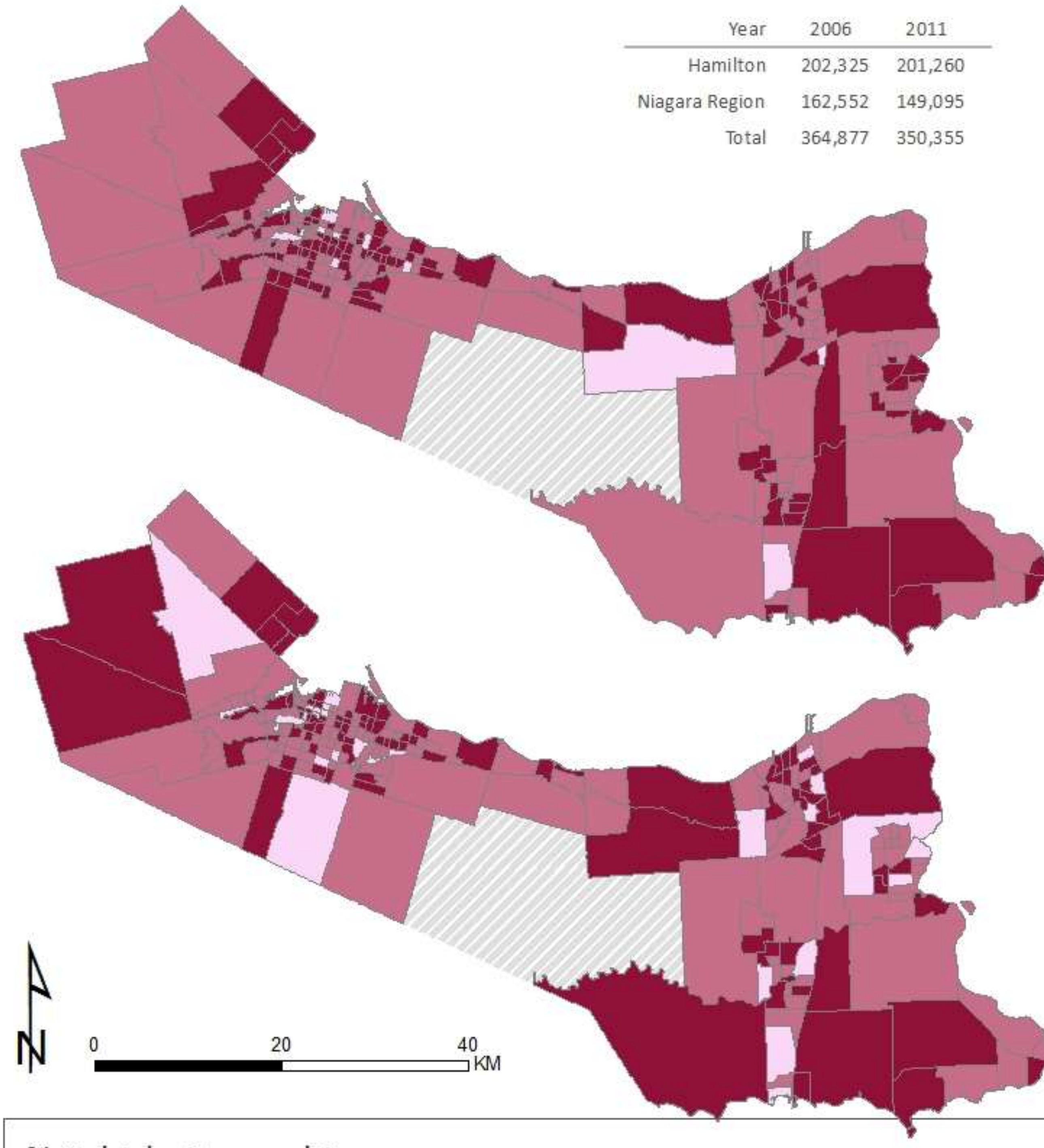
35% Increase
34% Increase
11.2% Increase
N
0
20
40
KM
Total Population By Census Tracts
No Data
0000 - 2,000
2,000 - 4,000
3,000 - 4,000
4,000 - 5,000
5,000 - 6,000
6,000 - 7,000
7,000 - 8,000
8,000 +
LJ
GEOMATICS
Date Created: May 30, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: Statistics Canada (2006, 2011)

% VEHICLE OWNERSHIP OF GTHA & NIAGARA REGION

FACTOR ANALYSIS MAP

% VEHICLE OWNERSHIP FROM 2006 TO 2011

Year	2006	2011
Hamilton	202,325	201,260
Niagara Region	162,552	149,095
Total	364,877	350,355



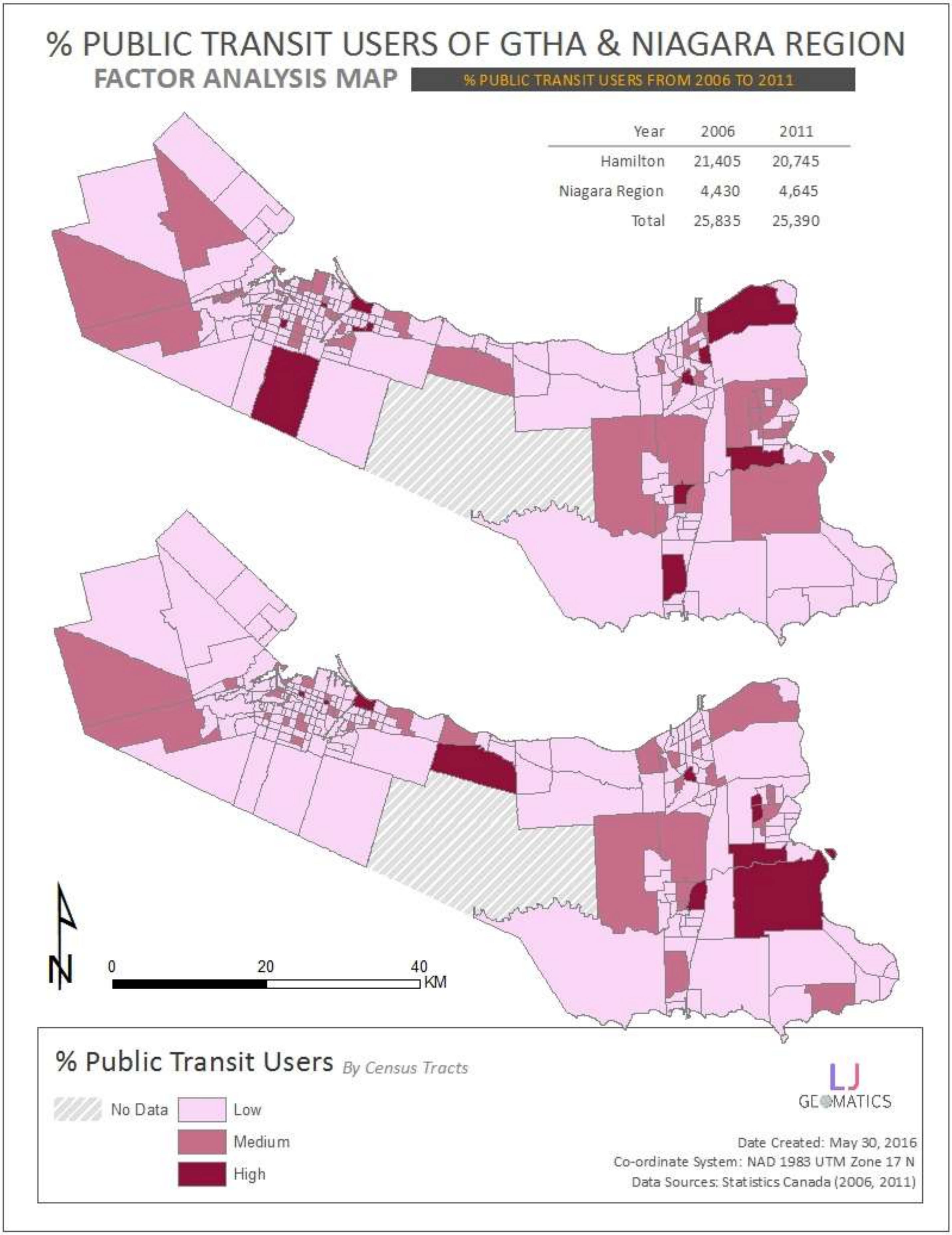
% Vehicle Ownership *By Census Tracts*

- No Data
- 20% and below
- 20% to 40%
- 40% and above

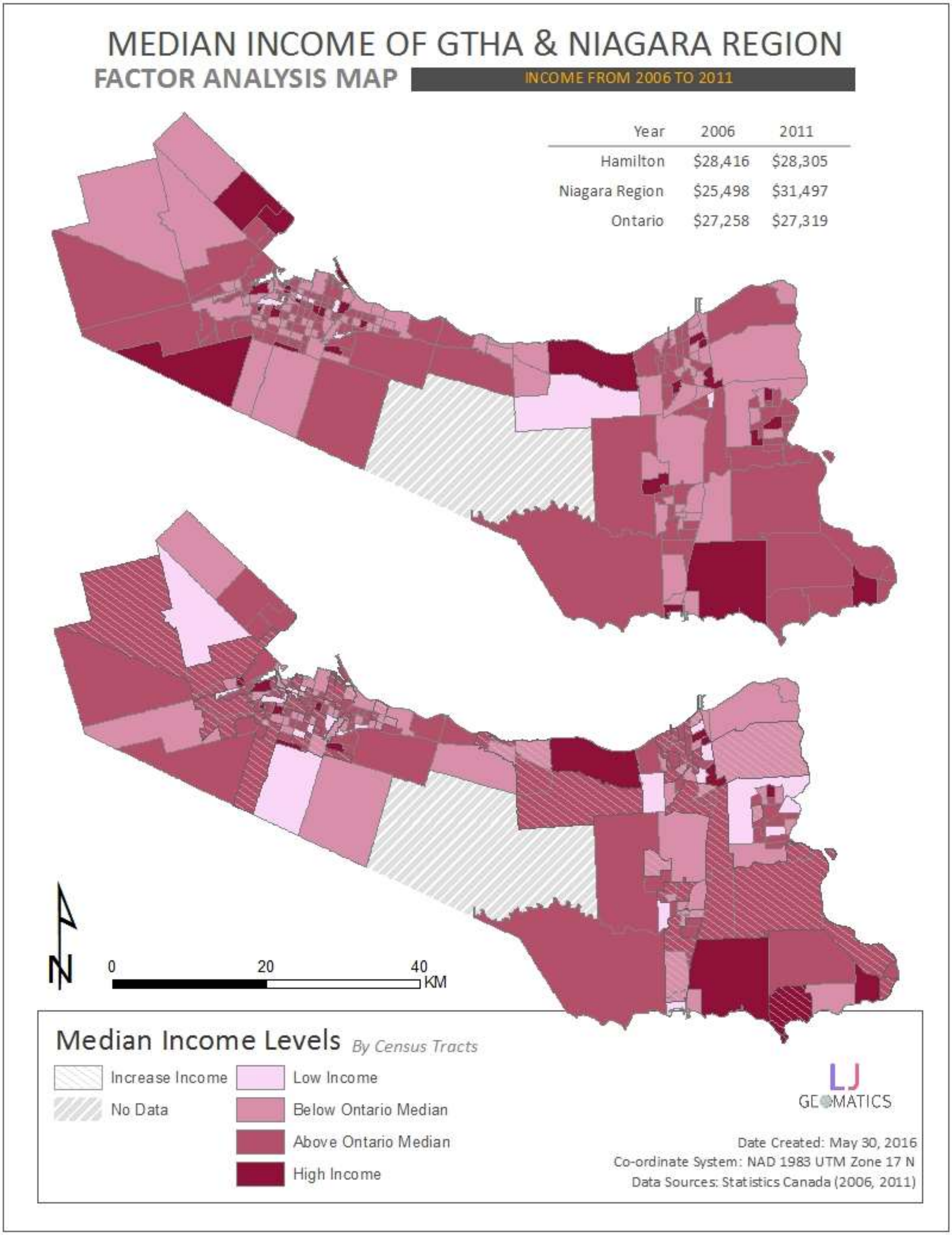
LJ GEOMATICS

Date Created: May 30, 2016
Co-ordinate System: NAD 1983 UTM Zone 17 N
Data Sources: Statistics Canada (2006, 2011)

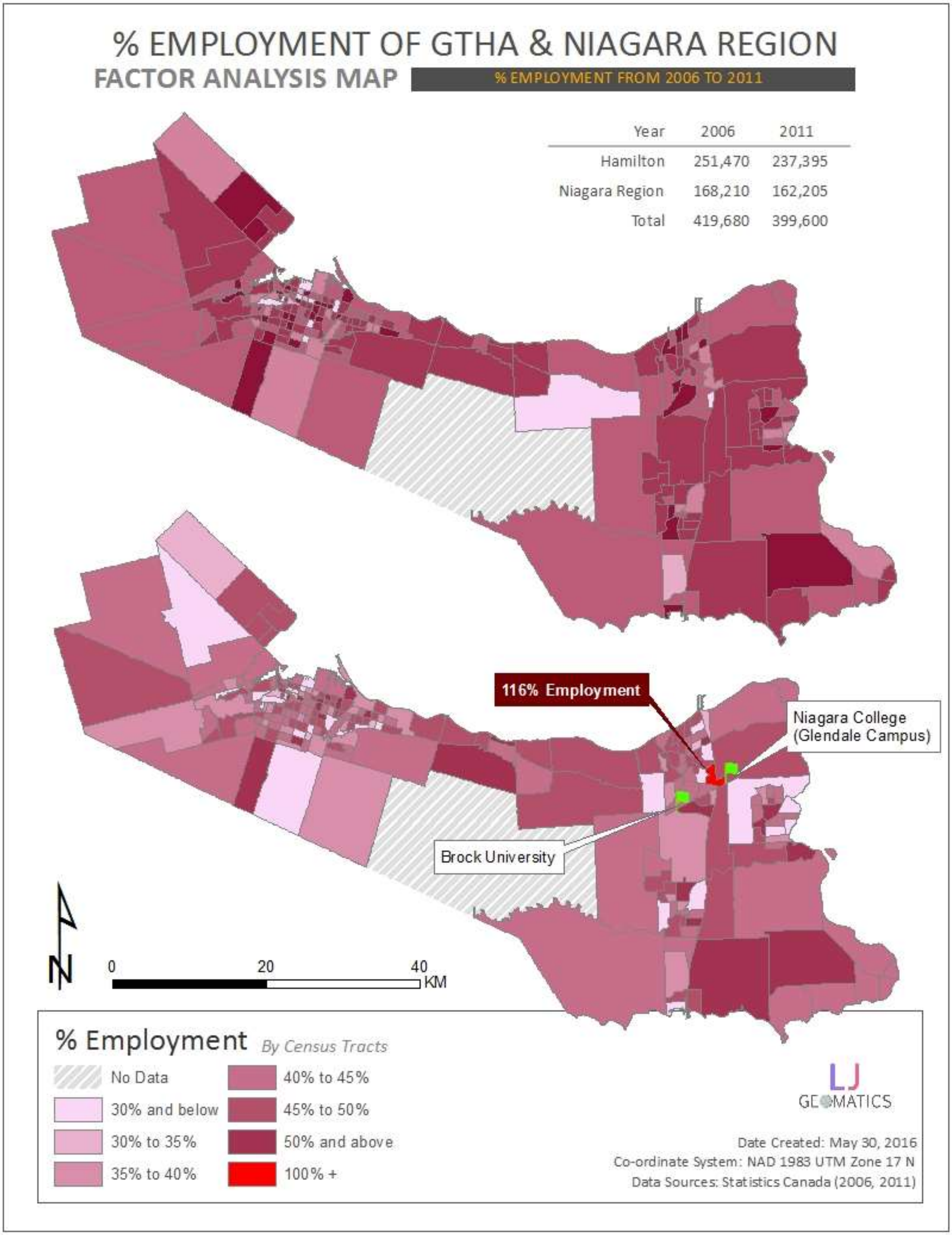
Appendix 5 – Factor Maps



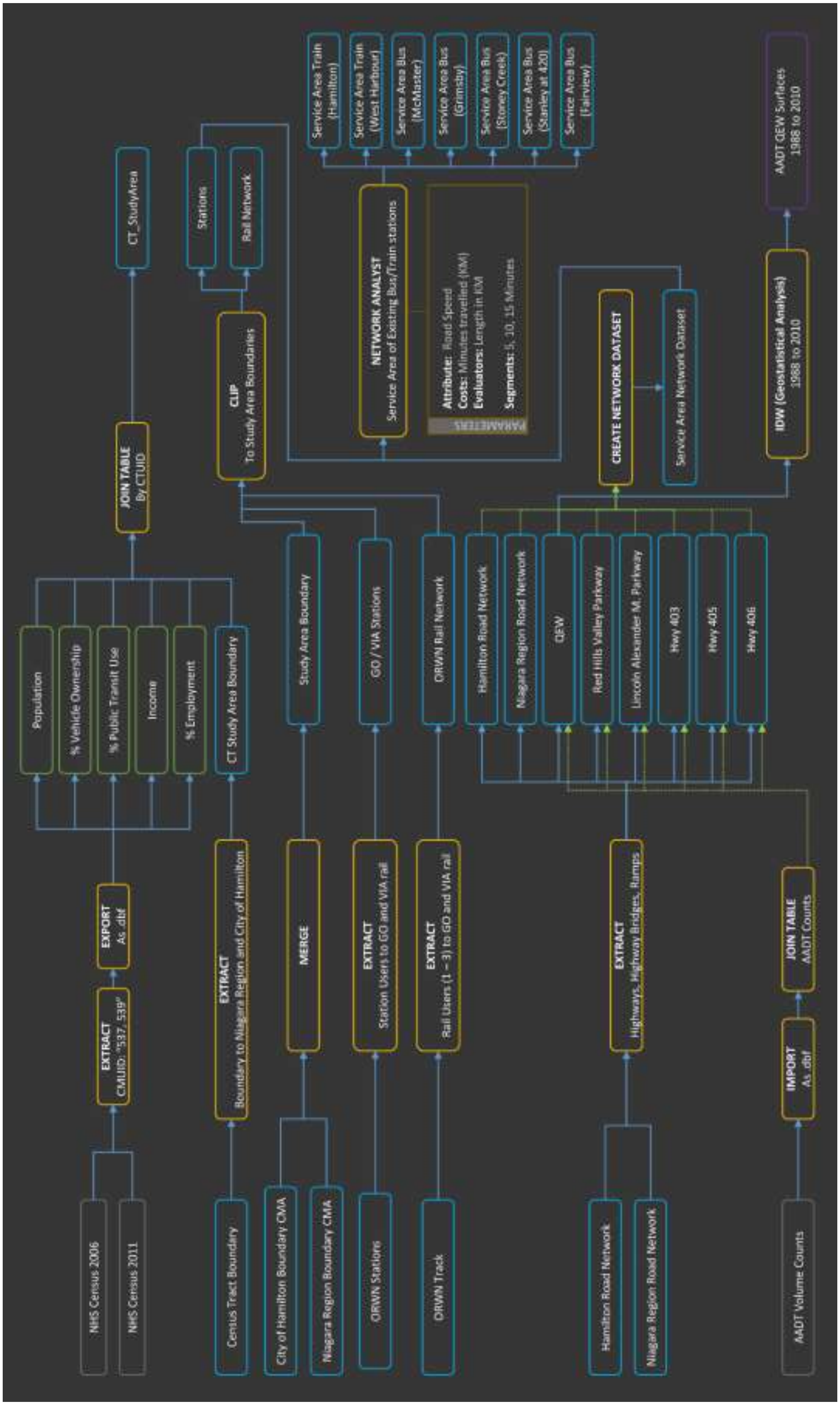
Appendix 5 – Factor Maps



Appendix 5 – Factor Maps



Appendix 5 – Factor Maps



Appendix 6 – Methodology Process

CTUID	CMAUID	CMANAME	POP2006	% VehOwn	% PubTran	% Empt	MedInco
5370001.01	537	Hamilton	2143	0.46	0.04	0.52	36913
5370001.02	537	Hamilton	5555	0.43	0.03	0.48	32856
5370001.04	537	Hamilton	5866	0.45	0.02	0.5	36805
5370001.05	537	Hamilton	3719	0.37	0.03	0.41	31263
5370001.06	537	Hamilton	5534	0.49	0.04	0.54	34276
5370001.07	537	Hamilton	3852	0.42	0.06	0.51	29278
5370001.08	537	Hamilton	5891	0.45	0.03	0.49	34210
5370001.09	537	Hamilton	4007	0.45	0.04	0.49	36886
5370002.01	537	Hamilton	4160	0.46	0.04	0.52	32289
5370002.03	537	Hamilton	3220	0.42	0.03	0.47	32535
5370002.04	537	Hamilton	4902	0.47	0.05	0.54	36490
5370002.05	537	Hamilton	5451	NoData	NoData	NoData	NoData
5370002.06	537	Hamilton	2578	NoData	NoData	NoData	NoData
5370003.01	537	Hamilton	5343	0.38	0.04	0.45	37033
5370003.02	537	Hamilton	3660	0.42	0.05	0.49	31944
5370003.03	537	Hamilton	3129	0.35	0.04	0.41	27594
5370003.04	537	Hamilton	5932	0.34	0.05	0.41	28937
5370004.01	537	Hamilton	3247	0.32	0.05	0.4	26955
5370004.02	537	Hamilton	4330	0.34	0.06	0.43	29469
5370005.01	537	Hamilton	5886	0.35	0.04	0.43	30385
5370005.02	537	Hamilton	3886	0.34	0.05	0.41	28272
5370005.03	537	Hamilton	4116	0.41	0.03	0.46	33473
5370006.00	537	Hamilton	4766	0.44	0.03	0.49	33501
5370007.00	537	Hamilton	3324	0.34	0.05	0.41	30522
5370008.00	537	Hamilton	2549	0.29	0.03	0.36	27282
5370009.00	537	Hamilton	3772	0.34	0.04	0.41	26987
5370010.00	537	Hamilton	3080	0.38	0.05	0.44	30443
5370011.00	537	Hamilton	2262	0.37	0.02	0.42	33387
5370012.00	537	Hamilton	1533	0.35	0.08	0.47	26214
5370013.00	537	Hamilton	2827	0.36	0.04	0.43	37544
5370014.00	537	Hamilton	2708	0.38	0.02	0.42	43646
5370015.00	537	Hamilton	1668	0.33	0.01	0.36	36145
5370016.00	537	Hamilton	351	0.46	0	0.47	56324
5370017.00	537	Hamilton	3518	0.4	0.04	0.49	53391
5370018.00	537	Hamilton	58	NoData	NoData	NoData	NoData
5370019.00	537	Hamilton	3883	0.4	0.05	0.49	39834
5370020.00	537	Hamilton	4092	0.42	0.04	0.49	33779
5370021.00	537	Hamilton	4559	0.44	0.07	0.55	31045
5370022.00	537	Hamilton	4758	0.37	0.07	0.47	29946
5370023.00	537	Hamilton	2295	0.39	0.04	0.45	34042
5370024.00	537	Hamilton	2563	0.35	0.05	0.43	38814
5370025.00	537	Hamilton	2779	0.41	0.04	0.47	31576
5370026.01	537	Hamilton	3372	0.32	0.07	0.43	27547

5370026.02	537	Hamilton	1841	0.26	0.07	0.36	29023
5370026.03	537	Hamilton	2185	0.47	0.02	0.5	36646
5370026.04	537	Hamilton	1615	0.4	0.03	0.44	36470
5370026.05	537	Hamilton	4356	0.34	0.05	0.4	29697
5370026.06	537	Hamilton	5701	0.37	0.08	0.47	26460
5370027.00	537	Hamilton	1054	0.37	0.07	0.47	31741
5370028.00	537	Hamilton	2842	0.4	0.04	0.47	30411
5370029.00	537	Hamilton	4255	0.39	0.07	0.49	30678
5370030.00	537	Hamilton	4223	0.42	0.06	0.52	35297
5370031.00	537	Hamilton	2180	0.37	0.07	0.47	32394
5370032.00	537	Hamilton	3398	0.3	0.08	0.41	27119
5370033.00	537	Hamilton	3244	0.33	0.07	0.44	29896
5370034.00	537	Hamilton	4965	0.29	0.12	0.49	29806
5370035.00	537	Hamilton	3894	0.25	0.11	0.42	25355
5370036.00	537	Hamilton	2542	NoData	NoData	NoData	NoData
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5370038.00	537	Hamilton	3668	0.24	0.09	0.42	34782
5370039.00	537	Hamilton	5140	0.31	0.11	0.54	28987
5370040.00	537	Hamilton	2037	0.35	0.08	0.57	37107
5370041.00	537	Hamilton	2134	0.3	0.09	0.5	26348
5370042.00	537	Hamilton	2730	0.42	0.08	0.57	34325
5370043.00	537	Hamilton	3633	0.32	0.07	0.45	39237
5370044.00	537	Hamilton	4585	0.31	0.09	0.45	29774
5370045.00	537	Hamilton	3351	0.31	0.06	0.53	48582
5370046.00	537	Hamilton	3212	0.31	0.06	0.46	33877
5370047.00	537	Hamilton	2871	0.31	0.04	0.44	27488
5370048.00	537	Hamilton	1761	0.16	0.1	0.35	20262
5370049.00	537	Hamilton	2597	0.17	0.05	0.3	23470
5370050.00	537	Hamilton	4442	0.22	0.07	0.33	21751
5370051.00	537	Hamilton	4236	0.25	0.07	0.37	23280
5370052.00	537	Hamilton	3778	0.32	0.1	0.47	29125
5370053.00	537	Hamilton	3263	0.36	0.07	0.48	26172
5370054.00	537	Hamilton	2743	0.36	0.07	0.48	28424
5370055.00	537	Hamilton	3113	0.36	0.09	0.48	28489
5370056.00	537	Hamilton	3292	0.41	0.05	0.48	28119
5370057.00	537	Hamilton	3084	0.34	0.06	0.45	25674
5370058.00	537	Hamilton	2510	0.25	0.1	0.38	23468
5370059.00	537	Hamilton	3200	0.27	0.09	0.4	24709
5370060.00	537	Hamilton	2694	0.28	0.07	0.39	26472
5370061.00	537	Hamilton	3196	0.29	0.06	0.37	23335
5370062.00	537	Hamilton	3538	0.26	0.06	0.37	23016
5370063.00	537	Hamilton	3182	0.22	0.08	0.36	19204
5370064.00	537	Hamilton	1821	0.29	0.05	0.43	23661
5370065.00	537	Hamilton	2389	0.33	0.06	0.45	22980
5370066.00	537	Hamilton	5252	0.29	0.08	0.42	27365

5370067.00	537	Hamilton	1831	0.29	0.07	0.42	21493
5370068.00	537	Hamilton	907	0.38	0.05	0.47	25080
5370069.00	537	Hamilton	836	0.36	0.05	0.46	25542
5370070.00	537	Hamilton	2177	0.4	0.04	0.48	28921
5370071.00	537	Hamilton	6832	0.27	0.07	0.38	23011
5370072.01	537	Hamilton	143	0.38	0	0.45	0
5370072.02	537	Hamilton	3993	0.31	0.03	0.37	26407
5370072.03	537	Hamilton	7048	0.32	0.05	0.42	23042
5370072.04	537	Hamilton	3493	0.42	0.03	0.48	30202
5370073.00	537	Hamilton	1103	0.46	0.04	0.51	38157
5370080.01	537	Hamilton	2368	0.48	0	0.51	38976
5370080.03	537	Hamilton	4110	0.51	0.02	0.53	39766
5370080.05	537	Hamilton	6119	0.48	0.01	0.5	37731
5370080.06	537	Hamilton	5606	NoData	NoData	NoData	NoData
5370080.07	537	Hamilton	2250	NoData	NoData	NoData	NoData
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5370082.00	537	Hamilton	3648	0.35	0.02	0.41	32633
5370083.00	537	Hamilton	2469	0.4	0.02	0.46	30600
5370084.01	537	Hamilton	2822	0.36	0.03	0.41	31094
5370084.02	537	Hamilton	3115	0.39	0.01	0.43	32488
5370084.03	537	Hamilton	2169	0.47	0.01	0.5	35940
5370084.04	537	Hamilton	1882	0.46	0.02	0.49	38895
5370084.05	537	Hamilton	2991	0.46	0.01	0.47	33434
5370085.01	537	Hamilton	4548	0.48	0.02	0.52	41521
5370085.02	537	Hamilton	6685	0.49	0.03	0.54	36794
5370085.03	537	Hamilton	2824	0.47	0.01	0.49	39680
5370086.00	537	Hamilton	6342	0.45	0.02	0.48	45770
5370100.00	537	Hamilton	5660	0.49	0	0.51	40865
5370101.01	537	Hamilton	5532	0.69	0.02	0.72	35987
5370101.02	537	Hamilton	4101	NoData	NoData	NoData	NoData
5370120.01	537	Hamilton	7116	0.43	0.01	0.45	50763
5370120.02	537	Hamilton	2175	0.46	0	0.49	44573
5370121.00	537	Hamilton	1811	0.44	0.01	0.46	51851
5370122.01	537	Hamilton	4835	0.47	0.02	0.5	47407
5370122.02	537	Hamilton	6394	0.45	0.02	0.48	56672
5370123.00	537	Hamilton	7085	0.42	0.01	0.44	57330
5370124.00	537	Hamilton	3816	0.45	0.01	0.47	68957
5370130.02	537	Hamilton	3955	0.38	0.02	0.44	45506
5370130.03	537	Hamilton	3946	0.36	0.03	0.41	50647
5370131.00	537	Hamilton	4721	0.42	0.03	0.48	42344
5370132.00	537	Hamilton	3104	0.38	0.01	0.48	35006
5370133.01	537	Hamilton	2894	0.62	0.03	0.72	23421
5370133.02	537	Hamilton	6082	0.3	0.02	0.34	23421
5370140.02	537	Hamilton	6863	0.45	0.01	0.5	43952
5370140.03	537	Hamilton	5395	0.47	0.01	0.5	46174

5370140.04	537	Hamilton	3548	0.49	0.02	0.54	48653
5370141.00	537	Hamilton	4181	0.45	0	0.48	44664
5370142.01	537	Hamilton	3818	0.48	0	0.51	41786
5370142.02	537	Hamilton	3798	0.39	0	0.43	34090
5370143.00	537	Hamilton	4043	0.42	0	0.45	36538
5370144.01	537	Hamilton	5549	0.31	0.01	0.33	26657
5370144.02	537	Hamilton	2025	0.84	0.02	0.9	26656
5370200.00	537	Hamilton	2661	0.37	0.02	0.41	63279
5370201.00	537	Hamilton	3432	0.43	0.04	0.49	49051
5370202.00	537	Hamilton	4255	0.42	0.03	0.47	51492
5370224.00	537	Hamilton	4873	0.34	0.01	0.38	77642
5370300.00	537	Hamilton	2079	0.43	0.01	0.46	38117
5370301.00	537	Hamilton	5130	0.48	0.01	0.51	45850
5370302.00	537	Hamilton	5689	0.41	0.01	0.48	34840
5370303.01	537	Hamilton	3646	0.5	0.01	0.53	41954
5370303.02	537	Hamilton	7393	0.43	0.01	0.47	46549
5390001.00	539	St. Catharines - Niagara	4212	0.46	0.02	0.5	26212
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5390007.01	539	St. Catharines - Niagara	4379	0.38	0.02	0.43	23025
5390007.02	539	St. Catharines - Niagara	5004	0.46	0.02	0.5	20918
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5390010.00	539	St. Catharines - Niagara	3798	0.36	0.02	0.47	22449
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5390013.01	539	St. Catharines - Niagara	4698	0.42	0.02	0.48	22128
5390013.02	539	St. Catharines - Niagara	4957	0.38	0.01	0.43	21708
5390014.01	539	St. Catharines - Niagara	3842	0.31	0.02	0.37	20961
5390014.02	539	St. Catharines - Niagara	5131	0.39	0.01	0.42	25128
5390014.03	539	St. Catharines - Niagara	3161	0.41	0.01	0.45	25271
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5390016.01	539	St. Catharines - Niagara	4976	0.39	0.02	0.43	24762
5390016.02	539	St. Catharines - Niagara	4391	0.49	0.02	0.51	27597
5390017.01	539	St. Catharines - Niagara	3824	0.46	0	0.47	32387
5390017.02	539	St. Catharines - Niagara	4520	0.4	0.02	0.43	31255
5390018.01	539	St. Catharines - Niagara	4923	0.43	0.02	0.48	26639
5390018.02	539	St. Catharines - Niagara	4871	0.41	0.02	0.46	29093
5390018.03	539	St. Catharines - Niagara	3922	0.49	0.01	0.51	34947

5390019.00	539	St. Catharines - Niagara	1328	0.36	0.01	0.4	32014
5390020.00	539	St. Catharines - Niagara	683	0.45	0	0.48	29705
5390100.00	539	St. Catharines - Niagara	2927	0.44	0.02	0.51	23312
5390101.00	539	St. Catharines - Niagara	5890	0.4	0.01	0.44	24228
5390102.01	539	St. Catharines - Niagara	4861	0.54	0.01	0.55	33630
5390102.02	539	St. Catharines - Niagara	3244	0.47	0	0.5	27631
5390102.03	539	St. Catharines - Niagara	1302	0.46	0	0.47	25882
5390110.00	539	St. Catharines - Niagara	3908	0.23	0.01	0.29	28645
5390111.00	539	St. Catharines - Niagara	6246	0.4	0	0.42	27670
5390112.00	539	St. Catharines - Niagara	4433	0.43	0	0.45	30377
5390200.00	539	St. Catharines - Niagara	2722	0.49	0	0.5	32098
5390201.00	539	St. Catharines - Niagara	5179	0.41	0.02	0.46	25518
5390202.00	539	St. Catharines - Niagara	296	0.39	0	0.42	20756
5390203.01	539	St. Catharines - Niagara	5232	0.41	0.02	0.46	22346
5390203.02	539	St. Catharines - Niagara	3661	0.48	0.01	0.51	24820
5390204.00	539	St. Catharines - Niagara	6720	0.39	0.01	0.48	23038
5390205.00	539	St. Catharines - Niagara	1672	0.28	0.03	0.46	19227
5390206.00	539	St. Catharines - Niagara	54156	0.03	0	0.04	21756
5390207.00	539	St. Catharines - Niagara	5732	0.39	0.01	0.47	22171
5390208.00	539	St. Catharines - Niagara	5932	0.46	0.01	0.48	26826
5390209.03	539	St. Catharines - Niagara	5312	0.44	0.01	0.46	22360
5390209.04	539	St. Catharines - Niagara	3398	0.48	0.02	0.51	28557
5390209.05	539	St. Catharines - Niagara	6461	0.5	0.02	0.53	29274
5390209.06	539	St. Catharines - Niagara	2964	0.47	0.01	0.49	30911
5390210.00	539	St. Catharines - Niagara	3124	0.44	0	0.44	30847
5390211.00	539	St. Catharines - Niagara	4555	0.52	0.01	0.54	29042
5390212.00	539	St. Catharines - Niagara	1944	0.38	0.03	0.44	23103
5390213.00	539	St. Catharines - Niagara	2998	0.47	0	0.49	27404
5390214.00	539	St. Catharines - Niagara	4734	0.44	0	0.47	25578
5390215.00	539	St. Catharines - Niagara	4392	0.36	0.03	0.46	20059
5390220.01	539	St. Catharines - Niagara	5897	0.45	0	0.46	36032
5390220.02	539	St. Catharines - Niagara	4483	0.42	0	0.44	34466
5390221.00	539	St. Catharines - Niagara	5775	0.42	0	0.44	28665
5390230.00	539	St. Catharines - Niagara	6601	0.44	0	0.46	26321
5390240.00	539	St. Catharines - Niagara	7473	0.36	0	0.4	26967
5390241.00	539	St. Catharines - Niagara	2936	0.44	0	0.45	28913
5390242.01	539	St. Catharines - Niagara	7046	0.48	0	0.51	27976
5390242.02	539	St. Catharines - Niagara	4267	0.4	0	0.43	27914
5390300.00	539	St. Catharines - Niagara	1274	0.48	0.01	0.5	25343
5390301.00	539	St. Catharines - Niagara	4815	0.4	0.01	0.44	22228
5390302.00	539	St. Catharines - Niagara	3363	0.44	0	0.48	24303
5390303.00	539	St. Catharines - Niagara	1537	0.48	0	0.49	33728
5390304.00	539	St. Catharines - Niagara	3753	0.38	0.01	0.44	24037
5390305.00	539	St. Catharines - Niagara	2375	0.35	0.01	0.4	17554
5390306.00	539	St. Catharines - Niagara	2121	0.33	0.01	0.41	18181

5390307.00	539	St. Catharines - Niagara	4630	0.36	0.01	0.41	22088
5390308.00	539	St. Catharines - Niagara	1801	0.4	0.01	0.47	25215
5390309.00	539	St. Catharines - Niagara	2605	0.45	0.01	0.48	27470
5390310.01	539	St. Catharines - Niagara	2676	0.4	0	0.43	26663
5390310.02	539	St. Catharines - Niagara	5481	0.43	0.01	0.45	28957
5390311.02	539	St. Catharines - Niagara	5862	0.46	0.01	0.5	29575
5390311.03	539	St. Catharines - Niagara	4877	0.44	0	0.47	30423
5390311.04	539	St. Catharines - Niagara	3161	0.48	0.01	0.5	28663
5390320.00	539	St. Catharines - Niagara	3416	0.38	0	0.41	21834
5390321.00	539	St. Catharines - Niagara	4856	0.4	0.01	0.43	27386
5390322.00	539	St. Catharines - Niagara	3536	0.33	0	0.38	21059
5390323.00	539	St. Catharines - Niagara	3193	0.42	0	0.44	24582
5390324.00	539	St. Catharines - Niagara	3598	0.44	0	0.45	27851
5390330.00	539	St. Catharines - Niagara	4718	0.33	0	0.38	21314
5390331.01	539	St. Catharines - Niagara	4009	0.45	0	0.47	25319
5390331.02	539	St. Catharines - Niagara	4008	0.45	0	0.47	25319
5390332.00	539	St. Catharines - Niagara	4535	0.4	0	0.42	24692
5390333.00	539	St. Catharines - Niagara	3070	0.42	0	0.44	26242
5390334.01	539	St. Catharines - Niagara	5912	0.39	0	0.43	22536
5390334.02	539	St. Catharines - Niagara	3673	0.46	0	0.47	27152

CTUID	CMAUID	CMANAME	POP2011	% VehOwn	% PubTran	% Empt	MedInco
5370001.01	537	Hamilton	2118	0.39	0.04	0.43	27879
5370001.02	537	Hamilton	5475	0.39	0.05	0.47	30131
5370001.04	537	Hamilton	6223	0.38	0.06	0.46	27931
5370001.05	537	Hamilton	4695	0.37	0.03	0.42	28256
5370001.06	537	Hamilton	5411	0.45	0.04	0.5	28213
5370001.07	537	Hamilton	3713	0.34	0.08	0.43	28096
5370001.08	537	Hamilton	6125	0.41	0.03	0.44	29703
5370001.09	537	Hamilton	4445	0.42	0.04	0.46	35147
5370002.01	537	Hamilton	5079	0.45	0.04	0.49	35541
5370002.03	537	Hamilton	3066	0.4	0.04	0.46	33629
5370002.04	537	Hamilton	4790	0.42	0.04	0.46	31097
5370002.05	537	Hamilton	6138	0.44	0.04	0.48	38386
5370002.06	537	Hamilton	2686	0.33	0.03	0.38	28987
5370003.01	537	Hamilton	5257	0.33	0.04	0.39	33548
5370003.02	537	Hamilton	3445	0.35	0.03	0.4	28900
5370003.03	537	Hamilton	2997	0.3	0.04	0.36	23847
5370003.04	537	Hamilton	5843	0.32	0.04	0.38	26810
5370004.01	537	Hamilton	3235	0.33	0.04	0.42	23300
5370004.02	537	Hamilton	4321	0.34	0.04	0.41	21724
5370005.01	537	Hamilton	6136	0.35	0.03	0.39	25732
5370005.02	537	Hamilton	3884	0.36	0.04	0.41	28252
5370005.03	537	Hamilton	4053	0.38	0.04	0.43	28145
5370006.00	537	Hamilton	4699	0.36	0.04	0.41	30917
5370007.00	537	Hamilton	3201	0.3	0.1	0.41	31112
5370008.00	537	Hamilton	2536	0.24	0.07	0.35	30109
5370009.00	537	Hamilton	3723	0.32	0.06	0.4	26202
5370010.00	537	Hamilton	3136	0.35	0.07	0.44	28717
5370011.00	537	Hamilton	2250	0.44	0.04	0.51	31383
5370012.00	537	Hamilton	1512	NoData	NoData	NoData	NoData
5370013.00	537	Hamilton	2816	0.36	0.03	0.42	34399
5370014.00	537	Hamilton	2728	0.37	0.03	0.41	35098
5370015.00	537	Hamilton	1471	0.42	0.01	0.45	41637
5370016.00	537	Hamilton	917	0.16	0	0.16	45947
5370017.00	537	Hamilton	3392	0.34	0.05	0.45	49715
5370018.00	537	Hamilton	62	NoData	NoData	NoData	NoData
5370019.00	537	Hamilton	3859	0.44	0.05	0.52	35760
5370020.00	537	Hamilton	4022	0.39	0.08	0.5	30471
5370021.00	537	Hamilton	4598	0.4	0.07	0.51	30144
5370022.00	537	Hamilton	4715	0.38	0.1	0.51	26677
5370023.00	537	Hamilton	2271	0.44	0.04	0.52	34941
5370024.00	537	Hamilton	2584	0.45	0.05	0.5	29131
5370025.00	537	Hamilton	2756	0.39	0.04	0.44	31061
5370026.01	537	Hamilton	3355	0.29	0.06	0.37	22486

5370026.02	537	Hamilton	1881	0.21	0.03	0.27	24373
5370026.03	537	Hamilton	2122	0.43	0.02	0.47	32567
5370026.04	537	Hamilton	1573	0.4	0.01	0.42	34317
5370026.05	537	Hamilton	4173	0.35	0.03	0.4	29110
5370026.06	537	Hamilton	5797	0.33	0.05	0.4	20832
5370027.00	537	Hamilton	1064	0.45	0.06	0.51	35624
5370028.00	537	Hamilton	2849	0.4	0.06	0.49	29632
5370029.00	537	Hamilton	4335	0.39	0.05	0.48	28971
5370030.00	537	Hamilton	4011	0.43	0.07	0.52	36116
5370031.00	537	Hamilton	2098	0.39	0.08	0.51	33155
5370032.00	537	Hamilton	3312	NoData	NoData	NoData	NoData
5370033.00	537	Hamilton	3178	0.34	0.09	0.45	27916
5370034.00	537	Hamilton	5019	0.27	0.11	0.48	25551
5370035.00	537	Hamilton	3669	0.25	0.1	0.4	18498
5370036.00	537	Hamilton	3243	0.19	0.11	0.4	20235
5370037.00	537	Hamilton	2464	0.23	0.06	0.35	18714
5370038.00	537	Hamilton	3633	0.21	0.11	0.41	21582
5370039.00	537	Hamilton	4982	0.29	0.12	0.49	25870
5370040.00	537	Hamilton	1985	0.41	0.07	0.54	24475
5370041.00	537	Hamilton	2001	0.32	0.06	0.44	26309
5370042.00	537	Hamilton	2685	0.35	0.04	0.48	31456
5370043.00	537	Hamilton	3977	0.29	0.06	0.41	20927
5370044.00	537	Hamilton	4369	0.33	0.07	0.43	24814
5370045.00	537	Hamilton	3014	0.27	0.06	0.44	28704
5370046.00	537	Hamilton	3165	0.27	0.08	0.43	26006
5370047.00	537	Hamilton	2867	0.27	0.07	0.44	25327
5370048.00	537	Hamilton	1858	0.2	0.08	0.38	20381
5370049.00	537	Hamilton	2473	0.13	0.06	0.24	17370
5370050.00	537	Hamilton	4341	NoData	NoData	NoData	NoData
5370051.00	537	Hamilton	4236	0.15	0.1	0.3	19851
5370052.00	537	Hamilton	3772	NoData	NoData	NoData	NoData
5370053.00	537	Hamilton	3096	NoData	NoData	NoData	NoData
5370054.00	537	Hamilton	2732	0.31	0.07	0.4	21088
5370055.00	537	Hamilton	2943	0.42	0.07	0.52	31103
5370056.00	537	Hamilton	3266	0.37	0.08	0.46	24801
5370057.00	537	Hamilton	3070	NoData	NoData	NoData	NoData
5370058.00	537	Hamilton	2361	NoData	NoData	NoData	NoData
5370059.00	537	Hamilton	3173	NoData	NoData	NoData	NoData
5370060.00	537	Hamilton	2770	0.26	0.07	0.36	21065
5370061.00	537	Hamilton	3151	0.23	0.06	0.33	21497
5370062.00	537	Hamilton	3395	NoData	NoData	NoData	NoData
5370063.00	537	Hamilton	3381	NoData	NoData	NoData	NoData
5370064.00	537	Hamilton	1658	NoData	NoData	NoData	NoData
5370065.00	537	Hamilton	2413	0.25	0.08	0.4	19637
5370066.00	537	Hamilton	5189	0.29	0.06	0.39	25210

5370067.00	537	Hamilton	1687	NoData	NoData	NoData	NoData
5370068.00	537	Hamilton	881	NoData	NoData	NoData	NoData
5370069.00	537	Hamilton	883	0.31	0.04	0.39	23789
5370070.00	537	Hamilton	2207	0.39	0.06	0.47	28067
5370071.00	537	Hamilton	6612	0.29	0.05	0.37	22934
5370072.01	537	Hamilton	120	NoData	NoData	NoData	NoData
5370072.02	537	Hamilton	3931	0.25	0.04	0.31	24338
5370072.03	537	Hamilton	7055	0.26	0.03	0.33	20976
5370072.04	537	Hamilton	3461	0.4	0.05	0.48	26667
5370073.00	537	Hamilton	1162	0.53	0.03	0.56	36226
5370080.01	537	Hamilton	2447	0.47	0.01	0.5	31830
5370080.03	537	Hamilton	4551	0.45	0.04	0.5	31194
5370080.05	537	Hamilton	6546	0.47	0.01	0.49	37949
5370080.06	537	Hamilton	5454	0.48	0.03	0.52	33314
5370080.07	537	Hamilton	2130	0.47	0.02	0.5	32490
5370081.00	537	Hamilton	2291	0.4	0.01	0.44	30056
5370082.00	537	Hamilton	3624	0.32	0.04	0.39	25365
5370083.00	537	Hamilton	2383	0.39	0.03	0.43	29072
5370084.01	537	Hamilton	2690	0.41	0	0.44	29797
5370084.02	537	Hamilton	3029	0.43	0.02	0.5	27874
5370084.03	537	Hamilton	2045	0.38	0.03	0.42	28250
5370084.04	537	Hamilton	1878	0.36	0.02	0.42	31480
5370084.05	537	Hamilton	2962	0.4	0.01	0.43	29007
5370085.01	537	Hamilton	4283	0.44	0.02	0.49	30027
5370085.02	537	Hamilton	6637	0.45	0.04	0.5	30791
5370085.03	537	Hamilton	3606	0.49	0.01	0.52	34347
5370086.00	537	Hamilton	8564	0.46	0.01	0.47	40389
5370100.00	537	Hamilton	11675	0.51	0.01	0.52	40867
5370101.01	537	Hamilton	6862	0.38	0.01	0.38	39174
5370101.02	537	Hamilton	3901	NoData	NoData	NoData	NoData
5370120.01	537	Hamilton	9531	0.43	0.02	0.46	41933
5370120.02	537	Hamilton	2203	0.45	0.01	0.48	34240
5370121.00	537	Hamilton	1791	NoData	NoData	NoData	NoData
5370122.01	537	Hamilton	5574	0.46	0.01	0.49	44932
5370122.02	537	Hamilton	6741	0.44	0.02	0.47	48236
5370123.00	537	Hamilton	7353	0.42	0.02	0.45	40932
5370124.00	537	Hamilton	3718	0.43	0.03	0.47	45781
5370130.02	537	Hamilton	3955	0.39	0.02	0.43	44539
5370130.03	537	Hamilton	3589	0.3	0.03	0.37	38259
5370131.00	537	Hamilton	4668	0.41	0.03	0.47	34772
5370132.00	537	Hamilton	3005	0.37	0.03	0.43	31363
5370133.01	537	Hamilton	3601	0.37	0.02	0.41	44306
5370133.02	537	Hamilton	6089	0.36	0.02	0.43	37646
5370140.02	537	Hamilton	7430	0.46	0.02	0.49	38393
5370140.03	537	Hamilton	6140	0.5	0.02	0.55	43729

5370140.04	537	Hamilton	3478	0.49	0.02	0.53	43512
5370141.00	537	Hamilton	4130	0.41	0.03	0.45	40418
5370142.01	537	Hamilton	3932	0.48	0	0.5	32473
5370142.02	537	Hamilton	4000	0.39	0.01	0.41	32406
5370143.00	537	Hamilton	3781	0.44	0.01	0.46	35304
5370144.01	537	Hamilton	5331	0.43	0.01	0.45	40369
5370144.02	537	Hamilton	1870	0.49	0	0.51	36943
5370200.00	537	Hamilton	2657	0.36	0.03	0.39	52703
5370201.00	537	Hamilton	3504	0.46	0.02	0.5	39162
5370202.00	537	Hamilton	5293	0.38	0.03	0.42	40476
5370224.00	537	Hamilton	4840	1.06	0.08	1.16	44369
5370300.00	537	Hamilton	1905	0.44	0	0.46	31380
5370301.00	537	Hamilton	6373	0.48	0.01	0.51	41289
5370302.00	537	Hamilton	5379	0.39	0.01	0.43	29993
5370303.01	537	Hamilton	3706	0.51	0.01	0.52	37271
5370303.02	537	Hamilton	7962	0.42	0.01	0.44	37802
5390001.00	539	St. Catharines - Niagara	4030	0.42	0.04	0.51	27508
5390002.00	539	St. Catharines - Niagara	5885	0.39	0.01	0.43	33774
5390003.01	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData
5390003.02	539	St. Catharines - Niagara	8005	0.47	0.02	0.51	36248
5390004.01	539	St. Catharines - Niagara	4305	0.39	0.01	0.41	30553
5390004.02	539	St. Catharines - Niagara	4040	0.35	0.02	0.41	25437
5390005.00	539	St. Catharines - Niagara	3025	0.26	0.1	0.44	20344
5390006.00	539	St. Catharines - Niagara	1925	0.37	0.03	0.43	30710
5390007.01	539	St. Catharines - Niagara	4270	0.4	0.03	0.46	26476
5390007.02	539	St. Catharines - Niagara	5415	0.46	0.02	0.49	29682
5390008.00	539	St. Catharines - Niagara	2560	0.39	0.02	0.44	27844
5390009.00	539	St. Catharines - Niagara	6080	0.36	0.04	0.48	19989
5390010.00	539	St. Catharines - Niagara	3685	0.39	0.03	0.49	24970
5390011.00	539	St. Catharines - Niagara	7105	0.38	0.02	0.45	26927
5390012.01	539	St. Catharines - Niagara	4130	0.34	0.01	0.43	23327
5390012.02	539	St. Catharines - Niagara	5890	0.38	0.02	0.44	27922
5390013.01	539	St. Catharines - Niagara	4670	0.38	0.02	0.43	23346
5390013.02	539	St. Catharines - Niagara	4910	0.33	0.02	0.39	23861
5390014.01	539	St. Catharines - Niagara	3715	0.25	0.01	0.28	22866
5390014.02	539	St. Catharines - Niagara	4990	0.43	0.01	0.46	31511
5390014.03	539	St. Catharines - Niagara	3190	0.41	0.01	0.47	26592
5390015.00	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData
5390016.01	539	St. Catharines - Niagara	4580	0.45	0.02	0.48	29527
5390016.02	539	St. Catharines - Niagara	4395	0.44	0.01	0.47	32725
5390017.01	539	St. Catharines - Niagara	3760	0.42	0.01	0.46	34985
5390017.02	539	St. Catharines - Niagara	4290	0.42	0.01	0.45	32101
5390018.01	539	St. Catharines - Niagara	4700	0.39	0.02	0.43	31213
5390018.02	539	St. Catharines - Niagara	4415	0.41	0.01	0.44	29631
5390018.03	539	St. Catharines - Niagara	3830	0.46	0.01	0.48	38815

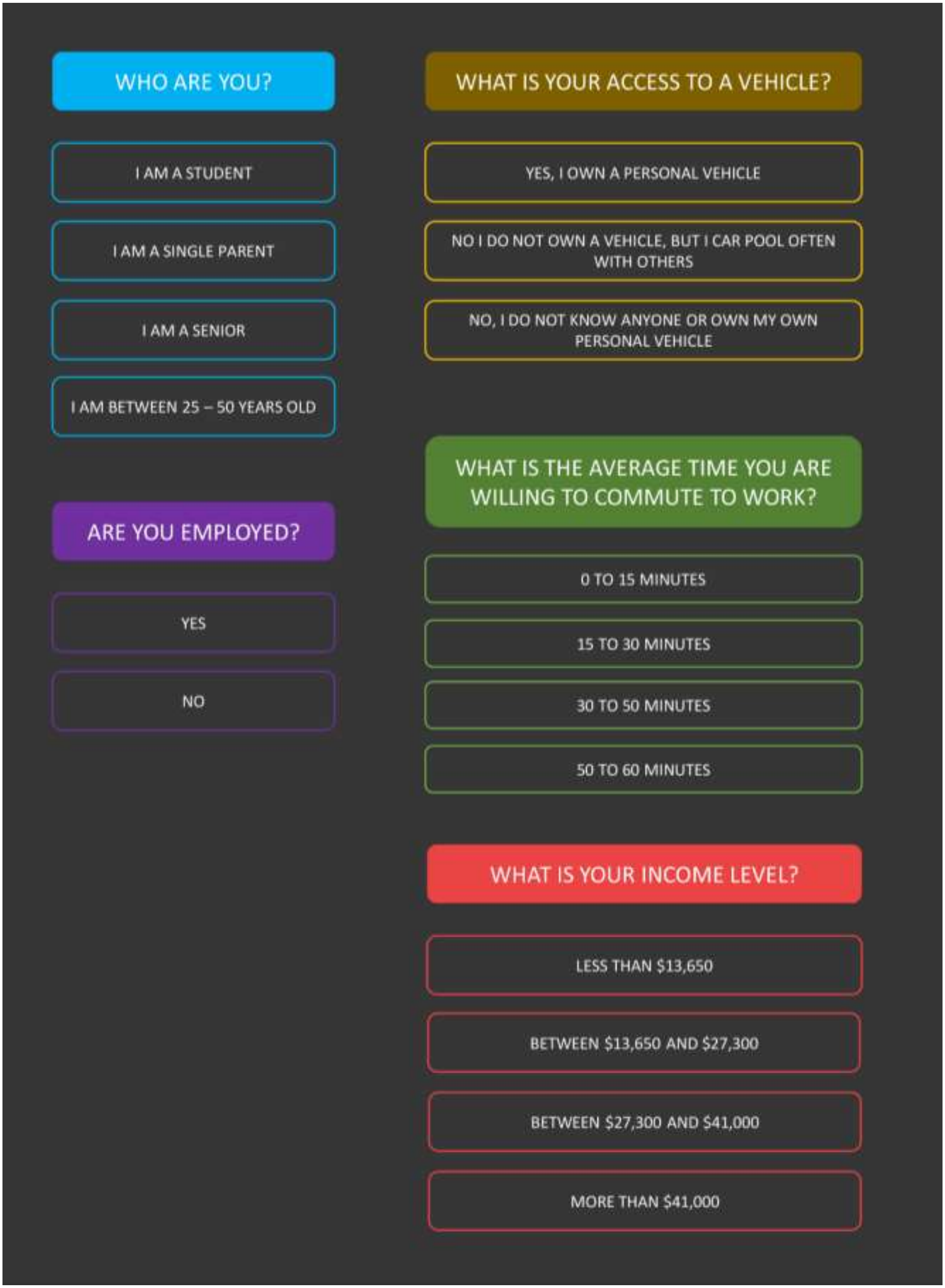
5390019.00	539	St. Catharines - Niagara	1250	0.42	0.04	0.46	28290
5390020.00	539	St. Catharines - Niagara	740	0.36	0	0.41	39691
5390100.00	539	St. Catharines - Niagara	2740	0.4	0.01	0.44	22123
5390101.00	539	St. Catharines - Niagara	5500	0.41	0.02	0.45	28805
5390102.01	539	St. Catharines - Niagara	4820	0.48	0.01	0.5	33261
5390102.02	539	St. Catharines - Niagara	3230	0.48	0.01	0.49	31787
5390102.03	539	St. Catharines - Niagara	1260	0.48	0	0.48	36972
5390110.00	539	St. Catharines - Niagara	3490	0.3	0	0.33	32847
5390111.00	539	St. Catharines - Niagara	6360	0.39	0.01	0.41	34140
5390112.00	539	St. Catharines - Niagara	4850	0.37	0	0.38	29658
5390200.00	539	St. Catharines - Niagara	2840	0.48	0	0.49	28074
5390201.00	539	St. Catharines - Niagara	4810	0.43	0.02	0.46	28964
5390202.00	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData
5390203.01	539	St. Catharines - Niagara	5385	0.36	0.02	0.42	23510
5390203.02	539	St. Catharines - Niagara	3355	0.49	0.02	0.52	25816
5390204.00	539	St. Catharines - Niagara	6625	0.37	0.02	0.45	23418
5390205.00	539	St. Catharines - Niagara	1400	0.32	0.02	0.5	20849
5390206.00	539	St. Catharines - Niagara	4800	0.35	0.03	0.46	23650
5390207.00	539	St. Catharines - Niagara	5440	0.38	0.02	0.46	25148
5390208.00	539	St. Catharines - Niagara	5710	0.43	0.01	0.46	28203
5390209.03	539	St. Catharines - Niagara	4740	0.46	0.02	0.5	26511
5390209.04	539	St. Catharines - Niagara	3395	0.42	0.02	0.45	28198
5390209.05	539	St. Catharines - Niagara	6530	0.49	0.02	0.52	31343
5390209.06	539	St. Catharines - Niagara	2880	0.43	0.01	0.45	32886
5390210.00	539	St. Catharines - Niagara	5470	0.44	0.01	0.46	37868
5390211.00	539	St. Catharines - Niagara	4385	0.45	0.01	0.47	33381
5390212.00	539	St. Catharines - Niagara	1845	0.36	0.01	0.39	25740
5390213.00	539	St. Catharines - Niagara	2975	0.45	0.01	0.48	33243
5390214.00	539	St. Catharines - Niagara	4540	0.45	0	0.46	24536
5390215.00	539	St. Catharines - Niagara	3940	0.33	0.03	0.43	20070
5390220.01	539	St. Catharines - Niagara	5900	0.43	0	0.44	41664
5390220.02	539	St. Catharines - Niagara	4625	0.42	0	0.44	35016
5390221.00	539	St. Catharines - Niagara	5695	0.45	0	0.46	34090
5390230.00	539	St. Catharines - Niagara	6300	0.4	0	0.41	29211
5390240.00	539	St. Catharines - Niagara	7040	0.37	0.01	0.41	32062
5390241.00	539	St. Catharines - Niagara	2785	0.4	0	0.43	30517
5390242.01	539	St. Catharines - Niagara	7425	0.44	0	0.46	30100
5390242.02	539	St. Catharines - Niagara	4445	0.4	0.01	0.45	34237
5390300.00	539	St. Catharines - Niagara	1455	0.43	0	0.44	32565
5390301.00	539	St. Catharines - Niagara	4730	0.42	0.02	0.45	25872
5390302.00	539	St. Catharines - Niagara	3355	0.38	0.01	0.42	24396
5390303.00	539	St. Catharines - Niagara	1490	0.46	0	0.48	34726
5390304.00	539	St. Catharines - Niagara	3640	0.41	0.01	0.46	22916
5390305.00	539	St. Catharines - Niagara	1805	0.22	0.02	0.28	19907
5390306.00	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData

5390307.00	539	St. Catharines - Niagara	4585	0.33	0	0.4	22860
5390308.00	539	St. Catharines - Niagara	2015	0.35	0.01	0.38	28258
5390309.00	539	St. Catharines - Niagara	2640	0.37	0	0.42	30236
5390310.01	539	St. Catharines - Niagara	2740	0.35	0.01	0.37	30095
5390310.02	539	St. Catharines - Niagara	6005	0.4	0	0.42	30114
5390311.02	539	St. Catharines - Niagara	5600	0.42	0.01	0.47	29671
5390311.03	539	St. Catharines - Niagara	4895	0.45	0	0.47	34333
5390311.04	539	St. Catharines - Niagara	3030	0.44	0.01	0.47	29443
5390320.00	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData
5390321.00	539	St. Catharines - Niagara	4515	0.4	0	0.42	32590
5390322.00	539	St. Catharines - Niagara	3225	0.36	0	0.4	26167
5390323.00	539	St. Catharines - Niagara	3360	0.4	0	0.43	30321
5390324.00	539	St. Catharines - Niagara	NoData	NoData	NoData	NoData	NoData
5390330.00	539	St. Catharines - Niagara	4205	0.36	0	0.43	24405
5390331.01	539	St. Catharines - Niagara	4770	0.44	0	0.45	29666
5390331.02	539	St. Catharines - Niagara	3305	0.38	0	0.39	24112
5390332.00	539	St. Catharines - Niagara	4225	0.41	0	0.44	27050
5390333.00	539	St. Catharines - Niagara	3335	0.41	0	0.42	32508
5390334.01	539	St. Catharines - Niagara	5810	0.38	0	0.41	28737
5390334.02	539	St. Catharines - Niagara	3725	0.45	0	0.48	28673

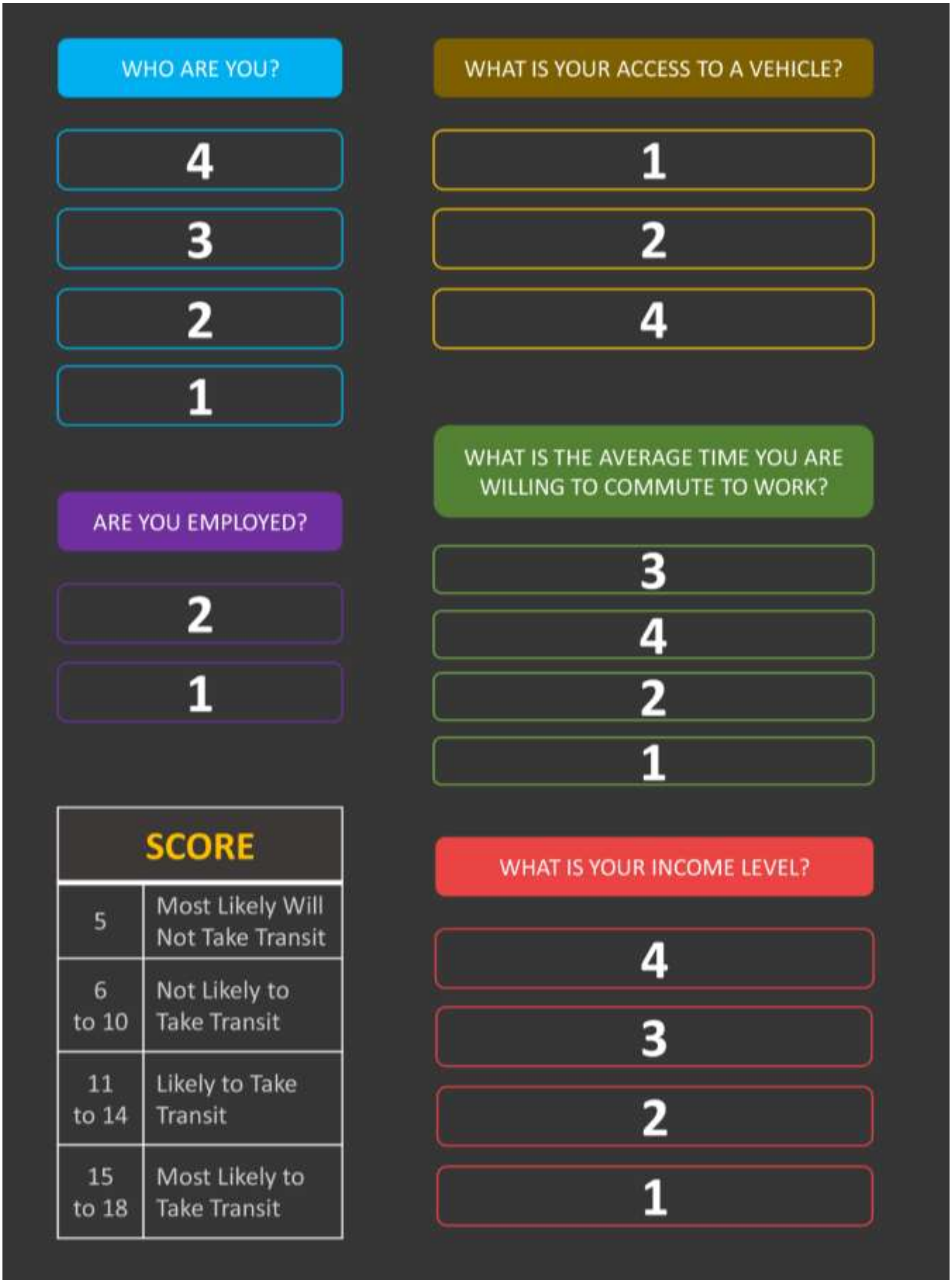
ROUTE OPTION FINANCIAL ASSESSMENT				
ROUTE OPTIONS				
DETAILS	**A**	**B**	**C**	**D**
Distance of Proposed Option (km)	70	94	94	-
No. of Trip per Day	4	4	4	-
Total Distance travelled per Day (km)	280	376	376	-
Annual No. of Trips	1,265	800	800	-
HOV Lane Distances km	-	15		-
Total annual travelled distance (km)	**88,550**	**75,200**	**75,200**	**-**
EXPENDITURES				
Equipment Maintenance	$17,710	$90,240	$90,240	$-
Train maintenance per km	$0.20	$-	$-	$-
Bus maintenance per km	$-	$1.20	$1.20	$-
Facilities	**$260,000**	**$65,000**		$-
No. of Stations	4	1	1	$-
Average cost per station	$65,000	$65,000	$65,000	$-
Operations Costs	**$1,040,463**	**$564,000**	**$564,000**	$-
Operations Cost Range	$1,483,213	$601,600	$601,600	$-
Rail costs / km	$11.75	$-	$-	$-
Rail costs / km range	$16.75	$-	$-	$-
Bus costs / km	$-	$7.50	$7.50	$-
Station Site Development	**$11,200,000**	**$5,950,000**	**$5,950,000**	$-
Niagara Falls Station	$5,950,000	$5,950,000	$5,950,000	$-
site preparation and demolition	$400,000	$400,000	$400,000	$-
parking, kiss and ride and access	$2,100,000	$2,100,000	$2,100,000	$-
municipal road modifications	$300,000	$300,000	$300,000	$-
bus facilities	$-	$-	$-	$-
bicycle facility	$-	$-	$-	$-
station building	$-	$-	$-	$-
station platform and mini platform	$2,900,000	$2,900,000	$2,900,000	$-
electrical, its, security, fare equipment	$200,000	$200,000	$200,000	$-
utility relocation	$50,000	$50,000	$50,000	$-
St. Catharines Station	$5,250,000	$-	$-	$-
site preparation and demolition	$150,000	$-	$-	$-
parking, kiss and ride and access	$2,700,000	$-	$-	$-
municipal road modifications	$600,000	$-	$-	$-
bus facilities	$400,000	$-	$-	$-
bicycle facility	$50,000	$-	$-	$-
station building	$-	$-	$-	$-
station platform and mini platform	$950,000	$-	$-	$-
electrical, its, security, fare equipment	$200,000	$-	$-	$-
utility relocation	$200,000	$-	$-	$-

Other Costs	$-	**$71,100**	$-	$-
HOV Lanes	$-	$71,100	$-	$-
Implmentation per km	$-	$4,740	$-	$-
Includes painting and signage				
Sub-Total	$12,518,173	$6,740,340	$6,669,240	
Contingency (10%)	$1,251,817	$674,034	$666,924	
Grand Total of Expenditures	**$13,769,990**	**$7,414,374**	**$7,336,164**	
*Stations for Option B and C exists only for Niagara Falls. University institutions have stops with existing university bus loops do not require station maintenance. NOTE: Expenditure grand totals do not include an assessment of supplies, labour and/or benefits.				
REVENUES				
Assessment of Revenue and Ridership Outlook (2017)				
Public Transit Users				
Total Population	940,000			
12% use public transit	112,800			
Commuters During Peak Time	9,000			
Seasonal Ridership				
Low	19,000			
High	25,000			
Ridership Projections				
Rail low	28,000	-	-	-
Rail high	34,000	-	-	-
Bus low	8,500	8,500	8,500	-
Bus high	10,325	10,325	10,325	-
RIDERSHIP OUTLOOK	**31,000**	**9,413**	**9,413**	**-**
Revenue Assessment				
Fare per Passenger Boarding	$14.35	$12.65	$12.65	-
Low Level	$401,800	$107,525	$107,525	-
High Level	$487,900	$130,611	$130,611	-
REVENUE OUTLOOK	**~$444,850**	**~$119,068**	**~$119,068**	**-**
Assessment of Revenue and Ridership Target (2017)				
Ridership	188,516	155,921	155,921	-
Revenue	$2,705,203	$1,466,400	$1,466,400	-
Fare per Passenger Boarding	$14.35	$12.65	$12.65	-
Government Approved Funding for Expansion Projects				
Station Site Development	**$11,200,000**	**$5,950,000**	**$5,950,000**	-
Niagara Falls Station	$5,950,000	$5,950,000	$5,950,000	-
St. Catharines Station	$5,250,000	$-	$-	-

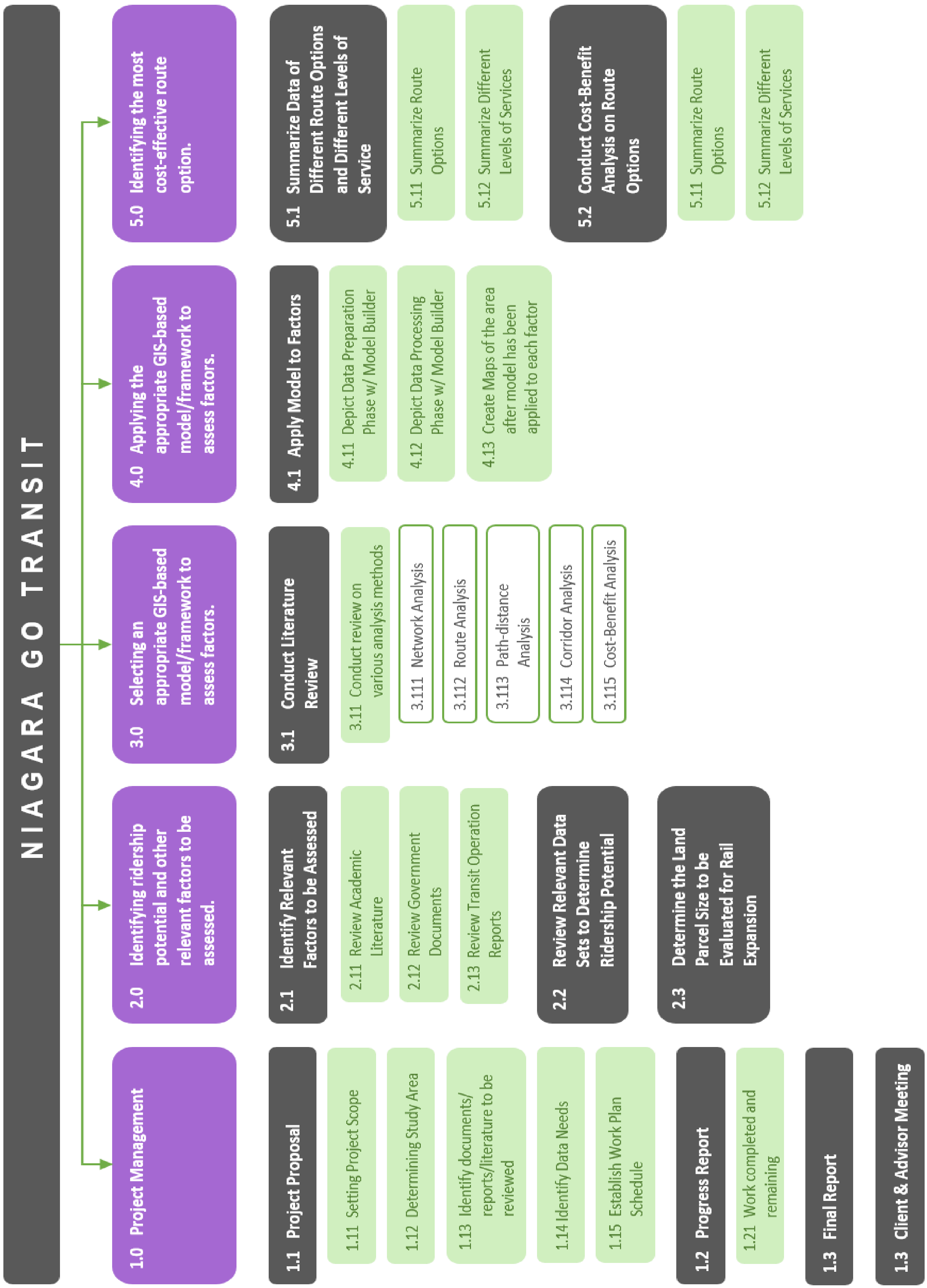
Implementing HOV Lanes	$-	$71,100	$-	-
Assessment of Social Benefits				
Carbon Emission Reduction	**$43,948**	**$4,852**	**$4,852**	$-
Carbon Emissions per KM	$0.496	$0.065	$0.065	$-
Carbon Tax Levy on Diesel Engines	$0.0767	$0.0767	$0.0767	$-
Engine Capacity (per Litre)	841.2	$84.12	$84.12	$-
Travel Speed (km / hr)	130	100	100	$-
Time Saved in Traffic ($)	**$1,680,840**	**$1,680,840**	**$1,680,840**	**($1,450,000,000)**
Average Wage (Hamilton Median in 2011 per hour)	$18	$18	$18	$-
Number of Days Worked	1,575	1,575	1,575	$-
Average Time Spent in Traffic	59	59	59	$-
Average AADT Volume of Skyway	181,172	181,172	181,172	$-
AADT Volume Threshold Causing Traffic	170,500	170,500	170,500	$-
Sub-Total	$12,518,173	$6,740,340	$6,669,240	$-
Contingency (10%)	$1,251,817	$674,034	$666,924	$-
Grand Total of Revenues	**$13,369,638**	**$77,825,860**	**$7,754,760**	**($1.45 Billion)**



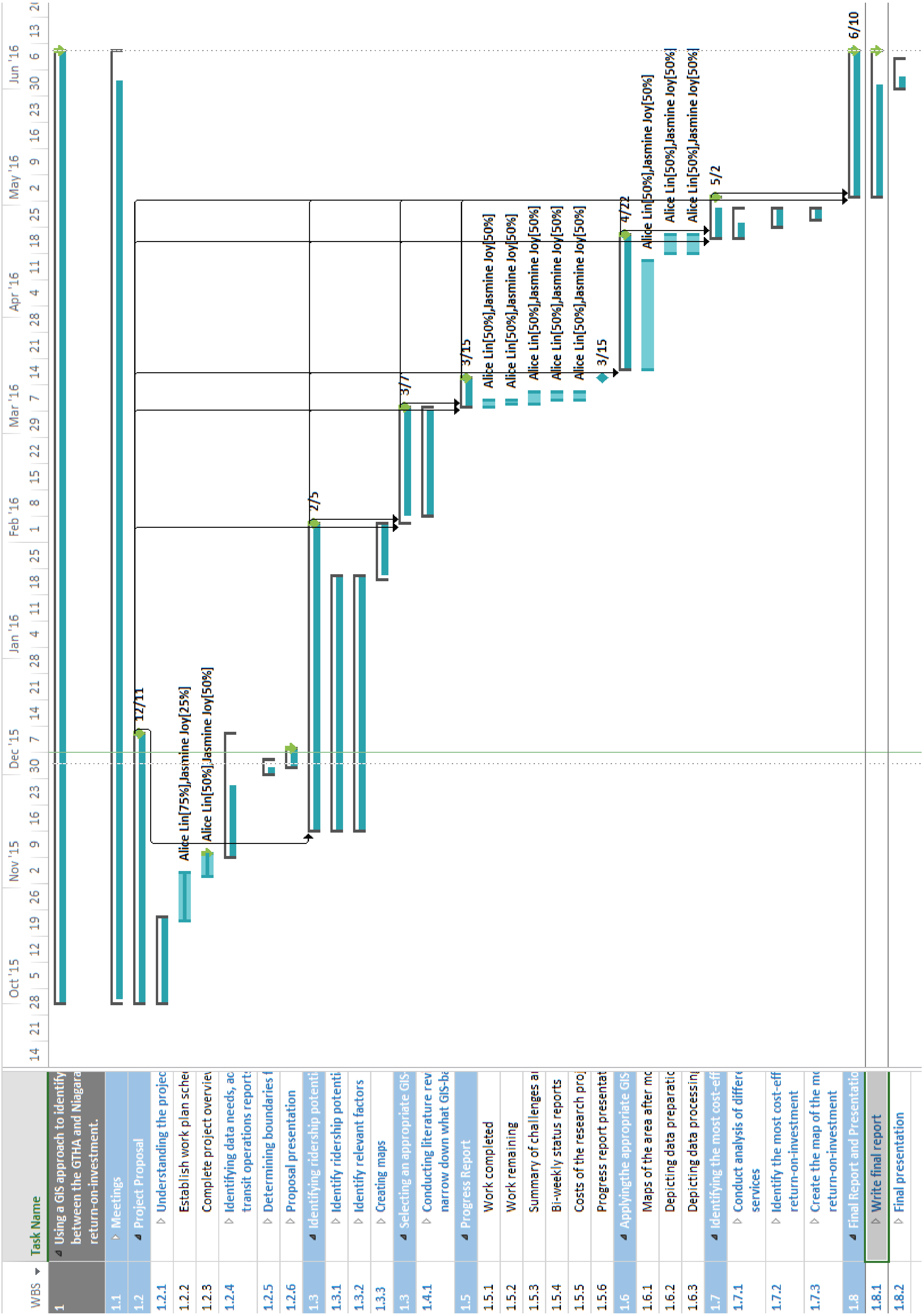
Appendix 10 – Framework to Identify Commuter Profile



Appendix 10 – Framework to Identify Commuter Profile



Appendix 11 – WBS Flowchart



Appendix 12 – WBS Gantt Chart

- - End of Report - -