Evaluating the Effectiveness of Cities Working with Ridesourcing Companies

by

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AUTHOR'S DECLARATION

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

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

Abstract

The process of using an application or web-based platform to hire a person with their personal vehicle to transport someone to their destination is also known as ridesourcing; and this is a new form of transportation that has risen quickly in the last decade. As an alternative to driving alone or taking transit, ridesourcing services have the ability to compete with public transit, increase congestion during peak periods, and challenge existing regulations and practices, leading to constant debates in the passenger transportation industry. Most of these debates have been caused by a lack of information on the full spectrum of the interactions that ridesourcing services may have with the existing mobility forms and the impacts that could result from these services and interactions. Therefore, there exists an urgent need for a comprehensive analysis on the potential mobility and environmental impacts of ridesourcing services.

A survey is first conducted to understand the current relationship that ridesourcing companies have with the cities that they operate in. The results from this survey show that majority of the transit agencies in Canada do not have much of a relationship at all with ridesourcing companies and are unwilling to start one. However, those that do try and create a relationship with ridesourcing companies, end up with positive outcomes, such as filling in the gaps in their public transit, which in turn increases ridership.

The case studies of this thesis look at some of the partnerships and relationships that have been formed by transit agencies / municipalities and ridesourcing companies. It is found that there are numerous ways a partnership can be formed whether in a large or small way. These case studies also demonstrated that the majority of rideshare or ridesourcing companies are open

to a partnership and they want to have a fruitful relationship with the cities in which they operate. It turns out that the best thing that cities and transit agencies can do when it comes to ridesourcing companies is to create a partnership and foster a positive relationship.

Lastly, an analytical model is proposed to investigate the viability of ridesourcing as a sustainable alternative to traditional transit service as related to various factors such as the size of the service and population density. A base case scenario was considered and examined based on the three pillars of sustainability, which are environment, economics, and society. It was found that a critical population density or demand level exists for any service area: traditional fixed route public transit is more sustainable when the population density is higher than this critical value otherwise ridesourcing services are more sustainable.

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Lastly, thank you to the cities who took the time to answer my survey. Without these insightful answers, many of the conclusions drawn from this thesis would not have been made.

Dedication

My parents Barbara and Michael Thompson without whom this thesis would not have been possible. Their love, guidance and persistent need for an update on my progress are what kept me going. And my husband Ryan Bojko, who handled all of my stress and late nights with love and patience. I appreciate everything you have all done for me.

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List of Abbreviations

App – electronic application
APTA – American Public Transportation Association
BPR – U.S. Bureau of Public Roads
BRT – Bus Rapid Transit
DEFRA – Department for Environment, Food and Rural Affairs
EIA – Energy Information Administration
EPA – Environmental Protection Agency
GC – Generalized Cost
GREET 1.8 – The Greenhouse gases, Regulated Emissions and Energy use in Transportation Model, version 1.8
GRT – Grand River Transit
LRT – Light Rail Transit
RTD – Regional Transportation District
TNC – Transportation Network Company

Chapter 1

Introduction

For many years, society has had the same transportation options available to choose from, and it appeared ample enough to be able to get people where they wanted to go. Then came the idea of ridesourcing, defined as an app-based service, providing on-demand rides, and it gained increasing popularity (Rayle, Dai, Chan, Cervero, & Shaheen, 2016). Ridesharing and ridehailing are other words used to describe ridesourcing. Some sources also use the term Transportation Network Companies (TNCs), which is in fact the online platform used to connect drivers and passengers. For the purposes of this research, this mode of transportation will be referred to as ridesourcing. The two companies that have become the most prominent in North America are Uber and Lyft.

This type of transportation is broadly defined as a modern-day form of carpooling where a set of riders who need transportation are able to contact a set of drivers who are willing to use the empty seats in their vehicles to carry passengers in exchange for monetary compensation (Masoud, Nam, Yu, & Jayakrishnan, 2017). The term ridesharing is actually defined as a not-for-profit arrangement to share a ride to a common destination, which is exempt from regulation (Strong, 2019). One thing specific for ridesharing is that the rider and driver have common routes and common schedules. This is akin to a type of work-place carpooling (Doppelt, 2018). Ridehailing is similar to hailing a taxi where one requests a driver for pick-up from a specific location and drop-off at another using a two-way mobile application (app) (Doppelt, 2018). A

TNC is referred to as an online platform that permits individual drivers to find passengers who are seeking one-way rides, which use app-based technology and riders pay using a virtual wallet (Doppelt, 2018). Most of the literature on this subject is now changing the terminology to ridesourcing (Yan, Levine, & Zhao, 2018). Ridesourcing services are app-based, on-demand ride services such as Uber or Lyft (Rayle, Dai, Chan, Cervero, & Shaheen, 2016). For this thesis, the definition that will be used for ridesourcing will be the process of using a mobile app, or an online program or website to order a vehicle which will take someone from an origin to a destination. The vehicle is often driven by someone who personally owns the vehicle and has been hired by the app or website to complete this task. Additionally, no physical money changes hand, compensation is transferred through the app.

Many people have taken issue with this sudden new mode of transportation, and their concerns appear to be justified. One of the many concerns with ridesourcing is the potential impact on public transit services. Due to the typically cheaper cost structure of ridesourcing services when compared to taxis, it seems to be competing with ridership of public transit. This is a concern because if more riders are pulled from public transit and into vehicles, this would increase the already growing number of vehicles on the road creating more congestion and delays. As well, if riders are pulled from public transit, this would decrease overall revenue of public transit services. If public transit revenue and ridership are declining this could lead to a reduction in service in terms of frequency and access, which would only lead to a further decrease in ridership and revenue.

Other than its effect on public transit, ridesourcing is thought to have negative impacts on safety, the environment as well as workers in the taxi industry. In terms of safety, the negative connotation is thought to come from the idea that both the driver and the passenger do not know each other, and therefore must trust that the other will not harm them for the duration of their transaction. Even though this is technically the same for taxi services and even public transit, there are differing amounts of licensing, background checks and regulations involved in each of these services, and for a new service that someone is unfamiliar with, this comes with certain level of extra precaution. As mentioned previously, the negative environmental impacts could become reality; if more people are using ridesourcing then there are more vehicles on the road leading to more congestion and delays, which in turn creates an increase in emissions. Lastly, the taxi industry has long been unhappy with the introduction of ridesourcing for reasons of direct competition. Ridesourcing more often than not will charge less for the same ride than taxis will (Strong, 2019). Due to this, less people are choosing taxis, which is decreasing the profits that taxi drivers would make. Section 2.5 in Chapter 2 outlines the difference in regulations from ridesourcing to Taxis.

However, many argue the opposite citing the benefits of ridesourcing. With a more cost-effective option of transportation available this could lead to the elimination of personal vehicles for many people and increase public transit ridership. The idea behind this is that if many people no longer use their vehicles and instead opt to take public transit for a majority of their day-to-day trips, then when the need for a vehicle arises, ridesourcing can be used. These instances, would be when the origin or destination of a trip is out of the public transit service zone, or when it is late at night when public transit is either not running or could be considered unsafe by some to travel by themselves, when there is inclement weather (e.g., blizzard, thunderstorm, heavy rains, etc.), or when the user is carrying many items or something heavy. Another benefit of this is that if more people opt to go this route, public transit ridership will increase, and if this happens, revenue and service can increase. If the revenue of public transit increases leading to an increase in service, then this would help to persuade more people to make the shift from personal vehicle to public transit and get rid of their own vehicle. While society may be several years away from this reality, this is the direction that ridesourcing can bring us in.

Given this information, should ridesourcing be welcomed, or should it be banned? What kind of setting, or relationship with the city does it need to have in order to create positive impacts? These are the types of questions that motivate this research. The ultimate goal of this thesis' research is to generate knowledge that would help municipalities to make a more informed decision on integrating ridesourcing into their public transportation service system. Since the introduction of ridesharing is such a brand-new mode, there has not been very much research done on its effects.

1.1 Brief History of Ridesourcing:

San Francisco California is the birthplace of Uber which is one of the first ridesourcing services and certainly one of the most widely known (Rayle, Dai, Chan, Cervero, & Shaheen, 2016). As of April 2020, Uber was in more than 900 cities worldwide, which includes 19 Canadian cities (Uber, 2020). It was interesting to see the variations in the history of Uber throughout the literature. Most resources said that Uber started in 2010 (Tremblay, 2016;

Doppelt, 2018), whereas others claimed that it started in 2012 (Strong, 2019). On Uber's website it says the idea came about in December 2008, the app was developed in May 2009, and the first Uber ride request was a trip across San Francisco on July 5th, 2010 (Uber, 2020).

From here things began to increase in popularity with Uber in one city in 2010, three cities in 2011, eight cities in 2012, and in 2016 Uber was in 300 cities (Tremblay, 2016). In 2018, over 600 cities worldwide were host to Uber (Hall, Palsson, & Price, 2018; Doppelt, 2018). As mentioned previously, in 2020 Uber is in more than 900 cities worldwide (Uber, 2020). Their great success has not come without battles. As mentioned in Chapter 3 (Section 3.2), many municipalities, transit agencies, taxi companies and citizens have fought to rid their cities of ridesourcing companies such as Uber.

1.2 Research Problem Statement and Objectives:

Ridesourcing as a new transport mode has become ubiquitous and pervasive, with much more to learn on its effects and how to better integrate it with fixed route transit. Some small municipalities have started to entertain the idea of replacing or supplementing transit services with ridesourcing, such as Uber. But little information is available to support their decision-making. It is important to know what kind of city or neighbourhood this would be worth implementing in and the key factor that would determine this is population density. There have been a few studies that have used surveys in order to discover how the introduction of ridesourcing has affected public transit ridership levels, the public perception, or car ownership. But these studies have almost exclusively been done in the U.S., and it cannot be assumed that these results are transferrable to other countries.

Other studies have taken to interviewing transit agencies or TNCs involved in partnerships. Generally, the conclusion was that using ridesourcing could enhance transit by replacing underutilized routes. However, it does not include why some partnerships succeed while others fail. Finally, some studies have looked at data trends such as traffic delays and congestions and attempted to correlate any changes to the introduction of ridesourcing. This however does not account for any extraneous factors that could also be the reasons behind this data. The literature review in Chapter 2 explains this in greater detail. None of these studies explain what type of setting a ridesourcing company would best fit in order to make a positive effect.

The gap in knowledge that this thesis will study will then be addressed by the following specific research questions:

1. What type of relationship do ridesourcing programs and public transit agencies in Canadian cities currently have?
2. Under what conditions do ridesourcing companies and public transit agencies working together create positive benefits?
3. Why is population density a critical variable in determining whether ridesourcing or public transit is a better option, and at what density is one more beneficial than the other when considering three sustainability criteria: maximizing the societal, environmental and economical benefits?

1.3 Research Methodology

As of the writing of this paper, data from Uber, Lyft or any other ridesourcing services are not being shared with the public. This means that any person attempting to research this topic has had to become quite creative in their methods of collecting data. For this thesis, there are three ways that data were collected in order to analyse this problem. First, a survey was sent out to municipalities in Canada to find out their relationship with ridesourcing programs. Second, case studies were researched on areas that have chosen to work with ridesourcing companies and the results of these programs were analysed. And lastly, a hypothetical street was created to analyse the effects of choosing ridesourcing over public transit in terms of social, environmental and economic impacts.

For the first question, a detailed survey (seen in Appendix A) on current relationships with ridesourcing companies was sent out to transit agencies in cities that have at least one ridesourcing program in their area. Their answers were then analysed to not only find out the type of relationship they have, but also the depth of said relationship. The second question can be answered after looking at the analysis of four different case studies of collaborations between ridesourcing companies and public transit agencies and accessing any benefits. And lastly, for the final question, using only a few inputs, three cities are compared based on their sustainability impacts when implementing ridesourcing compared to public transit. This methodology is outlined in more detail in Chapter 5 of the thesis.

1.4 Structure of the Thesis

The first chapter of this thesis introduces the topic by not only discussing the history of ridesourcing but also describing why it has become such a topic of interest. It also delves into the research questions that are to be answered later in the thesis. Chapter 2 will then provide an in-depth literature review on the past efforts on related research topics. This literature review will be divided into multiple sections, including effects on other modes, collaborations, city size, emissions, laws, technologies, and reason for using ridesourcing,

Chapters 3 and 5 will deal with the data collection, methodology, and analysis of two sets of data. Chapter 3 will discuss the survey that was conducted on 10 municipalities in Canada and their responses including a few cities that provided ridership levels for their public transit. Chapter 4 will present four different case studies on cities and ridesourcing companies working together and these will be analyzed for their benefits. Chapter 5 will introduce a theoretical model and its application for determining the social, environmental and economic impacts of choosing one mode over another.

Finally, Chapters 6 concludes this thesis providing the results, interpretations and limits as well as a conclusion with recommendations for future research.

Chapter 2

Literature Review

This chapter provides a condensed review of different approaches to and studies on the topic of ridesourcing and its overall effects. First, the effect that ridesourcing has on public transit and any other modes is discussed. Then, the topics of partnerships, outcomes in small towns, environmental emissions, Canadian laws, technologies and why people choose ridesourcing, follow. The chapter concludes with a summary of the findings and any gaps or limitations in the current literature.

2.1 Effects of Ridesourcing on Other Modes

2.1.1 Public Transit

Many of the articles reviewed on ridesourcing discussed the positive effects that ridesourcing can have on public transit. Some of these benefits include: decreasing commute times; solving the first/last-mile problem; and increasing transit use (Hall, Palsson, & Price, 2018). A lower cost to the consumer when compared to only using ridesourcing was also another benefit (Hall et al., 2018). Ridesourcing has also been found to enhance transit services by replacing underutilized routes, providing the first/last-mile connectivity, save money for both public transit and the rider, reduce wait times, and decrease out-of-vehicle travel times to 3 minutes or less, essentially resembling door-to-door services (Yan, Levine, & Zhao, 2018). These partnerships can help to lead to more efficient services, especially in terms of time, money and safety, between TNCs and transit companies by complementing each other to benefit the consumer (Tremblay, 2016). Together these partnerships can bridge service gaps in transit; address market demands for customers; and solve the first/last-mile issue (Murray, Chase, Kim, & McBrayer, 2012). Murray et al. (2012) went on to explain that a partnership can help reduce the need for more parking. This is especially helpful for train stations or public transit hubs.

The American Public Transportation Association, (2016) states that these new partnerships are helping to reduce car ownership by individuals, increasing the use of public transportation, enhancing urban mobility, having consumers drive less and walk more, and helping to save on consumer transportation costs. Doppelt (2018) also mentions that individuals are reconsidering the costs of owning a car when one, ready to pick them up, can be found around the corner. This in turn leads to more reliance on public transit. The American Public Transportation Association (2016) found that those who used multiple shared modes of transportation (carsharing, ridesourcing, and bikesharing), will drive alone or with family or friends about 10% less than other respondents. They also say that those who do not used shared modes have on average 1.5 versus 1.05 vehicles per household, and the number dropped to 0.72 vehicles per household for those who used multiple shared modes (American Public Transportation Association, 2016).

Despite all of these positive effects there were a couple negative effects that were mentioned in some of the ridesourcing literature. Hall et al. (2018) mention that Uber or any other ridesourcing company can increase congestion in larger urban centers by bringing more cars into the city center. Whereas, Masoud et al. (2017) say the exact opposite, that when ridesourcing is used to act as a feeder system to public transportation, congestion in the city center decreased. Another negative point was that when first introduced ridesourcing resulted in a 4% to 24.7% decrease in passenger trips on public transit vehicles (Doppelt, 2018).

O'Brien & Dunning (2014) noticed that most wait times for ridesourcing were around 5 minutes versus municipal bus routes with headways of up to 60 minutes, making the average wait time much longer than that of ridesourcing. Additionally, O'Brien et al. (2014) noticed that these bus routes did not contain the same amount of flexibility with their stops as ridesourcing. With wait times on opposite ends of the scale, it becomes hard to convince customers to choose public transit.

Jiao, Miro, & McGrath (2017) gave some specifics on how congestion has become worse in three different cities from 2015 to 2016. They stated that in these three cities, the in-vehicle travel time increased for commuters by 15 minutes for Washington, District of Columbia, by 23 minutes for Dallas-Fort Worth, Texas, and by 41 minutes for Portland, Oregon. Not only does this increase affect other vehicles on the road, but it also slows down public transit vehicles.

Overall, most resources claimed an increase to public transit use when a public transit company is combined with ridesourcing (Hall et al., 2018; Yan et al., 2018; Strong, 2019; Tremblay, 2016).

2.1.2 Walking, Biking, Driving, Taxicabs

Most of the research has shown that ridesourcing can help people live a car-free or car-light lifestyle (Strong, 2019). As mentioned above in Section 2.1.1, those who use forms of shared mobility own nearly half a car less than those who have not used any shared modes – 1.5 versus 1.05 cars per household. These numbers go even lower, to 0.72 cars per household, for what are called supersharers (American Public Transportation Association, 2016). Two-thirds of the supersharers are more physically active as they have been using other shared mobility options, such as bikesharing, carsharing, and ridesourcing (American Public Transportation Association, 2016). The American Public Transportation Association (2016) goes on to say that whether someone is carsharing or ridesourcing, both were the top modes for low- to moderate income residents and decreased as the income increased. Both carsharing and ridesourcing helped individuals avoid the costs of full-time car ownership. The American Public Transportation Association (2016) study described a few unique services, such as: Silverride – which is for older adults who prefer to not drive, and HopSkipDrive – which was designed for children. This shows ridesourcing further allows individuals to relinquish reliance on personal vehicles and turn to other modes. Some analysts predict that the ridesourcing economy could bring an end to automobile ownership entirely (Doppelt, 2018).

One market that is being especially affected by ridesourcing is the taxicab market. Doppelt (2018) says that ridesourcing has caused a negative change to the number of taxi drivers' jobs, and to the wages since Uber became active.

Most shared mobility refers to ridesourcing companies such as Uber and Lyft, but there are many other forms. Carsharing provides access to automobiles on a per hour, per mile/kilometre, and membership basis (Doppelt, 2018). So, people do not have to own a car, but they have access to one when they need it. Another form is bike-sharing which utilizes specified docks, where bicycles can be picked up and dropped off for a fee (Doppelt, 2018). This mode is particularly popular and is wide spreading in high-density cities.

2.2 Partnerships and Integrations

Several of the articles reviewed on ridesharing and ridesourcing involved partnerships between transit companies and ridesourcing companies, such as Uber. These cities included San Francisco, California (Rayle, Dai, Chan, Cervero, & Shaheen, 2016); Ann Arbor, Michigan, at the University of Michigan (Yan et al., 2017); Manhattan, New York, New York (Griswold, 2017); Washington, District of Columbia, Dallas, Texas, and Portland, Oregon (Jiao, Miro, & McGrath, 2017); and Lawrence, Kansas (O'Brien & Dunning, 2014). Schwieterman et al. (2018) looked at 29 different partnerships (22 of which are current) throughout the U.S. and one in Canada. The American Public Transportation Association (2016) looked specifically at partnerships in Austin, Texas; Boston, Massachusetts; Chicago, Illinois; Los Angeles, California; San Francisco, California; Seattle, Washington, and Washington, District of Columbia. Doppelt (2018) did not mention which partnerships were looked at, he just described the partnerships in general. There are many opportunities for ridesourcing partnerships with transit companies. Murray et al. (2012) describe two of the top reasons for creating these partnerships: to bridge service gaps for transit, and to address the demands of customers.

Ridesourcing can enhance transit services by replacing underutilized routes, providing first/last-mile connectivity, and as a result creates a slight increase in transit ridership, while reducing operating costs (Yan et al., 2018). In the study by Yan et al. (2018) at the University of Michigan in Ann Arbor, Michigan, the result was to go from 12 fixed bus routes, down to 4 fixed higher frequency routes together with on-demand shared shuttle services in the outer area. The results showed decreased wait times, convenient first/last-mile transit access, and a decrease in the out of vehicle time (walking to/from bus stops). One new method involves customers walking to a convenient corner. So, the customer has to walk a little, but can increase the frequency of shared shuttles. Newer ridesourcing partnerships which have people walking to convenient corners help to decrease in-vehicle travel times, and decrease first/last-mile distance to traditional bus stops, while permitting people to not have to own their own vehicle (Tremblay, 2016). Manhattan has partnered with UberPool, where they are using what they call “smarter pickups,” which prompts riders to walk to convenient corners for their shared ride (Griswold, 2017).

Many transit companies are facing financial pressures in delivering their services and as a result are looking towards partnerships (Coyle, 2017). Ridesourcing can provide a possible solution to this problem. Many U.S. cities are teaming up with ridesourcing companies to provide on-demand public transit as well as first/last-mile connections to transit services (Jiao et al., 2017). In this article they describe a suggestion to use school buses between their normal bus runs (Jiao et al., 2017). This may sound like a good option, however school buses are meant to transport large numbers of people, and most of the issues are with a smaller number of individuals. TNCs can and are providing an answer for the issues that face transit companies. Most partnerships are motivated by a desire to improve mobility in areas in which transit options are inadequate, do not exist, or where there are not enough parking spots available (Schwieterman & Livingston, 2018). Another area where partnerships are developing is in improving paratransit for those with disabilities (American Public Transportation Association, 2016; Schwieterman & Livingston., 2018).

Doppelt (2016) says that most transportation infrastructure is outdated, unreliable, and needs updating. Instead of spending money on new vehicles many transit companies are looking towards ridesourcing options as a solution. Interestingly, it was found that if a customer only used transit, they were more likely to only access the website provided by the transit agency. However, they were more likely to use third-party tools to find their travel information if they have used new shared modes (American Public Transportation Association, 2016). Transit ridership has steadily risen between 1973 and 2013, and Uber, or similar companies can help this continue, through complementing public transit by increasing the flexibility of a passenger's travel route (Doppelt, 2018).

2.3 Ridesourcing in Small Towns

TNCs have been around for about a decade. The majority of the places they operate in are larger cities. This is because Uber and similar companies impact larger cities differently than they do smaller towns. In denser areas, Uber can work in combination with large transit companies, which in turn would benefit the transit companies (Tremblay, 2016). However, as Hall et al. (2018) state, TNCs can create increased traffic congestion by adding more cars to the road. This congestion then in turn becomes responsible for delaying buses. As well, in less-dense areas, TNCs show a reduction in transit ridership (Tremblay, 2016). This is why there exists some hesitancies in small towns to allow Uber to operate within their towns. Murray et al. (2012) showed that there have been some benefits in less-dense areas in that ridesourcing helps with non-traditional work hours and for areas that are not dense enough to justify any transit service. Griswold (2017) agrees with this by saying that ridesourcing can be used in two ways – in combination with transit in high-density cities, and in lower-density towns as a substitute for some of their public transit system. Jiao et al. (2017) say that a number of U.S. cities are spread out, and with a lack of density makes it inefficient to run fixed route transit systems. Cities and transportation companies are having to become creative in their transportation planning.

Many cities are starting to look at ridesourcing options. According to O'Brien and Dunning (2014) modern ridesharing and ridesourcing concepts have focused on large dense populations, but that there is a gap for smaller cities. Going back 70 years, hitchhiking is what people used to fill this gap with. Hitchhiking was socially acceptable from 1920 to the 1950s, but in 1958 the American Automobile Association started an anti-hitchhiking campaign, which increased the populations fear around hitchhiking (O'Brien & Dunning, 2014). Since then, modern attitudes have evolved and research has shown that there is no reason for this. Baby boomers reminisce about hitchhiking, Generation X came of age at the height of anti-hitchhiking propaganda have expressed more wariness, and the Millennials who were raised in the age of the internet said, there should be an app for that (O'Brien & Dunning, 2014). As a result, hitchhiking has transformed itself into the ridesourcing systems around today with the use of technology.

Doppelt (2018) found that ridesourcing companies are a complement to other transit modes in denser population areas, whereas in low-density areas it becomes a substitute for public transit. Some smaller cities and towns are starting to look at ways they can partner with these ridesourcing companies as a substitute for areas of their towns in which bus routes are not cost effective.

2.4 Emissions

In the 21st century, the word green has become ubiquitous, indicating that something is better for our environment. In the U.S. 28% of the greenhouse gas emissions are from the transportation sector, and of this, two-thirds is from passenger vehicles (Strong, 2019). Congestion of vehicles leads to higher greenhouse gas emissions, which have been shown to be harmful to people's health and damaging to the environment (Masoud, Nam, Yu, & Jayakrishnan, 2017). Ridesharing has the capacity to alleviate some of these problems with vehicular emissions. A ridesharing system can act as a feeder system to public transit, thereby decreasing congestion and providing a greener transportation system (Masoud et al., 2017; Strong, 2019). Both ridesharing and public transit reduce energy consumption and emissions by reducing travel by single occupant automobiles (Murray et al., 2012). According to Murray et al. (2012) one of the most common reasons for transit companies and ridesharing to work together had to do with environmental concerns. It is important to note that these studies focused on ridesharing, and not ridesourcing which involves more vehicle travel to and from the pickup and drop off locations.

Throughout history there have been periods where people have been asked to perform different forms of ridesourcing/ridesharing. During World War II, it was to conserve rubber and more recently to reduce the strain on office parking lots in the more densely-populated cities (Strong, 2019). With the advent of the TNCs, ridesharing has been shown to decrease traffic congestion, decrease vehicle pollution and decrease the demand for parking for cars making similar trips (Strong, 2019). Uber has been shown to have positive effects by providing a service that reduces the need for individuals to purchase and own a private automobile (Tremblay, 2016).

According to Rayle et al. (2015), ridesourcing trips have been shown to be slightly shorter than bus trips for the same trip – on average 3.7 miles down to 3.2 miles. This shortening of trips lowers the amount of emissions overall (Masoud et al., 2017). Masoud et al. (2017) explains that with ridesharing, savings per vehicle miles travelled were increased the more the driver and the passenger were matched for their routes. As a result, less cars are required on the road. Ridesharing has been shown to reduce vehicle miles travelled overall, which will decrease the emission from automobiles and their environmental effects (Murray et al., 2012). It should be noted that this is for ridesharing, not ridesourcing, and that the reduction is for a per-vehicle-km basis and not per passenger-km. Those who choose ridesourcing tend to prefer to stick to automobiles. In a survey done by the American Public Transportation Association (2016) when asked which alternative mode would you choose if ridesourcing was not available, 34% said they would drive alone, or with a friend versus 14% using public transit. This would result in increased congestion and as a consequence leading to higher emissions.

Most of the research supports the theory that ridesharing helps to decrease emissions overall, and lower emissions are better for the environment. However, Strong (2019) does bring up the possibility that ridesourcing can increase the number of cars being brought into the city which can increase congestion and pollution levels. Overall, most research shows that if ridesharing is combined with public transit this does not occur, it actually decreases emissions. So, in theory if the driver and the passenger routes are matched this is good for the environment and emissions. However, most of this research does not include what happens before the passenger is picked up, and after the passenger is dropped off. Older forms of ridepooling had the driver and the passengers (usually multiple) travelling for the same purpose or route. For ridesourcing, the driver is not travelling for the same purpose as the passenger, consequently the driver has to get to the passenger, and then drive off after they have dropped the passenger off.

This topic has not been researched extensively. From what research there is, it is called deadheading. The term deadheading refers to the distance travelled without passengers or freight (Henao & Marshall, 2019). Deadheading can include: traveling from the driver's residence, cruising for a ride, from dispatch to pick-up location, and traveling home at the end of the shift (Henao & Marshall, 2019). Another source only refers to deadheading as: while a driver waits for a request with at least one app open, and the miles after a driver accepts a request and drives to the pick-up location (Pinto de Moura, Anair, Martin, & Goldman, 2020).

Ridesourcing aside, O'Brien and Dunning (2014) stated that in the United States in 2009, the occupancy rate in automobiles was on average 1.67 people per automobile on the road. Since most vehicles can handle more than this, this shows that many vehicles drive with empty seats. According to Henao and Marshall (2019), for ridesourcing, 40.8% of vehicle miles travelled are from deadheading without including commuting at the beginning of the shift. Pinto de Moura et al. (2020) say that deadheading is 41.8% of the vehicle miles travelled. Since the average of ridesourcing trips contained 1.36 passengers per ride, when they factor in deadheading miles travelled, the distance weighted vehicle occupancy was 0.78 passengers per vehicle (Henao & Marshall, 2019). Pinto de Moura et al. (2020) said that in their study there was 1.5 passengers on average per ride. So, basically it would be more beneficial for emissions for a person to drive their own vehicle by themselves. According to the literature, there is no consistent data on occupancy rates or percentages of deadheading, it appears to depend on the researcher's evaluation. A lot of the research does not even acknowledge deadheading as an issue. This topic would also be dependent on where the study is taking place; in a bigger city around a downtown core or high-density area, there would be less deadheading as there is a higher probability that someone would always need to be picked up close to the driver's location. Whereas in a small city or low-density area, deadheading would be a lot more prevalent. One study said that for every 100 miles with passengers, ride-hailing trips add 69.0 extra vehicle miles travelled (Henao & Marshall, 2019). Pinto de Moura et al. (2020) looked at 13 recent cities in other studies to see what percentage of the total trip was deadheading, and the values ranged from 33% to 47%, with most ranging from 40% to 45%.

2.5 Laws Around Ridesourcing

TNCs, such as Uber have often been compared to taxicabs, however there is a difference in regulations. Taxicab regulations began in the U.S. in the late 1920s (Strong, 2019). Strong (2019) states that Taxicab companies have regulations they must follow, whereas ridesourcing on the other hand is exempt from these regulations in the U.S. and Canada. Strong continues to explain that for drivers of ridesourcing companies, they are not required to hold a commercial license and, therefore there is no need for a commercial insurance policy as they are driving their own vehicle.

Regulations for ridesourcing remains an issue for public transit companies trying to create partnerships with TNCs (American Public Transportation Association, 2016). The lack of regulations can be a contentious issue. The emergence of ridesourcing in larger cities has been shown to have a negative impact on the taxicab industry (Doppelt, 2018). Without any regulations, ridesourcing companies find it easier to come on board.

Governments have struggled with decisions on how to regulate TNCs. According to Hall et al. (2018) TNCs have been accused of being unsafe, creating congestion, destroying stable jobs and, flouting the law. So, there are many who would welcome new regulations, but how and the specifics remain to be seen. Currently in the U.S., TNCs have not been subject to taxicab regulations, which in many cities limit the supply, determine fares, and set safety standards (Rayle et al., 2016). Because of support from customers many ridesourcing companies have developed quickly and have received regulatory support across the U.S. (Rayle et al., 2016). Taxicab companies have viewed ridesourcing as illegal services that skirt existing laws and offer an unfair competition because ridesourcing drivers lack a commercial license, drive their personal vehicle, and work part-time (Rayle et al., 2016).

The issue as to whether TNCs should be regulated or not, is challenging policymakers to up-date decades of regulations. The two ends of the spectrum are: one being a heavy regulated taxicab industry and the other end being an unregulated TNC. With this lack of regulation, many cities continue to challenge on-going operations of TNCs. In the U.S. most transportation laws are at the state level, with some states permitting cities to decide on whether TNCs are permitted to set up operations in an area (Strong, 2019). This is likely the only obstacle a company has to overcome to start up. In Canada transportation laws are under provincial authority, and currently there are no laws around TNCs, so most decisions are being made by individual cities.

2.6 Technologies and Ridesourcing

In a 2016 article by Tremblay, he estimated that by 2020 70% of the world will be using a smart phone. According to an article by Silver (2019), 81% of Americans and 66% of Canadians have a smartphone. However, this number would not be reflective of the world-wide figure as this does not account for the fact that in numerous third world countries many people cannot afford a smart phone, and the costs of services that go with them.

TNCs such as Uber, are successful due to their smartphone applications, with which users can request a trip from an Uber driver, who accepts through a similar GPS enabled Uber application interface on their smartphone (Tremblay, 2016; Coyle, 2017; O'Brien & Dunning, 2014). Schwieterman & Livingston (2018) state that developing programs to be used on smartphones is helping the development of partnerships between transit companies and TNCs. The American Public Transportation Association (2016) says that the lack of access to technology can be a barrier to widespread adoption of new shared modes especially for those with lower incomes and those who are less comfortable using technology. The convenience of technology and instant gratification are changing the market for goods and services in our world, why should it be different for transportation (Doppelt, 2018). Participants (rider and driver) rely on an application-based payment method, a system to rate the rider and driver, as well as making recommendations to their peers (Doppelt, 2018). The application-based system for ridesharing services provides ridematching services by linking a rider and a driver who have common routes and common schedules (Doppelt, 2018). Uber and similar companies are forcing transit agencies to adopt to technological and cultural shifts.

2.7 Reasons for Using Ridesourcing Companies

Many of the articles concerning ridesourcing and ridesharing discussed why people chose to use these modes. Rayle et al. (2015) said that the main reasons for using ridesourcing were: ease of payment, short wait times, fastest way to get there, easy to call a car, and not wanting to drink and drive. Of the trips 67% were for leisure/social reasons, 16% for work, 4% to an airport, and 5% were other reasons (Rayle et al., 2015). In two other articles, one of the biggest reasons to choose ridesourcing was that TNCs overcame the first/last-mile issue, enabling a person to get from public transit to/from their destination (Hall et al., 2018; Murray et al., 2012). Strong (2019) agrees with all of these reasons and adds that ridesourcing also eliminates the need to hunt for parking. Masoud et al., (2017) stated that most people prefer ridesourcing to driving alone. Many people find driving in big cities with dense populations to be very stressful and by using ridesourcing, they did not need to do the driving. Ridesourcing can also help decrease transportation costs, decrease commute time by using carpooling lanes, and decrease commute-related stress (Strong, 2019).

Tremblay (2016), points out that ridesourcing helps to reduce physical cash transactions, since all money is transferred electronically through the online applications. According to the American Public Transportation Association (2016), people who take greater advantage of shared modes report lower household vehicle ownership and decrease spending on transportation. Consistent with what other research showed, the American Public Transportation

Association (2016), found that ridesourcing was used for 54% recreational or social trips, 21% commuting, and 16% for shopping or errands. They also said that alcohol consumption was a major consideration in someone's mode choice especially when the recreational trip involved alcohol, and their choice was to not drink and drive. Another reason for frequent use was that shared-use modes helped to expand the options for lower income households (American Public Transportation Association, 2016).

The costs of owning a car are significant with expenses including the cost of the vehicle, insurance, licenses, maintenance, gas, and parking. When using public transit, the monetary costs are much lower, but one also has to think about costs other than monetary, such as walking to the station/stop, waiting for the bus/train, a possible transfer wait times, and walking to the destination. Doppelt (2016) describes how ridesourcing combines the best of both worlds by picking up and dropping the passenger off at the desired locations, at a competitive price, and you can track the driver before pick-up. Rayle et al., (2015) said that only 35% of people waiting for a taxi waited less than 10 minutes, whereas 90% of those waiting for ridesourcing waited less than 10 minutes and 67% waited less than 5 minutes. O'Brien and Dunning (2014) concur that most ridesourcing wait times are less than 5 minutes in the city and 7.1 minutes in rural areas.

When combining ridesourcing with public transit, there are further advantages for individuals. Travel time shortens on average from 33 minutes to 22 minutes since the customer does not need to walk to the stop, or wait for the bus/train (Rayle et al., 2015). The study also says that many people choose ridesourcing with public transit especially because of late night trips and feeling unsafe while waiting for transit, or walking from transit to their destination

(Rayle et al., 2015). Ridesourcing fills this need. Coyle (2017) talks about how when ridesourcing is combined with public transit it helps to service previously underserviced areas or helps people to be able to make trips they previously could not afford.

2.8 Chapter Summary

Many had benefits to speak to when it came to the effects of ridesourcing on other modes of transportation, but still there were some serious negative impacts that could not be ignored. Many researchers chose to speak to the positive effects, such as ridesourcing solving the first/last mile problem, or helping decrease commute times, supplement underutilized routes, lessen the need for additional parking, increase the share of active modes (walking; biking), and lastly encourage reducing car ownership. However, some did not ignore the deafening negative effects, for example, increasing congestion on roads, or causing delays for public transit. Interestingly there was arguments for ridesourcing causing both an increase and a decrease in public transit. Some proved that ridesourcing helped people rely less on a personal vehicle, while others argued the convenience on ridesourcing would draw passengers away from buses.

When cities partnered with ridesourcing/ridesharing companies to supplement parts of their public transit system, or solve the first/last mile problem, there tended to be more positive outcomes for the public transit. Many partnerships have been tried and tested and each one is unique unto its own given the city and transit characteristics, the ridesourcing company, and any by-laws or regulations needing to be followed. Given the individuality of each partnership, this explains the uniqueness in each of the results. These varying results then provide diverse user experiences which are then followed by different modal shifts. This also doesn’t account for any concurrent changes that happened during the time of the partnerships, such as population changes, employment fluctuations or economic conditions. Therefore, only a general statement could be made, that overall, partnerships seem to have a positive effect on the city as well as the transit company.

Ridesourcing affects small towns differently than it does in larger ones. This means that it needs to be utilized differently depending on where it is, in order to make a positive effect. In smaller towns, it can detract from public transit more, as the benefits are usually much greater in terms of wait times and area coverage. However, in larger cities ridesourcing can add more cars to the road which in turn creates extra congestion, which then is accountable for delaying public transit.

The topic of emissions, and what kind of effects TNCs have on the environment continues to be an area of study that does not have a definitive answer. It becomes very hard to prove if the individual rides are creating positive or negative effects. Especially when one considers the residual consequences of making other vehicles sit in traffic longer. One thing that seems to be rarely considered is the topic of deadheading. This appears to be quite a large issue for many to overlook.

Since the advent of ridesourcing and TNCs is relatively new, laws do not seem to have caught up to it in either Canada or the United States with the exception of a few cities that have taken matters into their own hands. As with most other things created in the last decade or so, ridesourcing requires technological access and knowhow. This then can create a barrier to those without access to the technology or a desire to learn how to use it. When it comes to a personal preference, ridesourcing has many appealing benefits. When compared to public transit, these benefits include ease of payment, shorter wait and commute time, more comfortable and convenient ride, and less stress.

Still a relatively new topic, there are of course gaps and limitations to the current literature. Long term trends are not available, and there isn't enough history yet to know what to change to make it better. Majority of the data from TNCs is also not available to the public making the analysis very hard to do.

Chapter 3

Survey

The first research question from Chapter 1 was, "What type of relationship do ridesourcing programs and public transit agencies in Canadian cities currently have?" In order to answer this question, a survey was created and distributed to several Canadian and one American municipal transit agency. The American city was chosen in order to be able to compare it to the Canadian cities. Most of the research on ridesourcing has been done in the United States, so this will help make comparisons. The questions for this survey and the respondent's answers can be found in Appendix A.

3.1 Methodology

The first thing that was decided for this survey was, which cities were going to be included in the survey. Some municipalities that were contacted to participate did not respond. The following Table 3-1 shows the municipalities that did respond and their corresponding areas of coverage.

Table 3-1: Transit Agencies and Corresponding Areas from Survey

Transit Agency	**Area of Coverage**
Edmonton Transit Service (ETS)	City of Edmonton, AB
Grand River Transit (GRT)	Region of Waterloo, ON
Toronto Transit Commission (TTC)	City of Toronto, ON
Guelph Transit	Guelph, ON
Hamilton Street Railway (HSR)	Hamilton, ON
TransLink	Metro Vancouver, BC
London Transit Commission (LTC)	London, ON
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia Metropolitan Area, PA

The majority of these cities were chosen due to connections with individuals willing to assist with research. However, the goal in these cities was also to have a mixture of different types of areas. Five of the eight cities are from Ontario, this was unintentional, but these cities had been introduced to ridesourcing already for a few years and not many cities in Canada outside of Ontario had. The cities demonstrate a variety of population and area sizes. Population variation ranges from Guelph at 151,984 to Toronto at 5,928,040 in 2016 (Statistics Canada, 2019). While density disparity ranges from Edmonton with 140 people / km^2 in 2016 to Toronto who in the same year had a density of 1,003.80 people / km^2 (Statistics Canada, 2019).

Once the cities were chosen for this survey, the questions had to be formulated. A full list of questions that appeared in the survey can be found in Appendix A, followed by the responses of each city. The first part of the survey asked the participating transit agencies to confirm the statistical information provided about their areas. With the help of the Statistics Canada website, populations, land area, population density, GDP (gross domestic product) per capita, median age, average age and average income were collected for each area for 2006, 2011, and 2016; this can be seen in Appendix A. Next the participants were asked to provide information about their current public transit systems including what modes of transportation they had and how many lines of each. These questions will help to determine if a city's relationship with ridesourcing companies has anything to do with the size of their city or the size of their transit agency.

This is where questions begin to inquire about each city's experiences with ridesourcing. First, they were asked when ridesourcing had arrived in their area both officially and unofficially, and which ridesourcing companies they were dealing with. For the purposes of this survey, unofficial ridesourcing referred to companies that were operating in a city with neither the permission nor the knowledge of the governing bodies responsible for transit in the given area. Up until this point, the questions had been mostly generic about their respective cities and transit systems in order to get a sense of the environment that ridesourcing was entering into. Respondents were asked about the unofficial entrance of ridesourcing because this helps to know firstly if they were aware of unofficial ridesourcing companies and second, the extent to which they had to deal with it.

The next few questions asked participants about their public transit ridership levels since ridesourcing came to their area. This was the initial first look at how cities were affected by the introduction of a possible mode competitor. While a change in public transit ridership does not necessarily mean an effect is from ridesourcing companies, it is definitely cause to keep looking. It also helped to see if the cities blamed any of their declines on ridesourcing or not. The next three questions prompted the municipalities to choose a number on a scale from -10 to 10 denoting an extreme negative response to an extreme positive one, depending on the question. The questions asked how ridesourcing/ridesharing affected their public transit, how it affected their city in general (not considering public transit), and how their team or department perceived ridesourcing. These answers will be able to discern the type of relationship that the cities believe they are dealing with when it comes to ridesourcing.

The transit agencies were then asked if they have taken any steps to increasing the ridership of their public transit. Then if the municipality said yes, they were asked what exactly those steps were and whether or not they worked. This question would help to explain any positive jumps in ridership that would not be attributed to ridesource introductions. It also helped to see how proactive the municipalities were with wanting to increase their ridership. The next question prompted the cities to state any noticeable changes (positive or negative) to their public transit since ridesource introductions. This was one last chance to see if there were any other external factors that could have an effect on the ridership.

The next three questions dealt with the presence on unauthorized ridesourcing programs running in their areas. First, the intention was to know if respondents were aware of any ridesourcing operations in the area. Then if respondents were aware, if they had any problems or positive experiences with the companies and to what extent. Lastly, a question was asked for respondents to elaborate on their experience with unauthorized ridesourcing programs. This helped to see whether or not the cities had a different relationship with illegal ridesourcing companies than they did with legal ones. The next two questions asked the participant if they have had any challenges or issues with ridesourcing programs and what steps they have taken to address these challenges or issues. It is important to know what kind of problems cities are experiencing when it comes to dealing with ridesourcing companies.

Next, the survey moved onto specific measures that some cities have taken when dealing with ridesourcing. The respondents were asked if they have ever implemented a surcharge to ridesourcing programs. Adding a surcharge would help regulate where the ridesourcing companies travelled, as the rider could be charged a couple of dollars extra for a trip that coincides with a public transit line. This would help to make sure riders reconsider calling a ridesourcing company instead of taking the bus. Then the respondents were asked if they have ever banned a ridesourcing company and if that fixed any problems that they were having with the ridesourcing companies. Likewise, respondents were also asked if they had limited the ability of ridesourcing programs either by areas of operation, or times they were allowed to be active, or number of drivers allowed. This allowed for seeing how proactive the cities were when dealing with the ridesourcing companies. But it also hopefully gave the cities ideas about proactive ways to solve their problems.

When the municipalities talked with the ridesourcing programs in the past, they were asked if the issue of public transit was ever considered, and to what degree. Next, they were asked if any policies had been changed or added that could affect ridesourcing programs. This was important because it indicated that cities had such a big change with ridesourcing programs, that it warranted a change in their laws. Then, they were asked to please elaborate on any other method that they tried that was not mentioned above just in case something important was missed. Lastly, the participants were asked if they had done any previous research on this topic that they would not mind sharing, or if they had any extra comments to add that would be helpful.

Once the surveys were sent out to the municipalities, the answers were collected and analyzed. The next two sections will outline the responses that were received and what they mean in relation to the research being done. The goal of this survey was to better understand the relationship that cities and transit agencies have with ridesourcing programs, how involved the municipalities are with them and to what degree. It is important to know what the participants in the survey are thinking when it comes to ridesourcing companies because their department would be the one working alongside them and they would be able to see the effects first hand.

3.2 Survey Results

Unfortunately, the number of cities willing to respond to this survey was very low. Of 17 different cities that were contacted, only eight filled out the survey. And of these eight only a few of them answered most of the questions. There could have been a number of reasons for this, but it is just speculation. The respondents may not have had enough time for the survey, but when looking at which questions were skipped and which were not, this does not seem the case for all of them. Potentially, the person's filling out the survey may have had little to no experience dealing with ridesourcing companies and preferred not to leave any answer at all, even though all questions had a comment box for them to explain. Either way, the response to the survey was much lower than expected.

3.2.1 City and Transit Characteristics

Table 3-2 shows the eight cities that participated in the survey and their distinct characteristics and transit sizes. They are ordered from smallest to largest in terms of populations that they service.

Table 3-2: Transit Agencies and Corresponding Areas from Survey

Transit Agency	Area of Coverage	Population (2016) [1]	Density (people/km^2)	Number of Bus Lines	Other Forms of Transit
Guelph Transit	Guelph, ON	151,984	256.1	25	Paratransit
London Transit Commission (LTC)	London, ON	494,069	185.6	34 [4]	Paratransit
Grand River Transit (GRT)	Region of Waterloo, ON	535,154	390.9	61	Paratransit LRT
Hamilton Street Railway (HSR)	Hamilton, ON	747,545	544.9	39	Paratransit Train Dial-a-ride
Edmonton Transit Service (ETS)	City of Edmonton, AB	1,321,426	140.0	184	Paratransit LRT
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia Metropolitan Area, PA	1,559,938 [2]	4491.5 [3]	121	Paratransit LRT BRT Subway Train Trolleybus Interurban Rail
TransLink	Metro Vancouver, BC	2,463,431	854.6	218	Paratransit BRT Subway (Skytrain) Train Dial-a-ride Seabus
Toronto Transit Commission (TTC)	City of Toronto, ON	5,928,040	1003.8	Over 140	Paratransit Subway Streetcar

1 (Statistics Canada, 2019)
2 (Open Data Network, 2018A)
3 (Open Data Network, 2018B)
4 (London Transit Commission, 2020)

From Table 3-2, it can be seen that the size of the transit agency is not always reflective of the size of the city itself. When comparing Toronto with Vancouver, or Waterloo Region with Hamilton, we can see that in each case, the area with the lower population and density actually has more transit lines to offer, or more options for the riders. For this case, size of the transit agency is being based upon the number of bus lines and other forms of transit available to users, this may not always be a good judge of size as some transit lines are much longer than others or may provide more or less coverage. But for the purposes of this survey, this was just to be able to get an idea of what is being offered already in each city.

3.2.2 The introduction of Ridesourcing

Now that we have become familiar with the characteristics of the cities and their transit agencies, we can begin to look at their relationships both past and current with ridesourcing companies. Only three cities volunteered the dates at which ridesourcing began in their area unofficially or even officially. Philadelphia and Waterloo saw their cities had unofficial ridesourcing companies operating in 2012 and 2015 respectively, and both had them operating officially in 2016 following changes to their by-laws. Vancouver's situation was different, with Uber operating officially in 2012, only to be quickly shut down by the government. After that ridesourcing companies not including Uber began operating non-officially in 2016. Despite this however, according to Uber's website where they name all of the cities that they operate in, all cities who filled out the survey (aside from Guelph) are on their list at the time of this survey (Uber Technologies Inc., 2019). This leads one to wonder if they truly do not have any contact with ridesourcing companies in their area, and no idea of how and when they are operating, or if they simply did not want to answer the question. Hopefully transit agencies are aware of other, non-agency modes of transit that are available in their city so that they can learn how to benefit from them.

Guelph's history with Uber and ridesourcing in general led this inquiry down a very interesting path. Guelph was included with the cities in this survey because it was known that as a city, they were trying to write new by-laws for the operation of Uber and other ridesourcing companies in their area. When their answer to the survey was received, not ignoring the questions, but stating that they did not have any ridesourcing companies in their city, it did not make sense. Looking into this further then solidified the need for a study such as this one. Guelph has had a tumultuous battle with ridesourcing, from their introduction to the area in 2015 (McNaughton, City of Guelph launches provincial guidebook on sharing economy, 2017). The mayor at the time was not even aware that Uber was coming to their area until they were already there. The City then quickly turned to their by-laws to review and make decisions, to ensure fairness they said between ridesourcing companies and the taxi industry (McNaughton, City of Guelph launches provincial guidebook on sharing economy, 2017). In April of 2018, a few months before the survey seen in Appendix A was distributed, Guelph finally approved a new set of rules overseeing how ridesourcing companies and taxis within Guelph's borders would operate (McNaughton, 2018). On top of this there have been numerous other new articles online outlining the City of Guelph's involvement in the sharing industry in their area. Given this information, the respondent for Guelph was perhaps unaware of the recent developments when asked about it in the survey.

3.2.3 Effects on Public Transit

When it comes to how the public transportation network was affected by ridesourcing programs, the cities were a little more forthcoming. Only London, Hamilton and Guelph skipped these questions. Philadelphia explained that their ridership levels decreased overall, in specific, bus and LRT levels decreased, whereas their subway and train levels stayed the same. They also commented on the fact that the decrease seemed to come from their off-peak times and that their peak times have remained constant. Waterloo stated their ridership had decreased as well. However, they blamed it on the significant construction happening in the area at the time for their new LRT which was set to start in 2019. It would be interesting to see if the levels increased or decreased after the LRT has been established for a while.

Toronto included a link to a report in their survey that stated that their ridership plateaued in 2015-2016 and began to decrease in 2017. As well, it stated that in February of 2017, their city saw 2 million Uber trips per month, with only 40,000 of those being to or from a TTC terminal (TTC Chief Executive Officer, 2017). Uber began operating in Toronto in 2012, and assuming it took a couple years to proliferate, this could potentially account for the ridership decrease (Elliott, 2014).

Edmonton specified that they did not have any data collected to support a change due to ridesourcing companies. This would be because their ridership data is collected from APC (Automatic Passenger Counting) system which is only on 25% of their fleet, and their annual ridership is estimated from a complex fare model. According to the ridership numbers on their website, the levels increased from 76,322,199 in 2010 to 89,283,008 in 2014, and then began to decrease afterwards and in 2017 the ridership fell to 86,997,466. This is interesting to see, as Uber began unofficially in Edmonton in December of 2014, becoming legal in March of 2016 (Stolte, 2016). The City however explains this decrease is due to other economic factors in the region. Unfortunately, they did not elaborate on what these factors were.

Vancouver’s ridership has not been affected by ridesourcing because according to the city, ridesourcing does not have a large or meaningful introduction in their area. Ridership for

Vancouver has had record setting levels in the past few years with all of their modes experiencing an increase. In 2018, Metro Vancouver's ridership boardings increased by 7.1% from the previous year, which was their largest ever annual growth (Translink, 2018). This increase could be due to any factor, and this is why the question that followed this is if the respondent knew of any reason for these changes, such as population growth, or construction.

3.2.4 Perceived Effects

For the next three questions, survey participants were asked to choose a number on a scale from -10 to 10 indicating a negative or positive effect respectively and a score of 0 indicating no effect at all. London and Hamilton skipped all of these questions. Nevertheless, the results for the other cities are shown in Table 3-3.

Table 3-3: Survey Answers of Perceived Affects

	Philadelphia	Toronto	Vancouver	Guelph	Waterloo	Edmonton
How ridesourcing has affected public transit	-7	N/A	N/A	0	N/A	0
How ridesourcing has affected the region	-7	N/A	N/A	0	0	0
Your department's perception of ridesourcing	-7	3	10	0	5	0

This table shows indicated that Canadian cities do not believe that ridesourcing companies have much or any effect on their public transit or the region as a whole. On top of this, all of the Canadian cities had a positive or neutral perception of these ridesourcing programs. The one American city in the survey had a drastically different opinion with having a fairly negative perception, as well, they believed that ridesourcing had a very negative effect on their public transit and region. In order to find out if this trend extends to other cities in Canada and the United States, more cities would have to be asked these questions.

3.2.5 Steps to Increase Ridership

When asked if the transit agencies have taken steps to increase their ridership, London, and Hamilton skipped the question. Guelph stated that they had not taken any steps to increase ridership on public transit. However, the rest of the cities seemed rather proactive in having plans to boost the ridership of their transit systems. Vancouver explained that they are planning to deploy a wide variety of ridership development programs and policies.

Philadelphia has increased enforcement on existing bus-only lanes, as well as working on implementing new dedicated bus and BRT lanes. They have also issued a transit-first transportation plan, are working on a bus network redesign, and are committed to do a city transit plan. They have noticed that their public transit has become a lot slower due to congestion since ridesourcing has started.

Toronto included a report in their survey that outlined the steps they have taken to increase ridership on public transit. According to the report, in September of 2018 they made four service and capacity improvements on their line 1 (subway line) and some of their bus routes. These enhancements included improving service reliability, relieving peak and off-peak crowding and implementing new express bus services (TTC Chief Customer Officer, 2018).

Waterloo also took steps to increase their ridership for their public transit in terms of service improvements and network redesign efforts in advance of the LRT launching. They stated that they had not seen any major positive or negative changes to their public transit since the introduction of ridesourcing. However, they did clarify that an extensive analysis has not taken place, so they cannot be sure.

Lastly, Edmonton has taken steps to increase ridership on public transit as well. They are in the midst of a complete redesign of their route network which will come into effect mid-2020. Ridesourcing programs are not formally included in this process, but are currently under study. They are looking at using them for the first/last mile problem where the network has gaps. There has been no comprehensive analysis of how ridesourcing services have affected their transit system, so there are no noticeable changes to their knowledge.

3.2.6 Unauthorized Ridesourcing Companies

When asked about unauthorized ridesourcing companies in their area, there was not much to be said on the topic. London, Toronto, and Hamilton skipped this question and Edmonton, and Guelph have never noticed them. Philadelphia and Vancouver have noticed unauthorized ridesourcing companies in their area with Philadelphia rating them a -5 on a -10 to 10 scale for being a negative problem for them. They elaborated that there is very little ability to regulate the operators of the unauthorized ridesourcing companies, leading to unsafe vehicles and much illegal activity.

Waterloo mentioned that they had never noticed unauthorized ridesourcing companies in their area, nevertheless they still stated on a -10 to 10 scale that the unauthorized programs were a -10 meaning a constant negative problem for them. This seemed out of place for Waterloo, as given their answers on the survey they maintained such a positive approach to ridesourcing companies.

3.2.7 Biggest Challenge or Issue

It was very interesting to see what each of the cities put as their biggest challenge/issue with ridesourcing programs, as they all had varied responses. London, Guelph, and Hamilton skipped this question and Edmonton was the only one to respond they had no challenges. This is interesting because after Uber started unofficially, Edmonton quickly tried to shut them down and were unsuccessful, it took over a year to create a by-law for them to continue legally (Stolte, 2016). Toronto explained that their biggest challenge was ridesourcing vehicles stopping to pick up and unload in TTC stop areas. This then causes delays to TTC buses and streetcars.

Philadelphia mentioned that their biggest issue is that they are actually responsible for the negative impacts that ridesourcing companies bring on the transportation system. The respondent did not expand on what type of impacts this means. Additionally, by state law they have little ability to control their level of influence. In order to address this, they have increased enforcement of illegal loading and other traffic violations.

Vancouver only admitted to having challenges/issues with ridesourcing companies, but did not elaborate on what kind of challenges/issues these were. They did however elaborate that in response to their issues they lobbied the provincial government to consider their concerns when crafting new ridesourcing legislation.

When asked about any perceived challenges or issues with ridesourcing, Waterloo had an interesting perspective to share. They stated that ridesourcing has an immense potential to help them solve the last-mile problem, but that this would require them to cooperate and integrate with the city as opposed to working in isolation. Waterloo has actually tried to do this with their 903 Flex pilot project that is explained more in Chapter 4. They wish to demonstrate to people that the challenge of integration is tractable by providing low-density, low-demand areas of town with a means of accessing transit stops using ridesourcing vehicles.

3.2.8 Measures of Controlling Ridesourcing

The next several questions dealt with if and how cities attempted to control or monitor the actions of the ridesourcing companies in their areas. London, Toronto, and Hamilton did not have anything to say on this question leading me to believe they have not tried any methods. Philadelphia, Vancouver, and Guelph mentioned that they have not tried implementing any surcharges. Though, when asked about banning ridesourcing companies or limiting their abilities Philadelphia and Vancouver explained that this is not within their authority, with the former adding that they can only enforce the traffic laws, while Guelph stated that they simply did not have enough information to make this decision. This seemed odd as we learned earlier in the survey that Vancouver shut Uber down shortly after they started, but perhaps their answer indicated that they had nothing to do with it because it was the provincial government behind the shutdown not the transit agency. In fact, the transit agencies do not have any say when it comes to drafting bylaws, so the respondents may be unaware if any have been passed or have not succeeded in passing. Lastly, all three of these cities stated that they have not changed or added any policies or tried any other methods that can affect ridesourcing programs; Philadelphia adding once again that this is out of municipal control. However, as we learned earlier Guelph did change the by-laws in their town to include a new set of rules overseeing how ridesourcing companies and taxis within Guelph's borders will operate. The reason for this may be that the respondent was unaware, because the transit agency is not the one responsible for changing the by-laws, this responsibility lies with the municipal or provincial governments.

Edmonton did not implement any surcharges as well. However, when asked about banning a ridesourcing company, they said that they did, but eventually took it back because insurance requirements were changed. They did not specify which ridesource program this was. In terms of limiting the ability of ridesourcing, they indicated that at the time of this survey Lyft was not authorized to service their region.

Waterloo has implemented a surcharge to ridesourcing companies being the only city on the survey to do so, by requiring them to pay the Region ~$0.18 per trip into an accessibility fund which allows the city to finance paratransit services. They have never banned ridesourcing companies, but they say they have limited them by requiring them to be insured and follow basic reporting, safety and financial rules. They did change a regulating by-law (By-law-16-044) that was originally only for taxis to include ridesourcing vehicles, which would from that point on require them to apply for a license the same as any other ride for hire service (The Regional Municipality of Waterloo, 2016). Waterloo explained that other than these they had not tried any other methods.

3.2.9 Communication

Lastly, when asked whether or not public transit is considered when addressing or conversing with ridesourcing companies, London, Toronto, Edmonton, and Hamilton skipped this question. This could be because some transit agencies do not converse with ridesourcing companies as they have no jurisdiction. Philadelphia said that when talking with ridesourcing companies, public transit is a constant issue. Vancouver explained that yes, they talk about it, but only sometimes. And, Guelph mentioned that they do not, but that they should. Waterloo interestingly added that it is not an issue for them as they view the services as complementary and not competitive. In the end, all the cities were kind enough to make themselves available for any follow-up questions with the exception of Hamilton and Guelph.

3.3 Survey Analysis

Overall, from these results, it can be seen that ridesourcing companies have in general a neutral effect on municipalities. Even with the lack of responses collected, this helped to show the cities lack of knowledge on the topic. The cities with the most to say on the topic, interestingly, did not have the same stance on ridesourcing programs. Reactions ranged from a downright constant nuisance that has caused a lot of problems and cannot be controlled to an incredibly helpful tool to use that has been easy to work with. The only U.S. city to participate in the survey saw it as much more of a nuisance than any Canadian city, but further study would have to be made to see if there is a relationship there. Larger cities seemed more likely to answer the questions than smaller ones with a couple of exceptions, likely because the ridesourcing presence is higher in larger centers. Some cities skipped a lot of the questions where the answer could be easily found sometimes even on their city websites. Perhaps this could mean that the cities did not have the time or that their departments do not have some of the answers for the questions being asked. Or, maybe the cities simply are not quite sure what to think about ridesourcing programs. One thing is for certain, there seems to be no correlation between the size of the city or their transit agency and their opinion on ridesourcing.

Some of the transit agencies are not even aware of when ridesourcing started or how many ridesourcing companies they have. Remarkably it was found that ridesource companies do not wait until it is legal for them to operate in a city, and in some cases, they do not even inform the city that they are going to begin operating; they only just show up. Perhaps if the ridesourcing companies made themselves known sooner to the cities when starting, they could better work together with them to make the public transit better. There seemed to be a different relationship between the city and legal ridesourcing companies than with illegal ones, they were treated as more of an annoyance when not operating legally.

Most of the cities in this survey saw a decrease in transit ridership. But, only a couple of them seemed to blame it partly on ridesource companies. Other blamed it on outside factors such as construction or economic factors. Almost all of the cities sounded as though they were active in taking steps to increase their ridership, which is not a surprise. Each city had very valid challenges and there is the possibility that if the cities and the ridesourcing companies worked together, it would help them with these challenges. For example, the Region of Waterloo explained that their challenge was avoiding working in isolation from ridesharing companies, and that working with them could help them overcome other challenges such as the last-mile problem.

When imposing a surcharge, or limiting the ridesourcing vehicle's ability to function, it seems to foster a more positive relationship between the ridesourcing company and the transit agency. Some of the cities were successful in changing their by-laws to make ridesourcing companies legal and it may have taken them some time, but they seemed to work together better afterwards having more of a sense of control over their actions. Only a few cities are in communication with ridesourcing companies or are even willing to talk about them at all. Perhaps if they were more open to discussions, they would have a more positive relationship. This is not always the case though as we saw with one city who seemed in constant communication with ridesourcing companies and still thought very negatively about them.

Referring back to the original research question that was being asked: "Do ridesourcing programs have a noticeable effect on public transit ridership in Canadian cities and what type of relationship do they currently have?" there is not just one clear answer. Perhaps if this survey was changed a bit and sent out to a larger number of cities willing to take the time to answer, the information collected would be somewhat clearer. From this survey however we can ascertain that it is how the city handles the situation of ridesourcing which can create a positive or negative effect on the city. It does not matter what your city or transit size is, if not handled properly, ridesourcing can create a lot of problems. It is also evident that because this is such a recent phenomenon, not a lot of cities are quite sure what to do about it yet, creating an uncertain relationship. This outlines the need for a study such as this one because hopefully it can help cities make better decisions and improve the relationship while also improving their transit in the process.

Chapter 4

Case Studies

Below can be found four different case studies on towns that have partnered with ridesourcing in some way and the outcomes of these partnerships. Each case presents a unique situation to see the wide variety of ways these partnerships can work. After each case study, questions will be analysed such as: what it was that made the partnership work, and what could make it work better. There were a great number of case studies to choose from with new ones popping up every day.

These case studies will help to answer the second research question: "Under what conditions do ridesourcing companies and public transit agencies working together, create positive benefits?" The answer to this question can help other cities that are struggling to deal with TNCs on top of trying to increase public transit ridership.

4.1 The Town of Innisfil and Uber

4.1.1 Description

This case study pertains to Canada's first ridesharing and transit partnership. This is between the Town of Innisfil, which is a small city south of Barrie in central Ontario, with a population of just over 36,000 people and the ridesharing giant Uber (Uber Canada, 2019). Previously having no public transportation options for the citizens of Innisfil, the town commissioned a consulting firm to produce a report on transit options (Uber Canada, 2019). Ultimately, it was considered too costly to implement a fixed route bus service which would not even be able to cover the whole town (Town of Innisfil, 2020). If the town wanted to operate two buses for one year between the hours of 7am to 5pm every day, the total cost to the town would be $1 million (Uber Canada, 2019). Not wanting to spend such a large amount of money on a service that likely would not be able to help many people, they opted to search for something better.

This is when the town reached out to Uber to help find a solution. Together in partnership, the two created a custom solution which is now called Innisfil Transit. This option would be operated by Uber, and the town would be subsidizing the cost (Uber Canada, 2019). The town decided to start with a 6-month pilot project, and a budget of $175,000 to be used to reduce the cost to users of contracting Uber. The rest of the cost of each ride would be coming from the user (Pelley, 2017). When the project first started in May of 2017 several key destinations for the citizens had set rates of $3 to $5, such as the Barrie GO transit Station or the recreational complex. All other destinations, riders would have $5 taken off of their regular fare. The rest of this fare was topped up by the town's budget, so that the drivers would still be paid in full (Pelley, 2017). For 2018, the town subsidized $5.62 per passenger for Innisfil Transit which was higher than their initial estimate. However, this is still much lower than the amount estimated for if they were going to subsidize a bus route, which would have been $33 per passenger (The Canadian Press, 2018). The town estimates that by choosing Uber over buses, they are saving over $8 million per year, which simultaneously providing their citizens with a more flexible option (The Canadian Press, 2018).

The pilot project was then extended to Stage 2, and as of April 2019, the fixed fares increased to $4 – $6, and the town took off $4 for all other destinations. As well, the town imposed a 30-trip maximum (Town of Innisfil, 2020). To help out some of the town's citizens who rely on this system more than others, due to low income or financial barriers, they created what is called the Fair Transit Program in October of 2019. If determined eligible via an online application, the citizen would take 50% off all rides and would not have to adhere to the 30-ride cap (Town of Innisfil, 2020). Otherwise, people could apply to have the trip limit increased to 50 rides, if they are someone who depends on this (Town of Innisfil, 2020).

During the beginning stages of the pilot project, the town sent out a survey to its residents who had used the service to find out how satisfied they were with it and what they were using it for. Of the almost 200 responses, 77% were satisfied or strongly satisfied and 10% were dissatisfied or strongly dissatisfied (Cane, 2018). From when the pilot started on May 15th 2017 until December 31st 2017, a number of data points for the project were collected. Innisfil Transit saw 26,688 trips were taken by 3,493 individuals in those 7 ½ months, and the town subsidized these trips to an amount of $147,234 (Cane, 2018). On average during this time 17% of the trips were shared, providing more than one person with a ride. As well each person waited on average 9 minutes for their ride to show up.

However, since the price increase and placement of the ride caps, citizens have started to become annoyed with the service. For Innisfil Transit, success is met with higher fares for customers and less service, whereas any other transit system, success would mean the opposite (Bliss, 2019). Town Planner Paul Pentikainen says, that the city will keep evaluating the best options for its residents as the situation evolves. Ultimately, they may decide to use Uber Bus which is a new transit like mode designed by Uber using larger vans and designated locations (Bliss, 2019). Alternatively, the city would also consider brainstorming for new ideas, such as a fixed route bus service, if ridesourcing is no longer feasible (Bliss, 2019).

The town mentions nothing about whether the decision to use Uber over a fixed route bus service is better or worse for the environment. There exist some concerns that many drivers in Innisfil are coming from outside of the community, in some cases from the Greater Toronto Area. In 2018, Uber registered 2,203 drivers, up from 1,393 registered drivers in 2017 (Myers, 2019).

4.1.2 Analysis

This case study was unique in that it was not just a ridesourcing company supplementing a transit company, it was a ridesourcing company becoming the transit company. Although, in order to become a transit agency fully, there would have to be regulations such as availability and maximum wait times, but the information collected from the Town of Innisfil did not include these details. This case did however have many positive outcomes; although still in the beginning stages. Given their need to decrease the subsidy and add a ride cap due to the extreme demand, there is no telling how successful this will continue to be. The positive responses from the public have begun to decrease since the change was made. Only time will tell whether or not a project like this one can be maintained in the long term.

One reason for the success of this system has to do with the size of the city and the density. The suggested bus routes were more expensive for less area coverage. But if done in a bigger city, this likely would not have been as feasible. A bigger city could however use this model for their lower density, outlying areas where bus service is not economically practical. This service could also bring passengers to the closest transit station/stop.

4.2 RideCo and Metrolinx at Milton GO

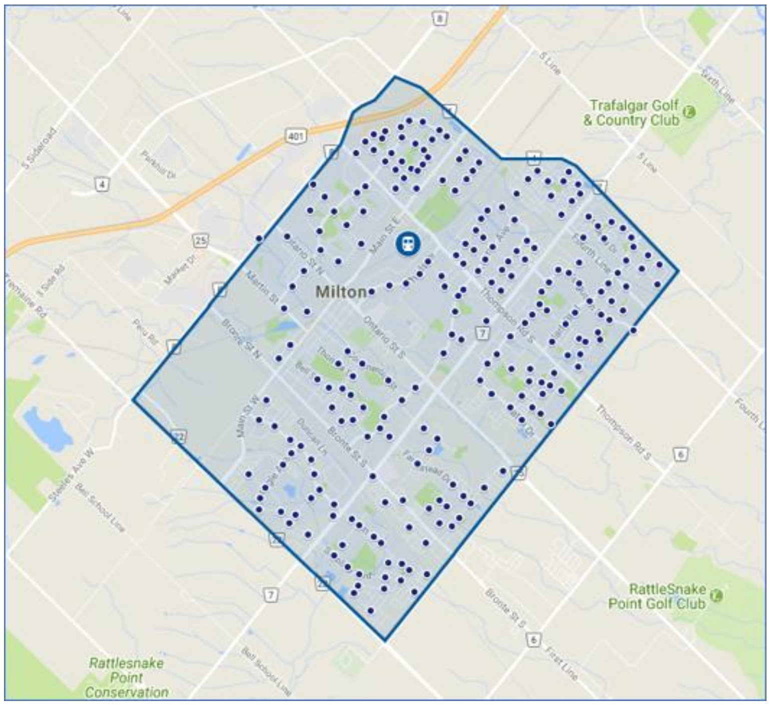
4.2.1 Description

This case study is of a successful pilot project between RideCo and Metrolinx at the Milton GO transit station in Milton, Ontario. RideCo is a ridehailing service that provides dynamically routed buses, vans or cars to their passengers by using a cloud-based software platform to provide on-demand shared rides (RideCo, n.d.). Metrolinx, a regional transportation agency created by the province of Ontario in 2006 (Metrolinx, 2019), partnered with RideCo in order to help them create an on-demand microtransit pilot called “Go Connect” (RideCo, 2018).

The pilot project was designed in order to solve the first/last mile problem at the transit station in Milton. The objective was to connect users with the local GO transit station, while at the same time relieving pressure on an over capacity parking lot (RideCo, 2018). Riders are able to book rides on demand or in advance using a computer or their smartphone. They are then given specific drop off or pick-up locations and will share rides with others going in the same direction (RideCo, 2018).

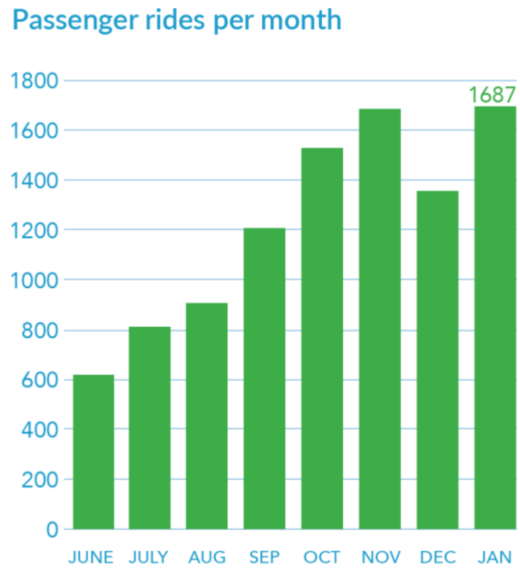
Between Metrolinx and RideCo, 240 virtual stops were mapped out, and can be seen in Figure 4-1 (RideCo, 2018). This ensured that the most a person had to walk, was three minutes to a stop. That is unless they wanted to pay an extra $0.50 to be picked up at their door. If not, the cost was $1.45 for the virtual stop pick up (RideCo, 2018). Metrolinx and RideCo did their best to guarantee an under maximum 10-minute wait time (95% accurate) for the service by deploying anywhere from 5-7 five-seater passenger vans (RideCo, 2018).

Figure 4-1: 240 Virtual Stops for GO Connect in Milton ON (RideCo, 2018)



This pilot was funded by Milton Transit and included co-fare contributions from Metrolinx with a total budget of $150,000 (RideCo, 2018). After only 6 months, the net cost per ride of the GO Connect pilot was less than that of the municipal bus; $5.71 and $7.28 respectively (RideCo, 2018). Figure 4-2 shows how ridership increased over the first 8 months of the project. The likely reason for the December dip was because of the holidays when people tend to take time off of work and are therefore not commuting.

Figure 4-2: Ridership Levels During GO Connect Pilot (RideCo, 2018)



The response to the project from the customers was extremely positive, with an almost 90% satisfaction rate (RideCo, 2018). Figure 4-3 and Figure 4-4 show the users' reasons for choosing this service as well as their level of satisfaction after using it respectively. Here it can be seen that the majority of people used the service because of the convenience and affordability. As well it is surprising that only a small fraction of the users were dissatisfied with the service (RideCo, 2018). These help to show just how positive and successful this pilot really was. After a full year of the pilot project, 45% of users switched to GO Connect from driving themselves and 7% of the users were newly attracted riders for Metrolinx (RideCo, 2018). In terms of less cars on the road causing congestion and decreased overall emissions, there would be positive environmental impacts.

Figure 4-3: Reasons for Using GO Connect (RideCo, 2018)

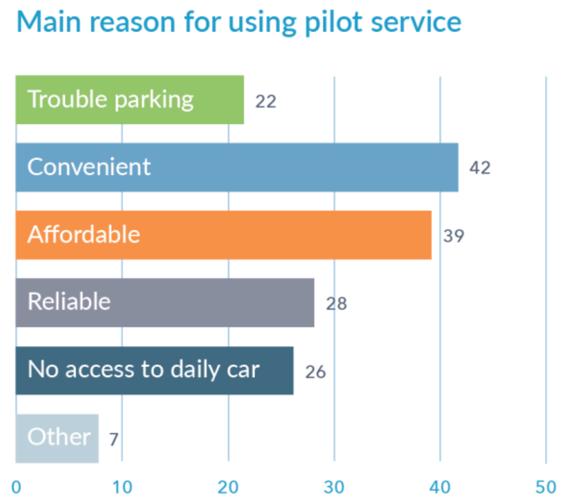
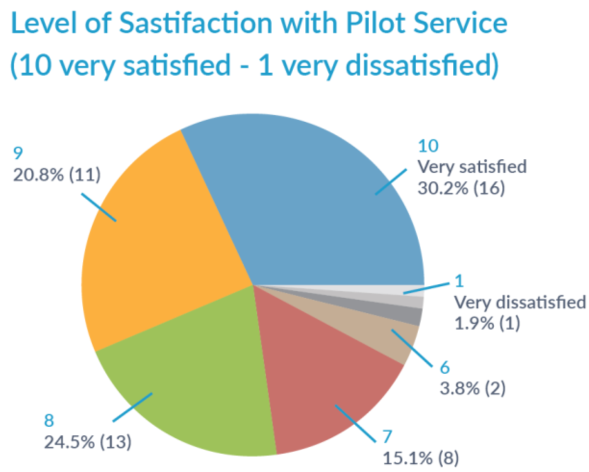


Figure 4-4: Level of Satisfaction with GO Connect (RideCo, 2018)



After the first year of the pilot, even with the success, it seems that the project has ceased as no word of it can be found on RideCo or Milton Transits websites as of 2020. However, it does seem that RideCo has replicated this formula by deploying a similar first/last mile gap solution in 2 communities just north of Calgary, Alberta with no transit options (Fast, 2019). This current one-year pilot connects users with 2 possible transit hubs within Calgary, allowing passengers to then access the whole city (Fast, 2019).

4.2.2 Analysis

This pilot was a very successful project for both the transit agency and the passengers. However, it is very curious that it seems to have stopped without a documented reason why. Perhaps the city of Milton was able to find a better solution for their initial problem, which was an over capacity parking lot. This partnership was unique in that it only transported passengers to and from the local train station and not anywhere else in the city, but this is the transit gap problem that the area needed a solution for. At the very least it is a positive note that RideCo was able to use their model for Milton to help other Canadian communities solve their first/last mile problems.

4.3 RideCo and Waterloo Flex Options

4.3.1 Description

GRT (Grand River Transit) is the transit agency for the Region of Waterloo which is mostly made up of three cities in Ontario: Waterloo, Kitchener and Cambridge (Region of Waterloo, 2017). Since there were many areas in the region that GRT buses could not easily access, the 2017 – 2021 GRT Business Plan looked at different options that could be used (Grand River Transit, 2017). This plan presented three different pilot projects, which have been compiled in Table 4-1 (Grand River Transit, 2017). All three of the areas with the pilots have no planned fixed transit routes any time before 2021 (Grand River Transit, 2017).

Table 4-1: GRT Flex Pilot Projects (Grand River Transit, 2017)

Pilot	Mode	Description	Price	Area of Coverage
1	Ridesharing	▪ Book, pay and track ride from smartphone (or computer/kiosk) ▪ Vehicle drops off and picks up customer at either a communal stop or a GRT transfer point.	Standard GRT fare applies	Northwest Waterloo
2	Subsidized Taxi	▪ Call GRT to book entire return trip from pre-scheduled pick up times ▪ Door-to-door from origin to GRT transfer point ▪ Can be shared	Standard GRT fare applies	Central Hespeler
3	Community Bus	▪ Call GRT to book entire return trip with personally preferred times ▪ Walk to communal stop (10 minutes early) ▪ BusPlus vehicles pick up multiple customers to bring to a GRT transfer point	Standard GRT fare applies	Trinity Village / Freeport Campus

This case study will only focus on option 1 from Table 4-1, known locally as the 903 Flex Ridesharing pilot for Northwest Waterloo. In order to deliver this service, GRT partnered with RideCo to service customers to a nearby GRT transit stop (Grand River Transit, 2017). The pilot project only operated on weekdays from 6:15 am - 11:45 am and 1:45 pm - 6:45 pm (Grand River Transit, 2017), presumably for the morning and afternoon work rush hours. It was open to any individual who wanted to use the service, they were only required to create a RideCo account first (Grand River Transit, 2017). The only caveat is that the service was not wheelchair accessible (Grand River Transit, 2017).

This service is able to be paid for by ticket, electronically, or with a monthly pass. If beginning the trip with RideCo, the ticket, pass, or electronic confirmation must be shown to the driver (Grand River Transit, 2017). When transferring to the bus, the transfer, the monthly pass, or the "trip completed" screen on the phone must be shown to the driver (Grand River Transit, 2017). Similarly, if starting on the bus, either cash/tickets, monthly pass or fare card must be given/shown to the driver. Then when transferring to the RideCo vehicle, a transfer, a pass or a card must be shown to the driver (Grand River Transit, 2017). The ride is able to be cancelled at no penalty as long as the driver has not left yet. If they have, the trip value is credited, however, a cancellation fee of $3.50 is charged (Grand River Transit, 2017).

The pilot began in November of 2018 (GRT, 2018), and ended in December of 2019 (Demarte, 2019). The second pilot project with the subsidized taxi is likewise no longer running. Nevertheless, the community bus pilot is still running, with two more new programs like it (Region of Waterloo, 2017). Reasons for this cancellation are due to the overall low ridership.

Despite a growth in ridership towards the end of the project, due to an increase in marketing efforts, the pilot still did not meet the projected threshold (Regional Municipality of Waterloo, 2019). Some users were also noted to be taking advantage of the system by only using it to travel to areas near bus stops, with a small percentage travelling to another GRT stop apart from the closest one to them, and one in five used it from one GRT stop to another in order to skirt the system (Wanek-Libman, 2020).

4.3.2 Analysis

This project contained many pilots which means the city is constantly looking to find as many ways as possible to close the gaps in their transit as can be seen in their response to the survey in Chapter 3. This is good, because this means that the city will just keep trying until they find a fix that seems to work. With the introduction recently of the two new projects, it sounds as if they are learning from past projects, making a few tweaks and trying again.

The failure of some of the pilots could potentially be due to any number of reasons. But the main reason laid out by the region was the low ridership levels. A cause of this was likely due to the lack of knowledge about the program. Unless the user reads up about the program on GRT’s website, there is no mention of it elsewhere online, with the exception of precious few articles one could easily miss. Other contributing factors could have been the apparent abuse of the system with the lack of clear and precise rules for using it. Perhaps if the rules were clearer and drivers could refuse service to those not using it properly, this could ensure success. Of course, however, these rules could drive away customers as well, so there is a fine line.

4.4 Denver RTD and Uber

4.4.1 Description

There is a program in Denver, Colorado where the RTD (Regional Transportation District) has partnered up with Uber. The Denver RTD is continually searching for opportunities to collaborate and integrate their public transit with new mobility services (Regional Transportation District, 2019). Since January 2019, the Uber app for the Denver area has allowed users to choose public transit as an option (Regional Transportation District, 2019). Upon typing in a destination on the Uber app, it will not only suggest the usual Uber options, but also the bus and rail options (Bosselman, 2019). Not only can the users buy their tickets, but real time schedules as well as walking directions are given. Ticket options even include the three-hour, one-day and monthly passes, and are available to users through the app even when offline (RTD, 2019). This was the only city that Uber had partnered with for this function (CBSN Denver, 2019). But after Denver, Uber Transit wants to use this option in other cities such as London and Boston (RTD, 2019).

The previous RTD mobile app before the partnership was not well liked; users perceived it to be lacking functionality and slow. This is the polar opposite to Uber's app and could be a reason for the partnership (Bosselman, 2019). Another could be that RTD's ride count from 2014 to 2018 dropped by 7.3 million. The idea is that regular Uber users will open the app and notice a potential public transit option could be just as fast (Bosselman, 2019). The hope is that this partnership could help curb Denver's extreme reliance on cars, but many worry that it seems risky to give reins to a private giant like Uber (Bosselman, 2019).

This pilot project was being released in phases, where in a subsequent phase, users were able to purchase their public transportation tickets as well as activate them through the app (Regional Transportation District, 2019). After only 2 months of this phase, 1200 tickets for public transit had been purchased through the app (CBSN Denver, 2019). By the last week of June, the app was selling over 200 transit tickets a week (RTD, 2019). Both Denver's RTD and Uber considered this to be a nice success (CBSN Denver, 2019). This is important because when these tickets were purchased, they were done so with the user having full knowledge of all of their options in front of them, including Uber (RTD, 2019). Additionally, from the January launch, until the beginning of July, Uber trips with origins or destinations at a transit stop increased by 11.6% (RTD, 2019).

4.4.2 Analysis

This is similar to the previous case studies in this chapter, except that the users had greater flexibility and were not penalized for using the app how they wanted to use it. Many people ended up using this to solve the first/last mile problem even though it was not advertised as such. Only time will tell whether a partnership such as this one does more harm than good to the public transit network as well as the city's congestion levels.

A delightful side effect of this partnership is that if a user only wants to use the Uber part of the app, they will also know what the public transit option is as well, even if that was not their intention. It also helps them learn where they can access it for the future, and visualize how easy it is to use. Additionally, it will surely attract more public transit users by allowing the user to take advantage of the app by seamlessly combining walking, rideshare, and public transit. One of the biggest obstacles to public transit seems to be access to the stops and this helps break down that barrier.

Chapter 5

Analytical Model Comparing Alternative Transportation Options

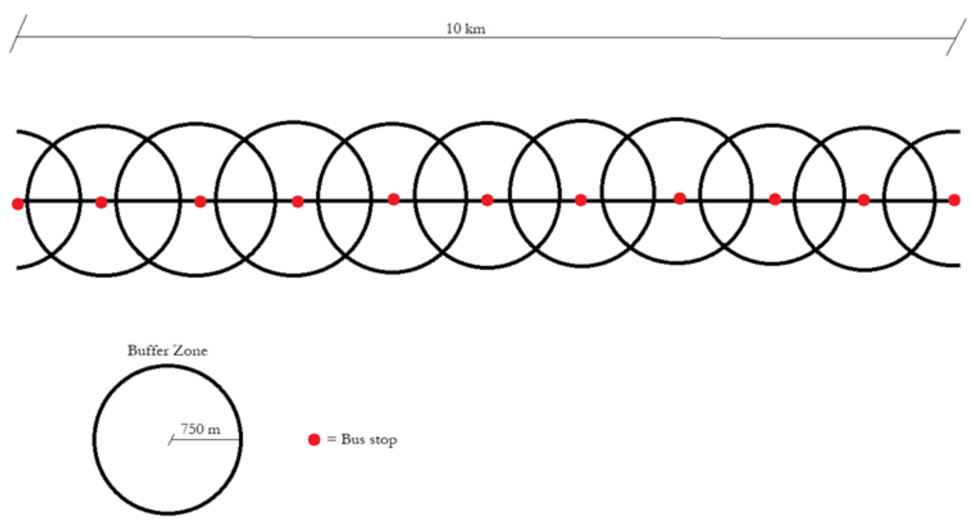
5.1 Introduction

For this chapter, the third research question will be answered: Why is density a critical variable in determining whether ridesourcing or public transit is a better option, and at what density is one more beneficial than the other when considering three sustainability criteria: maximizing the societal, environmental and economic benefits? In an effort to answer this question, an analytical model was created that compares the performance of two different modes of passenger transportation in fictional cities with different population densities. The first mode is traditional public transit buses while the second is a representation of ridesourcing services, also known as ridepooling, where several vans/shuttles will use predetermined stops on demand to pick up and drop off passengers who will share with other users. The performance measures used to make the comparison cover the three pillars of sustainability: social, environmental, and economical.

This idea stemmed from the case study done on the Town of Innisfil, which can be seen in Section 4.1 of this thesis. The town had to decide whether it would be better to implement traditional public transit, or trying something new. Ultimately, they chose to apply a ridepooling system. This led to the question of at what size of city would this be ineffective? Then in a further case study in Section 4.3, the Region of Waterloo put in a ridepooling service in certain underserved neighbourhoods where it was not prudent to use a bus, and brought the passengers to a bus route. This led to the more defined question of which types of neighbourhoods would work well with a ridepool system. Ultimately the answer seemed to lie in the population density. There comes a point when the population density of a city or of an area is not suitable for public transit by bus, and other options such as ridepooling should be examined.

Ideally, a model is available that could be used by municipalities or transit agencies to determine where best to utilize which mode of public transit, in certain areas, or the whole city. How this will be determined will be through the use of a hypothetical stretch of road upon which a forecast travel demand exists. A depiction of this stretch of road can be seen below, Figure 5-1, with bus stops and buffer zones shown around each stop. The actual length between stops and the size of the buffer zones would be changed to fit the specific scenario.

Figure 5-1: Hypothetical Road Configuration



A number of inputs will be placed into the model and can be seen in greater detail in Section 5.2.2 Calibration. Essentially, the model can be tailored to the specific area of question.

For example, the bus farefor the base model is $2.86 CAD, however, if the user of the model wants this to be higher or lower for their area, they may change this. A sensitivity of these inputs can be seen in Section 5.4, as well as Appendix B. For the purposes of this model, all monetary values will be in Canadian dollars (CAD).

The ideal outcome of this model will show us a critical population density (*Dc*), for each of the factors (social, environmental, and economical) as well as an overall *Dc*. This *Dc* will act as the turning point for using one transit mode over the other.

The following chapter outlines the methodology behind the model as well as the implementation and the results. The sensitivity of these results based on the factors put into the model will also be tested. Lastly, the restrictions of this model as well as any future work that could be done will be discussed in Chapter 6.

5.2 Methodology

For the purpose of this thesis, it was decided that three cities could be compared at one time. This was because if the user was looking at one city in particular, they could pick a city or area with a slightly higher density and one with a lower density, to be able to see where the Dc lies. The parameters for each city that were looked at were their population density, their percentage of people who take public transit, and the percentage of people who drive themselves as their main form of mode to work.

With this in mind, three cities were chosen from Ontario, that presented suitable ranges in terms of the above-mentioned variables that could be compared to each other. These cities were Innisfil, Sault Ste. Marie (SSM) and Hamilton. Innisfil was chosen because as seen in Section

4.1, their municipality opted to use a fully ridesourcing system as opposed to trying to implement a public transit system. This case could be used to examine what are the justifications behind this decision, or if it was the population density that was a factor in its success. The other cities Sault Ste. Marie and Hamilton were chosen because their densities and percentage of public transit users seemed to vary sufficiently from Innisfil's to allow a robust comparison.

The choice to compare the results in terms of social, environmental and economical indices stems from the fact that these are the three pillars of sustainability. In order for sustainability to be reached, each pillar must be maximized as much as possible without compromising one of the other pillars (Barbier & Burgess, 2017). This seemed an ideal way to analyse which mode would truly be better for which setting.

5.2.1 Specification

Each one of the aforementioned pillars is estimated using a series of equations, variables and coefficients. The next 3 subsections describe how each of these factors is calculated. These results will then be graphed against population density in order to find the critical density (Dc) in section 5.3 Application.

5.2.1.1 Social

The social value will be measured in terms of how well the transportation options provide the travelers choice. More specifically, the social benefits will be based on how each option will impact the generalized cost (GC) which is commonly defined as a weighted total of the out-of-pocket cost and the cost of time to the user for choosing a given option. This GC (or the associated weights) is often decided from the application of Utility Theory which models a person's preference toward an alternative using a scaler value called utility and the choice with the highest utility is always the one that is chosen. The utility (thus GC) can be formulated as a function of the attributes of each alternative, which can be calibrated using the observed choices that have been made by the users (Ben-Akiva & Bierlaire, 1999). The utility function or GC formula is one that calculates the total overall cost of a trip to a user. This cost not only includes monetary values, but also one's value of time. In this research, the GC model that has been proposed and calibrated in the literature was adopted, as shown in Equation 1 and 2.

$$GC_{i,j}^{m} = VOT(\Sigma\ time\ components) + out\ of\ pocket\ expenses \tag{1}$$

Where:

GC	=	*Generalized Cost*
i	=	*origin*
j	=	*destination*
m	=	*mode (conventional transit or rideshare)*
VOT	=	*value of time*
Time Components	=	*described in equation 2*

$$GC_{i,j}^{m} = VOT(\gamma_{at}T_{at} + \gamma_{wt}T_{wt} + \gamma_{ivt}T_{ivt} + \gamma_{tt}T_{tt} + \gamma_{et}T_{et}) + fare \tag{2}$$

Where:

γ	=	*weighting factor (due to the perception of time passed)*
T	=	*time*
at	=	*access time*
wt	=	*wait time*
ivt	=	*in-vehicle time*
tt	=	*transfer time (if applicable)*
et	=	*egress time*

As mentioned in the introduction for this Chapter, the ridesourcing services for this model are being treated as a ridepooling service, which means that the vehicle does not go door to door but instead uses designated pick up stops similar to bus stops. As well the vehicle can pick up more than one person along the way. This means that the access time, egress time and the in-vehicle times are treated as equal between the transit and ridesourcing options. Additionally, for this example, it is assumed that there are no transfers. This simplifies the equation to the following:

$$GC_{i,j}^{m} = VOT(\gamma_{wt} T_{wt}) + fare \quad (3)$$

The wait time is based upon the average wait time which has been calculated as half of the headway for each vehicle; and the weighting factor is assumed to be 1.0. It should be noted that for short headways it is reasonable for the wait time to be half of the headway, but for long headways it would actually be less due to the probability of the passenger checking scheduled departure times ahead. However, for the purposes of this model, the assumption will be that the wait time is half of the headway. The value of time will be based upon the mean Canadian after-tax income, taken from Statistics Canada in their 2016 Census. The fare for transit is based on the given transit fare amount that can be changed by the user of the model. And the fare for ridesourcing (which can also be changed at any time) is based on the fare for Uberpool which has a base amount of $4.25 and costing an additional $0.18 per minute and $0.81 per km (Uber, 2019). The other inputs for this section will be elaborated on in Section 5.2.2 Calibration.

The societal pillar can be seen as the impact on the users of the service, and their overall opinion, meaning if their opinion of one mode is greater than the other, then the impact of that mode is more positive. This is why the generalized cost formula is a good indicator, as it governs how the users will choose which mode they prefer.

5.2.1.2 Environmental

In order to calculate the environmental impact that both modes would have, the total amount of emissions for each service will be quantified. The emissions will be calculated in grams of carbon dioxide equivalents for every vehicle kilometer (gCO_2e/km). Mathematically, a conversion from L/100km to the desired output metric was found using a combination of manufacturing, fuel combustion and fuel production emissions. The equations for these three factors can be found in Table 5-1.

Table 5-1: Emission Types and How to Calculate (Wilson, n.d.)

Emission Type	Calculation	Description
Manufacturing	= 32 gCO_2e/km (4)	Assumed constant. Estimated using a manufacturing footprint of 8 t CO_2e per vehicle (250,000km life)
Fuel Combustion	= L/100km ÷ 100 × 2330 gCO_2e/litre (5)	Using the emissions factor of 2.33 $kgCO_2e$/litre
Fuel Production	= L/100km ÷ 100 × 430 gCO_2e/litre (6)	Using the emissions factor of 0.43 $kgCO_2e$/litre
Total	= Manufacturing + Fuel Combustion + Fuel Production × 1000 (7)	Units: gCO_2e/km

This table assumes the same emissions for manufacturing a standard bus and a van, and that the service lives of these vehicles would be the same. Where this is not always reasonable, it can be further explored in future versions of this model. The variations in these variables can be seen in the sensitivity portion of this chapter. Additionally, for the purposes of this model, it is assumed that the buses run on gasoline, and not diesel.

There are a number of different ways that the total emissions from a vehicle could be calculated and it would depend on the type of vehicle, the age and condition of the vehicle, the type of fuel being used etc. These equations in Table 5-1 are used because they employ a combination of sources from US agencies including DEFRA (Department for Environment, Food and Rural Affairs), EIA (Energy Information Administration), EPA(Environmental Protection Agency) and GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) version 1.8. As well, where other methods may only consider the fuel combustion of a vehicle, this considers the impact of fuel production and the emissions from manufacturing the vehicle. The values for these equations can be changed by the user of the model if more accurate values are known for the specific vehicles being used.

In an effort to complete these calculations, the fuel economy, measured as volume of fuel per unit of distance traveled, for each mode is needed. This can be found from the U.S. Department of Energy’s website for both a transit bus, and a car or a van (U.S. Department of Energy, 2020). This can always be changed of course by the user of the model, if a more accurate number in known. The gas mileage is given in miles per gallon (MPG) and converted to L/100km.

In order to then find the emissions in gCO_2e, the total number of kilometers for each mode type was needed. To find this, the number of vehicles needed to meet the demand, the number of runs each operated per day, and the total km of each cycle were found. The total emissions were finally calculated by multiplying the total vehicle km by the combination of emission types. This can be further understood in Section 5.3.2.

The environmental pillar for this model can therefore be viewed as the amount of greenhouse gases that the transit vehicles are producing. This is because these greenhouse gases will be the biggest effect on the environment. However, what is not explored in these equations is the increase in emissions resulting from the vehicles in the model creating congestion. Section 5.2.1.2.1 will explain how this will be incorporated. All additional inputs for this section will be elaborated on in Section 5.2.2 Calibration.

5.2.1.2.1 BPR Function

A true environmental impact involves the impact made when adding cars to the road increases congestion. In order to show this, a BPR function was used. The term BPR comes from the U.S. Bureau of Public Roads and it refers to a function relating travel time along a road to the demand and capacity on that same road (Akçelik, 2000). There have been a few iterations of this function over the years, but the one employed in this paper is the Davidson function, first proposed in 1966 (Akçelik, 2000). The equation is as follows (Akçelik, 2000):

$$t = t_o [1 + J_D x / (1 - x)] \quad (8)$$

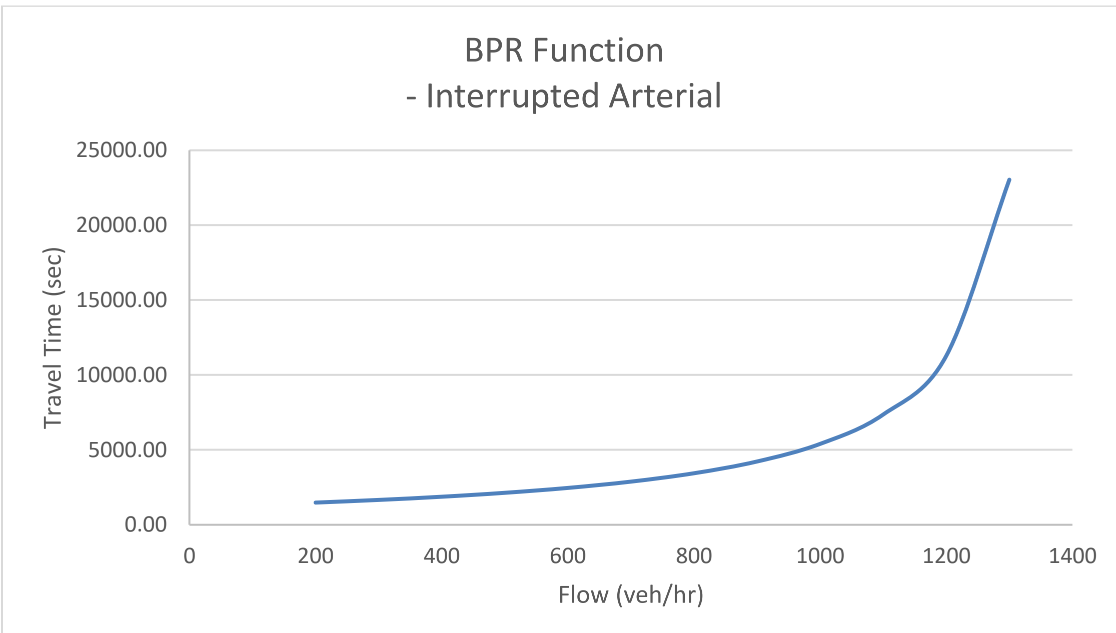
Where:

t	=	*average travel time*
t_o	=	*minimum travel time (at free flow)*
J_D	=	*delay parameter (0.4 for this model because the road is assumed to be an interrupted arterial* (Akçelik, 2000)*)*
x	=	*q/Q = degree of saturation*
q	=	*demand / flow rate (veh/h)*
Q	=	*capacity (veh/h)*

A version of the function for the road in this model is graphed and can be seen in Figure 5-2. The graph will help show whether or not the mode of transit being added to the road will increase the travel time significantly or not. As will be seen in the input section, the given speed for the vehicles will be 30 km/h making the minimum travel time of the 10km road, 1200 seconds. The capacity of the road is also set to 1400 veh/h and this was calculated based upon a reaction time of 2 seconds and an average vehicle length of 4.5 m (Sellén, 2019).

- *2 seconds x 30 km/h = 16.67 meters (space to stop)*
- *16.67 meters + 4.5 meters = 21.17 meters (total area per car)*
- *1000m/km / 21.17m/car = 47.24 veh/km (density)*
- *47.24 veh/km x 30 km/h = 1417.1 veh/h ~ 1400 veh/h*

Figure 5-2: BPR Function for Model Road based on Davidson's Formula



5.2.1.3 Economical

To calculate the economic portion of this model, the total cost of operating the system is calculated, less the revenue made. Since there are some one-time costs and some annual costs, this was done in 3 stages: 1) the cost of the first year with all of the initial starting costs; 2) the cost of every subsequent year; and 3) the long-term cost for a number of years determined by the user of the model. The different kinds of costs for the transit system can be seen in Table 5-2; if there is any other cost the user of the model requires; it can be added in here. The following shows how each stage is calculated:

Initial year *= Vehicle cost + 1 year (Driver Cost + Gasoline + Maintenance – Revenue)* (9)

Subsequent year *= 1 year (Driver Cost + Gasoline + Maintenance – Revenue)* (10)

Long Term *= Initial Year + (Long Term Duration – 1 year) (Subsequent year)* (11)

Table 5-2: Costs Included in the Model

Cost	Description
Vehicle Cost	Estimated from online sources: Bus - [1]$650,000 and Van - [2]$30,700
Driver Cost	([3]$35.56/hour + Miscellaneous costs) × 2 hours/day × 312 working days/year × the number of drivers needed per mode
Gasoline	Can be changed at any time to reflect current costs
Maintenance	Buses = [5]$0.37/km ($7,400/year)* Van = [6]$950/year ($0.0475/km)*
Infrastructure	Assumed the same for all modes (not included in model)
Revenue	The total fare amounts collected from passengers

1 - (The Canadian Press, 2014), adjusted for 2020 CAD value
2 - (FCA Canada Inc. , 2020), base model Dodge Grand Caravan plus tax
3 - (Glassdoor, 2020)
4 - A combinations of other miscellaneous costs associated with an employee, explained further under section 5.2.2 Calibration
5 - (Statistics Canada, 2020)
6 - (Canadian Automobile , 2020)
* Based on 20,000 km/year

The economical pillar of this model refers to the monetary impact of the system, in this case referring to how much it costs the municipality to start up and run. In the social section of this model, the cost to the passenger was analyzed, but for the economic portion it only makes sense to calculate what the cost would be to whomever is running the transit system. This stage of the model changes the most over time, not only because some of the costs are very high, but also because some are variable, such as gasoline prices. Further inputs for this section will be expanded upon in Section 5.2.2 Calibration.

5.2.2 Calibration

The following tables outline the inputs that the user of the model would provide. Table 5-3 shows the needed inputs that the user needs to enter into a user interface, where Table 5-4 shows the extra inputs that are optional to the model and are currently set at a base number. An explanation of how these model coefficients were estimated or determined follows the tables.

Table 5-3: Needed Inputs for Analytical Model

Inputs			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Population Density (persons/km^2)	480	328.6	139.2
Percent of Public Transit Commuters (%)	10.5	3.9	1.9
Percent of Driving Commuters (%)	75.9	83	89.4

Table 5-4: Extra Inputs for Analytical Model

(Sources for these values found on the pages following this table)

Other (optional)	
Sample Time Window (min)	120
Length of Road (km)	10
Buffer Zone Radius (km)	0.75
Area (km2)	15

Public Transit	
Bus Capacity (persons)	36
Bus Fare ($)	2.86

Ride-Hailing (RH)	
RH Vehicle Capacity (not incl. driver)	6
RH Vehicle Utilization (%)	83
Passenger Count	5

UberPool Fare Cost Equation	
Base Cost ($)	4.25
$ per minute	0.18
$ per km	0.81

Value of Time	
Income ($/year)	$ 57,000.00
Hours per week	37.5
Hourly Wage ($/hour)	$ 29.23
Minute Wage ($/min)	$ 0.49

Vehicle Speeds	
Bus (km/hr)	30
RH Vehicle (km/hr)	30
Length of Road (km)	10
Average Trip Length (km)	5
Bus Time to Traverse Road (min)	20
Bus Average Time (min)	10
RH Time to Traverse Road (min)	20
RH Average Time (min)	10

Gas Mileage	
RH Gas Mileage (mpg)	22.04
RH Gas Mileage (L/100km)	10.67
Bus Gas Mileage (mpg)	3.26
Bus Gas Mileage (L/100km)	72.15

Bus Emissions	
Manufacturing Emissions (g CO_2e/km)	32
Fuel Combustions (g CO_2e/km)	1681.18
Fuel Production (g CO_2e/km)	310.26
Total Emissions (g CO_2e/km)	2023

RH Emissions	
Manufacturing Emissions (g CO_2e/km)	32
Fuel Combustions (g CO_2e/km)	248.67
Fuel Production (g CO_2e/km)	45.89
Total Emissions (g CO_2e/km)	327

Wages	
Hourly Wage	$ 19.70
Additional Employee Costs/hr	$ 54.18
Yearly Wage (2hr/day)	$ 46,098.00

Vehicle Cost	
Cost of Bus	$ 650,000.00
Cost of Van	$ 31,000.00

Fuel Prices	
Price of Gasoline (¢/L)	100.00

Maintenance Cost	
RH Yearly Maintenance per Vehicle ($)	$ 950.00
Bus Yearly Maintenance per Vehicle ($)	$ 7400.00

The only information the user of the model would absolutely need to input is the population density, and percentage of commuters travelling by public transit and those by driving for each of the 3 cities being compared. These numbers do not include any person who is driving or taking public transit for purposes other than commuting during these times. This is seen in Table 5-3 with the boxes outlined in red being the required fields. These values do not need to be for an entire city and could be for only a neighbourhood, or area of the city. Ideally the city, neighbourhood, or area would be compared to 2 areas: one with higher density and percent of public transit commuters and the other with lower density and percent of public transit commuters. For the example seen in this chapter, the values for this table have been taken from Statistics Canada (2019), from the 2016 Canadian Census. The boxes in Table 5-4 that are shown outlined in orange are fields that can be changed by the user. These are already filled out with either an average or common number, but can be changed to reflect the environment of the study area. For instance, the value for bus fare is set at $2.86 as an average value, however if a city wants a higher or lower value and this is known to the user, they may change it. Many of these values are tested in terms of sensitivity to the overall results in Section 5.4. The values in the table with no outline at all, are numbers that have been calculated from the inputs.

The following is a description of why certain values were chosen for Table 5-4:

- Sample Window
    - 120 minutes (2 hours) simulates the work day morning rush, since the percent of public transit and driving users are commuters.
- Length of Road
    - The was arbitrary and can be changed to reflect the length of the real-world route being studied
- Buffer Zone Radius

    - 750m, almost double the recommended 400m (American Public Transportation Association, 2012), because it is likely to attract people from farther out.
- Bus Capacity
    - The bus capacity is assumed to be 36 passengers. According to Grand River Transit (GRT) website, their buses seat 36 people and are considered to be negative and overcrowded if the amount of people reaches 45 (Region of Waterloo, 2017). Therefore, the number of seats, 36, was chosen as an acceptable capacity number
- Bus Fare
    - This is based on the monthly discount or tap card discount for the Region of Waterloo. This is because it is assumed the passengers would be commuters and would be applying to some form of discount program for the cost of their fare.
- RH Vehicle Capacity
    - This is based on a seven-seater van (as seen below under "Cost of Van"). The capacity would not include the driver and would therefore be 6 passengers.
- RH Vehicle Utilization
    - It was further assumed that only 5 of the 6 available seats would be occupied at a maximum, as 6 passengers could fit but it would be considered uncomfortable.
- UberPool Fare Cost Equation
    - This was taken from Uber's website (Uber, 2019). The UberPool design was very close to what was proposed for the ridesourcing model, so their formula was then used. UberPool fare cost equation = \$4.25 + \$0.18 (minutes) + \$0.81 (km)
- Income
    - This is based on the median after-tax family income of \$57,000 for Canadians in 2016 taken from Statistics Canada (2019).
- Hours per Week
    - This is based on an average work week of 37.5 hours (Statistics Canada, 2020).
- Value of Time
    - The value of time is based on the above income being divided down into an hourly wage, and then further into a minute. This is certainly something that can be calculated differently depending on the person, but for this thesis, this variation can be seen the sensitivity section of this chapter.
- Vehicle Speeds
    - The average speed of a bus is assumed to be around 30km/h and 35km/h for the average personal vehicle down a city street. The personal vehicle speed is adjusted to 30km/h to account for picking up and dropping off passengers. It can be argued that the ridesourcing vehicle would probably move faster because it will not have as many

people to transport and the vehicle has the capability of reaching higher speeds, and this is reflected in Section 5.4 on sensitivity.

- Gas Mileage
  - These numbers came from the U.S. Department of Energy's Alternative Fuels Data Centre:
    - RH Gas Mileage
      - 22.04 mpg (U.S. Department of Energy, 2020)
    - Bus Gas Mileage
      - 3.26 mpg (U.S. Department of Energy, 2020)
- Manufacturing Emissions and Total emissions
  - The values and equations for this were explained in detail in Section 5.2.1.2 of the Method.
- Hourly Wage of Driver
  - This is a Canadian average salary of $35.56 per hour for Transit Operators (Glassdoor, 2020). An addition of $41 per hour is included to incorporate other costs of an employee such as benefits, training, insurance, licensing, registration, background checks and other miscellaneous costs. There is no reference to this type of cost and therefore it is noted that this value is assumed. This cost can be changed by the user of the model to reflect real world costs.
- Price of Gasoline
  - This was chosen to reflect local conditions and could be changed at any time to reflect the current gas prices of a city or area.
- The cost of each vehicle as well as the yearly maintenance per vehicle is outlined in Table 5-2 of Section 5.2.1.3

5.3 Application

After the user is satisfied with the inputs from the last section, the calculations are performed, and results are given. These results will be different for each of the pillars of sustainability: social, environmental, and economical. These calculations allow the user to arrive at a tangible value that each of the pillars can be measured in.

The final output of this model includes a graphical representation of the metric being used for each pillar against population density. When the two modes of transportation cross on the graph, this will allow for the critical density to be found. Originally public transit was to be compared against 5 passenger ridehails, but it seemed presumptuous to assume that ridehails would be so efficient all the time. Therefore, 2 passenger rideshares were added to show the drastic change that would happen to the results just by dropping a few passengers.

5.3.1 Social

Table 5-5 shows the calculations of the social aspect of the model using the inputs seen in the last section. Following this table is a description of how some of these calculations were made using both Innisfil and Hamilton as examples.

Table 5-5: Social Calculations for Analytical Model

Calculations			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Attraction (persons)	7200	4929	2088
Commuters (persons)	756	192	40
Public Transit			
Buses Needed	21	6	2
Headway (min)	5.71	20.00	60.00
Avg. Wait Time (min)	2.86	10.00	30.00
Cost per Passenger ($)	2.86	2.86	2.86
Wait per Passenger (min)	2.86	10.00	30.00
Cost of Waiting per Passenger ($)	1.39	4.87	14.62
GC per Passenger ($)	4.25	7.73	17.48
Ride-Hailing (RH) - Passengers =	5		
RH Vehicles Needed	152	39	8
Headway (min)	0.79	3.08	15.00
Avg. Wait Time (min)	0.39	1.54	7.50
Cost per Passenger ($)	10.10	10.10	10.10
Wait per Passenger (min)	0.39	1.54	7.50
Cost of Waiting per Passenger ($)	0.19	0.75	3.65
GC per Passenger ($)	10.29	10.85	13.75
Ride-Hailing (RH) - Passengers =	2		
RH Vehicles Needed	378	97	20
Headway (min)	0.32	1.24	6.00
Avg. Wait Time (min)	0.16	0.62	3.00
Cost per Passenger ($)	10.10	10.10	10.10
Wait per Passenger (min)	0.16	0.62	3.00
Cost of Waiting per Passenger ($)	0.08	0.30	1.46
GC per Passenger ($)	10.18	10.40	11.56

The 10 km stretch of road covers 10 km × 1.5 km = 15 km^2 of area (given 750 m radius buffer around each bus stop).

- How many people will be attracted to the road:
  - Hamilton = 480 ppl/km^2 × 15 km^2 = 7,200 people
  - Innisfil = 139.2 ppl/km^2 × 15 km^2 = 2,088 people
- How many people will use the service:
  - Hamilton = 7,200 people × 10.5% = 756 people
  - Innisfil = 2,088 people × 1.9% = 40 people
- How many buses are needed:
  - Hamilton = 756 people / 36 people/bus = 21 buses
    - Headway = 5.71 minutes
    - Avg. wait time = 2.86 minutes
  - Innisfil = 40 people / 36 people/bus = 1.1 = 2 buses
    - Headways = 60 minutes
    - Avg. wait time = 30 minutes
- How many rideshares are needed:
  - Hamilton = 756 people / 5 people/van = 151.2 = 152 vans
    - Headway = 0.79 minutes
    - Avg. wait time = 0.39 minutes
  - Innisfil = 40 people / 5 people/van = 8 vans
    - Headway = 15 minutes
    - Avg. wait time = 7.5 minutes

Due to the length of the road being 10 km, the average length of trip will be 5 km. Using the speed, the average trip will be 10 minutes. Using these numbers, we can calculate the fare cost of taking both rideshare and public transit.

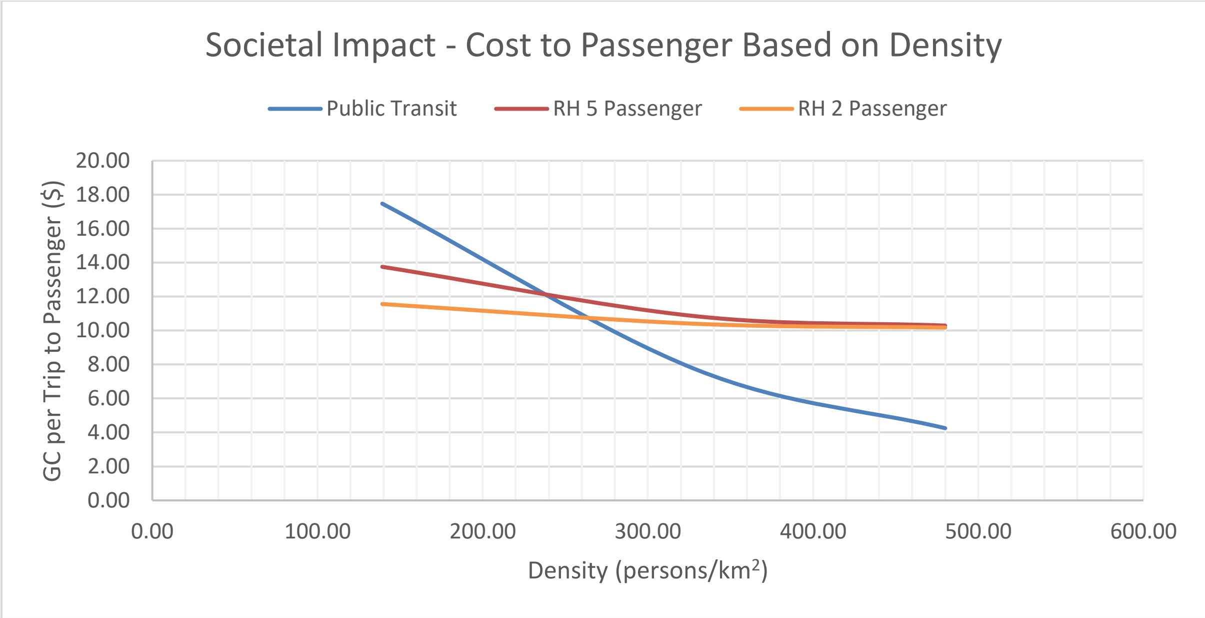
- Fare Cost:
  - UberPool = $4.25 + $0.18 (10 min) + $0.81 (5 km) = $10.10
  - Bus: The following numbers are based on the public transit costs in Waterloo ON (Region of Waterloo, 2017).
    - Basic Fare = $3.25
    - EasyGo Fare = **$2.86**
    - Monthly Fare* = $2.13
      - For this example, we will use the EasyGo fare card price as this is likely what a commuter would use.
      - ** Monthly fare was adjusted to show the cost per trip, just as the other fare structures. The pass = $90/month * 12 months / 253 work days / 2(return trip) = $2.13 per trip.

Following this, Equation 3 from Section 5.2.1.1 is used to find the generalized cost (GC) of both public transit buses and ridesourcing for each city. After these are all calculated, the final generalized cost for each city and for each mode of transportation can be seen below in Table 5-6 followed by the graph in Figure 5-3 showing where they intersect.

Table 5-6: Social Results for Analytical Model

Social Impact			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC ($)	4.25	7.73	17.48
Ridehail GC (5psgr) ($)	10.29	10.85	13.75
Ridehail GC (2psgr) ($)	10.18	10.40	11.56

Figure 5-3: Social Results for Analytical Model



Number of Passengers (RS)	5	2
Critical Density (people/km^2)	239	262

Figure 5-3 shows that at a lower population density, ridesourcing is better than public transit in terms of cost for the passenger. This is because of the large amount of time the passengers would be waiting for the bus. Likewise, public transit performed better at higher population densities because the buses would arrive so frequently, that wait time would barely factor in, leaving cost of journey to dictate choice. As well, whether or not the ridesourcing vehicle had 2 passengers, or 5, the generalized cost was the same at higher densities.

Ultimately, for ridesourcing with 5 passengers, the critical density was 239 people/km^2 and for ridesourcing with 2 passengers it was 262 people/km^2. This confirms that both Sault Ste. Marie and Hamilton would be better off with public transit in terms of a social impact, and

Innisfil would actually benefit from using ridesourcing, even if the ridesourcing had a lower passenger rate.

5.3.2 Environmental

Table 5-7 shows the calculations of the Environmental aspect of the model using the inputs seen in Section 5.2.2 Calibration. Following that is a description of how some of these calculations were made using both Innisfil and Hamilton as examples.

Table 5-7: Environmental Calculations for Analytical Model

Calculations			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Attraction (persons)	7200	4929	2088
Commuters (persons)	756	192	40
Commuters per hour (persons/hour)	378	96	20
Drivers (persons)	5465	4091	1867
Drivers per hour (persons/hour)	2732	2046	933
Public Transit			
Buses Needed	21	6	2
Headway (min)	5.71	20.00	60.00
Avg. Wait Time (min)	2.86	10.00	30.00
Full Trip Time (min)	40	40	40
Number of Vehicles	7	2	1
Laps	3	3	3
Total Car Km	420	120	60
Total Emissions (g CO_2e/km)	2023	2023	2023
kg CO_2e	849.84	242.81	121.41
Ride-Hailing (RH) - Passengers =	5		
RH Vehicles Needed	152	39	8
Headway (min)	0.79	3.08	15.00
Avg. Wait Time (min)	0.39	1.54	7.50
Full Trip Time (min)	40	40	40
Number of Vehicles	51	13	3
Laps	3	3	3
Total Car Km	3060	780	180
Total Emissions (g CO_2e/km)	327	327	327
kg CO_2e	999.27	254.72	58.78

Ride-Hailing (RH) - Passengers =	2		
RH Vehicles Needed	378	97	20
Headway (min)	0.32	1.24	6.00
Avg. Wait Time (min)	0.16	0.62	3.00
Full Trip Time (min)	40	40	40
Number of Vehicles	126	33	7
Laps	3	3	3
Total Car Km	7560	1980	420
Total Emissions (g CO_2e/km)	327	327	327
kg CO_2e	2468.79	646.59	137.15

The number of drivers is found the same way that the number of commuters was found in the previous section, by using the percentage of people commuting by personal vehicle.

- How many people will drive themselves:
  - Hamilton = 7,200 people × 75.9% = 5465 people
  - Innisfil = 2,088 people × 89.4% = 1867 people

In order to figure out how many of each vehicle the areas will need to buy, the user will need to find out how long one cycle takes each vehicle. Using the previous assumption that both buses and vans will be travelling an average 30 km/h, down a 10 km road it will take them 20 minutes to travel from one end to the other. In order to start their route again the vehicle will need to travel another 20 minutes back to the start. Therefore, each vehicle can only be used once every 40 minutes.

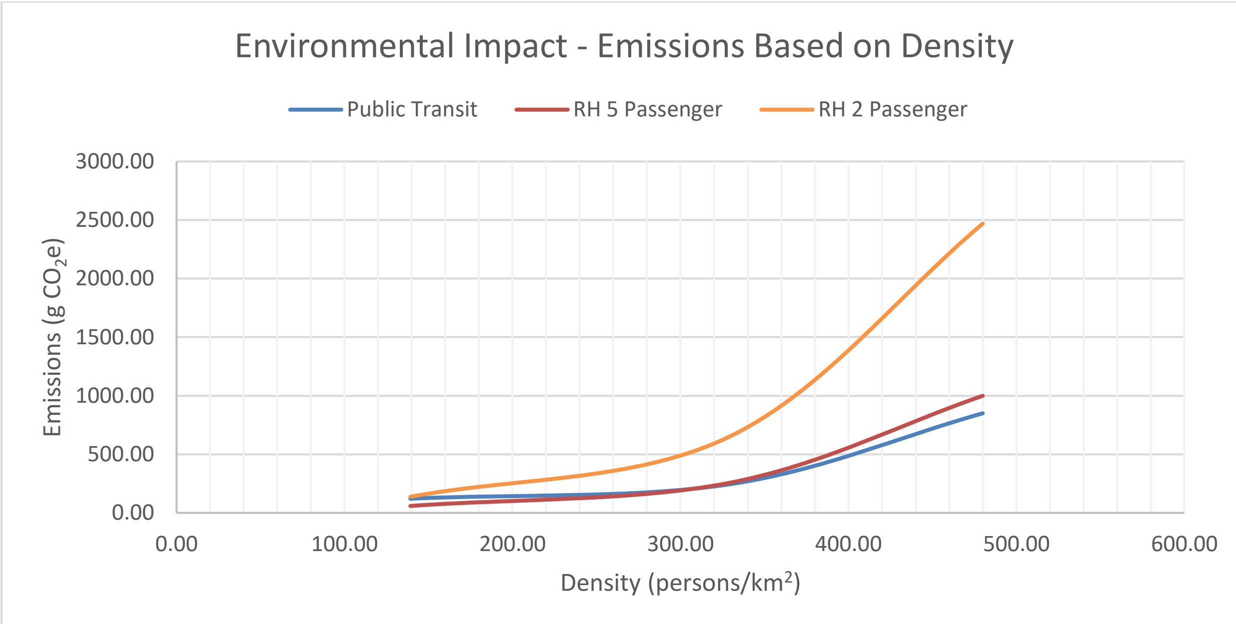
- How many vehicles are needed:
    - Hamilton
        - Buses = 40 minutes / 5.71 minutes headway/vehicle = 7 vehicles
        - Rideshares = 40 minutes / 0.79 minutes headway/vehicle = 50.63 = 51 vehicles
    - Innisfil
        - Buses = 40 minutes / 60 minutes headway/vehicle = 0.67 = 1 vehicle
        - Rideshares = 40 minutes / 15 minutes headway /vehicle = 2.67 = 3 vehicles

Each vehicle would then do 3 cycles through the route because the cycles were 40 minutes and the time window was 120 minutes. The total vehicle kilometers was subsequently the number of vehicles multiplied by the 3 laps and then multiplied by the 20 km route. Then, using the total emissions for each vehicle type (kgCO_2e) found in Section 5.2.2 Calibration, the total emissions for each mode of transportation was found for each of the cities. These values can be seen in Table 5-8 followed by the graph in Figure 5-4 showing where the modes intersect.

Table 5-8: Environmental Results for Analytical Model

Environmental Impact			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions (g CO_2e)	849.84	242.81	121.41
RH Emissions (5psgr) (g CO_2e)	999.27	254.72	58.78
RH Emissions (2psgr) (g CO_2e)	2468.79	646.59	137.15

Figure 5-4: Environmental Results for Analytical Model



Number of Passengers (RS)	5	2
Critical Density (people/km^2)	309	135

Figure 5-4 shows that at a lower population density, the results of environmental effects are rather negligible. Five passenger rideshare has the least environmental impact at lower densities with 2 passenger rideshare and public transit crossing at about 135 people/km^2; making 2 passenger rideshare only better than public transit under that density. At higher densities, the results are a little clearer, with public transit being the best for the environment, closely followed by 5 passenger rideshare and then at emissions incredibly worse is 2 passenger rideshare. Five passenger rideshare and public transit follow a similar trajectory only crossing at 309 people/km^2.

5.3.2.1 BPR Function

After deciding that the lane capacity was 1400 veh/hr (see Section 5.2.1.2.1), the number of lanes needed for each city was found. This was calculated based on the number of personal vehicle drivers who commute according to Statistics Canada (2019), which is found in Table 5-7. The flow for each lane was calculated and then again to include buses and further to include 5 and 2 passenger ridesourcing vehicles. Buses were counted as two vehicles given their length. The traffic flows for each of these scenarios can be seen in Table 5-9. Since the 2-lane flow for Hamilton was very nearly at capacity, both 2-lane and 3-lane roads for Hamilton were calculated.

Table 5-9: Flow per Lane for Each City

	Hamilton	Hamilton	SSM	Innisfil
Number of Lanes Needed	2	3	2	1
Flow (veh/hr/lane)	1366.20	910.80	1022.77	933.34
Number of Buses per hour	11	11	3	1
With Buses Flow (veh/hr/lane)	1376.70	921.30	1025.77	934.34
Number of Rideshare Passengers	5	5	5	5
Number of Vehicles per hour	76	76	20	4
With Rideshares Flow (veh/hr/lane)	1442.20	986.80	1042.77	937.34
Number of Rideshare Passengers	2	2	2	2
Number of Vehicles per hour	189	189	49	10
With Rideshares Flow (veh/hr/lane)	1555.20	1099.80	1071.77	943.34

These flow values were then visualized by finding their corresponding travel times and showing them on the BPR function graph. Table 5-10 shows the values used to create the graph, and Figure 5-5 through to Figure 5-8 show the visualizations. The values in a couple of the columns of Table 5-10 have negative values due to the degree of saturation (x) being greater than one. Realistically this number would only approach one and not exceed it when the demand is greater than the capacity of the road. The denominator of the equation is 1-x, meaning that if x is approaching one, the denominator is approaching zero and the equation would reach infinity. Therefore, when a negative number appears in the table, it is resultant of the road being at capacity and the travel time reaching infinity.

Table 5-10: Calculating Vehicle Travel Time

	Flow (veh/hr)	x	1-x	1+JDx	Travel Time (sec)	Travel Time (hour)
	200	0.1429	0.8571	1.0571	1480.00	0.411
	300	0.2143	0.7857	1.0857	1658.18	0.461
	400	0.2857	0.7143	1.1143	1872.00	0.520
	500	0.3571	0.6429	1.1429	2133.33	0.593
	600	0.4286	0.5714	1.1714	2460.00	0.683
	700	0.5000	0.5000	1.2000	2880.00	0.800
	800	0.5714	0.4286	1.2286	3440.00	0.956
	900	0.6429	0.3571	1.2571	4224.00	1.173
	1000	0.7143	0.2857	1.2857	5400.00	1.500
	1100	0.7857	0.2143	1.3143	7360.00	2.044
	1200	0.8571	0.1429	1.3429	11280.00	3.133
	1300	0.9286	0.0714	1.3714	23040.00	6.400
Hamilton 2 Lanes	1366.2	0.9759	0.0241	1.3903	69105.80	19.196
	1376.7	0.9834	0.0166	1.3933	100464.21	27.907
	1442.2	1.0301	-0.0301	1.4121	-56214.60	-15.615
	1555.2	1.1109	-0.1109	1.4443	-15634.64	-4.343
Hamilton 3 Lanes	910.8	0.6506	0.3494	1.2602	4327.85	1.202
	921.3	0.6581	0.3419	1.2632	4433.31	1.231
	986.8	0.7049	0.2951	1.2819	5212.16	1.448
	1099.8	0.7856	0.2144	1.3142	7354.78	2.043
Sault Ste. Marie	1022.8	0.7306	0.2695	1.2922	5754.92	1.599
	1025.8	0.7327	0.2673	1.2931	5804.91	1.612
	1042.8	0.7448	0.2552	1.2979	6103.99	1.696
	1071.8	0.7656	0.2345	1.3062	6685.71	1.857
Innisfil	933.3	0.6667	0.3333	1.2667	4560.07	1.267
	934.3	0.6674	0.3326	1.2670	4570.90	1.270
	937.3	0.6695	0.3305	1.2678	4603.65	1.279
	943.3	0.6738	0.3262	1.2695	4670.44	1.297

Figure 5-5: Innisfil Vehicle Flow on BPR Function

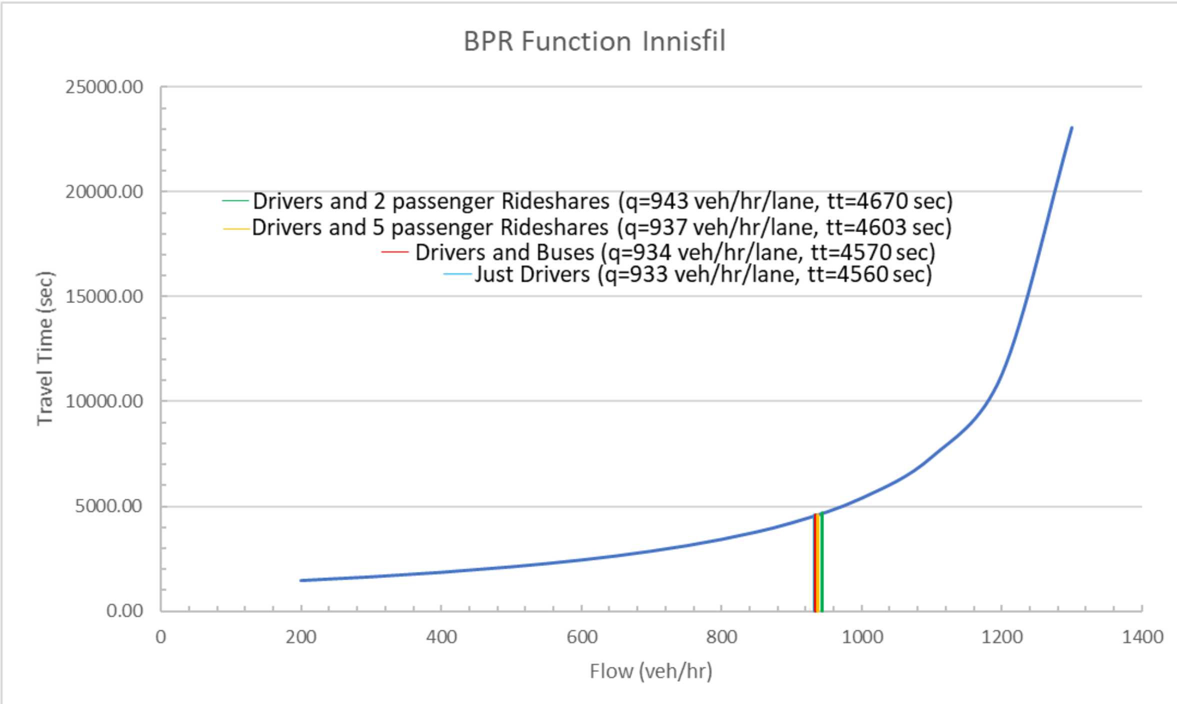


Figure 5-6: Sault Ste. Marie Vehicle Flow on BPR Function

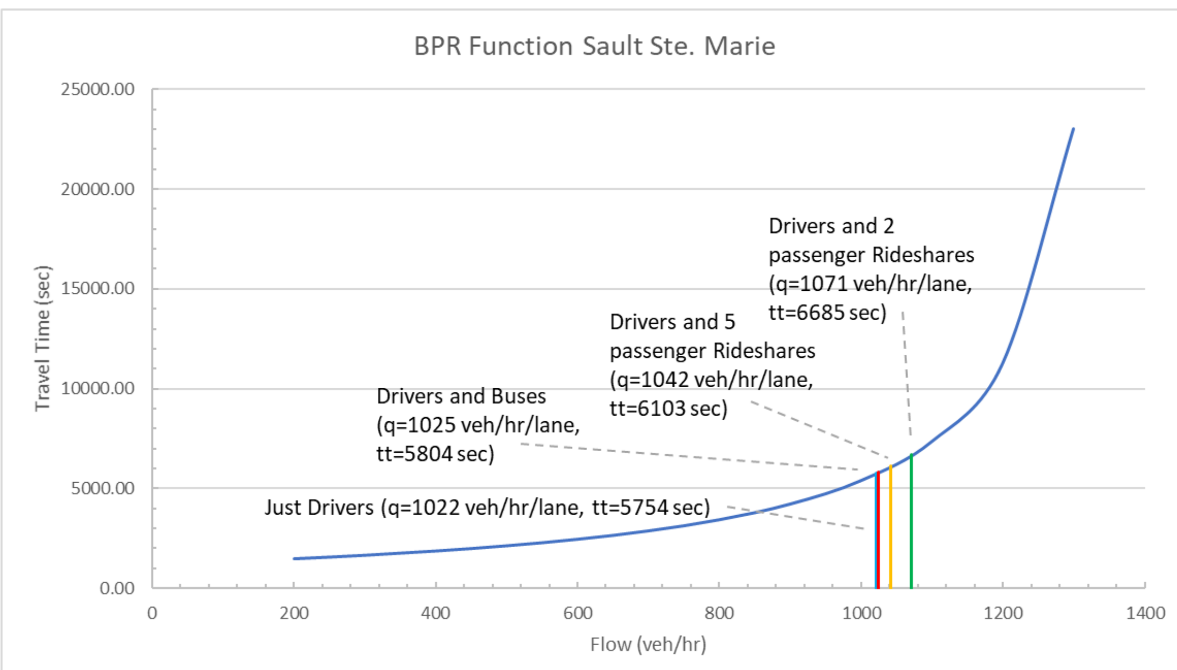


Figure 5-7: Hamilton 2 Lane Vehicle Flow on BPR Function

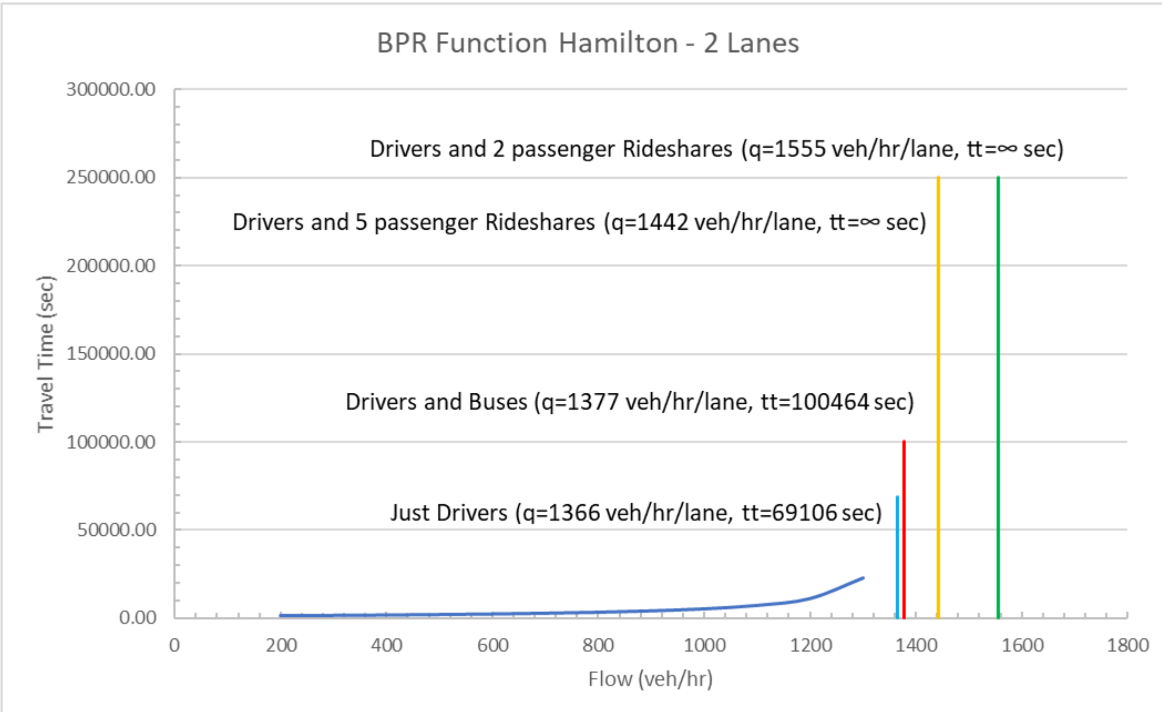
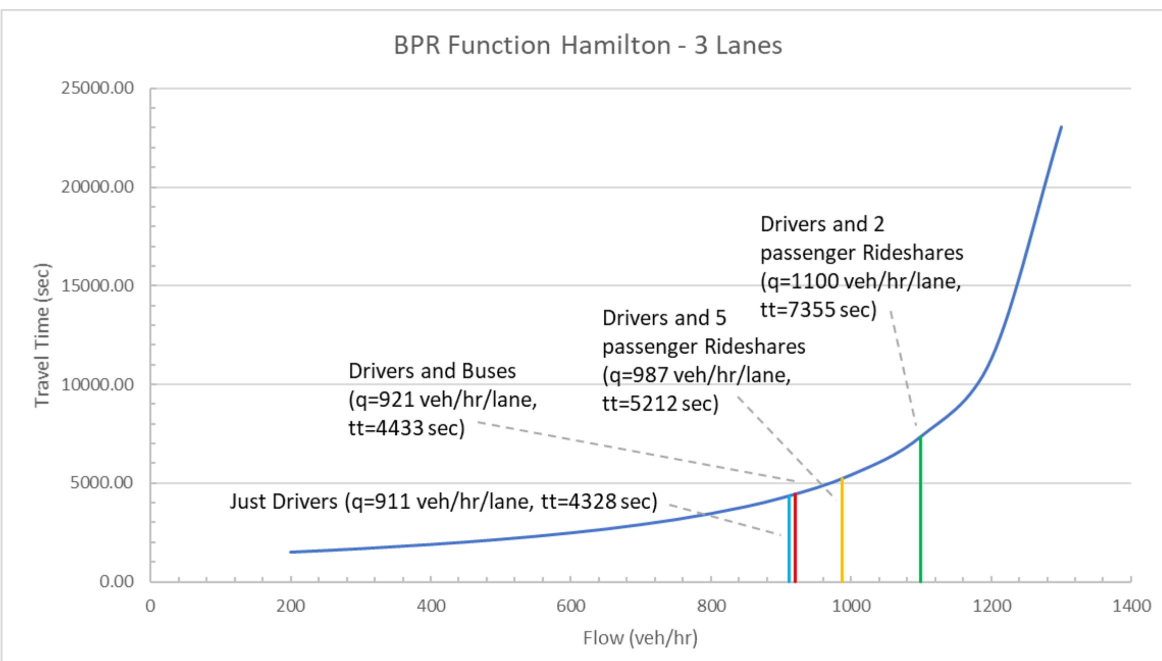


Figure 5-8: Hamilton 3 Lane Vehicle Flow on BPR Function



This shows us that no matter what mode small density cities like Innisfil use, it will not add congestion to their current roads. The travel times for adding each mode has a negligible effect. In Sault Ste. Marie, the 5 and 2 passenger rideshares would add about 6 and 16 minutes of travel time respectively which is not too bad but it is not as good as the 10 seconds that would be added to the trip by the bus.

For the two-lane Hamilton situation, it can clearly be seen that a two-lane configuration is not sustainable. In using equation 8, given a minimum travel time of 20 minutes, the result is 19 hours of travel time for even just the drivers of their own vehicles. Adding either one of the ridesourcing options would render the traffic immovable. Therefore, the three-lane situation will be looked at. This example is a perfect example of the effects that the ridesourcing can have on congestion. Introducing the bus to the base situation only adds 1 minute and 45 seconds to the travel time. But adding 5 and 2 passengers rideshares add 15 and 50 minute travel time to the road. This means that 2 passenger rideshares almost doubles the travel time which means that a substantial amount of congestion is added.

5.3.3 Economical

Table 5-11 shows the calculations of the Economical aspect of the model using the inputs seen in Section 5.2.2 Calibration. Following that is a description of how some of these calculations were made using both Innisfil and Hamilton as examples.

Table 5-11: Economical Calculations for Analytical Model

Calculations			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Attraction (persons)	7200	4929	2088
Commuters (persons)	756	192	40
Public Transit			
Buses Needed	21	6	2
Headway (min)	5.71	20.00	60.00
Avg. Wait Time (min)	2.86	10.00	30.00
Full Trip Time (min)	40	40	40
Number of Vehicles	7	2	1
Laps	3	3	3
Total Car Km	420	120	60
Driver Cost/year	$ 286,650.00	$ 81,900.00	$ 40,950.00
Vehicle Cost	$ 4,900,000.00	$ 1,400,000.00	$ 700,000.00
Gasoline Cost/year	$ 105,234.03	$ 30,066.87	$ 15,033.43
Maintenance Cost/year	$ 14,000.00	$ 4,000.00	$ 2,000.00
Transit Cost Initial	$ 5,305,884.03	$ 1,515,966.87	$ 757,983.43
Transit Cost Yearly	$ 405,884.03	$ 115,966.87	$ 57,983.43
Yearly Transit Revenue	$ 674,593.92	$ 171,531.57	$ 35,400.12
Ride-Hailing (RH)	5	Passengers	
RH Vehicles Needed	152	39	8
Headway (min)	0.79	3.08	15.00
Avg. Wait Time (min)	0.39	1.54	7.50
Full Trip Time (min)	40	40	40
Number of Vehicles	51	13	3
Laps	3	3	3
Total Car Km	3060	780	180
Driver Cost/year	$ 2,088,450.00	$ 532,350.00	$ 122,850.00
Vehicle Cost	$ 1,581,000.00	$ 403,000.00	$ 93,000.00
Gasoline Cost/year	$ 113,405.56	$ 28,907.30	$ 6,670.92
Maintenance Cost/year	$ 15,300.00	$ 3,900.00	$ 900.00
RH Cost Initial	$ 3,798,155.56	$ 968,157.30	$ 223,420.92
RH Cost Yearly	$ 2,217,155.56	$ 565,157.30	$ 130,420.92
Yearly RH Revenue	$ 2,382,307.20	$ 605,758.33	$ 125,014.41

Ride-Hailing (RH)	2	Passengers	
RH Vehicles Needed	378	97	20
Headway (min)	0.32	1.24	6.00
Avg. Wait Time (min)	0.16	0.62	3.00
Full Trip Time (min)	40	40	40
Number of Vehicles	126	33	7
Laps	3	3	3
Total Car Km	7560	1980	420
Driver Cost/year	$ 5,159,700.00	$ 1,351,350.00	$ 286,650.00
Vehicle Cost	$ 3,906,000.00	$ 1,023,000.00	$ 217,000.00
Gasoline Cost/year	$ 280,178.45	$ 73,380.07	$ 15,565.47
Maintenance Cost/year	$ 37,800.00	$ 9,900.00	$ 2,100.00
RH Cost Initial	$ 9,383,678.45	$ 2,457,630.07	$ 521,315.47
RH Cost Yearly	$ 5,477,678.45	$ 1,434,630.07	$ 304,315.47
Yearly RH Revenue	$ 2,382,307.20	$ 605,758.33	$ 125,014.41

The driver cost for this section is fairly simple, by just taking the number of vehicles needed, knowing that only one driver is needed per vehicle, and multiplying by the drivers yearly wage as seen in Section 5.2.2 Calibration. Vehicle cost was done in a similar fashion with multiplying the number of vehicles needed by the cost of that particular vehicle also found in Section 5.2.2 Calibration.

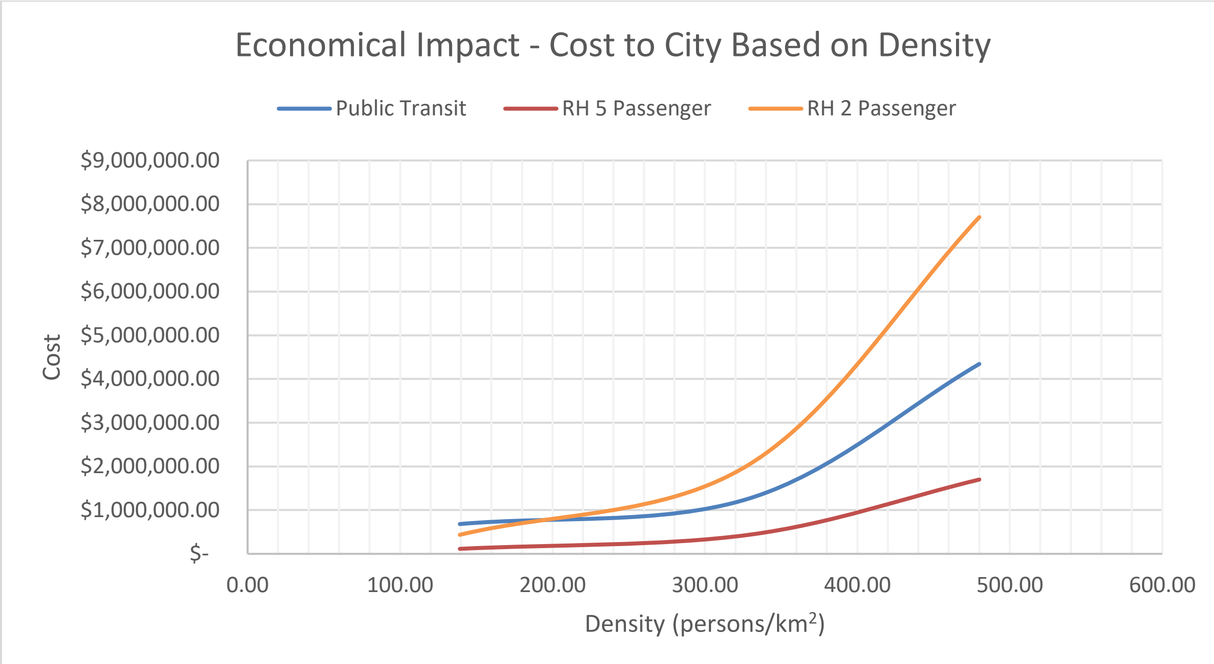
The cost of gasoline required more of a calculation, by taking the number of km driven by the vehicles in a day, changing that to year, multiplying by the gas mileage to find the litre amount and then finally using the cost of gasoline to find the total amount. This is one of the most dynamic variables in this model because of the fact that the cost of gasoline changes every day and is very different not only for every city, but also for every neighbourhood. Lastly, the maintenance cost was taken straight from Section 5.2.2 Calibration, where it was already converted to a yearly value.

The economical pillar is unique for this model in that there is more than one graph depicting the results. For this section, there are 3 ways that the results were calculated: initial year, subsequent years, and over a certain time span. The initial year uses all of the costs, but also includes the cost of the vehicles, but since the user would only have to buy a vehicle once, they are not included in subsequent years. The last results table and graph shows how much it would cost over the assumed lifetime of the vehicle. This could also be done by amortizing the cost of the vehicle over the life of the vehicle resulting in an equivalent annual cost. For this model, 12 years was chosen as the lifespan of the vehicles. These values were calculated for both the ridesourcing and public transit costs for all three cities and can be seen below in Table 5-12 through to Table 5-14 followed by Figure 5-9 to Figure 5-11 showing where the modes intersect.

Table 5-12: Economical Results for Analytical Model Initial Year

Economical Impact Initial			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 4,344,441.97	$ 1,262,478.69	$ 681,605.01
Ride-Hailing Cost (5psgr)	$ 1,700,032.59	$ 434,838.09	$ 115,123.23
Ride-Hailing Cost (2psgr)	$ 7,703,473.46	$ 2,035,755.66	$ 435,306.74

Figure 5-9: Economical Results for Analytical Model Initial Year



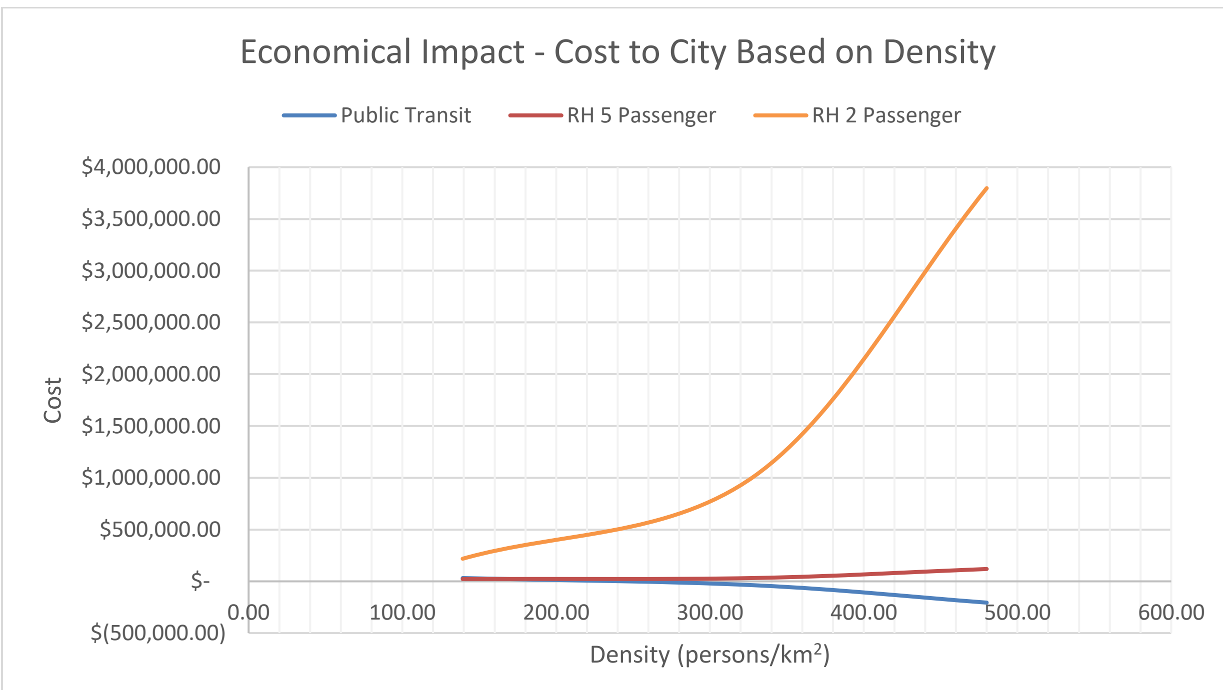
Number of Passengers (RS)	**5**	**2**
Critical Density (people/km^2)	**N/A**	**195**

For the initial year costs, it comes as no surprise that public transit is the most expensive at lower population densities. The biggest cost for the first year is the cost of vehicles and at low densities there are not enough rideshare vehicles to eclipse the cost of a bus. This quickly changes however, when at higher densities, the cost of buying many rideshare vans starts to add up swiftly. Since using 2 passenger rideshares would mean that a lot more vehicles than 5 passenger rideshares, they grow at a faster rate, and soon become the most expensive mode at 195 people/km^2. Public transit and 5 passenger rideshare vehicles never end up crossing on this graph, where public transit costs stay consistently more expensive than the rideshares, and moving down to lower densities it will likely stay this way as public transit becomes more unappealing at that density.

Table 5-13: Economical Results for Analytical Model Yearly Costs

Economical Impact Yearly			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	-$ 205,558.03	-$ 37,521.31	$ 31,605.01
Ride-Hailing Cost (5psgr)	$ 119,032.59	$ 31,838.09	$ 22,123.23
Ride-Hailing Cost (2psgr)	$ 3,797,473.46	$ 1,012,755.66	$ 218,306.74

Figure 5-10: Economical Results for Analytical Model Yearly Costs



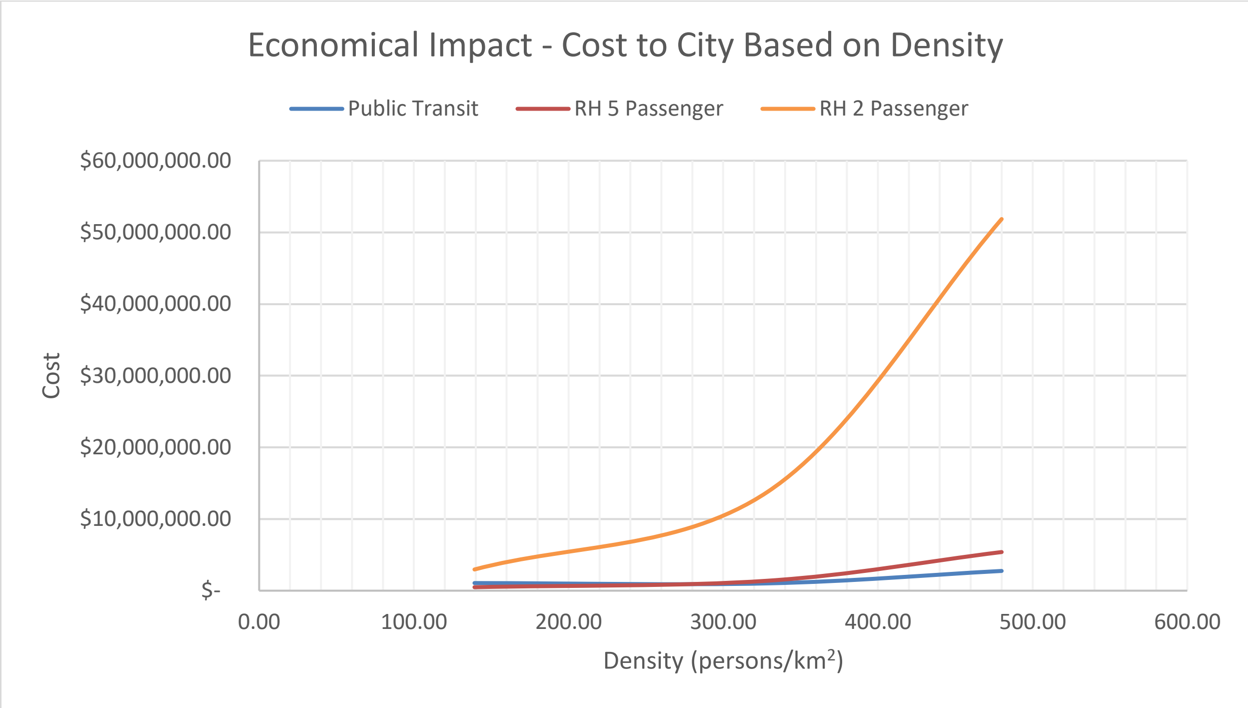
Number of Passengers (RS)	5	2
Critical Density (people/km^2)	164	N/A

For subsequent years, it can be seen that the most expensive mode is the 2 passenger rideshares, which does make sense, because the governing costs for this would be the per vehicle costs. Since the 2 passenger rideshares have the greatest number of vehicles by far, they will be the most expensive. Using the graph to extrapolate where public transit and 2 passenger rideshares would cross would be around 90 people/km^2. At lower densities, public transit and 5 passenger rideshares costs are around the same, only deviating greatly around 300 people/km^2. Public transit's yearly cost actually trends downwards, and this is because the revenue made each year is greater than the yearly costs. This is however, not consistent with real world observations, and this could be because there are likely a whole host of other expenses involved in running a transit system including but not limited to workers on the administrative side of things. Next it can be seen what happens when the initial costs and the yearly costs are amalgamated together.

Table 5-14: Economical Results for Analytical Model Over 12 Years

Economical Impact Over Duration: 12 years			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
Ride-Hailing Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
Ride-Hailing Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

Figure 5-11: Economical Results for Analytical Model Over 12 Years



Number of Passengers (RS)	5	2
Critical Density (people/km^2)	277	N/A

The overall costs over a specified time frame will be the values that will be used to find the overall critical density, as this is the most representative of what the user of the model would be looking for. In Figure 5-11, it can be seen that over 12 years, no matter what the population density is, the 2 passenger rideshares will be the most expensive mode to run. If the value is adjusted lower however, it can be estimated that 2 passenger rideshare would cross paths with public transit at around 100 people/km^2.

Public transit and 5 passenger rideshare follow a closer relationship, especially at lower densities. They cross paths at 277 people/km^2, making this the critical density. As one would expect, at lower densities, the public transit is more expensive, and at higher ones the rideshare is more expensive. This makes sense, as at higher densities, there would be an enormous amount of rideshare vans needed to alleviate the demand.

5.3.4 Overall

As mentioned previously, to achieve sustainability, all three of the pillars must be treated equally so that one does not diminish another. Therefore, in order to find an overall critical density, the densities from each of the 3 pillars will be averaged.

Figure 5-12: Critical Density Results of Analytical Model

Number of Passengers		5	2
Critical Density (people/km^2)	Social	239	262
	Environmental	309	135
	Economical	277	*100**
	Average	**275**	**166**

* As stated in the previous section, this value is an estimated value through extrapolation

If the rideshares were not going to be efficient (i.e. Hold at least 5 passengers each) then there is no point trying to incorporate them into a city or a neighbourhood that has a density over 166 people/km^2. If the rideshare vehicles were able to be efficient and carry at least 5 passengers at a time, then they would be more sustainable to population densities under 275 people/km^2.

Since Innisfil has a population density of 139.2 people/km^2, whether the rideshare vehicle is full or not does not have an impact on the fact that public transit is not as sustainable. Any city over 275 people/km^2 however, such as Sault Ste. Marie (328.6 people/km^2) and Hamilton (480.0 people/km^2) would not succeed sustainably from using rideshare in lieu of public transit. That is not to say that there may not be a neighbourhood or area of town with a low enough density that it could benefit from rideshare bringing passengers to other more populated areas. Overall, however it seems that rideshare only works well in place of public transit, when it is in an area of low population density.

5.4 Sensitivity Analysis

Since this model involves a great deal of assumptions and variables, the sensitivity of some of these variables was examined to see just how changes in their values would influence the conclusions drawn. The next 3 subsections demonstrate the sensitivity of the social, environmental, and economical results when certain variables are changed to higher and lower values. These results were then graphed in order to be seen visually. All the sensitivity graphs can be seen in Appendix B Figures B1 through B3. A summary of how the critical density changed with the variables can be seen in the next few subsections.

The range of values that were used in the sensitivity can be seen below in Table 5-15:

Table 5-15: Range of Values used in Sensitivity

Variable	Low Value	Original Value	High Value
Income	$20,000	$57,000	$100,000
Bus Fare	$2.00	$2.86	$4.00
RH Base Fare	$3.00	$4.25	$5.50
RH Speed	20km/h	30km/h	40km/h
Bus Capacity	28 people	36 people	50 people
Buffer Zone	0.5 km	0.75 km	1.00 km
Percent of PT Commuters	-1%	--%	+1%
Bus Speed	20km/h	30km/h	40km/h
Bus Gas Mileage	2.76 MPG	3.26 MPG	3.76 MPG
RH Gas Mileage	20 MPG	22.04 MPG	24 MPG
Bus Manufacturing Emissions	12 gCO_2e/km	32 gCO_2e/km	52 gCO_2e/km
RH Manufacturing Emissions	12 gCO_2e/km	32 gCO_2e/km	52 gCO_2e/km
Lifetime of Vehicles	9 years	12 years	15 years
Hourly Wage	$15	$19.70	$25
Price of Fuel	50₵/L	100₵/L	150₵/L
Cost of Bus	$500,000	$650,000	$800,000
Cost of Van	$25,000	$31,000	$37,000
Bus Yearly Maintenance	$5,000	$7,400	$10,000
RH Yearly Maintenance	$450	$950	$1,450

5.4.1 Social

The figures that correspond with the following values in Table 5-16 and Table 5-17 can be found in Appendix B Figure B1. These tables show the variability of critical population densities for the Social pillar when some of the variables are changed.

Table 5-16: Sensitivity of Social Critical Population Densities (people/km^2) - 5 Passenger Ridehails

Variables	Low	Original	High
Income	N/A	239	333
Bus Fare	212	239	260
RH Base Fare	270	239	203
Ridehail Speed	213	239	250
Bus Capacity	226	239	320
Buffer Zone	314	239	238
% PT Commuters	312	239	242

For the 5 passenger ridehails, the critical densities range from as low as 203 people/km^2 to as high as 333 people/km^2. This is not including the result from the low-income scenario where the two modes did not cross at all. The highest value then corresponded to the scenario with the high-income. This shows that a person's income plays a significant role in choosing which mode of transport a person will choose. The variable with the lowest variation turned out to be the high end of the buffer zone. This means that changing the buffer zone from 750 meters to 1000 meters did almost nothing to move the critical density.

Table 5-17: Sensitivity of Social Critical Population Densities (people/km^2) - 2 Passenger Ridehails

Variables	Low	Original	High
Income	N/A	262	340
Bus Fare	241	262	287
RH Base Fare	291	262	238
Ridehail Speed	242	262	273
Bus Capacity	251	262	326
Buffer Zone	321	262	247
% PT Commuters	321	262	258

In terms of the 2 passenger ridehails, the critical densities ranged from 238 to 340 people/km^2. As with the 5 passenger scenarios, the low income simulation did not even cross with public transit, and the high income simulation provided the highest critical density. Once again proving that the most influential variable for the Social pillar of this model is a person income. The variable with the least amount of change for this set of scenarios was the high end of the percent of public transit commuters. This means that if the city or area being looked at for this model has an increase in the percent of people choosing to use this service, it will not change the critical density.

5.4.2 Environmental

The figures that correspond with the following values in Table 5-18 and Table 5-19 can be found in Appendix B Figure B2. These tables show the variability of critical population densities for the Environmental pillar when some of the variables are changed.

Table 5-18: Sensitivity of Environmental Critical Population Densities (people/km^2) - 5 Passenger Ridehails

Variables	Low	Original	High
Bus Capacity	N/A	305	312
Bus Speed	289	305	440
Ridehail Speed	297	305	297
Bus Gas Mileage	485	305	256
RH Gas Mileage	278	305	348
Bus Manufacturing Emissions	303	305	306
RH Manufacturing Emissions	339	305	288
Buffer Zone	419	305	350
% PT Commuters	410	305	373

For the 5 passenger ridehails, the critical densities range from as low as 256 people/km^2 to as high as 485 people/km^2. This is not including the result from the low-bus capacity scenario where the two modes did not cross at all. The highest value then corresponded to the scenario with the low bus gas mileage and the lowest value is related to the scenario with the high bus gas mileage. This shows the user that the bus gas mileage is a very important indicator of how well public transit will perform environmentally. The variable with the lowest variation turned out to be the bus manufacturing emissions, on both the high and low end. This shows that the manufacturing emissions are not vital to the overall environmental footprint of the public transit bus.

Table 5-19: Sensitivity of Environmental Critical Population Densities (people/km^2) - 2 Passenger Ridehails

Variables	Low	Original	High
Bus Capacity	135	135	135
Bus Speed	N/A	135	152
Ridehail Speed	139	135	139
Bus Gas Mileage	141	135	125
RH Gas Mileage	127	135	138
Bus Manufacturing Emissions	134	135	135
RH Manufacturing Emissions	138	135	125
Buffer Zone	165	135	N/A
% PT Commuters	180	135	N/A

In terms of the 2 passenger ridehails, the critical densities ranged from 125 to 180 people/km^2. There were a few scenarios that resulted in a N/A result as seen above where the two modes did not provide any critical densities. Interestingly the three N/A results' opposite end variables corresponded to the three highest results. In other words, bus speed, buffer zone, and percent of public transit commuters provided the most variable critical density values. The percent of public transit commuters was the most variable of the three making it the most influential value. For the social results, this value was the least influential. However, the least influential value for the environmental results goes to bus capacity closely followed by bus manufacturing emissions which was the same for the 5 passenger results. Having bus capacity as the least influential is intriguing because one would assume that by increasing or decreasing the capacity, the number of buses would change and this would cause more or less of an environmental footprint.

5.4.3 Economical

The figures that correspond with the following values in Table 5-20 and Table 5-21 can be found in Appendix B Figure B3. These tables show the variability of critical population densities for the Economical pillar when some of the variables are changed.

Table 5-20: Sensitivity of Economical Critical Population Densities (people/km^2) - 5 Passenger Ridehails

Variables	Low	Original	High
Bus Capacity	N/A	277	292
Lifetime of Vehicle	299	277	259
Hourly Wage	N/A	277	166
Price of Fuel	273	277	280
Cost of Bus	235	277	317
Cost of Van	286	277	270
Bus Yearly Maintenance	269	277	285
RH Yearly Maintenance	287	277	270
Bus Speed	N/A	277	303
Ridehail Speed	145	277	N/A
Buffer Zone	384	277	243
% PT Commuters	364	277	263

For the 5 passenger ridehails, the critical densities range from as low as 145 people/km^2 to as high as 384 people/km^2. With the exception of a few scenarios that resulted in a N/A result as seen above where the two modes did not provide any critical densities. The highest value corresponds to scenario with a low buffer zone, this could be because if the buffer zone is smaller, the system takes on less passengers. The ridehail system would have a larger decrease in their number of needed vehicles decreasing their costs more than public transit making the critical density higher. The variable with the lowest variation turned out to be the high end of the price of fuel followed closely by the low end of the price of fuel. This is interesting because in the sensitivity analysis the price of fuel varies from 50¢/L to 150¢/L, which is generally considered to be a large deviation. The reasoning for this could be that in the grand scheme of things, the price of fuel does not compare to the many other large costs included.

Table 5-21: Sensitivity of Economical Critical Population Densities (people/km^2) - 2 Passenger Ridehails

Variables	Low	Original	High
Bus Capacity	N/A	N/A	N/A
Lifetime of Vehicle	N/A	N/A	N/A
Hourly Wage	N/A	N/A	N/A
Price of Fuel	N/A	N/A	N/A
Cost of Bus	N/A	N/A	N/A
Cost of Van	N/A	N/A	N/A
Bus Yearly Maintenance	N/A	N/A	N/A
RH Yearly Maintenance	N/A	N/A	N/A
Bus Speed	N/A	N/A	N/A
Ridehail Speed	N/A	N/A	N/A
Buffer Zone	N/A	N/A	N/A
% PT Commuters	N/A	N/A	N/A

In terms of the 2 passenger ridehails, there were no critical densities because they never crossed the line with public transit in the results. The 2 passenger ridehail system was always far more expensive, especially at the higher population densities. This shows that if rideshare systems hope to be able to compete with public transit in terms of costs, they will have to make sure they are very efficient and hold more than 2 passengers at once.

5.5 Discussion

In this chapter, it was shown at which population density a city or neighbourhood would be better off with a system of public transit buses, or ridesourcing vans. The ideal population density of the area, or critical density, that was found was 275 people/km^2. In a denser population, public transportation buses are more sustainable and in a less dense population, ridesourcing would be the better option. This number of course is only if the rideshare vehicles utilize a capacity of 5 or more people per van. If they run with 2 passengers per van, the critical population density lowers to 166 people/km^2.

This model involves a great deal of unknown variables, assumptions, and averages. It is understood that this model does not fit every city or neighbourhood in the world, let alone Canada. This is why so many of the variables are able to be changed easily and the results shifted to match.

Even changing one variable can have a critical alteration to the results. The most notable example of this is a change in a person's income. This drastically influenced their likelihood to take public transit. Another example is the percent of public transit commuters; when adjusting it in the environmental results it was the most influential in terms of changing the critical population density; however, when adjusting it for the social results, it was actually the least influential. In terms of the economic results, surprisingly the price of gasoline did not have much of an effect if any on the results. It should be noted that the 2 passenger rideshares were always more expensive than public transit no matter how any of the variables were changed.

Overall, this model has many places for improvement, not only because it is new, but because the transportation world is always changing. This model can be used as a guide to help cities decide whether or not to implement ridesourcing into their public transit, and how to do so. It can help, by giving a starting point and letting the user know whether incorporating ridesourcing is something they should pursue, they should do more research on, or they should not implement at all.

5.5.1 Model Limitations

This model includes many limitations to its ability to accurately estimate a critical population density. It is not intricate enough to be able to include more complex factors that could affect the outcome, such as, wider economic impacts, overhead transit agencies or spatially-dependent dead-heading. All models require a certain amount of assumptions and it is important to note that these assumptions limit the scope of the application for the model. Many of the values used in this model were also either assumed or averaged, which has a high impact on the general uncertainty of the final results. Overall, this means that the final number produced from this model should be taken with a certain amount of precaution. What works for some areas may not work the same for others and no amount of modelling would ever be able to perfectly predict the results.

Additionally, there could be an argument for every one of the variables that they should be different somehow from the ones that were chosen. An example of this is the decision to assume that the buses in this scenario run on gasoline and not diesel. Furthermore, there is acknowledgement of the fact that the rate chosen for value of time for this thesis may be too high. Every person values their time differently and it depends on what is going on in their life, or what they enjoy doing. This is why the sensitivity analysis was done on many of these variables though because with this particular one, we can see how the critical population density changes when the value of time is adjusted higher or lower.

Chapter 6

Conclusions and Future Research

6.1 Results and Interpretation

At the beginning of this thesis, it was questioned whether or not ridesourcing should be welcomed or if it should be banned? As it turns out based on the survey being conducted, the answer was much more complex than just one or the other. This question was further broken down into 3 questions, and each of these questions was explored and their answers explained on the basis of the survey results.

The first question asked: What type of relationship do ridesourcing programs and public transit agencies in Canadian cities currently have? The survey in Chapter 3 demonstrated that in Canada, there is generally no relationship at all. Most of the public transit agencies had no comments or experiences to add when it came to ridesourcing companies in their area. But the cities that chose to have a relationship, at least the ones in Canada, had a positive relationship if they looked at ridesourcing as a solution to some of the gaps in their public transit, rather than looking at them like competition. In terms of the survey responses, many cities did not answer several of the questions, which led to an assumption in their unfamiliarity of the benefits of working with ridesourcing companies. The transit agencies/cities themselves hold the influence to having a fruitful or non-existent relationship with these companies.

An open line of communication between the public transit agencies and rideshare companies can go a very long way to creating a positive relationship as opposed to a non-existent one. As a non-existent relationship means competition, and an open one could mean filling in the gaps and making public transit more appealing.

The next question asked: Under what conditions do ridesourcing companies and public transit agencies working together create positive benefits? From looking at a number of case studies in Chapter 4, it appears that the cities need only try to work together with the rideshare companies to create a beneficial relationship for both parties. There are an endless number of ways to work together with the rideshare companies; it could be a small partnership, a large one, or somewhere in between. It could also be in only one part of a public transit system (such as just for a train station), or in a few specific neighbourhoods, or in the whole system. It could also be certain times of day, or of the week, or of the year. There are an unlimited number of possibilities.

It is also seen that most ridesourcing companies are open to a partnership as they probably already have one going on in a different city. Most of these partnerships end up creating a surplus in service for both transit and rideshare. Meaning that a combination of both modes is really beneficial to transporting a person to their destination. Otherwise, people would choose to have their own vehicle. But with a fruitful partnership, people could rid themselves of personal vehicles resulting in higher public transit ridership, less costs for the consumer and less vehicles on the road.

The case studies were interpreted largely the same way as the survey results in that, as long as both sides are willing to work with each other, then it can be successful for both.

Working together can produce much better results in terms of ridership numbers, public perception, and revenue.

The final question asked: Why is density the critical variable in determining whether ridesourcing or public transit is a better option, and at what density is one more beneficial than the other when considering society, the environment, and the economy? Density is the determining factor because that is how neighbourhoods, or cities, can be differentiated from each other. It is this that determines how many passengers will be needing a ride and in turn how many vehicles will be needed. Any other factor does not describe the needs of one area better. The density at which both ridesourcing and public transit are equally as appealing is 275 people/km^2 in terms of the pillars of sustainability. This means that at higher densities, public transit is more sustainable and lower than 275 people/km^2, rideshare is more sustainable.

The interpretation of these results is that the density of a city or neighbourhood should be taken into account when deciding what kind of public transportation mode to service it with. When analyzing a lower density city, the concept of offering ridesourcing as a form of public transit should be considered. Any denser than the critical density and the city should consider a collaboration for underserved neighbourhoods.

In the end it was found that ridesourcing companies should not be banned, but they should not just be ignored either. The solution is to work with them to create a customized hybrid system. These results, and any future work on this topic, will hopefully serve to help cities and transit agencies make informed decisions on integrating with ridesourcing companies. The outcome of this thesis will hopefully help cities form a better relationship with these companies.

6.2 Conclusions

In conclusion, incorporating ridesourcing companies into a city's transit system is more complicated than just saying yes or no. Not only do the city's individual characteristics have to play a role in the decision, but the city must also be open to having a productive relationship with the ridesourcing company. This thesis asked transit agencies questions, studied past success stories and created a model for testing scenarios; and in the end found that it is possible to accept the proliferation of rideshare vehicles and have it not wreak havoc on a city's sustainability, if done correctly.

A partnership is essential to success, and it is up to the city/transit agency and the rideshare company to create a prolific relationship, which will end up beneficial to both sides. The partnership should also be tailored to the area's characteristics. If the population density is low (less than 275 people/km^2) then a system with heavy reliance on rideshare vehicles would probably be best suited. Likewise, if the population density is high (greater than 275 people/km^2), then a system that only relies on rideshare for outlying areas or off-peak times only would be best. Of course, there are many other options as well, that would suit individual areas, each city would have to discover their own.

In the history of transportation, ridesourcing is a new concept with very little in terms of predicting the future effects. Therefore, it is important to have studies done of the information that is available. Since the introduction of ridesourcing, people have taken issue with it especially when it comes to the impact on public transit services. These impacts being: lower ridership and in turn lower revenue on buses, and more cars on the road creating congestion. This thesis shows however that if done correctly these impacts can be lowered, or abolished altogether. But this is only if done correctly in terms of a fruitful and positive relationship.

6.3 Limits and Future Work

The survey in Chapter 3 is limited by the number of cities that were surveyed. Only a small number of cities took the time to respond to the survey, and even less filled it out to completion. This left the thesis with a small sample size to work with, which makes it hard to apply the results. Another limit would be the questions that were asked. If given more time, a second survey would have been created, omitting questions from the first and adding more relevant questions, once realizing any shortcomings of the first.

If future work were to be done on this topic, a revised survey would be made and sent out to a larger number of cities. As well, the surveys would be followed up with personalized questions from the answers given. This was not done originally, as this survey served as more of an introductory stage to further parts of this thesis, as opposed to the center of the research it had started out as. Additionally, the rideshare companies could also be surveyed to find out if they have ever tried to create a relationship with the city they are in, and been denied or if they are not open to collaboration.

The main limit of the case studies in Chapter 4, is the fact that if the pilots fail or are scrapped, there is no mention of it anywhere. Even if it is just one aspect of the partnership that fails, it disappears from mention and there is no explanation. It is hard to know why something has stopped working if no one clarifies it. It would be helpful for other cities or companies to learn from the flaws of other pilot projects or attempts at a partnership. It is understandable however, that no city or company is going to elaborate online or share in an interview that their partnership was a disaster or a failure. One of the case studies just abruptly stopped despite boasting about their immense success at the beginning. A reason as to why would be able to help other cities hoping to do the same thing.

Future work for the case studies would include continuing to follow the success/failure or growth of these case studies if at all possible. As well as monitoring other programs that these ones inspire. As well, it would be wise to dig deeper by trying to talk personally with those involved in running the partnerships and ask if they will learn from their mistakes and create another, better partnership.

The limits of Chapter 5 are mainly due to the fact that the scenario is fully hypothetical and a lot of the values used are averages, or they are assumed. As well, not everyone's perception of the modes are the same. For example, if someone had a horrible experience on a bus or in a rideshare, they may not care that it is economically better for them to take one over the other, their personal feelings would dictate their decision. More parameters could also be used to fine tune the results. There are an endless number of factors that could demonstrate the results, and only a small finite number of variables were used.

Given these limits there is a great deal of room for future work on this model. One direction for future work includes further replicating the scenarios to show 3 and 4 passenger rideshares. This would show how efficient the rideshares would have to be in certain neighbourhoods or cities in order to incorporate them sustainably. More variables in general could be included in order to make the results more specific. In addition, perhaps real data could be used to fuel the model such as an actual neighbourhood in a real city.

One of the many places to improve this model would be to not keep the three pillars separate. In other words, the results from one pillar, may have ripple effects on the others. For example, if the bus is not socially the choice, then the bus ridership may decrease, which would result in a decrease in percent of public transit commuters, which would in turn effect environmental and then economical outcomes. Many variables would have a domino effect, which are not shown in this model.

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Appendix A

Survey and Results

A.1 Survey Questions

Rideshare Programs and Their Effect on Public Transportation in Your Area

Page 1: Introduction (a confirmation of information)

This page is just to confirm information that I have collected about your area. If at any point during this survey you feel you don't have the answers for a lot of the questions, you can skip the questions and keep them blank. But if you know the contact information of someone else who may be better able to answer these questions, please reply to my email and let me know (michelle.thompson14@gmail.com).

1. Please write your name and the name of the city for which you are answering:

2. Attached to the email you were sent, is a spreadsheet showing information about your area and the other areas being studied. Please check to make sure the information about your area is correct. If it is, please check off "yes" and continue to the next page. If not, please check off "no" and state what about it is incorrect. For this information we are looking at the area that your current public transit network covers.

a) Yes
b) No
c) Explain if incorrect

Page 2: Information About Your Existing Public Transportation

This page asks you questions about your existing public transportation (PT) system so that I may compare it to similar cities.

3. What types of services does your PT system provide? (Please check all that apply)

a) Bus
b) BRT
c) Subway
d) LRT
e) Train
f) Paratransit
g) Dial-a-ride
h) Other
    - Please Specify

4. How many bus lines does your area have? (if none please enter "0")

5. How many BRT lines does your area have? (if none please enter "0")

6. How many subway lines does your area have? (if none please enter "0")

7. How many LRT lines does your area have? (if none please enter "0")

8. How many train lines does your area have? (if none please enter "0")

9. Are there any other lines not mentioned above that are included in your PT system?

Page 3: Information About Rideshare Programs in Your Area

This page asks you questions about Rideshare programs in your area so that I can get a sense of their effect on your public transit network.

10. To your knowledge, when did your area begin to host rideshare programs, officially and/or non-officially? (please enter a month and year if possible)

- Official date:
- Non-official date:

11. Please check all of the rideshare programs that your area contains:

a) Uber
b) Lyft

c) Rideco
d) Poparide
e) Amigo Express
f) Sidecar
g) Postmates
h) Shipt
i) Hoho ride
j) Kangaride
k) TappCar
l) InstaRyde
m) Facedrive
n) Taxify
o) Other
    - Please specify

12. Can you describe a change in ridership levels for your public transportation network after rideshare programs entered your area? (Please rate each from decreased - decreased somewhat - stayed the same – increased somewhat – increased – not applicable)

- Bus Ridership
- BRT Ridership
- Subway Ridership
- LRT Ridership
- Train Ridership
- Other (please explain)

13. If data is readily available, could you please upload a file containing ridership data for the years your area had rideshare programs and at least 5 years before it arrived? For example, if ridershare was introduced in 2010 could you please send me the statistics for 2005-2017? Please send this by email to michelle.thompson14@gmail.com. (If these statistics are not available please answer the next question)

14. If the above statistics are not available: Since rideshare was introduced to your area has public transit ridership

a. Decreased
b. Increased
c. Stayed the same
d. It increased, but we have another reason
e. It decreased, but we have another reason

- Explain how much it increase, or decreased by, or the other reasons why it changed.

15. On a scale of -10 to 10, please describe how your rideshare program has effected your public transit? -10 being extremely negative and 10 being extremely positive and 0 being that they haven't had any impact at all.

16. Public transit aside, do you think the rideshare has had a negative, positive, or neutral effect on your region? On a scale of -10 to 10, -10 being extremely negative and +10 being extremely positive and 0 being that they haven't had any impact at all.

17. On a scale of -10 to 10, do you (your team/department) have a positive (10) or negative (-10) perception of rideshare programs?

18. Have you taken any steps to increase ridership on your public transit?

a. Yes
b. No
c. Other (please specify)

19. If you answered yes to the previous question, what steps did you take to increase ridership, and did it work?

20. Have you had any other noticeable changes (positive or negative) to your public transit or your area in general since rideshare has been introduced?

21. Have you ever noticed unauthorized rideshare programs in your area?

a. Yes
b. No
c. Other (please specify)

22. If you answered yes to the previous question, have you had any problems with unauthorized rideshare programs on a scale of -10 to 10 (-10 being a constant negative problem, 10 being a constant positive presence and 0 being a basically unnoticeable existence.

23. If you have had issues with unauthorized rideshare programs or if you have had any positive outcomes from dealing with them, can you please elaborate on what happened below?

Page 4:

24. Have you perceived any challenges or issues with rideshare programs in your area?

a. Yes
b. No

- Please explain the nature of these challenges, if any.

25. If you have had perceived challenges, have you taken steps to address these challenges/issues?

a. Yes
b. No
c. We did not have perceived challenges

- If yes, explain how you addressed the challenges, if no, explain why you have not addressed them.

26. Have you implemented a surcharge to rideshare programs in your area?

a. Yes
b. No
c. Thought about it but didn’t
d. Tried it and took it back
e. Other (please specify)

27. Have you ever banned a rideshare company? For any of the below answers, please elaborate in the comment box that follows (explain what was done, and/or if it worked to solve the issue, etc.)

a. Yes
b. Yes, but we took it back
c. No
d. No, but we have thought about it

- Please explain

28. Have you limited the ability of rideshare programs to run? In terms of time, space, both etc? Check all that apply:

a. We limited the areas they could run
b. We limited the times they could run
c. We limited the number of drivers per rideshare company
d. We limited the number of hours they could run
e. We limited something else (explain in the comment field below)
f. We didn’t limit them at all
g. We would consider limiting them
h. We don’t have enough information to make this decision

- Other (please specify)

29. When you address/converse with the rideshare programs, do you consider public transit?

a. Yes, it’s a constant issue
b. Yes, sometimes
c. No, we’ve never had a problem
d. No, but we should be

- Other (please specify)

30. Have you changed or added any policies that can affect rideshare programs?

a. Yes
b. No

- Please explain and cite any policy numbers

31. Have you tried any other method? If yes, please explain what kind of methods:

a. Yes
b. No

- If yes, please explain what kind of methods:

Page 5: Conclusion:

I would like to thank you for your time and attention for helping me complete my research.

32. Have you done any previous research on this topic? Please email me with this research if possible (michelle.thompson14@gmail.com)

33. If you have any other comments to add that would be helpful to me please leave them here or feel free to email me directly at michelle.thompson14@gmail.com.

34. Some of the answers to this survey may prompt follow up questions. Do I have your permission to email you in follow up of the survey if needed?

a. Yes
b. No
c. Other (please specify)

A.2 Survey Responses

Unanswered questions are not included below:

A.2.1 Edmonton

1. Edmonton, AB

2. Yes

3. Bus, LRT, and Paratransit

4. 184

5. 0

6. 0

7. 2

8. 0

9. ETS has a large number of special trips designated for schools in the region. These operate during the school calendar and are synchronized to the start and end times of the individual schools.

10. Official date: N/A

Non-official date: N/A

11. Uber, Other (Pogo Car Share)

12. Bus Ridership – Not applicable

BRT Ridership – Not applicable

Subway Ridership – Not applicable

LRT Ridership – Not applicable

Train Ridership – Not applicable

Other (please explain): There has been no data collected to support changes in ridership pre or post rideshare implementation in Edmonton.

13. Edmonton's bus ridership data collection is based on sampling from its Automatic Passenger Counting system (APC). Edmonton does not use APC to report ridership in the region since APC's only represent about 25% of its fleet. Annulalized ridership is estimated on a complex fare model and those data are available on the city's web site, www.edmonton.ca.

14. It decreased, but we have another reason. Explain how much it increase, or decreased by, or the other reasons why it changed: Ridership has decreased due to tother economic factors in the region.

15. 0

16. 0

17. 0

18. Yes

19. ETS is in the process of a complete redesign of its route network effective mid-2020. Rideshare programs are not formally included in this process, but may be for first/last km where the network has gaps. Currently under study.

20. Unknown. There have been no comprehensive analyses of how ideshare services have affected ETS.

21. No

24. No

25. We did not have perceived challenges

26. No

27. Yes, but we took it back. Please explain: Insurance requirements were changed.

28. Other (please specify): Lyft is not yet authorized to service this region.

29. Other (please specify): N/A

32. There may be others in the City of Edmonton that have more information and resources regarding your topic. My expertise is mostly in the public transit sector.

34. Yes

A.2.2 Region of Waterloo

1. Planner with Grand River Transit – Region of Waterloo

2. Yes. Explain if incorrect: I assume these figures are accurate -- I'll leave it to you to ensure you've transcribed your source data correctly. The "% change 06-16" doesn't align for the GDP/capita section with the years included (2001, 2009, and 2013).

3. Bus, Paratransit, Other (LRT begins in a few months' time!)

4. 61

5. 0

6. 0

7. 1

8. 0

9. We have three "GRT Flex" services currently operating -- these are not conventional fixed-route services. They include an on-demand bus, subsidized taxi service, and ridesharing partnership. We also have paratransit services.

I'll also use this space to add caveats for the questions above:

- Q4: 61 (counting permutations -- i.e. 7A, 7B, etc.-- as individual routes)

- Q5: 0 on dedicated rights-of-way - GRT does have 5 limited-stop express routes and another coming online next fall

- Q7: the LRT line is constructed but service doesn't begin until spring 2019

- Q8: GRT operates 0 - Waterloo Region has a passenger rail corridor on which VIA and GO operate

10. Official date: 2016 (by-law came into effect)

Non-official date: 2015

11. Uber, Lyft, and Rideco

12. Bus Ridership – Decreased somewhat

BRT Ridership – Not applicable

Subway Ridership – Not applicable

LRT Ridership – Not applicable

Train Ridership – Not applicable

Other (please explain) - A confounding variable for decreasing ridership over the period from 2014-2017 was the significant construction taking place in the Region at the time (for LRT) -- this was the primary cause of decreasing ridership.

13. See email for generalized ridership stats for these years -- if you need route-specific information please let me know (specify the routes you'd like, etc.)

14. Decreased. Explain how much it increase, or decreased by, or the other reasons why it changed: Not possible to say that decrease is tied to ridesharing with the data we have available -- you might think about getting ridership data from Uber, Lyft, and RideCo for the area as well.

16. 0

17. 5

18. Yes

19. Not as simple as taking action to boost ridership in response to ridesharing -- we have, however, witnessed ridership growth over the past year. Service improvements and network redesign efforts have been made in advance of LRT launching.

20. No major impacts; however, extensive analysis has not taken place.

21. No

22. -10

23. N/A

24. Yes. Please explain the nature of these challenges, if any: The challenge is to avoid working in isolation; ridesharing has immense potential to help us solve the last-mile problem, but this requires cooperation and integration. Forging these new relationships is something we're trying to do (e.g. with our 903 Flex pilot project).

25. Yes. If yes, explain how you addressed the challenges, if no, explain why you have not addressed them: We're in the midst of a pilot partnership in a low-density, low-demand part of the region to bring people to conventional transit stops using ridersharing vehicles. We're attempting to demonstrate that the challenge of integration is tractable.

26. Other (please specify): In lieu of providing accessible services and under the auxiliary taxi by-law, ridesharing companies are obligated to pay the Region ~$0.18 per trip into an accessibility fund. This money is used to finance paratransit services.

27. No

28. We limited something else (explain in the comment field below): This is not something that's at the sole discretion of the transit authority -- please review the Region's auxiliary taxi by-law (which regulates ridesharing providers). There are no restrictions on time or geography, but they are required under this regulation to be insured and follow basic reporting, safety, and financial rules

29. Other (please specify): We view these services as complementary rather than competitive with transit.

30. Yes. Please explain and cite any policy numbers: You can read the regulating by-law here: https://www.regionofwaterloo.ca/en/resources/Bylaws/Bylaw-16-044.PDF We also have a partnership with RideCo for a pilot project, as advised under our business plan to focus on alternative methods of transit service delivery in low-demand parts of the Region.

31. No

32. No, but please review this 2016 APTA report re: synergies between transit and ridesharing: https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf

Also keep an eye out for pending research from the Conference Board of Canada re: the interactions of shared forms of mobility with transit systems.

33. Not at the moment -- please feel free to get in touch if anything else comes up, or if you require clarification.

34. Yes

A.2.3 City of Toronto

1. Toronto

2. Yes

3. Bus, Subway, Paratransit, Other (streetcar)

4. Over 140

5. 0

6. 4

7. 0

8. 0

9. 10 streetcar routes

13.

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2017/December_11/Reports/10_Ridership_Growth_Strategy_2018_2022_Preliminary_Report.pdf

17. 3

18. Yes

19.

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2018/May_8/Reports/7_Capacity_Improvements_on_Bus_and_Subway_Services.pdf

24. Yes. Please explain the nature of these challenges, if any: stopping to pick up and unload in TTC stop areas. Delaying TTC buses and streetcars.

34. Yes

A.2.4 Hamilton

1. City of Hamilton

2. Yes

3. Bus, Train, Paratransit, and Dial-a-ride

4. 39

8. 1

A.2.5 Guelph

2. No. Explain if incorrect: I’m afraid I cant confirm or deny the numbers.

3. Bus, and Paratransit

4. 25

5. 0

6. 0

7. 0

8. 0

9. No

10. Official date: none

Non-official date: none

11. Other (please specify): None

12. Bus Ridership – Not applicable

BRT Ridership – Not applicable

Subway Ridership – Not applicable

LRT Ridership – Not applicable

Train Ridership – Not applicable

13. n/a

14. Explain how much it increase, or decreased by, or the other reasons why it changed: n/a – no rideshare

15. 0

16. 0

17. 0

18. No

21. No

24. Please explain the nature of these challenges, if any: n/a

25. We did not have perceived challenges

26. No

27. No

28. We don't have enough information to make this decision

29. No, but we should be

30. No

31. No

A.2.6 Metro Vancouver

1. TransLink – Metro Vancouver Transportation Authority

3. Bus, BRT, Subway, Train, Paratransit, Dial-a-ride, Other (Seabus waterway transit, Skytrain elevated rail that sometimes acts as a subway (Which is why I've indicated subway))

4. 218

5. 3

6. 3

7. 0

8. 1

9. 1 Seabus line. Please consider "subway lines" answer as our elevated heavy rapid transit system.

10. Official date: 2012 but Uber was shut down quickly after by the government

Non-official date: 2016

11. Poparide, Other (Kater, Spare Rides, and RipeRides. RipeRides operated briefly and is on hold for now, Spare rides operated for a while but then collapse their busines model. Kater is a rideshare like service. Note that Companies like Poparide are a carpooling app and not a rideshare.)

12. Bus Ridership – Not applicable

BRT Ridership – Not applicable

Subway Ridership – Not applicable

LRT Ridership – Not applicable

Train Ridership – Not applicable

13. All of our ridership data is available through our Transit Service Performance Review. https://www.translink.ca/Plans-and-Projects/Managing-the-Transit-Network/Transit-Service-Performance-Review.aspx

14. Explain how much it increase, or decreased by, or the other reasons why it changed: TransLink's ridership hasn't been affected by ridesharing as ridesharing has not been introduced to our service area in any meaningful/ large deployment. TransLink's ridership has been growing for the past few years at record-setting levels.

17. 10

18. Yes

19. This question requires a qualifier. TransLink deploys a wide variety of ridership development programs and policies.

21. Yes

24. Yes. Please explain the nature of these challenges, if any: Please see an email I will send.

25. Yes. If yes, explain how you addressed the challenges, if no, explain why you have not addressed them: We lobbied the provincial government to consider our concerns when crafting new ridesharing legislation.

26. No

27. No. Please explain: Banning ridesharing companies is not under our authority.

28. Other: These controls are not under our authority.

29. Yes, sometimes

30. No

31. No

34. Yes

A.2.7 London

1. City of London (first respondent)

2. Yes

3. Bus, Paratransit

1. City of London (second respondent)

2. Yes

3. Bus, Paratransit

4. 0

5. 0

6. 0

7. 0

8. 0

9. None. VIA rail is adjacent, not used for public transit within London however.

32. No sorry, I have not.

34. Yes

A.2.8 Philadelphia

1. City of Philadelphia

2. No, as discussed, no spreadsheet

3. Bus, BRT, Subway, LRT, Train, Paratransit, Other (trolleybus, interurban rail)

4. 121

5. 1

6. 3

7. 9

8. 13

9. The bus lines include trolleybus. We have an interurban line (i.e. between LRT and heavy rail). I've interpreted "train lines" to mean our Regional Rail system

10. Official date: 2016

Non-official date: 2012

11. Uber, and Lyft

12. Bus Ridership – Decreased

BRT Ridership – Not applicable

Subway Ridership – Stayed the same

LRT Ridership – Decreased

Train Ridership – Stayed the same

Other (please explain) – Peak bus ridership is flat, but off-peak is way down

13. Are you talking about rideshare ridership or transit ridership? The former we don't have while the later can be had at the National Transit Database.

14. Decreased

15. -7

16. -7

17. -7

18. Yes

19. Increasing enforcement on existing bus-only lanes, working on implementing new dedicated bus lanes and BRT, issued a transit-first transportation plan, working on a bus network redesign, and committed to do a city transit plan.

20. A lot slower due to congestion.

21. Yes

22. -5

23. There is very little ability to regulate the operators leading to unsafe vehicles and much illegal activity.

24. Yes. Please explain the nature of these challenges, if any: We are responsible for their negative impacts on the transportation system but by state law have little ability to control of levers of influence.

25. Yes. If yes, explain how you addressed the challenges, if no, explain why you have not addressed them: Increased enforcement of illegal loading and other traffic violations.

26. No

27. No. Please explain: We don’t have that ability.

28. Other (please specify): We don’t have that ability. We can only enforce general traffic laws.

29. Yes, it’s a constant issue

30. No. Please explain and cite any policy numbers: As discussed above, this is out of municipal control.

31. If yes, please explain what kind of methods: As discussed above, this is out of municipal control.

34. Yes

A.3 City Statistics Spreadsheet

Figure A - 1: City Statistics for Survey

Region (Census Metropolitan Area)		Kitchener-Waterloo	Guelph	Hamilton	London	Toronto	Ottawa	Niagara Region	Montreal	Kingston	Edmonton	Calgary
Land Area km2		1,368.92	593.51	1,371.89	2,662.40	5,905.84	3,639.31	1,854.23	4,604.26	1,938.81	9,438.86	5,110.21
Population	2006	478,121	133,698	692,911	457,720	5,113,149	846,802	427,421	3,635,556	152,358	1,034,945	1,079,310
	2011	507,096	141,097	721,053	474,786	5,583,064	936,908	431,346	3,934,078	159,561	1,159,869	1,214,839
	2016	535,154	151,984	747,545	494,069	5,928,040	991,726	447,888	4,098,927	161,175	1,321,426	1,392,609
	Average	506,790.33	142,259.67	720,503.00	475,525.00	5,541,417.67	925,145.33	435,551.67	3,889,520.33	157,698.00	1,172,080.00	1,228,919.33
	% Change 06-16	57,033.00	18,286.00	54,634.00	36,349.00	814,891.00	144,924.00	20,467.00	463,371.00	8,817.00	286,481.00	313,299.00
Population Density per km2	2006	349.30	335.60	505.10	171.70	866.10	258.70	230.50	853.60	79.90	109.90	211.30
	2011	370.40	237.70	525.60	178.10	945.40	280.40	232.60	898.10	82.30	123.00	237.90
	2016	390.90	256.10	544.90	185.60	1,003.80	272.50	241.50	890.20	83.10	140.00	272.50
	Average	370.20	276.47	525.20	178.47	938.43	270.53	234.87	880.63	81.77	124.30	240.57
	% Change 06-16	41.60	-79.50	39.80	13.90	137.70	13.80	11.00	36.60	3.20	30.10	61.20
GDP per capita	2001	$ 35,258.00	$ 41,143.00	$ 30,570.00	$ 32,105.00	$ 41,397.00	$ 41,643.00	$ 27,761.00	$ 32,709.00	$ 28,303.00	$ 40,355.00	$ 44,438.00
	2009	$ 43,989.00	$ 44,217.00	$ 36,801.00	$ 40,905.00	$ 48,532.00	$ 55,506.00	$ 32,956.00	$ 41,505.00	$ 40,968.00	$ 59,941.00	$ 52,681.00
	2013	$ 49,508.00	$ 54,959.00			$ 55,316.00	$ 54,753.00				$ 76,355.00	$ 74,263.00
	Average	$ 42,918.33	$ 46,773.00	$ 33,685.50	$ 36,505.00	$ 48,415.00	$ 50,634.00	$ 30,358.50	$ 37,107.00	$ 34,635.50	$ 58,883.67	$ 57,127.33
	% Change 06-16	14,250.00	13,816.00			13,919.00	13,110.00				36,000.00	29,825.00
Median Age	2006	36.40	36.80	39.90	38.60	37.50	38.40	41.90	39.50	40.70	36.40	35.70
	2011	37.70	38.70	41.20	40.00	38.60	39.20	44.10	39.70	41.40	36.50	36.40
	2016	38.50	39.40	42.10	40.70	39.40	40.20	45.70	40.30	43.20	36.30	36.60
	Average	37.53	38.30	41.07	39.77	38.50	39.27	43.90	39.83	41.77	36.40	36.23
	% Change 06-16	2.10	2.60	2.20	2.10	1.90	1.80	3.80	0.80	2.50	-0.10	0.90
Average age	2016	39.10	39.80	41.60	40.90	39.70	40..20	43.80	40.60	42.50	37.80	37.40
Average Income	2005	38,381.00	38,601.00	38,299.00	36,720.00	40,704.00	43,441.00	33,170.00	34,196.00	36,386.00	39,901.00	48,878.00
	2010	42,303.00	43,648.00	42,543.00	39,361.00	44,462.00	49,657.00	37,085.00	38,281.00	41,118.00	49,266.00	56,600.00
	2015	46,906.00	49,494.00	48,455.00	44,220.00	50,479.00	54,379.00	41,858.00	44,742.00	47,125.00	60,781.00	69,177.00
	Average	42,530.00	43,914.33	43,099.00	40,100.33	45,215.00	49,159.00	37,371.00	39,073.00	41,543.00	49,982.67	58,218.33
	% Change 05-15	8,525.00	10,893.00	10,156.00	7,500.00	9,775.00	10,938.00	8,688.00	10,546.00	10,739.00	20,880.00	20,299.00

* Unknown information left blank

Appendix B

Analytical Model Inputs, Calculations, and Results

B.1 Social Sensitivity

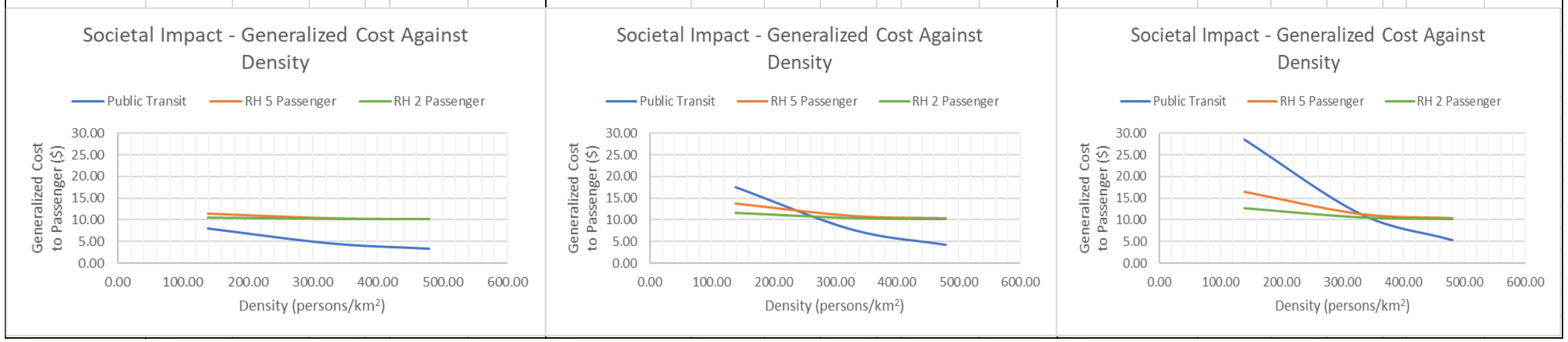
Figure B - 1: Analytical Model Sensitivity of the Social Pillar

Social Impact - Based Upon Variables

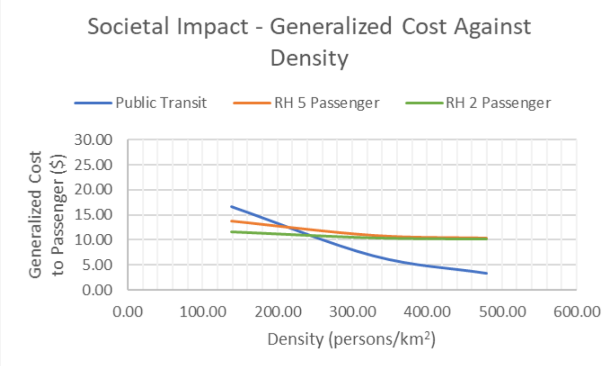
Low End					
Income	**$ 20,000.00**				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**N/A**	**N/A**
Public Transit GC	3.35	4.57	7.99	persons/km^2	
Ridehail GC 5psgr	10.17	10.36	11.38		
Ridehail GC 2psgr	10.13	10.21	10.61		

Original Variable					
$ 57,000.00					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**239**	**262**
Public Transit GC	4.25	7.73	17.48	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		

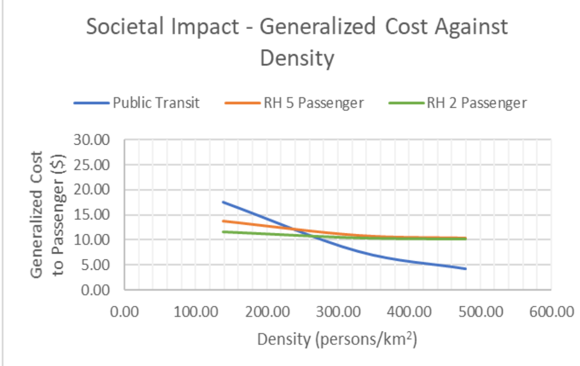
High End					
$ 100,000.00					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**333**	**340**
Public Transit GC	5.30	11.41	28.50	persons/km^2	
Ridehail GC 5psgr	10.44	11.41	16.51		
Ridehail GC 2psgr	10.24	10.63	12.66		



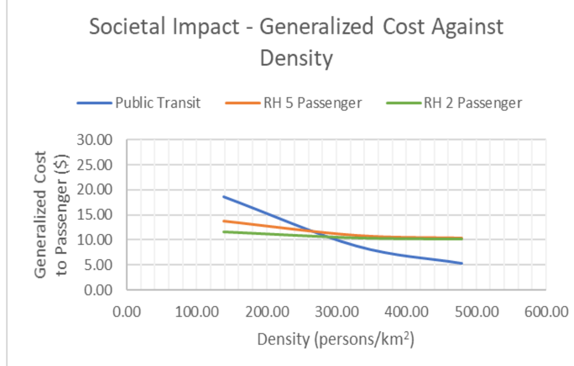
Bus Fare	$ 2.00				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**212**	**241**
Public Transit GC	3.39	6.87	16.62	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



	$ 2.86				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**239**	**262**
Public Transit GC	4.25	7.73	17.48	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		

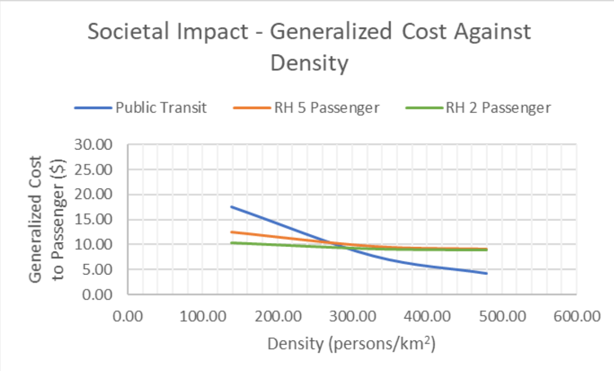


	$ 4.00				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**260**	**287**
Public Transit GC	5.39	8.87	18.62	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



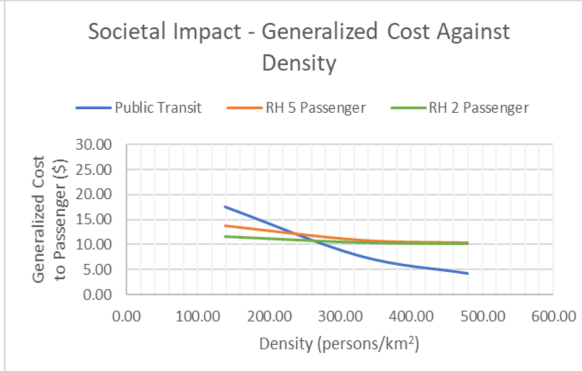
RH Base Fare	$ 3.00			
	Hamilton	SSM	Innisfil	
	City 1	City 2	City 3	
Density	480.00	328.60	139.20	
Public Transit GC	4.25	7.73	17.48	
Ridehail GC 5psgr	9.04	9.60	12.50	
Ridehail GC 2psgr	8.93	9.15	10.31	

Critical Density	
RH 5psgr	RH 2psgr
270	**291**
persons/km^2	



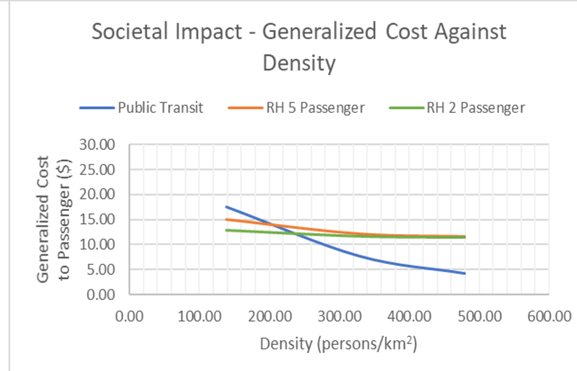
$ 4.25			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	10.29	10.85	13.75
Ridehail GC 2psgr	10.18	10.40	11.56

Critical Density	
RH 5psgr	RH 2psgr
239	**262**
persons/km^2	



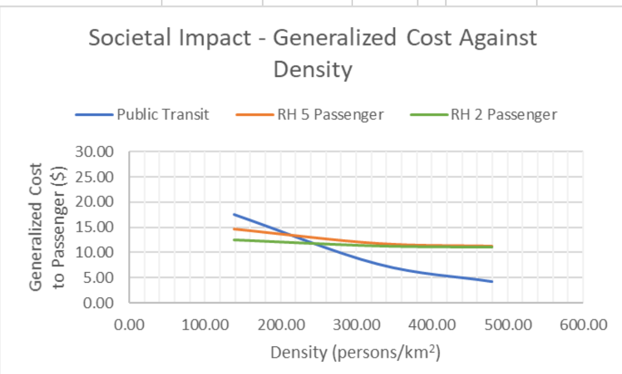
$ 5.50			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	11.54	12.10	15.00
Ridehail GC 2psgr	11.43	11.65	12.81

Critical Density	
RH 5psgr	RH 2psgr
203	**238**
persons/km^2	



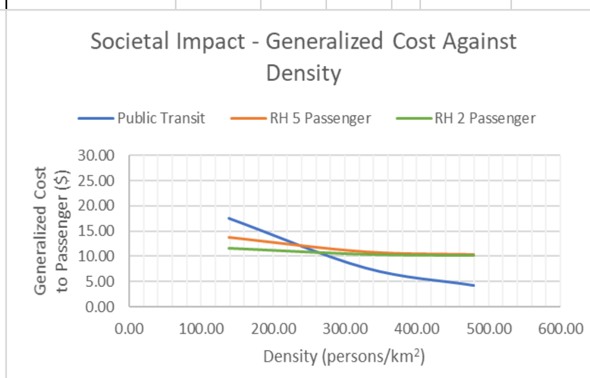
RideHail Speed	20km/h		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	11.19	11.75	14.65
Ridehail GC 2psgr	11.08	11.30	12.46

Critical Density	
RH 5psgr	RH 2psgr
213	**242**
persons/km^2	



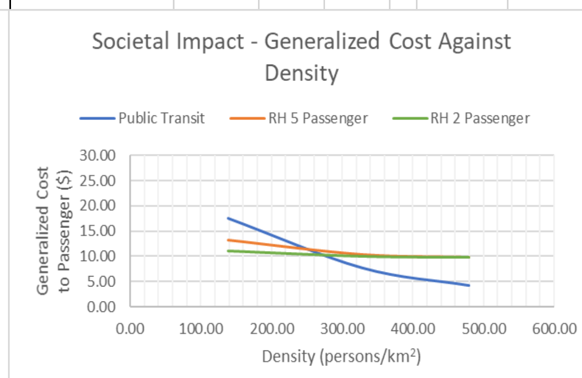
30 km/h			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	10.29	10.85	13.75
Ridehail GC 2psgr	10.18	10.40	11.56

Critical Density	
RH 5psgr	RH 2psgr
239	**262**
persons/km^2	

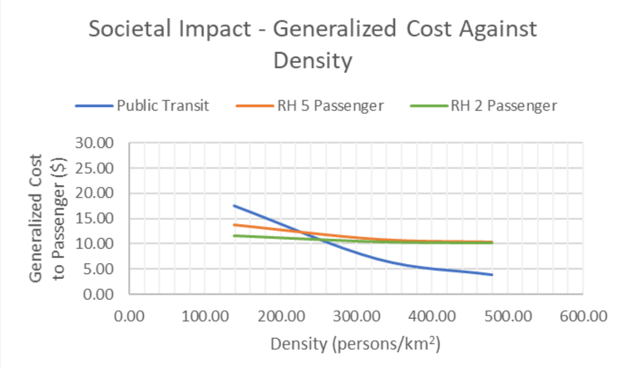


40 km/h			
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	9.84	10.40	13.30
Ridehail GC 2psgr	9.73	9.95	11.11

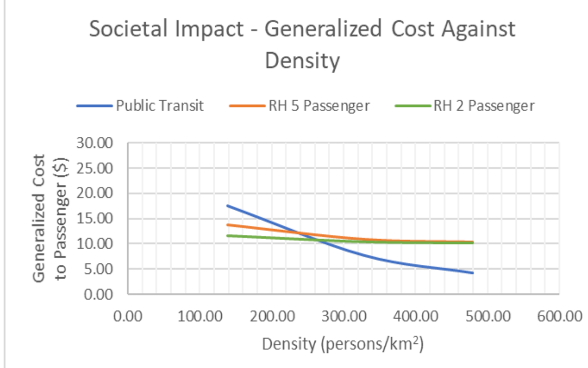
Critical Density	
RH 5psgr	RH 2psgr
250	**273**
persons/km^2	



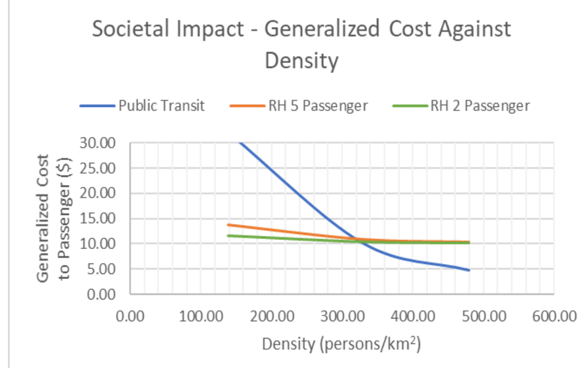
Bus Capacity	28 people				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**226**	**251**
Public Transit GC	3.94	7.04	17.48	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



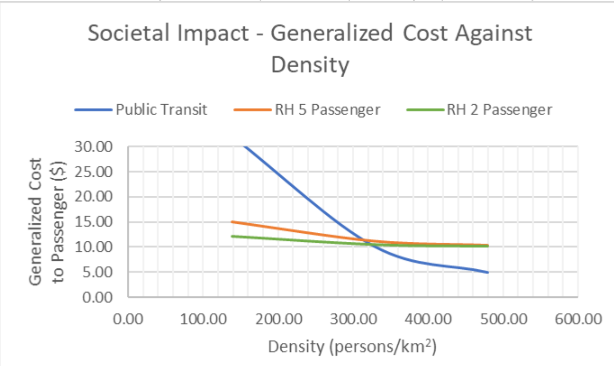
36 people					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**239**	**262**
Public Transit GC	4.25	7.73	17.48	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



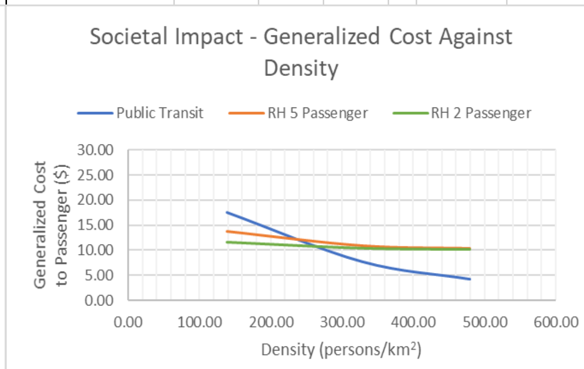
50 people					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**320**	**326**
Public Transit GC	4.69	10.17	32.09	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



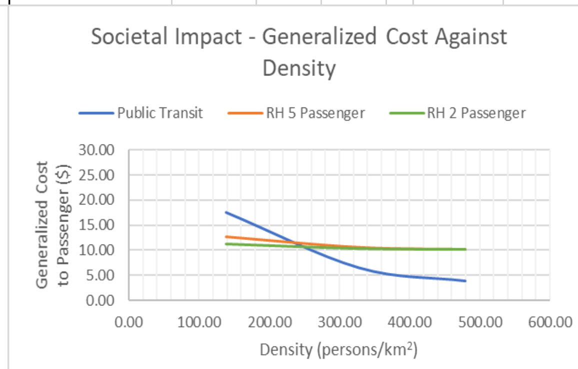
Buffer Zone	0.5 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**314**	**321**
Public Transit GC	4.95	10.17	32.09	persons/km^2	
Ridehail GC 5psgr	10.39	11.22	14.97		
Ridehail GC 2psgr	10.22	10.55	12.19		



0.75 km					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**239**	**262**
Public Transit GC	4.25	7.73	17.48	persons/km^2	
Ridehail GC 5psgr	10.29	10.85	13.75		
Ridehail GC 2psgr	10.18	10.40	11.56		



1.0 km					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**238**	**247**
Public Transit GC	3.90	6.51	17.48	persons/km^2	
Ridehail GC 5psgr	10.24	10.66	12.76		
Ridehail GC 2psgr	10.16	10.33	11.18		



Percent of PT Commuters

-1%

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit GC	4.40	10.17	32.09
Ridehail GC 5psgr	10.31	11.11	17.41
Ridehail GC 2psgr	10.19	10.51	13.02

Critical Density	
RH 5psgr	RH 2psgr
312	**321**
persons/km^2	

0%

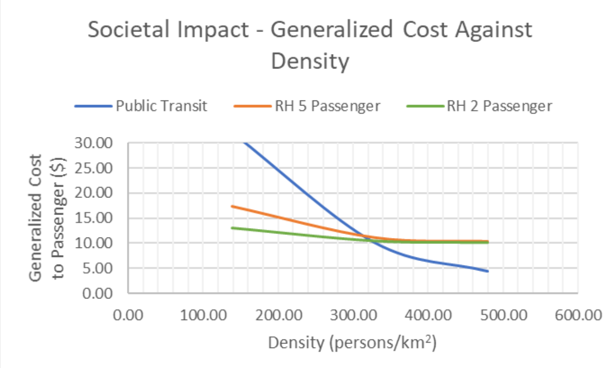
	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit GC	4.25	7.73	17.48
Ridehail GC 5psgr	10.29	10.85	13.75
Ridehail GC 2psgr	10.18	10.40	11.56

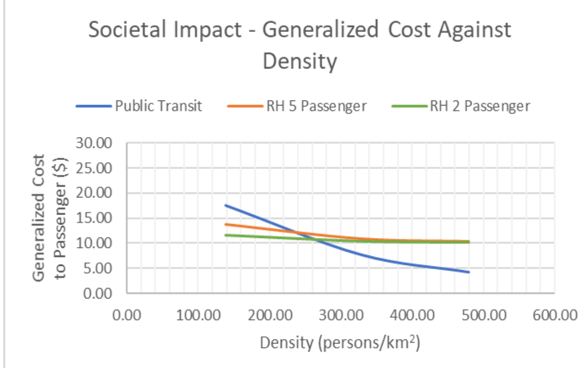
Critical Density	
RH 5psgr	RH 2psgr
239	**262**
persons/km^2	

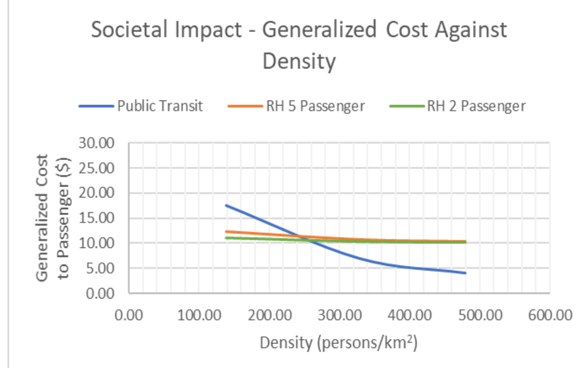
+1%

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit GC	4.13	7.04	17.48
Ridehail GC 5psgr	10.28	10.70	12.35
Ridehail GC 2psgr	10.17	10.34	11.04

Critical Density	
RH 5psgr	RH 2psgr
242	**258**
persons/km^2	







B.2 Environmental Sensitivity

Figure B - 2: Analytical Model Sensitivity of the Environmental Pillar

Environmental Impact - Based Upon Variables

Low End

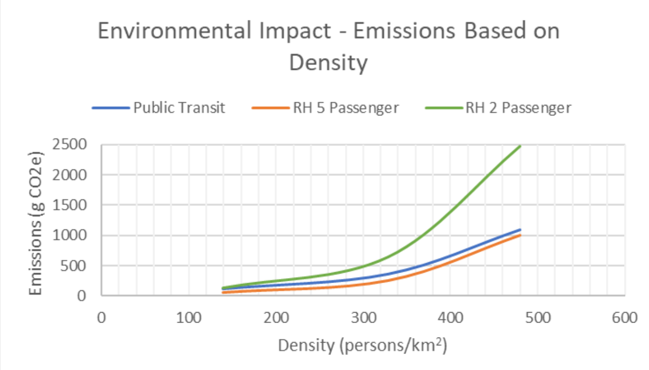
Bus Capacity	28			Critical Density	
	Hamilton	SSM	Innisfil	RH 5psgr	RH 2psgr
	City 1	City 2	City 3	**N/A**	**135**
Density	480.00	328.60	139.20	persons/km^2	
Public Transit Emissions	1092.66	364.22	121.41		
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

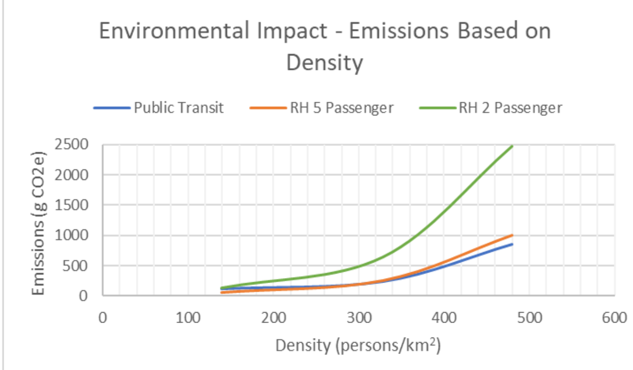
Original Variable

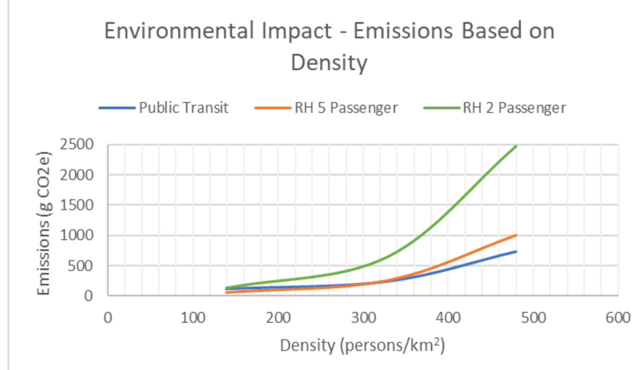
Bus Capacity	36			Critical Density	
	Hamilton	SSM	Innisfil	RH 5psgr	RH 2psgr
	City 1	City 2	City 3	**305**	**135**
Density	480.00	328.60	139.20	persons/km^2	
Public Transit Emissions	849.84	242.81	121.41		
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

High End

Bus Capacity	50			Critical Density	
	Hamilton	SSM	Innisfil	RH 5psgr	RH 2psgr
	City 1	City 2	City 3	**312**	**135**
Density	480.00	328.60	139.20	persons/km^2	
Public Transit Emissions	728.44	242.81	121.41		
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		







Bus Speed

20 km/h

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	890.31	242.81	80.94
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

Critical Density	
RH 5psgr	RH 2psgr
289	**N/A**
persons/km^2	

30 km/h

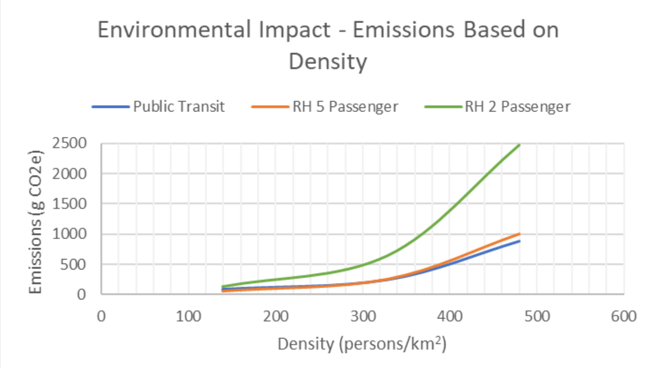
	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

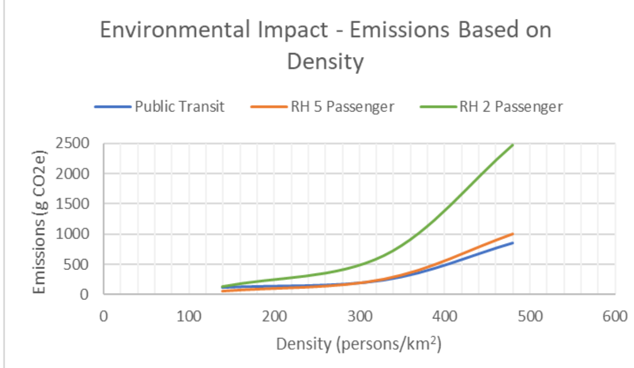
Critical Density	
RH 5psgr	RH 2psgr
305	**135**
persons/km^2	

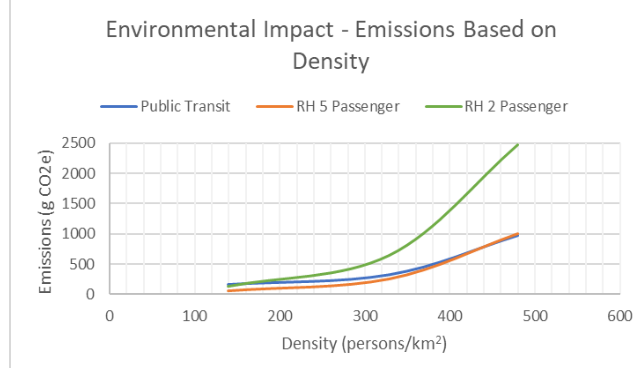
40 km/h

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	971.25	323.75	161.87
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

Critical Density	
RH 5psgr	RH 2psgr
440	**152**
persons/km^2	







Ridehail Speed

20 km/h

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	992.74	261.25	52.25
RH Emissions (2psgr)	2468.79	640.06	130.62

Critical Density	
RH 5psgr	RH 2psgr
297	**139**
persons/km^2	

30 km/h

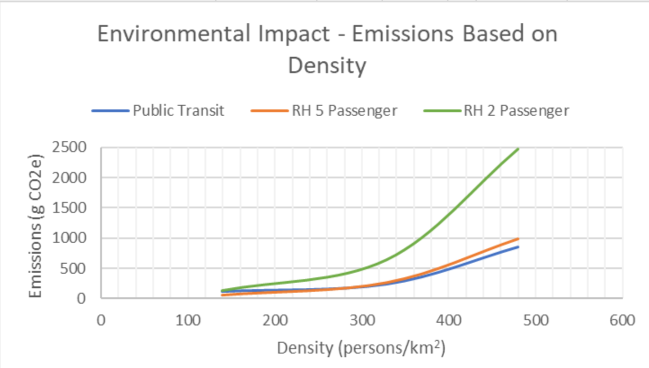
	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

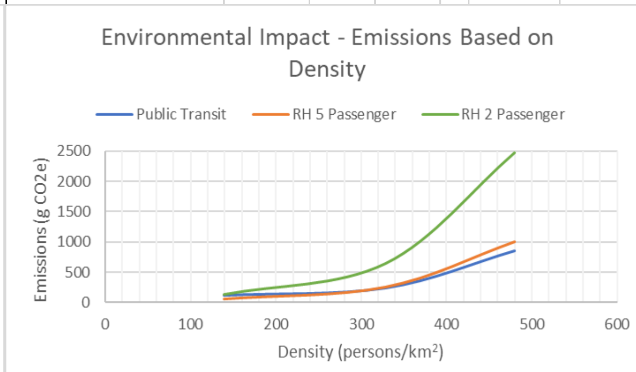
Critical Density	
RH 5psgr	RH 2psgr
305	**135**
persons/km^2	

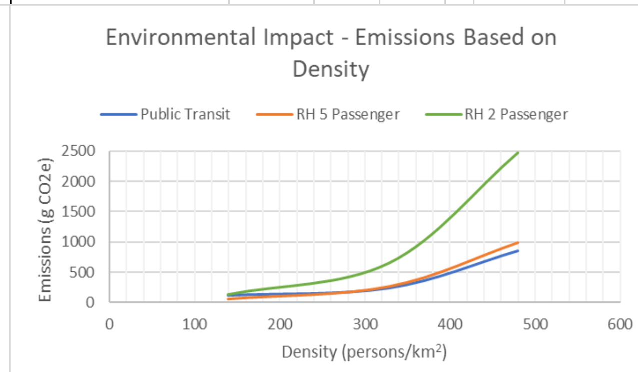
40 km/h

	Hamilton City 1	SSM City 2	Innisfil City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	992.74	261.25	52.25
RH Emissions (2psgr)	2481.85	653.12	130.62

Critical Density	
RH 5psgr	RH 2psgr
297	**139**
persons/km^2	



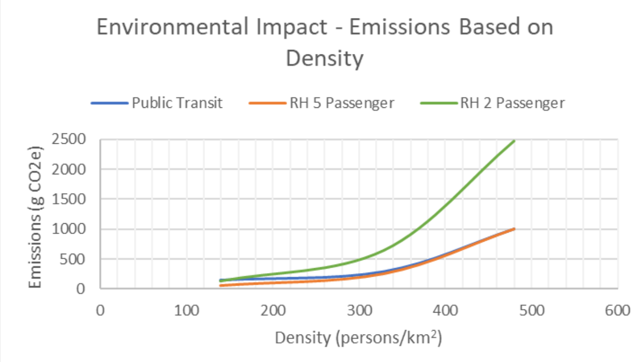


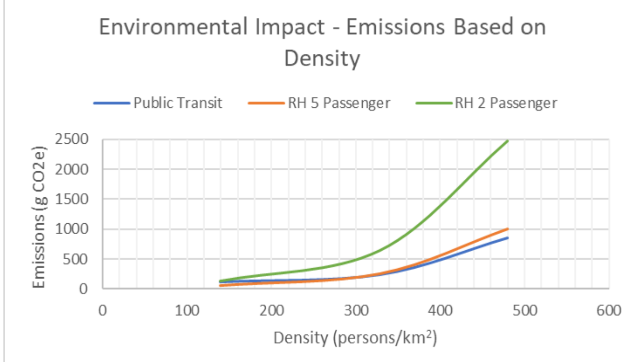


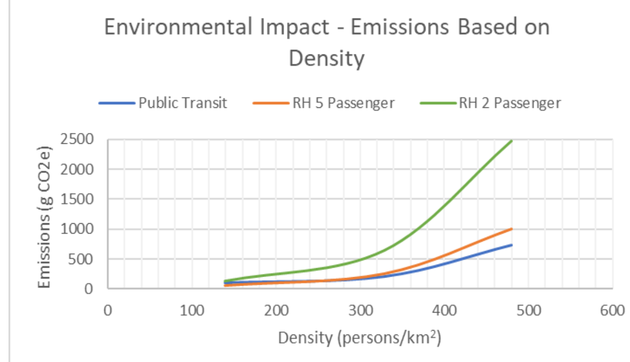
Bus Gas Mileage	2.76 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**485**	**141**
Public Transit Emissions	1001.37	286.10	143.05	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

	3.26 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**305**	**135**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

	3.76 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**256**	**125**
Public Transit Emissions	738.62	211.03	105.52	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		



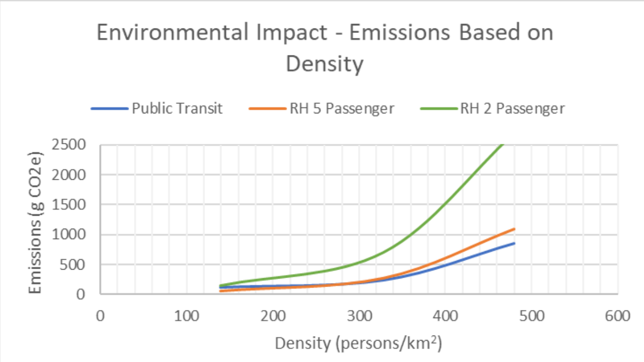


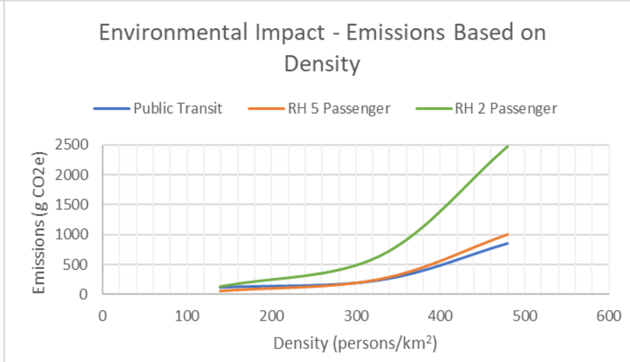


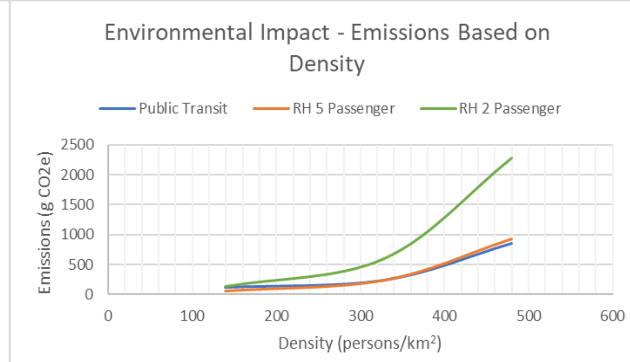
RH Gas Mileage	20 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**278**	**127**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	1091.21	278.15	64.19		
RH Emissions (2psgr)	2695.93	706.08	149.77		

	22.04 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**305**	**135**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

	24 MPG				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**348**	**138**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	925.66	235.95	54.45		
RH Emissions (2psgr)	2286.93	598.96	127.05		







Bus Manufacturing Emissions — **12 g CO2e/km**

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	841.44	240.41	120.21
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

Critical Density	
RH 5psgr	RH 2psgr
303	**134**
persons/km^2	

32 g CO2e/km

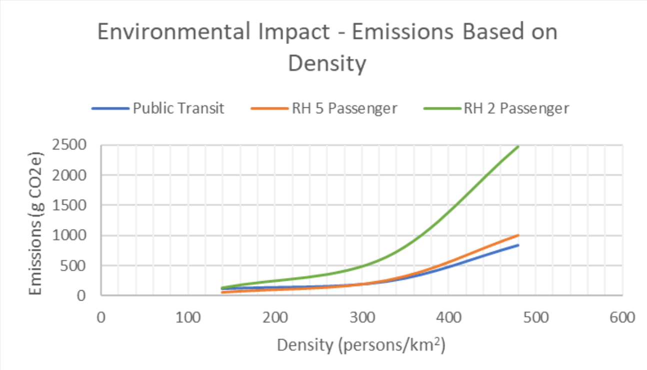
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

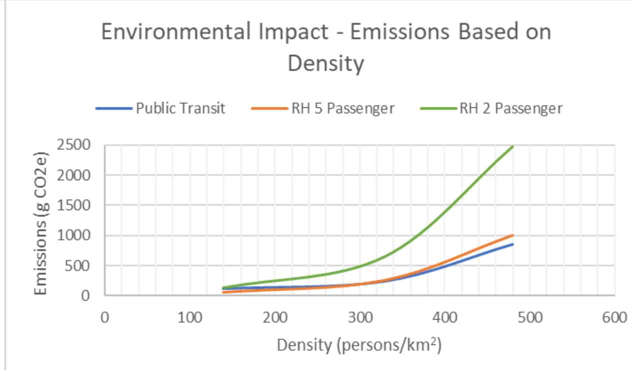
Critical Density	
RH 5psgr	RH 2psgr
305	**135**
persons/km^2	

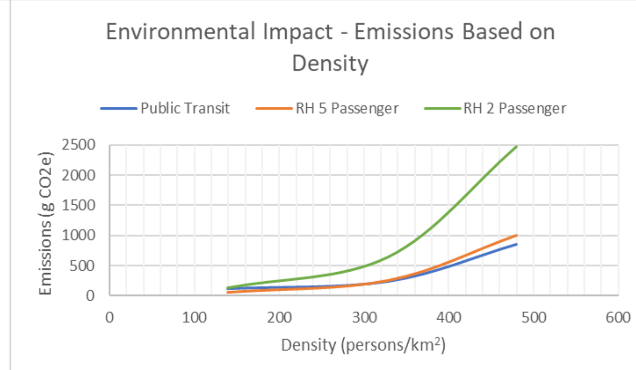
52 g CO2e/km

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	858.24	245.21	122.61
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

Critical Density	
RH 5psgr	RH 2psgr
306	**135**
persons/km^2	







RH Manufacturing Emissions — **12 g CO2e/km**

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	938.07	239.12	55.18
RH Emissions (2psgr)	2317.59	606.99	128.75

Critical Density	
RH 5psgr	RH 2psgr
339	**138**
persons/km^2	

32 g CO2e/km

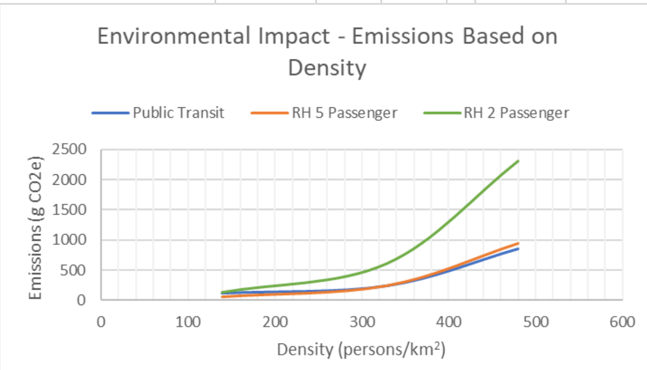
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	999.27	254.72	58.78
RH Emissions (2psgr)	2468.79	646.59	137.15

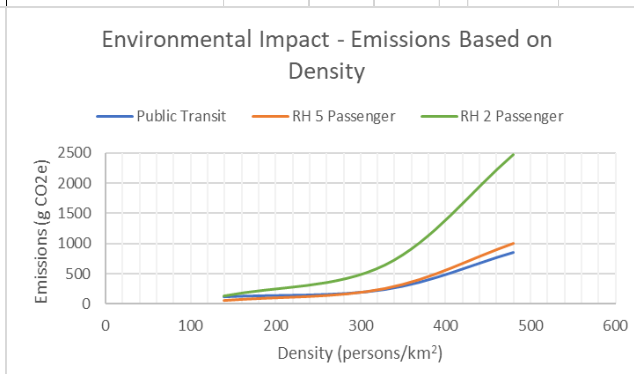
Critical Density	
RH 5psgr	RH 2psgr
305	**135**
persons/km^2	

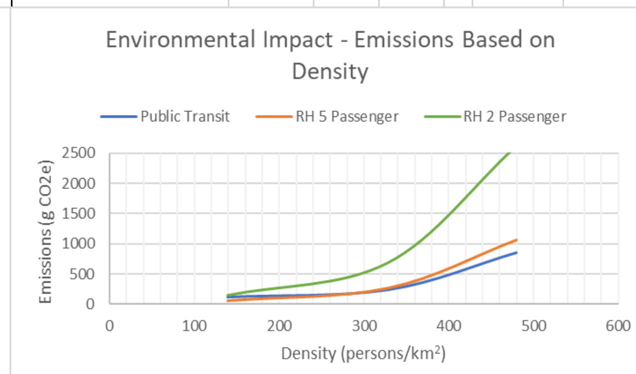
52 g CO2e/km

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Emissions	849.84	242.81	121.41
RH Emissions (5psgr)	1060.47	270.32	62.38
RH Emissions (2psgr)	2619.99	686.19	145.55

Critical Density	
RH 5psgr	RH 2psgr
288	**125**
persons/km^2	



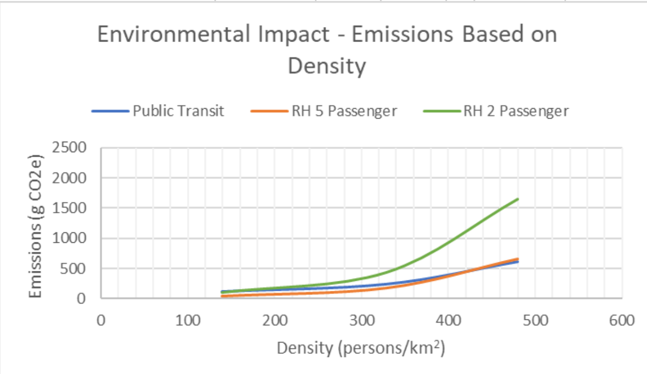


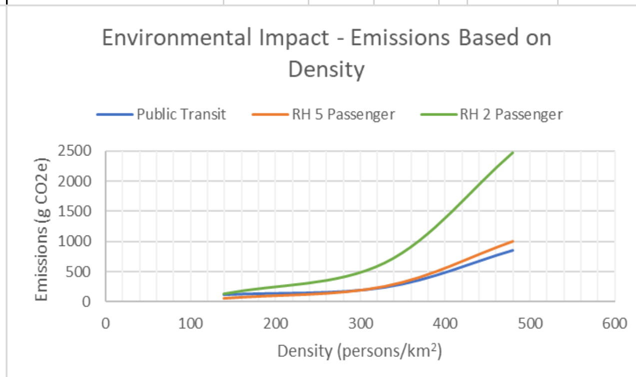


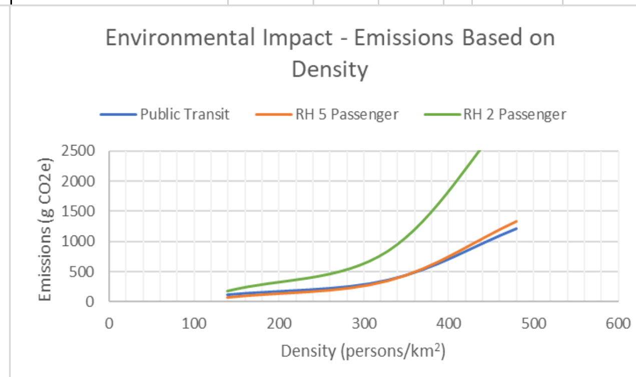
Buffer Zone	0.5 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**419**	**165**
Public Transit Emissions	607.03	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	666.18	176.34	39.19		
RH Emissions (2psgr)	1645.86	431.06	97.97		

	0.75 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**305**	**135**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

	1.0 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**350**	**N/A**
Public Transit Emissions	1214.06	364.22	121.41	persons/km^2	
RH Emissions (5psgr)	1332.36	352.68	78.37		
RH Emissions (2psgr)	3291.71	842.52	176.34		



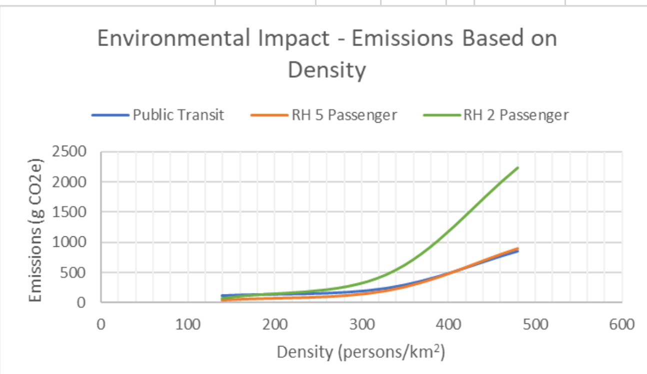


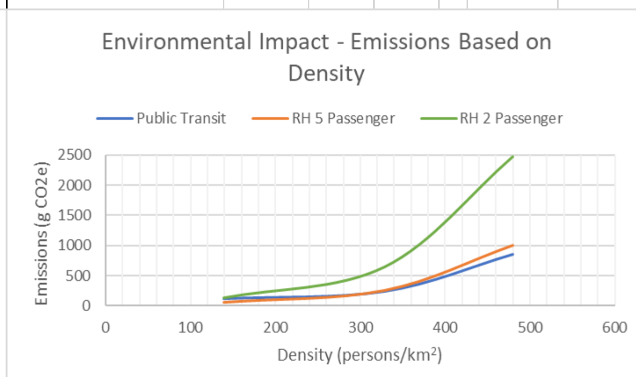


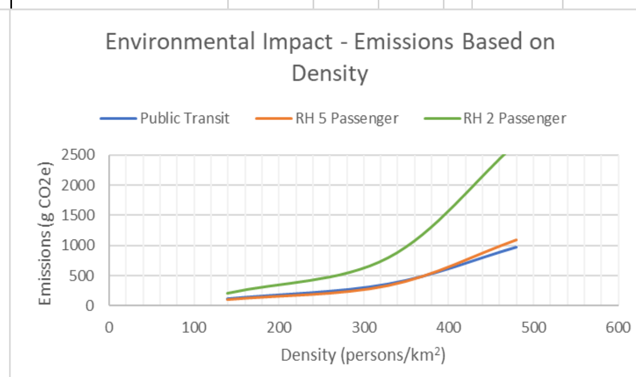
Percent of PT Commuters	-1%				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**410**	**180**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	901.30	195.94	39.19		
RH Emissions (2psgr)	2233.66	470.24	78.37		

	0%				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**305**	**135**
Public Transit Emissions	849.84	242.81	121.41	persons/km^2	
RH Emissions (5psgr)	999.27	254.72	58.78		
RH Emissions (2psgr)	2468.79	646.59	137.15		

	+1%				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**373**	**N/A**
Public Transit Emissions	971.25	364.22	121.41	persons/km^2	
RH Emissions (5psgr)	1097.24	333.09	97.97		
RH Emissions (2psgr)	2703.91	803.34	215.53		







B.3 Economical Sensitivity

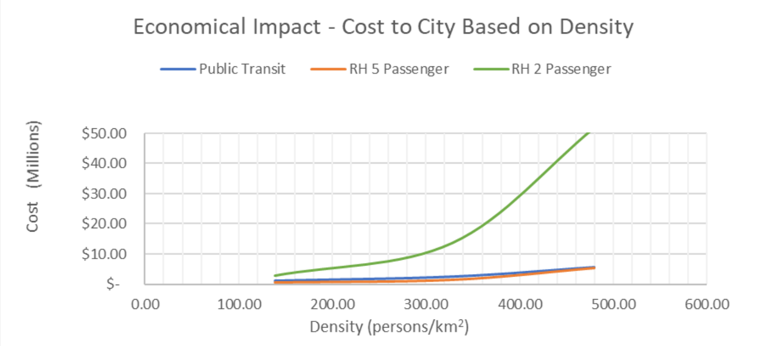
Figure B - 3: Analytical Model Sensitivity of the Economical Pillar

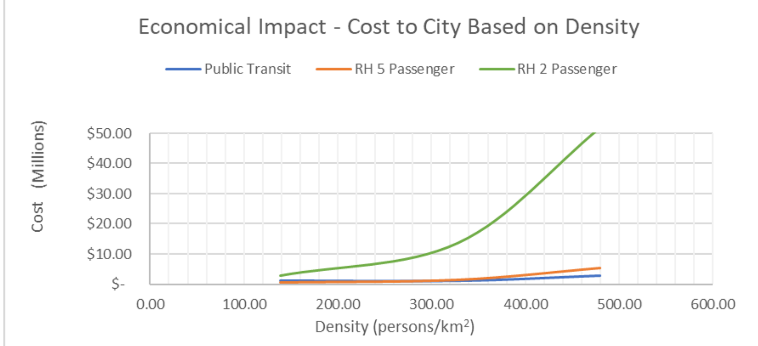
Economical Impact - Based Upon Variables

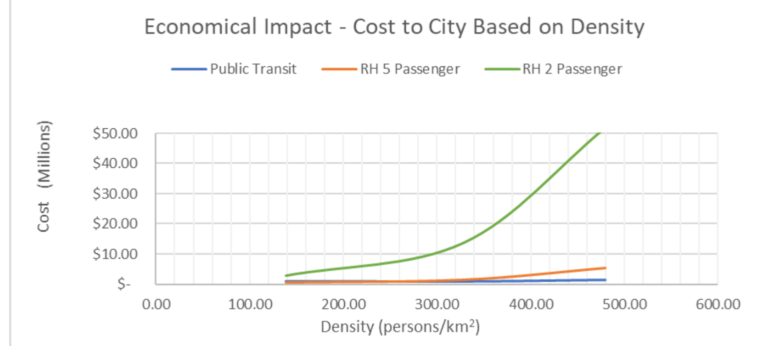
Low End					
Bus Capacity	**28**				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**N/A**	**N/A**
Public Transit Cost	$ 5,666,020.69	$ 2,475,337.38	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

Original Variable					
Bus Capacity	**36**				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

High End					
Bus Capacity	**50**				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**292**	**N/A**
Public Transit Cost	$ 1,303,836.09	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		





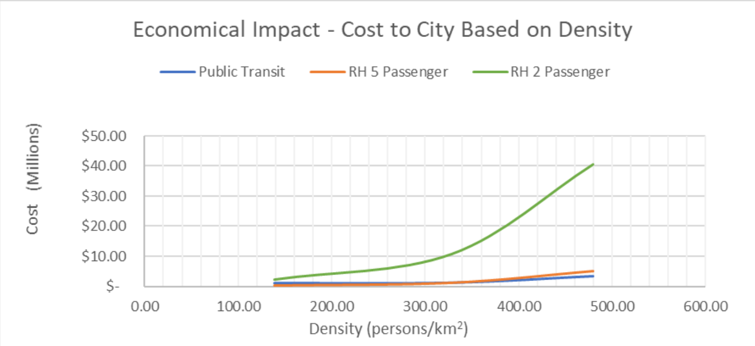


Lifetime of Vehicle

9 years

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 3,374,571.69	$ 1,133,839.77	$ 969,845.20
RH Cost (5psgr)	$ 5,034,600.52	$ 1,295,301.14	$ 417,123.46
RH Cost (2psgr)	$ 40,465,568.34	$ 10,743,559.23	$ 2,306,775.08

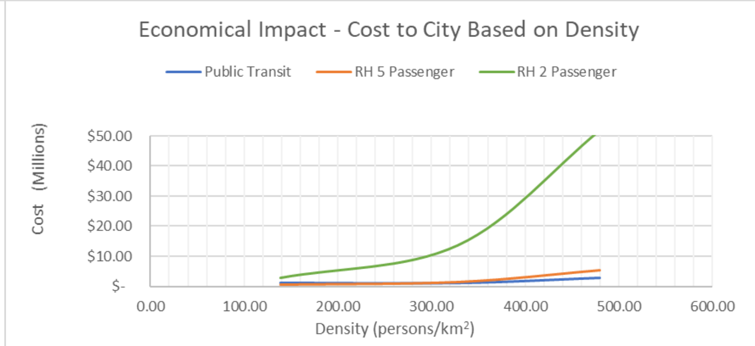
Critical Density	
RH 5psgr	RH 2psgr
299	**N/A**
persons/km^2	



12 years

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

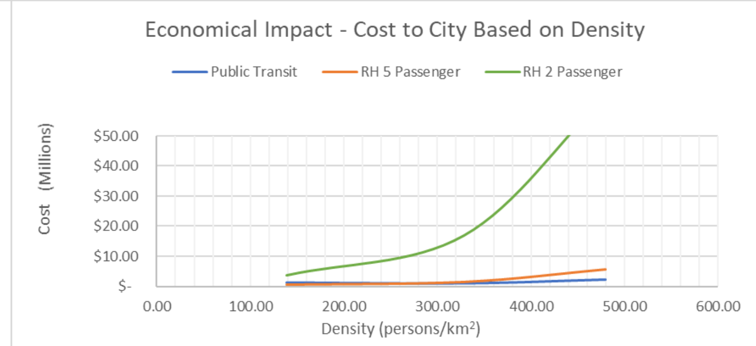
Critical Density	
RH 5psgr	RH 2psgr
277	**N/A**
persons/km^2	



15 years

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,141,223.54	$ 908,711.91	$ 1,159,475.25
RH Cost (5psgr)	$ 5,748,796.07	$ 1,486,329.68	$ 549,862.83
RH Cost (2psgr)	$ 63,250,409.11	$ 16,820,093.16	$ 3,616,615.53

Critical Density	
RH 5psgr	RH 2psgr
259	**N/A**
persons/km^2	

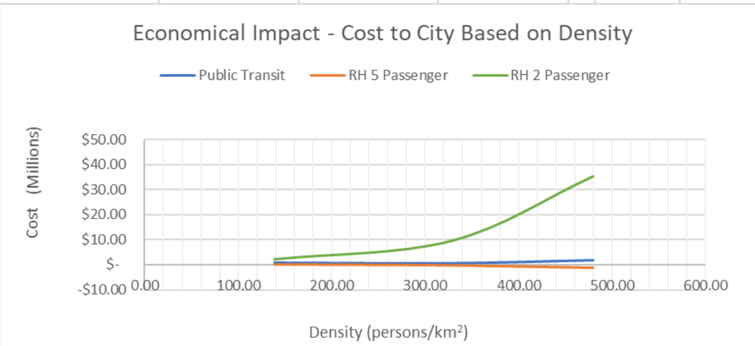


Hourly Wage

$15

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	1834065.62	757323.84	932684.22
RH Cost (5psgr)	-1339077.71	-324872.59	87565.15
RH Cost (2psgr)	35229012.73	9426618.19	2037863.30

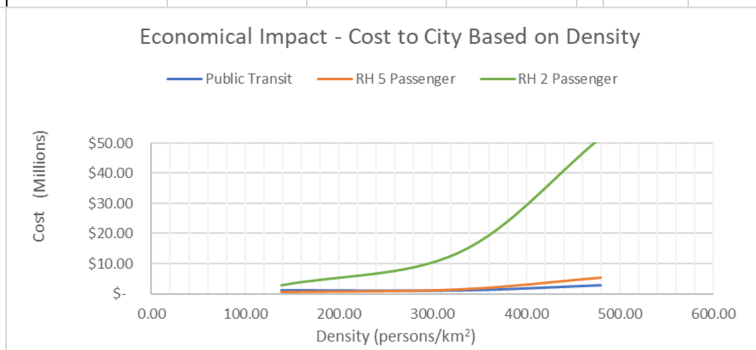
Critical Density	
RH 5psgr	RH 2psgr
N/A	**N/A**
persons/km^2	



$19.70

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

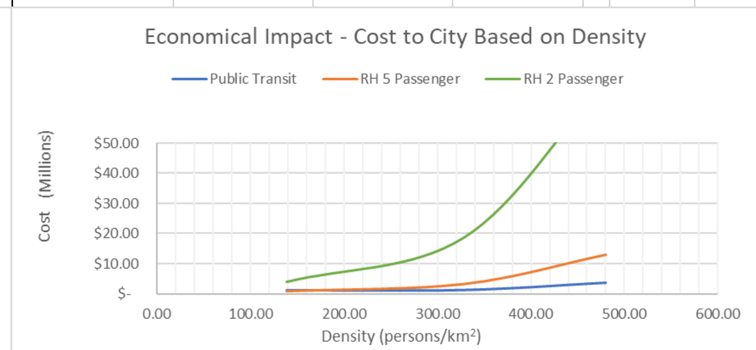
Critical Density	
RH 5psgr	RH 2psgr
277	**N/A**
persons/km^2	



$25

	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	3799665.62	1318923.84	1213484.22
RH Cost (5psgr)	12981722.29	3325527.41	929965.15
RH Cost (2psgr)	70609812.73	18693018.19	4003463.30

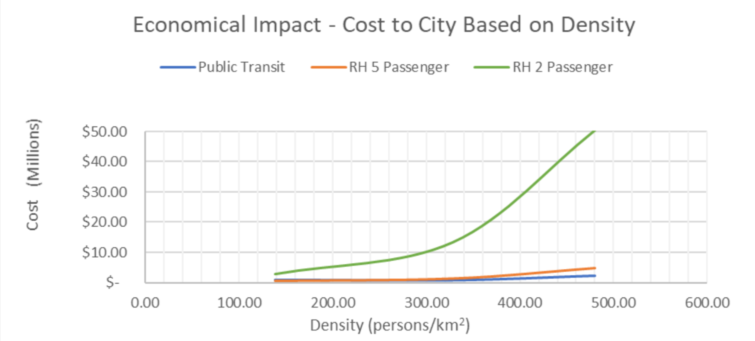
Critical Density	
RH 5psgr	RH 2psgr
166	**N/A**
persons/km^2	

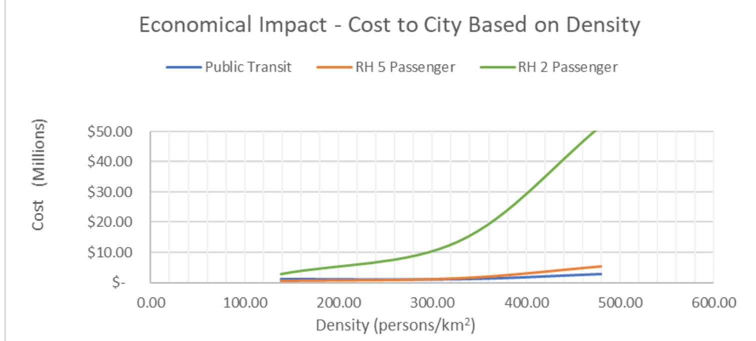


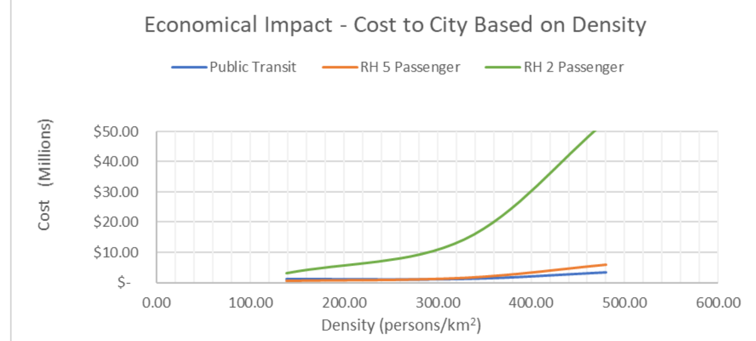
Price of Fuel	50 c/L				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480	328.6	139.2	**273**	**N/A**
Public Transit Cost	$ 2,190,598.25	$ 859,190.31	$ 983,617.46	persons/km^2	
RH Cost (5psgr)	$ 4,780,347.55	$ 1,234,980.90	$ 447,531.34		
RH Cost (2psgr)	$ 50,347,592.76	$ 13,386,246.30	$ 2,877,784.42		

	100 c/L				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

	150 c/L				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480	328.6	139.2	**280**	**N/A**
Public Transit Cost	$ 3,325,196.99	$ 1,183,361.38	$ 1,145,702.99	persons/km^2	
RH Cost (5psgr)	$ 6,003,049.04	$ 1,546,649.91	$ 519,454.96		
RH Cost (2psgr)	$ 53,368,384.69	$ 14,177,406.09	$ 3,045,606.19		



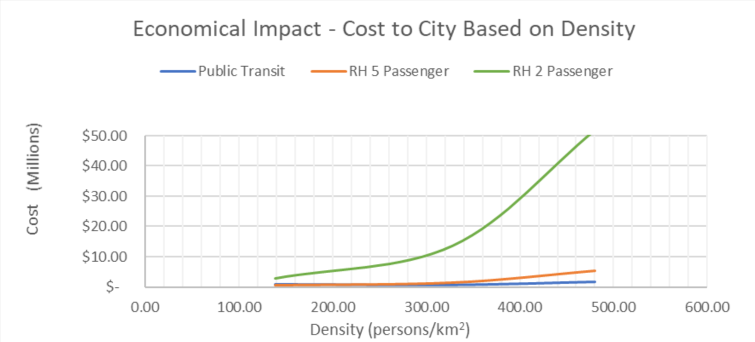


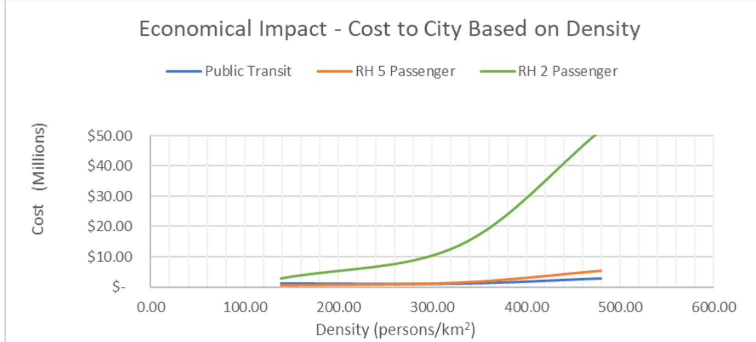


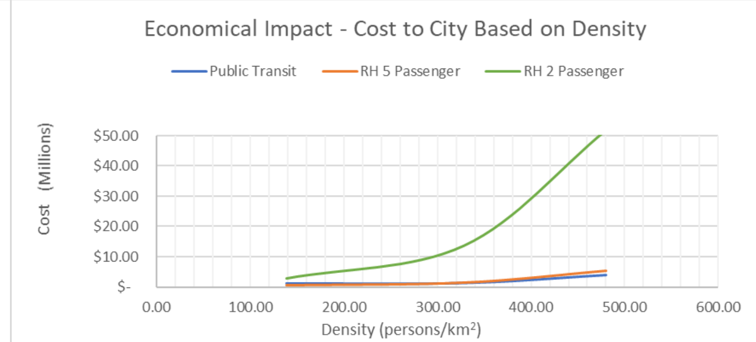
Cost of Bus	$500,000				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480	328.6	139.2	**235**	**N/A**
Public Transit Cost	$ 1,707,897.62	$ 721,275.84	$ 914,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

	$650,000				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

	$800,000				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480	328.6	139.2	**317**	**N/A**
Public Transit Cost	$ 3,807,897.62	$ 1,321,275.84	$ 1,214,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		

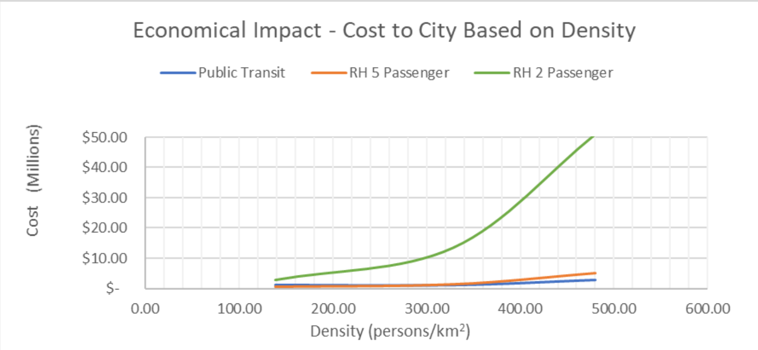






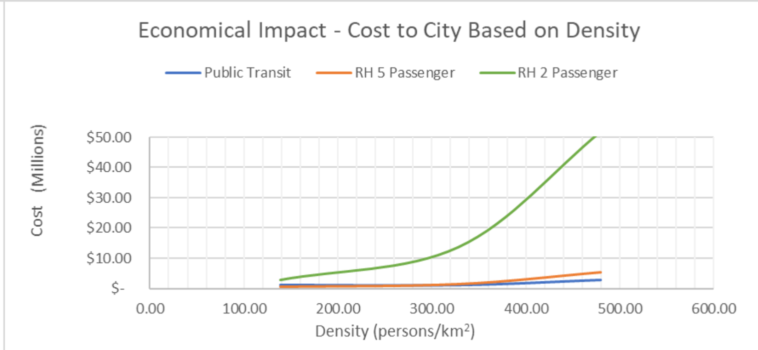
Cost of Van	$25,000		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,085,698.29	$ 1,312,815.41	$ 465,493.15
RH Cost (2psgr)	$ 51,101,988.73	$ 13,583,826.19	$ 2,919,695.30

Critical Density	
RH 5psgr	RH 2psgr
286	**N/A**
persons/km^2	



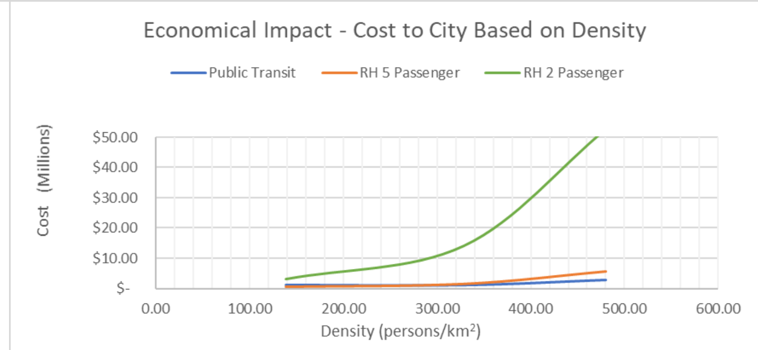
	$31,000		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

Critical Density	
RH 5psgr	RH 2psgr
277	**N/A**
persons/km^2	



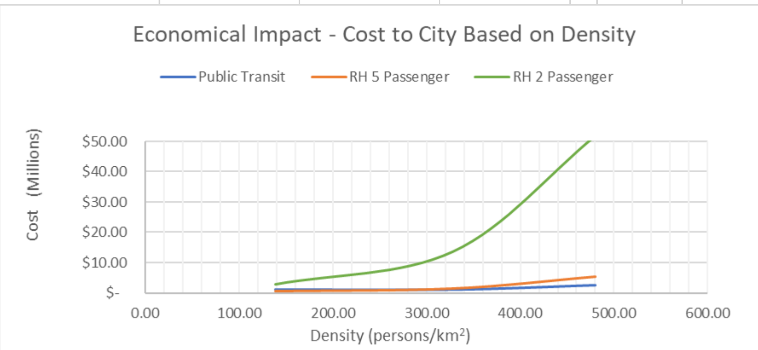
	$37,000		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,697,698.29	$ 1,468,815.41	$ 501,493.15
RH Cost (2psgr)	$ 52,613,988.73	$ 13,979,826.19	$ 3,003,695.30

Critical Density	
RH 5psgr	RH 2psgr
270	**N/A**
persons/km^2	



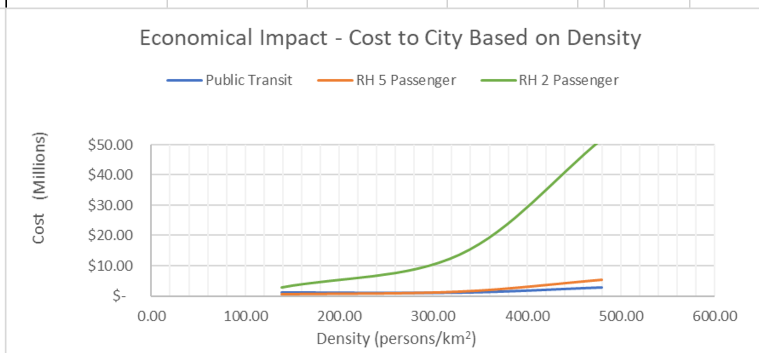
Bus Yearly Maintenance	$ 5,000.00		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,556,297.62	$ 963,675.84	$ 1,035,860.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

Critical Density	
RH 5psgr	RH 2psgr
269	**N/A**
persons/km^2	



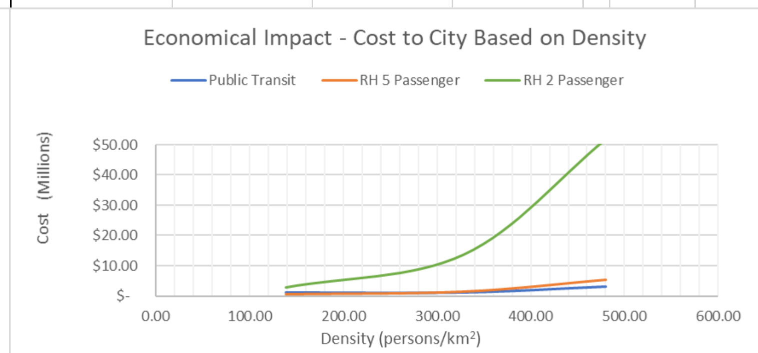
	$ 7,400.00		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

Critical Density	
RH 5psgr	RH 2psgr
277	**N/A**
persons/km^2	

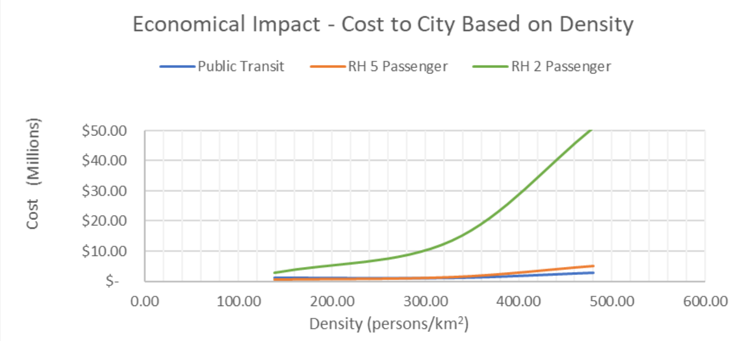


	$ 10,000.00		
	Hamilton	SSM	Innisfil
	City 1	City 2	City 3
Density	480.00	328.60	139.20
Public Transit Cost	$ 2,976,297.62	$ 1,083,675.84	$ 1,095,860.22
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30

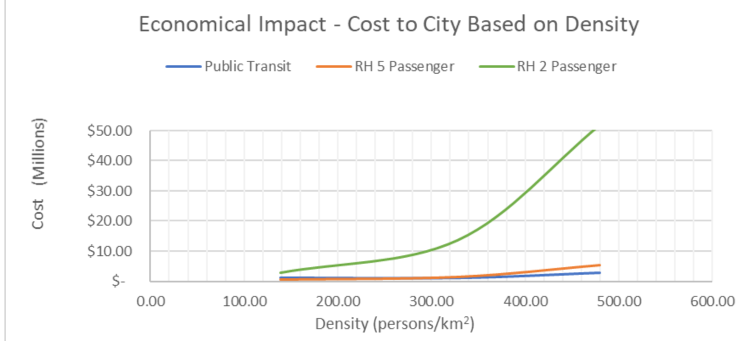
Critical Density	
RH 5psgr	RH 2psgr
285	**N/A**
persons/km^2	



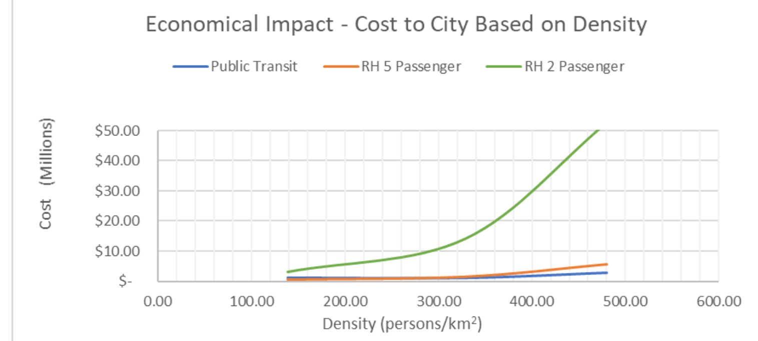
RH Yearly Maintenance	$ 450.00				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**287**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,085,698.29	$ 1,312,815.41	$ 465,493.15		
RH Cost (2psgr)	$ 51,101,988.73	$ 13,583,826.19	$ 2,919,695.30		



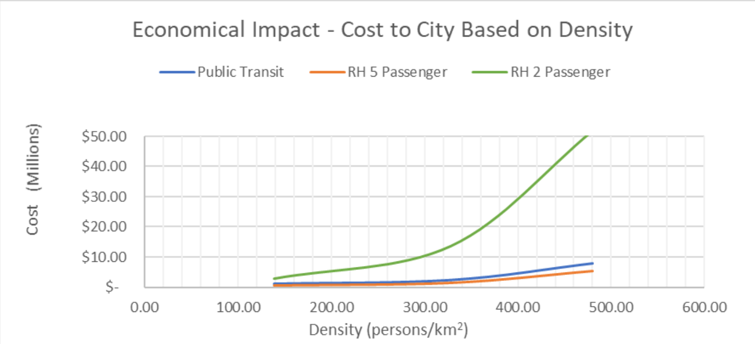
$ 950.00					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



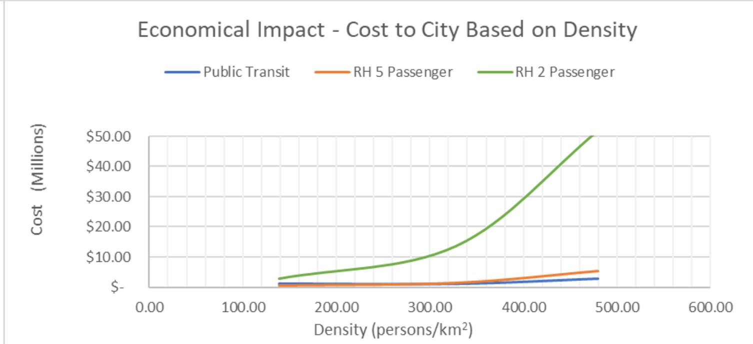
$ 1,450.00					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**270**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,697,698.29	$ 1,468,815.41	$ 501,493.15		
RH Cost (2psgr)	$ 52,613,988.73	$ 13,979,826.19	$ 3,003,695.30		



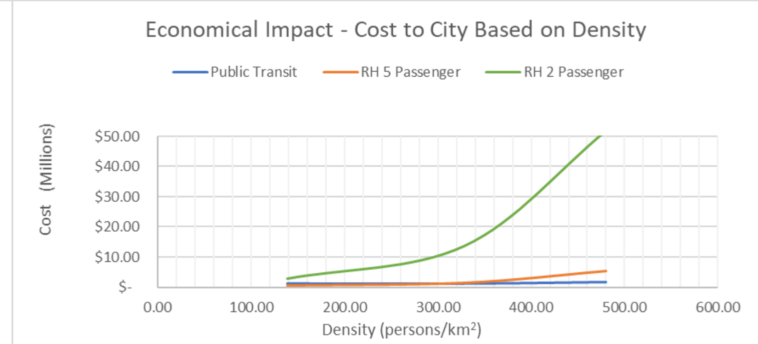
Bus Speed	20 km/h				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**N/A**	**N/A**
Public Transit Cost	$ 7,979,830.13	$ 2,313,251.84	$ 1,010,631.71	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



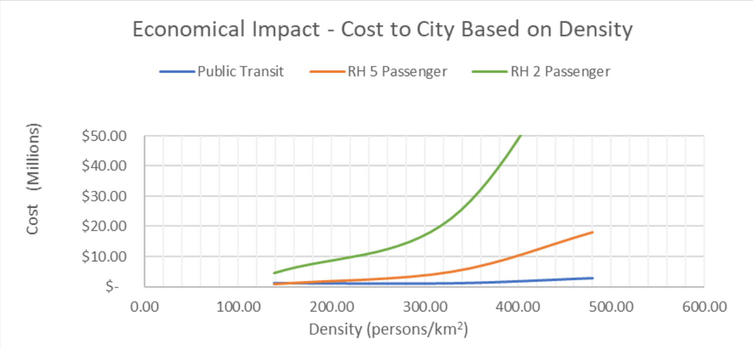
30 km/h					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



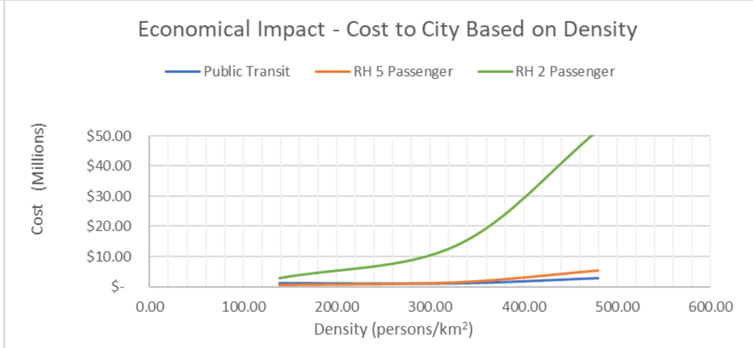
40 km/h					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**303**	**N/A**
Public Transit Cost	$ 1,628,007.15	$ 1,129,332.87	$ 1,118,688.74	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



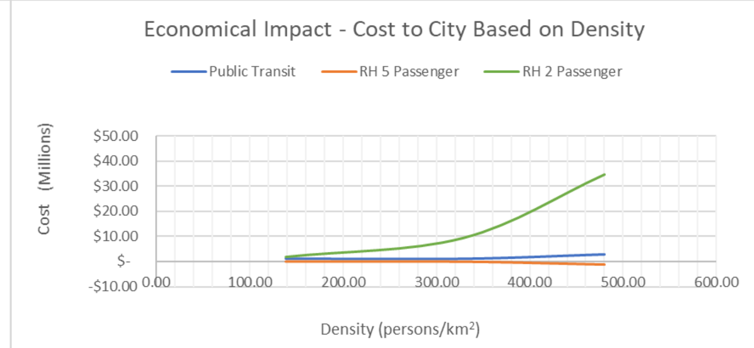
Ridehail Speed	20 km/h				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**145**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 17,937,973.98	$ 4,974,075.81	$ 948,538.76		
RH Cost (2psgr)	$ 87,044,143.93	$ 22,709,287.57	$ 4,617,892.92		



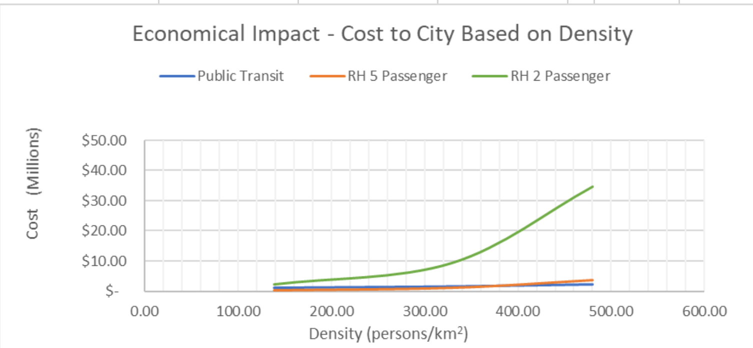
Ridehail Speed	30 km/h				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



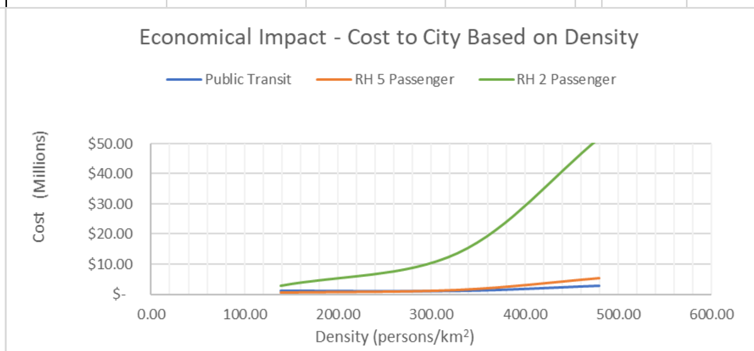
Ridehail Speed	40 km/h				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**N/A**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	-$ 1,191,214.82	-$ 91,039.52	-$ 58,804.93		
RH Cost (2psgr)	$ 34,578,682.15	$ 9,322,091.26	$ 1,823,821.23		



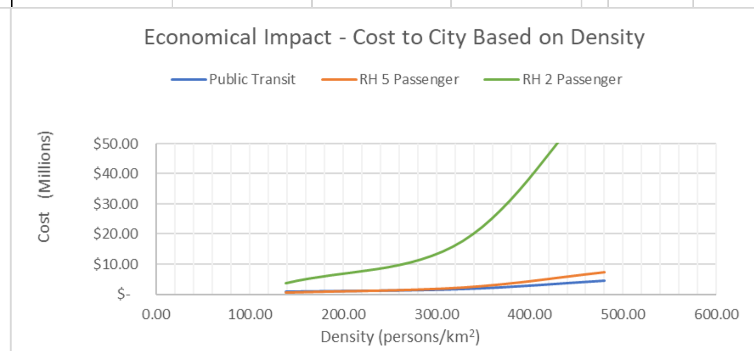
Buffer Zone	0.5 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**384**	**N/A**
Public Transit Cost	$ 2,323,285.59	$ 1,650,224.92	$ 1,194,460.66	persons/km^2	
RH Cost (5psgr)	$ 3,594,465.53	$ 1,133,727.12	$ 322,328.76		
RH Cost (2psgr)	$ 34,571,992.48	$ 9,187,884.13	$ 2,180,980.38		



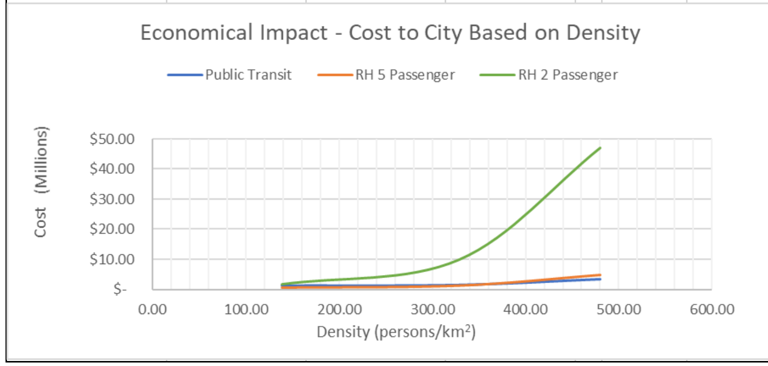
Buffer Zone	0.75 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



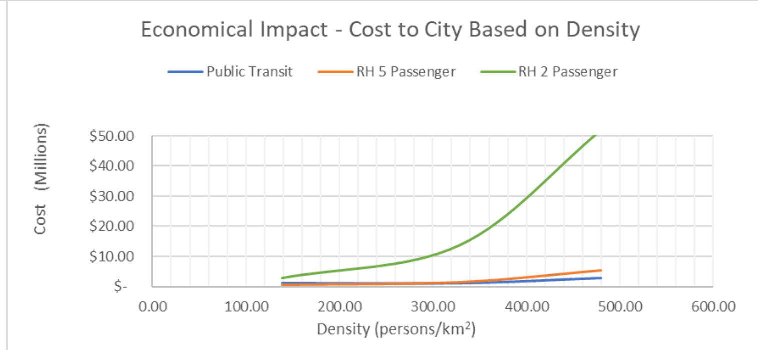
Buffer Zone	1.0 km				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**243**	**N/A**
Public Transit Cost	$ 4,646,571.18	$ 1,846,388.30	$ 934,859.79	persons/km^2	
RH Cost (5psgr)	$ 7,188,931.06	$ 2,267,454.24	$ 644,657.53		
RH Cost (2psgr)	$ 69,143,984.97	$ 17,756,217.72	$ 3,742,410.22		



Percent of PT Commuters	-1%				
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**364**	**N/A**
Public Transit Cost	$ 3,464,615.06	$ 1,505,082.82	$ 1,269,608.28	persons/km^2	
RH Cost (5psgr)	$ 4,789,696.00	$ 1,240,712.92	$ 587,710.22		
RH Cost (2psgr)	$ 46,919,132.66	$ 9,914,420.47	$ 1,826,811.30		



0%					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**277**	**N/A**
Public Transit Cost	$ 2,757,897.62	$ 1,021,275.84	$ 1,064,660.22	persons/km^2	
RH Cost (5psgr)	$ 5,391,698.29	$ 1,390,815.41	$ 483,493.15		
RH Cost (2psgr)	$ 51,857,988.73	$ 13,781,826.19	$ 2,961,695.30		



+1%					
	Hamilton	SSM	Innisfil	Critical Density	
	City 1	City 2	City 3	RH 5psgr	RH 2psgr
Density	480.00	328.60	139.20	**263**	**N/A**
Public Transit Cost	$ 3,505,241.71	$ 1,991,530.40	$ 859,712.17	persons/km^2	
RH Cost (5psgr)	$ 5,993,700.59	$ 2,160,468.44	$ 998,826.61		
RH Cost (2psgr)	$ 56,796,844.80	$ 17,029,681.38	$ 4,716,129.84